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Treatment of Displaced Intra-Articular Calcaneal Fractures With Combined Transarticular External Fixation and Minimal Internal Fixation

Te-Hu Fu, MD[1], Hao-Chen Liu, MD[1], Yu-Sheng Su, MD[1], and Ching-Jen Wang, MD[2]

Abstract

Background: The aim of this study was to evaluate clinical outcomes after surgery for displaced intra-articular fractures using an external fixator and minimal internal fixation.
Methods: In this retrospective observational study, a total of 39 patients (32 [82%] men and 7 [18%] women) with 48 displaced intra-articular calcaneal fractures were included. An extended lateral approach was used to stabilize fractures using multiple sagittal plane screws, axial percutaneous threaded Kirschner wires for the frontal fracture plane, and an external fixator for reduction assistance and maintenance. The following variables were assessed: preoperative and postoperative Böhler's angle; calcaneal length, height, and width; postoperative American Orthopaedic Foot and Ankle Society (AOFAS) scores; and complications. Mean duration of follow-up was 74 ± 26 months.
Results: The mean time from surgery to external fixator removal was 12 ± 1 weeks. The mean preoperative Böhler's angle (−3 ± 21 degrees), calcaneal length (7.9 ± 0.6 cm), and calcaneal height (3.6 ± 0.5 cm) were significantly increased ($P < .05$) at final follow-up (28.3 ± 6.5, 8.3 ± 0.6, and 4.5 ± 0.5, respectively), whereas the mean preoperative calcaneal width (4.2 ± 0.5) was significantly decreased from the final follow-up mean (3.8 ± 0.5). There were no significant differences between any of the normal and postoperative measures. The mean AOFAS score was 82 ± 12. Complications included superficial pin tract infection (n = 7, 15%), superficial wound edge necrosis (n = 4, 8%), and deep infection (n = 2, 4%).
Conclusion: Our findings suggest that use of an external fixator with minimal internal fixation is an effective option for treating displaced intra-articular calcaneal fractures.
Level of Evidence: Level IV, retrospective case series.

Keywords: external fixator, intra-articular calcaneal fracture, minimal internal fixation, displaced, Böhler's angle

Unfortunately, there is a lack of consensus as to the optimal means of treating displaced intra-articular calcaneal fractures.[3,7,11] Conservative/nonoperative treatment is thought to be optimal for certain patient populations, namely the elderly and others for whom surgery is considered too risky.[7] However, conservative treatment may be complicated by ongoing functional disability and pain.[15,26] The most common surgical approach for treating intra-articular calcaneal fractures is open reduction and internal fixation (ORIF). Although the effectiveness of this approach has been demonstrated in several studies,[7] the published findings do not overwhelmingly support the use of ORIF over conservative treatment.[7,20] Furthermore, ORIF has been associated with a variety of potentially serious complications, including wound dehiscence, necrosis, and infection, in 1.8% to 27% of patients.[10]

Another surgical approach for treating displaced intra-articular calcaneal fractures involves external fixation. External fixation, usually applied in conjunction with percutaneous or closed reduction, may decrease the risk of complications associated with the more invasive ORIF approaches. A number of different surgical approaches involving various means of reduction and external fixation have been found to be effective for treating intra-articular calcaneal fractures in small-scale studies.[1,4,5,17,18,21,25,28] Although external fixation has been found to be efficacious,

[1]Division of Emergency and Trauma Surgery, Department of Surgery, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan
[2]Department of Orthopaedic Surgery, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan

Corresponding Author:
Ching-Jen Wang, Department of Orthopaedic Surgery, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan, No. 123, Ta Pei Road, Niao-Sung Dist., Kaohsiung City 83301, Taiwan
Email: w281211@adm.cgmh.org.tw

many of the studies thus far have involved the use of complicated external fixation devices such as circular or ring fixators. Herein, we describe our experience using a novel surgical approach for displaced intra-articular calcaneal fracture repair, consisting of open reduction, structural bone grafting, and the use of a simple external fixator with minimal internal fixation.

Materials and Methods

Patients

From October 1999 to February 2008, 51 consecutive patients with calcaneal fractures were treated operatively at our institution by a single surgeon (F.T.H.). Most patients sustained multiple trauma as detailed below. Of the 51 patients, 12 (24%) patients were excluded from our analysis; 4 (8%) had type III open fractures, 4 (8%) had extra-articular fractures, and 4 (8%) were lost to follow-up. Thus, follow-up evaluations were performed for 39 (76%) patients. The mean duration of follow-up was 74 ± 26 months (range, 18-114 months).

