# Simple Solutions for Difficult Problems:
# A Beginner's Guide to Ring Fixation

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Most practicing orthopedic surgeons shudder at the thought of performing surgery with tensioned fine wire external fixation rings. The technique conjures up unpleasant memories from residency of complex deformity and leg-lengthening operations. They remember prolonged surgery, labor-intensive postoperative care, patients who had severe pain, and multiple pin- and frame-associated morbidities. They attend conferences with presentations of complex frame constructs with pins and rings applied in indiscernible directions and radiographs obscured completely by the frame. The goal of this discussion is to demystify ring fixation and provide guidelines for simple applications of this technology for solving difficult problems where the use of internal fixation is best avoided.

Engineering advances in modern frame construction and increased American experience have simplified the science and applicability of ring technology greatly. Most orthopedic surgeons are comfortable with the concept of obtaining correction of an angular deformity with osteotomy or arthrodesis. They also are comfortable maintaining that correction with rigid internal fixation.

This discussion begins with simple static applications of circular external fixation frame technology for simply maintaining a correction obtained at surgery, where foreign body implants or extensive surgical dissection is best avoided. The discussion moves to simple applications of dynamic uniplaner correction of simple deformities in poor hosts. Once surgeons achieve comfort on the learning curve of applying fine wire technology in a static fashion, they can progress to simple dynamic deformity correction.
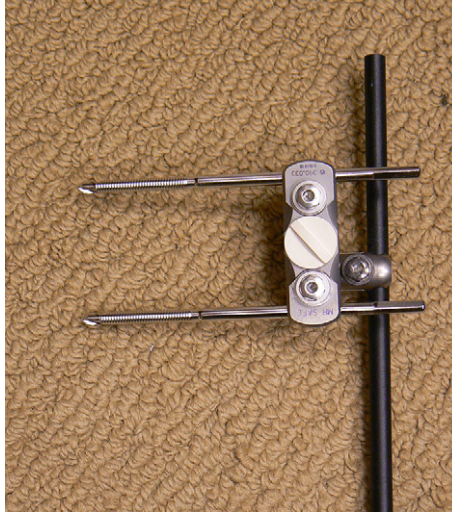
*E-mail address:* mpinzu1@lumc.edu

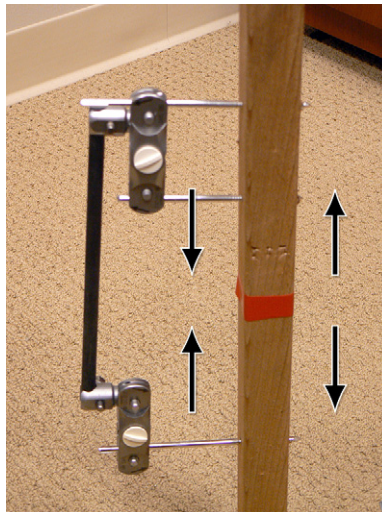Fig. 1. Threaded half-pins used for uniplaner external fixation.



Fig. 2. Biomechanical loading pattern when using uniplaner external fixation with half-pins. There is a compression load applied to the fracture or osteotomy site in the plane of the external fixation on the side of the external fixator. A distraction load is applied along the opposite side of the bone. This construct is least stable in the plane perpendicular to the plane of the external fixator.

### Simplified biomechanics of ring fixation

Threaded screws or pins achieve stability in bone by interdigitation with mechanically sound bone. The strength of that fixation stability is dependant on the quality of the bone and the intimacy of the bony interdigitation with the threads. Bioengineers measure that stability by pull-out strength. Classic external fixation historically has been accomplished with threaded half-pins or centrally threaded pins (Fig. 1). The stability of the construct is stiffer when loaded in the plane of the pins (ie, on the compression side of the loading). Conversely, the construct is less stiff on the tension side (Fig. 2). The construct is least stiff in a plane perpendicular to the plane of the pins. When a bending moment is applied to the bone, the pins or screws toggle, leading to bony absorption about the threads, loosening of the pins, and an overall decrease in construct stability. No matter the orientation of a threaded pin design, there must be an asymmetric plane of loading that produces that toggle affect [1].

