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Tendon Transfers Part II: Transfers for Ulnar Nerve Palsy and Median Nerve Palsy

Douglas M. Sammer, MD¹ and Kevin C. Chung, MD, MS²

¹Resident, Section of Plastic Surgery, Department of Surgery, The University of Michigan Health System, Ann Arbor, Michigan

²Associate Professor, Section of Plastic Surgery, Department of Surgery, The University of Michigan Health System, Ann Arbor, Michigan

Abstract

Objectives—After reading this article (part II of II), the participant should be able to: 1. Describe the anatomy and function of the median and ulnar nerves in the forearm and hand. 2. Describe the clinical deficits associated with injury to each nerve. 3. Describe the indications, benefits, and drawbacks for various tendon transfer procedures used to treat median and ulnar nerve palsy. 4. Describe the treatment of combined nerve injuries. 5. Describe postoperative care and possible complications associated with these tendon transfer procedures.

Summary—This article discusses the use of tendon transfer procedures for treatment of median and ulnar nerve palsy as well as combined nerve palsies. Postoperative management and potential complications are also discussed.

Keywords

Tendon transfer; paraplegia; brachial plexus; paraplegia; ulnar nerve palsy; median nerve palsy

Ulnar Nerve Palsy

Anatomy

In the arm, the ulnar nerve lies anterior to the triceps muscle. It travels through the cubital tunnel at the elbow, and then passes between the two heads of the FCU, which it innervates. As it courses distally, it lies on the volar aspect of the FDP, and innervates the FDP to the small and ring fingers. Approximately 7 cm proximal to the wrist, it gives off a dorsal sensory branch, which provides sensibility to the ulnar aspect of the dorsal hand. At the wrist, the main nerve passes into Guyon's canal along with the ulnar artery. Within Guyon's canal it divides into deep and superficial branches. The superficial branch gives sensibility to the small finger and the ulnar half of the ring finger. The deep motor branch innervates the hypothenar muscles, the ulnar two lumbricals, the interossei, the adductor pollicis, and the deep head of the flexor pollicis brevis (FPB). The most distal motor branch innervates the first dorsal interosseous. Anomalous ulnar nerve anatomy is common in the forearm and hand.¹ The Martin-Gruber connection is seen when the median nerve contributes motor fibers to the ulnar nerve in the forearm, resulting in median nerve innervation of intrinsic hand muscles.² This anomaly can

Corresponding author: Kevin C. Chung, MD, MS, Section of Plastic Surgery, University of Michigan Health System, 2130 Taubman Center, 1500 E. Medical Center Drive, Ann Arbor, MI 48109-0340, kechung@med.umich.edu, Phone: 734-936-588, Fax: 734-763-5354.

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result in intact intrinsic hand function following proximal ulnar nerve injury. The Riche-Cannieu anomaly is a connection between the motor branch of the ulnar nerve and the recurrent motor branch of the median nerve in the hand, with ulnar to median innervation.³ This anomaly can result in preservation of thenar function after median nerve injury at the wrist or more proximally.

Clinical Findings

Ulnar nerve palsy is a more devastating injury than radial nerve palsy (discussed in Part I). In both high and low ulnar nerve palsy, key pinch is lost because of absent adductor pollicis and first dorsal interosseous muscle function. Clawing occurs as a result of paralysis of the interosseous muscles in the presence of functioning extrinsic finger flexors. Clawing causes a loss of active IPJ extension and MCPJ flexion, which prevents the patient from cupping the hand around objects. In addition, integration of MCPJ and IPJ flexion is lost. In the normal hand, integrated finger flexion begins at the MCPJ powered by the intrinsic muscles, followed by flexion of all three finger joints powered by the FDP and FDS, folding the fingers smoothly into the palm. In ulnar nerve palsy, MCPJ flexion is not initiated by the intrinsic muscles, and finger flexion begins at the IPJ's, followed by late MCPJ flexion. This results in a rolling motion of the fingers, which prematurely closes them before they reach the palm, making it difficult to grasp objects. In addition to the above findings, high ulnar nerve palsy results in loss of the FCU and FDP to the ring and little fingers. This causes diminished grip strength as well as the loss of ulnar deviation with wrist flexion. A small benefit of diminished FDP function is that clawing is less severe than in low ulnar nerve palsy, in which the FDP to the ring and small fingers remains intact. Unlike radial nerve palsy, the sensory deficit in ulnar nerve palsy is clinically disabling. Protective sensation in the ulnar nerve distribution is important for preventing injury when the hand is placed in resting positions.

