Minimally Invasive Surgical Techniques for the Reconstruction of Calcaneal Fractures

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Two minimally invasive techniques are presented for the reconstruction of calcaneal fractures. The soft tissues play a crucial part in the stabilization of the multiple joint surfaces of the calcaneus; therefore, maintaining the soft-tissue envelope is vital to fracture treatment outcome.

Calcaneal fracture management is challenging. A recently published meta-analysis1 and a well-controlled, prospective, double-blind study2 have proven that no convincing evidence supports surgeons in their treatment choice for displaced intra-articular calcaneal fractures, which comprise up to 75% of all calcaneal fractures.3

This article re-evaluates the anatomy, function, and available knowledge on the role of the soft-tissue envelope in fracture healing.4,5 It also presents two minimally invasive techniques for the reconstruction of calcaneal fractures, the Essex-Lopresti and the hybrid thin wire ring external fixator.

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The authors thank N. Zarchovsky, MD, for her help with the statistical evaluation.

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ANATOMY

The heel bone is a rectangular block of cancellous bone with an outer shell of cortical bone, the thickness of which varies in different areas. It contributes articulating surfaces to joints in multiple planes, thus allowing simultaneous support of the body on weight bearing by providing an articulating platform for the talus, while also participating in subtalar joint movements. The latter are necessary for stabilizing the foot during the gait cycle.

The calcaneus is the cornerstone of the foot's longitudinal arch, and its anatomical alignment can be assessed by measuring the tuber angle described by Bohler.6 The normal range of this angle is 25°-40°. Together with the crucial angle of Gissane,7 formed by the downward slope and the upward portion of the posterior talocalcaneal articular surface (normal range: 100°-125°), these two angles mirror the physiological intra-articular relationship of the hindfoot and subtalar joints. Being the pillar for transmission of load during the heel-strike phase of the gait cycle, the calcaneus is covered in fat-padded soft tissues. Damage to this soft-tissue envelope has a direct bearing on the outcome of fracture treatment.

FUNCTION

Approximately 75% of all calcaneal fractures involve the subtalar joint.3,8 Reconstruction of the intra-articular scaffold of the longitudinal arch provides the basis for physiological function of the hindfoot and is expressed by Bohler's angle.

The cancellous bone core of the heel is easily compressed by external forces acting on it. When fractured, longitudinal distraction allows the cancellous bone to interlock and thus, the fracture is realigned. By adding dynamic stability to the distraction, fracture healing ensues, provided the soft tissues are preserved. The biomechanical function of the hindfoot and the interaction of bone and muscle have been described by Hansen.9

It therefore seems logical to assume that, in calcaneal fractures, distraction with minimally invasive surgical techniques may provide an optimal mechanical environment for the biological heal-
ing process. This approach is modular and minimizes the handling of soft tissues, preserving their vitality. The Essex-Lopresti and the hybrid thin wire ring external fixator meet these requirements.

**ESSEX-LOPRESTI**

The Essex-Lopresti percutaneous pin reduction and fixation method was pioneered by Essex-Lopresti\(^\text{10,11}\) and has been used by surgeons with consistent satisfactory results.\(^\text{12,14}\)

**Patient Population**

Over 10 years, 47 consecutive patients were treated by the Essex-Lopresti technique for displaced intra-articular calcaneal fractures in our department. Prior to surgery, all patients underwent computed tomography. The Sanders calcaneal fracture classification\(^\text{15}\) was not used due to its complexity. According to the Essex-Lopresti classification, all patients had joint depression type fractures, similar to Crosby and Fitzgibbon’s type II and III.\(^\text{16}\)

Only 25 of 47 patients underwent follow-up. They were compared with 27 age- and gender-matched patients who were treated conservatively for minimally displaced fractures. Mean follow-up was 8.5 years (range: 5-12 years). Twenty-two patients treated conservatively were lost to follow-up.

**Technique**

Under fluoroscopic control, with the patient on his or her side, a Steinmann pin mounted on a hand drill was introduced gently from the upper posterior calcaneal angle, along the longitudinal bone axis. It was used as a lever to reduce the fracture. With “joystick” maneuvers, bone fragments were elevated and realigned.

After achieving the reconstruction of Bohler's angle, the pin was advanced to the full length of the calcaneus, without perforating the calcaneocuboid joint. A second Steinmann pin was introduced parallel to the first to prevent rotation. The procedure was performed after soft-tissue swelling had resolved enough for the skin to wrinkle. Skin slough, necrosis, or infection was not reported.

**Results**

The variables of activities of daily living, a change in occupation after fracture healing, pain level, and range of hindfoot movement did not differ between the surgically and conservatively treated groups. However, when patients were subdivided into high- and low-energy injury groups:

- The time to fracture healing was significantly longer in the high-energy injury group (P=0.0025).
- Bohler’s angle in the low-energy group was 48° and 23.3° in the high-energy group (P=0.053).
- Of all range of motion parameters, only hindfoot inversion differed between the two groups—15° in the high-energy group and 8° in the low-energy group (P=0.053).

In the high-energy group, shoe size width did not change after treatment (63% were treated surgically). In the low-energy group, the shoe size of the injured foot increased by one size in 19 patients at follow-up (43% were treated surgically). The difference in shoe size was P=0.104.

Our results support the continuous use of the minimally invasive Essex-Lopresti surgical method in the treatment of displaced intra-articular calcaneal fractures. This is in agreement with other recently published studies.\(^\text{12,14,17}\) It is effective for fracture realignment and stabilization achieved by minimal soft-tissue trauma without reported complications from the latter.