Ring fixation uses smooth pins, ranging in diameter of 1.5 to 1.8 mm, that are pretensioned from 50 to 130 kg before being affixed to a circular ring. When rings are applied above and below a fracture or arthrodesis



Fig. 3. Biomechanical loading pattern applied with a circular ring external fixator. The biomechanical load is applied via a force vector through the center of the bone, without a bending moment about the fracture/osteotomy site.

site, loading displays almost universal behavior in all planes. The force vector applied to the focal point of the ring is axial in nature, virtually eliminating any bending moments applied to the bone (Fig. 3) [2].

Hybrid external fixation combines both methods. Although technically simpler to apply, this method does produce bending moments and decreased stiffness in planes perpendicular to the planes of the threaded pins.

## Static frame

Dynamic correction of bone or soft tissue deformity with external fixation entails osteotomy or soft tissue release combined with the application of an external fixator device that is applied to the extremity in the precorrected orientation. Asymmetric adjustment (ie, compression or distraction) gradually corrects the deformity over time. This dynamic change applies bending forces at the points of articulation (ie, connection) of the external fixator frame, leading to loosening of threaded nuts and bolts and tension on the skin. To prevent loss of fixation, the nuts and bolts must be checked and tightened frequently, and tented skin must be relieved to lessen the risk for pin tract infection.



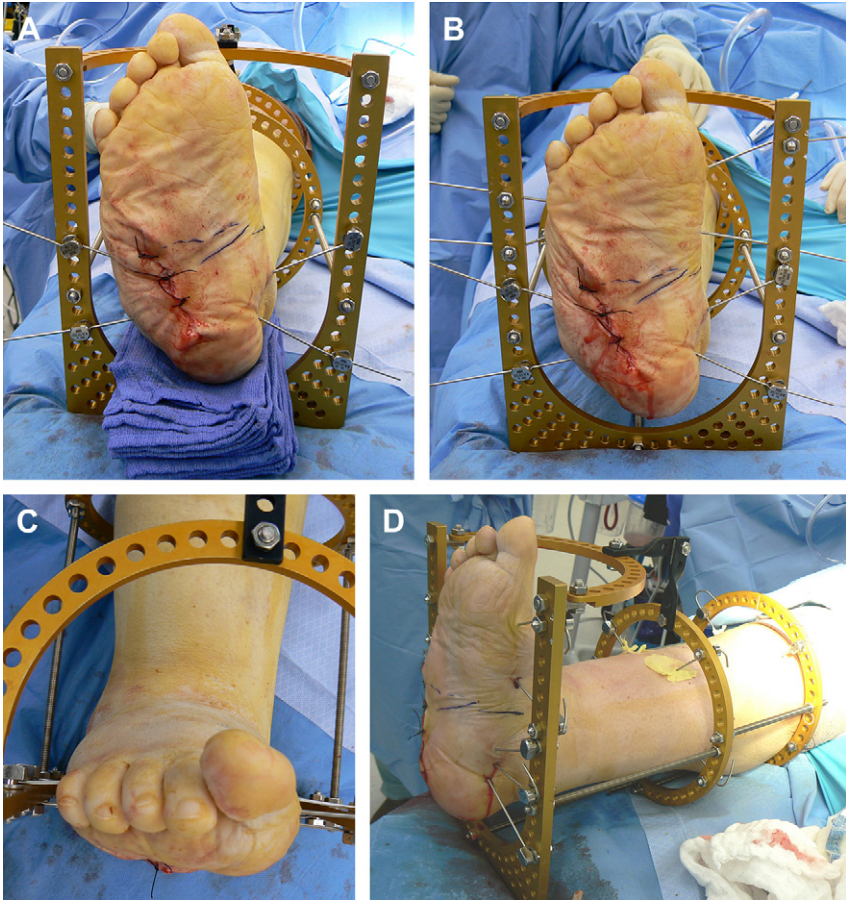Fig. 4. Preassembled static circular frame.

