JBJS ESSENTIAL Surgical Techniques

Surgical Treatment of Severe Cavovarus Foot Deformity in Charcot-Marie-Tooth Disease

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Introduction

A successful adjustable treatment algorithm for the correction of cavovarus foot deformity requires soft-tissue balancing procedures, in particular total split posterior tibial tendon transfer (T-SPOTT), in combination with adjunctive corrective procedures depending on the degree of deformity.

Cavovarus foot deformity can become debilitating, causing pain and decreasing the ability to perform daily activities[1-5]. The most common causes of the deformity are neurologic[6], and these require a more complex strategy combining soft-tissue balancing and osseous corrective procedures[7,8]. Hereditary motor and sensory neuropathy, also collectively known as Charcot-Marie-Tooth disease, describes a progressive disease of variable genetic inheritance pattern, resulting in malfunction of the myelin sheath leading to muscle atrophy and muscle imbalance[1-5]. This disorder is the most frequent neurologic cause of cavovarus deformity[9]. Various other disorders may result in cavovarus deformity—for example, central nervous system disorders (such as cerebral palsy and traumatic brain injuries, among others), spinal cord or peripheral nervous system disorders (spina bifida, syringomyelia, and neoplastic disorder, to name a few), and others (such as muscular dystrophy, arthrogryposis multiplex congenita, and compartment syndrome)[10]. Hence, it is of great importance to determine the underlying cause of the deformity prior to surgical correction, as some of the causes require specific treatment and may be associated with progressive disease. Furthermore, prior to surgical treatment, a variety of diagnostic tools should be used to determine the best treatment option. These include standardized clinical examination (range-of-motion measurements, muscle-power tests, and the Coleman block test), weight-bearing radiographic studies, and dynamic studies (dynamic pedobarography and instrumented three-dimensional gait analysis with a foot model).

In Charcot-Marie-Tooth disease, the deformity is often caused or aggravated by anterior tibial muscle and peroneus brevis muscle weaknesses[3], as well as by intrinsic muscle weakness, with subsequent overcompensation by the peroneus longus, resulting in more pronounced pronation and hindfoot varus[10-12]. Soft-tissue atrophy and secondary contractures can further complicate the already fixed deformity[12]. Consequently, soft-tissue corrections are of great importance to recreate a more physiologic soft-tissue balance and correct foot drop and pronation. The soft-tissue correction necessary to restore soft-tissue balance involves active tendon transfers, or tenodesis when active muscle control is not possible. Although a tenodesis does not permit a dynamic soft-tissue balance, a static soft-tissue correction can still be achieved to avoid foot drop. These tendon transfers can involve, for example, transfer of the posterior tibial tendon to the dorsum of the foot to correct a deficient anterior tibial tendon, which may then adapt to permit active dorsiflexion[13].

In addition, osseous deformities can develop. The osseous correction necessary is dictated by the presence and location of a fixed osseous deformity (thus, for example, a hindfoot varus due to flexion of the first metatarsal must be differentiated from a fixed hindfoot deformity by using the Coleman block test). Osseous procedures are required to correct fixed deformities, whereas flexible deformities can be treated with soft-tissue correction alone. The osteosynthesis material (Kirschner wires or cannulated screws and/or plates) used depends on the patient's age and physical constitution, bone quality, and the extent of the corrective procedure.

Since Charcot-Marie-Tooth disease and cavovarus foot deformity present in varying forms and severities, there have been few studies investigating which techniques are best to treat the deformity. In addition, the studies have often been heterogeneous in terms of the patient cohort and surgical techniques, with a variety of osseous corrections and soft-tissue procedures described but no clear recommendation of which procedure to use in any given situation[1,2,7,9,12].

We present a standardized, adjustable surgical decision-making algorithm that depends on the extent of the cavovarus deformity. The surgical corrections are based on two key principles: soft-tissue balancing and osseous correction. The first corrective measure is the release of the plantar aponeurosis (Steindler procedure). Afterward, the tendon transfers are carried out, beginning with the posterior tibial and extensor hallucis longus tendons. However, final suturing of the tendons to their respective transfer sites should be performed only after any necessary osseous correction has been done. The osseous corrections are performed to correct fixed cavus and hindfoot varus components. Osseous correction may be done with joint-sparing procedures (Cole[14], Dwyer[15], or similar procedures) or by joint fusion. We prefer stabilization of the Chopart joint line (Chopart fusion) and, in severe cases, triple or Lambrinudi[16] arthrodesis to obtain a stable correction. In order to correct the deformity of the first ray, we prefer a modified Jones procedure[17] or, in more severe cases, an extension osteotomy of the first metatarsal. Afterward, the hindfoot equinus deformity is assessed and, if needed, treated with calf muscle lengthening (in our experience this is rarely necessary). Rotational or axial deformities of the tibia are corrected with a supramalleolar varus derotation osteotomy. Tendon suturing should be carried out after any necessary osseous corrections. Clawing of the lesser toes should be treated toward the end of the surgical procedure by performing a distal tenotomy of the flexors and/or with a proximal interphalangeal joint fusion, depending on the extent of deformity.

Step 1: Surgical Preparation

Place the patient in a supine position and follow a standard aseptic surgical disinfection and draping protocol, allowing access to the iliac crest.

- Consider using regional anesthesia, including placement of a pain catheter for improved perioperative and postoperative pain management.
- Place the patient in a supine position and disinfect and drape the appropriate lower limb, allowing access to the ipsilateral iliac crest in case a bicortical or tricortical iliac crest graft is needed for osseous correction.
- Elevate the leg and use a sterile compressive bandage to decrease venous blood stasis.
- Apply a sterile tourniquet to the thigh, and remove the compressive bandage.
- Alternatively, apply a nonsterile tourniquet (for example an inflatable tourniquet) before disinfection and surgical draping.

Step 2: Steindler Release of the Plantar Aponeurosis (Video 1)

Use a medial approach to access and transect the plantar aponeurosis (Figs. 1-A, 1-B, and 1-C).

- Make a 2 to 3-cm longitudinal medial incision along the plantar border of the foot at the insertion of the plantar fascia at the calcaneus.
- Once the cutis and subcutis have been cut, carefully retract the skin and soft tissue to reveal the soft-tissue structures of the foot.
- Place a retractor deep to the aponeurosis to protect the important neurovascular structures.
- Transect the plantar aponeurosis using scissors as close to the calcaneal origin as possible.
- Place curved forceps deep to the aponeurosis, with the curved end directed in the plantar direction, and then spread them to reveal the most lateral fibers of the aponeurosis.
- Beginning in plantar flexion, dorsiflex the metatarsophalangeal joints and palpate to confirm aponeurotic transection and evaluate the degree of correction.

