

Corrective Midfoot Osteotomies

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Corrective osteotomies about the midfoot are indicated for angular and rotational deformities. Appropriate positioning of the osseous segments following midfoot osteotomy is challenging because of influential forces around the hindfoot/ankle and the forefoot that must be considered. Initially, midfoot osteotomies were reserved for the correction of the severe rigid pes cavus foot [1]. Currently, surgeons have used angular, rotational, and translational deformity corrections that can be achieved through the midfoot, expanding the indications for an osteotomy through this region of the foot [2–4]. In addition, midfoot osteotomies often avoid the extensive soft tissue exposure required for multiple joint arthrodesis procedures because these procedures can be performed through minimum or percutaneous incisions [5]. Typical indications for a midfoot osteotomy are rigid pes cavus, talipes equinus-varus, rigid metatarsus adductus, malunions associated with midfoot or rearfoot arthrodesis, and Charcot neuro-osteoarthropathy midfoot deformities [1,3,4,6–11].

The goal of a corrective midfoot osteotomy is to re-establish a plantigrade foot during stance, which implies that the first metatarsal head, fifth metatarsal head, and calcaneus are on the same plane during stance. Limited normal parameters exist for performing midfoot osteotomies and it is therefore imperative that the surgeon have detailed knowledge and sound understanding of all compensatory joint motions that exist proximal and distal to the intended osteotomy to achieve successful deformity correction through the midfoot.

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Physical examination

The physical examination must be systematic and should include evaluation of the entire lower extremity when non-weight bearing, during stance, and while ambulating. Emphasis is placed on identifying the apex of the deformity and compensatory motion or joint contractures that are present. Deformity should be evaluated in regards to its length, angulation, rotation, and translation. In the foot, particularly in the midfoot region, this evaluation can become challenging because of the short osseous segments and multiple articulations proximally and distally. For this reason, it is important to establish clinical parameters and to correlate those findings with the necessary radiographs to provide an adequate description of the deformity to be corrected. The contralateral extremity, if unaffected, facilitates the examination and serves as an internal control for the patient. The surgeon must evaluate the deformity in the frontal, sagittal, and transverse planes to plan adequately the necessary osteotomy, realignment, and adjunctive procedures that may be required to restore a plantigrade foot. Radiographs are obtained to evaluate the deformity and to create reference lines to facilitate precise surgical planning. Weight-bearing anterior-posterior and lateral radiographs of the lower leg, ankle, and foot, along with a hindfoot alignment view, must be obtained and correlated with the clinical examination. The importance of weight-bearing radiographs for the evaluation of the deformity cannot be overstated because subtle deformities not readily apparent on clinical examination become easily detected. If the patient's weight-bearing lower leg radiographs demonstrate proximal deformity or limb-length discrepancy, then weight-bearing anterior-posterior and lateral mechanical axis radiographs should be obtained from the hip to the ankle. The mechanical axis is a line drawn from the center of the femoral head to the center of the ankle joint. If the mechanical axis deviates more than 1 cm from the center of the knee joint, then a deformity proximal to the ankle is located in the tibia or femur. Understanding the influence of supra-pedal structural deformities is paramount, particularly when these supra-pedal structural deformities exceed the range of motion that is present in compensatory joints about the foot and ankle. For example, a varus deformity of the tibia can lead to fixed subtalar joint inversion and compensatory forefoot valgus. Conversely, a valgus deformity of the tibia can lead to fixed subtalar joint eversion and compensatory forefoot varus. The development of these foot and ankle deformities from proximal deformities of the tibia and femur depend on the compensatory range of motion throughout the foot and ankle. At times, these deformities may require osteotomies of the rearfoot/ankle, tibia, or femur, in addition to the midfoot, to achieve the desired correction.

