Tendon Transfers for Diseased and Injured Tendons in the Upper Extremity

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INTRODUCTION

Tendon transfers are commonly used to restore function when musculotendinous units are weak or paralyzed as a result of nerve injury or disease. They also are useful in restoring function when tendons are injured or ruptured due to disease such as rheumatoid arthritis. The alternatives to tendon transfers are direct repair, advancement with lengthening, free tendon graft, tenodesis, and arthrodesis. Unlike a free graft, a tendon transfer does not need to be harvested, does not require revascularization from surrounding tissue, and may only involve one tendon suture, which is well-vascularized from both ends. Use of a tendon transfer also has the advantage of bringing a muscle to motor the severed tendon that is normal in size, strength, and contractability.

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DORSAL SURFACE TENDON TRANSFERS FOR TENDON INJURY

The success of a tendon transfer in reestablishing finger extension depends upon joint mobility, elimination of intrinsic contracture, and utilization of a good muscle-tendon unit as a substitute for the ruptured or injured tendon.[1]

Trauma may result in laceration of tendons. In the case of the thumb, when the extensor pollicis longus is divided proximal to the midportion of the thumb metacarpal, it is likely to retract proximally. If repair is performed within four to five weeks of injury, the proximal end usually can be located and a direct repair performed. Beyond this time limit, the musculotendinous unit usually will have shortened, making direct repair impossible.

When primary or secondary suture of the divided extensor pollicis longus is not possible, tendon transfer is the procedure of choice. The extensor indicis proprius is the muscle-tendon unit of choice. Alternative units for transfer to the extensor pollicis longus are the extensor carpi radialis longus[1] and the extensor pollicis brevis.[2]

When extensor tendons to the fingers are divided, repair should be done primarily if the wound is clean, the tendons are viable, and there

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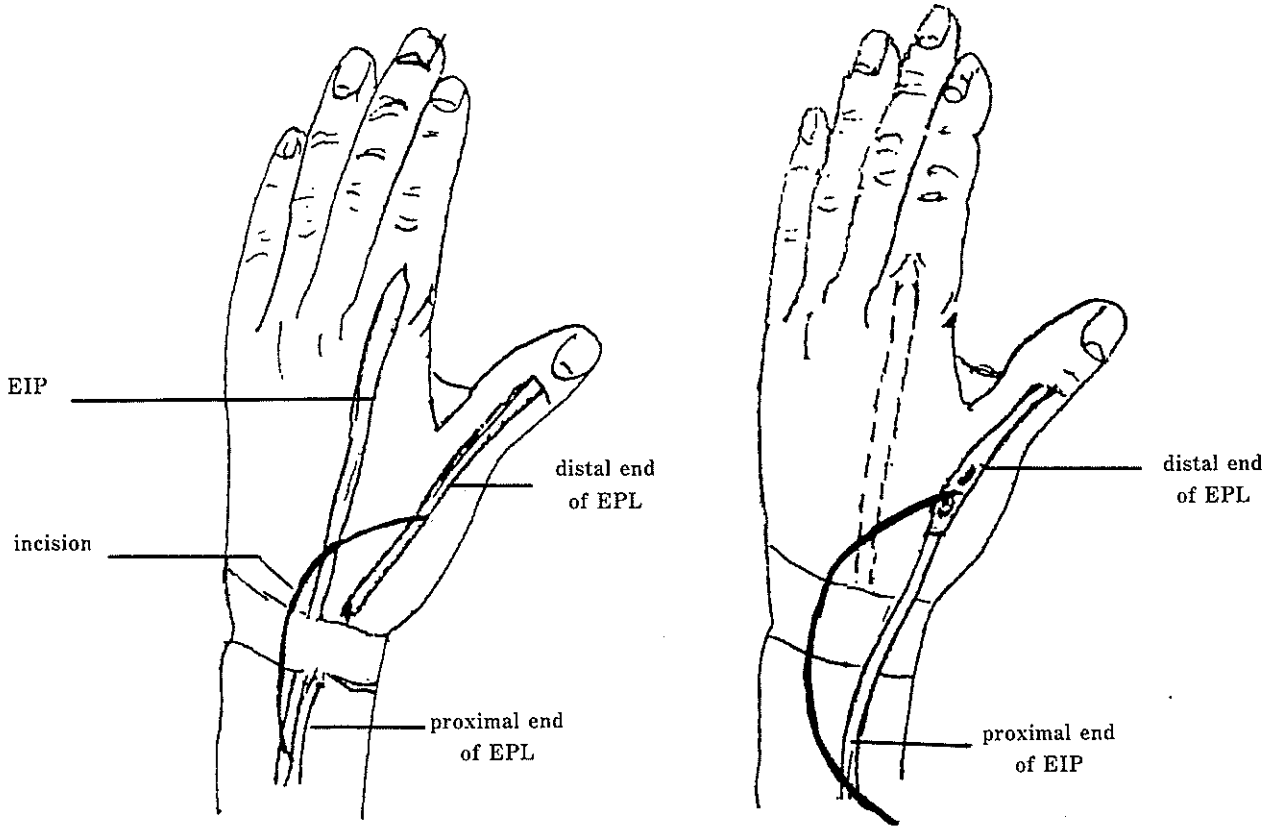