Fig. 5. Steps for application of a static frame. After correction of the deformity, the preassembled circular frame is slid over the limb. (*A*) Two or three olive wires are drilled through the calcaneus parallel to the weight-bearing orientation of the calcaneus, at a 30° angle. The wires are pretensioned and attached to the foot ring. Care is taken to orient the heel in the line of progression for eventual healing and walking and to avoid pressure between the foot ring and the foot. (*B*) The forefoot then is aligned to the hindfoot. (A percutaneous pins or pins may be placed prior to attaching the foot ring in order to maintain the correction achieved at surgery.) Two or three olive wires then are drilled through the metatarsals in the plane of weight-bearing at a 30° angle. They then are pretensioned and attached to the foot ring. (*C*) The foot now is aligned in a plantigrade position. (*D*) With the ankle positioned at 90°, and the leg centered in the proximal circular rings, olive wires are drilled through the tibia at sixty to 90°, pretensioned, and attached to the proximal ring first and the middle ring last.

Fig. 6. This morbidly 53- year-old diabetic man developed this impending soft tissue failure overlying the head of the talus while walking with a CROW. (*A*) Photo on presentation. (*B*) Initial weight-bearing anteroposterior radiograph. Photos (*C, D*) and radiographs (*E, F*) at 1 year after surgery.

The static frame is preassembled and has no moving articulations; hence, the likelihood for loosening of nuts and bolts is diminished greatly (Fig. 4). The deformity is corrected with standard surgical techniques of osteotomy, arthrodesis, or soft tissue release prior to application of the external fixator. Skin tenting is avoided, as the wires are applied in the corrected position. Surgical time also can be minimized, as the neutral frame can be assembled completely prior to surgery.

## Surgical indications

The static frame is used as a method of immobilization, when internal fixation devices or cast immobilization does not meet the specific needs of a patient's clinical problem. Clinical examples of appropriate clinical scenarios are

- Patients in whom standard methods of internal fixation are best avoided because of a poor soft tissue envelope, poor bone quality, or bony infection.
- High-energy bony injury, where bony stabilization is required to allow the soft tissue zone of injury to recover.
- Trauma or infection with soft tissue deficiency, where bony stability is required to access or manage soft tissue wounds.
- "Damage control" orthopedic management of extremity injuries [1]. External fixation generally is used as a temporary method to provide stability until the soft tissue zone of injury recovers sufficiently to allow open reduction or internal fixation. Occasionally, the soft tissue injury precludes internal fixation, and external fixation may be required for longitudinal management.

## Surgical technique

The first step is the correction of the deformity through a limited surgical approach. All infected bone should be removed. After wound closure, the steps for application of the static circular fixator are (Fig. 5).