Special attention should be paid to the examination of the clawed hand. Bouvier's test involves passively correcting the MCPJ hyperextension, and checking for improved IPJ extension. If the patient's flexed IPJ posture improves, then Bouvier's test is positive, and the clawing is defined as simple. If the IPJ's remain flexed even after passive correction of the MCPJ hyperextension, then Bouvier's test is negative, and the clawing is defined as complex.⁴

Tendon transfer procedures

The primary goals of tendon transfer procedures for ulnar nerve palsy are restoration of small and ring finger DIPJ flexion (in cases of high ulnar nerve palsy), restoration of key pinch, correction of clawing, integration of MCPJ and IPJ flexion, and improvement in grip strength.

Restoration of small and ring finger DIPJ flexion can be achieved by adjacent suturing of their respective FDP tendons to the functioning middle finger FDP. The index finger FDP should not be included in the adjacent suturing in order to preserve its independent functioning (Figure 1). It should be remembered that clawing may become worse after ring and small finger FDP function is re-established, and corrective measures will be required.

In the normal hand, key pinch is the result of combined first dorsal interosseous and adductor pollicis function. Many different tendon transfer procedures for restoration of key pinch have been described, including the use of wrist and finger extensors, finger flexors, and the brachioradialis to power adductor pollicis function. In most cases, it is only necessary to restore adductor pollicis function in order to restore functional key pinch, because the index finger can be stabilized against the adjacent fingers during pinch. Occasionally first dorsal interosseous reconstruction is necessary in patients who require very fine use of the fingers. Even though restoration of key pinch is considered to be one of the primary goals of tendon transfer procedures in ulnar nerve palsy, it should be noted that not all patients will complain of a loss

of key pinch. This may be due to the compensatory action of the FPL, or to anomalous innervation of the adductor pollicis muscle by the median nerve. A tendon transfer procedure should only be performed if the patient perceives a deficit.

Both the ECRB (Smith)⁵ and brachioradialis (Boyes)⁶ are strong donor MTU's that can be used to restore key pinch, and that do not leave a functional deficit when harvested. They must be lengthened by tendon grafts and then passed between the 2nd and 3rd metacarpals into the palm. Here they are routed towards the thumb, using the 2nd metacarpal as a pulley, and inserted on the adductor pollicis insertion (Figure 2). The direction change that occurs at the 2nd metacarpal pulley orients the tendon along the original direction of pull of the adductor pollicis.

The ring or middle finger FDS can also be used to restore adductor pollicis function (Littler).⁷ The FDS is divided distally in the finger and is retrieved into the palm. It is then passed across the palm to the thumb, passing deep to the flexor tendons, and is inserted on the adductor pollicis insertion. The direction of pull of this transfer does not replicate that of the adductor pollicis as well as the ECRB or brachioradialis transfers do. In addition, harvest of the FDS results in weakening of grip strength. It should be noted that ring FDS transfer should only be used in patients with low ulnar nerve palsy, in whom the ring FDP is functional. The use of finger extensors such as the EDQ, the index EDC, and the EIP has also been described. These tendons can be routed a variety of ways and inserted on the adductor pollicis. These transfers are generally weak and have suboptimal vectors of pull.

