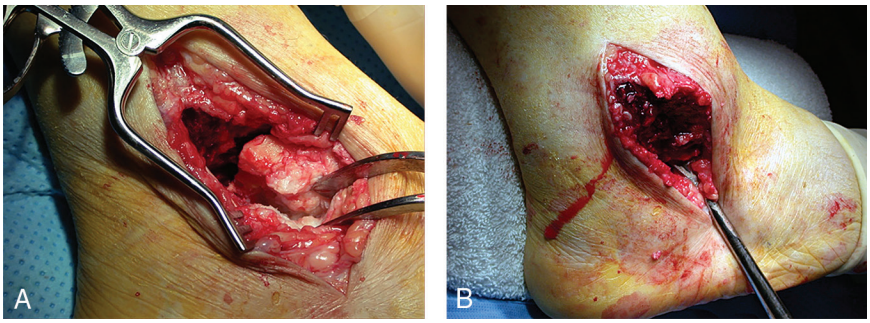

Figure 2 **A,** Intraoperative photograph demonstrates the transfibular approach used to expose the ankle and the subtalar joint in converting a failed ankle arthroplasty to arthrodesis. The loose prosthetic device has already been removed, and the subtalar joint is well visualized. **B,** Intraoperative photograph demonstrates cavitary defect in the distal tibia after removal of the failed prosthetic component.

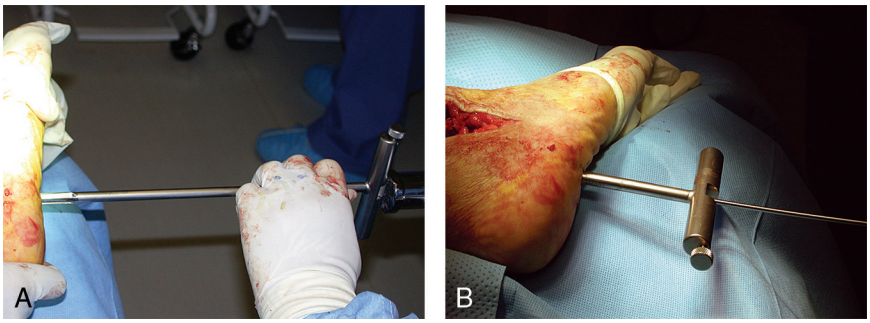

Figure 3 Intraoperative photographs demonstrate insertion of a T-handled broach through the plantar aspect of the heel. **A,** The insertion point on the plantar surface of the calcaneus lies at the junction of the medial and middle thirds of the calcaneus, with the incision at the anterior aspect of the heel pad. Placement must be as accurate as possible because only small errors in placement can be compensated for during the reaming process. **B,** The fully inserted T-handled broach is exchanged for a smooth guide pin before reaming the intramedullary canal.

of injury to the lateral plantar artery and nerve (**Figure 3, A**).

- A T-handled broach is passed from the plantar aspect of the heel, perpendicular to the plantar aspect of the foot, through the calcaneus, and across the remaining talar body into the tibial IM canal. The broach is then exchanged for a long smooth guide pin (**Figure 3, B**). The usual starting point for the broach is at the junction of the medial and middle thirds of the undersurface of the calcaneus.
- Sequential reaming to the desired implant diameter, usually the largest available within the implant system, is then done. The authors of this chapter do not overream because it may compromise rotational stability during insertion of the IM rod.
- The bony defect is then filled with bone graft. Bone graft options include freeze-dried cancellous chips with or without biologic stimulant, autograft, and femoral head structural allograft. The authors of the chapter prefer freeze-dried cancellous chips because the IM rod provides the structural support necessary as the graft incorporates. Bone morphogenetic protein-2 pads are placed along the margins of the cavitary defect. The authors of this chapter do not use autograft because of the risk of donor site morbidity, nor do they use femoral head structural allografts because they have led to a few instances of delayed settling (**Figure 4**).
- The appropriate size IM rod is then inserted into the plantar aspect of the heel. Lateral fluoroscopic views are used to confirm the appropriate depth of insertion.
- Two posterior-to-anterior calcaneal screws are placed under fluoroscopic guidance to confirm the appropriate depth of insertion. AP fluoroscopic live rotational views are obtained to confirm that the screws have passed through the rod (**Figure 5**).
- To allow for compression across both the ankle and the subtalar joints, talar screws are not placed.
- The arthrodesis site is manually impacted with a mallet, and a proximal dynamic locking screw is placed through the IM rod from lateral to medial. Placement of the screw in the proximal end of the dynamic slot is confirmed on AP and lateral fluoroscopic views.
- Final fluoroscopic views are obtained.

Wound Closure

- The wound is closed in layers using absorbable subcutaneous sutures and nonabsorbable cutaneous sutures.
- Skin tension should not be present during wound closure; to relieve skin tension, the underlying bony prominences should be resected.