Fig. 1 Schematic representation of extensor indicis proprius (EIP) transfer for division or rupture of extensor pollicis longus (EPL).

is no loss of substance. If primary or delayed primary repair is not performed and the injury is proximal to any tendinous interconnections or vinculae, retraction of the proximal end may occur. Delay beyond four to five weeks may lead to shortening of the musculotendinous unit and inability to perform a direct repair of the severed tendon. In this event, tendon transfer is the procedure of choice. Tendons available for transfer and restoration of function are the extensor indicis proprius, the extensor digiti minimi, the adjacent extensor digitorum communis, the extensor carpi radialis longus, the flexor carpi ulnaris,[3] and the superficial flexor tendons, usually the ring.[4]

Trauma to the Extensor Pollicis Longus

The extensor indicis proprius is the unit of choice for repairing trauma to the extensor pollicis longus. The method by which this is performed usually involves exposure of the proprius tendon at the appropriate level and rerouting the tendon to the long extensor of the thumb.

The entire procedure can be performed through a longitudinal incision exposing the extensor pollicis longus and extensor indicis proprius simultaneously (Fig. 1). There usually is no need to take the proprius tendon at the level of the extensor hood since this may provide more length than is required. If the extensor indicis proprius is taken at the level of the metacarpophalangeal joint, care should be taken to repair the extensor hood of the index metacarpal accurately without excessive tightness to prevent an extensor lag.[5]

Tension is adjusted at the distal tendon juncture. The tendon is repaired using a tendon weave technique. With the wrist flexed, the interphalangeal joint should lie in full extension, with the

metacarpophalangeal joint and carpometacarpophalangeal joints similarly extended. With the wrist extended, passive flexion of the thumb to the small finger pulp should be possible. The hand is splinted for five weeks with the wrist immobilized in approximately 30° of dorsiflexion and the thumb abducted and extended. Following removal of the splint, protected active thumb flexion and extension is performed for an additional three weeks, after which time unlimited activity is allowed.

Trauma to Finger Extensor Tendons

If the extensor proprius units are selected as motors, they are transected at or near their insertion, rerouted at the wrist, and sutured into the distal end of the divided tendon, usually with an interweaving techique. Before sacrificing the extensor digiti quinti, it is important to ascertain that there is a slip of the extensor communis to the little finger. An alternative procedure is transfer of the divided distal end of the injured tendon side-to-side to the adjacent entensor communis tendon. Transfers of the extensor carpi radialis longus or the superficial flexor may be sutured to the distal divided end either with a tendon interweave or side-to-side technique. Nonabsorbable suture should be used for suture of tendons.

