Introduction of a New Locking Nail for Treatment of Intraarticular Calcaneal Fractures

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Objectives: To reduce the complication rate associated with open reduction and internal fixation of displaced intraarticular calcaneal fractures through extensile approaches, a locking nail system (C-Nail) was developed for internal fixation.

Design: Prospective case–control study.

Setting: Two level I trauma centers (university hospital) and 1 large regional hospital in the Czech Republic and Germany.

Patients: One hundred three patients (89 male and 14 female; mean age, 45.6 years) with 106 calcaneal fractures were treated between February 2011 and October 2013.

Intervention: In all 106 cases, the stainless steel C-Nail with a length of 65 mm, a diameter of 8 mm, and 7 locking options was used for internal fixation. Previous reduction of the posterior facet was performed in 15 cases percutaneously, assisted by arthroscopy and fluoroscopy, and in 91 cases by a sinus tarsi approach. The reduced joint surface was fixed by 1 or 2 compression screws. All other fragments were fixed after reduction and temporary K-wire fixation with the C-Nail introduced percutaneously through the tuberosity and 5 to 6 interlocking screws. The latter were introduced into the sustentacular, the tuberosity, and the anterior process fragments with an aiming device consisting of 3 arms.

Main Outcome Measures: Patients were assessed for complications, restoration of Böhler angle, posterior facet reduction with postoperative computed tomography, and weight-bearing radiographs at 6 months. Functional outcome was assessed using the American Orthopaedic Foot & Ankle Society (AOFAS) ankle/hindfoot scale after 6 and 12 months for all patients.

Results: Wound edge necrosis was seen in 2 cases (1.9%), and soft tissue infection was observed in 1 case (0.9%). Böhler angle improved from 7.3 degree preoperatively to 28.7 degree at 6 months. The posterior facet step-off was reduced from 5.3 mm preoperatively to 0.7 mm postoperatively. The average AOFAS score averaged 89.5 at 6-month and 92.6 at 12-month follow-up.

Conclusions: The C-Nail is a new locking system for treatment of displaced intraarticular calcaneal fractures combining a primary stability with reduced soft tissue complications.

Key Words: calcaneal fracture, sinus tarsi approach, arthroscopy, fluoroscopy, locking calcaneal nail

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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INTRODUCTION

The best treatment of displaced, intraarticular calcaneal fractures (DIACFs) is still a matter of debate, and it seems that there is no single approach that is suitable for all types of fractures.[1,2] Rather, treatment should be tailored to the patient. Recently, published studies on open reduction and internal fixation of DIACFs with a plate using an extensile lateral approach showed reproducibly good long-term results, provided proper reduction of the calcaneal shape and joint congruity.[3–7] However, soft tissue complications including hematoma, skin necrosis, soft tissue infection, and even osteitis of the calcaneus have been reported in up to 25% using extensile approaches.[1,6,8–12] Therefore, alternative procedures including arthroscopically or fluoroscopically assisted percutaneous reduction and fixation, external fixation, and limited lateral or sinus tarsi approaches have been recommended.[13–20]

Internal fixation of DIACFs with an interlocking nail may offer the advantage of stable fixation without the need for an extensile lateral approach.[21] The use of a calcaneal nail has been proposed by Gussenbauer[22] as early as 1888; however, no results were ever reported. Recent preliminary reports of internal fixation of DIACFs with a locking nail using a sinus tarsi approach have been encouraging,[21,23] but a detailed follow-up of a substantial number of patients has not yet been provided. We therefore report the technique, complication rates, and radiographic and functional results

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of 106 consecutive cases of intraarticular calcaneal fractures treated with an interlocking nail by 4 surgeons at 3 institutions and followed completely for a minimum of 12 months.

PATIENTS AND METHODS

Implant Properties

The calcaneal nail used in this study (C-Nail; Medin, Nové Město na Moravě, Czech Republic) is an 8-mm diameter steel nail, 65 mm in length. Length can be extended using an end cap (5, 10, 15, 20 mms). The locking cortical screws are inserted through the nail by means of an aiming device with 3 arms: 1 for guiding the screws into the sustentacular fragment, 1 into the tuberosity from proximal, and 1 from lateral into the tuberosity and the anterior process.

Patient Data

During the period from February 2011 to October 2013, 103 patients with 106 intraarticular calcaneal fractures were treated with the C-Nail at 3 centers by 4 senior surgeons. The mean patient age was 45 years (±12.6 years). Eighty-nine patients (86%) were males and 14 patients were females. Fractures were evaluated on preoperative radiographs (Fig. 1) and computed tomography (CT) (see **Figure, Supplemental Digital Content 1**, http://links.lww.com/BOT/A586) according to the Sanders classification.[24] The soft tissue injury was graded according to Gustilo and Anderson classification for open fractures and Tscherne and Oestern classification for closed fractures (Table 1). Twenty-five of the 103 patients (26.2%) were cigarette smokers and 6 patients (5.8%) had noninsulin-dependent diabetes mellitus. Contraindications to surgery were poorly controlled insulin-dependent diabetes, neuropathy, severe vasculopathy, immunodeficiency, and poor patient compliance (substance abuse and psychiatric conditions).