Postoperative Regimen

The patient is placed in a posterior splint initially and, at the time of suture removal (approximately 2 weeks after surgery) placed in a non–weight-bearing short leg cast for a minimum of 2 months. The authors of this chapter routinely obtain a

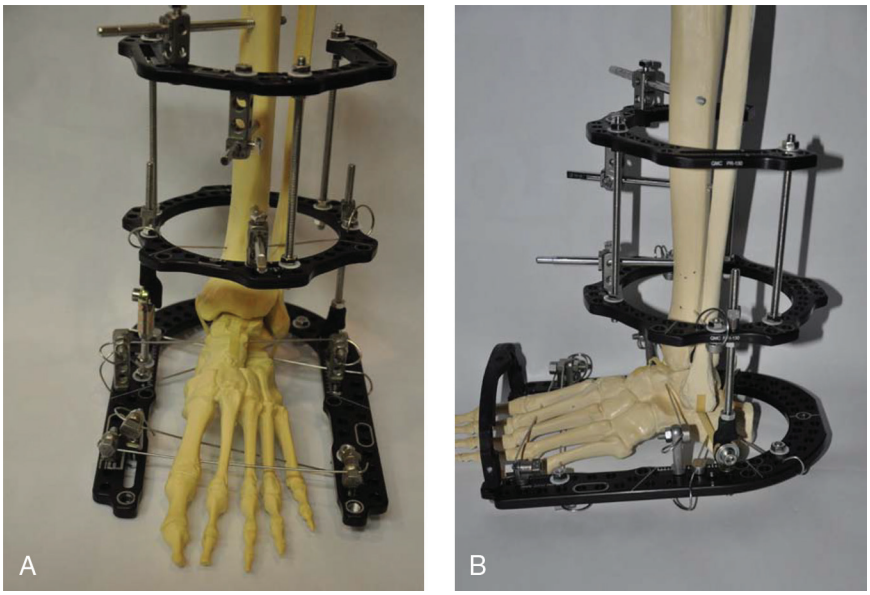

Figure 1 Photographs show a complete ankle distraction frame on a skeletal model. **A,** AP view. **B,** Lateral view.

motion compared with fixed distraction (**Table 1**).

Techniques

Setup/Exposure

- For ring fixator application, the patient position is generally supine with the patella forward to allow access to both the medial and lateral aspects of the limb and foot. This position often requires a small bump under the ipsilateral hip.
- In patients undergoing ankle distraction, adjunct procedures including anterior ankle bony débridement; osteotomy to correct tibial, ankle, or foot malalignment; and ligament or tendon reconstruction are commonly performed. These procedures are usually performed before frame application and may require different patient positions and surgical exposures (**Figures 3** and **4**).
- For gradual correction of tibial deformity, the osteotomy is typically performed after frame application

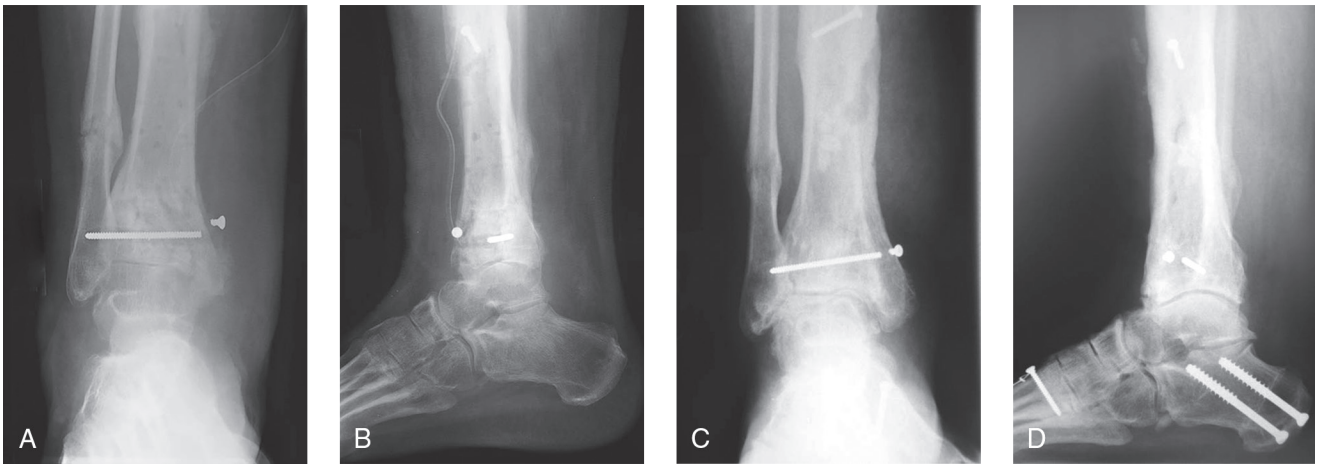

Figure 2 Weight-bearing AP (**A**) and lateral (**B**) radiographs of the right ankle of a 25-year-old patient demonstrate severe posttraumatic ankle arthritis following open pilon and distal tibia shaft fractures. The patient sustained substantial damage to the soft-tissue envelope surrounding the distal tibia. Note underlying cavovarus foot posture. AP (**C**) and lateral (**D**) radiographs of the same patient obtained 8 years after ankle distraction, cavovarus foot reconstruction, and management of localized distal tibia osteomyelitis. The patient was able to return to work in an occupation requiring considerable walking and experienced substantial improvement in pain level and function.

