Chapter 16
Tendon Transfers for Digital Deformities and Hammertoes

Lawrence A. DiDomenico, Frank A. Luckino III, and Danielle N. Butto

Presentation/History

Digital deformities may present in a variety of forms. Mallet toe, hammertoe, claw toe, and curly toe deformities have all been described [1]. Shoe gear, genetics, neuromuscular imbalances, inflammatory arthritis, and trauma have all been shown to be potential causes [1–3]. Though most of the literature would point to a biomechanical imbalance between the extrinsic and intrinsic musculature, three categories have been described for classification of digital deformities: flexor stabilization, flexor substitution, and extensor substitution [4].

Mallet toe is a flexion contracture in the sagittal plane of the distal phalanx on the middle phalanx at the distal interphalangeal joint (DIPJ). The deformities are usually fixed; however, they can present as flexible or semirigid too. Pain is caused due to repetitive trauma of the distal toe hitting the ground or the irritation to the dorm of distal interphalangeal joint. This trauma can cause a distal toe callus and/or ulceration with an associated bursitis to the interphalangeal joint. Correction of a mallet toe is achieved by removal of the deforming flexor digitorum longus tendon force [5] and releasing the interphalangeal contracture if needed.

L. A. DiDomenico (✉)
Department of Surgery, St. Elizabeth Health Center, Youngstown, OH, USA

Northside Medical Center, Youngstown, OH, USA

F. A. Luckino III
Northeast Ohio Foot and Ankle Specialists, Canton, OH, USA

Mercy Medical Center, Canton, OH, USA

D. N. Butto
Trinity Health of New England Medical Group, Hartford, CT, USA

Saint Francis Hospital, Hartford, CT, USA

E. A. Cook, J. J. Cook (eds.), *Hammertoes*,
https://doi.org/10.1007/978-3-319-16552-3_16

A hammertoe is a deformity which is typically associated with a contracture in the sagittal plane at the proximal interphalangeal joint (PIPJ). This deformity can have a component of transverse and frontal plane deformity too. The middle phalanx is plantarflexed on the proximal phalanx. The deformity sometimes involves a dorsal contracture at the metatarsophalangeal joint. The distal interphalangeal joint is in either a flexed, extended, or neutral position [6]. A dorsal, painful callus or ulceration is often present over the PIPJ.

A curly toe is characterized by a flexion contracture, internal rotation, and varus deformity of the interphalangeal joints of the affected toes. Curly toe deformities are often seen in pediatric patients [7]. On the other hand, an adductovarus deformity occurs at the proximal interphalangeal joint in the frontal and sagittal planes. The deformity commonly occurs with a pronated foot type. The quadratus plantae loses its normal vector pull. The direction of pull is shifted medially, therefore creating a varus and adductus pull on the digit [8].

The crossover hammertoe presents with pain and swelling at the plantar aspect of the metatarsophalangeal joint capsule. As the deformity progresses, the proximal phalanx hyperextends and deviates in a coronal or sagittal plane and usually crosses over the great toe. The second digit is the most common digit affected [9]. The plantar plate is often ruptured in this deformity.

A heloma dura can be present at either the proximal interphalangeal joint or distal interphalangeal joint. When present on the lateral nail fold, the lesion is called a Lister's corn. An interdigital heloma molle develops because of the malalignment of the toes associated with deformity resulting in increased pressure between the lateral aspect of the base of the fourth digit proximal phalanx and the medial aspect of the head of the fifth digit proximal phalanx. The etiology is secondary to malalignment of an enlarged or deformed distal, middle, or proximal phalanx [8].

A claw toe is characterized by hyperextension of the MTP joint and flexion of the PIP and DIP joint. With a claw toe, there may be an associated callosity beneath the involved head of the metatarsal, overlying the PIP joint, and even at the tip of the toe [10].

Each of the types of hammertoes can be associated with pain, soft tissue irritation, and callus formation than can lead to ulceration. In addition, when a hammertoe deformity is present and there is a dorsal contracture at the metatarsalphalangeal joint causing retrograde pressure, there is a significant increase in plantar pressure present at the metatarsal head and a distal displacement in the fat pad which can lead to pain, soft tissue changes, callus formation, and ulceration [11].

It is important to identify the underlying cause of the hammertoe deformity. Flexor stabilization typically occurs in a pronated foot type. As the foot pronates, the flexor digitorum longus fires earlier in the gait cycle gaining a mechanical advantage over the interossei muscles. An adductovarus rotation of the fourth and/or fifth digit is typically present [12, 13]. Flexor substitution is often associated with a weak triceps surae. The deep posterior group musculature overpowers to accommodate for the weak triceps surae. The flexors gain an advantage over the interossei [12].

Extensor substitution occurs in the swing phase of gait with the long extensors gaining a mechanical advantage over the lumbricals [12]. Generally there is contracture at the metatarsalphalangeal joint level with bowstringing of the extensor tendons [13]. Neuromuscular disorders such as Charcot-Marie-Tooth (CMT), poliomyelitis, muscular dystrophies, and lumbar disc disease may lead to contractures at the metatarsophalangeal and interphalangeal joints (IPJ) of the lesser digits [2] manifesting most commonly as a claw toe deformity. A high-arched, cavus foot type is often exhibited with this type of deformity as well [14]. Hibbs originally termed this foot type a “claw foot” where there are high arch, plantar calluses, and prominent metatarsal heads secondary to the digital deformities [15]. Though this type of digital contracture is typically seen in patients with neuromuscular disease [16], it can be seen in a flatfoot deformity, as well as rheumatoid and diabetic patients [4].

A thorough history from the patient is crucial. Patients may relate a positive family history of a high-arched foot type with neuropathic type symptoms. Muscle weakness with complaints of a foot drop with tripping or instability with gait may be present [17]. A patient may describe difficulty with shoe gear secondary to prominences at the dorsal and proximal IPJs. Callus formation secondary to prominent metatarsal heads leads to metatarsalgia as a common complaint [14, 16].

Diagnosis/Assessment

A thorough weight-bearing and non-weight-bearing exam, as well as gait analysis, should be performed on all patients. One should employ the Silfverskiold test to assess for underlying equinus deformity. Next, the overall foot type should be classified, and attention is then drawn to the digital deformity or deformities. The involved toes should be evaluated in the sagittal, transverse, and frontal plane. One should determine whether the deformity is flexible, semirigid, or rigid. A push-up test as described by Kelikian with plantar pressure applied at the metatarsalphalangeal joint (MTPJ) will allow one to determine the flexibility of the deformity [14]. Long-standing deformities may lead to dislocation at the level of the MTPJ. The Lachman test can be employed to assess for pathology at the metatarsalphalangeal joint. With the metatarsal immobilized and proximal phalanx held in 20–25° of dorsiflexion, the proximal phalanx is translated vertically. A positive test is greater than 2 mm of dorsal displacement or 50% subluxation to the vertical height of the metatarsal head [18].

Standard, three-view radiographs should be evaluated. The anterior-posterior projection is utilized to assess transverse and sagittal plane deformity [13]. The “gun-barrel sign” is a hallmark of sagittal plane deformity as one visualizes the medullary canal of the middle phalanx [13, 14]. The lateral view clearly demonstrates sagittal plane pathology.

In deformities where pathology of the plantar plate is in question, an MRI can be ordered for further evaluation. On T1-weighted images, the plantar plate is seen as a continuous low-signal structure. On gradient-echo images, the plantar plate is slightly hyperintense from the flexor tendons. In plantar plate rupture, the signal is higher in intensity and more widespread, extending beyond the immediate area of the plate attachment on the proximal phalangeal base. Proximal-to-distal continuity of the plate is lost and the rupture is isointense with synovium and joint fluid. Associated findings include MTPJ synovitis and synovitis or effusion in the flexor tendon sheath [19].