The tension should be adjusted at the distal tendon juncture. With the wrist extended, the metacarpophalangeal joints should be extended to a neutral position. With the wrist flexed, the metacarpophalangeal joints should be hyperextended to -10°. When the wrist is dorsiflexed, the fingertip-distal palmar crease distance should be 1cm. The tension can be adjusted using intravenous block anesthesia, releasing the tourniquet, and allowing the patient to move the transfer when voluntary motion returns. The wounds are closed using local infiltration block anesthesia.

To relieve tension on the repair, immobilization should be established with the wrist extended to 30° and the metacarpophalangeal joints flexed 10°. After three weeks, the metacarpophalangeal joints are splinted at about 60° of flexion and immobilization is continued for an additional three weeks. Protected active flexion exercises then are performed for a further three weeks, with unlimited activity allowed thereafter.

DORSAL SURFACE TENDON TRANSFERS FOR DISEASED TENDONS

Closed rupture of the extensor pollicis longus tendon classically occurs following fractures around the wrist,[6,7] as well as following tenosynovitis in rheumatoid disease. It also may occur as a so-called spontaneous rupture where the tendon has been subjected to repeated trauma. Such a lesion was described by Dums as occurring as an occupational hazard of drummer boys in the Prussian army.[8] Redden described two cases of closed rupture due to rotational trauma to the forearm.[9]

In rheumatoid disease, it is not uncommon for multiple tendon ruptures to occur as a result of synovitis, ischemic necrosis,[10] and attrition over displaced and eroded bones. The most common sites of attrition are Lister's tubercle and the distal end of the ulna. The extensors to the thumb, little, and ring fingers are most commonly involved. Rupture of the extensor tendons to the fingers usually starts with the little finger and sequentially affects the remaining fingers from the little to the index finger.

Prevention is preferable to cure. Although prevention may be achieved by early tenosynovectomy, transposition of the extensor retinaculum, and excision of bony prominences,[11-15] rupture can occur even after these procedures.[10]

Due to the diffuse nature of rheumatoid disease and the difficulty in finding other tendons that are relatively undamaged, tendon transfers may not be as satisfactory in this condition as they are following trauma. The proprius, extensor communis, extensor pollicis brevis,[2] extensor carpi radialis longus,[1] and flexor digitorum sublimis[14] are tendons available for transfer without sacrifice of motion elsewhere. In order of preference, Flatt recommends use of the extensor indicis proprius, extensor carpi radialis longus, extensor carpi ulnaris, and brachioradialis.[12] No imbalance of wrist motion was noted by Goldner after use of

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the extensor carpi radialis longus.[1] Millender describes use of the flexor digitorum sublimis, routing it around the radial aspect of the forearm, attaching it at the distal end to the common extensor tendons of the ring and little fingers.[10] These transfers may be used singly or in combination. When multiple tendons are ruptured, the tendons to the ring and little fingers most often are involved.

Only a few studies have provided long-term follow-up methods of repair of ruptured extensor tendons in rheumatoid disease.[2,3,11,16]

Rupture of the Extensor Pollicis Longus

Following a rupture of the extensor pollicis longus tendon, due to the contribution of the abductor pollicis brevis and adductor pollicis to the dorsal extensor expansion, there may be no loss of active thumb interphalangeal joint extension. However, resisted extension will be lost. The options for repair are end-to-end suture, tendon transfer, and tendon graft.[17] Due to shortening, direct repair usually is not possible, and tendon transfer is the procedure of choice.

The extensor indicis proprius is the unit of choice[18] and is used in a manner similar to that described for transfer following trauma. Midgley considers the extensor indicis proprius to be the ideal motor, describing it as being expendable, straight, synergistic, and subcutaneous.[19] Vainio obtained the best range of motion when the extensor indicis proprius (EIP) was used.[16] Shannon found that use of the extensor carpi radialis longus provided extension equal to that achieved by an EIP transfer.[3] Although there was a greater flexion deficit of the thumb, this was not considered a handicap. In addition, the EIP was spared for other transfers.

If necessary, a dorsal synovectomy and excision of dorsal bony spicules, i.e., Lister's tubercle, should be carried out at the same time as the transfer. The dorsal retinaculum should be transposed deep to the dorsal tendons to provide a smooth surface on which they can glide.

