Complex Foot Injuries

PV Fearon

21st March 2011

The Newcastle upon Tyne Hospitals NHS
NHS Foundation Trust

- Talus
- Os calcus
- Mid foot
- Compartment syndrome

Biomechanics of foot

Ankle Biomechanics

- Axis of the ankle is oblique
- Movements therefore triplanar
- Everts (valgus) and abduction during dorsiflexion
- Inverts (varus) and adduction during plantarflexion

Joint reaction force in stance is 4 times body weight

At least 10 degrees of dorsiflexion is needed for normal gait

1mm of lateral talar shift decreases tibio/talar surface contact up to 40%

Talus

- Many ligaments attachments
- No muscles
- >70% of its surface is covered by articular cartilage
- Circulation precarious
- Posterior tibial, dorsal and peroneal arterial trees, entering on the ligaments and the rough area of the neck from an anastomosis in the tarsal canal
- Body blood supply mostly reaches it by a retrograde route from the neck.

Neck fracture
fracture line exits inferiorly
anterior to posterior subtalar facet

Body fracture
fracture line exits inferiorly into
posterior subtalar facet

Pathomechanics

- Talar neck fractures
- Pure vertical shear against the plafond
- Petersen

Subtalar joint

- Allows eversion / inversion
- Hindfoot position locks and unlocks the midfoot
- 3 Facets

Lateral Process

- Lateral talocalcaneal ligament & subtalar joint capsule
- axial loading dorsiflexed ankle, eversion
- 15% of ankle injuries in a large study of snowboarding injuries

von Knoch et al(2007)'s V-sign

fracture of the process
disrupts the "V" shape

McCrory and Bladin

- 1 single small fragment ankle and subtalar
- 2 single large fragment ankle and subtalar (sometimes carrying a substantial proportion of the subtalar joint surface)
- 3 comminuted fracture
  - Clin J Sports Med 1996; 6:124-8