- Two crossed olive wires are drilled through the calcaneus at a 30° angle. The plane of the wires should be parallel to the weight-bearing surface of the foot. A third olive wire can be placed in larger individuals to increase the strength of the construct.
- The olive wires are pretensioned to 90 to 100 kg and attached to the foot ring of the preassembled circular frame. Care is taken to position the foot in the same orientation as the foot ring.
- The forefoot is aligned to the hindfoot and two crossed olive wires are placed at a 30° angle through the metatarsals. The olive wires are pretensioned to 90 to 100 kg and attached to the foot ring of the preassembled circular frame. Care is taken to maintain a plantigrade alignment in the
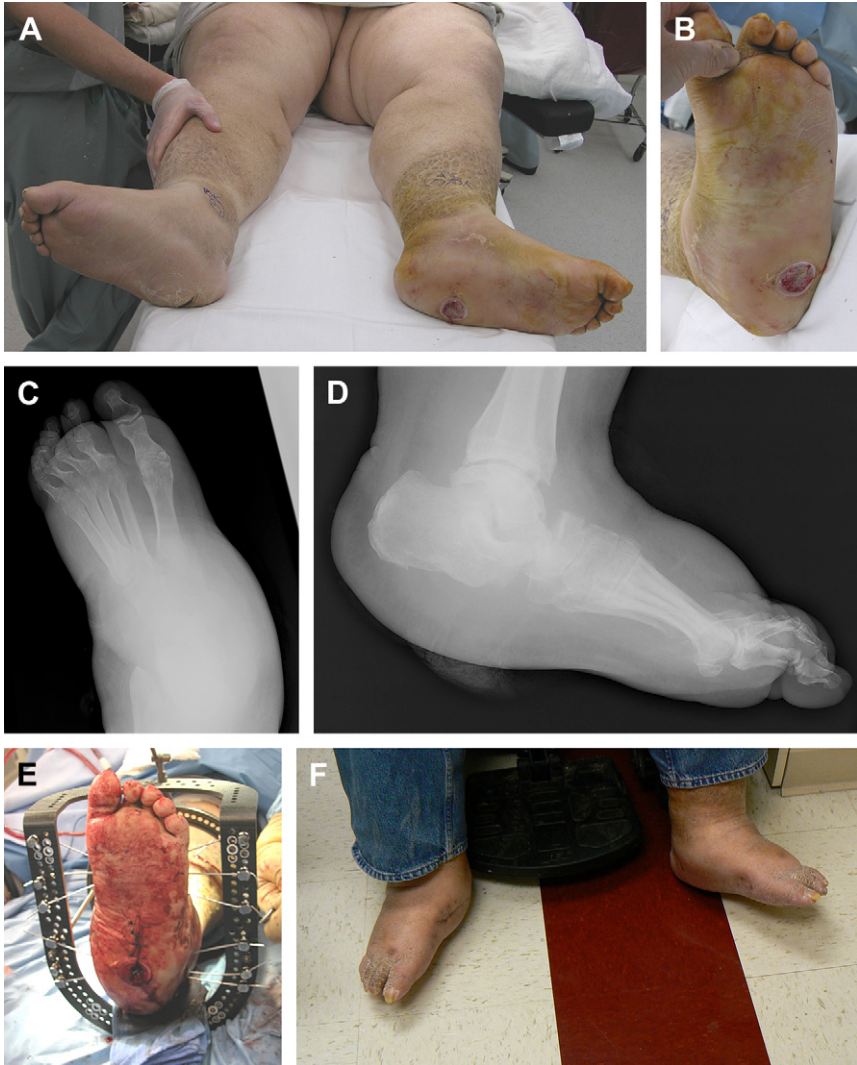
Fig. 7. This diabetic patient weighed 480 pounds, had bilateral Charcot's foot deformity, and had a chronic draining wound of the left lower extremity. (*A, B*) Preoperative photographs. (*C, D*) He was not able to stand for these radiographs. (*E*) He underwent percutaneous tendon Achilles lengthening and an open wedge resection of bone at the apex of the deformity. He applied weight "only" to the foot during transfers from bed to chair. Photographs (*F, G*) and radiographs (*H, I*) at 1 year after bilateral surgical correction. He has lost 100 pounds and is able to walk.

Fig. 7 (*continued*)

orientation of the foot ring. A third olive wire can be placed in larger individuals to increase the strength of the construct.

- The ankle then is positioned at 30° with the tibia centered within the upper circular rings. Two or three olive wires are drilled through the tibia, pretensioned to 90 to 100 kg, and attached to the upper ring.
- Two or three olive wires then are placed similarly at the level of the middle ring.