If the thumb interphalangeal joint is unstable, an arthrodesis may be the procedure of choice. Arthrodesis of the metacarpophalangeal joint also is an alternative to tendon repair or transfer in cases of rupture of the extensor pollicis brevis.

Case 1

A 37-year-old Caucasian female patient sustained a nondisplaced fracture of the right distal radius and was treated in a short-arm cast. Twenty-five days after injury, while still in plaster, she reached for a car door and felt a sudden "pop" in her right thumb and pain in her right forearm. She was unable to extend the thumb after that episode. The patient was next seen for reevaluation six weeks later. On examination out of plaster, the fracture was clinically united, but there was no extension at the thumb metacarpophalangeal joint and extension at the interphalangeal joint was weak when the proximal phalanx was stabilized. Radiographs revealed a united fracture in good position. Diagnosis of a spontaneous rupture of the extensor pollicis longus was made and the patient was scheduled for exploration.

Although intravenous anesthesia usually is preferable in order to obtain precise tendon tension, at the patient's request in this case the procedure was performed under general anesthesia with pressure cuff hemostasis. A curved incision was made over the dorsal aspect of the thumb, and the ruptured tendon was identified. The extensor indicis proprius was detached at the level of the distal third of the metacarpal. Following a route comparable to that of the ruptured tendon, it was transferred into the distal end of the long extensor and secured using 4-0 Prolene in a tendon weave repair (Fig. 1).

After the tension was adjusted appropriately, a circular cast was applied with the wrist in 10° of extension and the thumb in full extension. The thumb and wrist were immobilized for five weeks, after which active flexion and extension were begun, followed by passive flexion after an additional three weeks. When the patient was last seen 14 weeks after surgery, there was 55° flexion and full extension of the interphalangeal joint of the thumb.

Rupture of Finger Extensor Tendons

In the case of rupture of an extensor tendon to a single finger, transfer of the extensor indicis proprius to the little and ring finger tendons or lateral suture to the adjacent extensor communis may be a satisfactory solution. Because of the diffuse nature of rheumatoid disease, lateral transfer is preferred to use of an independent extensor. In multiple tendon involvement following trauma, this is not a consideration, provided the transferred units are uninjured. In cases of rheumatoid disease, Shannon recommends transfer of the extensor indicis proprius or flexor carpi ulnaris in preference to adjacent structures.[3]

The index extensor need not be taken at the level of the extensor hood since sufficient length is available when dividing it proximal to this point. If necessary, a dorsal synovectomy, excision of bony spicules, and transposition of the extensor retinaculum may be performed at the same time. Occasionally, the ulnar head may be excised and replaced with a Silastic prosthesis, which preserves ulnar length and provides a smooth surface over which the tendons can glide. In our experience, this prosthesis can be used without complications necessitating removal in situations in which there is a bony spicule or prominence in the area of transferred tendons that might cause abrasion or rupture of the tendons.

In the case of a double rupture of the long and ring finger extensor tendons, the distal ends may be sutured to the common extensors of the index and little fingers, respectively. However, double ruptures usually involve the ring and little finger. The ring finger extensor tendon will reach the common extensor to the long finger, but frequently the little finger extensor will not. In such cases, the extensor indicis proprius can be used to restore extension to the little finger. A greater postoperative range of extension is likely to be obtained if separate motors are used for each distal ruptured tendon.[3] The extensor carpi ulnaris is unsuitable because of insufficient amplitude and because of its importance in maintaining wrist alignment and power.

If more than two extensors are involved, the extensor indicis proprius is insufficient, and use of the flexor digitorum sublimis is a suitable solution.[4] The superficial flexor to the ring finger is brought around the radial aspect of the forearm and is transferred to the distal ends of the common extensors of the ring and little fingers using a tendon interweave or end-to-side suture. The distal end of the long finger extensor tendon is sutured end-to-side or interweaved into the common extensor of the index. An alternative arrangement is to transfer the superficial flexor to the middle and ring fingers, and the extensor indicis proprius to the little finger.[4] Shannon recommends transfer of the flexor carpi ulnaris around the wrist to the little finger, transfer of the extensor indicis proprius to the ring finger, and adjacent suture of the middle finger tendon to the index finger extensor digitorum communis.[3]

In the case of quadruple tendon ruptures, two superficial flexors are used. As described previously, the transfer should be tight enough to have a tenodesis effect. If the wrist has been fused previously, although their excursion is limited, the wrist extensors can be sacrificed without loss of function.