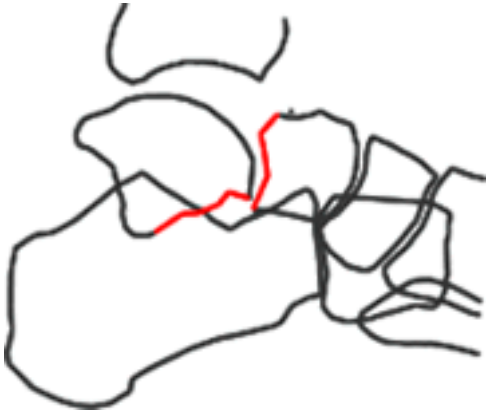
1 Conservative
2 Surgical

Most series report about 15% late subtalar arthritis,

Talar Neck #s

Hawkins 1 - undisplaced

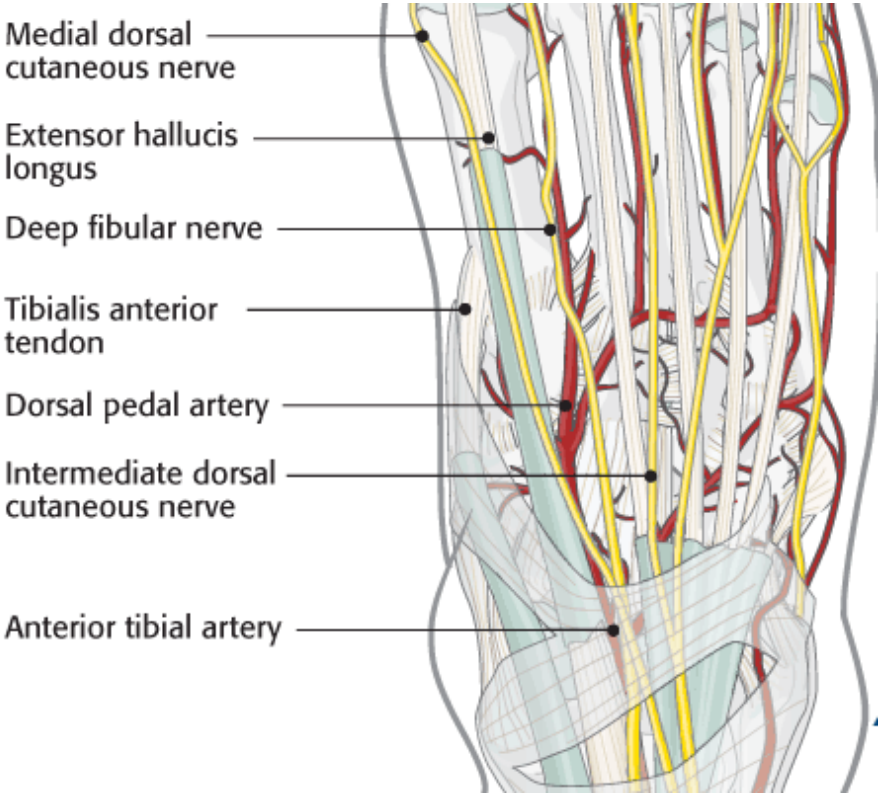
Hawkins 2 - subtalar joint incongruent



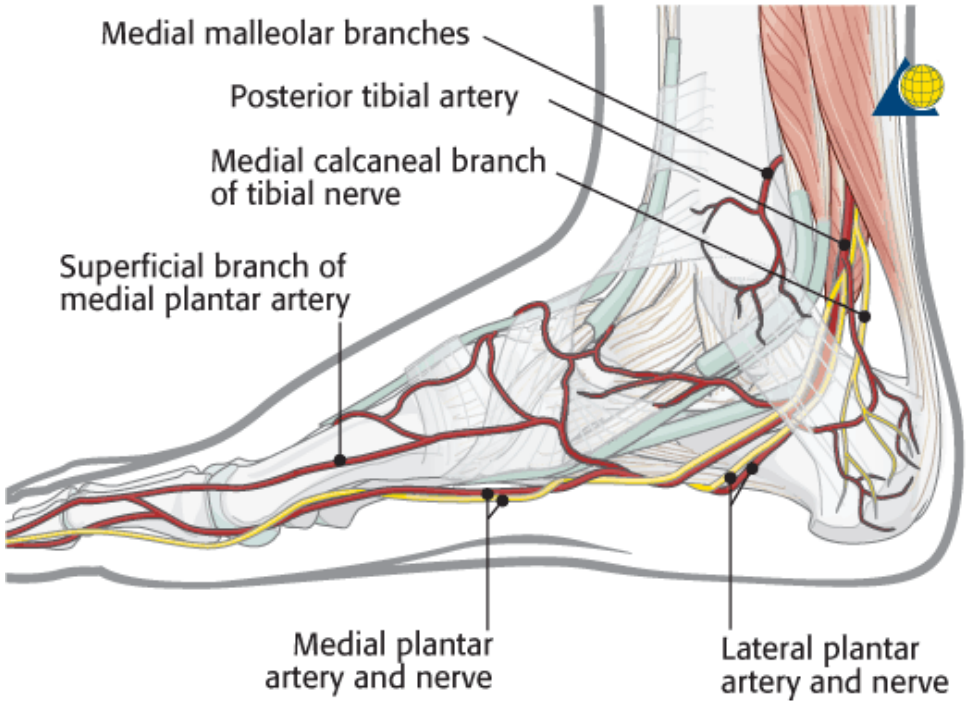
Hawkins 3 - ankle incongruent

Hawkins 4 - talonavicular joint incongruent

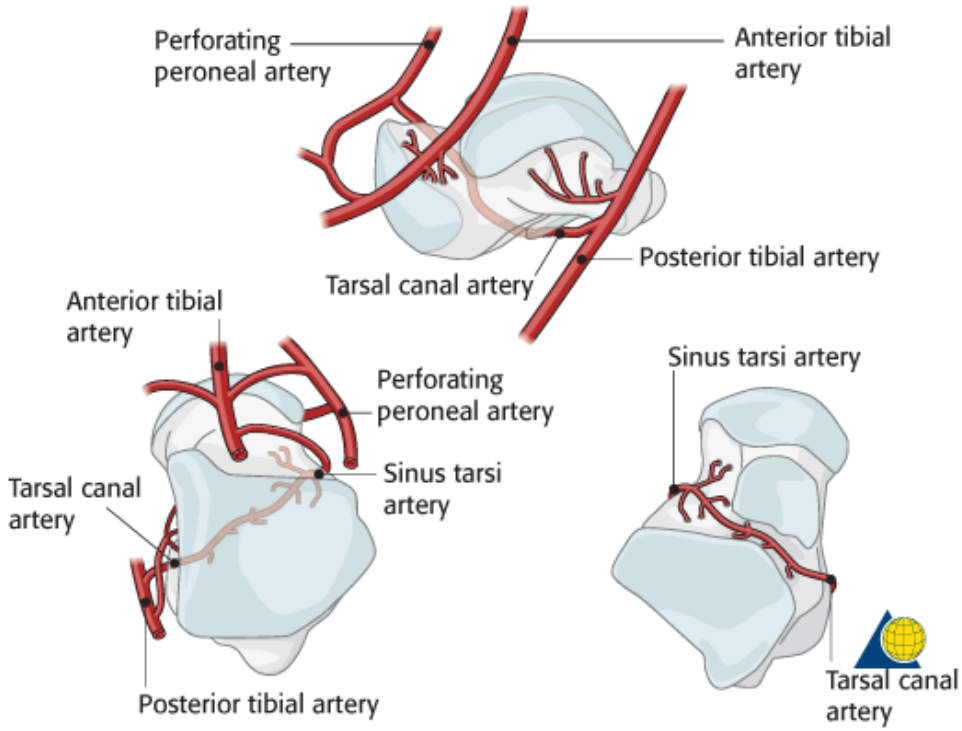
Blood Supply

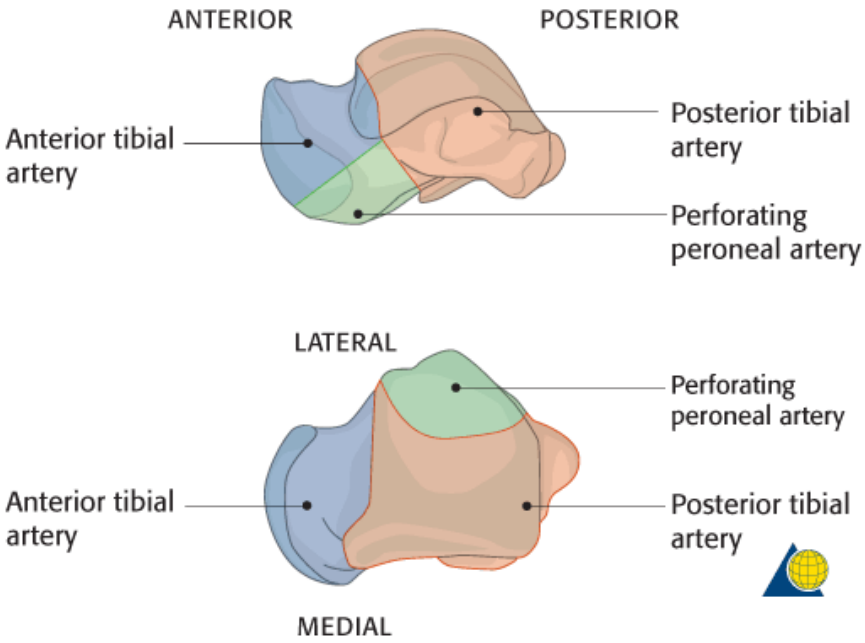


- Neck of the talus receives branches from the medial and lateral side
- Body of the talus is supplied almost exclusively from its posteromedial aspect.



- Anteromedial approach avoids these two neurovascular bundles and provides access to the medial talus and surrounding joints.


Perforating peroneal artery
Anterior tibial artery
Posterior tibial artery
Tarsal canal artery
Anterior tibial artery
Perforating peroneal artery
Sinus tarsi artery
Tarsal canal artery
Posterior tibial artery
Sinus tarsi artery
Tarsal canal artery



- The deltoid branches are important to supply blood to the medial talar neck and talar body
- Branches from the dorsalis pedis supply the talar head and most of the dorsal talar neck
- The artery of the tarsal canal coming from branches off of the posterior tibial artery supply most of the talar body
- The peroneal artery has the least contribution laterally.

Overall function

- most accurately predicted by the:-

- severity of the initial injury
- with open, comminuted fractures of high Hawkins-Canale grade doing worse even with good treatment
- Residual varus also predicted a poor result

- Vallier
- Sanders
- about 70% returned to their previous work, some times with some modification
- AVN in displaced fractures is about 30-60%
- 100% in grade IV injuries
- but 10% apparently undisplaced fractures