Step 3: Release the Posterior Tibial Tendon at the Foot (Video 1)

Transect the posterior tibial tendon near its insertion point (Figs. 2-A and 2-B).

- Make another incision at the medial border of the foot above the palpable posterior tibial tendon along the plantar border of the talus and navicular bones. Curve the incision slightly dorsally so that the anterior tibial tendon sheath can be reached through the same approach.
- After preparation and incision of the posterior tibial tendon sheath, transect the posterior tibial tendon with a scalpel near its insertion point.
- An optional step is to thread the most distal portion of the tendon using a number-1 polyglycolic acid suture to serve as a safety suture to pull the tendon back to its original location if necessary. The tendon will later be split in half, and each half will be woven to the target tendons with a Pulvertaft technique.

Step 4: Retract and Split the Posterior Tibial Tendon at the Calf and Transfer It Through the Interosseous Membrane (Video 1)

Make a medial incision in the distal part of the calf, retract the posterior tibial tendon (and flexor digitorum tendon if necessary), split it longitudinally in half, and pass it through the interosseous space (Figs. 3-A through 3-H).

- Make a longitudinal incision along the medial aspect of the shank, approximately 3 to 5 cm above the ankle and dorsal to the tibia. After incising through the cutis and subcutis, expose the fascia surrounding the posterior tibial tendon.

- Perforate the fascia with a scalpel, and separate it in a longitudinal direction to display the underlying tendon. Flex and extend the toes to confirm that this is the posterior tibial tendon and not the flexor digitorum longus tendon.
- If a transfer of the flexor digitorum longus is required, extend the skin incision and mobilize the gastrocnemius-soleus to display the fascia of the deep posterior compartment to access the posterior tibial, flexor hallucis longus, and flexor digitorum tendons. Take care not to damage the neurovascular structures that are dorsal to these muscles and tendons.
- Extending and releasing the previously cut posterior tibial tendon, and flexor digitorum tendon if necessary, reveal their respective corresponding muscle and tendon in the calf.
- Using curved forceps, carefully retract the tendon(s) out of the calf incision site, keeping the end of the forceps pointed away from the neurovascular structures.
- Longitudinally split the posterior tibial tendon in half with a scalpel and suture the ends of both halves.
- In order to be able to retrieve the tendon if necessary prior to tenodesis, loop a safety suture around the tendon; this will be removed later after the tendon transfer is completed.
- Use the hemostat clamp to perforate the interosseous membrane from posterior to anterior, spreading the forceps at the level of the membrane to make room for the tendon and muscle.
- Make a longitudinal skin incision above the protruding hemostat clamp to make a portal for the tendon transfer.
- Push the hemostat clamp through, spreading it several times en route to ensure a free passage for the tendon transfer and provide sufficient room in the interosseous space.
- Place a looped suture into the clamp of the forceps, place the posterior tibial tendon into the loop, and pull the posterior-tibial-tendon halves through the anterior incision site using the suture.
- During subsequent corrections keep the tendons and muscles moist with a sterile gauze sponge.

Step 5: Reveal the Target Tendons and Pull the Posterior-Tibial-Tendon Halves to These Tendons

Expose the anterior tibial and peroneal tendons and pull the posterior-tibial-tendon halves (and flexor digitorum longus tendon if it is being used) to these tendons (Figs. 4-A through 4-J).

- Incise the talonavicular joint to reveal the joint surface and the anterior tibial tendon insertion. Expose the anterior tibial tendon sheath using the prior incision that was employed to transect the posterior tibial tendon.
- Incise the anterior tibial tendon sheath, and drive a hemostat clamp into it and along the anterior tibial tendon through the extensor retinaculum.
- Grasp the suture of one-half of the posterior tibial tendon using the hemostat clamp and pull it through the tendon sheath to the insertion site of the anterior tibial tendon.
- Palpate the lateral edge of the foot for the peroneus brevis tendon at the base of the fifth metatarsal bone and for the neighboring peroneus longus.
- Make a 4 to 5-cm-long curved incision above the peroneal tendons toward the dorsum of the foot.
- Carefully expose the sural nerve and mark it with a vessel loop.
- If the Jones procedure and posterior tibial tendon transfer provide a complete correction, we do not address the peroneus longus. In cases with severe relative overpull in which the first ray cannot be corrected without tenotomy of the peroneus longus, we perform a peroneus longus-to-brevis transfer.
- Longitudinally incise the tendon sheaths of the peroneal tendons to expose the tendons. The peroneus longus tendon is now identified.
- Incise the tendon sheath of the peroneus brevis.
- Drive a hemostat clamp into the sheath and along the peroneus brevis tendon to retrieve one-half of the posterior tibial tendon.
- Grasp the suture of the posterior tibial tendon with the hemostat clamp and pull the tendon to the target tendon (peroneus brevis), to which it will later be attached with a Pulvertaft weave technique. Again, in order to be able to retrieve the tendon if necessary prior to the tenodesis, loop a safety suture around the tendon half prior to pulling it to its target site; remove this later, after tendon transfer is completed.

Step 6: Chopart, or Triple or Lambrinudi, Arthrodesis (Videos 2 and 3)

Perform a Chopart, or triple or Lambrinudi[16], arthrodesis when osseous correction and stabilization are required for fixed deformities (Figs. 5-A through 5-M).

- Once the talonavicular joint has been incised, place two Viernstein or Taeger bone levers dorsally to expose the joint and protect the neurovascular bundle.
- Using a curved chisel, remove the cartilage in

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a concave-convex manner so that the talonavicular joint retains its congruous contours. Use an arthrodesis spreader to reveal the remaining joint surface and remove any additional cartilage. Both joint surfaces can be milled using a 2.0-mm drill-bit to promote osseous consolidation.