In recovery of function, extension is more important in the index and middle fingers, while flexion is the primary requirement of the ring and little fingers.[3] Shannon found that operations to restore finger extension seldom achieved full extension and there also was an overall flexion deficit. Only the group having combined ring and little finger ruptures regained reasonably full flexion. Postoperative immobilization of the metacarpophalangeal joints in full extension should not exceed three weeks since this may contribute to the loss of flexion at these joints.

Since the outcome of surgery for multiple finger extensor tendon ruptures often is poor, in some cases conservative management using dynamic bracing as practiced by Savill may give equal or better functional results.[20]

If metacarpophalangeal joint disease is severe, joint motion should be restored first. Unless the metacarpophalangeal joint can be extended passively, the tendon transfer will become adherent. A staged reconstruction can be performed. The first stage consists of replacement arthroplasties,

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followed by a second stage of dynamic splinting in which both optimal flexion and extension are obtained. The tendon transfer is performed as a third stage. An alternative is to perform the replacement arthroplasties and tendon transfers at the same time. However, the results fall short of those expected when either joint replacement or tendon transfer is performed alone.[10]

Postoperative care is similar to that for transfers following tendon injury. Patients who are on steroids should be immobilized longer to allow secure tendon healing to occur. Goldner recommends doubling the period of immobilization.[1]

VOLAR SURFACE TENDON TRANSFERS FOR TENDON INJURY

Tendon transfers on the volar surface of the hand are more limited in application because there are fewer instances in which an available tendon can be spared to replace the loss of function of an injured tendon.

Following a laceration in the flexor synovial sheath, the proximal end of the flexor will be tethered by the vinculae if these remain intact. If they are no longer in continuity, the tendon can retract into the palm to the level of the lumbrical origin (in the case of the deep flexor) or more proximally into the wrist (in the case of the superficial flexor or the flexor pollicis longus). If repair is delayed, the muscle belly will shorten, fibrose, and atrophy as a result of division and disuse, making direct repair impractical. This is particularly true in the case of the flexor pollicis longus, which is unrestrained by a lumbrical attachment and therefore will not be subject to the stretching effect of wrist extension.

Secondary reconstruction of a divided flexor tendon may be accomplished by:

a) free tendon grafting (to the original musculotendinous unit or to an adjacent, undamaged unit)[21-23]
b) advancement with tendon lengthening[24]
c) tendon transfer[25]
d) excision of the damaged tendons and placement of a silicone rod beneath the old or reconstructed pulleys to promote the development of a synovium-lined pseudosheath, allowing improved gliding of a later tendon graft or transfer
e) suture of the profundus to the sublimis tendon in the palm followed in four to six weeks by detachment of the sublimis tendon near its origin, with insertion of the proximal end of the sublimis to the distal phalanx as a replacement graft for the injured profundus[26-29]
f) arthrodesis,[30] which is useful in cases in which the interphalangeal joint of the thumb is stiff and in a poor functional position or where simpler procedures are more appropriate.[30]

Whether or not thumb interphalangeal motion needs to be replaced is controversial. As Urbaniak and Goldner[24] have reported, although flexion is not essential for thumb function, it is desirable, particularly in patients whose occupation requires fine workmanship such as a watchmaker or a tool dye maker. In the case of division or rupture of the flexor digitorum profundus, arthrodesis of the distal interphalangeal joint may be combined with transfer of a tendon to the base of the middle phalanx.