The 39 patients consisted of 32 (82%) men and 7 (18%) women, with a mean age of 43 ± 14 years (range, 22-77 years) (Table 1). The mechanism of injury was falling from a height in 34 (87%) patients, motor-vehicle accident in 4 (10%) patients, and blunt trauma from an explosion in 1 (3%) patient. Thirty (77%) patients had unilateral fractures, and 9 (23%) had bilateral fractures. The 48 fractures included 23 (48%) type II fractures, 21 (44%) type III fractures, and 4 (8%) type IV fractures. Associated injuries included 12 (31%) spinal fractures, 11 (28%) multiple fractures (including 7 spinal fractures), 5 (13%) lower extremity fractures, and 1 each (3%) of the following: upper extremity fracture, pelvic fracture, blunt abdominal trauma (and L2 fracture), hemothorax (and L2 fracture), and head injury.

Patients were initially treated with bed rest, elevation, ice packing, and compressive bandaging. Splinting materials were not used, and active muscular contraction of the injured foot was encouraged to decrease the swelling. Radiographic studies included calcaneal axial and lateral views and injured foot anteroposterior and oblique views. Computed tomographic scans were also performed. Fractures were classified according to Sanders's classification system.[22] Lateral and axial radiographs were examined to determine Böhler's angle and calcaneal length, height, and width (Figure 1). Comparisons were also made between the injured and the noninjured foot, unless both feet were injured.

Operative Treatment

The operative procedure was performed when the swelling had subsided. Patients were placed in a prone position, and the affected limb was exsanguinated before application of a tourniquet. The ankle was elevated using a 30-degree foam wedge to facilitate eversion of the subtalar joint during reduction and fixation of the posterior facet. The approach began with a boomerang-shaped incision,[29] creating a full-thickness flap deepened to the tuberosity, which was reflected anteriorly and superiorly. The subtalar joint was then everted (assuming the posterior facet was not seen) and 1 or 2 pieces of the comminuted and bulged lateral cortex were detached, allowing for detection of the depressed and anteriorly rotated lateral parts (Sanders II-IV) of the posterior facet at the collapsed neutral triangle area. The fractured lateral parts of the posterior facet were derotated and elevated, anatomically reduced with the medial part of the posterior facet under direct visualization, and fixed at the thalamic portion using 2 or 3 cancellous screws (3.5 mm). A triangular external fixator frame was temporally set using 2 half-pins in the distal tibia and 2 full pins in the calcaneal tuberosity. Both ends of the full pins were held by the assistant, and an even distraction force was applied posteroinferiorly to restore the Böhler's angle and the varus-deformed tuberosity. A small bone elevator

Table 1. Summary of Patient Demographics and Characteristics of Fractured Feet[a]

Variable	
Patient demographics	(N = 39)
Age, y	43 ± 14
Sex, n (%)	
Men	32 (82)
Women	7 (18)
Time from fracture to surgery, d	11 ± 5
Time from surgery to EF removal, wk	12 ± 1
Returned to work after surgery, n (%)	
No	7 (18)
Yes	23 (59)
Yes (changed jobs)	9 (23)
Characteristics of fractured feet	(N = 48)
Fracture, n (%)	
Right side	22 (46)
Left side	26 (54)
AOFAS score	82 ± 12
Bone grafting, n (%)	
Autograft	36 (75)
Allograft	1 (2)
Substitute	1 (2)
None	10 (21)
Postoperative complications, n (%)	13 (27)
Superficial pin tract infection	7 (15)
Superficial wound edge necrosis	4 (8)
Deep infection	2 (4)

Abbreviations: AOFAS, American Orthopaedic Foot and Ankle Society; EF, external fixation.
[a]Data are summarized as mean ± standard deviation for continuous variables and number (%) for categorical variables.