Correction of clawing is another primary goal in the treatment of ulnar nerve palsy. This requires correction of MCPJ hyperextension, the problem that initiates clawing. Procedures can be categorized as static or dynamic. If Bouvier's test is positive, static procedures may be successful. Osseous blocks on the dorsum of the metacarpal head have been described.⁸ Zancolli described an MCPJ capsulodesis, in which a distally based flap of the volar plate was advanced proximally and sutured to the metacarpal neck, effectively limiting MCPJ extension.⁹ Bunnell described a partial release of the A1 and A2 pulleys to allow bowstringing of the flexor tendons.¹⁰ This results in increasing the moment arm of the flexor tendons at the MCPJ, thereby preventing MCPJ hyperextension. Static tenodesis with a tendon graft can also be performed. The tendon graft is sutured to the deep transverse intermetacarpal ligament, passed through the lumbrical canal, and sutured to the extensor apparatus or to the lateral band. This type of static tendon graft effectively limits the amount of MCPJ extension.¹¹

Dynamic tenodesis can also be performed, as popularized by Fowler and Tsuge.^{12, 13, 14} A tendon graft is looped through the extensor retinaculum at the wrist (Figure 3). The two free ends of the tendon graft are passed through the intermetacarpal spaces into the palm, along the course of the lumbricals, and out to the fingers where they are inserted to the lateral bands. When the wrist is flexed, an active tenodesis effect occurs, resulting in MCPJ flexion and IPJ extension. Both the static procedures and the active tenodesis procedure are most useful in patients with simple clawing.

There are a number of tendon transfer procedures available that provide dynamic correction of clawing, integrate MCPJ and IPJ flexion, and in some cases augment grip strength. These can be divided into superficialis transfers and transfers powered by wrist motors. In the modified Stiles-Bunnell procedure,^{10, 15} the middle finger superficialis tendon is divided distally in the finger and retrieved into the palm. It is then split into four slips. Each slip is then passed along the path of the lumbrical, volar to the deep transverse metacarpal ligament, and back into the finger, where it is inserted on the lateral band. One drawback to this procedure is that PIPJ hyperextension can occur, particularly in patients with lax joints. This is because the main flexor of the proximal phalanx, the superficialis tendon, is removed, and power is added to the extensor apparatus simultaneously. Burkhalter recommended inserting the tendon

on the proximal phalanx instead of the lateral band, thereby preventing PIPJ hyperextension.¹⁶ Zancolli described a “lasso” insertion, wherein the FDS is passed through the A1 pulley, then sutured back onto itself, resulting in improved MCPJ flexion while avoiding PIPJ hyperextension.¹⁷ An insertion into the lateral band may be preferred if Bouvier’s test is negative (clawing is complex), but it should be remembered that PIPJ hyperextension may occur. The main drawback of superficialis transfers is that although they reliably correct clawing and integrate finger flexion, they do not improve grip strength, and may even result in further weakening of an already diminished grip.

Brand, Riordan, and others described the use of wrist-level motors to treat clawing and integrate finger flexion as well as augment grip strength.^{16, 18, 19} The FCR, ECRL, ECRB, or brachioradialis may be used. These MTU’s require a free tendon graft which is split into two or four slips to pass through the intermetacarpal spaces into the corresponding lumbrical canals (Figure 4). It should be noted that if adhesions develop in the intermetacarpal space, the excursion of these transfers will be severely limited. It is important to make the opening large enough that the tendon graft can easily pass through this area. The insertion can be into the lateral band, the proximal phalanx, or the A1 or A2 pulley. The main advantage of these tendon transfer procedures over the superficialis transfers is that they improve rather than worsen grip strength. In addition, there is no great loss of function at the level of the wrist. Also, because the superficialis tendon is preserved, the transfer can be inserted on the lateral band with less chance of developing PIPJ hyperextension.