improvement increased over time, and joint distraction had markedly better results than ankle joint débridement alone. In a subsequent review by the same researchers at a minimum follow-up of 7 years after ankle distraction for osteoarthritis, 16 of 22 patients had substantial improvement in all clinical parameters and treatment failed in 6 patients (73% and 27%, respectively). In a study of 23 patients with a mean follow-up of 30.5 months, 74% of patients had substantial improvement in the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot score (mean preoperative score, 55; mean postoperative score, 74). A prospective, randomized controlled study published in 2012 demonstrated substantial improvement in distraction results with

Figure 2 Illustration of amputations to manage lesions of the forefoot. **A,** Lisfranc. **B,** Chopart. **C,** Pirogoff. **D,** Boyd. **E,** Syme.

of mainly medial and lateral gastrocnemius and a portion of the soleus muscle. The tibia is cut 10 to 15 cm below the joint line, and the fibula is shortened 1 cm further. Through- or above-knee amputation is less desirable because rehabilitation is more difficult and ambulation consumes more energy.

Results

Large prospective cohort studies on the Pirogoff procedure are lacking; the available studies offer only small series of patients treated with different surgical techniques. Good functional results have been reported in young patients who underwent the procedure because of trauma or tumor without any vascular compromise. No problems with prosthesis fit have been described.

The Pirogoff amputation always shortens the leg. A mean limb-length discrepancy of 2.5 cm (range, 1.0 to 4.5 cm) was calculated among 24 patients who underwent unilateral amputation. In the group who underwent Pirogoff amputation, the minimal limb-length discrepancy enables walking without a prosthesis, which offers both functional and psychological advantages. Prostheses can be fitted for cosmetic purposes. The shortening of the leg makes the swing phase easier and results in a lower risk of tripping.

A literature review of complications after Pirogoff amputation included 60 patients from nine studies. Follow-up ranged from 7 months to 15 years, and 85% of the patients were male. In this mixed group of patients, the rate of reamputation due to infection was 13%, stump revision was performed in 3.5% of the patients, and early failure due to debilitating pain was seen in 18% of the patients.

Techniques

Setup/Exposure

- In developed countries, amputation is frequently performed for patients with severe peripheral artery disease. Because of the large number of comorbidities, this patient population presents a challenge to the anesthesiologist.
- Peripheral nerve blocks are associated with minimal hemodynamic disturbance and are a suitable option for these high-risk patients.
- Prophylactic antibiotics (third-generation cephalosporins) are administered intravenously 30 minutes before incision in accordance with the local hospital regimen.
- To prevent wrong-site surgery, the surgeon initials the surgical site before the procedure. This mark should also be visible to the surgeon after the patient has been prepped and draped.
- A time-out procedure is mandatory.
- The patient is positioned supine.
- The use of a tourniquet remains optional. Many surgeons are reluctant to use tourniquets on a regular basis, especially in patients with vascular compromise.
- Grafts of previous bypass surgery are at risk if a tourniquet is used, and patients report thigh pain postoperatively.
- Active bleeding of the wound edges has to be estimated intraoperatively.
- An above-knee tourniquet could be applied as a safety measure. The tourniquet is inflated to control bleeding only in the case of a severe hemorrhage.
- A radiolucent table allows for fluoroscopic imaging in the AP plane during the procedure.
- The leg is internally rotated and a sandbag is positioned under the ipsilateral buttock to simplify the approach, osteotomy, and imaging of the ankle mortise.
- For lateral imaging, the contralateral leg is lowered to prevent a double contour.
- If a nonhinged surgical table is used, a folded surgical gown is