The Essex-Lopresti technique allows effective reconstruction of Bohler angle and the anatomical shape of the os calcis in three planes, as expressed by shoe size.

**HYBRID THIN WIRE RING EXTERNAL FIXATOR**

External skeletal fixation is widely used for reduction and stabilization as an alternative to internal fixation of compound fractures with extensive soft-tissue involvement.\(^\text{18}\) Of the various methods available, the Ilizarov method is highly modular, allows three-dimensional reduction, and stabilization of small bone fragments, thus providing the means, if necessary, to correct and realign the fracture during all phases of healing.

**Patient Population**

Six patients (two females and four males) with severely displaced and comminuted calcaneal fractures were treated by closed reduction in distraction with hybrid thin wire ring external fixator stabilization (Figures 1 and 2). Average patient age was 35 years (range: 17-55 years). Two patients sustained high-energy injuries, and four patients low-energy injuries. No associated neurovascular injuries were reported.

**External Fixator Construct**

The fixation frame consisted of two proximal rings placed at the middle third of the tibia, and in the supra-malleolar area, <=4 cm above the malleolar (Figure 3). The proximal ring was fixed to the tibia by two Schanz screws or one Schanz screw and one transverse Kirschner wire, whereas the distal ring was fixed by two 1.8-mm K-wires crossed at 60°. Four equally spaced longitudinal bars connected the three rings. Thus, a three-plane-stabilizing frame with minimal muscle transfixation was built (Figure 3). Following the frame mounting, one 1.8-mm transverse K-wire was introduced in the posterior third of the calcaneus, near its tuberosity, and tensioned on a half-ring. A second 1.8-mm K-wire was introduced transversely through the metatarsal bones, connected, but not tensioned, to a second half ring (Figure 3). The forefoot half ring was connected to the distal tibial ring with three bars to stabilize the ankle in the physiological 90° plantigrade position.

The metatarsal half ring was connected to the calcaneal half ring with
threaded rods to allow distraction and restoration of the calcaneal longitudinal axis. If the calcaneal fracture is comminuted, two olive K-wires are inserted near the tuber calcanei, one on the medial cortex and the other on the lateral calcaneal cortex. When tensioned, the fractured bone fragments are reduced in the coronal plane. The calcaneal half ring is then connected to the tibial frame with three or four threaded rods that are used to distract the calcaneus in the tibial length axis, thus restoring its height (Figure 3).

In osteoporotic bone, washers are used to prevent olive penetration into bone. If the fracture is severely comminuted, a threaded half pin is introduced distal to the tendo-Achilles insertion and used as a joystick to reconstruct craniocaudal bone depression.

After locking the frame in the corrected alignment, the half pin can be removed or connected to the distal tibial ring, depending on the degree of comminution.

Mountings of the fixation frame and fracture reduction were performed under digital fluoroscopic control, which has a good resolution and minimal irradiation.

**Results**

Fracture consolidation was achieved in all six patients within an average 60 days (range: 50-85 days). Bone grafting was not necessary in any patient.

Throughout fracture healing, all patients, except one with bilateral upper and lower limb fractures, were fully ambulatory, living at home. They were nonweight bearing with crutches for 6 weeks, and gradually progressed to full weight bearing.

No patient had neurologic complications as a result of mounting the external fixation frames. Superficial pin-tract infection in one patient was treated successfully by local antiseptic treatment and oral antibiotic administration. No patient developed deep infections or reflex sympathetic dystrophy.

The fixation frame was removed after 2 months (average: 52 days, range: 45-65 days) (Figures 4 and 5). For addi-

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**Figure 1:** Intra-articular, compound, displaced high-energy fracture of the calcaneus with depression of the posterior articular facets. The Bohler and Gissam angles are flattened. **Figure 2:** Reduction of fracture fragments by longitudinal distraction of the foot in the external fixation frame. **Figure 3:** Lateral (A) and anterior (B) photographs of the hybrid thin wire ring fixation frame. Note the separate longitudinal axis distraction of the foot, hindfoot, and calf. **Figure 4:** Lateral photograph of the hindfoot alignment during weight bearing after fracture healing (A). Axial photograph of the hindfoot during toilettine phase of the gait cycle (B). The left heel (healed fracture) is slightly wider. **Figure 5:** Realigned hindfoot with reconstructed Bohler and Gissam angles.
tional protection, a walking cast or boot with a pressure relieving sole was used.

In the four patients with low-energy injuries, subtalar movement returned to functional range within 4 weeks of physiotherapy. In the two patients with high-energy injuries, the range of subtalar movement remained restricted to 5° of pronation and 5° of supination.

One patient developed pain due to a calcaneal bone fragment impinging on the fibula. The bone fragment was resected, and convalescence continued uneventfully. No patient had signs of peroneal tendon stenosis.

**SUMMARY**

The soft tissues play a crucial part in both the stabilization of the multiple joint surfaces of the calcaneus and in allowing propulsion as needed. Therefore, minimally invasive functional stabilization of heel bone fracture is a promising technique, which may bypass all published controversies.

Experience has shown that ligamentotaxis, which means the use of mechanical forces applied to the soft-tissue envelope of fractures without the surgical disruption of the latter, contributes to fracture healing and reconstruction. Therefore, based on our results, minimally invasive techniques are useful and promising in calcaneal fracture treatment.

**REFERENCES**


11. Essex-Lopresti P. The mechanism, reduc-