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ESSENTIAL SURGICAL TECHNIQUES

SUBSPECIALTY PROCEDURES

Interlocking Nail Fixation for the Treatment of Displaced Intra-Articular Calcaneal Fractures

Michael Amlang, MD, PhD, Hans Zwipp, MD, PhD, Martin Pompach, MD, PhD, Stefan Rammelt, MD, PhD

Published outcomes of this procedure can be found at: *J Orthop Trauma*. 2016 Mar;30 (3):e88-e92.

Introduction

Less invasive restoration of joint congruity and calcaneal shape in displaced intra-articular calcaneal fractures via a sinus tarsi approach followed by percutaneous internal fixation with an interlocking nail results in a low rate of soft-tissue complications and good short-term outcomes[1] (Video 1).

Open reduction and internal fixation of displaced intra-articular calcaneal fractures aims at anatomic reduction of the overall shape of the calcaneus and meticulous restoration of subtalar joint congruity in order to achieve reliable long-term results[2-4]. An important concern when extensile approaches are used is the development of soft-tissue complications such as hematoma, skin necrosis, soft-tissue infection, and possibly osteitis of the calcaneus. Recently, small direct lateral approaches directly below the fibular tip toward the vertex of the Gissane angle (the sinus tarsi approach) have gained increasing popularity for less invasive reduction and fixation of calcaneal fractures as they allow control of joint reduction without extensile soft-tissue dissection[5,6].

Definitive fixation can be achieved with percutaneous screws or bolts[7,8], an intramedullary nail with locking screws[1,9], or a small plate placed through the approach and tunneled beneath the peroneal tendons[8,10]. The interlocking calcaneal nail (C-Nail; Medin) was developed to combine the advantages of a minimally invasive approach and stable percutaneous fixation. The interlocking calcaneal nail is a steel nail with a diameter of 8 mm and a length of 65 mm that can be extended using an end cap of 5 to 20 mm. Separate nails are available for the left and the right calcaneus. The locking cortical screws are guided by an aiming device with 3 arms: first into the sustentacular fragment, second into the tuberosity through the

Video 1 Complete surgical procedure. (The small arrow that appears in part of the video is a cursor from the editing software.)

Disclosure: On the **Disclosure of Potential Conflicts of Interest** forms, *which are provided with the online version of the article*, one or more of the authors checked "yes" to indicate that the author had a relevant financial relationship in the biomedical arena outside the submitted work and "yes" to indicate that the author had a patent and/or copyright, planned, pending, or issued, for the device that is the subject of this article (http://links.lww.com/JBJSEST/A193).

proximal arm, and third through the lateral arm into the anterior process fragment (Fig. 1). The main fragments of the calcaneus are manipulated percutaneously in a so-called joystick fashion using a handle attached to a Schanz screw while the joint fragments can be manipulated directly through the approach. A main feature of the nail is the stable fixation of the calcaneal tuberosity to the sustentaculum tali and the anterior process. In a recent biomechanical study comparing the C-Nail, the Calcanail (FH ORTHO), and a variable angle interlocking plate (Rimbus; Intercus)[11], the C-Nail showed significantly fewer dynamic failures ($p < 0.01$) and a higher load to failure (mean and standard deviation, 2,808 ± 974 N) than the Calcanail (mean, 1,751 ± 756 N) and the Rimbus plate (mean, 2,041 ± 604 N). The difference relative to the latter did not reach significance, and there was also no significant difference between the implants with regard to stiffness, Böhler angle, or interfragmentary motion[11].

Fig. 1

Fig. 1 The C-Nail with mounted 3-armed aiming device.

Indications & Contraindications

Indications

- Displaced intra-articular calcaneal fractures in adults.
- Displaced extra-articular calcaneal fractures in adults.