In order to understand the disease process, one must have a sound understanding of the anatomy. The MTPJ, PIPJ, and DIPJ are stabilized by collateral ligaments obliquely on either side of the joint. Plantar stability is provided by the plantar plate, a thick fibrocartilaginous structure that prevents dorsal subluxation of the digit at the MTPJ level [13]. The extensor digitorum longus tendon acts as a dorsiflexor of the ankle through the swing phase of gait. The tendon splits once it passes the ankle into four separate slips which insert on the dorsal aspect of the middle and distal phalanges of digits 2–5. The extensor digitorum brevis tendon has three separate slips to digits 2, 3, and 4 and inserts at the extensor expansion of the corresponding EDL tendon. The extensor expansion has attachments plantarly with the capsule, plantar plate, and flexor tendon sheath at the level of the MTPJ. Therefore, the pull of EDL and EDB causes significant dorsiflexory power at the level of the MTPJs and minimal at the IPJs. The flexor digitorum brevis originates at the medial calcaneal tuberosity. It courses distally and splits into two slips that attach to the plantar aspect of middle phalanx. The flexor digitorum longus originates in the posterior compartment of the leg and courses to the digits through the split in FDB tendon to insert on the distal phalanx.

When non-weight-bearing, the long flexor flexes the MTPJ and IPJ. During weight-bearing, the long flexor tendon will pull the distal phalanx proximally, buckling the toe. In a weight-bearing situation, firing of the long flexor alone will produce a claw toe, while pull of the long and short flexors will recreate a true hammertoe [13].

With extensor substitution typically presenting in a neuromuscular disease patient, such as CMT or polio/post-polio, a thorough neuromuscular exam is paramount. The pathomechanics of CMT is well documented; however, this may not correlate with nonprogressive causes for the cavus foot type. Typically in the CMT population, the disease process begins with atrophy of the intrinsic musculature. With loss of stability of the lumbricales at the level of the MTPJ, there is unopposed pull of the long extensor tendons and the long flexor tendons. This causes extension at the MTPJ and flexion of the phalanges. Subsequently, there is a generalized weakness of the tibialis anterior tendon as well as the peroneus brevis tendon. The muscle strength to the long flexors and peroneus longus is preserved. The weakness in the anterior compartment requires the extensor digitorum longus (EDL) tendon to compensate for the lack of dorsiflexion at the level of the ankle. This further exacerbates the hyperextension, hammertoe contracture [20].

DM and RA Foot Types Similar to CMT

The long extensor to the hallux will cause a similar deformity at the great toe as seen in the lesser digits [20]. In Hibbs' original description, he felt there were two concerns that needed to be addressed surgically. First, correction of what he called an "exaggerated arch" and secondly removal of the extensor overpowering to the digits. The former could be corrected through a Steindler stripping and latter correction achieved by the release of the long extensor tendons and transfer of the proximal portion to the lateral cuneiform [15].

Before surgery is being considered for any type of digital contracture, vascular status must always be assessed. Should there be a concern, noninvasive vascular studies with digital pressures and/or toe-brachial indices (TBIs) can be ordered. Further neurologic workup may include an electromyographic (EMG) or a nerve conduction velocity (NCV) study. If the foot deformities have been progressive versus static, this should prompt a more in-depth workup by a neurologist [21].

In preparing the patient for surgery, the surgeon should educate the patient that the digital deformity is a chronic soft tissue pathologic process that has occurred because of tendon imbalance and secondary soft tissue contractures at each segment of the involved joint/joints of the proximal, middle, and distal phalanx. Although the digit as an entity may present as a deformity, each separate segment (proximal, middle, and distal phalanx) does not exhibit any bony pathology. The goal for a successful outcome is to balance the toe and "weaken" the overpowering tendon and "strengthen" the weaker tendon pull to balance the toe. Essentially, the surgeon is removing the deforming soft tissue attachments from the toe, placing the toe in the desired position and then rebuilding the attachments to the toe with tendon transfers under physiologic tension to improve digital alignment and function. The end result should provide a stabile, neutrally placed toe with some weakening in one part of the toe and some strengthening in another part of the toe.

Treatment/Surgical Technique

The Modified Girdlestone–Taylor Procedure (Flexor Digitorum Longus Transfer)

The modified Girdlestone-Taylor procedure is used to treat flexion contractures of the distal interphalangeal joint and/or proximal interphalangeal joint. One can perform the procedure through a midline incision approach on the lateral aspect of the hallux and the medial or lateral aspect of the second, third, and fourth toes and the medial aspect of the fifth toes. By placing the incision on the lateral aspect of the hallux and the medial aspect of the fifth toe, this provides a good location for cosmetic purposes.

It is recommended that one use fine double skin hooks for retraction in order to avoid soft tissue compromise. Deepen the incisions in the same plane being careful to avoid the neurovascular bundles. The dissection is carried to the plantar aspect of the soft tissues of the respective toe. Identify the flexor digitorum longus and trace it distally to its attachment to the distal phalanx. Detach the distal aspect of the flexor digitorum longus, clamp with an Allis clamp, and retrieve proximally within the wound to the web space.

Next, attention is directed to the flexor digitorum brevis tendon. Detach (both the medial and lateral slips) of the tendon from the base of the middle phalanx. A capsulotomy at the interphalangeal joint (for a flexion contracture of the proximal interphalangeal joint) and/or the distal interphalangeal joint is performed allowing the contracture to be reduced.

A K-wire (preferably 0.062 inches) is inserted from the distal tip of the distal phalanx to the base of the proximal phalanx. It has been the authors' experience to be cautious not to overcorrect the flexion contracture by placing the distal interphalangeal joint and the proximal interphalangeal joint into a neutral or extended position and to place it into a neutral to slight plantar flexion position. If an isolated flexor digitorum longus tendon transfer is being performed, there should not be a contracture at the metatarsalphalangeal joint; therefore, there is no need to pin across the metatarsalphalangeal joint with the K-wire. Next, while the toe is held in anatomical alignment and held into the desired position, the flexor digitorum longus tendon is transferred and sutured into the extensor soft tissue (extensor hood) of the proximal phalanx under physiologic tension. The excess tendon of the flexor digitorum longus is resected and the skin is lightly re-approximated with typical skin closure.

Advantages: With the scars located on the lateral aspect of the hallux and the medial or lateral aspect of the second, third, and fourth toes and the medial aspect of the fifth toe, the procedure leaves a much more cosmetic pleasing result. Additionally, by performing the flexor digitorum longus transfer, this removes the pathologic sagittal plane force as well as any additional pathological pull in the frontal and transverse plane allowing the toe to be placed in a neutral position. Postoperatively, there is a much more natural clinical look in terms of the length of the toe. The digits retain stability in the transverse and frontal plane as the medial and lateral collateral ligaments are left intact. The toe is not shortened as there is no bone resection. There is minimal postoperative edema since all the directions consist of soft tissue only and there is no bony involvement which often occurs with bony procedures. Any resulting bursa, hyperkeratosis, and ulceration eventually dissipate as the deforming forces are removed and relieve the pressures.

Since there is no surgery on the bony structures, there is no rotation, shifting, malalignment, or shortening of the digits. The tendon transfer treats the underlying pathology, the dynamic/static deforming force of the tendon, therefore, eliminating the need to disturb the natural osseous structures of the three phalanxes. Postoperatively, the K-wire is removed at approximately 7–10 days based on the patients' preoperative deformity. Lastly, if a problem would occur postoperatively, one could always perform a bony procedure if necessary.

Disadvantages: In terms of disadvantages, this is a more technically challenging surgical procedure in terms of dissection. The approach makes for a difficult space to work between toes. While possible complications are similar to those with any other digital surgery, more unique complications to this procedure consist of overcorrection or hyperextension leading to a recurvatum deformity of the corrected joints, maceration, and wound issues of the incision sites secondary to interdigital contact.

The Modified Hibbs Procedure (Extensor Tendon Transfers)

The modified Hibbs procedure is indicated for patients who exhibit extensor substitution/recruitment. Dorsal subluxations/dislocations at the metatarsalphalangeal joints are frequently linked with claw toes and hammertoes. These deformities typically result with the recruitment of a tight extensor digitorum longus (extensor substitution/recruitment) to support dorsiflexion against a tight posterior muscle group (equinus contracture).