Median Nerve Palsy

Anatomy

The median nerve enters the forearm between the two heads of the PT, which it innervates, and then runs deep to the FDS. It innervates all four muscle bellies of the FDS, the FCR, and the palmaris longus (PL) muscles. About 6–8 cm distal to the medial epicondyle it gives off a deep motor branch, the anterior interosseous nerve (AIN). This branch innervates the FPL, the FDP of the index and middle fingers, and the pronator quadratus (PQ) muscles. The palmar cutaneous branch arises from the median nerve a few centimeters proximal to the wrist, and provides sensation to the radial palm. The median nerve then passes through the carpal tunnel. The recurrent motor branch innervates the thenar muscles, including the abductor pollicis brevis (APB), the opponens pollicis, and the superficial head of the FPB. The distal branches of the median nerve provide sensibility to the volar aspect of the thumb, index, middle, and radial half of the ring fingers. Short motor branches arising from the common digital nerves innervate the index and middle finger lumbricals.

Clinical Findings

Median nerve palsy is perhaps the most devastating single nerve injury of the upper extremity. Not only is there a loss of fine motor control and opposition, but sensibility is lost over the area of the hand used for precision movements and prehensile functioning. Tendon transfer procedures to restore movement may be ineffective if sensibility cannot be restored. High median nerve palsy is defined as an injury proximal to the innervation of the forearm muscles. Although PT and FCR functions are lost, forearm pronation and wrist flexion are compensated for by other muscles, and do not need to be restored. Although the FDS to all four fingers is lost, flexion is maintained in the ring and small fingers by the functioning ulnar-innervated FDP muscle bellies. However, even though ring and small finger flexion is preserved, grip strength is diminished. More importantly, there is a loss of thumb IPJ flexion and index and middle finger DIPJ flexion due to loss of the AIN innervated muscles. This results in a lack of fine motor control of the hand, which is normally provided by precise movements of the IPJ of the thumb and the IPJ’s of the index and middle fingers. In addition to these deficits, crucial

thumb opposition is lost. Low median nerve palsy, on the other hand, results in loss of thumb opposition and sensory loss only. The fact that some degree of sensory reinnervation is likely when a low median nerve injury has been repaired makes this a potentially less devastating injury than high median nerve palsy.

Tendon transfer procedures

The most devastating loss of movement following high or low median nerve injury is the loss of thumb opposition. This can be restored with an opponensplasty, or opposition transfer. Thumb opposition is a complex movement that involves palmar abduction, pronation, and flexion of the thumb metacarpal and proximal phalanx. The ideal insertion for an opposition transfer is the APB insertion. Insertion at this point most reliably causes the combination of movements that result in thumb opposition. The angle of pull should be from the location of the pisiform, because this approximates the normal direction of pull of the APB. A pulley is often necessary to create the proper line of pull. The transverse carpal ligament, the palmar fascia edge, a loop of the FCU tendon, and the FCU tendon itself have all been used as pulleys.

The superficialis opponensplasty, described by Royle in 1938,²⁰ involves dividing the ring finger FDS distally in the finger, retrieving the FDS proximal to the carpal tunnel, re-directing the tendon distally through the FPL sheath, and inserting it into the thumb. This transfer was later modified by Thompson²¹ by re-directing the tendon subcutaneously to the thumb, instead of through the FPL tendon sheath. Bunnell recommended rerouting the tendon around a looped strip of FCU to achieve a more effective line of pull.²² The main disadvantage of the superficialis opponensplasty is that it can only be used in cases of low median nerve palsy, because the FDS is paralyzed in high median nerve palsy (Figure 5).

The EIP opponensplasty, however, is available in cases of both low and high median nerve injury, and is the most commonly employed opposition transfer in high median nerve palsy (Figure 6). Although the EIP is a weak motor, it is sufficiently strong to move the thumb into opposition. The EIP is tunneled around the ulnar aspect of the wrist, routed across the palm from the level of the pisiform, and inserted on the APB. It is important to close the extensor hood of the index MCPJ after EIP harvest to prevent postoperative extension lag at the index MCPJ. Functional loss with the EIP transfer is minimal, and retraining the EIP to perform thumb opposition is not difficult.