Contraindications

- "Beak" fractures with a fracture at the insertion point for the nail.
- Fractures of the sustentaculum tali with multiple fragmentation of the medial facet.
- Children with an open calcaneal apophysis.
- Patients with a very small calcaneus (shorter than 65 mm).
- Patients with a known allergy to chromium or nickel (nail is available in steel).
- Infected soft tissues.
- Poorly controlled insulin-dependent diabetes mellitus.
- Manifest neuropathy including Charcot arthropathy.
- Severe vasculopathy (Fontaine stage-IIB peripheral vascular disease).
- Manifest immunodeficiency.
- Poor patient compliance (substance abuse or psychiatric conditions).

Step 1: Patient Placement

Place the patient in the lateral decubitus position, supporting the involved extremity with a soft radiolucent pillow, flex the contralateral knee, check with fluoroscopy before draping, and obtain lateral radiographs.

- Place the patient in the lateral decubitus position with a slightly flexed knee.
- Support the involved extremity with a soft cylindrical radiolucent pillow.
- Flex the contralateral knee more in order to avoid interference with fluoroscopy.
- Check with fluoroscopy (including 3-dimensional [3D] imaging) before draping of the injured leg.
- Ensure that lateral radiographs of both calcanei and computed tomography (CT) scans of the fractured calcaneus are available (Figs. 2-A, 2-B, and 2-C).

Fig. 2-A

Fig. 2-B

Fig. 2-C

Figs. 2-A, 2-B, and 2-C Preoperative images of a displaced intra-articular calcaneal fracture. **(**Reproduced from: Amlang MH, Pompach M. Intraartikuläre Kalkaneusfraktur, minimalinvasive Technik mit Nagelosteosynthese (C-NAIL). In: Hamel J, Zwipp H., editors. Sprunggelenk und Rückfuß. Berlin: Springer; 2016. p 199-205. With permission of Springer.) **Fig. 2-A** Lateral radiograph. **Figs. 2-B and 2-C** Coronal (**Fig. 2-B**) and axial (**Fig. 2-C**) CT scans.

Step 2: Incision

Use a sinus tarsi approach for control of the articular reduction.

- Identify the tip of the lateral malleolus.
- Start the incision distal to the fibular tip and continue 3 cm toward the base of the fifth metatarsal (Fig. 3).
- Take care not to damage the sural nerve and peroneal tendons when exposing the subtalar joint (Fig. 4).
- Gently mobilize the peroneal tendons within their tendon sheath and hold them away as needed with a retractor.
- Identify the articular fragments and clear out hematoma and debris (Fig. 5).

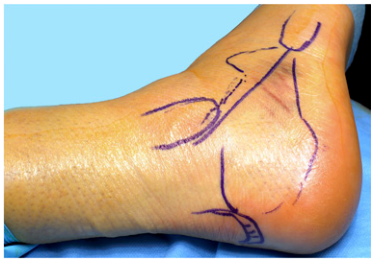

Fig. 3

Fig. 4

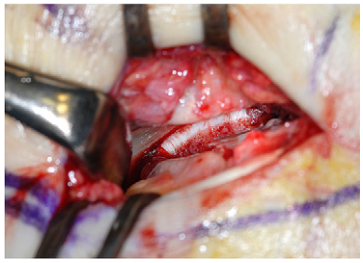

Fig. 5

Fig. 3 Sinus tarsi approach to the calcaneus. The landmarks (fibular tip and tuberosity of the 5th metatarsal) are depicted with skin markers. (Reproduced from: Amlang MH, Pompach M. Intraartikuläre Kalkaneusfraktur, minimalinvasive Technik mit Nagelosteosynthese (C-NAIL). In: Hamel J, Zwipp H., editors. Sprunggelenk und Rückfuß. Berlin: Springer; 2016. p 199-205. With permission of Springer.)

Fig. 4 The skin incision over the sinus tarsi has a length of 3 cm (the lateral talar process becomes visible in the wound). (Reproduced from: Amlang MH, Pompach M. Intraartikuläre Kalkaneusfraktur, minimalinvasive Technik mit Nagelosteosynthese (C-NAIL). In: Hamel J, Zwipp H., editors. Sprunggelenk und Rückfuß. Berlin: Springer; 2016. p 199-205. With permission of Springer.)

