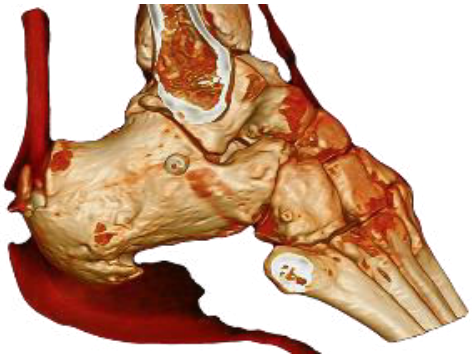
Minimal-invasive surgery of intra-articular calcaneus fractures

Indications, Concepts and Technique



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Content

Introduction

Calcaneal fractures occur at a rate of approximately 2% of all fractures of the human body. Eighty to 90% of all calcaneal fractures are intra-articular, and these fractures are the main focus of this manuscript. Rare fracture patterns such as non-articular fractures, duckbill fractures or avulsion fractures will not be discussed in this paper.

Multifragment- and comminuted fractures are common in intra-articular fractures. Additional trauma of the soft tissues could have a significant impact on surgical treatment, adjunctive procedures and patient outcomes.

Due to the many patient and fracture characteristics and the lack of standardized protocols, the optimal type of treatment of intraarticular calcaneal fractures is still controversial. Treatment modalities vary between conservative, open reduction and internal fixation and many different minimal invasive approaches.

Prolonged and insufficient healing of the malreduced fracture fragments leads to poor outcomes and sustained disability.

Due to the complexity of the fracture pattern, many different classification systems have been described. Scientifically and clinically, the most relevant and commonly used classification systems are the Essex-Lopresti, Sanders, Zwipp and Crosby classifications. The most useful classifications are good in pairing the fracture characteristics with treatment and expected outcomes. [1) 2)]

Current treatment concepts

Three different treatment concepts are described

1. Conservative care without reposition. This is managed with or without cast immobilization. Non-weight bearing during fracture consolidation is maintained for 6-12 weeks.
2. Open repair through an “extended lateral approach” and fixation of the fracture with a stable-angle plate and screws. This has historically been described as the “gold standard” for the treatment of intra-articular fractures.
3. Minimal invasive procedures with various described techniques and concepts.

1) Conservative approach

Operative treatment has generally been superior as it yields better functional outcomes with less pain and disability. [3) 4)] The conservative approach is recommended for patients with comorbidities like diabetes, peripheral arterial disease or smokers, heavy laborers or patients above 50 years. Furthermore, it is primarily indicated for simple, non, or minimally dislocated (<2mm) fracture patterns.

Due to our experience, we nearly have no limitations for surgery. With our minimal invasive concepts, we can provide an anatomical reduction on minimally displaced fractures and good correction of length and axes, loss of height, broadening and impingement in severe fractures. The patients benefit from early surgery, decompression by evacuation of hematoma, reduction and fixation of the fracture, shorter duration of the surgery, surgery under regional anesthesia and an early functional follow-up without plaster cast fixation - together with the moderate soft tissue trauma.

Fig. 1-3 simple intra-articular fracture, minimal invasive surgery, soft tissue appearance after 12 months

Even on complex fractures, having an abutment of lateral malleolus, deviation of the axis, talus tilt, broadening and shortening of the foot a good correction through operative surgery can be achieved with this technique.

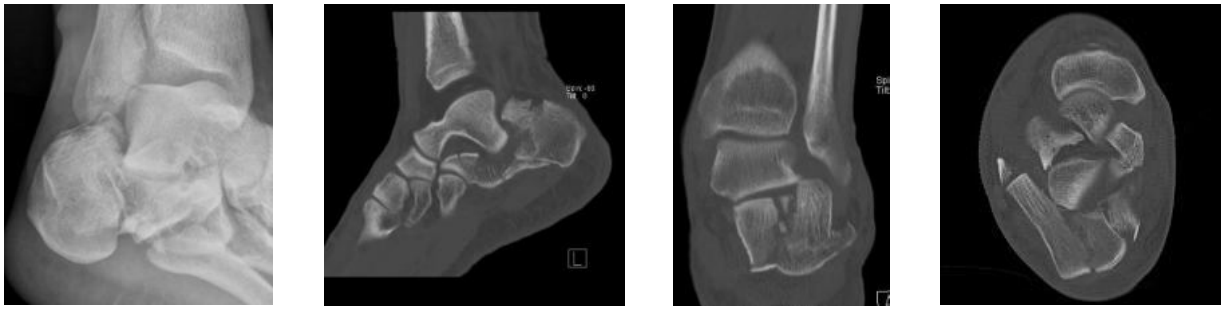
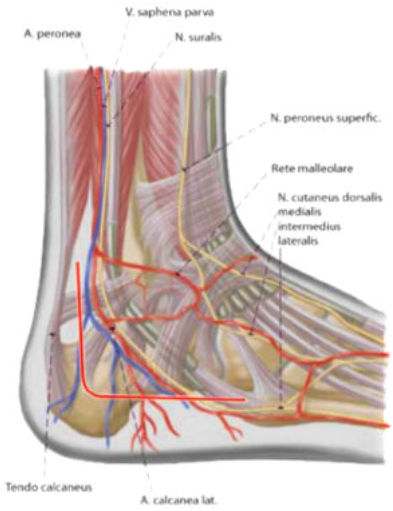
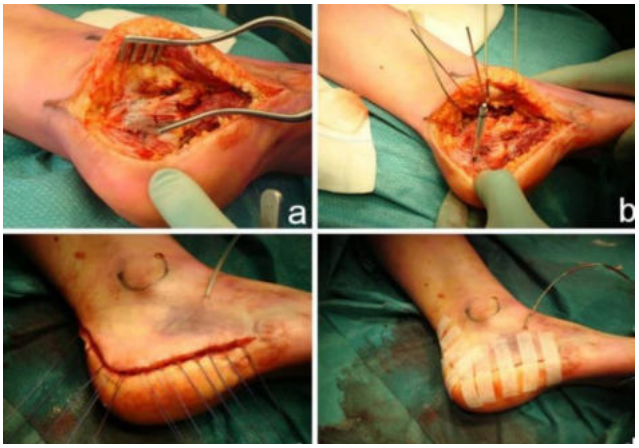


Fig. 4 – 7 impingement *tilting of talus loss of height* *broadening* *shortening, varus*

2) ”Gold standard “

Due to the blood supply and the course of the sural nerve, the “extended lateral approach” should be utilized for direct visualization of the fracture segments. This technique, with the subsequent reduction and internal fixation through an osteosynthesis, with angular-stable plates is labeled as the “gold standard” in the literature [6) 7) 8) 9)]





2 H. Zwipp. Oper. Orthop Traumatol 2013 Fig 8 *2 Tim Schepers;The Journal of foot and ankle surgery, 2013 Fig 9*

Based on a recent multicenter study of 250 German trauma centers, the “gold standard” was utilized in 77% of surgically treated calcaneal fractures. [13)]

The benefit of this technique is the direct visualization of the fracture with direct reposition of the fragments. This is also a standardized procedure, most commonly described and reported in the scientific literature.

Disadvantages from our point of view are

1) Due to the swelling and poor condition of the soft tissue envelope, and the iatrogenic trauma of the open reduction technique, surgery must often be delayed for 7 to 21 days following the injury.
2) You find of blood-filled blisters after some hours to several days due to the severe internal tissue pressure (hematoma, fracture dislocation). We never see it after early decompression.
3) The likelihood of post-operative wound healing complications is described as to be 5 to 25% [10)].

Fig 10

Fig. 11

Fig. 12

4) The emergence of scar tissue due to the severe soft tissue trauma.
5) Even through the direct visualization anatomical reconstruction is not always possible, especially with comminuted fractures
6) Recent studies show less stability of plates compared to central stress carriers like nails or screws [11) 12)]
7) Preceding implant removal as a requirement for a secondary subtalar arthrodesis is common and associated with a high wound complication rate when approach through the scar tissue is needed.
8) Standard approaches (Ollier, dorso-lateral) for an arthrodesis are aggravated through the extended lateral approach

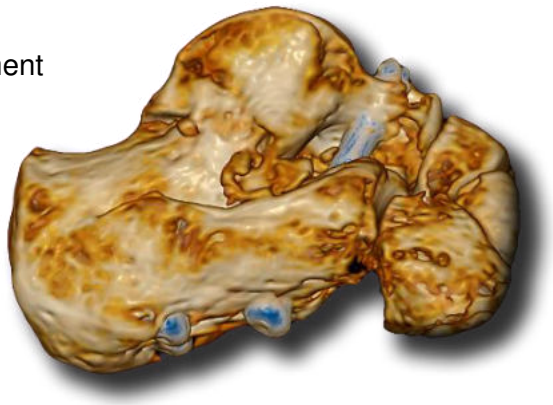


Fig. 13 subtalare Arthrodese

3) Minimally-invasive techniques

Due to these disadvantages of the "gold standard", several minimally-invasive techniques have evolved. Currently, more evidence is needed to support our anecodatal advantages and outcomes realized with minimally-invasive techniques.