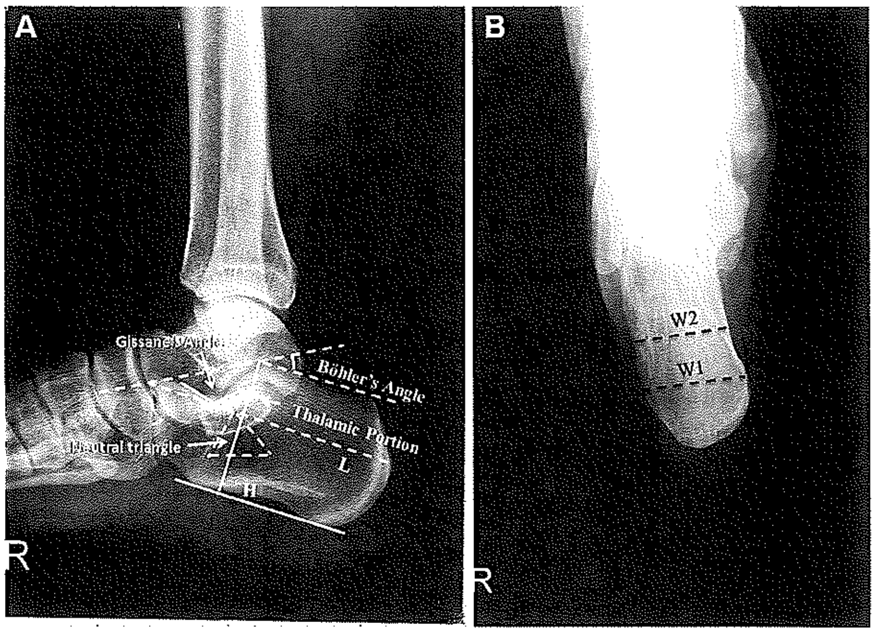

Figure 1. (A) Normal calcaneal lateral view radiography showing the measurements of Böhler's angle and calcaneal length (L) and height (H). The thalamic portion, neutral triangle, and Gissane's angle are identified. (B) Normal axial view radiographs showing the widest (W1) and narrowest (W2) portion of the calcaneal tuberosity. The presented value (W) is the mean of W1 and W2.

was inserted into the neutral triangle area to manipulate the fracture fragments and to facilitate reduction of the whole calcaneus. The bone defect was then evaluated, adequate cancellous bone was harvested from the posterior ilium (usually 10-15 cc), and the defect was autografted with particular attention paid to the crushed neutral triangle area. The detached pieces of lateral cortex were reattached, reduced anatomically, and held with lateral to the medial screws for fixation of the sagittal fracture plane. The external fixator frame was tightened and the ankle joint maintained in the neutral position. The forefoot was then mobilized, and the fracture stability was checked in the Gissane's angle area. If fracture motion was apparent, the frontal fracture plane was transfixed percutaneously using 2 or 3 partially threaded Kirschner wires (K wires: 2.5 mm). Finally, the soft tissue flap was reduced, and the operative wound closed in 2 layers without a suction drain.

Postoperative Management

Patients were restricted to bed rest for the first 3 to 5 days after surgery, with the injured foot or feet elevated. Thereafter, patients were instructed on correct ambulation using crutches or a walker with toe-touch weight bearing. Patients were discharged once wound healing was complete and they were ambulatory. Outpatient department follow-up visits occurred weekly for 4 weeks upon discharge, during which pin tract condition was examined. Progressive weight-bearing exercise was initiated at this time. Oral antibiotics were prescribed if there was any suspicion of pin tract infection.

Patients were then seen monthly until the external fixator was removed approximately 3 months after surgery; walking aids were discarded 4 to 6 weeks later. Functional and radiographic evaluations were performed 1 year after surgery, and American Orthopaedic Foot and Ankle Society (AOFAS)[13] hindfoot scores were determined at the most recent follow-up visit. In cases of unilateral calcaneal fracture, AOFAS scores were calculated as follows: Ankle motion and subtalar motion of the affected side were compared with those of the normal side to evaluate the percentage of motion lost. In cases of bilateral calcaneal fracture, AOFAS scores were calculated as follows: Ankle motion and subtalar motion of the affected side were compared with assumed normal values (dorsiflexion = 20 degrees, plantar flexion = 50 degrees, inversion = 25 degrees, and eversion = 15 degrees) to evaluate the percentage of motion lost.

Statistical Analysis

Patient demographics were summarized as mean ± standard deviation (SD) for continuous variables and as number (%) for categorical variables. Radiographic variables were sum-

Table 2. Comparison of Normal, Preoperative, and Postoperative Radiographic Measurements (N = 48 Feet)[a]

Measurement	Normal (n = 30)[b]	Preoperative (n = 48)	Postoperative (n = 48)	*P* Value[c]: Normal vs Preoperative	*P* Value[c]: Preoperative vs Postoperative	*P* Value[c]: Normal vs Postoperative
Böhler's angle, degrees	33 ± 4	−3 ± 21	28 ± 7	<.001	<.001	.318
Calcaneal length, cm	8.1 ± 0.6	7.9 ± 0.6	8.3 ± 0.6	.252	.013	1.000
Calcaneal height, cm	4.5 ± 0.5	3.6 ± 0.5	4.5 ± 0.5	<.001	<.001	1.000
Calcaneal width, cm	3.6 ± 0.5	4.2 ± 0.5	3.8 ± 0.5	<.001	<.001	.295

[a]Data are presented as mean ± standard deviation.
[b]Nine patients who received surgery on both right and left feet did not contribute normal measurement values. Normal measurement values were obtained from noninjured feet.
[c]Derived from linear mixed model analysis with Bonferroni pairwise comparison.

marized as mean ± SD. Linear mixed model analysis with a Bonferroni pairwise comparison was used to compare the differences among normal, preoperative, and postoperative radiographic measurements. Differences were considered to be statistically significant when $P < .05$. All statistical analyses were performed using SPSS 15.0 statistical software (SPSS Inc, Chicago, IL).