Fig. 5 After clearing out the hematoma and obtaining an adequate view over the posterior facet of the subtalar joint, a 3-part (Sanders type-III[12]) fracture of the joint is visualized. (Reproduced from: Amlang MH, Pompach M. Intraartikuläre Kalkaneusfraktur, minimalinvasive Technik mit Nagelosteosynthese (C-NAIL). In: Hamel J, Zwipp H., editors. Sprunggelenk und Rückfuß. Berlin: Springer; 2016. p 199-205. With permission of Springer.)

Step 3: Percutaneous Manipulation of the Main Fragments

Percutaneously manipulate the main fragments to facilitate reduction of the main tuberosity fragment toward the sustentacular fragment and subsequent joint reduction.

- Introduce a 6.5-mm cancellous Schanz screw with a T-handle through a stab incision into the posterior tuberosity or tongue type of fragment (if present).
- Manipulate the T-handle to loosen the main fragments and correct lateral translation, varus or valgus malposition, and plantar tilting of the tuberosity (Fig. 6).

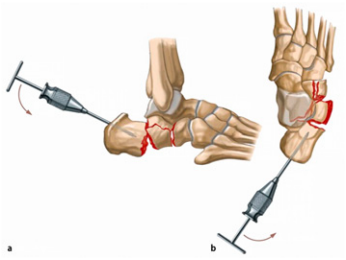

Fig. 6

Fig. 6 Manipulation of the main fragments with a Schanz screw introduced from posterior into the tuberosity (the Westhues/Essex-Lopresti maneuver). (Reproduced from: Amlang MH, Pompach M. Intraartikuläre Kalkaneusfraktur, minimalinvasive Technik mit Nagelosteosynthese (C-NAIL). In: Hamel J, Zwipp H., editors. Sprunggelenk und Rückfuß. Berlin: Springer; 2016. p 199-205. With permission of Springer.)

Step 4: Joint Reduction with Direct Manipulation of the Main Fragments through the Sinus Tarsi Approach

Reduce the joint with direct manipulation of the main fragments through the sinus tarsi approach.

- Introduce a periosteal or smooth elevator below the posterolateral joint fragment and between the tuberosity and sustentacular fragments (Fig. 7-A).
- Mobilize the tuberosity fragment beneath the sustentacular fragment, thus restoring calcaneal height and the medial wall (Fig. 7-B).
- Reduce the posterior facet fragment(s) under direct vision using a smooth or periosteal elevator followed by temporary Kirschner wire fixation from the lateral to the medial aspect of the posterior facet (Fig. 8).
- In the presence of displaced intercalary fragments of the posterior facet (Sanders types III and IV[12]), an inside-out-inside Kirschner wire fixation technique may be employed[13].
- Use additional Kirschner wires to stabilize the tuberosity against the anterior process and further fragments as needed.
- Do not introduce the Kirschner wires centrally into the tuberosity so that they do not interfere with the introduction of the nail.