Although the use of the palmaris longus (PL) for restoring thumb opposition was first described by Bunnell, it was popularized by Camitz.²³ Although the PL transfer effectively restores palmar abduction, the pronation and flexion components of opposition are not re-established. The primary indication for performing a Camitz transfer is to augment palmar abduction in patients who have motor loss from severe carpal tunnel syndrome. A strip of superficial palmar fascia is raised in continuity with the PL tendon to achieve enough length for the transfer. The greatest advantage of the Camitz transfer is that there is no functional loss, and it can be easily performed at the time of carpal tunnel release. The main disadvantages are that the PL is a weak motor, and that true opposition is not restored.

The Huber transfer employs the ulnar nerve-innervated abductor digiti minimi (ADM) to restore opposition.²⁴ This transfer is usually used in cases of congenital absence of the thenar muscles, and in cases where the FDS and EIP are not available. The ADM is released from its insertion, turned over 180 degrees, and inserted on the APB insertion (Figure 7). Because the entire muscle is turned over into the thenar area, this transfer provides bulk to the thenar eminence, which is cosmetically appealing in cases of thenar atrophy or congenital absence. Strength and excursion are well matched to the deficit, and the transfer is synergistic. However, the palmar abduction component of opposition is not corrected to the degree that the pronation and flexion components are. The EDQ, ECU, and ECRL can all be used to restore opposition

if the above MTU's are not available. These transfers are all routed around the ulnar border of the wrist, and across the palm subcutaneously to the thumb. In many cases, tendon grafting is required.

In cases of high median nerve injury, thumb IPJ flexion and index finger DIPJ flexion can be restored with transfer of the BR, the ECRL, or ECU. The most common transfers are BR to FPL and ECRL to index FDP. However, it should be remembered that reinnervation of the FPL and FDP is common after a high median nerve injury has been repaired. If a return of function is anticipated, an end-to-side transfer should be performed. If recovery is not expected, an end-to-end transfer results in a more direct line of pull.

In median nerve injury, the loss of sensibility is of critical importance. Complete median nerve distribution sensory loss is considered by some to be a contraindication to tendon transfer. A hand in which median nerve sensibility is present, or in which a return of sensation is expected, will have a much better outcome following the tendon transfer procedures. Although they are beyond the scope of this article, sensate flaps or sensory nerve transfers have been used prior to or following tendon transfer procedures to improve outcomes in median nerve palsy.

Combined Palsies

Combined peripheral nerve injuries are usually the result of severe trauma to the extremity, and are often associated with substantial soft tissue, vascular, and bony injuries. Multiple MTU's may be lacerated and require repair, making them unsuitable donors for tendon transfer. Loss of sensibility and proprioception is often more profound than with single nerve palsies, making reconstruction much more complicated.²⁵ In addition, because of the extensive scarring that is often present, it becomes difficult to route a tendon transfer through an unscarred bed. Outcomes are worse than with single nerve palsies, both because of the lack of donor MTU's and the severity of the associated injuries. Standardized tendon transfer procedures are often not possible and treatment must therefore be individualized. Attention to the principles of tendon transfer is more important than ever if there is to be a successful outcome. The staging and timing of multiple procedures must also be carefully thought out, and only those tendon transfer procedures that can be rehabilitated together should be performed at the same time.

The most common combined injury is a low median-ulnar palsy, usually due to laceration of the volar wrist.²⁶ This injury results in complete palmar numbness throughout the hand, fingers, and thumb. All four fingers become clawed and integration of finger flexion is lost. Key pinch and thumb opposition are also lost. In addition, the wrist extrinsic flexors have often been lacerated in the injury and have been repaired, making them unsuitable donor MTU's. Treatment requires restoration of opposition and key pinch, reintegration of MCPJ and IPJ flexion, and treatment of clawing.²⁶ Radial nerve-innervated MTU's and more proximal median and ulnar nerve-innervated MTU's (if they haven't been injured) are available donors for reconstruction. One potential reconstructive plan might include ECRB or FDS transfer for key pinch, FDS or EIP opponensplasty, and an ECRL or BR transfer to integrate finger flexion and improve clawing.