Results

Surgery was performed a mean of 11 ± 5 days (range, 5-23 days) after fracture (once soft tissue swelling had subsided) (Table 1). Most (75%) patients received structural autografts. The majority (82%) of participants returned to work or changed jobs after surgery. The mean time from surgery to external fixation removal was 12 ± 1 weeks (range, 9-15 weeks) (Table 1).

The overall mean AOFAS score for the 38 patients was 82 ± 12 (range, 45-100). One patient with a unilateral fracture (Sanders type IV) who sustained paraplegia (due to fracture-dislocation of the L3 vertebral body) after a third-floor fall was excluded from this and all AOFAS calculations. The mean AOFAS score for the 29 (74%) patients with unilateral fractures was 83 ± 12 (range, 52-100). The mean AOFAS score for the 9 (23%) patients with bilateral fractures was 81 ± 14 (range, 45-100). According to AOFAS criteria, 41 (85%) fractures were associated with normal or mildly restricted ankle motion and 6 (13%) with moderately restricted ankle motion. A total of 32 (67%) feet had normal or mildly restricted subtalar motion, 14 (30%) had moderately restricted subtalar motion, and 1 (2%) had a subtalar arthrodesis.

Fractures successfully healed in all patients, and there were no instances of further collapse of the subtalar joint. Furthermore, the morphological characteristics of the whole calcaneus were maintained during progressive weight-bearing ambulation in all patients.

There were 13 (27%) postoperative complications, including superficial pin tract infection, superficial wound edge necrosis, and deep wound infection (Table 1). None of the 7 (15%) instances of pin tract infection were associated with pin tract osteomyelitis or deep infection. Pin hole curettage occurred during external fixator removal in 3 (6%) instances of pin tract infection. Cultures were negative in each instance of pin tract infection, and all 7 patients recovered uneventfully after 3 to 5 days of oral antibiotic therapy. All 4 (8%) patients with wound edge necrosis recovered uneventfully (wounds healed) without further treatment. Two (4%) patients experienced deep wound infection 2 to 3 weeks after surgery. Both of these patients suffered multiple fractures, including Sanders type IV fractures. Treatment for infection included debridement, removal of external and internal fixators, and administration of parenteral antibiotics. Once infection was controlled, bone grafting was performed to repair bone defects associated with the removal of necrotic bone during debridement. The first of these patients subsequently developed subtalar arthritis because of fracture malunion. This patient underwent subtalar arthrodesis 1 year after the original procedure for pain relief. In follow-up assessment, this patient had the lowest AOFAS score (52 points) of all patients with unilateral calcaneal fractures. The second patient who experienced deep wound infection was paraplegic and did not undergo subtalar arthrodesis after bone grafting.

Table 2 summarizes the normal, preoperative, and postoperative radiographic measurements. The mean postoperative Böhler's angle, calcaneal length, and calcaneal height were significantly increased from the corresponding preoperative means ($P < .001$, $P = .013$, and $P < .001$, respectively), whereas the mean postoperative calcaneal width was significantly decreased from the corresponding preoperative mean ($P < .001$). The mean normal Böhler's angle and calcaneal height were significantly greater than the corresponding preoperative means (both $P < .001$), whereas the mean normal calcaneal width was narrower than the

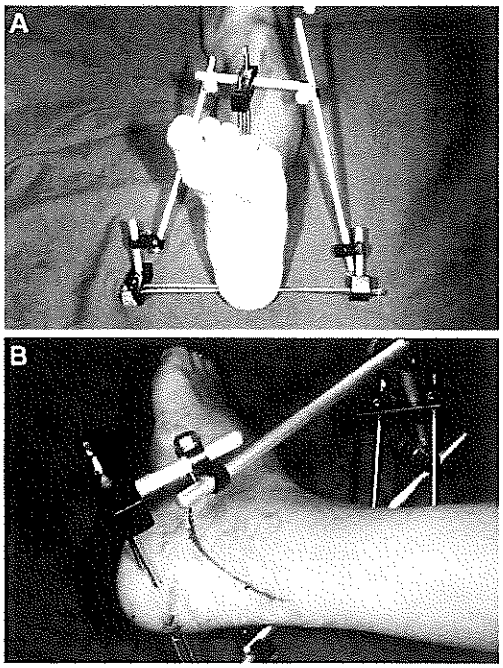

Figure 2. Postoperative photographs before the removal of the external fixator and K wires. (A) Triangular external fixator frame. (B) The pin tract was clean and the ankle joint had been maintained in a neutral position.

corresponding preoperative mean ($P < .001$). Normal and postoperative measures did not differ significantly, including Böhler's angle (33 ± 4 degrees vs 28 degrees ± 7 degrees), calcaneal height (4.5 ± 0.5 cm vs 4.5 ± 0.5 cm) and calcaneal width (3.6 ± 0.5 cm vs 3.8 ± 0.5 cm).