## Surgical applications

- Patients in whom standard methods of internal fixation are best avoided because of a poor soft tissue envelope, poor bone quality, or bony infection. The first example (Fig. 6) is a morbidly obese 53- year-old diabetic man who had Charcot's arthropathy and impending soft tissue failure
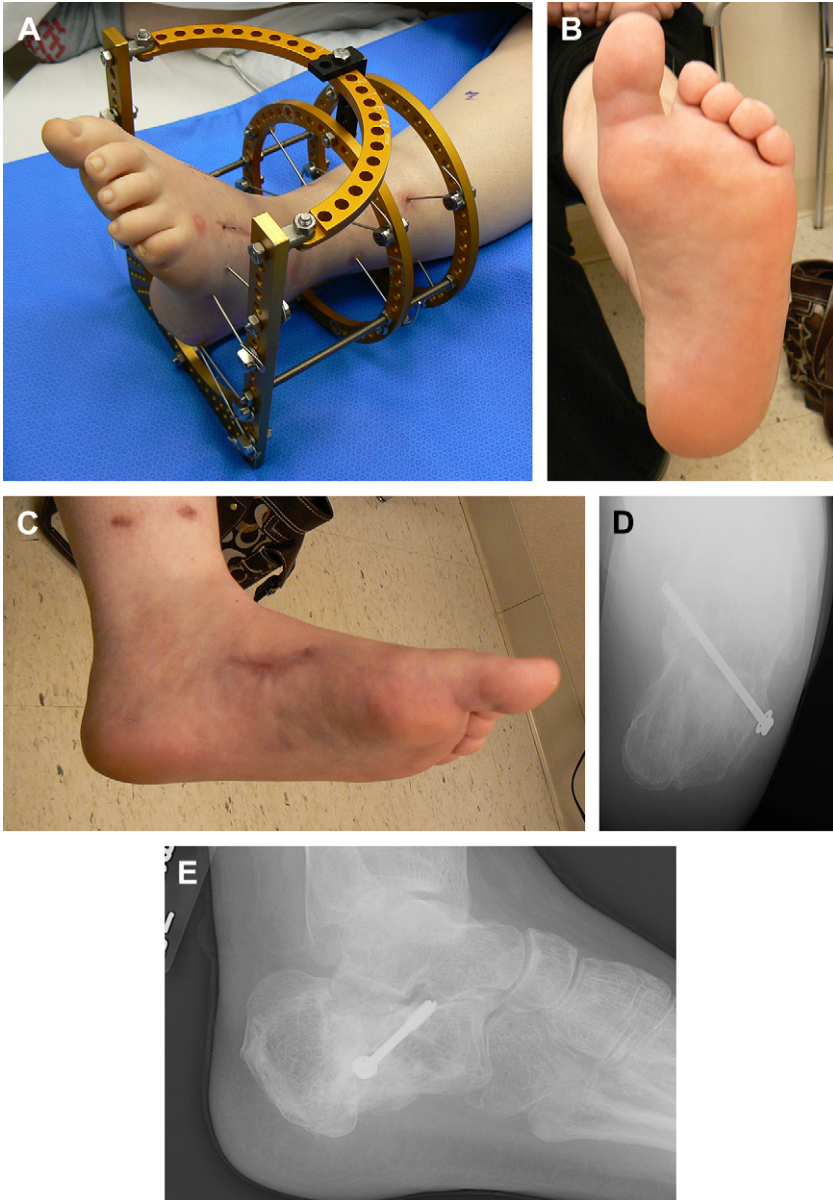
Fig. 8. This 31- year-old teacher sustained a closed calcaneus fracture complicated by a foot compartment syndrome. She was transferred after open fasciotomy. Under fluoroscopic control, a joystick was passed percutaneously from posteriorly to attempt reduction of the posterior facet. A percutaneous cannulated screw was placed to attempt reduction of the sustentaculum talus. (*A*) This neutral frame (photo taken at 2 weeks after surgery) was applied to allow the zone of soft tissue injury to recover and attempt to maintain calcaneal height and alignment. Photographs (*B, C*) and radiographs (*D, E*) at 1 year after injury.

overlying the bony deformity. This impending soft tissue failure developed while the patient was using a Charcot restraint orthotic walker (CROW) for ambulation. A biplaner wedge of bone was removed at the apex of the boney deformity through a small incision. This allowed correction of the deformity and established plantigrade alignment of the foot. The circular frame was used simply as a method of maintaining the correction that was obtained at surgery. He was allowed 30 to 40 pounds of weight bearing while in the frame for 8 weeks. He then was transitioned to a weight-bearing total contact cast for 4 weeks. He progressed to commercially available depth-inlay shoes and custom accommodative foot orthosis for longitudinal management. The patient in Fig. 7 weighed 480 pounds and had bilateral deformity complicated with chronic draining osteomyelitis of the hindfoot.