High median-ulnar nerve palsy is a less common but much more severe injury that is more difficult to treat than low median-ulnar nerve palsy. Restoration of key pinch, opposition, and simple grip are the primary reconstructive goals.²⁶ Only radial nerve innervated MTU's are available as donors. In some cases wrist fusion may be considered so that the ECRL, ECRB, and ECU can be used as donor MTU's. A potential reconstructive plan might include an ECRB, BR or EIP transfer to restore key pinch, and an ECRL to FDP transfer to restore finger flexion and grip. Clawing could be corrected with tenodesis or MCPJ volar capsulodesis. Thumb opposition might be provided by EIP, EPL, or ECU opponensplasty. Unfortunately, with this

injury the loss of sensibility is profound, and unless sensory return is expected, tendon transfer procedures probably will not be successful.

High ulnar-radial palsy requires transfers to restore both flexion and extension functions at the wrist and in the hand, and therefore reconstruction must be staged. Fortunately, median nerve sensibility in the palmar hand is intact, so tendon transfer procedures have the potential to result in functional improvement. A PT to ECRB transfer can be used to restore wrist extension, while finger and thumb extension can be achieved with an FDS transfer. Ring and small finger DIPJ flexion can be re-established with side-to-side suturing of the ring and small finger FDP's to the functioning middle finger FDP. MCPJ and IPJ integration during flexion as well as treatment of clawing can be accomplished with static procedures or with an FDS transfer. Key pinch can also be restored with an FDS transfer.²⁷

High median-radial palsy is a devastating injury that is extremely difficult to reconstruct. Unfortunately, even after multiple reconstructive operations, the hand often does not work much better than a prosthesis.²⁷ All wrist MTU's are lost except the FCU, making wrist arthrodesis necessary. The FDP tendons are usually side-to-side sutured creating simultaneous flexion, innervated by the ulnar nerve. After wrist arthrodesis, the FCU is available and can be used to power finger and thumb extension. Opposition can be restored with a Huber transfer. Thumb flexion is accomplished by FPL tenodesis. Again, loss of median nerve sensibility is a critical problem. If sensory reinnervation is not expected and another procedure cannot be performed to establish protective sensibility, tendon transfer procedures should not be attempted.

Brachial Plexopathy, Cerebral Palsy, and Tetraplegia

Brachial plexus injuries, cerebral palsy, tetraplegia, and other disabilities commonly present complex and challenging reconstructive problems. Standard tendon transfer motors are often not available for a given functional deficit in the hand. It is often necessary to use alternatives such as splinting, tenodesis, arthrodesis, nerve transfer, or free functional muscle transfer in combination with tendon transfer procedures to improve the function of the extremity.

Postoperative Management

A bulky plaster splint or cast is made in the operating room. This splint should take tension off the tendon transfer(s) performed. For example, if a transfer was performed to improve clawing, the splint should keep the MCPJ's flexed and the IPJ's extended. If an extensor MTU was used for the transfer, the wrist should be placed in thirty degrees of extension. However, if an FDS transfer was performed, the wrist should be in a more neutral position or slightly flexed. If an MTU that crosses the elbow (such as the brachioradialis) was used in the transfer, an above-elbow splint or cast should be made, keeping the elbow in ninety degrees of flexion.

The postoperative splint should be changed one to two weeks after surgery to check the incisions and re-fit the splint. At four weeks, a thermoplastic splint should be made by the occupational therapist. During these first four weeks it is important to maintain mobility in the non-immobilized joints of the upper extremity.

At four weeks, the therapist will begin mobilization. Mobilization should start with gentle active and assisted range of motion exercises. It is important to mobilize one joint at a time to prevent placing too much tension on the transfer. For example, if an ECRB transfer to treat clawing was performed, the therapist should mobilize the MCPJ's while keeping the wrist and IPJ's immobile. The patient should wear the thermoplastic splint except when doing the prescribed exercises.

