CME

Secondary Procedures following Flexor Tendon Reconstruction

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Learning Objectives: After studying this article, the participant should be able to: 1. Understand the indications and management options for secondary flexor tendon reconstruction, including tenolysis, tendon grafting, and tendon transfers. 2. Understand the reconstructive options for pulley reconstruction. 3. Understand the options for management of isolated flexor digitorum profundus injuries.

Summary: Despite current advances in flexor tendon repair, complications can still occur following surgery. This article presents the spectrum of treatment options for secondary flexor tendon reconstruction ranging from tenolysis to one- and two-stage tendon grafting, and tendon transfers. In addition, an overview of pulley reconstruction and the treatment of isolated flexor digitorum profundus injuries are discussed. A management algorithm for secondary flexor tendon reconstruction is provided. (*Plast. Reconstr. Surg.* 149: 108e, 2022.)

The incidence of flexor tendon injury is 33 injuries per 100,000 person-years.[1,2] Advancements in flexor tendon repair, including wide-awake surgery, have led to improved outcomes.[3] In studies using multiple strand repairs and active range of motion, excellent results (defined as total active range of motion more than 150 degrees[4]) have been noted in up to 86 percent of cases.[5,6] Despite this, reoperation still occurs. In a retrospective review of 5229 patients undergoing primary flexor tendon repair, there was a 6 percent reoperation rate, with 58 percent of these patients requiring tenolysis alone, 38 percent requiring rerepair alone, and 4 percent requiring both.[7] In such cases, the surgeon must have an understanding of the available reconstructive options for the treatment of patients with neglected, failed, or scarred tendon repairs. This article will review the indications and management options for failed flexor tendon surgery.

THE MECHANICAL IMPACT OF FAILED FLEXOR TENDON REPAIR

Complications following flexor tendon repairs include decreased range of motion, tendon bowstringing, quadriga, and lumbrical-plus deformity.[8–10] Compared to patients with primary flexor tendon repair, who have a mean QuickDASH score of 19.3, patients who require two-stage tendon reconstruction have a mean QuickDASH score of 34.4, emphasizing the importance of successful primary repair.[11]

Flexor tendon pulley injury and tendon bowstringing can contribute to poor results. The pulley system consists of several fibro-osseous tunnels that run from the metacarpal head to the distal interphalangeal joint. These tunnels hold the tendons close to the joint's axis, allowing maximal motion for small amounts of tendon excursion. Biomechanical cadaver studies show an 8.5 percent increase in tendon excursion with loss of the A2 pulley, a 9.9 percent increase with loss of the A4 pulley, and a 33.7 percent increase with loss of both A2 and A4.[12] The loss of both pulleys leads to a 107 percent increase in the work of flexion.[12] This can lead to loss of motion and joint contracture. Pulley damage can be avoided by accessing and performing the tendon repair through the cruciate pulleys. Recent reports have shown that

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the entire A4 pulley and up to two-thirds of the A2 pulley can be vented, if necessary, without producing bowstringing, given that the other pulleys are intact.[13] Similarly, in a study of 33 digits undergoing flexor tendon repair, Moriya et al. demonstrated that the entire A2 pulley and adjacent C1 pulley can be entirely released without bowstringing, when the other pulleys were left intact.[14]

Other complications of tendon repair include the development of the quadriga. The quadriga phenomenon causes limitations of full flexor digitorum profundus excursion of the adjacent uninjured digits.[15] Quadriga can result from any abnormality that limits joint motion. Following tendon repair, quadriga can result from adhesions or repairs that are tensioned too tightly.[9,16] The long, ring, and small fingers share a common flexor digitorum profundus muscle belly. Therefore, proximal excursion is limited by the shortest tendon in the group. Tendon shortening by 10 mm can produce a quadriga effect, which is most pronounced in the ring and small fingers.[9] In a cadaveric model, shortening of the ring and small finger flexor digitorum profundus tendons produced the greatest adverse effect on the tip-to-palm distance of the adjacent digits.[9] To avoid quadriga, tendon grafting should be considered when there is a tendon gap.

The lumbrical-plus deformity describes paradoxical interphalangeal joint extension with attempted flexion in the injured digit. This occurs when the flexor digitorum profundus tendon distal to the lumbrical insertion is too loose or absent, such as in a rupture, or if a tendon graft is too long.[10] In this scenario, the force of the flexor digitorum profundus tendon is transmitted to the lumbrical, leading to interphalangeal joint extension. Management includes lumbrical release or retensioning of the tendon grafts.[10,17]

OPTIONS FOR LIMITED TENDON MOTION

Tenolysis

Peritendinous adhesions can form any time the tendon surface is damaged.[18] Tendon adhesions are present if the patient maintains full passive range of motion of the joint with limited active range of motion. Tenolysis, the surgical release of adhesions, is indicated in patients with limited active range of motion but full passive range of motion. Retrospective reviews indicate that tenolysis rates are higher, at 14.4 percent, following zone 2 flexor tendon repairs of both the flexor digitorum superficialis and flexor digitorum profundus,[19] and this has led some surgeons to suggest leaving the flexor digitorum superficialis tendon unrepaired.[20] Furthermore, flexor digitorum superficialis resection may be required at the time of tenolysis if there are extensive adhesions or the need to release proximal interphalangeal joint contractures.[21] The higher risk of adhesion formation with flexor digitorum superficialis and flexor digitorum profundus repair should be balanced with the patient's functional requirements.