Trauma to the Flexor Pollicis Longus Tendon

Division of the flexor pollicis longus tendon at the level of the proximal phalanx is a common situation in which a tendon transfer may be indicated to restore function. If the laceration is proximal to the vincular attachment or this is divided, the tendon often will retract to the level of the volar carpal ligament. If delay or soft tissue injury with excessive fibrosis prevents a direct repair, a tendon transfer is an excellent means of restoring function to the distal end of the flexor pollicis longus tendon.

The ring finger sublimis tendon is suitable for this procedure. It can be detached 3cm proximal to its insertion through an incision distal to the distal palmar crease[31] to prevent recurvatum or flexion deformities of the proximal interphalangeal level. It is rerouted proximally at the wrist through the sheath of the flexor pollicis longus tendon. A tendon clamp is passed retrograde between the two heads of the flexor pollicis brevis to the carpal canal; the sublimis tendon is grasped

and pulled distally through the canal and pulleys and is sutured into a transverse slot at the base of the distal phalanx with the aid of a pull-out suture. If the area of scarring is severe enough to preclude this, the tendon may be passed subcutaneously to the flexor synovial sheath distal to scar tissue, or a staged reconstruction may be required with insertion of a Silastic rod and reconstruction of pulleys as the initial stage. The oblique pulley at the base of the proximal phalanx is critical,[32] and this should be the site of a pulley reconstruction.

The correct tension should be judged by repairing the tendon with the interphalangeal joint flexed to 90°, the metacarpophalangeal joint fully flexed, and the wrist in moderate dorsiflexion. The advantages of such a transfer are that it provides sufficient length to be inserted into the distal phalanx and allows normal excursion and power of the muscle-tendon unit.[33] The disadvantage is the risk of recurvatum or flexion contracture at the PIP joint of the donor finger.[34] This is preventable[31] and is not a problem in patients with tight joints who have no possibility of developing a recurvatum deformity.

Postoperative care includes immobilization of the wrist in flexion and the thumb in flexion and abduction to relieve tension on the repair. Limited passive flexion utilizing some form of dynamic traction is acceptable to prevent excessive adhesions. After three weeks, active extension is encouraged for one week; if motion at the interphalangeal joint still is not increasing at that time, active and passive assisted extension may be started. Although a full range of flexion may not result, stability, control, and strength will exist at the interphalangeal joint,[1] which contributes to an increase in pinch strength.

Both before and after division of the ring finger sublimis, the proximal interphalangeal joint of the ring finger should be checked to determine whether there is a tendency to hyperextension. If this is the case, the ulnar slip of the tendon may be sutured to the periosteum of the proximal phalanx or the fibrous flexor sheath to tenodese the joint in 10-15° of flexion. The tendon should be divided according to the method of North.[31] Postoperative care of the ring finger should include early active and passive extension to prevent a flexion contracture of the PIP joint.

Patient cooperation is vital for a successful result. The patient should be taught to exercise the transfer with the metacarpophalangeal joint stabilized in extension to maximize the excursion of the tendon distally at the interphalangeal joint. The patient is encouraged to gradually increase wrist extension. A program of active and passive extension exercises is performed five to six times a day by the patient at home. Passive motion is particularly helpful in lysing adhesions in the region of the proximal and distal phalanx.

The causes of loss of thumb interphalangeal joint flexion have been described by Apfelberg.[35] In summary, these are thought to be: a) excessive tension due to shortening of the muscle unit in cases of primary repair, secondary repair and advancement, or in cases of short tendon graft or short transfer; b) loss of the digital pulley with bowstringing at the metacarpophalangeal joint,[36] which lessens the effective excursion at the interphalangeal joint; c) adhesions at or distal to the metacarpophalangeal joint or proximal in the thumb or wrist with failure of pull-through distally; d) hypermobile metacarpophalangeal joints[37] with loss of effective excursion distally due to hyperflexion at the metacarpophalangeal joint.

Case 2

A 12-year-old right-handed male patient reported a history of having sustained a laceration to this left thumb six weeks prior to his initial consultation. The skin laceration was closed at the time of injury. Since that time the patient had been unable to flex the interphalangeal joint. On examination, a scar was seen 1cm distal to the interphalangeal joint of the thumb. Although there was no active flexion at the interphalangeal joint, there was full passive range of motion and full active extension, and sensibility was normal. A diagnosis of a division of the flexor pollicis longus tendon was made and the patient was scheduled for surgical exploration.