- High-energy bony injury, where bony stabilization is required to allow the soft tissue zone of injury to recover. This 31-year-old teacher (Fig. 8) sustained a closed comminuted calcaneus fracture complicated by a compartment syndrome of the foot. She underwent fasciotomy of the foot at an outside institution and was transferred for definitive care with healing fasciotomy wounds. She underwent percutaneous manipulation of the calcaneus fracture, followed by an attempt at reduction of the sustentaculum of the talus with a cannulated screw. The reduction was ''neutralized'' with a static circular frame.

- Trauma or infection with soft tissue deficiency, where bony stability is required to access or manage soft tissue wounds. The young man sustained a traumatic degloving amputation of his left lower extremity and a comminuted open pilon fracture with bone loss on the right lower extremity. He underwent initial debridement and placement of a ''damage control'' external fixator. He was returned to surgery for placement of a static frame. The contralateral calcaneus was morselized to use to fill the distal tibial bone loss. Adjustable compression/distraction motors were used to make the frame construct more adjustable over time. A soleus muscle flap was used to obtain adequate soft tissue coverage (Fig. 9).

## Discussion

Ring external fixation has become an accepted surgical method for leg lengthening and deformity correction. It allows limited surgical exposure and dissection in complex patient problems and can be tolerated for prolonged periods as compared to threaded uniplaner or multiplaner constructs. Because of the complexity