- Return to the lateral incision to expose the calcaneocuboid joint, extending the incision if necessary.
- Once the extensor brevis origin has been found, release it from the underlying bone using a chisel from a dorsal direction to lift off the muscle to expose the calcaneocuboid joint.
- Resect the joint capsule to reveal the joint cartilage.
- Place two bone levers to retract the soft tissue and protect the neurovascular structures as well as to reveal the calcaneocuboid joint and lateral aspect of the talonavicular joint.
- Remove the remaining cartilage in the calcaneocuboid and lateral talonavicular joints using a curved chisel in the same manner as before. If a dorsal wedge resection is necessary, an oscillating bone saw can be used instead of, or in addition to, the chisel.
- If the Chopart (calcaneocuboid and talonavicular) fusion does not provide sufficient stability or correct the hindfoot varus deformity sufficiently then continue with a triple arthrodesis:
    - o Extend the lateral incision to expose the tarsal sinus and subtalar joint capsule.
    - o Incise the subtalar joint capsule and place an osteotomy spreader to access the joint surface.
    - o Again remove the cartilage with a chisel or oscillating saw.
    - o If the patient has severe hindfoot varus, resect a lateral-based wedge from the talus.
    - o If the anterior portion of the talar neck and head impinge on the tibia, then perform a Lambrinudi arthrodesis by resecting an anterior-based wedge from the subtalar joint.
- To perform and fix the osseous correction, begin by using a c-grip to hold the foot along the metatarsals.
- Dorsiflex the forefoot and midfoot, while keeping the hindfoot in slight valgus.
- Palpate the calcaneocuboid joint with your fingers while supporting the lateral foot border with your thumb.
- To fix the calcaneocuboid joint, place Kirschner wires through the dorsum of the foot, beginning with two wires (2.5 mm for adults and 2.2 mm for children) through the cuboid and into the calcaneus with the skin insertion point between the fourth and fifth metatarsals. Then place Kirschner wires into the talonavicular joint, again from the dorsum in an anteroposterior direction. If a triple or Lambrinudi arthrodesis is needed, insert two additional Kirschner wires into the lateral border of the foot, directing them from posterolateral plantar to anteromedial dorsal, thereby fixing both the calcaneus and the talus.
- Check the implant location (excluding Kirschner wire placement in the midfoot and forefoot bones) on intraoperative radiographs.
- After arthrodesis, check the range of motion, particularly of the talocrural joint, and consider calf muscle lengthening if the Silfverskiöld test shows equinus to be still present. Generally, we aim for dorsiflexion of 10° measured in knee extension and 15° to 20° measured in 90° of knee flexion (see Step 10).

Step 7: Modified Jones Procedure (Videos 4 and 5)

If the cavovarus foot displays flexible clawing of the big toe, carry out a modified Jones procedure[17] (Figs. 6-A through 6-I).

- Evaluate the first metatarsal and big toe to determine whether correction is needed. If the cavovarus foot displays flexible clawing of the big toe (hyperextension of the first metatarsophalangeal joint and flexion of the interphalangeal joint) carry out a modified Jones procedure[17] (tendon transfer of the extensor hallucis longus and arthrodesis of the interphalangeal joint of the big toe).
- Make an s-shaped bayonet incision dorsal to the interphalangeal joint, wherein the middle of the "s" is parallel to the joint line.
- Retract the skin to expose the long extensor tendon, and incise and transect the tendon at its insertion point. Thread the tendon with a number-1 polyglycolic acid suture for later fixation to the first metatarsal (or, alternatively, to the short extensor tendon).
- Incise the joint parallel to the joint line to display the cartilage. Using a pincer finger grip, retract the joint and remove all cartilage with Luer rongeur forceps, making sure that the joint lines are congruent.
- Place two crossing Kirschner wires through the end of the big toe into the proximal phalanx. Make sure that the Kirschner wires do not cross at the level of the joint to ensure rotational stability.
- Expose the distal part of the first metatarsal, and divide the periosteum.

- Expose the subperiosteal bone, and drill a 3.2-mm hole (adjust according to the caliber of the tendon and the diameter of the first metatarsal if necessary) centrally through the distal part of the first metatarsal.
- Thread the tagged extensor hallucis longus tendon through the drill-hole and suture it to itself. Alternatively, the extensor hallucis longus tendon can be sutured to the extensor brevis tendon.

Step 8: Extension Osteotomy of the First Metatarsal

If the first metatarsal remains in a fixed plantar flexed position and cannot be corrected with the Jones procedure, perform a dorsal-based wedge extension osteotomy (Figs. 7-A through 7-E).

- Reevaluate the first metatarsal and big toe to determine whether correction is needed. If the first metatarsal is in an equinus position, extend the initial medial foot incision distally to the middle of the first metatarsal.
- Retract and expose the first metatarsal bone.
- Incise the periosteum, and place small Hohmann retractors medial and lateral to the metatarsal bone.
- Using an oscillating saw, remove a dorsal-based wedge from the first metatarsal, being careful to leave the plantar cortical bone intact. Then dorsiflex the distal part of the first metatarsal to close the wedge.
- Place two crossing Kirschner wires (one distal and one proximal) to keep the osteotomy site in fixed reduction. Again, it is important that the Kirschner wires not cross at the level of the joint to ensure rotational stability.

Step 9: Clawing of the Lesser Toes

Incise the plantar tendons, transect the long flexor tendons, and place a single Hohmann wire through the end of each claw toe.

- Evaluate the foot and determine if flexible clawing of the toes (hyperextension of the metatarsophalangeal joint and flexion of the interphalangeal joints) needs to be addressed (Figs. 8-A and 8-B). If claw toes are present, incise the plantar tendons with a central toe incision, roughly 3 mm in length, on the plantar surface of each toe.
- Transect the long flexor tendons of each toe, being careful not to injure the medial and lateral neurovascular structures.
- Place a single Hohmann wire through the end of the tenotomized toe (extending through the phalanges of each toe) to temporarily immobilize each.

Step 10: Soft-Tissue Equinus Correction (Rarely Needed)

Depending on the severity of the remaining equinus, correct it with calf muscle or calcaneal tendon lengthening (the more severe the equinus, the more distal the corrective measure).

- Evaluate residual soft-tissue equinus with the Silfverskiöld test.
- Make or extend the longitudinal incision (about 5 cm) along the medial aspect of the calf, approximately in the middle of the shank (depending on whether Baumann, Strayer, or calcaneal tendon lengthening is used as the corrective measure).
- After incision through the cutis and subcutis, expose the gastrocnemius fascia surrounding the superficial posterior compartment. Perforate the fascia with a scalpel, and separate it in the longitudinal direction to display the underlying gastrocnemius.
- Display the aponeurosis and retract the soft tissue with retractors.
- Separate the aponeurosis using scissors, while holding the aponeurosis with the other hand using surgical pincers.
- Dorsiflex the foot while palpating for any remaining aponeurotic fibers, and sever these if necessary.
- If the correction is insufficient, additional correction can be done by cutting the soleus aponeurosis in the same fashion.

Step 11: Supramalleolar Varus Derotation Osteotomy

If foot external rotation is increased after foot correction, supramalleolar derotation osteotomy should be added to avoid lever-arm problems postoperatively.

- Evaluate tibial torsion or axial deformity and consider whether to perform supramalleolar varus derotation osteotomy. Some patients with severe cavovarus foot deformity develop ankle malrotation that is unmasked after correction of the foot, making it necessary to consider a possible supramalleolar derotation. If foot external rotation is increased after foot correction, supramalleolar derotation should be added to avoid lever-arm problems postoperatively. The goal is to align the second ray of the foot with the tibial crest.
- Extend the previously made medial longitudinal incision to reveal the distal part of the tibia.