Tenolysis is indicated in patients whose progression in range of motion has plateaued despite being involved in a vigorous hand therapy regimen. Recommendations for the timing of tenolysis range from 3 to 9 months following the original surgery (**Level IV Evidence**).[22–24] A recommended minimum waiting period is 3 months after primary surgery.[22] This is based on histologic studies demonstrating that the collagen fibers within the scar form bundles resembling the normal tendon at 3 months.[25] Furthermore, animal studies on chicken tendons demonstrated devascularization and weakening of the flexor tendon when tenolysis was performed before 12 weeks.[26] Many authors agree that tenolysis should be offered only when inflammation and edema from the initial surgery has subsided.

A "wide-awake" technique is recommended, when feasible, to allow the patient to actively range the affected digit and confirm release of all adhesions (**Level IV Evidence**).[27,28] While comparative outcomes data are lacking, the logical advantages of wide-awake tenolysis over general anesthesia include confirmation of full release of adhesions, testing of pulley integrity, and direct visualization of tendon integrity through active range of motion.[29] Small transverse incisions are made into the sheath and tenotomies, tenolysis knives, a 25-gauge fine wire, or Freer elevators are passed under the sheath and pulley system to release peritendinous adhesions.[30] [**See Video (online)**, which displays a clinical example of flexor tendon tenolysis of previously repaired zone II flexor tendon injury.]

Postoperative therapy is directed by the intraoperative findings. Immediate mobilization following tenolysis is preferred to prevent tendon adhesions[31–33] (**Level IV Evidence**); however, this should be balanced against the risk of rupture in tendons with poor integrity.[34] In these cases, Strickland's "frayed tendon" protocol is suggested (**Level V Evidence**).[35] The tenolysed digit is passive flexed and then the patient actively maintains the flexed position. This is then gradually progressed to gentle active range of motion. Use of continuous passive motion following tenolysis does not provide significant gains in range of motion and

was associated with increased number of therapy clinic visits (**Level III Evidence**).[36] Following tenolysis, more than 80 percent of patients will notice improvement, whereas 10 percent may have a worse outcome[22,37–39] (**Level IV Evidence**). The overall rate of flexor tendon rupture following tenolysis ranges from 10 to 16 percent.[22,37–39]

Adjuncts to Tenolysis

Recent studies have examined the use of adjunctive barrier films and surface treatment agents to prevent the reformation of adhesions.[40,41] A randomized, controlled, multicenter trial showed the efficacy of Hyaloglide (Anika Therapeutics, Bedford, Mass.), a hyaluronan-based gel, in improving range of motion up to 180 days after flexor tenolysis.[42] VersaWrap (Alafair Biosciences, Austin, Texas) is another hyaluronic acid based bioabsorbable hydrogel used to protect tendon gliding; however, no clinical data exist yet for this adjunct. Other products such as type 1 collagen and decellularized porcine peritoneal membrane are also available; however, comparative clinical trials are still lacking.[43]

TENDON GRAFTING

Single-Stage Grafting

Before the 1970s, the standard of care for flexor tendon injuries in "no-man's land" was tendon resection and single-stage tendon grafting.[44–48] The transition toward primary repair is credited to Kleinert's successful primary repairs in zone II and Lister's introduction of controlled early range of motion.[49] Thus, there is a paucity of contemporary literature on single-stage grafting, and the largest case series remains the report on 1000 cases by Boyes and Stark.[48]

Single-stage tendon grafting involves excision of the injured flexor tendons and reconstruction using a free tendon graft secured to the base of the distal phalanx and powered by a proximal motor in the palm or forearm. The indications for single-stage grafting include segmental tendon loss, soft-tissue loss that precluded primary repair, and delayed diagnosis.[16,24,47] Primary tendon repair can be attempted up to 3 weeks following injury. Beyond this, myostatic shortening and sarcomere degeneration causes tendon retraction.[16,50] Single-stage grafting is most suitable for Boyes grade 1 (Table 1) injuries in digits with an intact pulley system and supple joints (**Level IV Evidence**).[47,48,51] The presence of joint contractures, extensive soft-tissue loss, or pulley incompetence necessitates a two-stage procedure (**Level IV Evidence**).

Table 1. Boyes Preoperative Classification of Flexor Tendon Injuries

Grade	Preoperative Condition	Description
1	Good	Minimal scar, mobile joints no trophic changes
2	Cicatrix	Heavy skin scarring from injury or previous surgery; deep scarring from failed primary repair or infection
3	Joint damage	Injury to joint with decreased range of motion
4	Nerve damage	Digital nerve injury
5	Multiple system injury	Combination of above

Surgical Technique

A wide-awake approach is preferred, as the patient can actively participate in range of motion to help with tensioning of the graft.[52] When this is not feasible, the tendon graft should be tensioned to restore the normal digital cascade. Passive flexion produced by compression of the volar forearm musculature and the tenodesis effect can be used to aid in intraoperative assessment.[53] The flexor tendon sheath and pulley system should be preserved as much as possible.[54] The damaged flexor digitorum superficialis (flexor digitorum superficialis) tendon should be excised leaving the distal 2 cm to provide a smooth posterior gliding surface and help prevent proximal interphalangeal joint hyperextension.[55] If available, the distal 1 cm of the flexor digitorum profundus tendon is preserved for distal coaptation of the tendon graft.

Source of Donor Tendon

Donor tendon selection depends on the length of graft required and individual patient anatomy (Table 2). Extrasynovial tendon grafts are thought to incite a larger inflammatory response, resulting in a higher propensity to form adhesions compared to intrasynovial tendons.[56,57] Biomechanical

Table 2. Donor Tendon Graft Options for Use in Secondary Flexor Tendon Reconstruction

Donors	Length (cm)	Anatomical Presence (%)
Extrasynovial		
Palmaris longus	16	84
Plantaris	35	90
Extensor digitorum brevis		100
Extensor digitorum longus	35	100
Extensor hallucis longus	35	100
Abductor pollicis longus	14	85 (accessory)
Flexor carpi radialis	10	100
Intrasynovial		
Flexor digitorum superficialis		100
Flexor digitorum longus	12	100
Extensor indicis proprius	13	100

studies report improved gliding under the A2 pulley with intrasynovial tendons.[58,59] No direct comparison has demonstrated the superiority of intrasynovial to extrasynovial grafts.[60,61] The most commonly used donor grafts are the extrasynovial palmaris longus or plantaris tendons.