Different techniques are described for

- Positioning of the patient
- Medical imaging
- Reduction
- Surgical approaches
- Fixation
- Implants
- Aftercare
- Physiotherapy

Reduction (manual, with extension/compression, raspatory, Schanz screw, chisel...)

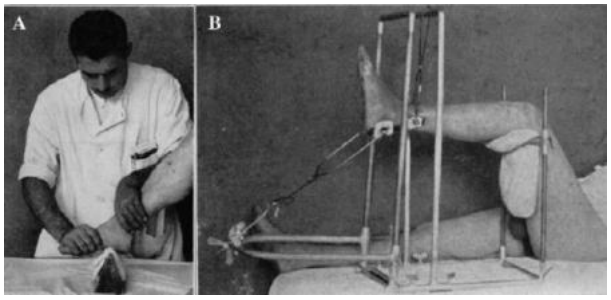


Fig. 14 Böhler 1931, J Bone Joint Surgery

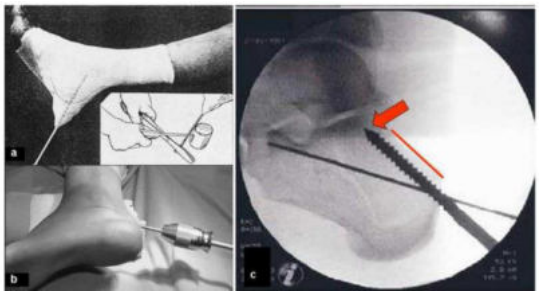


Fig.15 Westhues 1935

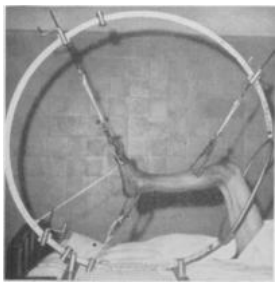


Fig. 16 Harris 1946

*Fig.17 Hertz/Böhler 2003^*

Fig. 18 Lippincott 2014

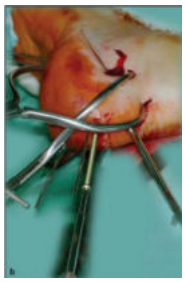


Fig. 19 Rammelt 2012

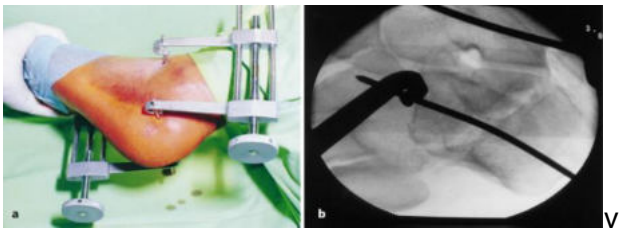


Fig. 20 2 point distractor Fröhlich 1999

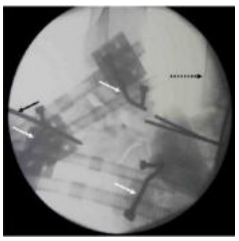


Fig. 21 3 point distractor Forgon

Positioning of the patient (Supine, lateral, prone with or without braces…)

Fig. 22 22 lateral decubitus

Fig. 23 prone decubitus

Fig. 24 Zwipp lateral decubitus

Visualization (combination of a second image intensifier, arthroscopic, 3D-Scans, navigation)

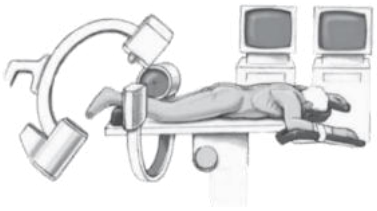


Fig. 25 with 2 image intensifiers

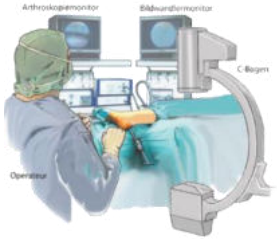
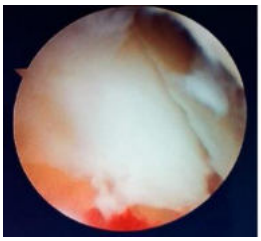


Fig. 26 arthroscopic assisted



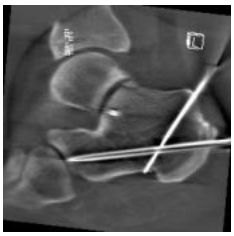


Fig. 27 3D Scan

Fixation/surgical approaches (Kirschner wires, screws, plates normal/stable, mini-plates, pins, Endobutton, Endobon, Fixateur externe, Balloon,…)

Fig. 28 S. RAMMELT 2014

Fig. 29 SICOT 2015

Fig. 30 O.Wang 2010

Fig. 31 Andrew R. Hsu 2010

Fig. 32 Injury 2014

Fig. 33 JBJS 2006

Fig. 34 J. of Foot and Ankle

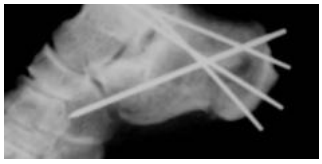


Fig. 35 Journal of Medicine 2013

Fig. 36 AAMJ, Vol.9 2011

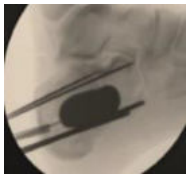
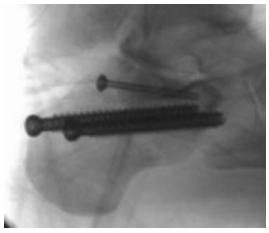
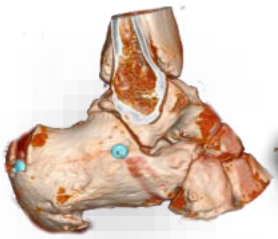


Fig. 37 Balloon-assisted

Fig. 38 Rammelt 2012

Fig. 39 Tim Schepers 2009





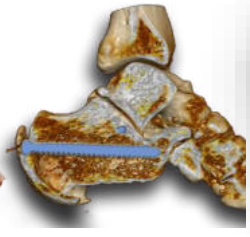


Fig. 40-44 UKH Linz 2017

Minimal-invasive surgery technique Traumacenter Linz

(stage of development 2017)

Benefits of the minimally-invasive techniques:

- Early surgery is possible and should be attempted
- Good opportunities for anatomical reconstruction of the fracture
- Easing internal pressure to the surrounding soft tissue through reduction, stable fixation, little implants and early evacuation of fracture hematoma
- Reduction of pain, lowering the risk of blisters and compartment syndrome through early stabilization and fixation of the fracture
- Early mobilization is generally possible
- Much less risk of developing post-operative wound healing complications and infections ([5)], own study).
- Small incisions and slight surgical preparation with minimal iatrogenic trauma
- In most of the cases, surgery is even possible under swollen and sensitive soft tissues
- Minimization of surgery time (standardization, training, skill provided)
- Cost reduction of the osteosynthesis material in comparison to plate fixation
- Implant removal possible in local anesthesia and through stab incisions
- No significant damage to the periosteum of the fragments and less post-operative adhesions and post-traumatic pain
- Additional Mini-Open approaches (such as Sinus-tarsi approach) possible if needed
- Significant shorter stay in hospital, early date of surgery
- Less likelihood of later STJ arthrodesis

Disadvantages of the minimally-invasive techniques:

- Surgery should be conducted within the first three days following the injury. After this time minimal-invasive reposition of the fragments is aggravated due to adhesions and beginning consolidation of the fracture
- No direct visualization of the fracture – except for additional arthroscopy or mini-open technique (Sinus-tarsi approach). Need of experienced radiological technician.
- If adequate anatomical reconstructions cannot be accomplished, it is often questioned if open reduction and internal fixation could have led to a better result
- Higher radiation exposure
- Until now, we have no modern, radiolucent and multiaxial extension device
- Marginal interest for the industry due to low costs of current fixation options

Special Problems

The ”learning curve”

- Minimally-invasive reduction of comminuted fractures in this extent is only applied on calcaneal fractures. There is slight evidence with other fractures (tibial plateau, humeral head, etc.)
- Time for surgical preparation and table positioning, for fracture evaluation, reduction and fixation technique
- Evaluation of the anatomical reconstruction during surgery is difficult
- Positioning of the sustentaculum screw is difficult
- Experience with this technique is needed to anticipate the most realistic outcome
- No standardized technique and slight evidence in literature

Effort: **M**inimal **I**nvasive (MI) **P**rocedure ------ **M**aximal **I**ntensive **P**reparation

For minimal-invasive techniques, the exact evaluation of the fracture situation and planning the general procedure is always necessary. The treatment of a fracture with MI-techniques is not easier than in an open approach!!!

Besides standard radiographs, 3D CT reconstruction imaging should always be conducted.

Fig. 45-47 UKH Linz 2017

Indication and contraindication

Indications include dislocated and/or comminuted intra-articular calcaneal fractures. As mentioned, we recommend this technique also with non, or minimally dislocated fractures through regional anesthesia due to its low complications risk. Early fixation through screw osteosynthesis allows earliest possible physiotherapy.

Contraindications, in comparison to the open reduction technique, are rare. Due to the decreased wound complications risks, even older patients, smokers, and patients with co-morbidities can be treated with this technique in most cases and profit from early mobilization.