Heelstrike

Tib ant contracts eccentrically

STJ everts and aligns (unlocks) the midtarsal joints

Allows foot to pronate and accommodate to absorb energy of heelstrike

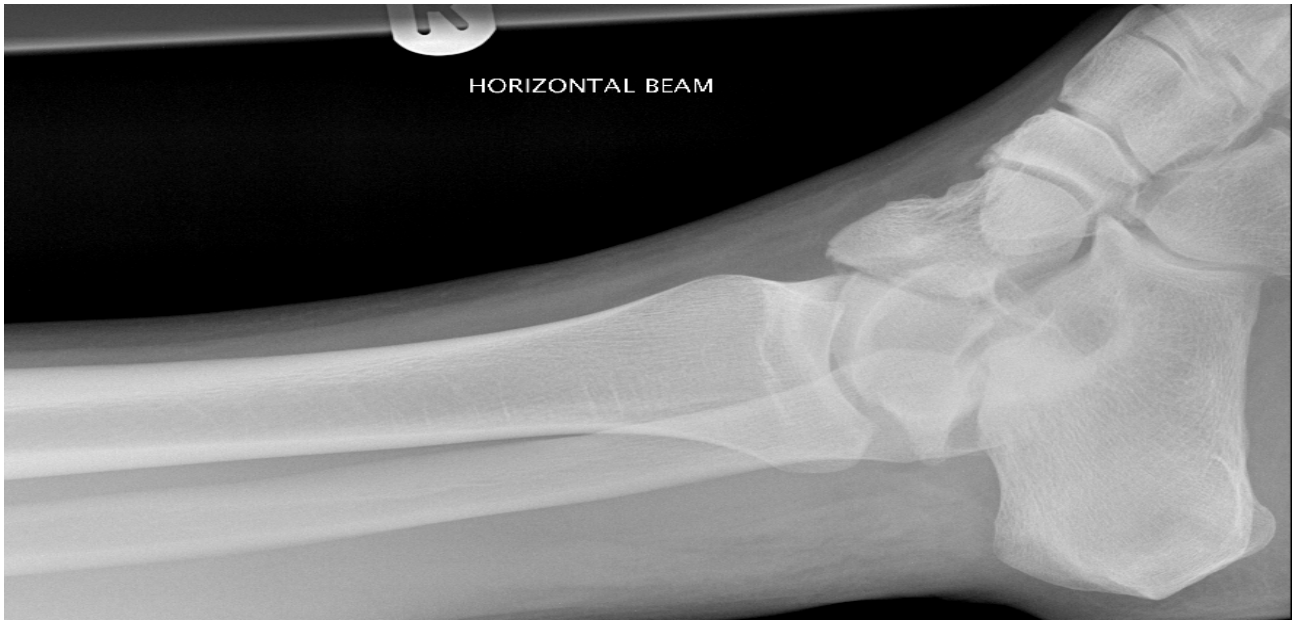
Tibia internally rotates

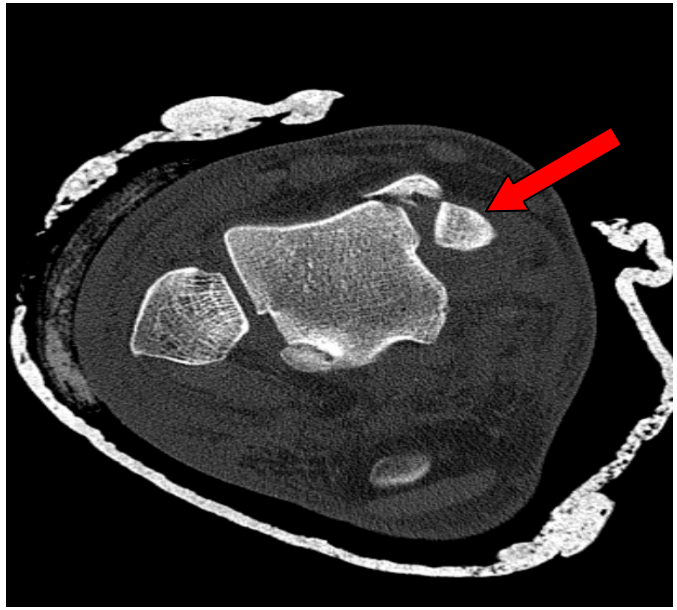
Toe-off