For treating hammertoes 2–5, beginning at the second metatarsalphalangeal joint, make an oblique dorsal incision proximal to the base of the fourth metatarsal. Deepen this incision in the same plane and avoid all neurovascular structures. Be sure to avoid and preserve the superficial nerves in the subcutaneous tissues as these will be running longitudinally. Great care of the soft tissue is essential, and fine double skin hooks are recommended for retraction in order to avoid soft tissue compromise. Identify the extensor tendons (extensor digitorum longus and brevis) and separate only these tendons from the subcutaneous tissues. There is no need to dissect any other tissues other than separating the soft tissues from the extensor digitorum longus and brevis tendon. The extensor digitorum longus and brevis tendons lie deep to the superficial nerves. The surgeon should separate and track the extensor tendons longitudinally. Isolate the second, third, and fourth extensor digitorum longus tendons, respectively, and cut these tendons as far proximal within the incision site. Clamp each one of the most distal aspect of the proximal portion of the cut extensor digitorum longus with a small mosquito hemostat. Clamp the most proximal aspect of the distal cut portion of the extensor digitorum longus tendon with an Allis clamp. The distal cut portions of the extensor digitorum longus tendons are then reflected from the remaining soft tissues as far distally within the incision site and retracted out of the way. The distal portion of the second extensor digitorum longus tendon is reflected distally and temporarily placed in the first web space of the foot. The third extensor digitorum longus tendon is placed similarly in the second web space, and the fourth extensor digitorum longus tendon is placed in third web space. The fifth extensor digitorum longus tendon is identified, and a Z-lengthening procedure is performed allowing the tension and contracture to be released from the fifth extensor digitorum longus tendon.

Attention is directed to the second, third, and fourth metatarsalphalangeal joints as far distal in the incision site. The second, third, and fourth extensor digitorum brevis tendon is traced as far distal within the incision site, and a tenotomy is performed as far distal as possible. An Allis clamp is applied to most proximal portion of the cut second, third, and fourth extensor digitorum brevis tendons, and these tendons are retracted proximal. At this time, complete exposure of the metatarsalphalangeal joint is achieved. A capsulotomy at the second, third, fourth, and fifth metatarsalphalangeal joints is completed. This facilitates release of all contractures via sharp and blunt dissection and/or the use of a McGlamry elevator. Following this release, the surgeon should realize that all the soft tissue deforming forces have now been removed and the digits should naturally revert to a "neutral position."

In most scenarios, when a digit involves the extension contracture, there is also a flexion component in the deformity. In deformities which exhibit both flexion and extension deformities, additional soft tissue procedures need to be performed to address flexion contractures of the second, third, fourth, and fifth digits (flexor tendon transfers). The flexor tendon transfer is then performed at each toe. Once this is accomplished, insert a 0.062 K-wire from the distal aspect of the toes through the distal interphalangeal joint, the proximal interphalangeal joint, and the metatarsophalangeal joint to the base of the second, third, fourth, and fifth metatarsals. Ensure there is good anatomical alignment of the toe relative to the metatarsal. Be sure the distal interphalangeal joint, the proximal interphalangeal joint, and the metatarsophalangeal joints are maintained and the toe is in the desired position.

Next, proceed to back to the dorm of the foot and perform a tendon transfer (a weave graft) of the distal stump of the proximal extensor digitorum brevis into the most proximal portion of the distal extensor digitorum longus stump of digits 2, 3, and 4 under physiologic tension. This tendon transfer will essentially weaken the extensor pull of the respected toes. Suture the Z-lengthened fifth extensor digitorum longus with physiologic tension while maintaining good anatomic alignment. Next, pass the distal stumps of the proximal portion of the second and third extensor digitorum longus tendons deep to the soft tissue structure (to avoid pressure on the neurovascular structures)with the fourth extensor digitorum longus. Suture together the distal stumps of the proximal portion (we typically use 0 Vicryl) of the second, third, and fourth extensor digitorum longus tendons, and transfer them into the peroneus tertius or the periosteum of the intermediate cuneiform with the surgical assistant loading the ankle at 90° relative to the leg. Again, this tendon transfer should be executed under physiologic tension. This method facilitates a mechanical gain in dorsiflexion. We typically close the deep subcutaneous tissues with 4-0 Monocryl. Be sure to avoid the superficial neurovascular structures. Close the skin using 4-0 Prolene. Following K-wire removal, one should emphasize physical therapy for the patient in order to help resolve any edema and soften the postoperative fibrosis and scar tissue formation. Emphasize active and passive manipulation of the joints that underwent surgery. Typically one instructs patients about home exercise programs they can use to maintain plantarflexion and dorsiflexion at the surgical sites.

In scenarios that involve the great toe individually or in combination, the same decision and principle should be maintained.

A key component to performing tendon transfer for the correction of digital deformities is identifying which procedure to perform for the given pathology. Most digit deformities are associated with an abnormal pull and biomechanics of the short and long flexors and extensors that have caused the toe or multiple toes to deform. The goal of the surgery must balance the flexors and extensors in order to prevent recurrence or continued progression of the deformity. Once the surgeon removes the deforming force, a recurrence should not occur. If the surgeon appropriately addresses the multiplanar digital deformity, he or she should be able to correct the toe in all planes.

A modified Girdlestone-Taylor procedure can transfer the flexor digitorum longus tendon to the extensor hood of the proximal phalanx. The modified Hibbs procedure can decrease the extensor tendon retrograde buckling on the respected metatarsal in the sagittal plane. Furthermore, this release will assist the surgeon to mobilize the respected toes out of frontal and transverse plane deformities while providing excellent exposure to the metatarsophalangeal joint.

Making a sound decision in which procedure or combination of surgical procedures (flexor tendon transfer and/or extensor tendon transfer) to perform is paramount. The foot and ankle surgeon must be able to identify the appropriate pathological process in order to perform the proper surgical procedure to address given underlying pathology. Digital deformities present in many ways. The pathology can present to an isolated joint of a toe, multiple joints of a toe, a single toe, and multiple toes, bilaterally, and can also involve other components of pathology such as an equinus contracture; metatarsals deformities; systemic diseases such as rheumatoid arthritis, diabetes mellitus, polio, and Charcot-Marie-Tooth disease; and other neuromuscular diseases.

For example, a patient may present with heloma dura at the lateral aspect of proximal interphalangeal joint of the fifth toe (often referred to as a "HD5"). Often times, this deformity can present with a flexion contracture at the proximal interphalangeal joint and/or distal interphalangeal joint. In addition, a varus rotation and a transverse pull medially can be involved. In presentations such as this, there is no extensor pathological process involved; therefore, the surgeon would need to make the decision to address this three-plane deformity involving only the flexion contracture. In a scenario such as this, the surgeon would proceed with a flexor digitorum longus tendon transfer to the extensor hood of the proximal phalanx. This will remove the deforming force of the flexion contracture plantarly, the medial and transverse pull, as well as the frontal plane rotation. The flexor digitorum brevis (both the medial and lateral) insertion is removed from the base of the middle phalanx; a capsulotomy is performed at the contracted joints (DIPJ and/or PIPJ) essentially removing the remaining sagittal plane (flexion) deforming forces. This allows each segment of the toe to realign into a neutral position. Next a K-wire is used to stabilize the DIPJ and PIPJ. The surgeon should attempt to insert the K-wire from the distal tip of the distal phalanx to the base of the proximal aspect of the proximal phalanx keeping the joints in a neutral to slight plantar flexion. Once the toe is fixated and positioned in the desired position, the tendon transfer should be completed under physiological tension.