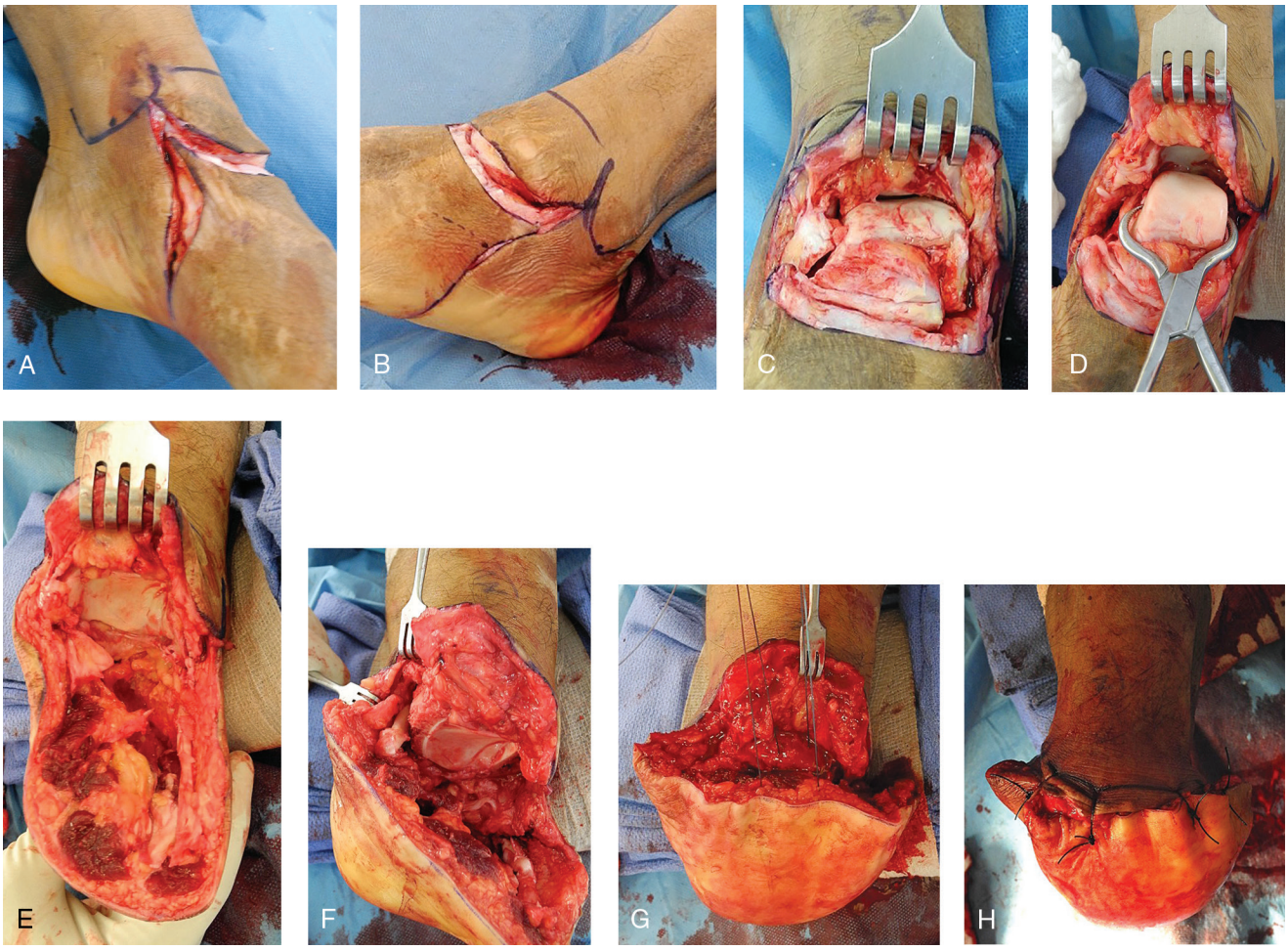

Figure 3 Intraoperative photographs demonstrate single-stage Syme amputation. Fish-mouth skin flaps are made with the medial (**A**) and lateral (**B**) apices of the incision located at the anterior midpoint of the medial and lateral malleoli, respectively. **C,** The anterior capsule of the ankle joint is cut and the medial and lateral ligaments are released, taking care to retain the full-thickness flap. **D,** Traction is exerted on the talus using a bone-holding clamp. **E,** With traction applied to the talus, the talus and calcaneus are sharply dissected, taking care to maintain the full-thickness flap and not damage the posterior tibial artery. **F,** The medial and lateral malleoli have been removed to a level flush with the articular surface of the tibia. The flare of the medial malleolus has been removed using a power saw to narrow the eventual amputation stump. **G,** To secure the heel pad, nonabsorbable sutures are passed through holes drilled in the anterior tibia. **H,** The appearance of the layered wound closure using sutures.

using a power saw to both narrow the eventual amputation stump and provide a raw surface area of bone that will allow flap adherence.

- Hemostasis of the soft tissues should be obtained. To secure the heel pad and prevent migration, nonabsorbable sutures can be placed through two or three oblique drill holes made in the anterior distal tibia (**Figure 3, G**). Alternately, the heel pad may be secured by tenodesing the Achilles tendon to the posterior distal surface of the tibia.
- The use of a postoperative drain is at the surgeon's discretion; if used, the drain hole should not be directed through the heel pad.

Wound Closure

- The incision is closed in two layers.
- First, the deep tissues are reapproximated using a layer of heavy absorbable sutures. The skin can then be closed using sutures or staples (**Figure 3, H**).