Position of the forefoot and the rearfoot is paramount in planning for a midfoot osteotomy. The surgeon should examine rearfoot position when non-weight bearing and during stance. It should be determined if forefoot

position is influencing rearfoot deformity and vice versa. The forefoot should be plantigrade, allowing for equal transfer of weight throughout the foot. Forefoot varus produces increased weight transfer to the lateral border of the foot and may cause a compensatory calcaneal valgus deformity. Conversely, forefoot valgus deformities produce increased weight transfer to the medial border of the foot and may cause a compensatory calcaneal varus deformity. Deformities about the forefoot can usually be corrected with midfoot osteotomies. Forefoot varus and valgus are usually corrected through rotation of the forefoot segment following midfoot osteotomy. Sagittal and transverse plane forefoot deformities can be corrected with wedge-based midfoot osteotomies and translation, respectively. However, an attempt to correct noncompensatory deformities and fixed compensatory deformities about the rearfoot, particularly the calcaneus and subtalar joint, with midfoot osteotomies should not be attempted. A calcaneal osteotomy or subtalar joint arthrodesis, in addition to a corrective midfoot osteotomy, is needed for these associated rearfoot deformities [6]. Correction through the midfoot will not correct a rearfoot deformity unless the deformity was compensatory to the deformed forefoot position and joint contracture has not developed. An example would be a fixed forefoot varus with a compensatory heel valgus. When a block is placed preoperatively under the forefoot, the calcaneus inverts from its valgus position, resuming a neutral position. In this case scenario, a midfoot osteotomy to correct the fixed forefoot varus will simultaneously correct the calcaneal valgus that was compensatory with no evidence of subtalar joint contracture.

Sagittal plane deformities in the pes cavus foot are a frequent indication for a midfoot osteotomy [1,7,11]. The osteotomy is designed with a dorsally based wedge to dorsiflex the forefoot and decrease the arch height [1,7,11]. At times, a wedge osteotomy has to be taken from the navicular-cuneiform joint extending into the cuboid to obtain adequate correction. Anterior equinus of the forefoot can be corrected with a midfoot dorsally based wedge osteotomy. Procurvatum deformities and ankle equinus cannot be corrected with a midfoot osteotomy, and additional soft tissue or osseous procedures about the ankle are required. It is important to evaluate the ankle on lateral weight-bearing radiographs for procurvatum and recurvatum deformities of the ankle. At times, dorsiflexory stress radiographs are indicated to ensure an anterior osseous impingement is not evident at the ankle and that sufficient ankle joint dorsiflexion remains when considering correction of an anterior equinus by way of a midfoot osteotomy. In addition, posterior osseous cavus deformities should be corrected with calcaneal osteotomies, as opposed to midfoot osteotomies [6,9]. Plantar-based midfoot wedge osteotomies can be used to correct a Charcot midfoot deformity [8]. The authors have found that a midfoot osteotomy in a Charcot foot is best performed if complete consolidation and stability exist about the midfoot [12–14]. The clinical scenario in which a midfoot osteotomy would be indicated for a Charcot foot is one with a plantar midfoot ulcer as a result

of a rigid, stable, “rocker-bottom” deformity [13,14]. If instability persists, a midfoot osteotomy should be avoided and an extended joint arthrodesis should be considered instead [13,14].

Rotational alignment should be determined and quantified. Radiographs to measure rotation are difficult and not routinely used. Clinical examination is used to determine the presence and degree of rotational malalignment. With the patient seated, the knee is flexed at 90°, the patellar tubercle is placed directly anterior, and the malleoli position is obtained and assessed for rotational deformity. At this point, a line drawn along the anterior tibial crest is made and the bisection should be aligned with the second metatarsal. The degree of internal (ie, abduction) and external (ie, adduction) rotation is then quantified using a goniometer. In difficult cases with marked rotation and suspected proximal deformity, it may be necessary to obtain computerized axial tomography of the hip, distal femur, proximal tibia, and ankle malleoli to define the rotational deformity more accurately.

Evaluation of joint range of motion is paramount and cannot be overlooked. Flexibility of the foot is determined. Compensatory rigid joint contractures, particularly of the subtalar joint, need to be determined. In addition, hypermobility and joint laxity of the first ray are considered relative contraindications for performing a midfoot osteotomy unless they are addressed. Soft tissue contractures should be evaluated and adjunctive soft tissue releases performed in conjunction with the midfoot osteotomy [15]. A good example is the release of the plantar fascia in conjunction with a midfoot osteotomy for the correction of a semirigid pes cavus foot [1,15]. The surgeon must also consider tendon balancing of the foot to determine if a tendon transfer should be performed. In the paralytic foot with deformity, tendon transfers are often necessary, in addition to osseous deformity correction, to improve function and establish a plantigrade foot [15].