In another scenario, a patient may present with an isolated second digit crossover hammertoe and plantar plate tear. Typically this involves a three-plane deformity involving both the extensor and flexor tendons along with associated soft tissue contractures at the metatarsalphalangeal joint, at the proximal interphalangeal joint, and possibly at the distal interphalangeal joint. The surgeon would address this case with an isolated extensor tendon transfer, a complete metatarsalphalangeal joint capsulotomy, and flexion tendon transfer. By completing this, all deforming forces are removed from the respected deformed toe, and the toe should be able to be placed in the neutral position. Remember, there is no bony pathology to any segment of the proximal, middle, and distal phalanx in digital deformities – the digits are deformed because of the soft tissue contractures and malalignment that occur secondary to chronic abnormal biomechanical pull from the tendon imbalance. Once the surgeon has adequately reduced the deforming forces, the toe should be able to retain a neutral position. A K-wire is inserted from the distal aspect of the distal phalanx across the DIPJ, PIPJ (maintaining a neutral-slight plantar flexion position) across the metatarsalphalangeal joint and into the base of the metatarsal. Once the surgeon identifies the "new neutral desired position," then the appropriate tendon transfers are performed under physiologic tension so that the new insertion of the tendons on the toes provides adequate function to each component of the toe.

When performing a modified Hibbs procedure for an isolated crossover hammertoe, one can make an incision that is approximately 2–3 cm. Begin the incision at the second metatarsalphalangeal joint, and direct it proximal and lateral parallel to the long extensor tendon. Deepen the incision in the same plane to the level of the extensor digitorum longus tendon. Lateral to the extensor digitorum longus tendon lies the smaller extensor digitorum brevis tendon. Transect the extensor digitorum longus as far as proximal in the incision site, and transect the extensor digitorum brevis as far as distal in the incision site. At this time, one can appreciate fantastic exposure to the second metatarsalphalangeal joint. The exposure of the metatarsalphalangeal joint will allow the surgeon to perform a complete release of the contracted and fibrous/deformed capsular tissue, essentially removing all deforming forces of the metatarsalphalangeal joint. This facilitates the release of all contractures via sharp and a blunt dissection using a McGlamry elevator, which allows for anatomic restoration of the metatarsalphalangeal joint. At this time, the toe should be relaxed into a neutral “limp position” as all the deforming forces of the second metatarsalphalangeal joint are gone.

Next, attention is directed to the medial aspect of the second digit where one can perform a modified Girdlestone-Taylor procedure. Use a midline incision approach on the medial aspect of the toe. We recommend that the surgeon use fine double-prong skin hooks for retraction in order to avoid soft tissue compromise. Then deepen the incision in the same plane, taking care to avoid the neurovascular bundles. Carry the incision deep to identify the flexor digitorum longus and trace it distally to its insertion of the distal phalanx. Detach the distal insertion of the flexor digitorum longus from the distal phalanx and direct it proximal to the web space. Proceed to direct the attention to the flexor digitorum brevis tendon where a release (both the medial and lateral slips) of the flexor digitorum brevis from the base of the middle phalanx and capsulotomy at the interphalangeal joint (for a flexion contracture of the proximal interphalangeal joint) is done. If the distal interphalangeal joint is contracted, perform a capsulotomy there as well. At this time, the deforming forces are removed from the appropriate joints. The surgeon can place the second toe into the desired anatomic position and insert a 0.062-inch Kirschner wire to stabilize and align the digit in the corrected position. Insert the K-wire from the distal tip of the distal phalanx to the base of the second metatarsal. With all the deforming forces gone and the digit in the desired anatomic position (in relation to the metatarsal), suture the flexor digitorum longus to the extensor hood under physiologic tension. It is imperative to suture this under physiologic tension as this tendon transfer will assist the lumbricales with plantarflexion and allow the toe to purchase the ground postoperatively.

Direct attention back to the dorsum of the second metatarsalphalangeal joint, and transfer the distal stump of the proximal end of the extensor digitorum brevis tendon into the proximal end of the distal stump of the extensor digitorum longus tendon via a weave graft under physiologic tension. Again, it is important to do this under physiologic tension in order to allow for the extensor digitorum brevis to dorsiflex the toe. Essentially, the modified Hibbs procedure allows the patient to maintain dorsiflexion of the toe but essentially "weakens" the dorsiflexor of the second digit. The modified Hibbs procedure is indicated for patients who exhibit isolated extensor substitution/recruitment or global extensor substitution/recruitment to the forefoot. Dorsal subluxations/dislocations at the metatarsalphalangeal joint are frequently linked with claw toes and hammertoes, including the crossover toe variety.

In scenarios when patients present with global deformities of all toes, the respected procedures can be done for each involved segment. Again, these procedures can be performed on isolated individual toes or multiple toes. Each segment of each toe needs to be appropriately assessed.

Outcomes/Case Resolutions

The flexor tendon transfer is reported as the most consistent and successful treatment in eliminating pain and normal function of the MTPJ [18]. Flexor tendon transfers were first described in the literature by Taylor in 1940 and Girdlestone in 1947. The objective of the procedure is to allow the long flexor to substitute for intrinsic muscle weakness and provide plantarflexion of the digit along with releasing the plantar contracture at the distal digit allowing extension of the IPJ [22].

Bhatia et al. validated the flexor tendons ability to stabilize the digit at the MTPJ level in their biomechanical study [18, 23].

In a caderveric study by Ford et al. in 1998, it was found that transfer of the FDL stabilized the second MPJ similarly to a primary plantar plate repair. In addition, this stabilization was found to be similar to the stability provided by an intact plantar plate [18].

A finite element analysis of the FDL transfer revealed that the tendon transfer achieves a strong and sufficient reduction in the dorsal placement proximal phalanx [24].

Boyer and DeOrio treated both flexible and rigid hammertoe deformities utilizing the flexor tendon transfer with K-wire fixation. They reported an 89% success rate with no postoperative floating toe [25].

Gadzag and Cracchiolo reported success with the flexor tendon transfer is treating instability of the second metatarsophalangeal joint in 11/18 patients. All of their patients achieved postoperative stability and had complete relief of pain [26].

It has been almost 100 years since Hibbs' original description, which involved release of all soft tissue structures from the plantar heel and release of the long extensors with transfer to the lateral cuneiform. Hibbs reported no complications with the 25 operations that were performed [15]. This was a common procedure in the 1970s; however, it fell out of favor secondary to postoperative complications. According to Ruch, complications included flail lesser digits and flexor contractures at the distal IPJ. There was also little improvement in forefoot equinus visualized following the procedure [27, 28]. There have been some modifications of the procedure since that time [12].

Brody and Grumbine reported on 30 patients over a 3.5 year period that were treated with a combination of extensor transfers and peroneus tertius reconstruction for flexible claw toe deformities. Good to excellent results were reported in 28/30 patients, or 93.3%. Complications reported included pain, swelling, numbness, infection, and scarring [29].

Boffeli et al. recently reported on early minimally invasive techniques for CMT disease. In contrast to our technique, Boffeli describes the long extensor transfer being performed through a separate 3 cm longitudinal incision. The EDL tendons were bundled together and then transferred to the lateral cuneiform with an interference screw. It was noted for hammertoe correction that tenotomy of the long extensor tendons and capsulotomy at the level of the MTPJ may be adequate in early stages of the disease process when the deformity is still flexible. A plantar IPJ capsulotomy and flexor tenotomy may be needed for additional correction. They added that an IPJ fusion of the hallux, PIPJ fusions of digits 2–4, and arthroplasty of digit 5 may be employed as well [30].

Clinical Pearls/Pitfalls

- In terms of advantages with this proposed approach, the scars with the flexor tendon transfer procedure are located on the medial or lateral aspect of the respected digit or digits so the procedure leaves a much more cosmetically pleasing result. There is also a much more natural appearance to the digits postoperatively. Additionally, no shortening occurs, and the medial and lateral collateral ligaments remain intact so no frontal plane or transverse plane complications can occur. The cubic volume of bone is not altered so instability and shortening cannot occur. Because one limits dissection to soft tissue only, the postoperative edema is minimal in relation to bony procedures. Of note, any resulting bursa, hyperkeratosis, and ulceration eventually dissipate without specifically addressing them surgically. This is because the surgeon has corrected the deforming forces and relieved the abnormal pressures.
- It has been the authors experience when addressing patients who suffer from plantar plate tears that keeping the treatment simple and direct is best. The suggested treatment consists of a modified Hibbs procedure to the specific joint coupled with a flexor tendon transfer. The modified Hibbs procedure removes the deforming force by releasing the long and short extensor tendon. This provided excellent exposure to the metatarsalphalangeal joint. This should remove all dorsal and transverse and/or frontal plane deformity from the toe on the metatarsal. The flexor tendon transfer then will release the flexion contracture of the toe and correct all planes of deformity. Once this is accomplished, and the tendon transfers are done, the toe will maintain its position.
- Oftentimes, the authors will be questioned, does the plantar plate need to be directly repaired? Our experience is no. Once the deforming forces are

removed and the tendon transfer and balancing of the joint are complete, the deformity should not occur and the plantar plate will heal itself given the deformity and the abnormal pressures and position are no longer causing a pathologic process.