- Longitudinally incise the tibial periosteum and retract it using a ventrally and dorsally placed Hohmann lever.
- In children, perform osteosynthesis using four crossing Kirschner wires (two from the medial malleolus and two from laterally). In adolescents and adults, distal tibial angle-stable locking plate fixation is preferable.
- Lay the locking plate onto the medial tibial surface, drill the holes, and place the screws into the distal part of the tibia.
- Drill a Kirschner wire into the tibia below and above the desired osteotomy line, in order to measure the rotation angle.
- Mark the osteotomy height with an oscillating saw (distal diaphysis/proximal metaphysis).
- Remove the locking plate, and use an oscillating saw to cut through the distal part of the tibia while protecting the lateral structures with the Hohmann levers.
- Screw the locking plate onto the distal part of the tibia using the previous screws and holes.
- Rotate the tibia to correct for malposition to the desired foot progression angle.
- Drill and place the remaining locking screws into the proximal locking plate holes.
- If an axial deformity is present, a wedge osteotomy can also be performed to correct it. (This is rarely needed.)

Step 12: Complete the Tendon Transfers

Attach the transferred tendons to their respective target tendons using a Pulvertaft needle with a Pulvertaft weave technique, while keeping the foot in a plantigrade position (Figs. 9-A through 9-J).

- The transferred tendons are sutured to their respective target insertions after all necessary osseous corrections have been made.
- Retract the target tendon several centimeters from its insertion point with a hook retractor, using moderate pull, to provide tension to the target tendon along its distal portion. This allows fixation of the posterior-tibial-tendon half under appropriate tension.
- Take care to keep tendons under sufficient tension prior to and during the suturing. Keep the foot plantigrade during suturing to prevent undercorrection or overcorrection. Make certain each tendon has a sufficient degree of tension. The tendons should be taut when the foot rests in the corrected position.
- Insert a Pulvertaft needle through the target tendon (the peroneus brevis or anterior tibial tendon), approximately 3 to 4 cm from its insertion, and grasp the suture at the end of the transferred posterior tibial tendon. Pull the suture and tendon through the target tendon.
- Insert a Pulvertaft needle through the other target tendon distal to the initial site and pull the transferred half of the posterior tibial tendon through this target tendon.
- Once the tendons have been woven through their respective target tendons two or three times, suture the transferred tendons to their target tendons with a number-1 polyglycolic acid suture. To do this, thread the tendons to each other where they intersect one another.
- Again, confirm appropriate tension of the tendons, which should be taut when the foot rests in a plantigrade position.

Step 13: Wound Closure

Reevaluate the foot and determine if all corrections have been made, perform necessary final radiographic documentation, release the tourniquet, perform hemostasis, clean the wounds, and close them.

- Reevaluate the operative results, and perform all necessary radiographic documentation to make certain that the desired result has been achieved.
- Shorten all Kirschner wires and bend over the ends into a c-shape using two pliers (one to hold the patient side of the Kirschner wire and the other to bend the wire).
- Reapproximate and suture the extensor brevis muscle.
- Clean the wounds.
- Release the tourniquet and use electrocautery as necessary.
- After cleaning the wounds, approximate and close the respective wound layers.
- Place a subfascial drain if the bleeding is expected to result in a large hematoma.
- After wound closure and application of sterile dressings, immobilize the leg and foot in an open plaster cast.
- Cool and elevate leg.

Step 14: Postoperative Management and Aftercare

The achieved operative correction is only as good as the postoperative treatment allows.

- Immobilize the foot in a cast or splint in the operating room, while the patient is still under anesthesia, to prevent tendon transfer insufficiency.
- Remove the wound drain early (on the first or

second postoperative day), and immobilize the foot and lower leg with a non-weight-bearing short leg cast. Confirm the foot position in the cast with radiographs.

- Change the non-weight-bearing cast as needed to remove skin sutures and to ensure proper fit when postoperative swelling decreases.
- Children should wear the cast for four weeks and adolescents and adults, for six weeks. After this time, obtain radiographs without the cast to evaluate osseous consolidation.
- Remove the Kirschner wires with flat-nose pliers, with sedation and analgesia (optional).
- If osseous consolidation is good, consider use of a partial weight-bearing short leg cast for an additional four to six weeks.
- Afterward, initiate physical therapy to mobilize the ankle, increase muscle strength, and improve coordination.
- Six to twelve months after cast removal, prescribe shank orthotics for the patient to wear for walking longer distances.

Results

Various authors have recommended posterior tibial tendon transfer to the dorsum of the foot to correct foot drop[18-20]. However, few studies have evaluated the resulting ankle function. In our prospective study, fourteen patients (twenty-three feet) who underwent total split posterior tibial tendon transfer (T-SPOTT) for cavovarus foot deformities resulting from Charcot-Marie-Tooth disease displayed significant increases in tibiotalar and foot-tibia dorsiflexion during the swing phase[13]. In addition, the T-SPOTT did not decrease the active range of motion. This improved function and retained range of motion were reflected in a significant improvement in the AOFAS (American Orthopaedic Foot & Ankle Society) score. The results were not conclusive with regard to whether or not the T-SPOTT acted as an active tendon transfer. However, the increased dorsiflexion during the swing phase and the harmonious plantar flexion motion after transfer (indicating that the T-SPOTT did not act as a counterbalance to the remaining plantar flexors) imply that the tendon transfer acts as an active transfer.

As noted by Holmes and Hansen[21], there are a variety of procedures to address cavovarus deformity. However, given the lack of standardized evaluation methods and treatment options, comparison of the results of these different operations remains difficult. Consequently, there is no standard procedure or treatment algorithm for patients with cavovarus deformity.

Despite the favorable results of T-SPOTT, we believe that the correct treatment depends on the exact defect pathology of the particular foot.