Corrective midfoot osteotomies: surgical technique

The surgical technique for a midfoot osteotomy begins with the patient under general anesthesia and fully paralyzed. A popliteal block can be placed preoperatively for postoperative analgesia. The leg should be directly supine, avoiding any internal or external rotation. In addition, it is imperative to have the entire foot, ankle, and lower leg fully prepped and draped to allow evaluation of the alignment of the foot, ankle, and lower leg intraoperatively. Any concomitant procedures to the hindfoot, ankle, or tibia for deformity correction should be performed before the midfoot osteotomy, starting with the most proximal deformity and working distally. If functional tendon transfers are required, the authors prefer to delay the tendon transfer until clinical and radiographic healing of the osteotomy is complete. The rationale for staging the tendon transfer is to avoid delay of the rehabilitation phase that is required early in the postoperative period for a successful functional tendon transfer. Typically, range of motion for

a functional tendon transfer begins at 3 weeks and muscle strengthening at 6 weeks, which cannot be accomplished if the tendon transfers have been performed concomitantly with an osteotomy because the immobilization period for healing of the osteotomy is generally 10 to 12 weeks.

Osteotomy techniques for the midfoot vary according to the deformity present. Osteotomies can be performed through four percutaneous incisions or through two or more minimum incisions. Rotational and translational deformities can be corrected through a percutaneous osteotomy placed over the central aspect of the cuneiforms and cuboid. The osteotomy should never be placed along the metatarsal bases or along the tarsal-metatarsal joint, even if a previous tarsal-metatarsal joint arthrodesis was performed. An osteotomy that passes in this direction will cause vascular injury to the distal perforating arteries in the intermetatarsal spaces. A Gigli saw can be used through appropriately placed percutaneous incisions. If wedge osteotomies are necessary to correct the deformity, the authors use two minimum incisions placed medially and laterally, which allow precise wedge resection and removal of the osseous wedge, and ensure appropriate positioning of the two segments to achieve the desired correction. Regardless of the osteotomy technique, the goals are to protect the neurovascular bundle, preserve the periosteal blood supply, and minimize thermal necrosis [1,7,16].

Percutaneous Gigli saw technique for an osteotomy of the midfoot is performed through four percutaneous incisions. The incisions are placed dorsal-medial, dorsal-lateral, plantar-lateral, and plantar-medial. The incisions are made directly to bone, avoiding injury to the neurovascular bundle and tendon structures. A periosteal elevator is then used to create a tunnel deep to the soft tissue structures dorsally and plantarly. Periosteal stripping is minimized and only created over the path of the osteotomy. The location of the incisions should be confirmed with intraoperative image intensification. In addition, Kirchner wires can be inserted medially and laterally in the path of the planned osteotomy. This technique provides a cutting guide for the Gigli saw. The Gigli saw is first passed plantarly, then dorsally, with the use of a large hemostat to facilitate transfer from one incision to the next. This procedure can be performed without a tourniquet to ensure the neurovascular bundle is not transected. The osteotomy should not be performed from dorsal to plantar or plantar to dorsal because this can lead to neurovascular injury. Typically, the osteotomy is performed from medial to lateral but can be performed cautiously from lateral to medial (Fig. 1).