FIGURE 1. Example of operative treatment of a Sanders type II A fracture of the right calcaneus in a 38-year-old man fallen from a height of 3 m. The lateral radiograph shows the tilted posterior facet fragment and decreased Böhler angle of 14 degree.

TABLE 1. Main Characteristics of the 103 Patients and 106 Calcaneal Fractures Treated With the C-Nail.

Variable	Mean ± SD, Frequency, and Percentage (%)
Age (yrs)	45.6 ± 12.6
Sex	
Male	89 (86.4)
Female	14 (13.6)
Sanders classification	
I	9 (8.5)
II A	36 (33.9)
II B	25 (23.6)
II C	3 (2.8)
III AB	20 (18.9)
III AC	6 (5.6)
III BC	3 (2.8)
IV	4 (3.7)
Gustilo and Anderson classification	
0 I	2 (1.9)
0 IIa	1 (0.9)
Tscherne and Oestern classification	
c 0	36 (34.0)
c I	58 (54.7)
c II	9 (8.5)
Calcaneocuboidal joint involvement	
Yes	75 (70.8)
No	31 (29.2)
Bilateral calcaneal fracture	
Yes	3 (2.9)
No	100 (97.1)
Current cigarette smoker	
Yes	27 (26.2)
No	76 (73.8)
Noninsulin-dependent diabetes mellitus	
Yes	6 (5.8)
No	97 (94.2)

Variables are expressed as mean ± SD, frequency, and percentage (%).

Surgical Technique

Patients were placed in a lateral decubitus position with a slightly flexed knee. The involved extremity was supported by a soft cylindrical radiolucent pillow. The other knee is flexed more to avoid interference with fluoroscopy. A sinus tarsi approach was used in 91 calcaneal fractures (Fig. 2). The incision started below the tip of the lateral malleolus and continued 3 cm toward the base of the fifth metatarsal (see **Figure, Supplemental Digital Content 2**, http://links.lww.com/BOT/A587). Care was taken not to damage the peroneal tendons when exposing the subtalar joint. To facilitate reduction of the tuberosity fragment toward the sustentacular fragment and subsequent joint

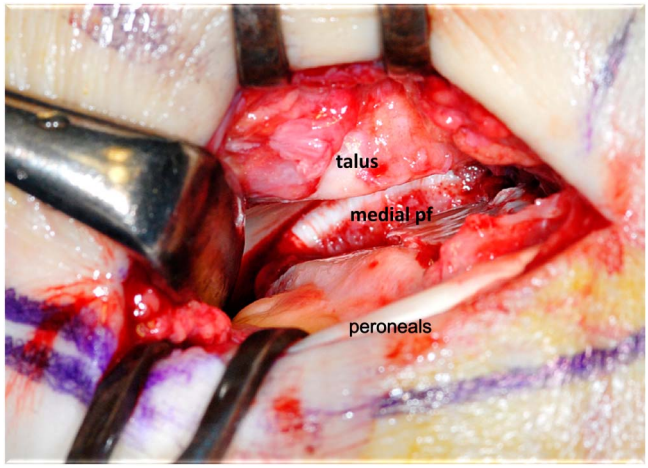

FIGURE 2. The fractured posterior facet (pf) is visualized through a small, direct incision over the sinus tarsi, showing the amount of articular displacement.

reduction, a 6.5-mm cancellous Schanz screw with T-handle (Fig. 3) was inserted through a stab incision over the posterior tuberosity or tongue type fragment, if present. Manipulation of the T-handle allowed for correction of lateral translation, varus, or valgus malposition, and plantar tilting of the tuberosity.[12] If needed, a periosteal elevator was introduced below the posterior facet fragment(s) to mobilize the tuberosity fragment