Figure 2 shows representative photographs of the external fixator, and Figure 3 shows preoperative and postoperative radiographs and photographs from a representative case.

Discussion

In this article we have described our experience using a novel surgical approach for displaced intra-articular calcaneal fracture repair: open reduction, structural bone grafting, and minimal internal fixation with simple external fixation. Other methods are not appropriate without open reduction since they cannot restore anatomical reduction of the posterior facet, with the result of posttraumatic arthrosis or arthritis. In addition, if the anatomical reduction of the posterior facet is not obtained, the surgical outcome is questionable. Indeed, in a previous study involving 200 AO plates, it was found that there were fractures in 8.2% of plates where the Y limb joined the main plate.[23] We found our approach to be effective for reduction of the calcaneus as indicated by notable improvements in Böhler's angle and calcaneal length, height, and width at 74 ± 26 months after surgery.

A number of reports have described the use of external fixators to treat calcaneal fractures.[1,4,5,17,18,21,25,28] Of the more recently published reports, those by McGarvey et al[17] and Ali et al[1] describe techniques using indirect and minimally invasive reduction, respectively, and Ilizarov external fixators, whereas Roukis et al[21] described a technique involving manual reduction and distraction with a triangular tube-to-bar external fixator. Further recent reports include that by Besch et al,[5] who described closed reduction and use of a hinged external fixator, and that by Talarico et al,[25] who described minimally invasive open reduction and use of an external ring fixator. Although these reports have described external fixation as being associated with favorable outcomes, the approaches used have various limitations including technical difficulty[17,25]; increased operating time[17]; extensive use of K wires, which may increase the risk of pin tract infection[25]; problematic reduction of the posterior facet[5,17,25]; and complex external fixator design.[1,17,18,25] The approach described in this report overcomes several of these limitations, in particular that of a complex fixator design.

In the cohort of patients described in this report, we used external fixation with a simply designed fixator in conjunction with minimal internal fixation in an effort to eliminate soft tissue complications, maintain reduction, and minimize hardware irritation in the treatment of these complex fracture patterns. The keys to success in the treatment of calcaneal fractures include anatomical reduction of subtalar joint congruency, restoration of calcaneal shape, and careful soft tissue management.[19,24,29] With the technique described herein, a balanced traction force was applied through both ends of the full pins, allowing for easy adjustment of the varus or valgus of the deformed tuberosity and reduction of the entire calcaneus. This traction force may also work against the "constant deforming force of the Achilles tendon" previously implicated in anatomical reduction difficulty.[8] Equinus contracture is prevented and fracture reduction is maintained by the triangular external fixator frame (Figure 2B).

We suggest that our approach has a number of advantages over standard ORIF. First, in the ORIF with plating, the plate is placed lateral to the calcaneus, where the soft tissues are very thin. Thus, the calcaneus and skin as well as soft tissues were separated by the plate, which may interrupt blood flow from the lateral calcaneal artery. Because this artery is the main source of blood supply to the surrounding wound in the extended lateral approach, interruption of lateral calcaneal artery may cause wound edge healing problem and avascular bone necrosis under the plate.[2] Additionally, in the study by DeWall et al,[10] the infection rate of the plate group undergoing ORIF was very