Postoperative Regimen

The use of a bulky dressing, splint, or cast is at the surgeon's discretion. The authors recommend the placement of a well-padded cast before hospital discharge to protect the wound from external trauma in the event of a fall. When the surgeon deems the wound to be secure, a well-padded cast with a rubber walking heel can be used for weight-bearing ambulation, which can

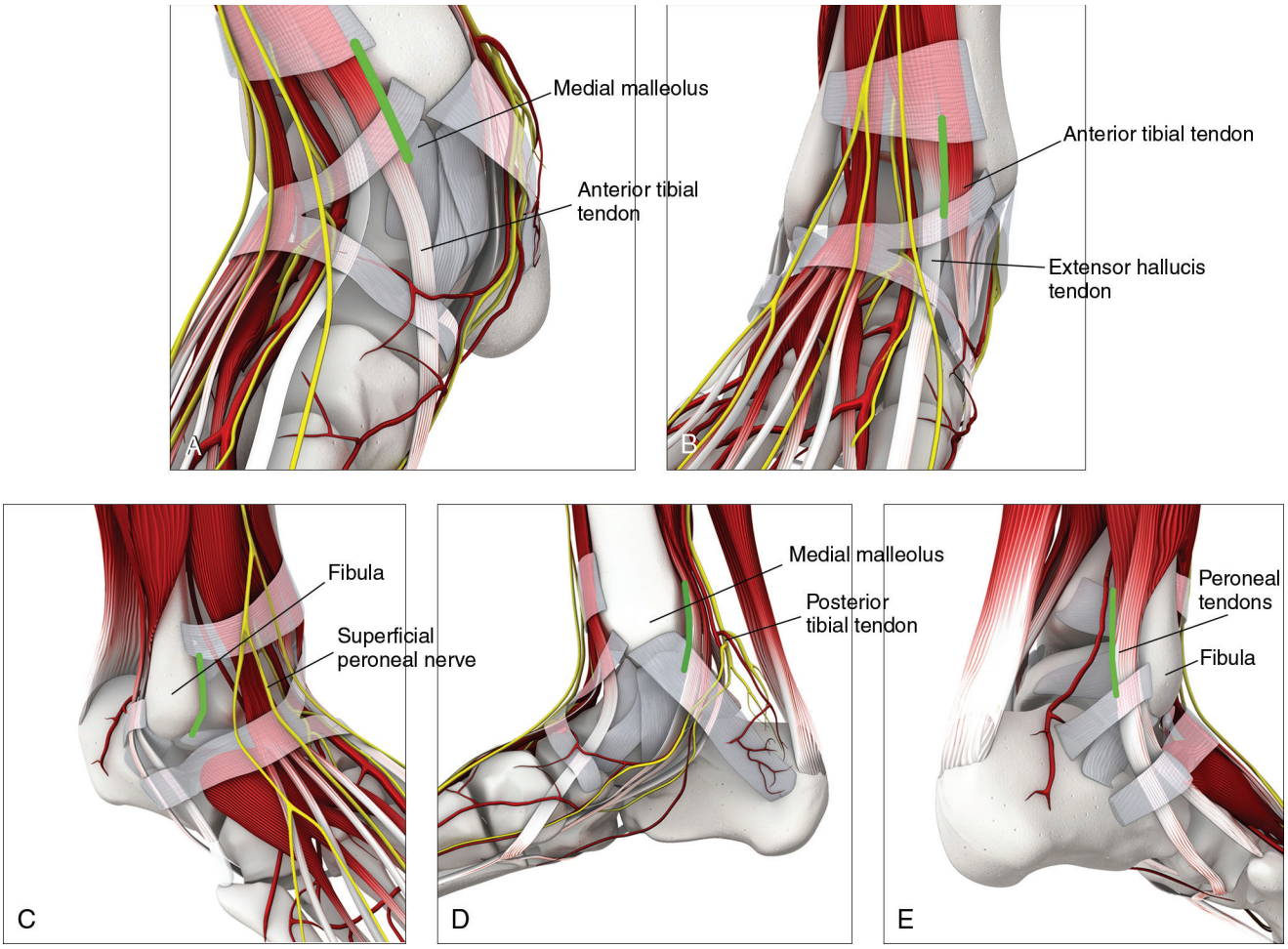

Figure 2 Illustrations demonstrate the various surgical approaches for matrix-based reconstruction of osteochondral lesions of the talus. In each illustration, the green line indicates the location of the incision and the dissection. **A,** The ventromedial approach, medial to the anterior tibial tendon. **B,** The ventrocentral approach, between the anterior tibial tendon and the extensor hallucis longus tendon. **C,** The ventrolateral approach, between the peroneus tertius tendon and the distal fibula. **D,** The dorsomedial approach, between the medial malleolus and the posterior tibial tendon. **E,** The dorsolateral approach, between the peroneal tendons and the distal fibula.

medial defect using the ventromedial approach, a dorsomedial approach between the medial malleolus and posterior tibial tendon can be used (**Figure 2, D**). The patient is placed on the ipsilateral side and can be stabilized with a short vacuum mattress. The contralateral leg is cushioned on a foam mattress. The affected leg should be freely movable, allowing flexion of the knee joint, to ensure sufficient dorsal extension of the ankle joint. Care must be taken to avoid pressure on the peroneal nerve at the proximal fibula.