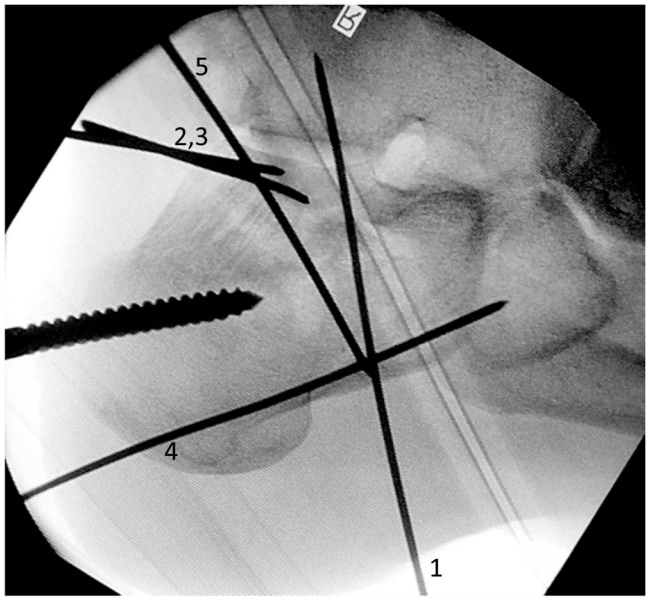

FIGURE 3. Sequence of K-wire transfixation. For manipulation of the tuberosity fragment (Westhues/Essex-Lopresti maneuver), a Schanz screw with handle is inserted. If the sustentacular fragment is tilted, it is reduced to the talus and temporarily fixed from the plantar side with a K-wire toward the talus (1). The lateral fragment of the posterior facet is reduced and fixed with 2 K-wires toward the medial fragment of the posterior facet (2 and 3). After fine reduction, the tuberosity fragment fixed to the anterior process fragment (4). The so called balcony fragment is held with another K-wire (5).

beneath the sustentacular fragment, thus restoring calcaneal height and the medial wall.[23] After this, initial reduction maneuver anatomic reduction of the posterior facet was performed under direct vision using a smooth or periosteal elevator followed by temporary K-wire fixation from the lateral to the medial aspect of the posterior facet. After final reduction, the tuberosity fragment was fixed with 1 or 2 K-wires to the sustentacular fragment.

If the sustentacular fragment was tilted, it was reduced initially to the medial part of the posterior facet, absolutely parallel to the talus and fixed temporarily to the talus from plantar. In the presence of displaced intercalary fragments of the posterior facet (Sanders types III and IV), an inside-out-inside K-wire fixation technique was used.[23] Congruency of the posterior subtalar joint was checked fluoroscopically using Brodèn projections or using open arthroscopy.[25] In 1 case, anatomic joint reduction could not be achieved through a sinus tarsi approach, and consequently, the incision was enlarged to a lateral Kocher approach. In 15 cases, reduction was achieved percutaneously with arthroscopic and fluoroscopic control. Definite fixation of the posterior facet was achieved by inserting 2 separate 4.0-mm subthalamic cancellous screws compressing the lateral joint fragment to the sustentaculum (see **Figure, Supplemental Digital Content 3**, http://links.lww.com/BOT/A588). In the case of calcaneocuboidal joint involvement, congruity of the cuboidal facet was checked with a lateral and dorso-plantar fluoroscopic projection. An intraarticular fracture was secured by one or two 4.0-mm cancellous screws inserted percutaneously parallel to the calcaneocuboidal joint and in the plantar aspect of the anterior process in order not to obstruct the subsequent insertion of the nail.

For insertion of the C-Nail, a 10-mm vertical incision below the attachment of the Achilles tendon was made, slightly lateral to the center of the posterior heel. The guide wire was directed toward the center of the calcaneocuboidal joint and then reamed stopping 5 mm short of the posterior facet. The nail with the attached aiming device was introduced by slight pressure combined with rotational motion. Care was then taken to position the proximal 2.0-mm olive K-wire into the sustentacular fragment close to the middle facet using the aiming device. A second K-wire was then inserted, and the original wire was exchanged for a cortical screw of proper length. Depending on the individual fracture anatomy, up to 7 locking screws were introduced through the 3 arms (sustentacular, superior, and lateral) of the aiming device. The middle hole in the lateral arm was not used if central comminution was present. An end cap was applied if needed. Proper reduction and implant position were verified with a 20 degree Brodèn view, lateral, axial, and dorso-plantar projections or fluoroscopy. A suction drain was applied if a sinus tarsi approach was used (see **Figure, Supplemental Digital Content 4**, http://links.lww.com/BOT/A589). Postoperative CT was obtained to insure anatomic reduction of the joint and the overall shape of the calcaneus and also proper screw placement (see **Figures, Supplemental Digital Content 5–7,** http://links.lww.com/BOT/A590 and http://links.lww.com/BOT/A591 and http://links.lww.com/BOT/A592 for further examples of preoperative and postoperative CT scans).

Continuous passive motion and active range of motion exercises of the ankle and subtalar joints were started on the second postoperative day. After treatment was functional with partial weight bearing of 20 kg on two crutches for 6–10 weeks in the patient's own shoe.

RESULTS

No intraoperative complications occurred. Superficial wound edge necrosis was seen in 2 cases (1.9%). Both healed with local wound care. One deep infection was observed (0.9%) in a patient with a Gustilo/Anderson type II open calcaneal fracture. After early C-Nail removal, repeat debridement, and defect filling with antibiotic impregnated bone cement, the infection resolved. All fractures except the one (above deep infection) were solidly healed at 3 months.