Incision placement is paramount in performing the osteotomy through two limited incisions and cannot be overlooked. A 3-cm skin incision is made dorsal-medial over the medial cuneiform and extends proximal to the navicular-cuneiform joint and distal to insertion of the tibialis anterior tendon. It is not necessary to carry the incision distally to the first metatarsal-cuneiform joint or to transect the tibialis anterior tendon. This incision should be placed just proximal and inferior to the anterior tibial tendon and distal and dorsal to the insertion of the posterior tibial tendon. The

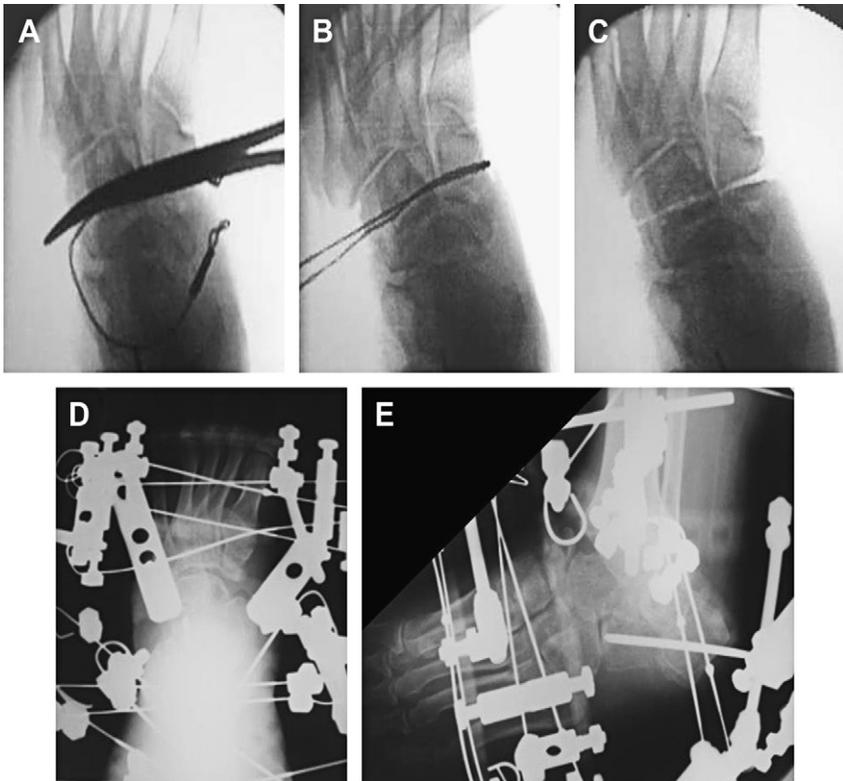


Fig. 1. (A) Intraoperative image intensification anterior-posterior view demonstrating proper passing of the Gigli saw through four percutaneous incisions. Intraoperative image intensification anterior-posterior view before (B) and following (C) completion of the midfoot osteotomy. Postoperative non-weight-bearing anterior-posterior (D) and lateral (E) radiographs demonstrating realignment of the forefoot following corrective midfoot osteotomy fixed with a ring-type external fixation device.

lateral incision is 3 cm in length and is placed on the dorsal-lateral aspect of the cuboid, just dorsal to the peroneal brevis and longus tendon and plantar to the peroneus tertius tendon. The incision is placed beginning just distal to the calcaneal-cuboid joint and extends to the fourth and fifth metatarsal bases as they articulate with the cuboid. Caution should be used to avoid placing the lateral incision too plantar because this placement creates difficult exposure of the cuboid and retraction of the peroneal tendons. Arthrotomy and transection of the joints surrounding the osteotomy medially and laterally should not be performed; instead, an 18-gauge needle can be placed to identify the location of the joint, if needed. Ligament structures to these joints should be preserved to accomplish deformity correction after appropriate positioning of the osteotomy. A midfoot osteotomy using two minimum incisions is performed initially with a sagittal saw and then

completed with an osteotome or flexible chisel. Kirchner wires are again placed with intraoperative image intensification to serve as a guide for the wedge resection and to serve as an osteotomy guide. In addition, hash marks are made perpendicular to the planned osteotomy with a small sagittal saw blade or electrocautery. This technique is advantageous in establishing orientation of the proximal and distal segments after the osteotomy is completed. The use of a sagittal saw is to establish the orientation of the planned osteotomy. Hand instrumentation, such as an osteotome, should be used to prevent thermal necrosis associated with the use of power instrumentation [16]. A narrow osteotome or flexible chisel should be used to prevent fracture propagation perpendicular to the osteotomy. After the osteotomy is performed, it is loosened with an osteotome, a smooth lamina spreader is inserted, and the osteotomy is distracted for 3 to 5 minutes to relax the surrounding soft tissues. Distraction in this manner mobilizes the distal segment, facilitating positioning and deformity correction. In addition, for wedge-based osteotomies, it is advantageous to maintain a periosteal hinge at the apex of the wedge to facilitate closure (Fig. 2).