- A dorsolateral approach between the lateral malleolus and the peroneal tendons allows access to defects that lie very dorsally on the lateral side (**Figure 2, E**). The patient is placed on the contralateral side. This can be done with the help of a U-shaped foam pillow or a beanbag positioner, which also offer good surfaces for positioning the affected leg. To enable adequate dorsal extension, flexion of the knee joint must be possible.
- If harvest of cancellous bone from the head of the tibia or the iliac crest is required for bone graft, the skin overlying the donor site should be prepared and draped appropriately.
- General and/or regional anesthesia may be used.
- A tourniquet at the thigh is recommended. Below-knee tourniquet application may compromise ankle flexibility during the procedure and has not been proven in practice.

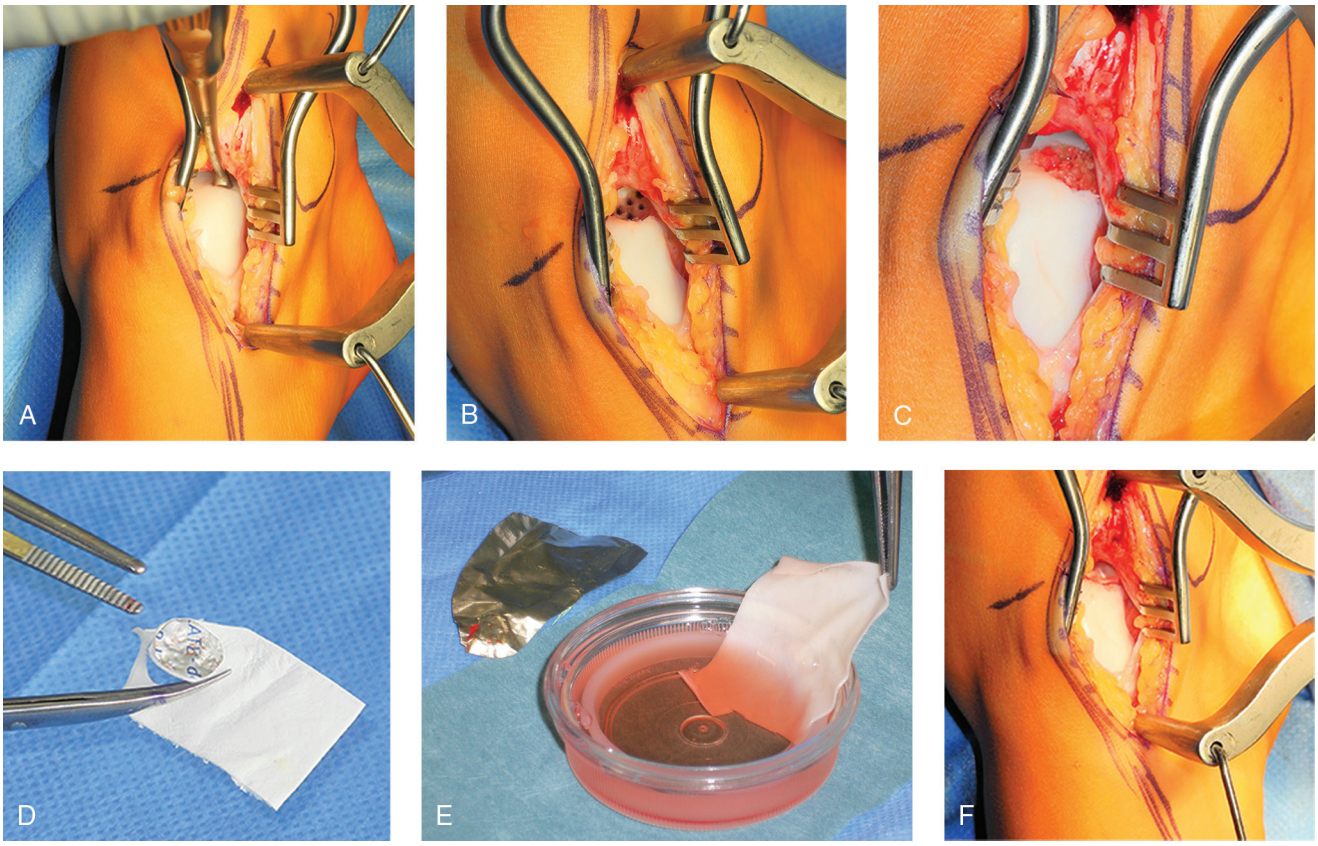

Figure 4 Intraoperative photographs demonstrate matrix implantation for cartilage reconstruction using a ventromedial approach. **A,** Débridement of the unstable cartilage with a curet. The amount of joint distraction and anterior talar subluxation using a small joint distractor are illustrated. **B,** The appearance of the walls and the base of the cyst after débridement and drilling with a 1.2-mm drill bit. **C,** The appearance of autologous bone graft used to fill the osseous defect. **D,** A template of sterile foil is used to cut the membrane to the size needed. **E,** The appearance of matrix used in matrix-induced chondrocyte implantation when used directly from the sterile transport medium. **F,** The appearance of the defect after treatment. The matrix has been placed and fixed with fibrin glue.