Böhler angle improved from an average of 7.3 degree preoperatively to 31.2 degree at 3-month follow-up when all patients were allowed full weight-bearing (Fig. 4). At 6-month follow-up, Böhler angle had decreased to an average of 28.7 degree. The posterior facet step-off in the subtalar joint was reduced from an average of 5.3 mm preoperatively to 0.7 mm postoperatively as confirmed by CT scanning (Figs. 7–9). The mean AOFAS ankle/hindfoot score averaged 89.5 at 6-month follow-up and 92.6 at 12-month follow-up. Implant removal was performed in 3 cases (2.8%) without complications. No early or secondary loosening or implant failure with loss of reduction was seen. No symptomatic arthritis of the subtalar joint was observed, necessitating secondary fusion during the study period of 1 year.

DISCUSSION

The ideal treatment of DIACFs is controversial. Nonoperative treatment of DIACFs is unlikely to result in normal function because of secondary arthritis requiring fusion and malunion of the calcaneus leading to a painful foot deformity.[1,11,12,24,26,27–30] When performing open reduction and internal fixation of DIACFs, anatomic reduction of overall shape of the calcaneus and meticulous restoration of subtalar joint congruity is prerequisites for reliable long-term results.[3–7,11,26] The most widely used extended lateral approach allows adequate exposure for anatomic reduction of the posterior, medial, and cuboidal facet, restoration of the lateral wall, and application of a locking or nonlocking plate.[9,12,24,31] A major concern when using extensile approaches is the development of soft tissue complications including hematoma, skin necrosis, soft tissue infection, and even osteitis of the calcaneus. Reported rates of superficial wound edge necrosis vary between 2% and 25%, hematomas requiring revision between 0% and 7%, and deep infections between 1% and 7%.[6–12,24,32] Deep infections may require repeated debridements, early plate removal, local or free flap coverage, and even amputation in cases of recalcitrant infection.[24,26,33] Therefore, limited surgical approaches have been advocated including medial approaches,[34–36] percutaneous reduction with fluoroscopic and arthroscopic control,[14,15,19,25,37–40] and fixation by limited lateral or sinus tarsi approaches.[13,14,16,21]

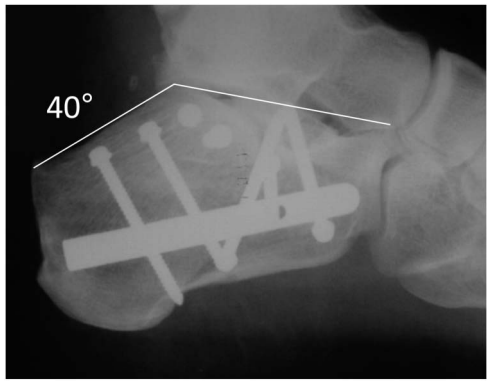

FIGURE 4. Postoperative lateral radiograph with the C-Nail inserted. The Böhler angle has improved from 14 degree initially (Fig. 1) to 40 degree.

The interlocking calcaneal nail (C-Nail) was developed to combine the advantages of a minimally invasive approach, stable percutaneous fixation. Although the idea of using a nail for calcaneal fracture fixation is not new,[22] only few results have been reported so far. Godzak et al[21] reported on 10 patients treated with the Calcanail (FH Orthopaedics, Heimbrunn, France). In that series, there were no wound infections, and the average AOFAS score was 84. On biomechanical testing, the calcanail displayed a significantly higher stiffness and load to failure than the interlocking AO calcaneal plate.[41]

The C-Nail is not designed to obtain a reduction. Anatomic restoration of the articular surfaces and the shape of the calcaneus must be accomplished before introducing the nail. The subtalar joint fragments should be initially fixed with screws introduced from lateral to medial to prevent secondary displacement of the fracture fragments. Alternatively, even with an open approach, dry arthroscopy may be used to precisely assess joint reduction.[25] Despite this, articular reconstruction of Sanders type III and IV is challenging with limited approaches, and it is the responsibility of the surgeon to convert to a more extensile approach if anatomic reduction cannot be achieved or controlled sufficiently. Like other approaches to the calcaneus, the proposed technique requires sufficient experience and skills of the surgeon in both calcaneal fracture fixation and subtalar arthroscopy combined with percutaneous procedures.[14,15,18,20] We believe that the use of the C-Nail is not useful for fractures of the sustentaculum tali with multiple fragmentation of the medial facet and comminuted fractures of the anterior process.

CONCLUSIONS

In summary, our initial experience in the treatment of DIACFs with a sinus tarsi approach combined with an interlocking nail results in fracture healing with a low rate of soft tissue complications. Anatomic restoration of joint congruity and calcaneal shape must be accomplished before nail insertion and is a prerequisite for good outcomes.

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