Proximal and Distal Junctures

Both tenorrhaphy sites should be performed outside of the tendon sheath to minimize adhesions.[16,62,63] The graft tension is set slightly tighter than the normal digital cascade. If the graft is tensioned too tightly, quadriga can develop, limiting flexion; if it is tensioned too loosely, a lumbrical-plus finger may develop.[8,15] Distally, the graft can be sutured or woven into the flexor digitorum profundus stump. If the flexor digitorum profundus stump is deficient, a Bunnell tendon-to-bone pull-out technique, bone tunnel, or bone anchor can be used.[64,65] Bertelli et al. describe harvesting the plantaris tendon with calcaneal bone to allow for distal juncture osteosynthesis with miniscrew fixation.[66,67]

The proximal motor is ideally the flexor digitorum profundus of the injured digit. The donor tendon is secured distal to the lumbrical insertion in the palm or more proximally in the wrist using a Pulvertaft weave or side-to-side repair. Alternative proximal motors include the injured flexor digitorum superficialis tendon, end-to-side weaves into an adjacent flexor digitorum profundus, or end-to-end weave to an adjacent flexor digitorum superficialis tendon. Traditionally, patients were immobilized for 3 weeks after tendon grafting; however, many surgeons are now using early protected active motion protocols.[16,68,69]

The most important predictor of success following single-stage grafting is the extent of preoperative injury.[48] In a review of 607 digital flexor-tendon grafts by Boyes and Stark, 23 percent of patients with Boyes class 1 injuries achieved full flexion of the fingertip pulp to the palmar crease, compared to 9 percent of Boyes class 2 and 0 percent of Boyes class 5 injuries.[48] In a review of single-stage grafting in 264 digits, Kotwal and Gupta demonstrated good to excellent results in 88.5 percent of patients and poor results in 11 percent.[70] In a study of four patients with single-stage reconstruction using intrasynovial donor tendons by Leversedge et al., there was 64 percent recovery of active range of motion.[61]

STAGED TENDON GRAFTS

A two-stage approach is advised for Boyes grade 2 to 5 injuries (Fig. 1 and Table 1). Discussion with the patient regarding expectations is important before surgery. One study of 43 patients undergoing two-stage flexor tendon reconstruction reported an average of 44 days away from work after the first procedure and 104 days after the second. Furthermore, 42 percent required a tertiary procedure such as tenolysis. Twenty-eight percent of patients would not have gone through with surgery in retrospect.[71]

First Stage

At the first stage, pulley reconstruction is performed and a silicone rod is inserted to maintain space within the flexor sheath.[72,73] This incites an inflammatory response with a mesothelium-like pseudosheath developing around the rod, providing a smooth gliding surface for tendon graft.[74] Distally, the silicone rod is sutured below the flexor digitorum profundus stump. Proximally, the silicone rod is passed deep to the superficial flexor tendons. The rod is not sutured proximally but allowed to glide. Postoperatively, hand therapy is focused on obtaining maximal passive range of motion.

Second Stage

At the second stage, the silicone rod is replaced with the tendon graft, sutured with a 3-0 or 4-0 braided polyester suture. This is typically performed 3 months after the first stage, although some authors advocate for proceeding at 8 to 10 weeks.[75,76] The tendon graft is secured to a proximal motor, similar to the one-stage grafting technique. The distal tendon end is sutured to the silicone rod and pulled through a distal incision and secured as for the one-stage grafting technique.

In the retrospective review by Sun et al. of 106 digits undergoing two-stage tendon reconstruction using a Hunter rod and early range-of-motion protocol, 84 percent of patients achieved a good to excellent result based on total active motion measurements.[77] Concomitant extensor tendon injuries, infection, and associated joint injury are identified as predictors of poorer outcome.[78]

Paneva-Holevich Modifications

In 1969, Paneva-Holevich described a two-stage method for flexor tendon reconstruction by creating a proximal tenorrhaphy between the flexor digitorum superficialis and flexor digitorum profundus proximal tendon stumps at the first stage and then using the flexor digitorum superficialis tendon as a graft at the second stage.[79]