- With the incision placement with these particular procedures, neurovascular bundles will be readily visible, so gentle retraction with fine skin hook retractors is vital to prevent complications with wound healing.
- Since there is no work actually performed on the bone itself, there is typically minimal swelling localized to the digit, postoperatively.
- With the incision of the FDL transfer being placed either medial or laterally, the scars are well hidden and allow for excellent cosmesis.
- Since there is no osseous involvement, there is no shortening, translation, or rotation of a toe.
- Because the collateral ligaments are not invaded with an FDL transfer, this eliminates the concern of transverse and rotational malalignment.
- With respect to the modified Hibbs procedure, upon skin closure one needs to pay attention to detail in order to avoid significant scar tissue formation to the dorm of the foot and aggravation to superficial nerves. Typically the dorsum of the foot has a thin soft tissue envelope; therefore, the surgeon must take caution with retraction to protect the dorsal tissues in order to prevent wound issues.
- Following a Hibbs procedure, patients will have weakness with dorsiflexion power of their digits as well as limited range of motion with dorsiflexion to the involved toes. Following an FDL transfer, the patient will have increased plantar flexion power to the involved toe at the MTP and decreased power and limited range of motion of the PIPJ and DIPJ. These consequences should be discussed preoperatively with the patient.
- As pins are being placed for stabilization in the digits, slightly plantarflexing the digit at the PIPJ will help reduce chances for a recurvatum deformity.
- One must remember to dorsiflex the ankle as the long extensor tendon is being transferred to the dorsolateral aspect of the midfoot or peroneal tertius tendon under physiologic tension, so it will continue to aid with dorsiflexion at the level of the ankle.
- A recurvatum deformity at the level of the PIPJ can be a complication seen with the FDL tendon transfer procedure. Slight plantar flexion at the PIPJ when fixated should help reduce the potential complication.
- Patients with progressive, neuromuscular disease may show a recurrence of the contracture when an isolated arthroplasty procedure is performed; however, once a tendon transfer is complete, a recurrence should not be possible as the deforming force is removed.
- By avoiding osseous procedures on the phalanges such as an arthroplasty, one can avoid instability from decreasing the cubic volume of bone that is removed. This loss of cubic volume of bone can cause destabilization to

the respective joint. In addition, the secondary skin changes and edema can be diminished and potentially avoided.

- By not performing arthrodesis of the IPJ, one can avoid shortening, as well as malalignment of the transverse, sagittal, and frontal plane. Additionally, the long-term sequela of secondary skin changes and postoperative edema can be minimized and/or avoided.
- The authors suggest using an Allis clamp and small mosquito hemostats on the tendons. The Allis clamps are used to coordinate the extensor digitorum brevis tendonsinto the distal portion of the extensor digitorum longus tendon with the transfer. The mosquito hemostat is used to coordinate the proximal portion of the extensor digitorum longus tendon into the peroneal tertius or midfoot. Additionally, the use of the two distinct clamps assists in keeping the tendons organized throughout the dissection and transfer.
- Lastly, if complications with a tendon transfer do occur, the surgeon always has the ability to proceed with a bony procedure if needed.

Case 1

Photo 16.1 A preoperative AP radiograph demonstrating well-maintained metatarsalphalangeal joints 1–5 and flexion contractures of the proximal interphalangeal joints 1–5. Note the flexion contracture of the distal interphalangeal joint too as well as varus rotation of the third, fourth, and fifth toes

Photo 16.2 A lateral preoperative radiograph demonstrating flexion contracture at the interphalangeal joints

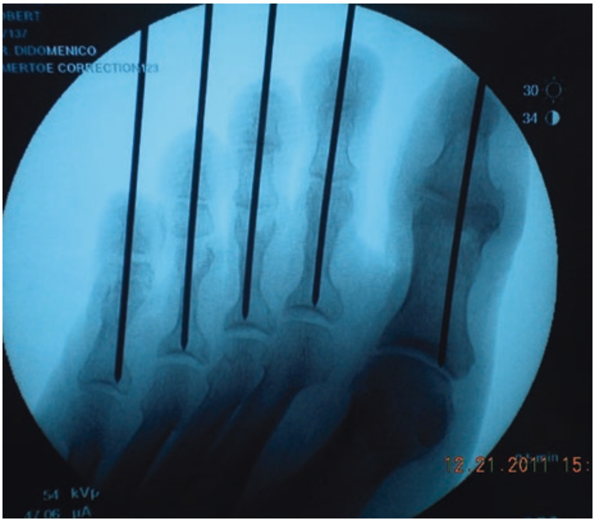
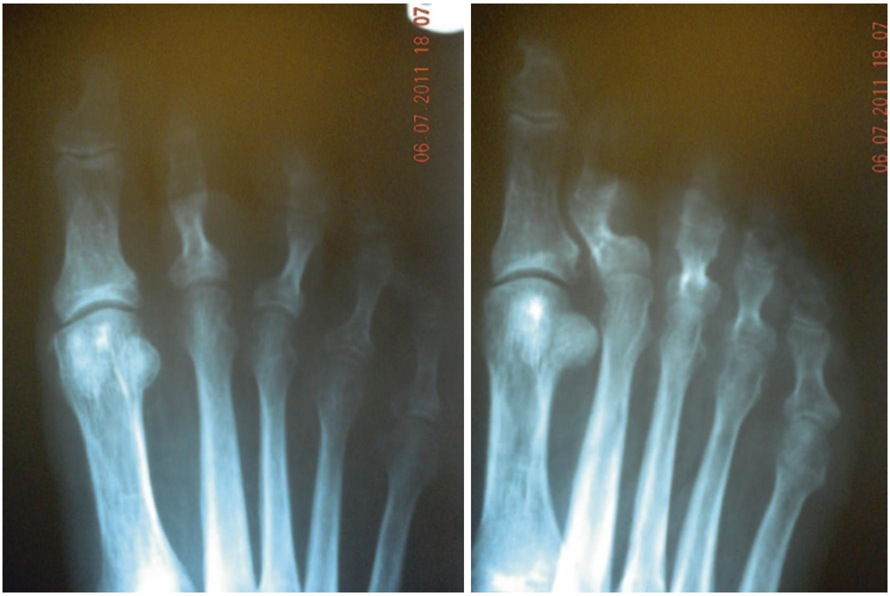


Photo 16.3 An intraoperative AP view following the performance of a flexor digitorum longus tendon transfer of second, third, fourth, and fifth toes as well as a flexor hallucis longus tendon transfer of the great toe. The toes are out to their natural length; each joint is preserved and well maintained

Case 2

Photo 16.1 A clinical view of a patient who had previous surgery for hammertoe correction surgery done on the second and third toe. The patient now presents with a recurrent hammertoe of the second and third toe with the addition of hammertoe pain of the lesser toes



Photos 16.2 and 16.3 An AP and medial oblique preoperative radiograph demonstrating hammertoe deformities 2–5. Please note there is some medial pulling of the distal aspect of toes 3, 4, and 5

Photo 16.4 Postoperative view of this patient who underwent an extensor digitorum brevis to extensor digitorum longus tendon transfer coupled with a flexor digitorum longus tendon transfer of the second toe. This patient also had a flexor digitorum longus tendon transfer of the third, fourth, and fifth toes too