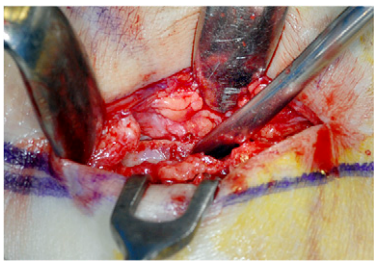

Fig. 7-A

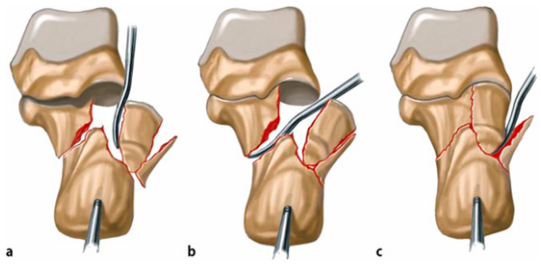

Fig. 7-B

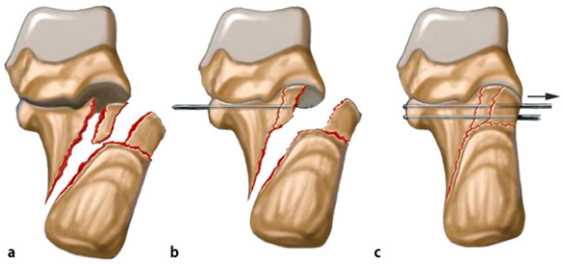

Fig. 8

Figs. 7-A and 7-B Intraoperative photograph and diagram showing the reduction of the lateral joint fragment to the medial joint (sustentacular) fragment. (Reproduced from: Amlang MH, Pompach M. Intraartikuläre Kalkaneusfraktur, minimalinvasive Technik mit Nagelosteosynthese (C-NAIL). In: Hamel J, Zwipp H., editors. Sprunggelenk und Rückfuß. Berlin: Springer; 2016. p 199-205. With permission of Springer.) **Fig. 7-A** A smooth elevator is introduced between the joint fragments in order to mobilize the tuberosity fragment below the medial fragment, thus reconstructing the medial wall. **Fig. 7-B** This maneuver facilitates reduction of the lateral joint fragment to the medial joint fragment.

Fig. 8 Stepwise reduction of the posterior facet fragments from medial to lateral. In case of intercalary fragments, an inside-out-inside technique is employed. (Reproduced from: Amlang MH, Pompach M. Intraartikuläre Kalkaneusfraktur, minimalinvasive Technik mit Nagelosteosynthese (C-NAIL). In: Hamel J, Zwipp H., editors. Sprunggelenk und Rückfuß. Berlin: Springer; 2016. p 199-205. With permission of Springer.)

Step 5: Joint Fixation with Screws

Check the congruency of the posterior subtalar joint facet, stabilize the posterior facet with 2 screws, reduce the tuberosity against the joint block and anterior process, and temporarily fix with Kirschner wires.

- Check the congruency of the posterior subtalar joint facet visually, fluoroscopically using Broden projections, or with the use of open subtalar arthroscopy[14].
- Stabilize the posterior facet by inserting 2 separate 3.5 to 4.0-mm subthalamic cancellous steel screws, compressing the lateral joint fragment to the sustentaculum tali (Fig. 9) to obtain appropriate stability.
- In the case of calcaneocuboid joint involvement, the approach can be extended anteriorly, and the joint reduced under direct vision and secured by one or two 3.5 to 4.0-mm cancellous steel screws parallel to the calcaneocuboid joint and in the plantar aspect of the anterior process in order not to obstruct the subsequent insertion of the nail.
- Then meticulously reduce the tuberosity fragment against the joint block and the anterior process and temporarily fix with Kirschner wires along the axis of the calcaneus[2,13].

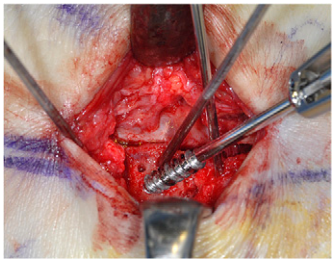

Fig. 9

Fig. 9 A cortical screw is inserted parallel to the joint surface from the lateral calcaneal wall into the sustentaculum tali in order to stabilize the reduced joint fragments. (Reproduced from: Amlang MH, Pompach M. Intraartikuläre Kalkaneusfraktur, minimalinvasive Technik mit Nagelosteosynthese (C-NAIL). In: Hamel J, Zwipp H., editors. Sprunggelenk und Rückfuß. Berlin: Springer; 2016. p 199-205. With permission of Springer.)