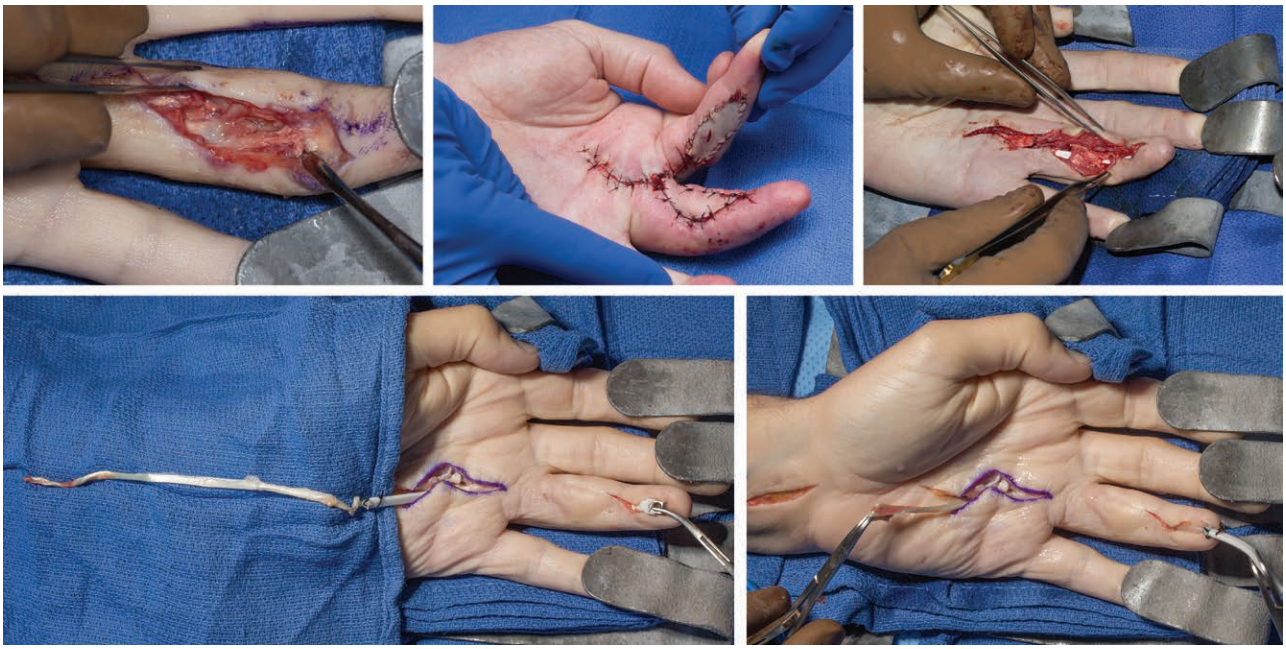

Fig. 1. A 50-year-old man requiring a two-stage tendon graft who had undergone tendon repair of the left ring finger elsewhere followed by subsequent infection and skin loss. (*Above*, *left*) Intraoperative image of finger following débridement of necrotic skin and tendon. (*Above*, *center*) A heterodigital flap is taken from the adjacent finger for soft-tissue coverage. (*Above*, *right*) Once the infection has been cleared, pulley reconstruction is performed in conjunction with silicone rod placement as the first stage of a two-stage tendon reconstruction. (*Below*, *left*) At the second stage, a palmaris tendon graft is harvested from the ipsilateral arm and attached to the silicone rod in the proximal palm. The palmaris graft is then drawn distally with the rod to avoid exposing the area of pulley reconstruction (*below*, *right*). The tendon is then sewn to the remaining profundus stump distally and the profundus stump proximally in the hand.

The advantage of the technique is that the proximal tenorrhaphy site is healed by the second stage. In addition, an intrasynovial tendon can be used without an additional donor site. Kessler modified the Paneva-Holevich technique, combining the first stage with the insertion of a silicone rod, and then passing the flexor digitorum superficialis graft through the established pseudosheath at the second stage.[80]

At the first stage, the proximal tendon ends are sutured end-to-end at the level of the lumbrical in the midpalm (Figs. 2 and 3). At the second stage, the flexor digitorum superficialis is transected at the musculotendinous junction and sutured to the proximal end of the silicone rod. Through a distal finger incision, the silicone rod is removed, which pulls the tendon through the pseudosheath. The flexor digitorum superficialis graft is then tensioned and secured distally.

In a review of 116 patients treated with the modified Paneva-Holevich technique with average 9.5-year follow-up, 74 percent of patients achieved good or excellent results based on total active motion.[24] Seventy-eight percent stated they were satisfied with the procedure, and 92 percent of patients that were manual laborers were able to return to their original workplace.[24]

Pulley Reconstruction

The flexor pulley system maximizes the biomechanical function of the flexor tendons by translating excursion of the tendon into movement of the joint.[13] Whereas the A2 and A4 pulleys are most commonly reconstructed, some authors recommend reconstruction of three or more pulleys for optimal function.[16] Salvage of damaged pulleys is more desirable than complete reconstruction. Various techniques of "pulley plasty" to increase the volume within the scarred pulley have been described.[81–83] Pulley reconstruction can be performed using damaged tendon, a tendon graft, or extensor retinaculum. Techniques for reconstruction are divided into two types, those that loop around the phalanx and those that do not.

Methods that do not encircle the phalanx involve suturing a graft to the remaining native pulley or fibro-osseous floor of the flexor sheath.[84] Weilby described a graft interweaved between the remaining rim of the native pulley, resembling a