Photos 16.5 and 16.6 Clinical and radiographic postoperative following extensor digitorum brevis to extensor digitorum longus tendon transfer coupled with a flexor digitorum longus tendon transfer of the second toe. This patient also had a flexor digitorum longus tendon transfer of the third, fourth, and fifth toes too. Note on photo 6 how the toes lay more in a more neutral position and all the joint spaces are maintained

Case 3

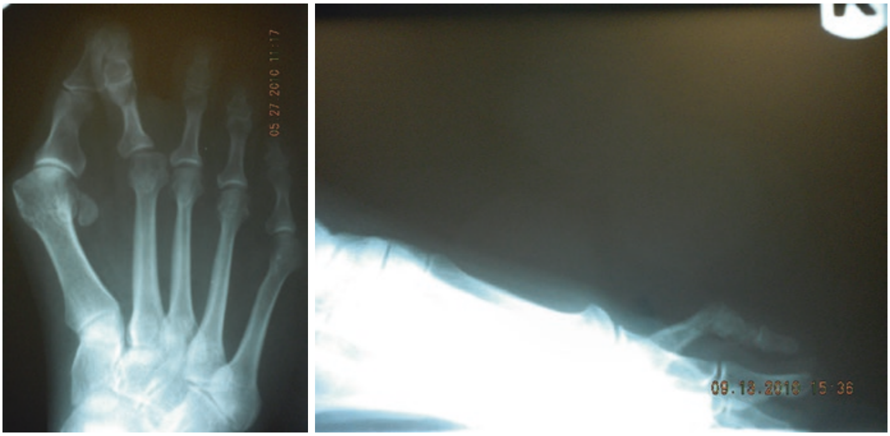
Photo 16.1 An AP radiograph of a patient who had previous bunionectomy and second hammertoe correction where an arthroplasty of the proximal interphalangeal joint of the second toe was done. Note the dorsal dislocation of the base of the proximal phalanx on the second and third toes on the second and third metatarsals. The patient presents with a recurrent bunion and second hammertoe

Photo 16.2 This suffers from a recurrent bunion and second hammertoe and a plantar plate tear of the second and third metatarsalphalangeal joint

Photo 16.3 An intraoperative AP view demonstrating post bunion reduction, K-wire fixation of second and third toes. This patient underwent and extensor digitorum brevis to extensor digitorum longus tendon transfer coupled with a flexor digitorum longus tendon transfer of the second toe and third toe. In this view, an Allis clamp is visualized from a lateral approach which would be holding the flexor digitorum longus tendon prior to transferring the flexor digitorum longus to the extensor hood

Photo 16.4 A postoperative AP view demonstrating post Lapidus bunionectomy and hammertoe correction of the second and third toes. This patient underwent a Lapidus bunionectomy and extensor digitorum brevis to extensor digitorum longus tendon transfer coupled with a flexor digitorum longus tendon transfer of the second toe and third toe for the plantar plate tears and hammertoe deformities

Case 4



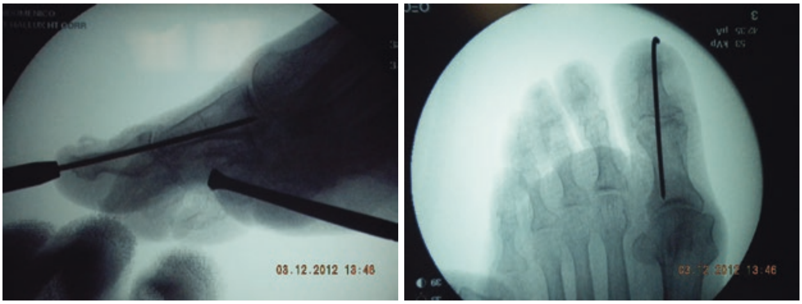
Photos 16.1 and 16.2 An AP preoperative and lateral X-ray demonstrating a large hallux abducto valgus deformity along with a crossover hammertoe. An MRI demonstrates a plantar plate tear of the second metatarsalphalangeal joint

Photo 16.3 A postoperative AP view demonstrating post Lapidus bunionectomy and hammertoe correction of the second toe. This patient underwent an HAV reduction via a Lapidus bunionectomy and extensor digitorum brevis to extensor digitorum longus tendon transfer coupled with a flexor digitorum longus tendon transfer of the second toe for the plantar plate tear and hammertoe deformity

Photos 16.4 and 16.5 Postoperative clinic views demonstrating post Lapidus bunionectomy and hammertoe correction of the second toe. This patient underwent an HAV reduction via a Lapidus bunionectomy and extensor digitorum brevis to extensor digitorum longus tendon transfer coupled with a flexor digitorum longus tendon transfer of the second toe for the plantar plate tear and hammertoe deformity

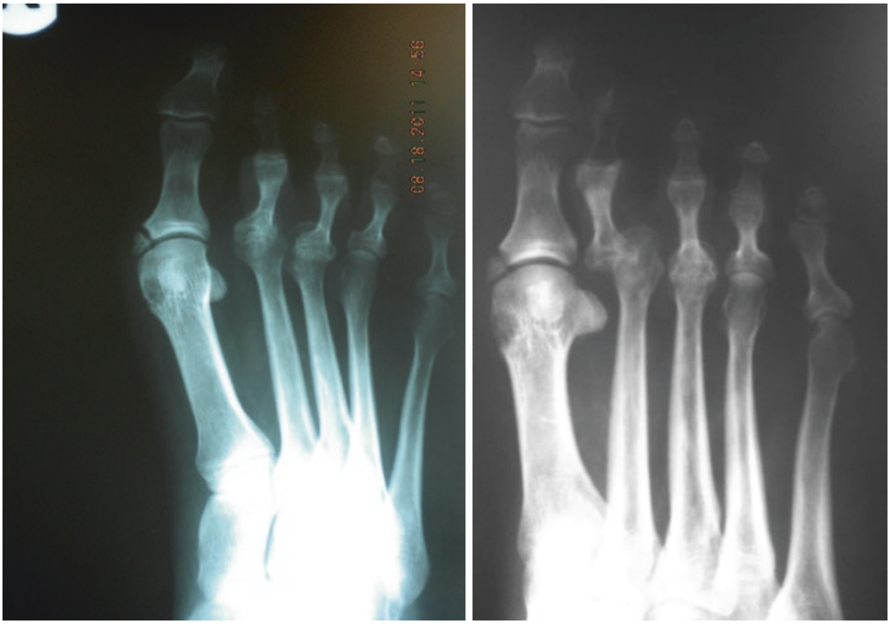
Case 5

Photo 16.1 A preoperative clinic view of a diabetic patient who gets a recurrent ulcer at the dorsal aspect of the interphalangeal joint of the hallux secondary to a dynamic flexor contraction during gait



Photos 16.2 and 16.3 Intraoperative AP and lateral views demonstrating K-wire fixation following a flexor hallucis longus tendon transfer of the great toe. The tendon transfer removes the underlying cause of a flexion contracture. Note the interphalangeal joint is reduced and well maintained

Case 6



Photos 16.1 and 16.2 AP and medial oblique radiographs demonstrating hammertoe deformities of digits 2, 3, 4, and 5. This patient also has a plantar plate tear of the second and third metatarsal-phalangeal joint

Photos 16.3 and 16.4 Clinical views of this patient who suffers from bilateral hammertoe deformities, plantar plate tears, and painful plantar lesions of the foot secondary to severe hammertoe deformities and plantar plate tears

Photo 16.5 An intraoperative view of a modified Hibbs being performed to correct the severe hammertoes 2–5 and plantar plate tears/ deformities of the second and third metatarsal-phalangeal joint

Photo 16.6 An AP postoperative X-ray demonstrating good anatomic alignment following a Lapidus arthrodesis (to stabilize the first tarsal-metatarsal joint) and a modified Hibbs and flexor tendon transfer of toes 2–5. Note that the metatarsalphalangeal joints as well as the interphalangeal joints are well aligned and reduced appropriately

Case 7

Photos 16.1 and 16.2 An AP X-ray and clinical view of a rheumatoid patient who underwent an arthrodesis of the first metatarsalphalangeal joint along with a modified Hibbs and flexor tendon transfer of toes 2–5