Because the patient was very apprehensive, surgery was performed under axillary block com-

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bined with general anesthesia and pressure cuff hemostasis. This allowed the patient to be asleep during the procedure and provided some analysis of the operated extremity in the immediate postoperative period to prevent tension on the transferred tendon in the event the patient became excited. A zig-zag shaped incision was made over the volar aspect of the left thumb, identifying the lacerated distal flexor tendon. The tendon sheath was explored over the proximal phalanx, and the proximal end of the tendon could not be identified. An additional incision was made over the wrist, and it was found that the flexor pollicis longus tendon had retracted back to the area of the thenar muscles and would not reach to the distal stump.

A separate incision was made over the proximal interphalangeal joint of the ring finger, and the sublimis tendon was detached from its insertion. A second incision was made in the palm. The tendon was withdrawn into the palm, positioned at the level of the wrist, and transferred beneath the median nerve through the old sheath of the flexor pollicis longus. The incisions were closed except for the one over the distal thumb. Using one slip, the transferred sublimis tendon was sutured with 4-0 Prolene over the distal phalanx into the remaining stump of the flexor pollicis longus. Tension was adjusted so that with the wrist flexed the thumb was abducted 1cm and the interphalangeal joint was flexed to 5°; with the wrist extended the thumb was opposite the index fingertip and the interphalangeal joint was flexed to 25°. The remaining skin wound then was closed.

A pressure dressing and a short-arm cast were applied with the wrist in moderate flexion. A dorsal extension block was applied to the thumb with the metacarpophalangeal joint at 30° and the interphalangeal joint at 45° of flexion. Four weeks after surgery, the splint was removed and the patient was started on active flexion and extension exercises. Fourteen weeks after surgery, there was active interphalangeal joint flexion to 48° and all wounds were well-healed.

Trauma to Finger Flexor Tendons

Tendon transfer is particularly useful in restoring function to the little finger in which both tendons have been divided. The insertion of the ring finger sublimis is at the same level as the insertion of the profundus tendon to the little finger. Although the sublimis tendon to the long finger also may be used, it is a powerful flexor that is essential for a power grip and should not be sacrificed. The ring finger sublimis transfer also can be inserted into the middle phalanx of a finger to restore sublimis action, combining this procedure with an arthrodesis of the distal interphalangeal joint.

Tension should be set so that with the wrist flexed the metacarpophalangeal joints are at 0° and the proximal interphalangeal joints are at 25°. In full wrist dorsiflexion, the fingertip-distal palmar crease distance should be 3cm on the index side, progressing to 2cm on the little finger side, depending upon the finger to which the tendon is transferred.

Case 3

A 56-year-old Caucasian female patient presented with a history of having sustained a laceration over the palmar aspect of the proximal interphalangeal joint of the right little finger three months previously. At that time it was noted that both flexor tendons and the the radial digital nerve were divided. The superficial flexor was repaired at the time of injury, but attempts to repair the deep flexor failed. The patient was reexplored several days later with the same result. The digital nerve was not repaired.

On examination, a scar was visible on the volar aspect of the proximal interphalangeal joint, as well as in the volar flexion creases on the ulnar aspect of the palm. There was no active flexion at the distal interphalangeal joint. Passive flexion was to 60°. Active and passive flexion at the proximal joint were 60°, with an extensor lag of 15°. Two-point discrimination was reduced on the radial side of the finger distal to the laceration. A diagnosis of a divided deep flexor tendon and radial digital nerve was made and the patient was scheduled for exploration.

Surgery was performed on an outpatient basis under intravenous block anesthesia. A volar zig-zag incision was made in the little finger, extending proximally into the palm. The superficial flexor was identified and found to be small and

tethered in scar tissue adherent to the flexor sheath. The distal end of the deep flexor was identified and excised except for the distal 1cm. The sheath was excised, leaving adequate pulleys; a #4 Silastic rod was inserted through the pulleys and brought into the palm. On pulling the rod, the tip of the little finger could be made to touch the palm. The postoperative course was complicated by overuse. The patient developed an inflammatory response to the Silastic rod that resolved with rest.