What to Watch For

Indications

- Adolescent or adult patients with debilitating cavovarus deformity resulting from hereditary motor and sensory neuropathy (Charcot-Marie-Tooth disease)
- Other neurogenic cavovarus foot deformities with muscular imbalance due to muscle weakness
- Weakness of the dorsiflexors

Contraindications

- Cavovarus deformity of non-neurologic etiology, which requires a different algorithm
- Spastic cavovarus foot deformity, as there is a potential for overcorrection
- Severe painful ankle osteoarthritis
- Patient age younger than ten years
- Mild deformities (relative indication); conservative treatment should be attempted first
- A cavovarus foot in a diabetic patient
- Patient noncompliance
- Severe peripheral vascular disease

Pitfalls & Challenges

- It is important to consider the indication and the underlying pathomechanics before the surgery.
- A combination of osseous corrections and soft-tissue balancing is mandatory.
- The correct balance of soft-tissue and osseous correction is important.
- Only a few cases require calf muscle lengthening at the end of the correction. Since it may decrease calf muscle strength, it should be avoided if possible. If performed, then it must be done sparingly. In other words, refrain from lengthening the soleus aponeurosis as well; choose a more proximal incision and lengthening procedure.
- Severe deformity can pose a challenge with regard to wound closure and wound-healing if the tension on the wound is too great. Approximate; don't strangulate!
- Correct hindfoot repositioning is important. Accept forefoot pronation during hindfoot repositioning and correct it later during the surgery with a modified Jones procedure and extension osteotomy of the first metatarsal.
- Avoid overcorrection or undercorrection of the deformity (residual cavovarus deformity, talipes, planus, and skewfoot).
- Care must be taken not to damage or disturb neurovascular structures, especially during the

tendon transfer steps. We routinely use safety sutures looped around the tendons to allow the opportunity to retract the tendons at any step of the surgery (for example, if vascular perfusion appears insufficient after tensioning of the transfers).

- Neurologic disease in its early stages can naturally progress, worsening the deformity. Thus, surgical correction done too early may not sufficiently address or hinder progression of the deformity. Determining the correct time for surgical correction is very difficult, with no consensus in the literature.

Clinical Comments

- We believe that the tendon transfer is the most important aspect of the procedure to correct the foot-drop component. Muscular balance, in our opinion, is very important to avoid early recurrence of the deformity. However, despite optimal soft-tissue balancing, natural disease progression can tip this balance and result in overcorrection or undercorrection caused by increased muscle weakness. Will a tenodesis effect remain after the transferred muscle has lost its strength?
- Does the transfer of the posterior tibial tendon to the dorsum of the foot really work as an active dorsiflexor substitution or is it the tenodesis effect that improves dorsiflexion during the swing phase of gait? Additional studies are needed to answer this question.
- Dynamic evaluation of this challenging foot deformity is mandatory in order to better understand the pathology. Three-dimensional foot analysis is a useful method to assess dynamic muscle function in a reliable and objective manner.

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Fig. 1-A

Fig. 1-B

Fig. 1-C

Fig. 1-A Incision for the Steindler plantar aponeurosis release at the plantar edge of the calcaneus. The curved incision for exposure of the anterior and posterior tibial tendons and the first metatarsal and for the modified Jones procedure can be seen at the plantar-medial edge of the foot. **Fig. 1-B** Cut the plantar aponeurosis as close to the calcaneus as possible. **Fig. 1-C** Palpate for remaining aponeurotic fibers.

Fig. 2-A

Fig. 2-B

Fig. 2-A Expose the posterior tibial tendon. **Fig. 2-B** Cut the posterior tibial tendon at its insertion point.

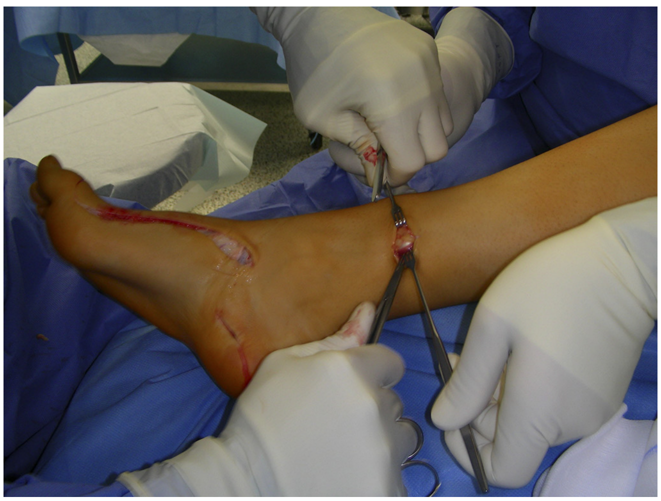

Fig. 3-A

Fig. 3-B

Fig. 3-C

Fig. 3-D

Fig. 3-A Incise along the medial aspect of the distal part of the shank to reveal the posterior tibial tendon. **Figs. 3-B and 3-C** Retract the posterior tibial tendon using curved forceps. (Reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.) **Fig. 3-D** Halve the posterior tibial tendon.

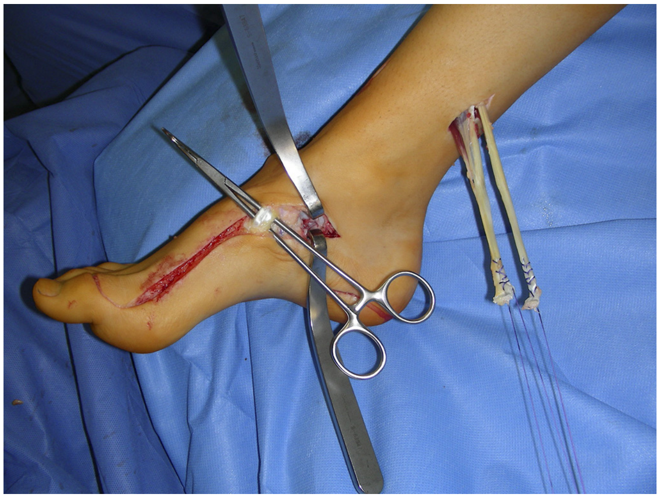

Fig. 3-E

Fig. 3-F

Fig. 3-G

Fig. 3-H

Fig. 3-E The two tendon halves of tibialis posterior are tagged with sutures. Distally, the anterior tibial tendon insertion is marked here with the curved forceps. (Reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.) **Fig. 3-F** Use a hemostat clamp to perforate the interosseous membrane, incise the skin above the forceps, and pull back the looped suture. (Reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.) **Fig. 3-G** Place a safety suture over the tendons, and loop the posterior-tibial-tendon halves to pull them to the anterior aspect of the shank. (Reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.) **Fig. 3-H** Pull both posterior-tibial-tendon halves through the interosseous membrane and through the portal in the anterior aspect of the shank. (Reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.)