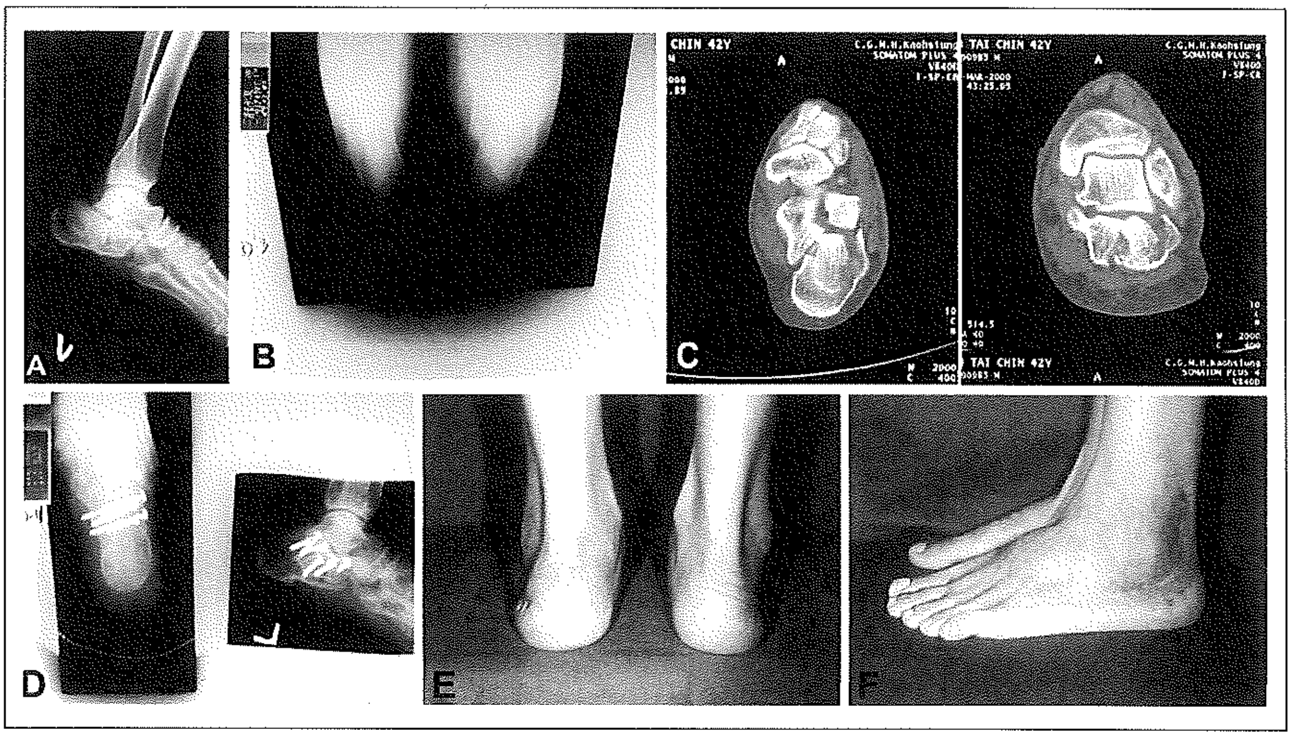

Figure 3. Radiographic images illustrating operative treatment of a displaced intra-articular calcaneal fracture. (A) Lateral and (B) axial views showed flattening and broadening of the fractured calcaneus with a Böhler's angle of 0 degrees and a depressed superolateral thalamic portion (arrows). (C) Axial and coronal computed tomographic images. (D) Postoperative radiography showed anatomical reduction of the whole calcaneus with a Böhler's angle of 30 degrees and only screws remaining. (E) and (F) Photographs demonstrating normal calcaneal width and plantigrade posture of the hindfoot.

high. All our patients remained in the hospital until wounds were healed. Another advantage of this technique is that casts, splints, or night boots are not required. In contrast, casts or fracture boots are often required after ORIF.[8,12,19,27] The lack of a need for casting is a particular advantage in subtropical regions such as Taiwan. Only 3 (6%) patients in our cohort complained of heel pad pain. We suggest that this low incidence of heel pad pain compared with standard ORIF[27] may have been a consequence of early postoperative ambulation with desensitization of the heel pad.[18] A further advantage of our approach is that no implants were used other than the minimal internal fixation; only the screws remained after external fixator and K-wire removal. Importantly, no patients developed symptomatic hardware problems, and no secondary surgery was needed for implant removal. In contrast, symptomatic hardware problems requiring implant removal are not uncommon with standard ORIF.[10] A further advantage of our external fixation approach over standard ORIF is cost. Specifically, under Taiwan National Health Insurance regulations, the hardware cost associated with calcaneal fracture repair by minimal internal fixation with an external fixator is approximately $280 to $290, of which the patient pays 10%, whereas the hardware cost associated with ORIF using the AO Synthes calcaneal locking plate system is approximately $2200 to $2300. This latter cost is fully borne by the patient.

Although subtalar motion (6 points) is weighted less than is alignment (10 points) in the AOFAS grading system, subtalar motion is important for normal gait, especially on uneven surfaces. Leung et al[14] reported that more than 67% of active and 80% of passive subtalar joint motion could be retained after intra-articular calcaneal fracture repair by ORIF. The authors attributed this mobility to resection of the calcaneofibular ligament, rigid anatomical reduction, and energetic postoperative rehabilitation. In our study, excellent plantigrade foot alignment was achieved because of the application of an external fixator. However, a total of 14 (29%) feet in our study had moderate restriction with a loss of more than 25% of subtalar motion in the follow-up period. This leads to the question, does subtalar motion become limited after 3 months of external fixation? Soft tissue tension and compliance were restored during the initial application of the external fixator, which was beneficial for reducing swelling. Further shrinkage and contraction of the damaged soft tissues were limited by keeping the injured foot in a neutral position. The subtalar joint was constrained, but forefoot motion was possible,[4] and subtalar joint accommodation was regained in most patients after progressive weight-bearing ambulation during external fixation. In contrast to Leung's study, in which most patients had low-impact injuries,[14] the majority of the patients in our study had high-impact injuries resulting in broadening and flattening of the calcaneal bodies and severely traumatized soft tissues. This difference likely explains the higher proportion of patients with restricted subtalar joint motion in our study compared with Leung's study[14] and leads us to speculate that severely traumatized soft tissues may be the predisposing factor for limited subtalar motion in some but not all patients. The use of external fixation may also have contributed to restricted subtalar motion. Additional study is warranted to investigate these possibilities and identify the risk factors for limited subtalar motion.