During the sixth week, the therapist should add exercises that activate the muscles used in the tendon transfer, and should begin muscle retraining. Electrical stimulation and biofeedback may be used to assist with retraining. For example, neuromuscular electrical stimulation (NMES) uses a pulsating current to stimulate specific muscle bellies.²⁸ Whether NMES is capable of preventing atrophy or improving muscle strength is debated. However, it can be used to help the patient become accustomed to the transferred muscle being activated in its new location. Another commonly used modality, EMG biofeedback, is a method of giving the patient a visible or audible signal when he or she activates the transferred muscle. By attempting to control the signal, the patient learns to voluntarily activate the transferred muscle.²⁹

At eight weeks postoperatively, strengthening exercises should be initiated, and the splint can be weaned off over the next four weeks. Full activity is resumed at twelve weeks.

Complications of Tendon transfer procedures

Some potential complications that are unique to tendon transfer surgery include tendon adhesions, transfer rupture, and transfer weakness. Adhesions around the transferred tendons will invariably occur if the transfer passes through a scarred or inflamed tissue bed. Adhesions frequently complicate multiple simultaneous tendon transfer procedures, particularly if one transferred tendon passes over or adjacent to another tendon. They can also occur following a postoperative infection. If adhesions develop, management should begin with aggressive hand therapy. Tenolysis sometimes is necessary, but should not be carried out until tissue equilibrium has again been reached following the transfer. During this waiting period, it is crucial to continue therapy to maintain passive mobility of the joints. Within 24 hours of performing tenolysis, aggressive active and passive mobilization should begin. Tendon rupture is unusual, but can occur, particularly if postoperative immobilization is inadequate, or if the transfer is set under excess tension. Once the rupture is recognized, the patient should return to the operating room as soon as possible for repair.

Occasionally, a tendon transfer turns out to be too weak to be effective. This is usually due to poor preoperative planning, such as choosing a donor MTU that has a poor strength match with the muscle that is being replaced, or because an atrophied or injured donor MTU was used. Sometimes, however, the problem occurs because the transfer was set at inadequate tension or because the moment arm was not great enough. It is difficult to precisely determine the cause of inadequate strength postoperatively. However, if the donor MTU was healthy and appropriate for the transfer, it may be necessary to return to the operating room to reset the tension of the transfer, or to increase the moment arm by moving the insertion further from the joint axis of rotation. Occasionally, weakness can occur if the transfer is set under too much tension. In most cases this problem will resolve spontaneously with time as the transferred MTU elongates.

Questions

1. Which of the following tendons is not suitable for opponensplasty in high median nerve palsy? (THE ANSWER IS D)
 - a. EIP
 - b. EDQ
 - c. EPB
 - d. FDS ring finger
 - e. Hypothenar muscles

2. In high median nerve palsy, which of the following tendons is still functional? (THE ANSWER IS A)
 - a. FDP to the ring finger
 - b. FDS to the ring finger
 - c. FDS to the index finger
 - d. FPL
 - e. PL
3. For a patient with low ulnar nerve palsy who is able to extend the PIP joint when checking the MCP joint at 90 degrees, the most appropriate treatment is? (THE ANSWER IS A)
 - a. MCP volar capsulodesis
 - b. fusion of PIP joint
 - c. FDS to FDP transfer
 - d. EIP transfer
 - e. Adjacent FDP tendon suturing
4. Which is a finding of ulnar nerve palsy? (THE ANSWER IS E)
 - a. Weak opposition
 - b. Loss of index finger DIP flexion
 - c. Inability to perform planar abduction of the thumb
 - d. Loss of cutaneous sensibility of the middle finger
 - e. Weak key pinch
5. If clawing is simple (Bouvier's test is positive), which of the following is true? (THE ANSWER IS A)
 - a. The ability to extend the IP joints will improve when the MCPJ is passively flexed
 - b. The ability to extend the IP joints will worsen when the MCPJ is passively flexed
 - c. IPJ extension will not change when the MCPJ is passively flexed
 - d. Passive extension of the wrist results in improved MCPJ flexion
 - e. Passive IPJ extension results in improved MCPJ flexion
6. High ulnar nerve palsy results in (THE ANSWER IS D)
 - a. Worse clawing than low ulnar nerve palsy
 - b. The same degree of clawing as low ulnar nerve palsy
 - c. Clawing primarily in the index and middle fingers
 - d. Less clawing than low ulnar nerve palsy
 - e. An inability to extend the wrist
7. The Zancolli "lasso" wraps around the (THE ANSWER IS E)