Fig. 4-A

Fig. 4-B

Fig. 4-C

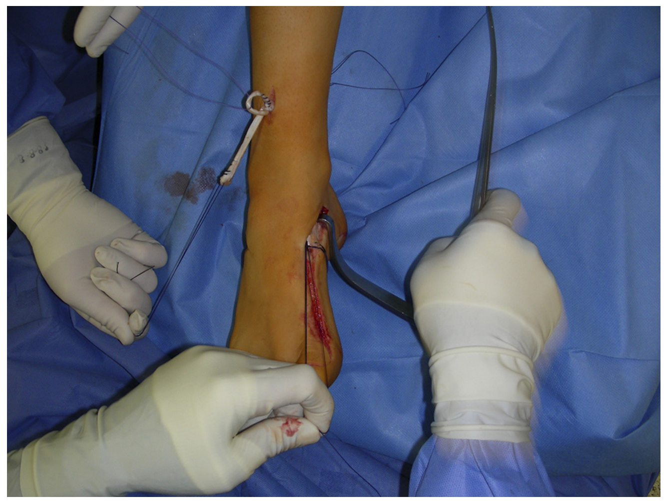

Fig. 4-D

Fig. 4-E

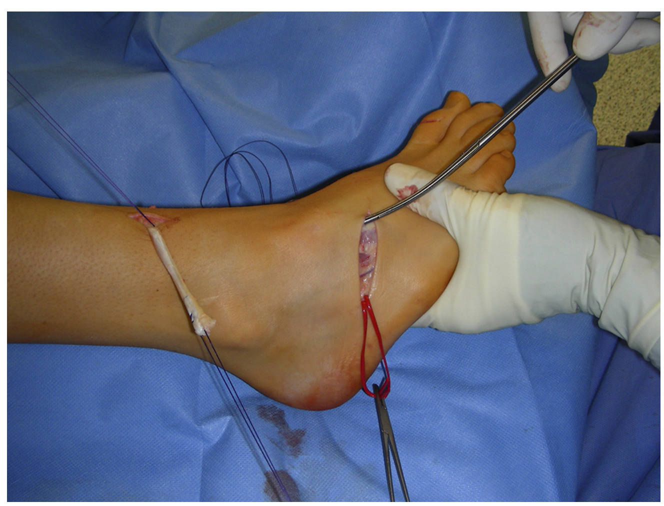

Fig. 4-F

Fig. 4-A Expose the anterior tibial tendon insertion (marked here with the curved forceps). (Reproduced, with modification, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531. Reproduced with permission of Elsevier.) **Figs. 4-B and 4-C** Pass a hemostat clamp along the tendon and through the extensor retinaculum toward the transfer portal. (Fig. 4-C reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.) **Fig. 4-D** Loop a safety suture around the half of the tendon to be transferred. Grasp the sutured end of the tendon half to be transferred with a hemostat clamp and pull the tendon to the target site (in this case the anterior tibial tendon). **Fig. 4-E** Make a lateral incision for transfer of half of the posterior tibial tendon to the peroneus brevis (or tertius). Mark the sural nerve with a vessel loop. **Fig. 4-F** Again, use a hemostat clamp to travel along the target tendon inside the tendon sheath.

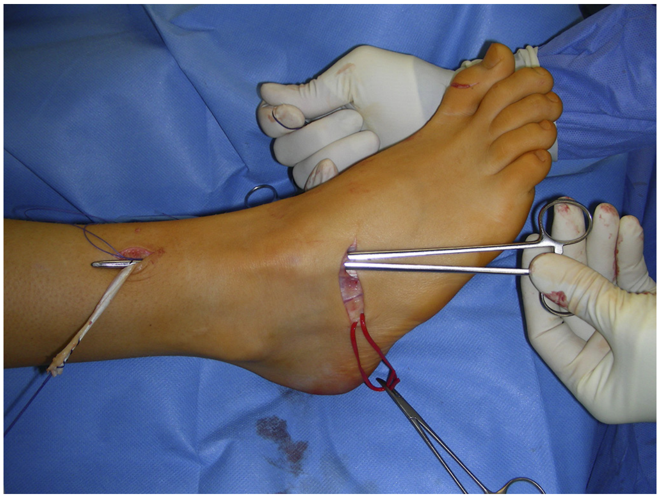

Fig. 4-G

Fig. 4-H

Fig. 4-I

Fig. 4-J

Fig. 4-G Pass the forceps through the transfer portal. (Reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.) **Fig. 4-H** Place a safety loop and grasp the posterior-tibial-tendon half. **Fig. 4-I** Pull the posterior-tibial-tendon half to the target (in this case the peroneus brevis). Note the safety loops still visible in the transfer portal. **Fig. 4-J** Check the posterior-tibial-tendon halves and their respective paths to their targets. (Reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.)