In our study, 15% of the feet developed superficial pin tract infections, whereas 8% had wound edge necrosis. These rates of infection and necrosis are lower than those reported in previous studies involving external fixation.[1,17,25] We did observe 2 (4%) cases of deep wound infection. In both cases, infection was controlled after removal of external and internal fixators, antibiotic therapy, and bone grafting. For these 2 cases, both were Sanders type 4 with multiple injuries. The younger patient had paraplegia and presented with malnutrition during surgery. The older patient was a heavy smoker (1 pack of cigarettes per day) who later underwent subtalar arthrodesis; the same patient who had a deep wound infection exhibited fracture malunion, subsequent subtalar arthritis, and markedly restricted subtalar motion. The fracture malunion was likely a consequence of fracture reduction lost during debridement surgery following internal and external fixation removal. All other complications resolved uneventfully. In a recent study, DeWall et al[10] reported much higher rates of deep wound infection (14.3%) and other minor wound complications (21.4%) after ORIF. The low rate of complications in our study may be explained at least in part by the use of external fixation and minimal internal fixation. In the study by DeWall and colleagues,[10] the deep infection rate in the ORIF group was 6 of 42 (14.3%). In contrast, the deep infection rate of percutaneous reduction and screw fixation in our cohort was 0 of 83 (0%).

The use of bone graft in calcaneal fracture repair is controversial. Following completion of a prospective randomized study, Longino and Buckley[16] reported that bone graft offered no clinical benefit for intra-articular calcaneal fracture repair. In our study, unlike in traditional ORIF, structural bone graft was typically used to strengthen the crushed neutral triangle and provide mechanical support to the previously depressed thalamic portion. We found that bone graft increased fracture stabilization to the extent that K wires were not required in several cases.

Patients in our study had higher rates of concurrent spinal (31%) and multiple (28%) fractures than previously reported.[6,8,9,17,27] Furthermore, a lower proportion (59%) of our patients returned to their previous job after surgery and took a longer length of time off work (average 36 weeks) than previously reported. [6,8,9,17,27] The relationship between concurrent fracture and postoperative work status and time away from work warrants further investigation.

Our procedure has a number of limitations and elicited several patient concerns. These included pin care and pin tract infection stress and the physical inconvenience of the external fixator. Furthermore, there is a risk of deep wound infection, as with any open reduction approach. A secondary procedure is required to remove both the external fixator and K wires; however, this procedure does not involve skin incision. From a patient perspective, however, this procedure is substantially cheaper than ORIF with AO Synthes calcaneal locking plate system, because in Taiwan the patient pays for hardware under the rules of the National Health Insurance, as detailed earlier.

Our study has several limitations. First, 4 patients treated using the approach outlined in this report were lost to follow-up. Given the relatively small number of patients included in the study, the outcomes for these 4 patients may have affected our overall findings. Second, we did not have a control group of patients who received nonoperative or standard ORIF for comparison. Including a control group would have allowed us to make general comparisons of efficacy and complications as well as more specific comparisons related to procedural and treatment features such as use of bone grafting and postoperative weight bearing. Comparison with other operative approaches, such as percutaneous fixation, is also warranted.[10] Third, we did not assess arthritis of the subtalar joint during follow-up.

In conclusion, we suggest that the combination of an external fixator and minimal internal fixation through the extended lateral incision is an effective approach, with reasonably low complication rates and reasonably good clinical outcome at 6 years, for treating displaced intra-articular calcaneal fractures. A larger scale prospective study is needed to confirm our findings and directly compare outcomes with other surgical approaches.

Declaration of Conflicting Interests

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Reference

1. Ali AM, Elsaied MA, Elmoghazy N. Management of calcaneal fractures using the Ilizarov external fixator. *Acta Orthop Belg*. 2009;75:51-56.