After the osteotomy is performed and placed in the desired position, it can be fixated with internal fixation, external fixation, or a combination of both. The authors have found it advantageous to stabilize the osteotomy with Steinmann pins if external fixation is used, or guide wires for cannulated screws if internal fixation is to be used, to allow assessment of the desired position before definitive fixation. A metallic instrument cover is typically used to simulate weight bearing to ensure a plantigrade foot is obtained intraoperatively. Circular ring-type external fixation is advantageous in the presence of severe deformities requiring gradual corrections, osteopenia, Charcot neuro-osteoarthropathy, and neuromuscular deformities, and in patients who require early weight bearing [5,12,14,17,18].

Postoperatively, admission with in-patient observation is necessary for 24 hours for pain management and neurovascular monitoring. If internal fixation was used, the patient is initially placed in a bulky, well-padded dressing from toes to knee and a sugar-tong plaster splint for immobilization until edema has subsided. Patients who have external fixation are treated with weekly dressing changes and inspection of the pin sites. Initial radiographs are taken at 2 weeks, followed by gradual removal of all skin sutures and metallic staples.

Patients who have external fixation may be permitted to weight share with a modified shoe after suture removal at 2 weeks if peripheral sensory neuropathy is not present [19]. Patients who have internal fixation are maintained non-weight bearing until radiographic evidence of healing is evident, usually at 6 to 8 weeks postoperative. At that time, a short leg, weight-bearing cast is applied for 2 weeks, followed by a removable walking boot, until complete clinical and radiographic healing is apparent, generally at 10 to 12 weeks postoperative. The patient is then placed into extradePTH shoe gear with in-shoe accommodative orthoses or brace therapy, as indicated for life.