Fracture type and methods

Regarding the reduction technique, we differentiate 4 groups of fracture types to allow the best possible outcome. The Essex-Lopresti classification is used because of its simple characteristics and good correlation with the prognosis.

1) Essex-Lopresti tonque-type fractures
2) Essex-Lopresti depression-type fractures
3) Comminuted fractures mainly because of a severe depression-type fracture
4) Atypical fractures with uncommon fractures lines, mainly following a direct trauma

1) tongue-type fracture

With these fractures, there is a large, connected dorsal segment of the tuber calcaneus and a calcaneal subtalar segment. In most of the cases, there is a large lateral joint fragment. Shortening and varus malalignment of the foot normally is slight. The Westhues maneuver allows good reduction of this types of fractures.

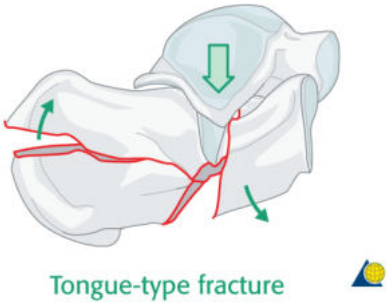
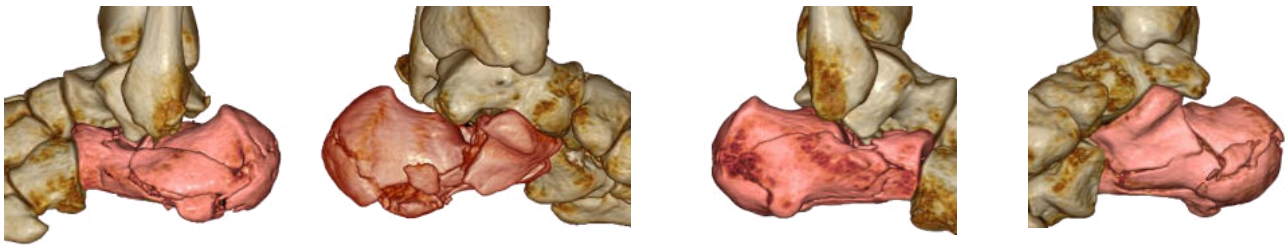


Fig. 48 Copyright by AO Foundation, Switzerland

Fig. 49 UKH Linz 2017

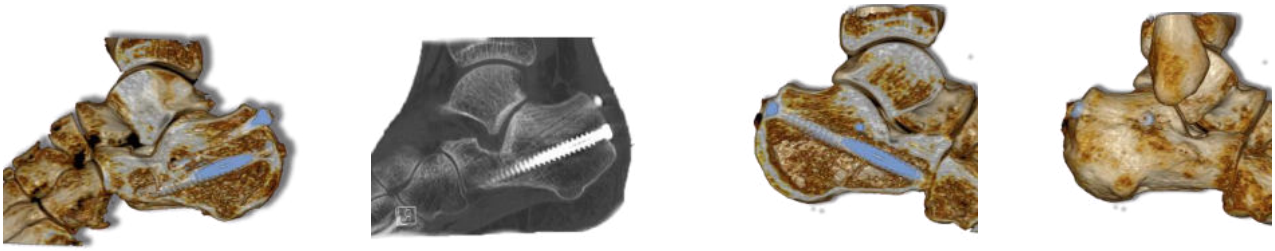
Fig. 50 UKH Linz reduction Westhues

Case report; tongue-type fracture on both sides



left right

surgery 14 hours after trauma



radiological outcome after 6 months

Soft tissue appearance after 6 months

During follow up and 2 years after the trauma, the patient is completely free of symptoms and the function of the subtalar joint is completely intact.

Fig. 51 – 60 UKH Linz Tongue-fracture on both sides, early surgery, functional after-treatment

2) depression-type fracture

With this type of fractures, the characteristic fracture line runs between tuber calcanei and the central part of the calcaneal body. As a result, shortening, varus malalignment, depression of the subtalar joint, tilting of the talus, broadening, break out of the lateral wall often with impingement of the upper ankle joint and/or fracture of the lateral ankle is common. In this case, the extension technique is indicated!

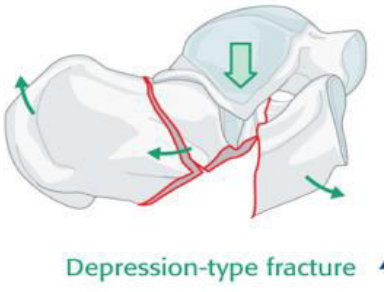


Fig. 61 Copyright by AO Foundation, Switzerland

Fig. 62 UKH Linz 2017

Fig. 63 UKH Linz 2017

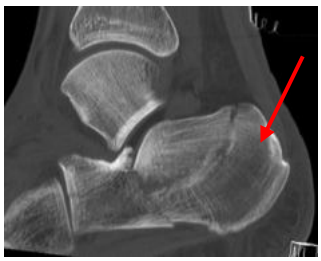


Fig. 64-65 isolated tuber fragment, varus, shortening

,

Fig. 66-67 isolated central joint fragments

Fig. 68-69 bursted lateral wall

,

Fig. 70-71 lateral abutment, lateral malleolus fracture

,

Case example: simple joint depression-type fracture

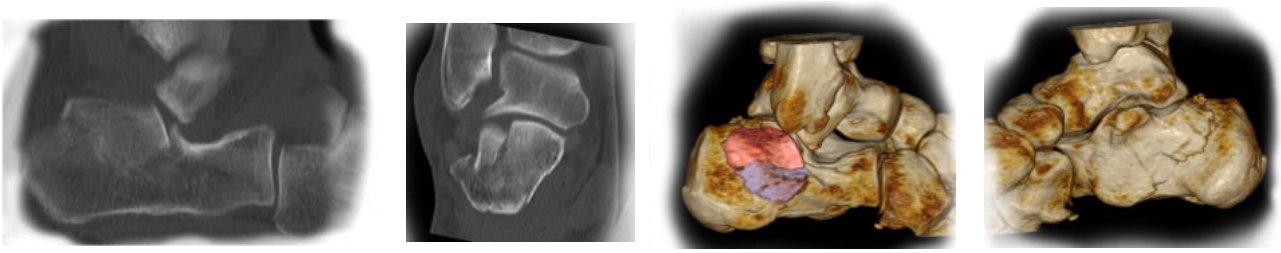


Fig. 72-75 depression – type fracture UKH Linz

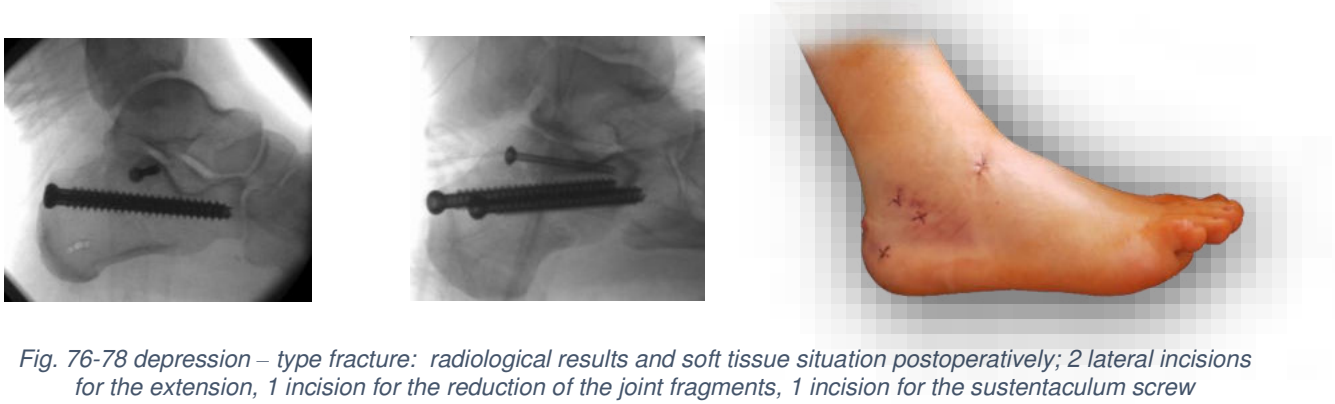


Fig. 76-78 depression – type fracture: radiological results and soft tissue situation postoperatively; 2 lateral incisions for the extension, 1 incision for the reduction of the joint fragments, 1 incision for the sustentaculum screw

3) comminuted fractures

Comminuted fractures, especially comminuted fractures of the subtalar joint are a main indication for our minimal-invasive technique with the 2-point distractor.

Usually a correction of the axis, length, broadening and height and fixation of the main fragments can be achieved.