in application and adjustment of the frame constructs during treatment, most practicing orthopedic surgeons avoid using these devices. There is a learning curve to achieving proficiency with any complex surgical technique. Surgeons are advised to apply these techniques initially to less complicated clinical situations, expanding the
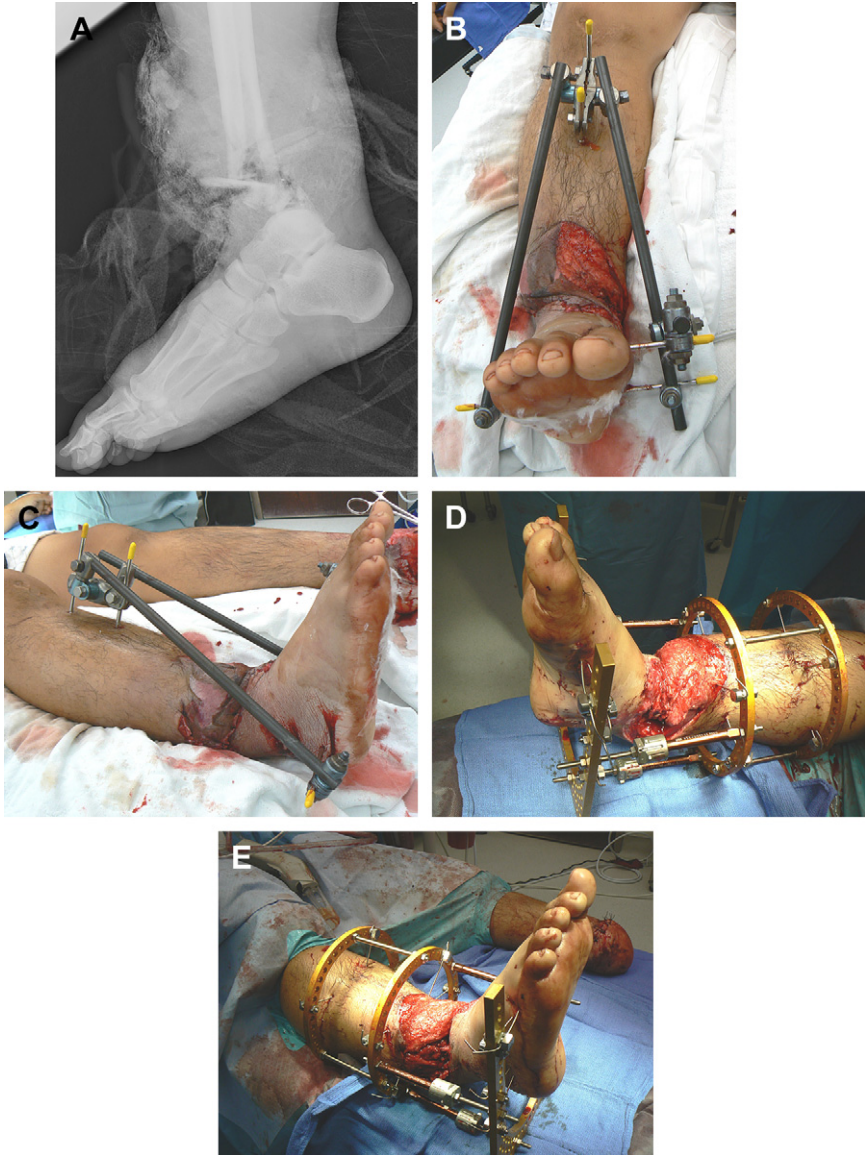
Fig. 9. (*A*) Initial radiograph of a young man who sustained bilateral lower extremity injuries in a motor vehicle collision. (*B, C*) A damage control fixator was applied the night of injury after débridement of the open wound. (*D, E*) The contralateral calcaneus was morselized and packed into the distal tibial defect. This simple adjustable circular frame was applied for longitudinal management. (*F*) Anteroposterior radiograph after intial bone graft. (*G*) Interim photograph after soleus muscle flap.
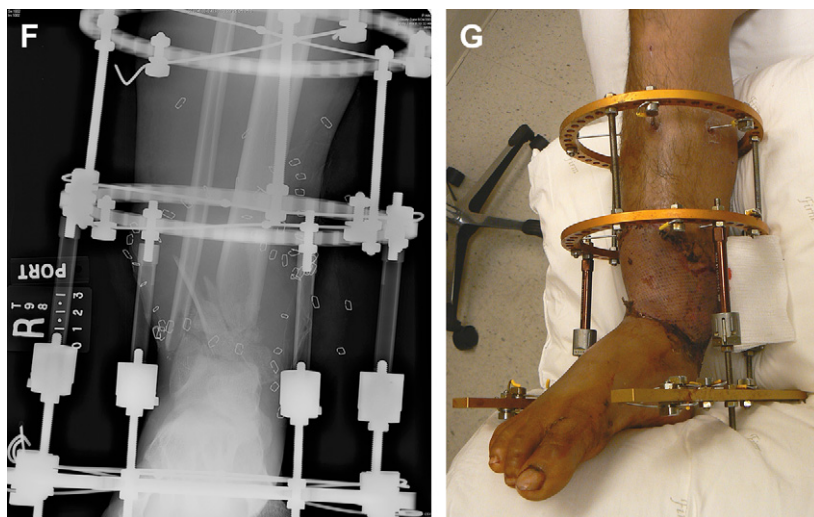
Fig. 9 (*continued*)

application with comfort and proficiency. The goal of this discussion is to provide an introduction to ring fixation and provide guidelines for using simple applications for otherwise complex problems. It is hoped that the experience gained with these simple applications will allow surgeons to expand their spectrum of proficiency and provide alternatives for solving complex clinical problems.

## References

[1] Ziran BH, Smith WR, Anglen JO, et al. External fixation: how to make it work. J Bone Joint Surg Am 2007;89A:1620–32.
[2] Podolsky A, Chao EYS. Mechanical performance of Ilizarov circular external fixators in comparison with other external fixators. Clin Orthop Relat Res 1993;293:61–70.