Fig. 5-A

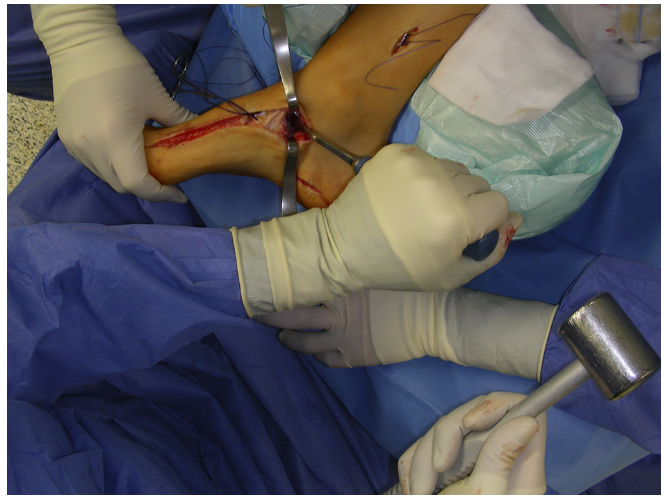

Fig. 5-B

Fig. 5-C

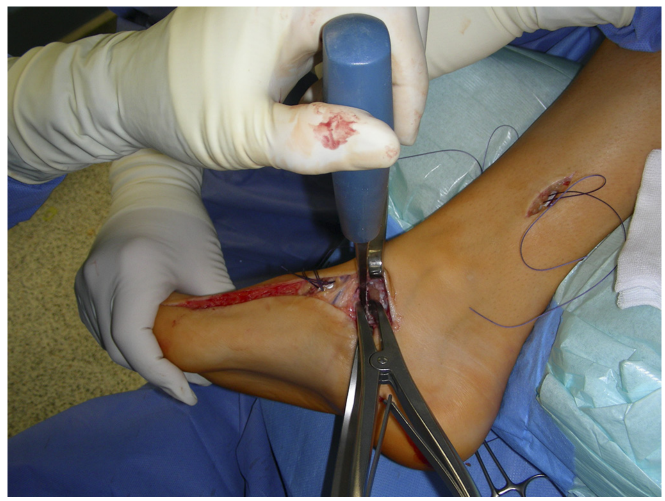

Fig. 5-D

Fig. 5-E

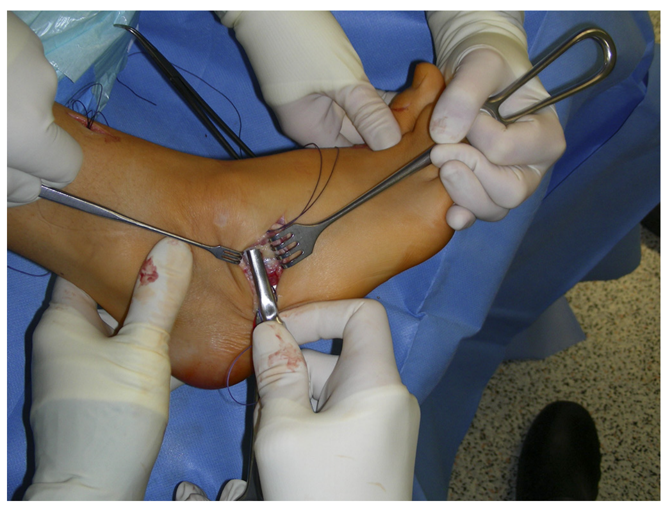

Fig. 5-F

Fig. 5-A Incise the talonavicular joint, and place Viernstein retractors. **Figs. 5-B, 5-C, and 5-D** Chisel the cartilage from the talonavicular joint. (Fig. 5-D reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.) **Fig. 5-E** Locate the extensor brevis origin and remove it from the bone with a curved chisel. (Reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.) **Fig. 5-F** Use a rasp to free space for the placement of Viernstein levers as necessary.

Fig. 5-G

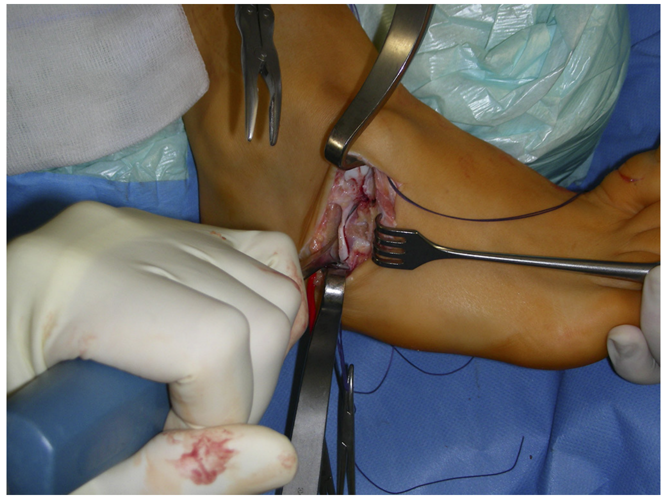

Fig. 5-H

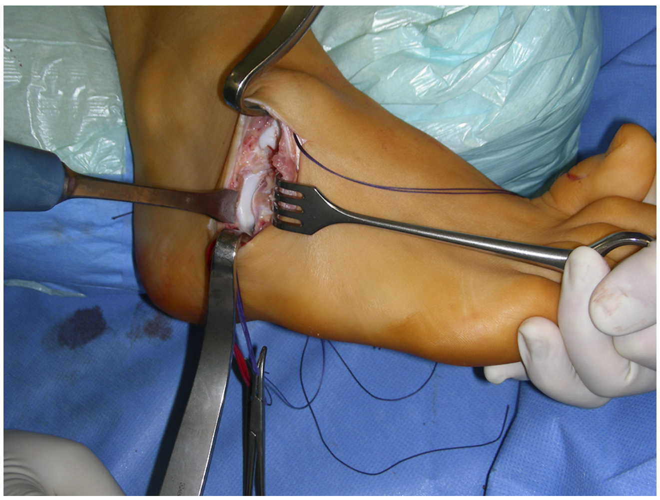

Fig. 5-I

Fig. 5-J

Fig. 5-K

Figs. 5-G through 5-K Place the Viernstein retractors and remove the cartilage from the remaining Chopart joint line in a convex-concave manner. Arthrodesis spreaders are useful to reach deeper areas. (Figs. 5-H and 5-I reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.)

Fig. 5-L

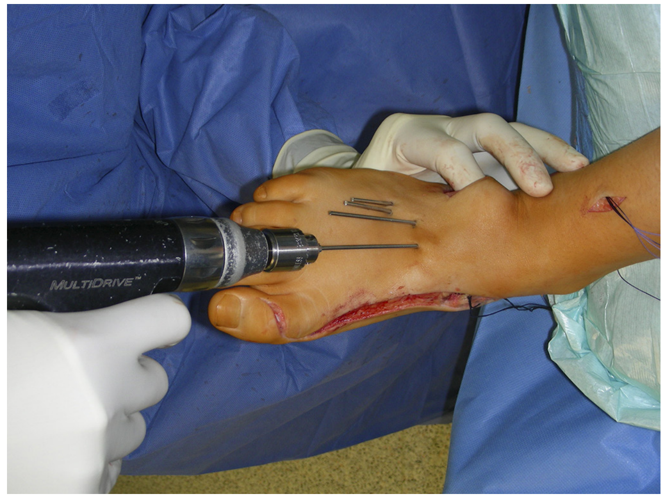

Fig. 5-M

Figs. 5-L and 5-M Grasp the foot with a c-grip. While keeping the hindfoot in place, drill two Kirschner wires between the fourth and fifth metatarsals to fix the calcaneocuboid joint in the correct position. Now drill in the remaining Kirschner wires to stabilize the entire Chopart fusion. (Reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.)

Fig. 6-A

Fig. 6-B

Fig. 6-C

Fig. 6-D

Fig. 6-E

Fig. 6-F

Fig. 6-A Retract the soft tissue to reveal the extensor hallucis longus tendon. **Fig. 6-B** Cut the extensor hallucis longus tendon close to its insertion. **Fig. 6-C** Place Hohmann retractors subperiosteally. (Reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.) **Fig. 6-D** Use a 3.2-mm drill-bit to drill through the distal part of the first metatarsal in a dorsal-to-plantar direction. **Figs. 6-E and 6-F** Pull the sutured end of the extensor hallucis longus tendon through the drill-hole, loop it back, and suture the tendon to itself. (Fig. 6-F reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.)