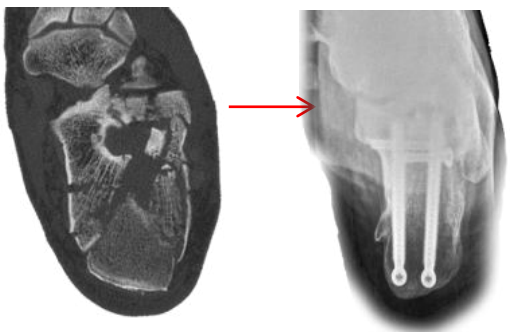


Fig. 79-80 correction of lenght and axes

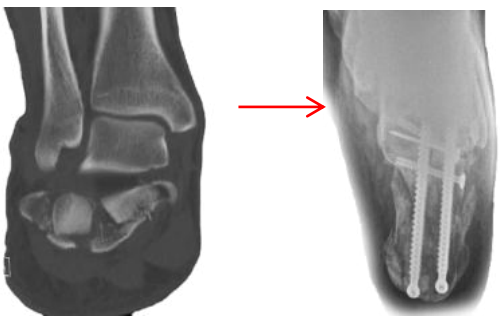


Fig. 81-82 correction of broadening

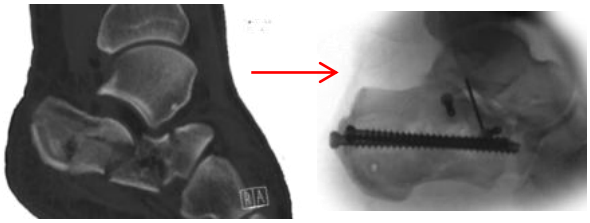


Fig. 83-84 correction of height

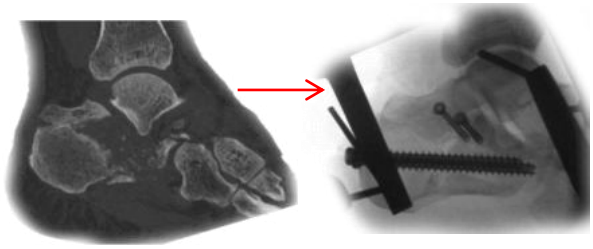


Fig. 85-86 reduction and fixation of the main fragments

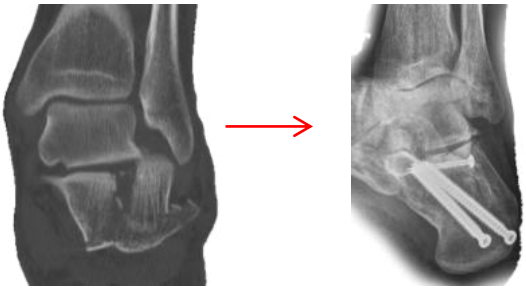


Fig. 87-88 reduction of the impingement

Case example: Comminuted fracture

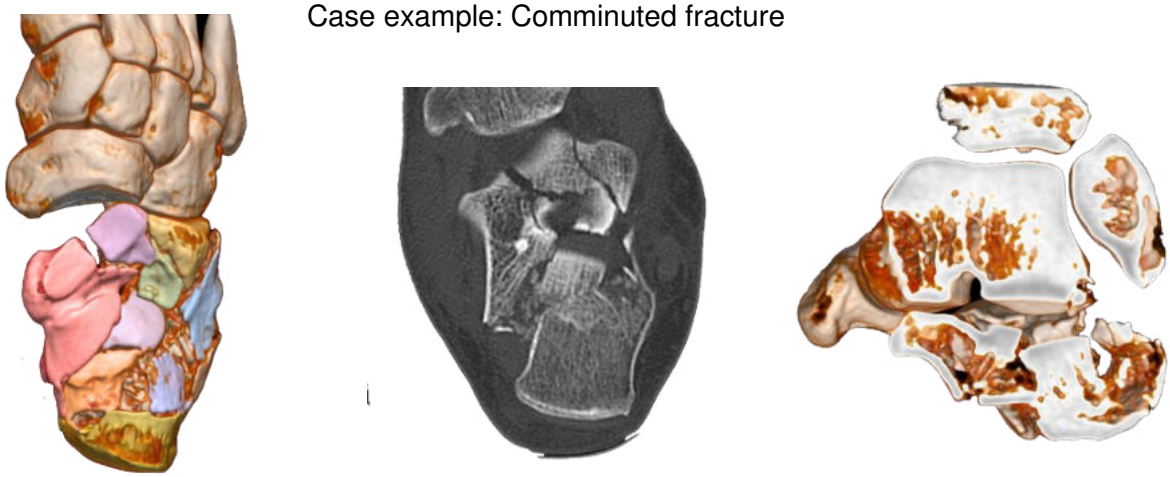


Fig. 89-91 fracture situation

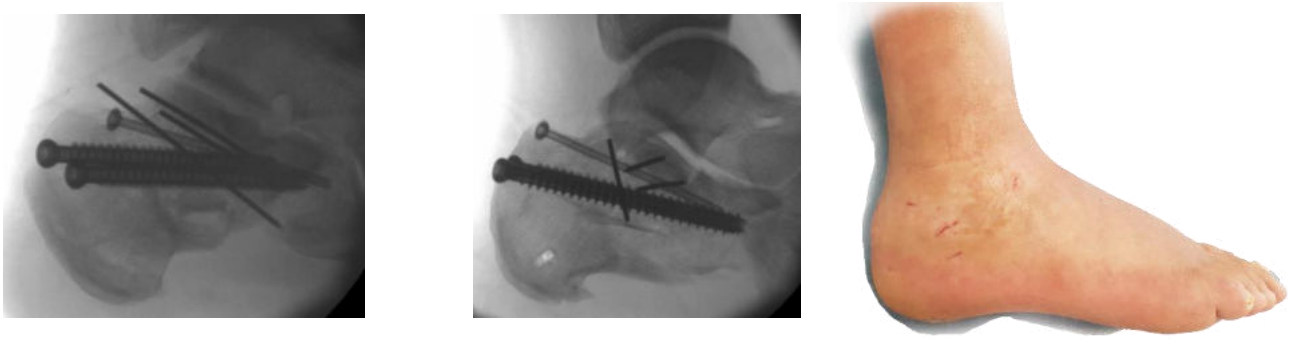


Fig. 92-94 closed reduction and internal fixation, soft tissue 6 weeks after surgery UKH Linz

4) atypical fractures

Fractures with an atypical injury mechanism and an uncharacteristic progression of the fracture lines are mostly result of a direct trauma. In most cases, standard reduction techniques with screw fixation are indicated. Depending on the fracture pattern, alternative ways of reduction and fixation techniques should be considered.

Fig. 95 comminuted fracture of the anterior process of the calcaneus stabilized with an external fixator to reduce and maintain length UKH Linz

open fractures

Open fractures are treated with aggressive debridement and soft tissue management. Primarily, we perform fixation of the fracture with screw fixation, and in some cases, with external fixation.

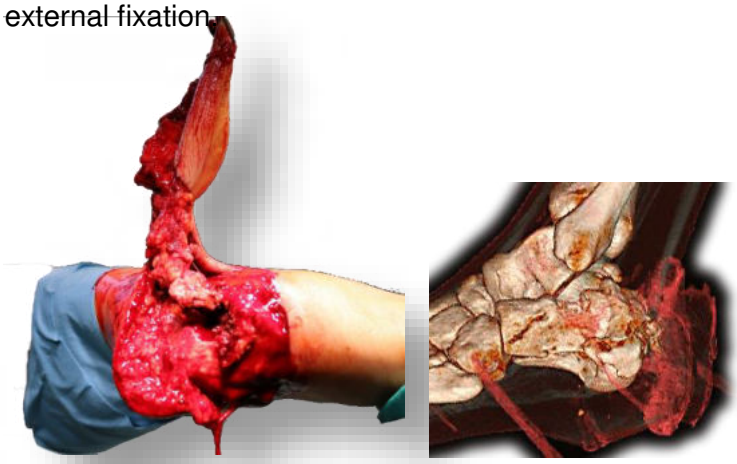


Fig. 95-96 open calcaneal fracture after direct trauma UKH Linz

Fig. 97 after surgery

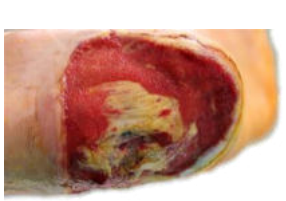


Fig. 98 soft tissue situation 6 weeks postoperatively and subsequent flap surgery

Fig. 99 radiological results 9 months postoperatively, soft tissue situation healed

Surgical technique with 2-point-distractor by Fröhlich

In our opinion, the minimal-invasive technique with the 2-point distractor is ideal for the treatment of joint-depression-Type fractures and comminuted fractures.

Instruments - osteosynthesis

- We use the distraction device branded by I.T.S. and described by P. Fröhlich 1999

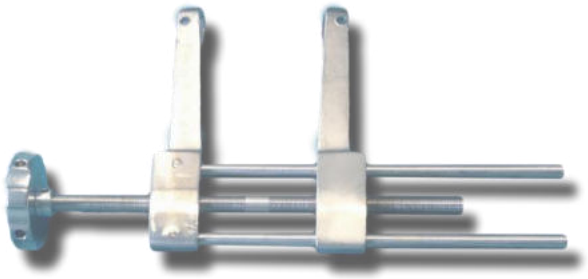


Fig. 100 Distractor

  - 2 x 3 mm Kirschner wires for extension
  - Bolt cutter
  - 7.3 mm fully threaded cannulated screws
  - 4.0 mm cannulated screws for fixation of the joint fragments (sustentaculum screw) and smaller fragments (example: anterior process fracture)
  - Possibly K-Wires in different sizes for fixation of smaller fragments or as a joystick for traction and aid in the reduction process
  - Different raspatories, awls, elevators, tappets for the reduction.
  - Iso-centric image intensifier with the option for intraoperative CT-imaging is recommended. Without this, the intraoperative Broden-views could only be applied with additional height adjustment.