Step 6: Introduction of the Intramedullary Nail

Make a 10-mm vertical incision below the attachment of the Achilles tendon, direct the guidewire toward the center of the calcaneocuboid joint, place the guidewire centrally within the calcaneal body, ream over the guidewire, and introduce the intramedullary nail with the attached aiming device.

- For insertion of the C-Nail, make a 10-mm vertical incision below the attachment of the Achilles tendon, slightly lateral to the center of the posterior part of the heel (Fig. 10).
- Direct the guidewire toward the center of the calcaneocuboid joint (Figs. 11-A, 11-B, and 11-C).
- Place the guidewire centrally within the calcaneal body in the lateral projection and slightly lateral in the anteroposterior (dorsoplantar) projection. (Check the correct position fluoroscopically before reaming.)
- Ream over the guidewire with an 8-mm drill, using a protection sleeve and stopping 5 mm short of the calcaneocuboid joint.
- Introduce the nail with the attached aiming device by slight pressure combined with rotational motion (Fig. 12).
- Maintain reduction with the Kirschner wires, which should be introduced in a manner so that they do not interfere with the nail position (see Steps 4 and 5 and Figs. 11-A, 11-B, and 11-C).

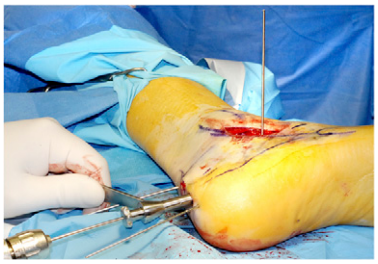

Fig. 10

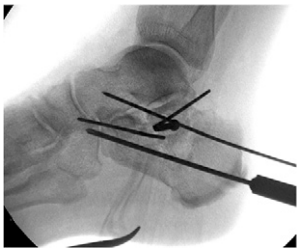

Fig. 11-A

Fig. 11-B

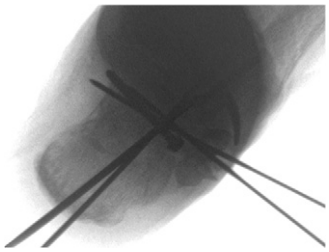

Fig. 11-C

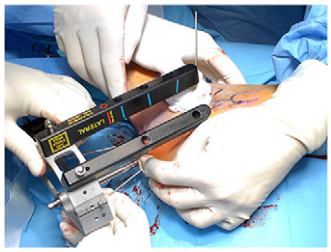

Fig. 12

Fig. 10 After making the skin incision for insertion of the calcaneal nail, a guidewire is advanced. (Reproduced from: Amlang MH, Pompach M. Intraartikuläre Kalkaneusfraktur, minimalinvasive Technik mit Nagelosteosynthese (C-NAIL). In: Hamel J, Zwipp H., editors. Sprunggelenk und Rückfuß. Berlin: Springer; 2016. p 199-205. With permission of Springer.)

Figs. 11-A, 11-B, and 11-C The correct position of the guidewire along the calcaneal axis is verified fluoroscopically with lateral (**Fig. 11-A**), dorsoplantar (**Fig. 11-B**), and axial views (**Fig. 11-C**). (Reproduced from: Amlang MH, Pompach M. Intraartikuläre Kalkaneusfraktur, minimalinvasive Technik mit Nagelosteosynthese (C-NAIL). In: Hamel J, Zwipp H., editors. Sprunggelenk und Rückfuß. Berlin: Springer; 2016. p 199-205. With permission of Springer.)

Fig. 12 After reaming, the nail with the aiming device is introduced over the guidewire. (Reproduced from: Amlang MH, Pompach M. Intraartikuläre Kalkaneusfraktur, minimalinvasive Technik mit Nagelosteosynthese (C-NAIL). In: Hamel J, Zwipp H., editors. Sprunggelenk und Rückfuß. Berlin: Springer; 2016. p 199-205. With permission of Springer.)