Case 8

Photos 16.1 and 16.2 A clinical photo demonstrating marked flexion contracture at the proximal interphalangeal joints of toes 2–5. A pre-op AP X-ray demonstrating flexion contractures at the proximal interphalangeal joints 2–5. Please note the well-maintained joint space at the metatarsal-phalangeal joint demonstrating a lack of pathological changes at metatarsalphalangeal joints 2–5

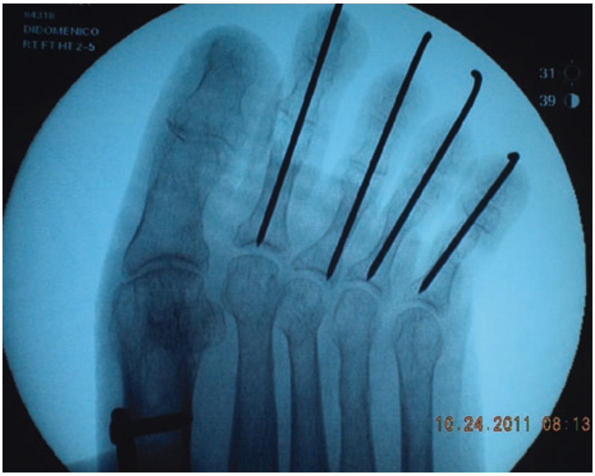


Photo 16.3 An intraoperative AP X-ray demonstrating correction of the flexion contractures at the proximal interphalangeal joints 2–5 via flexor tendon transfers. Note there is no loss of cubic volume of bone, the interphalangeal joints are stabile as the medial and collateral ligaments were left intact, and the joint spaces of the metatarsalphalangeal joints, PIPJ and DIPJ, are all maintained

Case 9

Photos 16.1 and 16.2 Preoperative clinical views of a neuropathic patient who experiences recurrent ulcers secondary to multiple plane digital deformities and a hallux valgus deformity

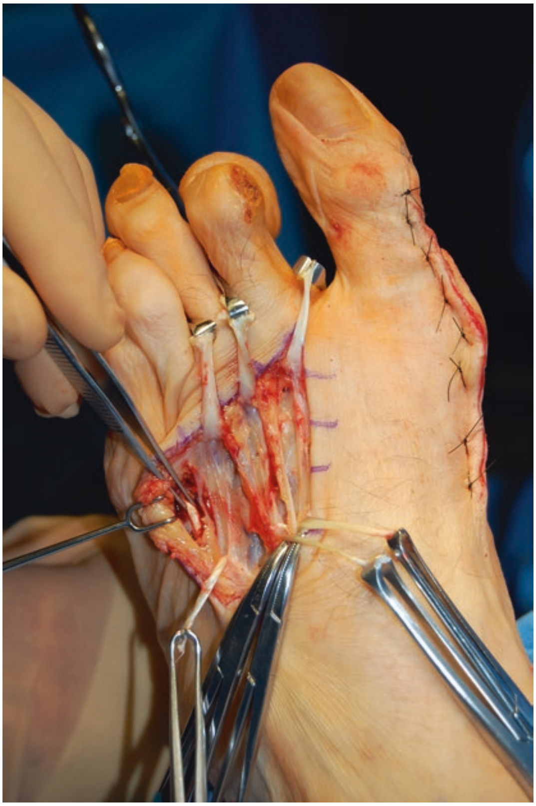


Photo 16.3 An intraoperative view while performing the modified Hibbs procedure. This view demonstrates the distal stump of extensor digitorum longus tendons 2, 3, and 4 being held by Allis clamps placed in the first, second, and third web spaces, respectively. The proximal portion extensor digitorum brevis tendons 2, 3, and 4 are reflected proximal and held by Allis clamps. Mosquito hemostats are holding the proximal portion of the extensor digitorum longus tendons 2 and 3. In this photo a Mosquito hemostat is not holding the fourth extensor digitorum longus tendon. The fifth extensor digitorum longus tendon is being held within the pickups

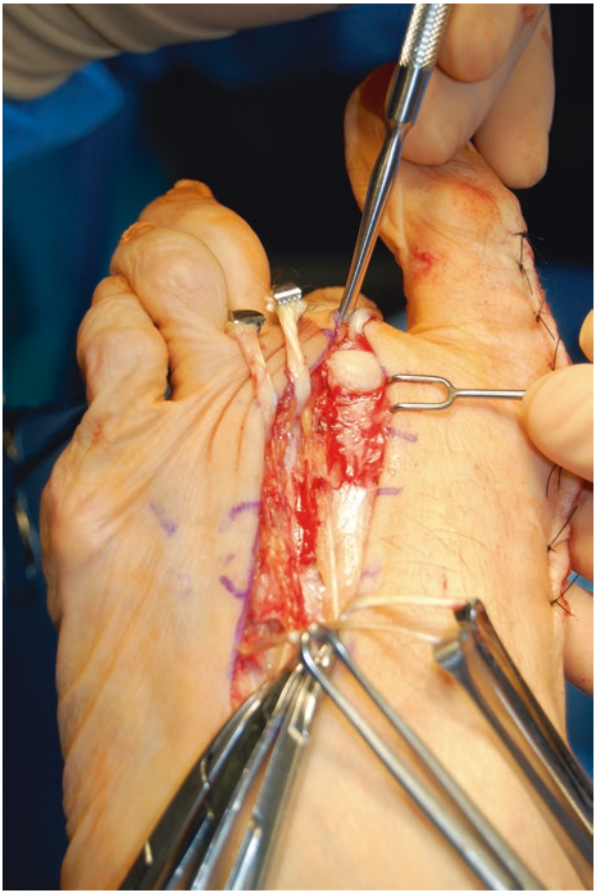


Photo 16.4 An intraoperative view while performing the modified Hibbs procedure demonstrating the access the surgeon has to the metatarsalphalangeal joints. In this photo, the second metatarsal head is exposed

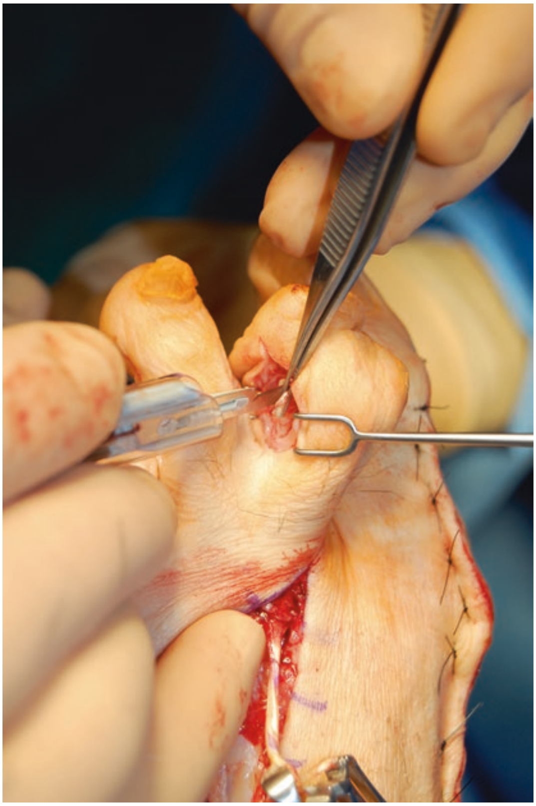


Photo 16.5 An intraoperative view of performing a flexor digitorum longus transfer on the lateral aspect of the second toe. The flexor digitorum longus tendon is identified and the soft tissues are freed from the tendon