Anesthesia

Surgery is typically applied through regional anesthesia or general anesthesia.
Tourniquet isn't utilized.

Positioning

A standardized, stable position of the patient with an ideal approach to the foot and a properly adjusted image intensifier is inevitable for the success of this surgical technique. The patient is placed laterally with the injured foot on a leg-holder in upper and strictly horizontal position. A free approach to the whole foot is essential for the proper mounting of the distraction device and the ideal positioning of the image intensifier. It should be possible to move the C-Arm at 360 degrees around the foot without changing the height of the image intensifier itself. It is highly recommended to prepare, standardize, document and train the positioning and usage of the equipment altogether with the surgical and X-ray technicians prior to the surgery.

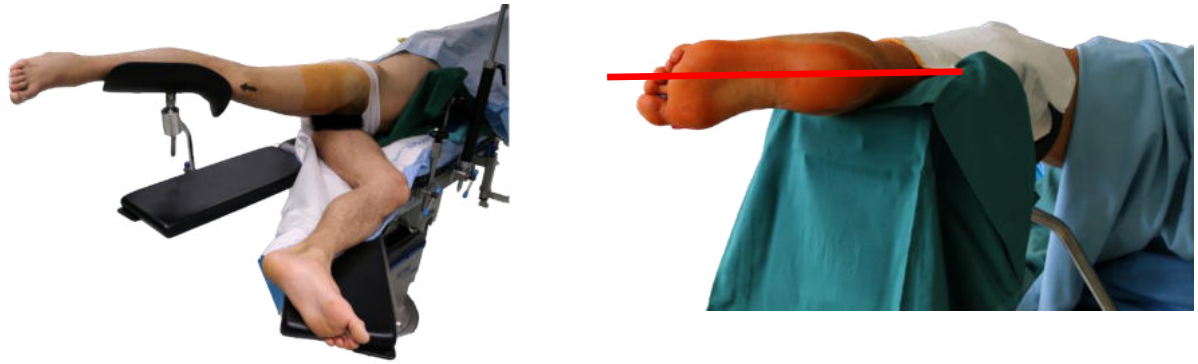


Fig. 101- 102 standard positioning UKH Linz

Imaging

With the minimal-invasive approach the fracture segments are not directly visualized so the perfect intraoperative imaging is necessary for success. It is essential that the surgeon is totally familiar with the imaging technique in order to be capable to accurately instruct the X-ray technicians. Uncertainties regarding the imaging during surgery should be avoided via preparation. With our technique, we need 3 standardized intraoperative views – lateral, Broden and axial views.

The image intensifier is positioned exactly in line with the length axis of the calcaneus.

Fig. 103- 104 standard positioning UKH Linz adjustment of the image intensifier

Together with the X-ray assistant all 3 intraoperative views are set and eventually marked. Afterwards the image intensifier wheels are locked in position, and only the C-arm remains moveable. Only 3 different instructions for intraoperative imaging are needed afterwards. Surgery should only be started when the imaging unit is appropriately positioned.

Lateral view: It is important to focus the joint surface of the talus. The calcaneus should be disregarded for the adjusting of the image intensifier (it is broken and out of shape). Lateral ligament instability due to subluxation can impede the adjustment of the image intensifier.

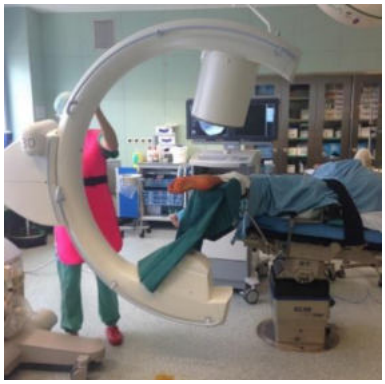


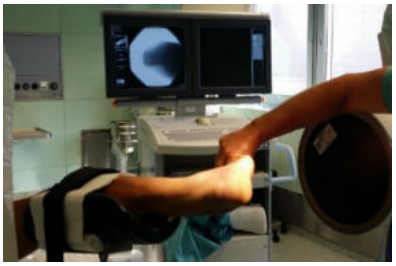
Fig. 105 - 106

standard positioning UKH Linz

lateral view with the image intensifier

the exact orthogonal adjustment of the talus joint surface is essential!

Axial view: The C-arm is adjusted horizontally. In manual dorsal flexion of the foot evaluation of the axis of the calcaneus is possible. This view is essential for the exact positioning of the pins.



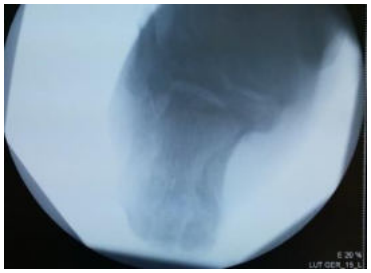


Fig. 107 - 108

Standard positioning UKH Linz

Axial view

Broden view: This projection is used to evaluate the subtalar joint and the posterior facet congruency. Proceeding from the previous adjustment, the C-arm just needs to be angled 45 degrees towards the head, while using an iso-centric image intensifier. With conventional image intensifier, a height adjustment of the tube is unfortunately needed. Practicing and specifying this procedure preoperatively is highly recommended.

Fig. 109 - 110

Standard positioning UKH Linz Broden view

Attention: Because of the curvature of the talus, a ´rotated' fracture fragment could be seen as normal with the Broden view at different degrees. To avoid missing a rotated dislocated fragment, the posterior facet should always be checked at a tube angle of 35 and 55 degrees during surgery. It is only perfect if it is perfect in all views!!!

Overview of the technique

- Insertion of the pins in the talus and calcaneus
- Reduction of the varus malalignment
- Extension with the distraction device and reconstruction of the length
- Lateral incision, evacuation of the hematoma
- Reduction of the central joint fragments with the raspatory, joy-stick, tappet
- Insertion of K-wires in preparation for the insertion of the 4.0 mm sustentaculum screws
- Insertion of the 4.0 mm lag screw
- Reduction and fixation of the anterior process, tuber fragment, etc.
- Dorsal K-wire insertion in preparation for the insertion of the 7.3 mm fully-threaded screws with the distraction device locked in position
- Insertion of the 7.3 mm fully-threaded screws for fixation of the axis and length and to neutralize forces across the joint fragments
- Wound closure

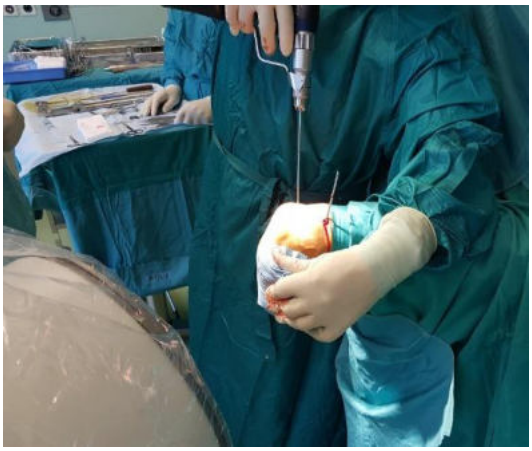
Extension

After reduction of varus rotation, extension of the foot is needed for reconstruction of the calcaneal length and to relieve the central joint fragments and stabilize the foot in preparation for the screw fixation.

Insertion and positioning of the pins

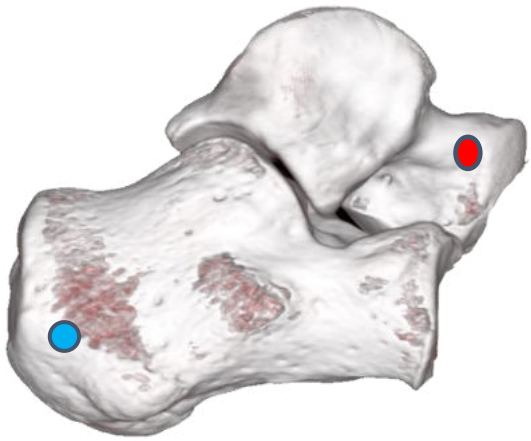
The first pin is inserted in the anterior process of the talus exactly in frontal and axial plane while assessing alignment via the lateral view.

Fig. 111 talus PIN



The second pin is inserted into the distal plantar region of the tuber calcaneus. The lateral view is used to mark the entry point of the pin. Afterwards, a change to the plantar view is needed to determine the axis of the tuber fragment. Pin location here does not interfere with later screw insertion. It is important to insert the pin in manual dorsal flexion of the foot and exactly perpendicular to the angulated axis of tuber fragment. As a result, with a varus malalignment of the foot a significant convergence of the pins on the medial side is obvious. After the manual correction of the varus, the medial and lateral distraction devices can be mounted.

Fig. 112 calcaneus PIN in axial view undr dorsal flexion oft he foot



The position of the pins in these locations allows minimal overlay and interference of the distractor device and the joint. Furthermore, stabilization of the fracture is ensured through the mounted distraction devices.