Step 7: Locking of the Nail

Use the aiming device to position the proximal Kirschner wire into the sustentacular fragment, place the nail so that it hits the sustentaculum tali properly, insert a second Kirschner wire through the other hole of the guiding arm, exchange the wires after drilling for locking screws, apply an end cap to extend the length of nail, if needed, and then verify proper reduction and implant position fluoroscopically.

- Position the proximal 2.0-mm olive Kirschner wire into the sustentacular fragment close to the middle facet using the aiming device (Figs. 13-A and 13-B).
- Determine the correct rotation of the nail according to the exact position of the first sustentacular Kirschner wire; thereafter, correct placement is controlled fluoroscopically. If this Kirschner wire does not hit the sustentaculum tali properly, withdraw it, rotate the nail accordingly with the aiming device, and place the Kirschner wire again.
- Insert a second guided Kirschner wire through the other hole of the sustentacular guiding arm and through the nail into the sustentaculum tali. Again, control its correct positioning fluoroscopically. Then exchange the original wires 1 for 1 after guided drilling and measuring for a cortical screw of proper length.
- Depending on the individual fracture anatomy, introduce up to 2 locking screws via the sustentacular arm, 2 locking screws via the superior arm, and 2 to 3 via the lateral arm of the aiming device.
- Apply an end cap to extend the total length of the nail by 5 to 20 mm, if needed.
- Verify proper reduction and implant position with a fluoroscopic 20° Broden view; lateral, axial, and dorsoplantar projections; or ideally with a 3D fluoroscopy scan (Figs. 14-A, 14-B, and 14-C).

Fig. 13-A

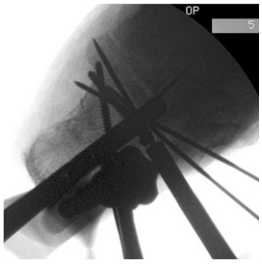

Fig. 13-B

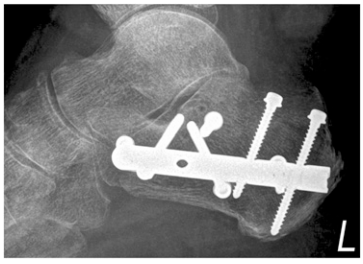

Fig. 14-A

Fig. 14-B

Fig. 14-C

Figs. 13-A and 13-B The first locking screw is placed into the sustentaculum tali via the "sustentacular" arm of the aiming device. (Reproduced from: Amlang MH, Pompach M. Intraartikuläre Kalkaneusfraktur, minimalinvasive Technik mit Nagelosteosynthese (C-NAIL). In: Hamel J, Zwipp H., editors. Sprunggelenk und Rückfuß. Berlin: Springer; 2016. p 199-205. With permission of Springer.) **Fig. 13-A** Intraoperative photograph. **Fig. 13-B** Fluoroscopic image used to check the correct position of the screw.

Figs. 14-A, 14-B, and 14-C Proper reduction and implant position. (Reproduced from: Amlang MH, Pompach M. Intraartikuläre Kalkaneusfraktur, minimalinvasive Technik mit Nagelosteosynthese (C-NAIL). In: Hamel J, Zwipp H., editors. Sprunggelenk und Rückfuß. Berlin: Springer; 2016. p 199-205. With permission of Springer.) **Fig. 14-A** Fluoroscopic lateral image. **Fig. 14-B** 20° Broden image. **Fig. 14-C** Axial image. (The dorsoplantar view is shown in Figure 11-B.)

- Close the wound with single interrupted sutures (Fig. 15).
- Obtain postoperative CT scanning to ensure anatomic reduction of the joint if no intraoperative 3D fluoroscopic control has been performed.

Fig. 15

Fig. 15 The appearance of the heel after wound closure. (Reproduced from: Amlang MH, Pompach M. Intraartikuläre Kalkaneusfraktur, minimalinvasive Technik mit Nagelosteosynthese (C-NAIL). In: Hamel J, Zwipp H., editors. Sprunggelenk und Rückfuß. Berlin: Springer; 2016. p 199-205. With permission of Springer.)