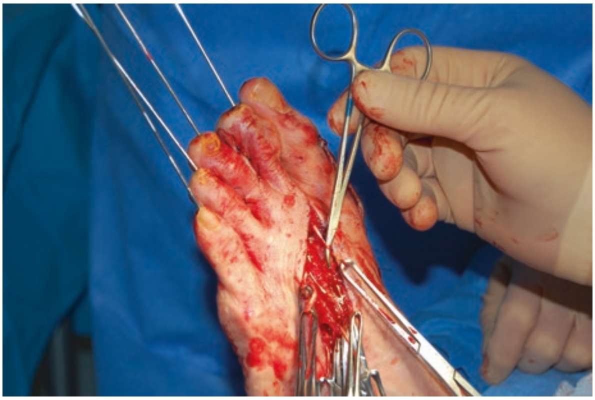
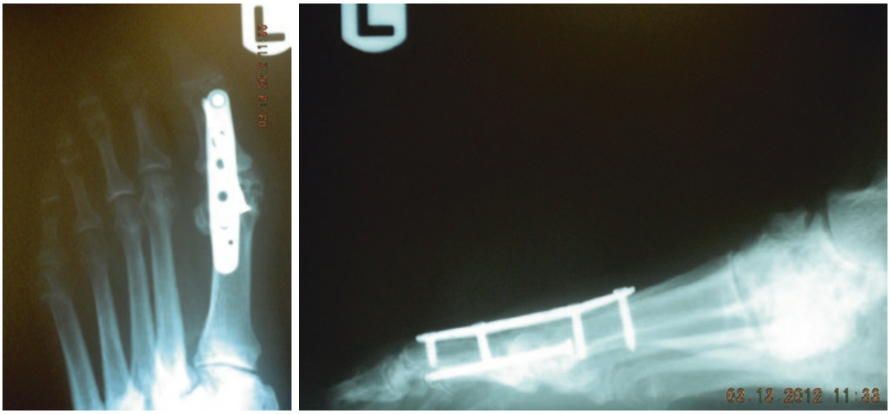


Photo 16.6 An intraoperative view while performing the modified Hibbs dissection and completion of flexor tendon transfer of digits 2, 3, 4, and 5. Note the toes are placed in the desired anatomic position and the extensor tendons are now being transferred. In this photo a vasectomy clamp is within the distal stump of the second extensor digitorum longus tendon and to receive the proximal stump of the second extensor digitorum brevis tendon being held by the an Allis clamp



Photos 16.7 and 16.8 A postoperative AP and lateral X-ray demonstrating good anatomic alignment following an arthrodesis of the first MTP, a modified Hibbs procedure of digits 2–5, flexor tendon transfers 2–5

Photos 16.9 and 16.10 Postoperative clinical views following an arthrodesis of the first MTP, a modified Hibbs procedure of digits 2–5, flexor tendon transfers 2–5

References

1. Shirzad K, Kiesau CD, DeOrio JK, et al. Lesser toe deformities. J Am Acad Orthop Surg. 2011;19:505–14.
2. Coughlin MJ. Lesser toe abnormalities. Instr Course Lect. 2003;52:421–44.
3. Dipreta JA. Metatarsalgia, lesser toe deformities, and associated disorders of the forefoot. Med Clin North Am. 2014;98:233–51.
4. Boberg J, Eilts C. Lesser digital deformities: etiology, procedure selection, and arthroplasty. In: McGlamry's comprehensive textbook of foot and ankle surgery. Philadelphia: Lippincott; 2013. p. 117–23.
5. Mizel M. Correction of hammertoe and mallet toe deformities. Oper Tech Orthop. 1992;2(3):188–94.
6. Coughlin M, Dorris J, Polk E. Operative repair of the fixed hammertoe deformity. Foot Ankle Int. 2000;21(2):94–104.
7. Biyani A, Jones DA, Murray J. Flexor to extensor tendon transfer for curly toes-43 children reviewed after 8 (1–25) years. Acta Orthop Scand. 1992;63(4):451–4.
8. Niklas B. Surgical Management of Digital Deformities. In: Hallux Valgus and forefoot surgery. New York: Churchill; 1994. p. 359–77.
9. Nery C, Coughlin M, Baumfeld D, Mann T. Lesser metatarsophalangeal joint instability: prospective evaluation and repair of plantar plate and capsular insufficiency. Foot Ankle Int. 2012;33(4):301–11.
10. Coughlin M. Review article- common causes of pain in the forefoot in adults. J Bone Joint Surg. 2000;82-B(6):781–90.
11. Busa S, Maasb M, de Langc A, Michelsa R, Levia M. Elevated plantar pressures in neuropathic diabetic patients with claw/hammer toe deformity. J Biomech. 2005;38(9):1918–25.
12. DiDomenico L, Rollandini J. A closer look at tendon transfers for crossover hammertoe. Podiatry Today. 2014;27(6):44–51.
13. Boberg JS. Surgical decision making in hammertoe surgery. In: Vickers NS, et al., editors. Reconstructive surgery of the foot and leg: update '97. Tucker, GA: Podiatry Institute; 1997. p. 3–6.
14. Bouchard JL, Castellano BD. Clawtoe deformities and contractures of the forefoot. In: Camasta CA, Vickers NS, Ruch JA, editors. Reconstructive surgery of the foot and leg, update 88. Tucker, GA: Podiatry Institute Publishing; 1998. p. 14–21.
15. Hibbs RA. An operation for "clawfoot". JAMA. 1919;73:1583–5.
16. Hansen S Jr. Transfer of the extensor digitorum communis to the midfoot. In: Functional reconstruction of the foot and ankle. Philadelphia: Lippincott; 2000. p. 451.
17. Rosenbaum AJ, Lisella J, Patel N, et al. The cavus foot. Med Clin N Am. 2014;98:301–12.
18. Ford L, Collins K, Christensen J. Stabilization of the subluxed second metatarsophalangeal Joint: flexor tendon transfer versus primary repair of the plantar plate. J Foot Ankle Surg. 1998;37(3):217–22.
19. Yao L, Do H, Cracchiolo A, Farahani K. Plantar plate of the foot: findings on conventional arthrography and MR imaging. AJR Am J Roentgenol. 1994;163:641–4.
20. Schwend RM, Drennan JC. Cavus foot deformity in children. J Am Acad Orthop Surg. 2003;11:201–11.
21. Piazza S, Ricci G, Ineco EC, et al. Pes cavus and hereditary neuropathies: when a relationship should be suspected. J Orthop Traumatol. 2010;11:195–201.
22. Baravarian B, Thompson J, Nazarian N. Plantar plate tears: a review of the modified flexor tendon transfer repair for stabilization. Clin Podiatr Med Surg. 2011;28:57–68.
23. Bhatia D, Myerson M, Curtis M, Cunningham B, Jinnah R. Anatomical restraints to dislocation of the second metatarsophalangeal joint and assessment of a repair technique. J Bone Joint Surg Am. 1994;76-A(9):1371.
24. Gonzalez A, Bayod J, Prados-Frutos JC, Losa-Inglesias M, Jules K, Bengoa-Vallejo RB, Doblare M. Finite-element simulation of flexor digitorum longus or flexor digitorum brevis tendon transfer for the treatment of clawtoe deformity. J Biomech. 2009;42:1697–704.

25. Boyer M, DeOrio J. Transfer of the flexor Digitorum longus for the correction of lesser-toe deformities. Foot Ankle Int. 2007;28(4):422–30.
26. Gazdag A, Cracchiolo A. Surgical treatment of patients with painful instability of the second metatarsophalangeal joint. Foot Ankle Int. 1998;19(3):137–43.
27. Ruch JA. Surgical classification of the cavus foot deformity. In: Camasta CA, Vickers NS, Ruch JA, editors. Reconstructive surgery of the foot and leg. Update 43. Podiatry Institute Publishing: Tucker, GA; 1994. p. 205–9.
28. Vlachou M, Beris A, Dimitriadis D. Modified Chuinard-Baskin procedure for managing mild-to-moderate cavus and claw toe deformity in children and adolescents. J Foot Ankle Surg. 2008;47(4):313–20.
29. Brody PJ, Grumbine N. Peroneus tertius reconstruction for flexible clawtoes associated with cavus deformity: a preliminary report. J Foot Surg. 1984;23(5):357–61.
30. Boffeli TJ, Tabatt JA. Minimally invasive early operative treatment of progressive foot and ankle deformity associated with Charcot-Marie-tooth disease. J Foot Ankle Surg. 2015;54:701–8.