Fifteen weeks after the initial surgery, a second-stage reconstruction was performed using a tendon transfer of the ring finger sublimis. The sublimis tendon and the Silastic rod were identified through an incision in the palm. A second incision was made over the proximal interphalangeal joint of the ring finger. Both slips of the superficial flexor were divided and pulled into the palm. One slip was removed and the other was attached to the proximal end of the Silastic rod. A third incision was made at the tip of the little finger and the Silastic rod was identified. The attached slip of the ring finger sublimis was drawn into the wound over the distal phalanx of the little finger. The incisions in the ring finger and palm were closed. A hole was drilled in the distal phalanx of the little finger and a pull-out suture of 4-0 wire was used to attach the distal end of the tendon to the distal phalanx. Tension was adjusted with the wrist in neutral, the metacarpophalangeal joint flexed to 70°, the proximal interphalangeal joint to 70°, and the distal interphalangeal joint to 20°.

The hand was immobilized with a pressure dressing and a dorsal splint to maintain the wrist and little finger metacarpophalangeal and interphalangeal joints in slight flexion. The pull-out wire was removed on the 35th postoperative day, and active flexion and extension were commenced. The patient was able to touch the palm within 1cm of the distal crease 14 weeks after operation.

VOLAR SURFACE TENDON TRANSFERS FOR DISEASED TENDONS

As in tendon transfer for trauma, there is less versatility in transferring tendons interrupted by disease on the volar surface than on the dorsal surface.

Rupture of the Flexor Pollicis Longus

The flexor pollicis longus is the tendon most often ruptured in rheumatoid disease. The cause usually is attrition over a bony spicule arising from the carpal scaphoid. Index finger flexors frequently will go on to rupture for the same reason. Tendon transfer utilizing the superficial flexor to the ring finger can be used to replace the long thumb flexor as described above. Goldner recommends use of the extensor carpi radialis longus.[1] The bony spicule should be excised and covered with adjacent soft tissues.[10] A carpal tunnel release and a flexor tendon tenosynovectomy can be done at the same time.

Rupture of Finger Flexor Tendons

Rheumatoid synovitis involves deep and superficial flexors with equal frequency. Rupture may occur in the finger, palm, wrist, or forearm. If only the sublimis tendons are involved, restoration of function is not indicated.

If the rupture occurs in the palm or wrist and the profundus tendon is interrupted while the sublimis is still intact, the sublimis can be sutured end-to-end or interwoven to the distal profundus tendon. If the tendon is ruptured in the flexor synovial sheath, surgery should be performed to remove diseased tenosynovium and protect the superficial flexor from later rupture. The distal interphalangeal joint may be fused.

If rupture occurs at the wrist, side-to-side suture or tendon grafting of the deep flexor can be performed with the junctions proximal and distal to the carpal tunnel. In the palm, suture to an adjacent profundus tendon or transfer of an intact superficial flexor to the distal profundus stump may be performed.

Rupture of both tendons in the finger has a poor outlook, worse than that following division secondary to trauma because of the diffuse nature of the rheumatoid involvement and the poor bed that it provides for tendon graft or transfer. A sublimis tendon from an adjacent finger may be trans-

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ferred as described above. A two-state reconstruction may be necessary using the ring finger sublimis or a "pedicled" sublimis transfer.[29] In the case of severe joint disease, advanced age, or severe general disease, it may be more appropriate to fuse the proximal and distal interphalangeal joints as a last resort.

SUMMARY

Tendon transfer is a useful method of restoring function to musculotendinous units that have been interrupted by injury or disease. There is greater versatility on the dorsal surface than on the volar surface and following injury rather than disease. The limiting factors are the condition of the tissues, the passive mobility of the joints to be motored, and the availability of nondiseased tendons whose function is less important than that of the one to be restored.

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