Step 8: Postoperative Management

Manage the patient with continuous passive motion and active range-of-motion exercises of the ankle beginning on postoperative day 2 and allow partial weight-bearing of 20 kg for 6 to 10 weeks.

- Manage the patient with continuous passive motion and with active range-of-motion exercises of the ankle and subtalar joints starting on the second postoperative day.
- Allow the patient to function after treatment with partial weight-bearing of 20 kg for 6 to 10 weeks in his or her own shoe.

Results

Recently, we reported on 103 patients with 106 intra-articular calcaneal fractures treated with the C-Nail by 4 senior surgeons from February 2011 to October 2013[1]. The mean age of the patients was 45 years, and 86% were male. Anatomic joint reduction was controlled via a sinus tarsi approach in 91 cases and arthroscopically in 15 cases. No intraoperative implant-related complications occurred. Superficial wound edge necrosis that healed with local wound care was observed in 2 cases (1.9%). One deep infection (0.9%) developed in a patient with a Gustilo-Anderson type-II[15] open calcaneal fracture, necessitating early C-Nail removal, repeat debridement, and defect filling with antibiotic-impregnated bone cement. All other fractures were solidly healed at 3 months.

At 3 months, the Böhler angle had improved from a mean of 7.3° preoperatively to 31.2° and full weight-bearing was allowed for all patients. At the 6-month follow-up evaluation, the Böhler angle had decreased to a mean of 28.7°. The posterior facet step-off in the subtalar joint had decreased from a mean of 5.3 mm preoperatively to 0.7 mm postoperatively, which was confirmed by CT scanning. The mean American Orthopaedic Foot & Ankle Society Ankle-Hindfoot Score (AOFAS-AHS) was 89.5 at 6 months and 92.6 at 12 months of follow-up[16]. No early or secondary loosening or failure of the implant was seen[1].

Pitfalls & Challenges

- Malreduction: 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 fixed initially with screws introduced from lateral to medial, to prevent secondary displacement of the joint fragments.
- Inadequate control of reduction: The sinus tarsi approach does not provide a full visualization of fractures that run far medially or in cases of multiple fractures of the posterior facet. In those cases, control of the reduction should also be obtained fluoroscopically and/or with open arthroscopy to precisely assess joint reduction[6,14].
- Learning curve: Articular reconstruction of Sanders type-III and IV fractures is challenging with limited approaches, and it is the responsibility of the surgeon to either perform a more extensile approach (e.g., a modified Kocher approach) primarily or convert to one if anatomic reduction cannot be achieved or controlled sufficiently. Like other approaches to the calcaneus, the technique in the present report requires a surgeon with sufficient experience and skills in calcaneal fracture fixation[1]. It is well established that calcaneal fracture fixation has a considerable learning curve[2,12]. A thorough knowledge of the complex anatomy and previous experience with different (open) approaches is useful before embarking on this technique.
- Inadequate fixation: The nail and screws should not be introduced through main fracture lines. The middle hole in the lateral arm should not be used if central comminution is present. When using this hole, special care has to be taken not to injure the peroneal tendons.
- Soft-tissue irritation: Protrusion of the locking screws or nail end should be avoided by intraoperatively checking to ensure that the screw is the proper length, and protruding hardware should be exchanged or removed.

Michael Amlang, MD, PhD[1]
Hans Zwipp, MD, PhD[1]
Martin Pompach, MD, PhD[2]
Stefan Rammelt, MD, PhD[1]
[1]University Center for Orthopaedics and Traumatology, University Hospital Carl-Gustav Carus, Dresden, Germany
[2]Department of Traumatology, Regional Hospital Pardubice, Pardubice, Czech Republic

E-mail address for S. Rammelt: strammelt@hotmail.com

ORCID iD for S. Rammelt: 0000-0003-1141-6493

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