Fig. 113 PIN positioning of the talus and calcaneus

It is essential to insert the second PIN perpendicular to the angulated axis of the tuber fragment. Otherwise, correction of the varus malalignment is not possible and the reduction will not succeed!

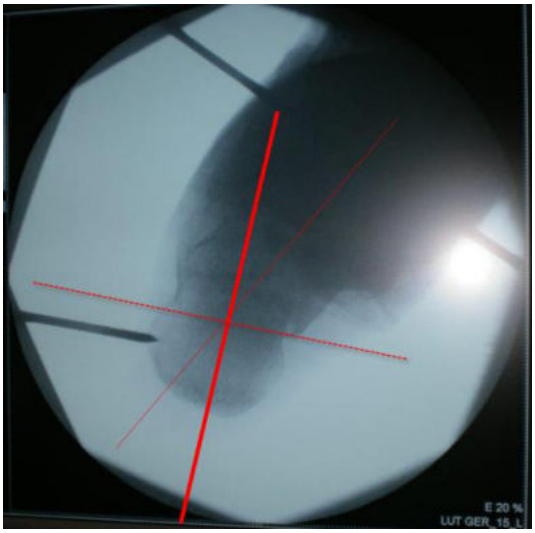


Fig. 114 calcaneal PIN insertion exactly 90 degrees to the varus angulated axis of the tuber calcanei. This must be measured through the axial view

Fig. 115 significant convergence of the PINs on the medial side

Fig. 116 – 117 manual reduction of the varus

afterwards montage of the medial distraction device

Mounting of the lateral distraction device.

Fig. 118

to avoid slipping of the distraction devices, bending of the K-Wires is recommended. Afterwards you can shorten the PIN`s

Extension is applied alternately medial and lateral while using the lateral and axial view until adequate reduction of the length is completed. As indicated by the bending of the K-wires, significant traction is needed to successfully reduce the fracture. Without adequate distraction (respectively wrong positioning of the pins) it is not possible to anatomically reduce the central joint fragments. Hint: If you have problems for reduction of central fragments, you normally have less extension.

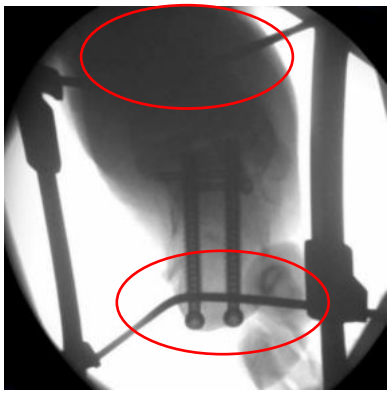


Fig. 119 - 120

Significant bending of the pin during reduction of the varus and length

Screw fixation should be achieved during the already mounted distraction devices after the reduction and fixation of the central joint fragments (depending on case possibly decrease extension)

Although we use an angle-stable 2-point distraction device, the tension of the ligaments of the foot (particularly the plantar fascia) can help to raise the longitudinal arch – via ligamentotaxis as calcaneal length is restored. This is a big aid to correct Boehler's angle.

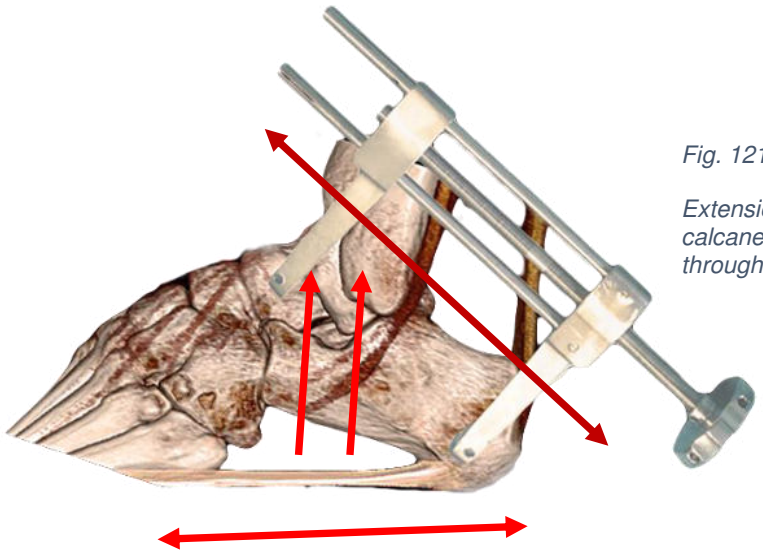


Fig. 121

Extension between the talus and the calcaneus causes raising of the foot arch through tension of the plantar fascia

Reduction of the central joint fragments

In joint-depression-type fractures we usually find one or more joint fragments in increasing severity of the fracture from lateral to medial. Bursting of the lateral wall is common. We do not typically require a sinus tarsi approach. If there is only one lateral fracture segment, we generally do not need it. If we have additional fragments, located medial and to the sustentaculum, I cannot visualize them through this incision anyway, however, I can see them in the Broden view! Reduction of the joint fragments can be applied with a raspatory through stab incisions from lateral foot. This is the common approach. Alternatively, you can try it with a tappet through a stab incision from plantar or from lateral dorsal calcaneus. For fixation, the sustentaculum screw should be inserted through a separate stab incision in the lateral foot.



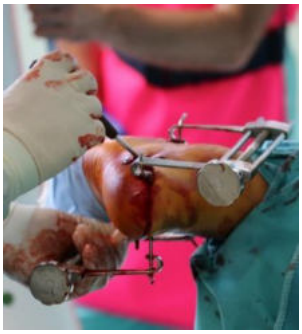


Fig. 122 – 123 Incision insertion of the rasptory reducing of the tilted joint fragment

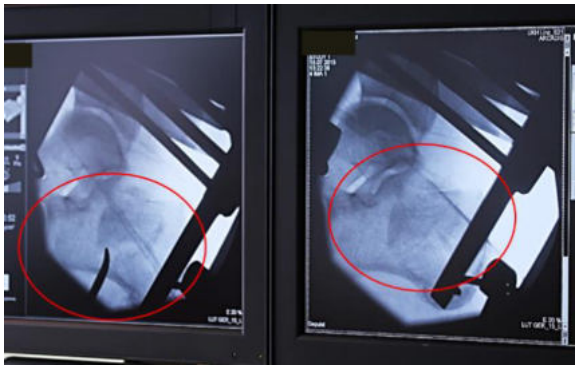
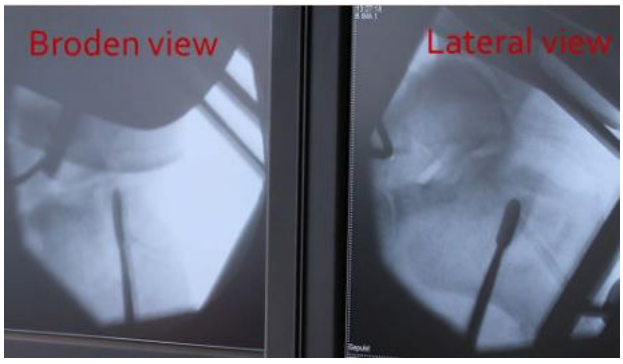



Fig. 124 – 125 Reduction of a lateral fragment examination through Broden- and lateralen view

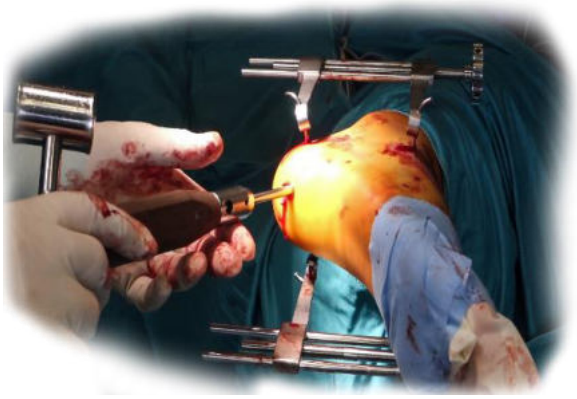


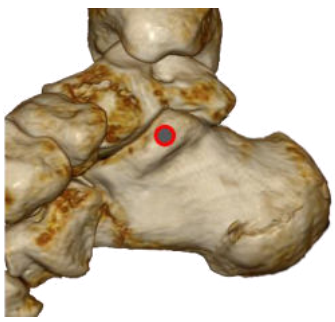

Fig. 126 – 127 Raising with a bone tamper; left through extension; right through reduction technique by Westhues

Sustentaculum screw

The sustentaculum usually remains intact, due to the typical fracture mechanism, the powerful talocalcaneal ligaments and the strong trabecular structure of the sustentaculum tali itself. Because of this, the sustentaculum is an excellent fixation point for attachment of the dislocated postero-lateral and –medial joint fragments, as well for the eventually bursted lateral wall. The osteosynthesis with the so called sustentaculum screw is an often-mentioned procedure in the literature. Although due to the complex anatomical shape of the sustentaculum and the difficult visualization, the correct placement of the sustentaculum screw is hard to achieve. [14)]

Positioning of the sustentaculum screw

The sustentaculum screw is placed from lateral-superior to medial-ventral direction. The target for the stab incision to insert the K-Wire and cannulated screw is directly below and dorsal the center location of the medial malleolus. With a correctly placed incision K-wire, insertion is easily to apply. Medial fixation of the K-wire with a clamp is recommended to avoid loosening of the position while placing the cannulated screw. Usually a 4.0 mm cannulated lag screw is used. The measurement of the screw length varies, but generally about 40 mm long. With narrow osteochondral fragments (comminuted fractures), fixation is alternatively achieved with only using K-wires. With transverse fractures of the sustentaculum it is important not to place the screw in the fracture gap. The correct placement of the sustentaculum screw through all 3 X-ray views is essential. The reduction of the posterior facet is optimally visualized with the Brodèn views.