Additional sutures are not necessary (**Figure 4, F**).

- After the bone spreader is removed, the position of the joint is maintained for 3 minutes until the fibrin glue has hardened. The implant is then checked for stability by moving the joint several times. The optimal postoperative range of motion can be checked at this step. If delamination of the implant has occurred as a result of joint movement and the implant extends beyond the defect border, the excess should be shaved off. Another reason for delamination is overfilling of the bone defect. If necessary, the thickness of the bone graft should be reduced.

Wound Closure

- If the implant remains in position, the wound is closed layer by layer. An intra-articular drain without suction can be inserted before wound closure and left in place for 24 to 48 hours.
- Associated pathobiomechanical factors should be corrected after the cartilage reconstruction procedure is performed. In the setting of chronic instability, this includes reconstruction of the ligaments (medial, lateral, or combined). Axial malalignment should be managed with corrective osteotomy (supramalleolar, talar, or calcaneal).
- For matrix-based cartilage reconstruction, a miniarthrotomy is preferred. If surgical access is inadequate, the procedures can be performed during the preceding medial or lateral osteotomies.

Postoperative Regimen

Thrombosis prophylaxis using low-molecular-weight heparin is recommended until the patient has reached more than 50% weight bearing. NSAIDs can be administered as analgesics. Sufficient elevation and cryotherapy are important.

The foot is placed in a cast for 48 hours. Following cast removal,

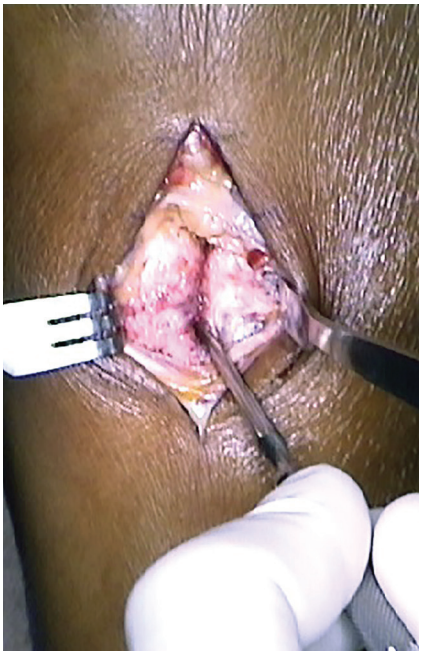

Figure 1 Intraoperative photograph shows the joint exposure in the Lisfranc region.

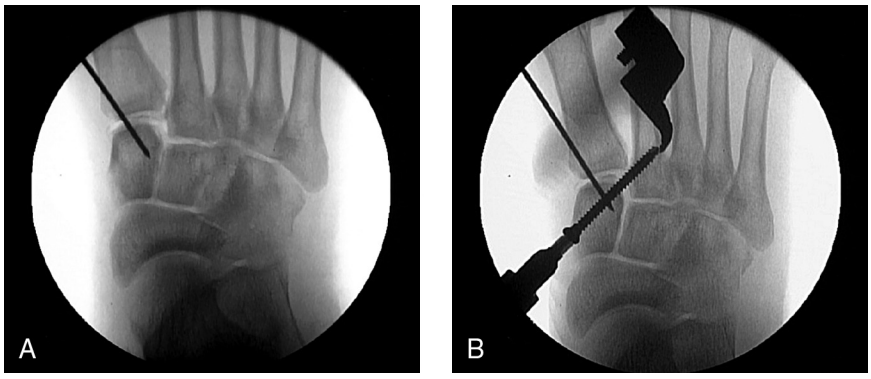

Figure 2 Intraoperative AP fluoroscopic images show the midfoot. **A,** Reduction and provisional pin fixation of the first tarsometatarsal joint is performed. **B,** A clamp is used to reduce the second tarsometatarsal joint, and provisional fixation is placed.