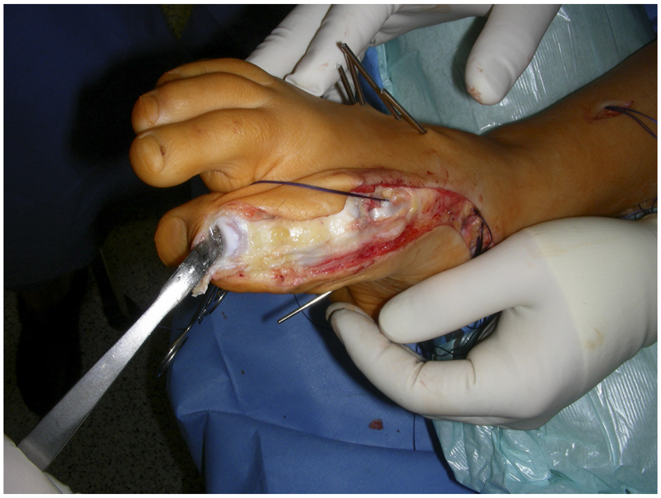

Fig. 6-G

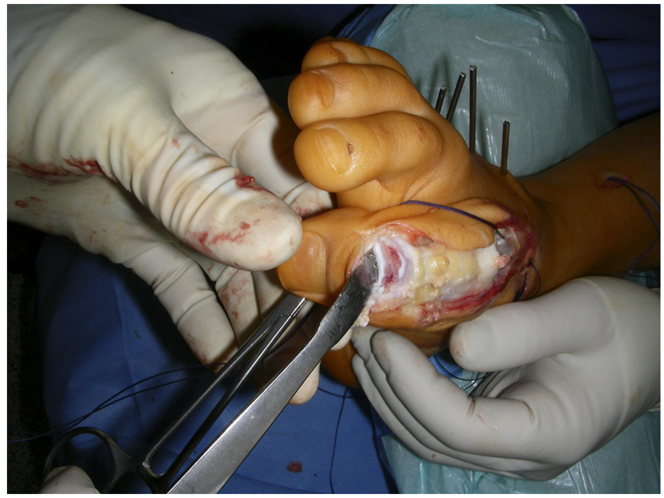

Fig. 6-H

Fig. 6-I

Figs. 6-G and 6-H Make a bayonet incision in the interphalangeal joint of the big toe, incise the joint, retract the joint, and remove the cartilage.
Fig. 6-I Percutaneously pin the interphalangeal joint of the big toe with two crossing Kirschner wires.

Fig. 7-A

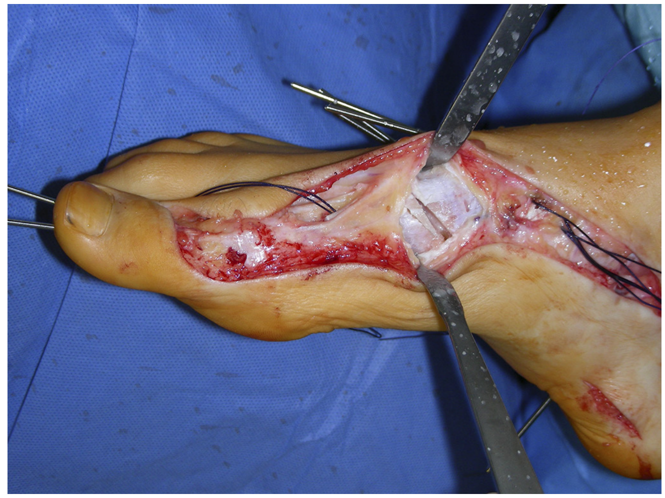

Fig. 7-B

Fig. 7-C

Fig. 7-D

Fig. 7-E

Fig. 7-A Retract the first metatarsal periosteum. (Reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.) **Figs. 7-B and 7-C** Use an oscillating saw to cut a dorsal-based wedge out of the first metatarsal while sparing the plantar cortical bone. **Fig. 7-D** Dorsiflex the distal portion of the first metatarsal. (Reproduced, with permission of Elsevier, from: Dreher T, Hagmann S, Wenz W. Reconstruction of multiplanar deformity of the hindfoot and midfoot with internal fixation techniques. Foot Ankle Clin. 2009 Sep;14[3]:489-531.) **Fig. 7-E** Percutaneously pin the osteotomy site to keep it in fixed reduction with use of two Kirschner wires.

Fig. 8-A

Fig. 8-B

Fig. 8-A Plantar incisions for tenotomy of the flexor tendons. Temporary percutaneous Kirschner wires keep the toes in the appropriate position.
Fig. 8-B Distal view of the Kirschner wire placement.

Fig. 9-A

Fig. 9-B

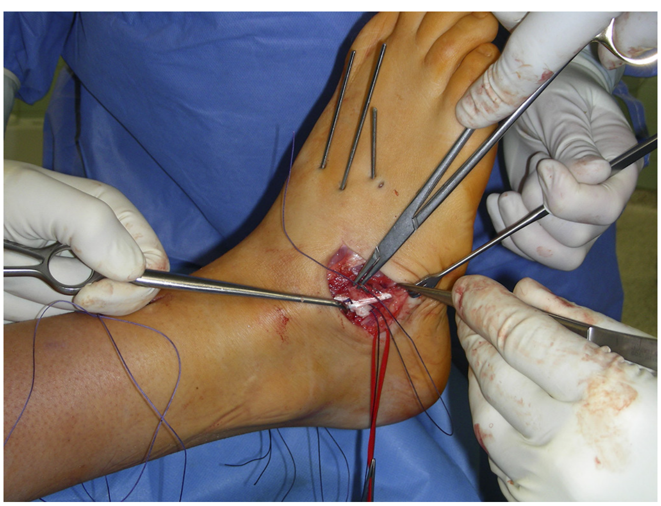

Fig. 9-C

Fig. 9-D

Figs. 9-A through 9-D Using a Pulvertaft needle, weave half of the posterior tibial tendon to the peroneus brevis tendon, and then suture under tension.

Fig. 9-E

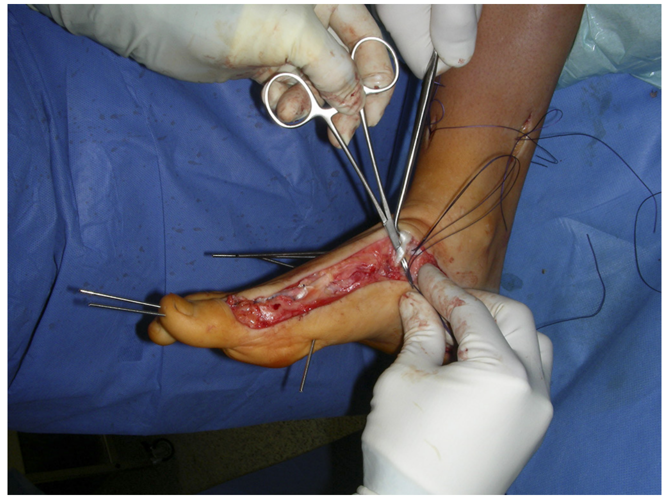

Fig. 9-F

Fig. 9G

Fig. 9-H

Fig. 9-I

Fig. 9-J

Figs. 9-E through 9-J Again, use a Pulvertaft needle and weaving technique to conjoin half of the posterior tibial tendon through the anterior tibial tendon. Suture the tendons together, making sure to thread both tendons at their intersections. Keep the tendons under tension while doing so.

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