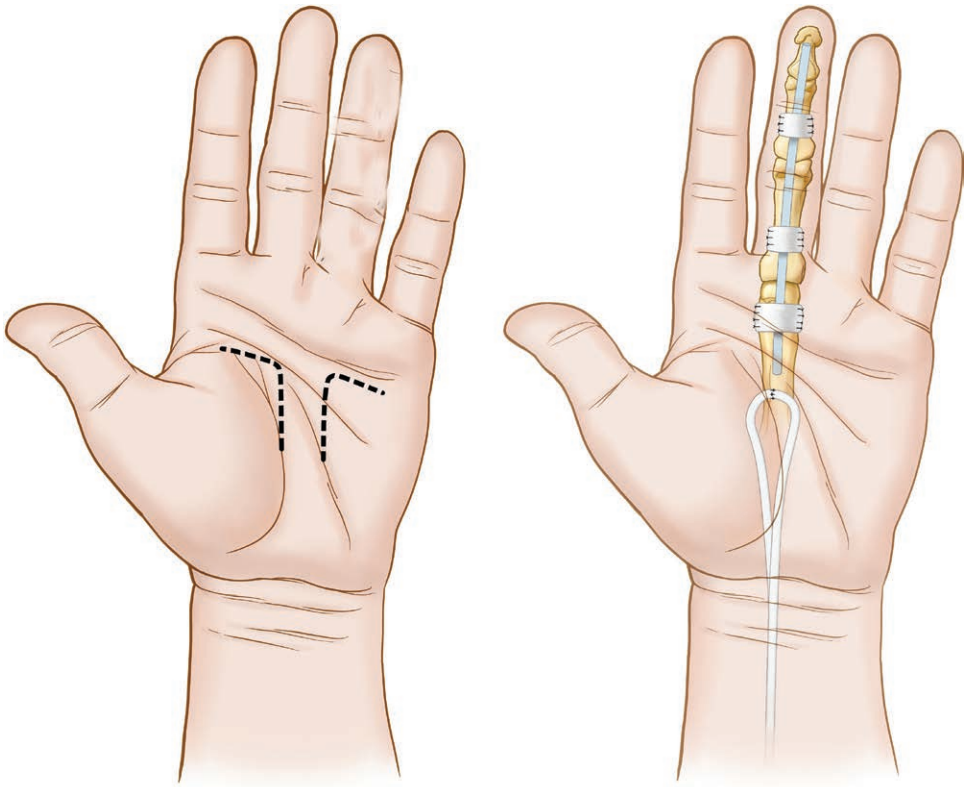

Fig. 2. Artistic rendition of modified Paneva-Holevich two-stage reconstruction. (*Left*) Recommended incisions consist of an inverted-L incision in the midpalm for proximal end-to-end tenorrhaphy of flexor digitorum superficialis and flexor digitorum longus tendons. (*Right*) The technique involves sewing the distal stump of the superficialis tendon stump to the profundus tendon stump at the time of silicone rod placement. This allows the tenorrhaphy to heal before removing the silicone rod. In the second stage, the flexor digitorum superficialis tendon is tenotomized at the musculotendinous junction through a longitudinal incision in the proximal forearm and then pulled through using the silicone rod and secured at the distal juncture. (Images adapted from Beris AE, Darlis NA, Korompilias AV, Vekris MD, Mitsionis GI, Soucacos PN. Two-stage flexor tendon reconstruction in zone II using silicone rod and a pedicled intrasynovial graft. *J Hand Surg Am*. 2003;28:652–660. Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.)

shoelace (Fig. 4, *above*, *left*). Modifications of this technique involve using one slip of flexor digitorum superficialis or extensor retinaculum, which provides an intrasynovial pulley reconstruction producing less resistance to tendon gliding.[85–87] Karev described a "belt-loop" reconstruction where two transverse incisions are made into the volar plate and the tendon is passed beneath (Fig. 4, *above*, *right*). Cadaveric studies have demonstrated that the Weilby technique is mechanically weaker than the Karev technique, with failure occurring at the junction of the graft and remnant rim. Both are weaker than looped reconstruction techniques.[88,89]

There are several loop techniques. Okutsu described the triple-loop technique, which affords the strongest biomechanical properties (Fig. 4, *below*, *left*).[89,90] The tendon graft is passed between the extensor mechanism and proximal phalanx at the level of the A2, and superficial to the extensor mechanism at A4.[91] Other looped configurations include the extensor retinaculum as a single loop (Fig. 4, *below*, *center*) and Widstrom's "loop-and-a-half" technique (Fig. 4, *below*, *right*).[88,92] In an effort to increase mechanical strength, others have proposed passing the graft through a bone tunnel or securing with bone anchors.[93,94] General recommendations are that nonencircling reconstructions are immobilized for 4 weeks and that looped reconstructions can be started on early active range of motion.[24,87,90,95]

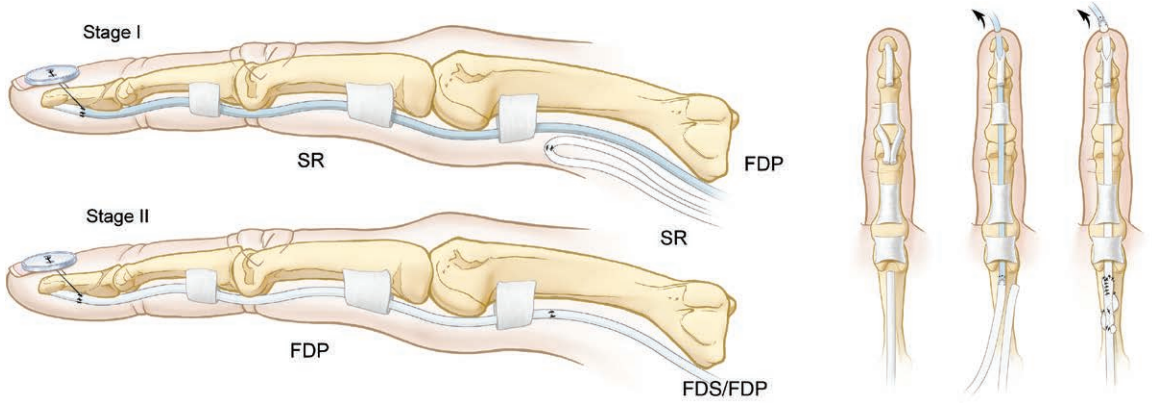

Fig. 3. (*Above*, *left*) Silicone rod (*SR*). *FDP*, flexor digitorum profundus. (*Below*, *left*) *FDS*, flexor digitorum superficialis. (Images adapted from Beris AE, Darlis NA, Korompilias AV, Vekris MD, Mitsionis GI, Soucacos PN. Two-stage flexor tendon reconstruction in zone II using silicone rod and a pedicled intrasynovial graft. *J Hand Surg Am*. 2003;28:652–660. Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.)