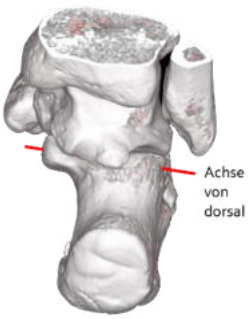


Fig. 128 - 131 Mediales Ziel *Achse von oben* *von dorsal* *Eintrittsstelle lateral*

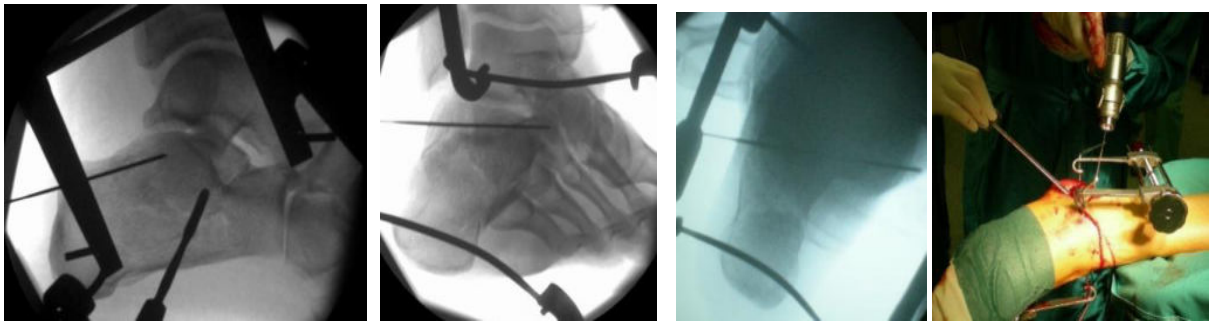


Fig. 132 - 135 *Insertion of the K-Wire,while fixing the joint fragment examination through axial and Broden view*

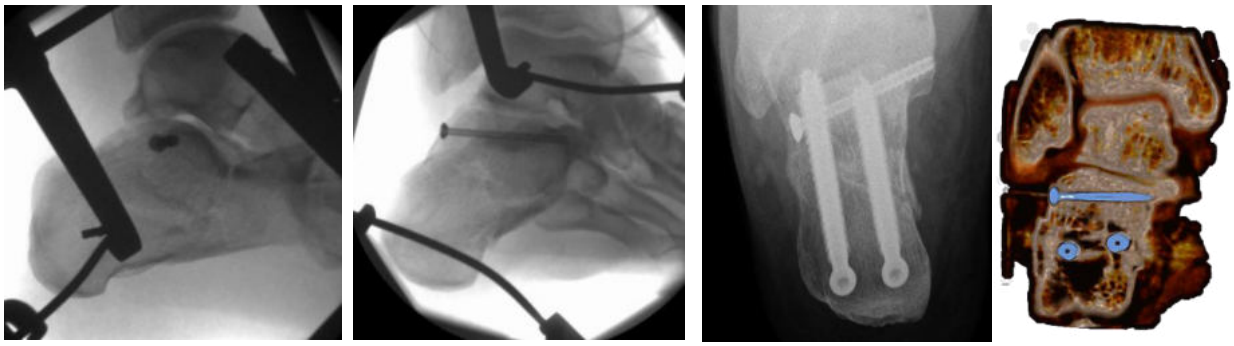


Fig. 136 - 139 Lage der Sustentaculumschraube lateral, Broden, axial und im Schnittbild

Static fixation with the 7.3 mm screws

For the fixation of the axis, length and height, usually two 7.3 mm cannulated fully threaded screws are used. In the literature, are many different placement techniques described. Usually, the screw is positioned superior to the transverse tuber pin and angulated in adorsal to plantar direction.

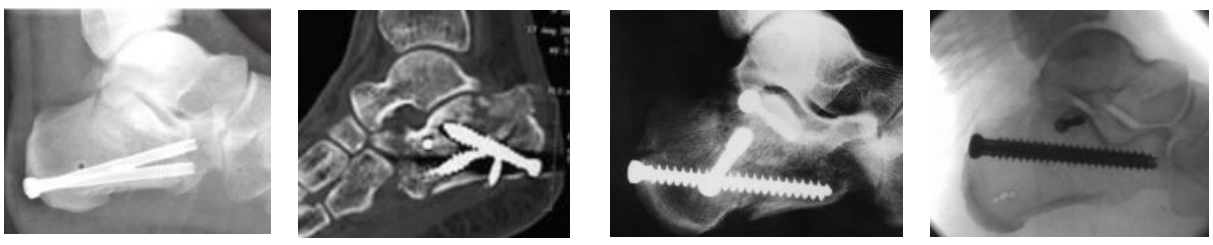


Fig. 140 - 143 screw positioning a) Tim Schepers 2014, b) A. Gomaa 2012, c) Fröhlich 1999 d) UKH Linz 2017

In our experience, of about 10 years, we insert the screw in parallel from proximal to distal.

With the entry point above the upper border of the insertion of the Achilles tendon, local soft tissue complications are significantly reduced. We typically find a stronger and thicker cortex here for the head of the screws to purchase. In the central area, the parallel screws work like "roof beams" supporting the central joint fragments. This is even more important when you have bone defects after reduction because of the compression of cancellous bone. The insertion of autologous bone or bone substitute grafts is not necessary and is not recommended necessary as per recent literature. The usage of fully threaded cannulated screws is necessary because we need do not need or want to acheive compression. These position screws providea static strut of fixation to maintain calcaneal length and alignment.

The head of the screws should be subcortical to prevent soft tissue irritation.

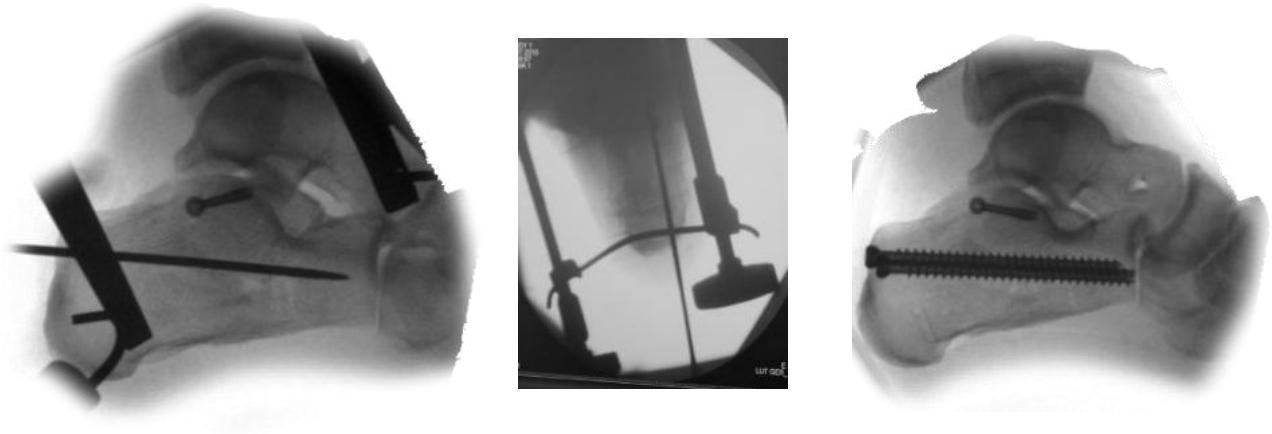


Fig. 144 - 146 Insertion oft the K-Wire and of the cannulated full threated screws

Fig. 147 - 148 surgical situation with axial view to control the position and the parallel insertion oft he screws

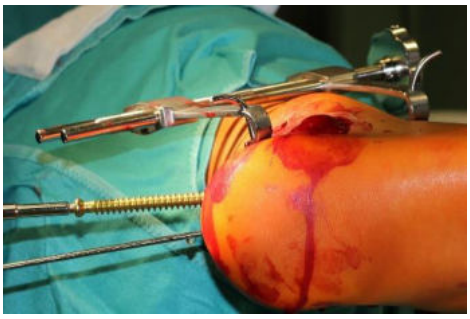


Fig. 149 - 150 Screw fixation simultaneously to the mounted device; soft tissue status 1 day after surgery

Follow-up treatment

In our experience, functional treatment after fixation through screw osteosynthesis is usually possible. A plaster cast during the first postoperative phase is generally used as a supporting splint for the first few days.