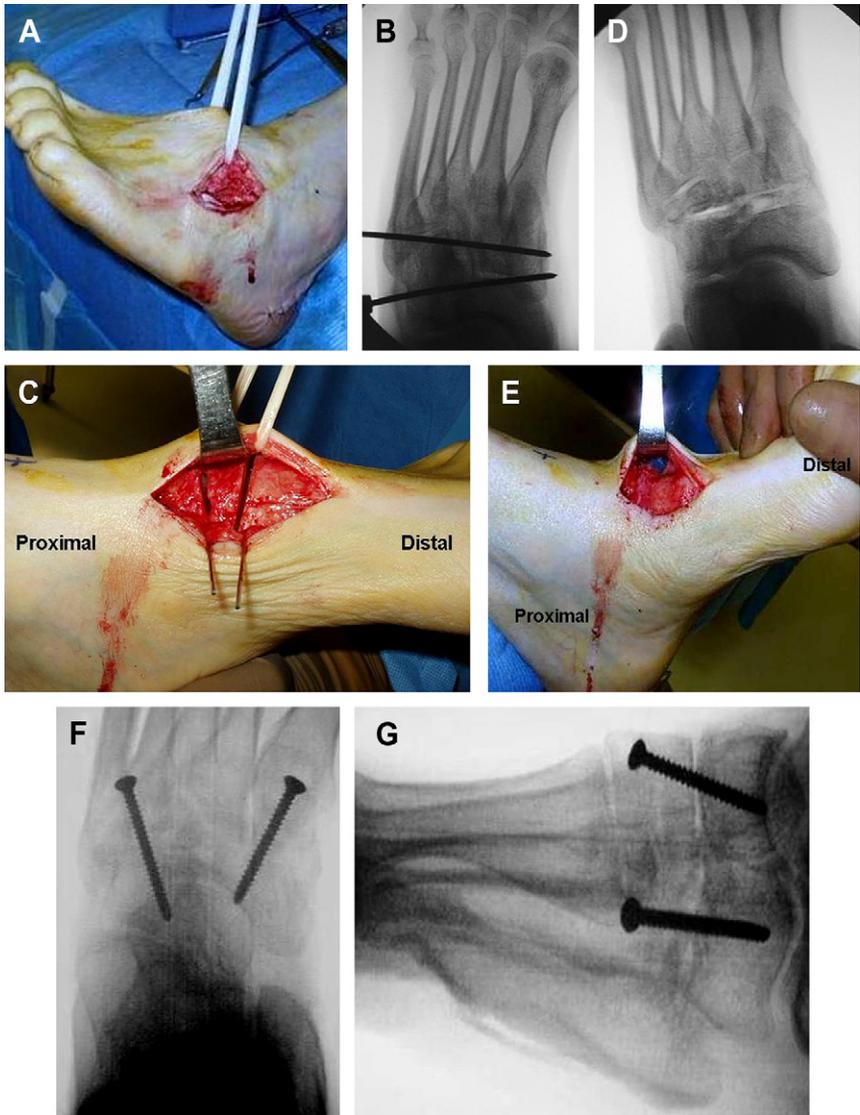


Fig. 2. (A) Intraoperative lateral photograph following subperiosteal dissection with a two-incision approach to the midfoot. Note the use of a rubber drain to elevate and protect the dorsal soft tissues and neurovascular structures. Intraoperative image intensification anterior-posterior (B) and medial photograph (C) of the same foot demonstrating use of medial-to-lateral Kirschner wires as an osteotomy guide. Note the precise osteotomies that have been created to perform a dorsiflexory-abductory wedge osteotomy. Intraoperative image intensification anterior-posterior (D) and medial photograph (E) following removal of the osseous wedge demonstrating multiplanar deformity correction. Intraoperative image intensification anterior-posterior (F) and lateral (G) radiographs following placement of internal fixation to stabilize the corrective midfoot osteotomy.

Patients who have Charcot neuro-osteoarthropathy deformities who undergo a midfoot osteotomy are not permitted weight bearing, regardless of the method of fixation used. These patients are kept non-weight bearing until radiographic healing and then 50% longer to ensure complete osseous incorporation before transitioning into a weight-bearing cast or removable walking boot. In addition, total contact casts are preferable to walking boots in this patient population, to minimize torque on the osteotomy while initial weight bearing is permitted, generally at 4 to 6 weeks following removal of the external fixation device. A removable walking boot is then continued until clinical and radiographic evidence of healing is complete.

Complications

Soft tissue complications are usually associated with severe deformities, vascular insufficiency, or previously traumatized tissues. Corrections that place excessive tension on the soft tissue envelope and the neurovascular structures can lead to significant complications. These patients should be corrected gradually over a period of time using a ring-type external fixation system that limits the potential to develop skin necrosis and neurovascular insult.

Delayed unions and nonunions are rare but can occur, particularly in high-risk patients, such as those who have diabetes or Charcot neuroarthropathy, those who abuse tobacco or use corticosteroids, or those who have avascular bone associated with previous trauma. These patients may benefit from judicious use of orthobiologic technology and bone growth stimulation to facilitate primary osseous healing.

Malunion often occurs from inadequate preoperative planning, poor intraoperative positioning, or early weight bearing. Attention to detail during the preoperative physical examination is paramount in understanding associated deformities, joint contractures, and compensatory motion proximal and distal to the osteotomy to prevent malunion and resultant deformity. In addition, time spent intraoperatively to ensure appropriate osteotomy placement and positioning cannot be overstated. Postoperative transition to full weight bearing should not occur until radiographic healing is evident, unless an external fixator is used to prevent motion across the osteotomy.

Summary

Corrective midfoot osteotomies represent an effective surgery to treat select pedal deformities. Knowledge of deformity planning and normal anatomic relationships is important to allow foot and ankle surgeons to achieve their goal of re-establishing a plantigrade foot capable of withstanding the repetitive stress associated with ambulation. Percutaneous or minimum incision surgical techniques to realign the midfoot in the high-risk patient are master level techniques that require extensive surgical experience and detailed knowledge of lower extremity biomechanics.

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