ISOLATED FLEXOR DIGITORUM PROFUNDUS INJURIES

The treatment of delayed isolated flexor digitorum profundus injuries is controversial. Patients can adapt remarkably well and maintain function with only a flexor digitorum superficialis tendon.[96] Furthermore, distal interphalangeal joint arthrodesis or flexor digitorum profundus

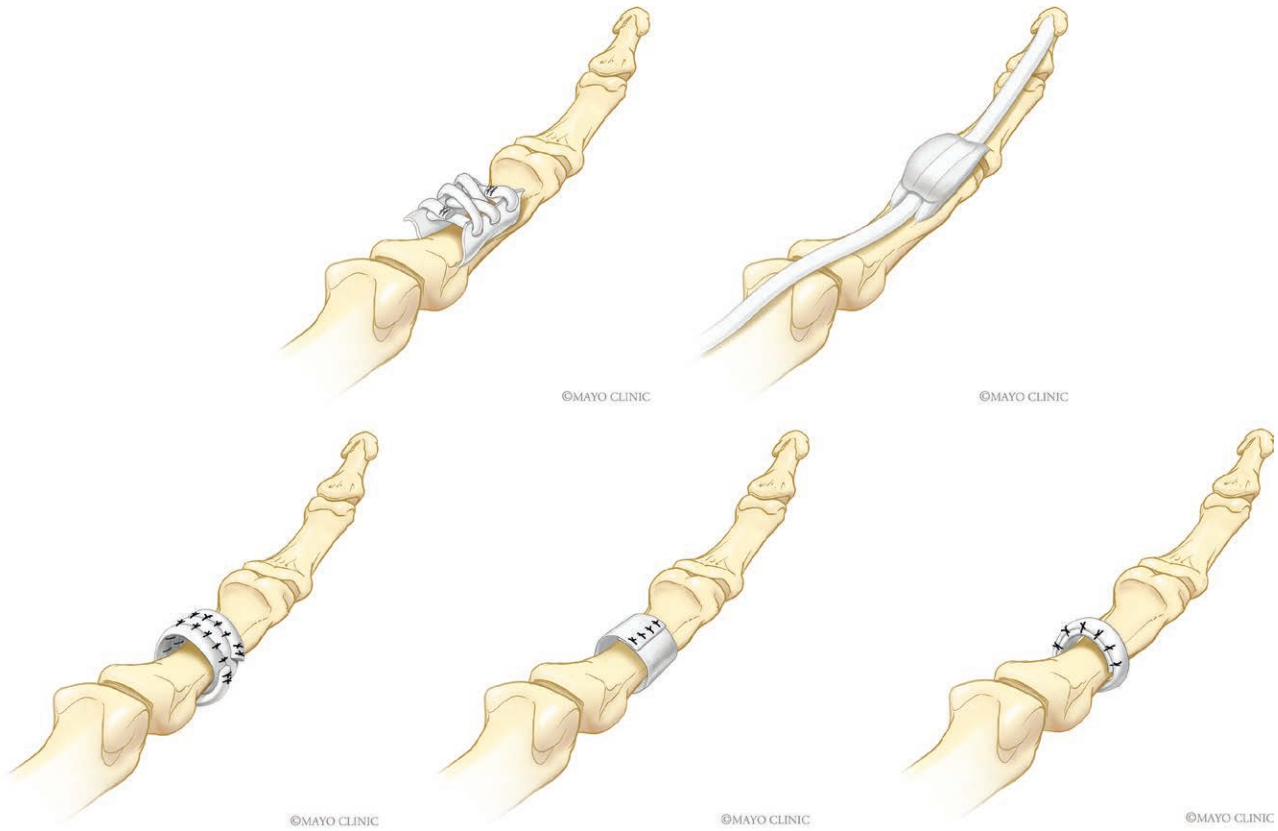

Fig. 4. Various methods of flexor pulley reconstruction including nonencircling (Weilby and Karen) and encircling (Widstrom, Okutsu, and Lister) techniques. (*Above*, *right*) Weilby shoelace technique. (*Above*, *left*) Karev belt loop technique. (*Below*, *left*) Okutsu triple-loop technique. (*Below*, *center*) Lister single-loop technique using extensor retinaculum (*Below*, *center*) Widstrom "loop-and-a-half" technique. (Images adapted from Clark TA, Skeete K, Amadio PC. Flexor tendon pulley reconstruction. *J Hand Surg Am*. 2010;35:1685–1689. Used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.)

dynamic tenodesis can be offered to patients who desire distal interphalangeal joint stability. The added functional gain of independent distal interphalangeal joint flexion should be weighed against the risk of postoperative stiffness.

Tendon grafting in isolated flexor digitorum profundus injuries should be limited to skilled technicians or musicians requiring fine dextrous control of their digits.[97] Single-stage grafting is more justifiable for the ulnar two digits to restore power grip.[24] Good results have been reported for children undergoing this procedure.[97–100] Two-stage grafting is also an option. [**See Figure, Supplemental Digital Content 1**, which displays (*left*) planned incisions for exploration of injured small finger and proximal forearm incision for silicone implant insertion; (*center*) findings at the time of exploration showing intact flexor digitorum superficialis tendon and proximal end of ruptured flexor digitorum profundus tendon; and (*right*) reconstructed A4 pulley and insertion of silicone rod implant passed through flexor tendon sheath in the first stage of reconstruction. *FDS*, flexor digitorum superficialis; *FDP*, flexor digitorum profundus, ***http://links.lww.com/PRS/E792***.]