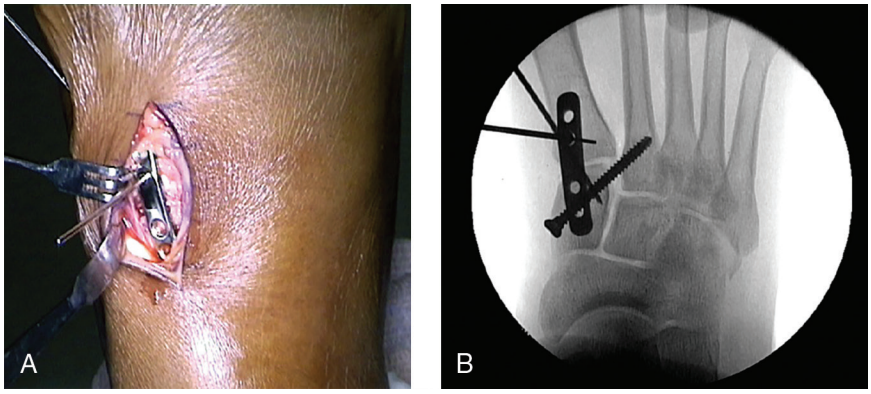

Figure 3 **A,** Intraoperative photograph shows the spanning plate provisionally secured over the first tarsometatarsal joint. **B,** Intraoperative AP fluoroscopic image demonstrates placement of the plate and home run screw.

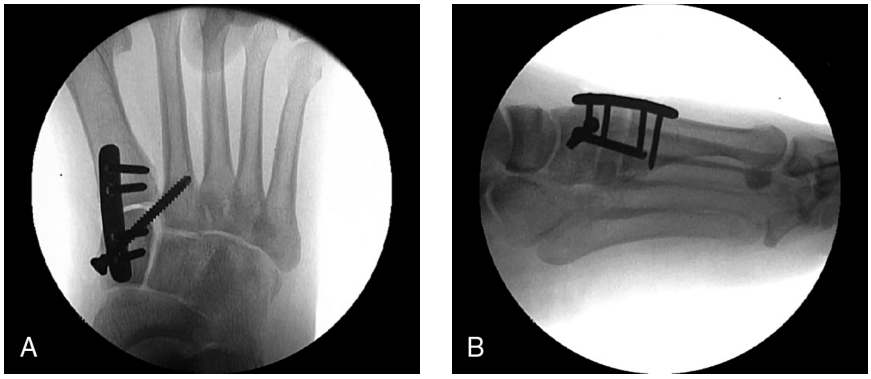

Figure 4 Final AP (**A**) and lateral (**B**) fluoroscopic images show fixation of the first and second tarsometatarsal joints.

postoperatively. The patient is cautioned that the plate or screws may break. The patient is given a longitudinal arch support for long-term use in the shoe. The plate and screws are removed at 12 to 16 weeks postoperatively. Some surgeons do not routinely remove the hardware, however.

Avoiding Pitfalls and Complications

In both the single- and dual-incision approaches, disruption of the neurovascular bundle involving the dorsalis pedis artery and deep peroneal nerve must be avoided. Careful elevation of these structures allows access to the first and second metatarsal bases. With medial or dorsomedial placement of the spanning plate, the most frequently injured structure is the dorsomedial cutaneous nerve, which is a branch of the superficial peroneal nerve.

The distal portion of the anterior tibial tendon insertion is directly in the region of plate placement when the plate is applied in a medial position; thus, a dorsal position is recommended. An additional concern with the medial position is that the trajectory of the screws can violate the intercuneiform joint. Violation of this joint does not necessarily cause a clinical problem but is not ideal.

Dorsal plates may break when the patient begins to bear weight. The plates also may be prominent and may cause irritation, especially if thicker plates are used.

Figure 1 AP (**A**) and lateral (**B**) radiographs show the posterior pilon injury. Note the double density on the AP view of the distal tibia, representing the large posterior tibial fragment. Sagittal (**C**) and axial (**D**) CT scans reveal the large posterior tibial articular fragment. The talus is subluxated posteriorly relative to the anterior tibia, and several small osteochondral fragments are present in the fracture at the level of the joint.

Figure 2 Lateral radiograph shows a posterior pilon fracture that was fixed with percutaneous anterior-to-posterior screws. Following hardware removal 1 year after injury, the articular incongruity is obvious.

fracture fragments.

Results

Few studies have focused on the large posterior malleolus/pilon fracture pattern. One author suggested that the posterior pilon fracture is a more severe injury than routine malleolar fractures. In a recent study, 16 patients with a large posterior pilon fracture were followed for an average of 3 years. The surgeons were able to achieve anatomic reduction of the distal tibial articular surface with posterior approaches in most patients. No infections or neurovascular injuries were reported. One nonunion of the medial malleolus occurred, presumably because of the difficulty of accessing the medial malleolus when the fracture is more anterior. Two patients needed hardware removal.

Despite the good reduction, the outcome scores in that series showed moderate functional limitations closer to those of a true pilon fracture than a routine malleolar injury. Of the nine patients who had weight-bearing radiographs available beyond 2 years, three had moderate to severe tibiotalar arthritis. The early onset of arthritis despite a good reduction and the mediocre functional outcomes suggest that the posterior pilon injury is substantially more devastating than routine malleolar fractures.

Technique

- The first step consists of preoperative planning.
- Axial CT scans, preferably made following closed reduction of the dislocation, will reveal the nature of the posterior pilon fragment.
- In some patients, the fragment is predominantly posterolateral, and