We usually don't need drains. However, a bandage replacement on the next day is advised because of post-operative bleeding. Early supervised physical therapy should be prescribed. We believe that it allows for reduced swelling, increased mobility and limits post-operative decalcification of the bones. Additionally, we believe slight passive movement of the joint decreases' incidence of chondral lesions.

In the past, the non-weightbearing period was done for 12 weeks. With stable reduction and fixation construct, good wound healing is expected. We believe that the calcaneus should be stable itself after 6 weeks.

Thereafter, we begin with the active weight-bearing recovery phase. During this phase, we usually use heel-offloading shoes or allow simple partial weight-bearing with increasing load.

Patient overview UKH Linz/Austria

The following retrospective data analysis was performed as a thesis of Mr. Ronny Krenn, from the Medical University of Vienna in November 2017. We would like to sincerely thank him for his work.

298 patients with calcaneal fractures have been treated in the UKH Linz from 2007 to 2015. Of all patients, 236 were male and 62 were female. The youngest patient was 15 and the oldest was 82 years old. 212 patients (71.1%) were treated operatively and 86 patients (28.9%). were treated conservatively. Most of the operations (88.7%) were performed within two days of the injury.

	ORIF		MIRF with the 2-point-distractor		K-Wire fixation or another combination		Total
Year	number	% per year	number	% per year	number	% per year	number
2007	1	5,3%	16	84,2%	2	10,5%	19
2008	3	13,6%	17	77,3%	2	9,1%	22
2009	0	0,0%	27	90,0%	3	10,0%	30
2010	2	8,0%	19	76,0%	4	16,0%	25
2011	0	0,0%	24	96,0%	1	4,0%	25
2012	0	0,0%	20	87,0%	3	13,0%	23
2013	1	4,5%	17	77,3%	4	18,2%	22
2014	0	0,0%	24	88,9%	3	11,1%	27
2015	0	0,0%	18	94,7%	1	5,3%	19
Total	7	3,3%	182	85,8%	23	10,8%	212

	Deep infection - MIRF 2-Punkt-Distraktor		Deep infection - ORIF + BaK	
Year	number	% per year	number	% per year
2007	1	5,3%	0	0,0%
2008	0	0,0%	1	4,5%
2009	0	0,0%	1	3,3%
2010	1	4,0%	1	4,0%
2011	1	4,0%	1	4,0%
2012	1	4,3%	0	0,0%
2013	0	0,0%	1	4,5%
2014	0	0,0%	0	0,0%
2015	1	5,3%	0	0,0%
Total	5	2,7%	5	16,7%

Table 2 Overview of the occurrence of deep infections

	Necessary implant removal		Elective implant removal		Secondary Subtalar Arthrodesis	
Year	number	% per year	number	% per year	number	% per year
2007	1	5,3%	12	63,2%	1	5,3%
2008	3	13,6%	5	22,7%	2	9,1%
2009	1	3,3%	9	30,0%	1	3,3%
2010	2	8,0%	14	56,0%	1	4,0%
2011	1	4,0%	9	36,0%	0	0,0%
2012	1	4,3%	7	30,4%	2	8,7%
2013	0	0,0%	8	36,4%	0	0,0%
2014	0	0,0%	9	33,3%	3	11,1%
2015	0	0,0%	1	5,3%	0	0,0%
Total	9	4,2%	74	34,9%	10	4,7%

Table 3 Overview of performed implant removals and secondary subtalar fusions. Patients who have been treated in other trauma centers aren't included

Epilog

If you have questions and if you would like to comment on this work, feel free to contact us. We would be pleased about feedback. We appreciate your input to further develop our technique and new devices to aid in this technique. We sincerely look forward hearing from you. We also would appreciate to receive invitations to presentations or workshops from your company as well.

Project: MPCD Multiplanar Calcaneus Distractor

With the support of the AUVA we are in the final stages of developing a new distraction device. The concept has been made by C. Rodemund. The technical realization is supported by PMU Innovation GMBH in cooperation with the Paracelsus Privatuniversität Salzburg

PARACELSUS
MEDIZINISCHE PRIVATUNIVERSITÄT

PMU INNOVATIONS GMBH

We are intensely in search of new colleagues who are interested in our concepts and would like to join us to support completion and the clinical implementation of our project.

Contact:

Christian Rodemund: med.rodemund@gmail.com Tel.: 0043 664 5778077

Georg Mattiassich georg.mattiassich@gmx.at

Updates, infos and case reports

https://www.calcaneal-fracture.com

Additional documents

"Minimal invasive Versorgung intra-artikulärer Fersenbeinfrakturen mit dem 2-Punkt-Distraktor" issue from April 2017 of the journal "Operativen Orthopädie und Traumatologie" Oper Orthop Traumatol (DOI 10.1007/s00064-016-0478-0)

http://www.springermedizin.de/operative-orthopaedieund-traumatologie

2 presentations on the medical video platform VuMedi: www.vumedi.com

https://www.vumedi.com/video/minimal-invasive-surgery-of-intraarticular-fractures-of-the-calcaneus-update-2017/

https://www.vumedi.com/video/minimal-invasive-treatment-of-intra-articular-calcaneal-fractures/

Thesis Ronny Krenn:

Analyse der Versorgung von Fersenbeinbrüchen im Unfallkrankenhaus Linz unter besonderer Berücksichtigung minimal-invasiver Operationsmethoden

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Literature

1) Bernstein, J. & Clahsen, H., 1997. Taxonomy and treatment – a classification of fracture classifications. J Bone Joint Surg [Br], pp.706–707.

2) Schepers, T. et al., 2009. Calcaneal Fracture Classification: A Comparative Study. Journal of Foot and Ankle Surgery, 48(2), pp.156–162.

3) Schepers, T., 2016. Calcaneal Fractures: Looking Beyond the Meta-Analyses. Journal of Foot and Ankle Surgery, 55(4), pp.897–898.

4) Rammelt, S. & Zwipp, H., 2004. Calcaneus fractures: Facts, controversies and recent developments. Injury, 35(5), pp.443–461.

5) Guerado, E., Bertrand, M.L. & Cano, J.R., 2012. Management of calcaneal fractures: What have we learnt over the years? *Injury*, 43(10), pp.1640–1650.

6) Eastwood, D.M., Langkamer, V.G. & Atkins, R.M., 1993. Intra-articular fractures of the calcaneum. Part II: Open reduction and internal fixation by the extended lateral transcalcaneal approach. *J Bone Joint Surg Br*, 75(2), pp.189–195. Available at: http://www.ncbi.nlm.nih.gov/pubmed/8444935.

7) Andermahr, J. et al., 1999. The vascularization of the os calcaneum and the clinical consequences. *Clinical orthopaedics and related research*, (363), pp.212–8. Available at: http://www.ncbi.nlm.nih.gov/pubmed/10379325.

8) Rammelt, S. & Zwipp, H., 2004. Calcaneus fractures: Facts, controversies and recent developments. *Injury*, 35(5), pp.443–461.

9) Letournel E., 1993. Open treatment of acute calcaneal fractures. Clin Orthop 1993;290:60—7

10) Schepers, T. & Backes, M., 2013. Wound_infections_following_open_reduction with extended lat Approach. *International Orthopaedics*.

11) Goldzak, M. et al., 2014. Primary stability of an intramedullary calcaneal nail and an angular stable calcaneal plate in a biomechanical

testing model of intraarticular calcaneal fracture. *Injury*, 45(SUPPL. 1), pp.S49–S53. Available at: http://dx.doi.org/10.1016/j.injury.2013.10.031.

12) Zwipp, H. et al., 2013. Osteosynthese dislozierter intraartikulärer Kalkaneusfrakturen. *Operative Orthopadie und Traumatologie*, 25(6), pp.554–568.

13) Pastor T. et al., 2016. Displaced intra-articular calcaneal fractures: is there a consensus on treatment in Germany?. International Orthopadics, vol.40, issue10, pp 2180-2190

14) Gras, F. et al., 2010. Sustentaculum-tali-Schraubenplatzierung bei der Versorgung von Kalkaneusfrakturen - Verschiedene Navigationsverfahren im Vergleich zur konventionellen Technik. *Zeitschrift fur Orthopadie und Unfallchirurgie*, 148(3), pp.309–318.

15) Mattiassich, G. et al., 2017. Minimal-invasive Versorgung intraartikulärer Fersenbeinfrakturen mit dem 2-Punkt-Distraktor. *Operative Orthopädie und Traumatologie*, (August). Available at: http://link.springer.com/10.1007/s00064-016-0478-0.

16) Sharr, P.J. et al., 2016. Current management options for displaced intra-articular calcaneal fractures: Non-operative, ORIF, minimally invasive reduction and fixation or primary ORIF and subtalar arthrodesis. A contemporary review. *Foot and Ankle Surgery*, 22(1), pp.1–8. Available at: http://dx.doi.org/10.1016/j.fas.2015.10.003.

17) Sanders, R. et al., 2014. The Operative Treatment of Displaced Intra-articular Calcaneal Fractures (DIACFs): Long Term (10-20 years) Results in 108 Fractures using a Prognostic CT Classification. *Journal of orthopaedic trauma*, 28(10), pp.551–563. Available at: http://www.ncbi.nlm.nih.gov/pubmed/24983429.

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