The technique for grafting is similar to that described previously. Passing the grafted tendon through the flexor sheath in addition to the flexor digitorum superficialis tendon can be difficult, and the use of the thin plantaris tendon is ideal. Harrison advocated for excising one-half of the flexor digitorum superficialis tendon[45]; however, some would argue against any compromise of flexor digitorum superficialis in case the flexor digitorum profundus procedure fails.

Flexor Digitorum Profundus Tenodesis

Dynamic flexor digitorum profundus tenodesis is indicated in patients who experience distal interphalangeal joint hyperextension during tip pinch, but still wish to retain some range of motion (**Level V Evidence**).[101] Various methods of tenodesis exist. In Kahn's technique, the distal portion of the affected flexor digitorum profundus tendon is split in half, looped around both slips of the flexor digitorum superficialis tendon, and then sutured back to itself distally.[101] If the distal flexor digitorum profundus stump is too short, lengthening can be achieved either by splitting the tendon in half but kept intact proximally or with use of a free tendon graft.[101] Other methods of achieving tenodesis include use of a tendon graft secured to the volar distal phalanx, curved around the middle phalanx, and secured to the dorsal proximal phalanx.[102] Static techniques include securing the distal flexor digitorum profundus stump to the middle phalanx directly. Although there are biomechanical and cadaveric studies demonstrating efficacy of these techniques in ideal conditions,[102,103] there remains a lack of clinical data on outcomes following tenodesis.

Hemi–Flexor Digitorum Superficialis and Flexor Digitorum Profundus Tendon Transfers

Sita-Alb and Durand describe using the ulnar half of the ring flexor digitorum superficialis for isolated flexor digitorum profundus tendon injuries of the small finger.[104] The ulnar half of the ring flexor digitorum superficialis tendon is transected at its insertion, split proximally until enough length is obtained for transfer. The hemi–flexor digitorum profundus technique can be used for flexor digitorum profundus reconstruction in the index, ring, and small fingers. Anatomical studies have shown that the hemi–flexor digitorum profundus tendon has a larger cross-sectional area than the palmaris longus.[105] It is not suitable for long finger injuries because of the length limitations in the adjacent tendons. The flexor digitorum profundus tendon is exposed at the level of the A1 pulley, where one can identify the radial and ulnar bundle of the flexor digitorum profundus.[106] The hemi–flexor digitorum profundus is detached from the distal phalanx and then retracted proximally into the palm. The donor hemi–flexor digitorum profundus tendon is passed superficial to the lumbrical and deep to the neurovascular bundle, into the flexor sheath, and is tensioned at the distal juncture.

Sita-Alb and Durand reported good results in two of four patients with the hemi–flexor digitorum superficialis and flexor digitorum profundus transfer, respectively.[104] Bommier et al. reported on 23 patients with single-stage hemi–flexor digitorum profundus tendon transfer for delayed or failed flexor digitorum profundus repairs.[107] Functional outcomes were excellent for 14 patients, good for seven, and poor for two. The advantages of the hemi–flexor digitorum superficialis or flexor digitorum profundus transfers are the use of an intrasynovial donor tendon with similar excursion. Larger studies are necessary to determine the full impact on the donor finger.

TREATMENT ALGORITHM

A recommended treatment algorithm is provided (Fig. 5). Primary repair of flexor tendons should be performed whenever possible and attempted in patients presenting within 3 weeks of injury. In patients with decreased of motion