- a. A4 pulley
 - b. The proximal phalanx through a drill-hole
 - c. The radial lateral band
 - d. The extensor apparatus
 - e. The A1 pulley
8. The median nerve does not innervate which muscle? (THE ANSWER IS C)
- a. The FDS
 - b. The index and middle finger FDP
 - c. The adductor pollicis
 - d. The opponens pollicis
 - e. The flexor pollicis brevis
9. The Huber opposition transfer is most often used in the setting of (THE ANSWER IS A)
- a. Congenital absence of the thenar muscles
 - b. Weakness of opposition in carpal tunnel syndrome
 - c. Proximal laceration of the median nerve
 - d. Absence of the palmaris longus
 - e. Absence of the hypothenar muscles
10. Outcomes in low median nerve palsy are better than in high median nerve palsy primarily because of which of the following? (THE ANSWER IS B)
- a. Loss of thumb opposition is less common with low median nerve palsy
 - b. Sensibility is more likely to return after nerve repair in low median nerve palsy
 - c. High median nerve injury is usually due to high energy trauma
 - d. The middle finger FDP is usually not involved in low median nerve palsy
 - e. Sensibility is not usually lost when the median nerve is injured more distally

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Figure 1.
Adjacent suturing of ring and small finger FDP to middle finger FDP for restoration of DIP flexion in ulnar palsy.

Figure 2.
ECRB (with tendon graft) transfer to adductor pollicis insertion for restoration of key pinch in ulnar palsy.

Figure 3.
Dynamic tenodesis with tendon graft for correction of clawing.

Figure 4.
ECRB transfer (extended with tendon graft to all four fingers) for correction of clawing.

Figure 5. Superficialis opponensplasty using ring finger FDS for restoration of opposition in low median nerve palsy.

Figure 6.
EIP opponensplasty for restoration of opposition in high median nerve palsy.

Figure 7.
Exposure of abductor digiti minimi for use in Huber transfer.

CPT codes commonly used for tendon transfers in median and ulnar nerve palsy

CPT CODE	DESCRIPTOR
25310	Tendon transplantation or transfer, flexor or extensor, forearm and/or wrist, single; each tendon
25312	Tendon transplantation or transfer, flexor or extensor, forearm and/or wrist, single; with tendon graft(s) (includes obtaining graft), each tendon
26471	Tenodesis; of proximal interphalangeal joint, each joint
26474	Tenodesis; of distal joint, each joint
26480	Tendon transplantation or transfer, carpometacarpal area or dorsum of hand; without free graft, each tendon
26483	Tendon transplantation or transfer, carpometacarpal area or dorsum of hand; with free tendon graft (includes obtaining graft), each tendon
26485	Transfer or transplant of tendon, palmar; without free tendon graft, each tendon
26489	Transfer or transplant of tendon, palmar; with free tendon graft (includes obtaining graft), each tendon
26490	Opponensplasty; superficialis tendon transfer type, each tendon
26492	Opponensplasty; tendon transfer with graft (includes obtaining graft), each tendon
26494	Opponensplasty; hypothenar muscle transfer
26496	Opponensplasty; other methods
26497	Transfer of tendon to restore intrinsic function; ring and small finger
26498	Transfer of tendon to restore intrinsic function; all four fingers
26499	Correction claw finger, other methods
26516	Capsulodesis, metacarpophalangeal joint; single digit
26517	Capsulodesis, metacarpophalangeal joint; 2 digits
26518	Capsulodesis, metacarpophalangeal joint; 3 or 4 digits