2. Andermahr J, Helling HJ, Landwehr P, et al. The lateral calcaneal artery. *Surg Radiol Anat.* 1998;20:419-423.
3. Bajammal S, Tornetta P III, Sanders D, Bhandari M. Displaced intra-articular calcaneal fractures. *J Orthop Trauma.* 2005;19:360-364.
4. Baumgaertel FR, Gotzen L. Two-stage operative treatment of comminuted os calcis fractures: primary indirect reduction with medial external fixation and delayed lateral plate fixation. *Clin Orthop Relat Res.* 1993;290:132-141.
5. Besch L, Radke B, Mueller M, et al. Dynamic and functional gait analysis of severely displaced intra-articular calcaneus fractures treated with a hinged external fixator or internal stabilization. *J Foot Ankle Surg.* 2008;47:19-25.
6. Buckley R, Tough S, McCormack R, et al. Operative compared with nonoperative treatment of displaced intra-articular calcaneal fractures: a prospective, randomized, controlled multicenter trial. *J Bone Joint Surg Am.* 2002;84-A:1733-1744.
7. Buckley RE. Evidence for the best treatment for displaced intra-articular calcaneal fractures. *Acta Chir Orthop Traumatol Cech.* 2010;77:179-185.
8. Clare MP, Sanders RW. Fractures and dislocations of the calcaneus. In: Bucholz RW, Heckman JD, Court-Brown C, Tornetta P, eds. *Rockwood and Green's Fractures in Adults*, 6th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2005;2293-2336.
9. Coughlin MJ. Calcaneal fractures in the industrial patient. *Foot Ankle Int.* 2000;21:896-905.
10. DeWall M, Henderson CE, McKinley TO, et al. Percutaneous reduction and fixation of displaced intra-articular calcaneus fractures. *J Orthop Trauma.* 2010;24:466-472.
11. Gougoulias N, Khanna A, McBride DJ, Maffulli N. Management of calcaneal fractures: systematic review of randomized trials. *Br Med Bull.* 2009;92:153-167.
12. Harvey EJ, Grujic L, Early JS, Benirschke SK, Sangeorzan BJ. Morbidity associated with ORIF of intra-articular calcaneus fractures using a lateral approach. *Foot Ankle Int.* 2001; 22:868-873.
13. Kitaoka HB, Alexander IJ, Adelaar RS, et al. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. *Foot Ankle Int.* 1994;15:349-353.
14. Leung KS, Chan WS, Shen WY, et al. Operative treatment of intra-articular fractures of the os calcis—the role of rigid internal fixation and primary bone grafting: preliminary results. *J Orthop Trauma.* 1989;3:232-240.
15. Leung KS, Yuen KM, Chan WS. Operative treatment of displaced intra-articular fractures of the calcaneum: medium-term results. *J Bone Joint Surg Br.* 1993;75:196-201.
16. Longino D, Buckley RE. Bone graft in the operative treatment of displaced intra-articular calcaneal fractures: is it helpful? *J Orthop Trauma.* 2001;15:280-286.
17. McGarvey WC, Burris MW, Clanton TO, Melissinos EG. Calcaneal fractures: indirect reduction and external fixation. *Foot Ankle Int.* 2006;27:494-499.
18. Paley D, Fischgrund J. Open reduction and circular external fixation of intra-articular calcaneal fractures. *Clin Orthop Relat Res.* 1993;290:125-131.
19. Rammelt S, Zwipp H. Calcaneus fractures: facts, controversies and recent developments. *Injury.* 2004;35:443-461.
20. Richards PJ, Bridgman S. Review of the radiology in randomised controlled trials in open reduction and internal fixation (ORIF) of displaced intra-articular calcaneal fractures. *Injury.* 2001;32:633-636.
21. Roukis TS, Wünschel M, Lutz HP, Kirschner P, Zgonis T. Treatment of displaced intra-articular calcaneal fractures with triangular tube-to-bar external fixation: long-term clinical follow-up and radiographic analysis. *Clin Podiatr Med Surg.* 25:285-299, 2008.
22. Sanders R, Fortin P, DiPasquale T, Walling A. Operative treatment in 120 displaced intra-articular calcaneal fractures: results using a prognostic computed tomography scan classification. *Clin Orthop Relat Res.* 1993;290:87-95.
23. Sanders R. A new plate for calcaneal fractures: results in 200 fractures. Paper presented at: the AOFAS Summer Meeting; July 2000; Vail, CO.
24. Stapleton JJ, Kolodenker G, Zgonis T. Internal and external fixation approaches to the surgical management of calcaneal fractures. *Clin Podiatr Med Surg.* 2010;27:381-392.
25. Talarico LM, Vito GR, Zyryanov SY. Management of displaced intra-articular calcaneal fractures by using external ring fixation, minimally invasive open reduction, and early weightbearing. *J Foot Ankle Surg.* 2004;43:43-50.
26. Thordarson DB, Krieger LE. Operative vs. nonoperative treatment of intra-articular fractures of the calcaneus: a prospective randomized trial. *Foot Ankle Int.* 1996;17:2-9.
27. Thordarson DB, Latteier M. Open reduction and internal fixation of calcaneal fractures with a low profile titanium calcaneal perimeter plate. *Foot Ankle Int.* 2003;24:217-221.
28. Zgonis T, Roukis TS, Polyzois VD. The use of Ilizarov technique and other types of external fixation for the treatment of intra-articular calcaneal fractures. *Clin Podiatr Med Surg.* 2006;23:343-353.
29. Zwipp H, Tscherne H, Thermann H, Weber T. Osteosynthesis of displaced intra-articular fractures of the calcaneus: results in 123 cases. *Clin Orthop Relat Res.* 1993;290:76-86.