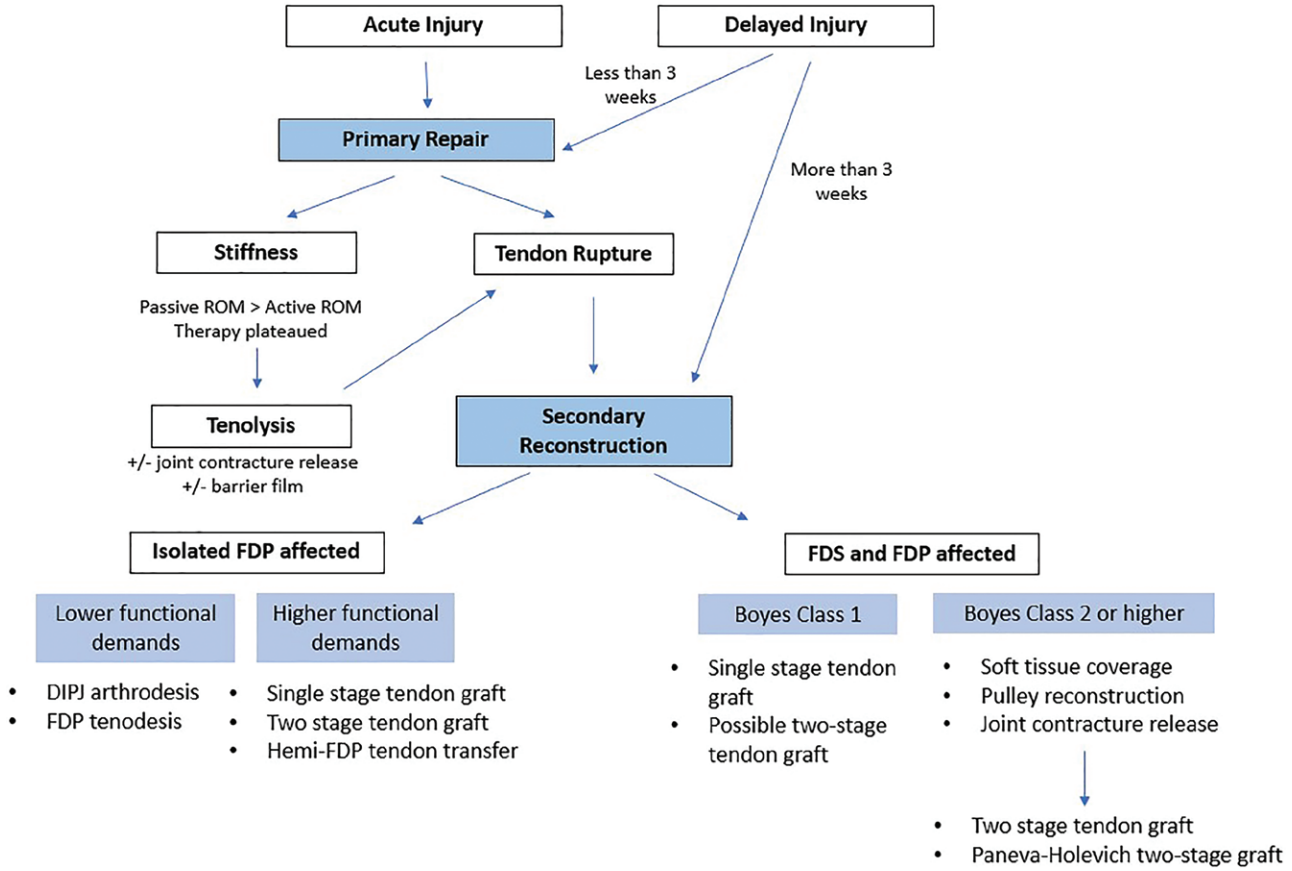

Fig. 5. Management algorithm for secondary flexor tendon reconstruction. *ROM*, range of motion; *FDP*, flexor digitorum profundus; *FDS*, flexor digitorum superficialis; *DIPJ*, distal interphalangeal joint.

or stiffness following primary repair, a thorough physical examination should be performed to determine whether this is the result of stiffness (joint contracture or tendon adhesions) or tendon rupture. Secondary reconstruction of isolated flexor digitorum profundus injuries depends on the patient's specific functional demands. Single-stage grafting, two-stage grafting, or tendon transfer procedures may be offered to patients with high occupational demands or requirement of fine dexterity. Reconstruction of combined flexor digitorum superficialis and flexor digitorum profundus injuries depends on whether other adjunctive procedures (pulley reconstruction, bony fixation, soft-tissue coverage) are required. Single-stage grafting is indicated for Boyes class 1 injuries, whereas patients with unfavorable scars, pulley incompetence, bony instability, or nerve injury should be managed in a staged fashion.

FUTURE DIRECTIONS

The unsolved problems in flexor tendon reconstruction remain the length of time required for the recovery of tendon strength and the formation of adhesions. Advancements in the molecular understanding of tendon healing and biomaterials engineering continue to propel the development of novel compounds that promote healing and decrease adhesion formation.[108] Future developments in tendon allografts with ideal strength and gliding properties will negate the need for donor tendon harvest.[109,110]

CONCLUSIONS

Secondary flexor tendon reconstruction represents some of the most challenging cases for both the surgeon and the patient. Patients must be motivated and counseled on the full spectrum of available options, including alternatives to reconstruction. Patient selection, preoperative counseling, and a tailored postoperative therapy regimen are crucial to the success of any reconstructive procedure

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CODING PERSPECTIVE

Coding perspective provided by Dr. Raymond Janevicius is intended to provide coding guidance.

Tenolysis

26440	Tenolysis, flexor tendon; palm OR finger, each tendon
26442	Tenolysis, flexor tendon; palm AND finger, each tendon

Tendon Grafting

26358	Repair or advancement, flexor tendon, in zone 2 digital flexor tendon sheath (e.g., no man's land); secondary, with free graft (includes obtaining graft), each tendon
26372	Repair or advancement of profundus tendon, with intact superficialis tendon; secondary with free graft (includes obtaining graft), each tendon
26390	Excision flexor tendon, with implantation of synthetic rod for delayed tendon graft, hand or finger, each rod
26392	Removal of synthetic rod and insertion of flexor tendon graft, hand or finger (includes obtaining graft), each rod
26489	Transfer or transplant of tendon, palmar; with free tendon graft (includes obtaining graft), each tendon

Pulley Reconstruction

26500	Reconstruction of tendon pulley, each tendon; with local tissues (separate procedure)
26502	Reconstruction of tendon pulley, each tendon; with tendon or fascial graft (includes obtaining graft) (separate procedure)

- Code 26440 is reported for a flexor tenolysis involving the palm OR the digit. If the tenolysis is performed in the palm AND the digit, code 26442 is used.
- The flexor tenolysis code is reported *for each tendon*. Thus, for a tenolysis in the palm and digit of the and flexor digitorum profundus of the right ring finger, two codes are reported:

26442	Flexor digitorum sublimis tenolysis right ring finger
26442-59	Flexor digitorum profundus tenolysis right ring finger

- The tendon grafting codes *include* tendon harvest, which should not be reported in addition to the primary code.
- In the Paneva-Holevich technique, the flexor digitorum sublimis and flexor digitorum profundus tendons are sutured in the palm in a first stage. This is a flexor tenorrhaphy, not in zone 2: 26350.
- In stage 2 of the Paneva-Holevich technique, the silicone rod is removed and the flexor digitorum sublimis passed through the pseudo sheath as a tendon graft: 26392.

CODING PRINCIPLE: Most tendon grafting procedures (including flexor reconstruction and pulley reconstruction) indicate "(includes obtaining graft)." Harvest of the tendon graft, including closure of the donor site, is included in the primary code, and code 20924 is not separately reportable.

Disclosure: Raymond Janevicius, M.D. (janeviciusray@comcast.net), is the president of JCC, a firm specializing in coding consulting services for surgeons, government agencies, attorneys, and other entities.

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