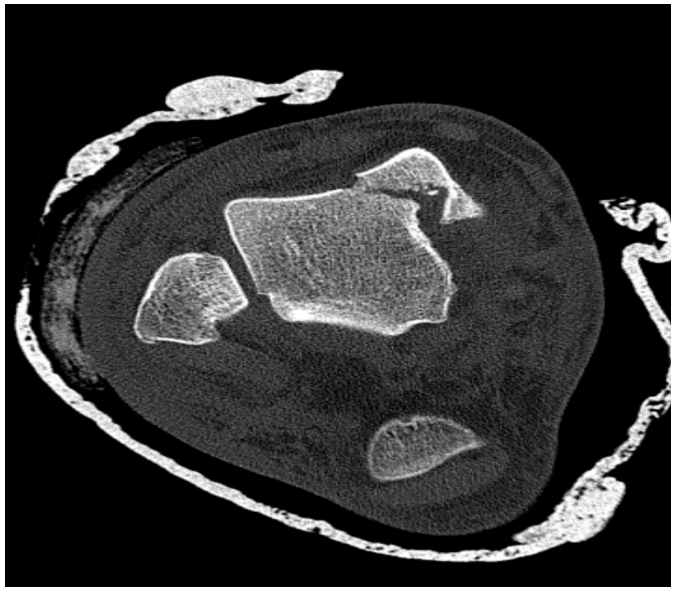
Tib post inverts hindfoot and locks midfoot

Foot more rigid for toe-off

As toes dorsiflex, plantar aponeurosis tightens

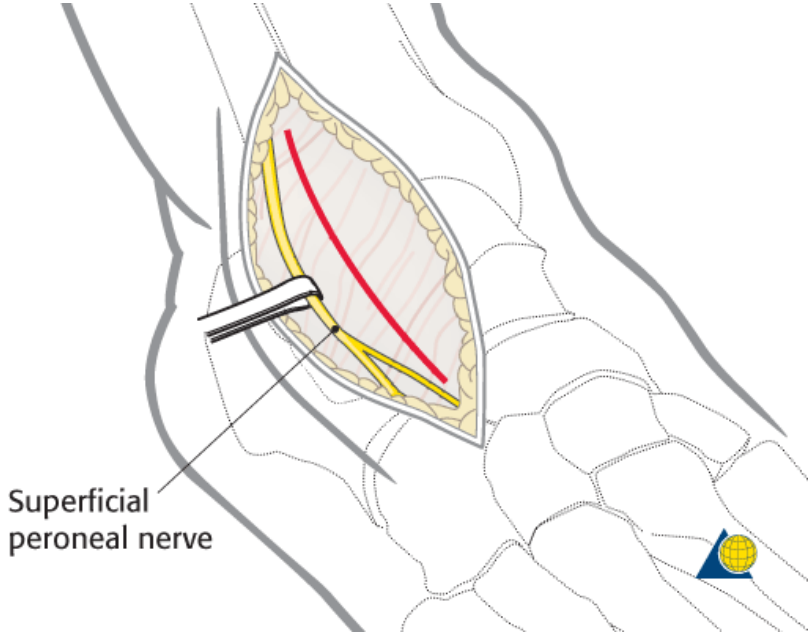

HORIZONTAL BEAM



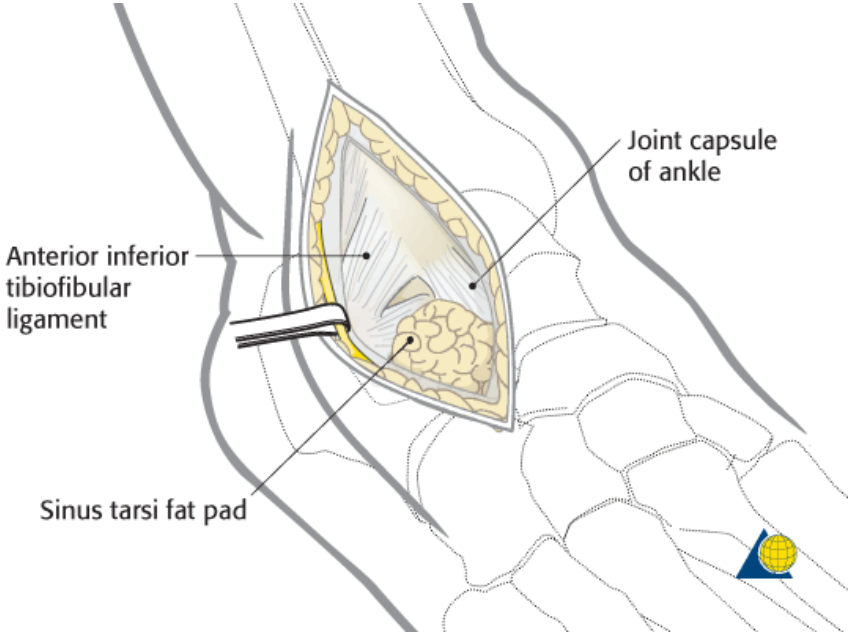



Spin: 17
Tilt: 0
A

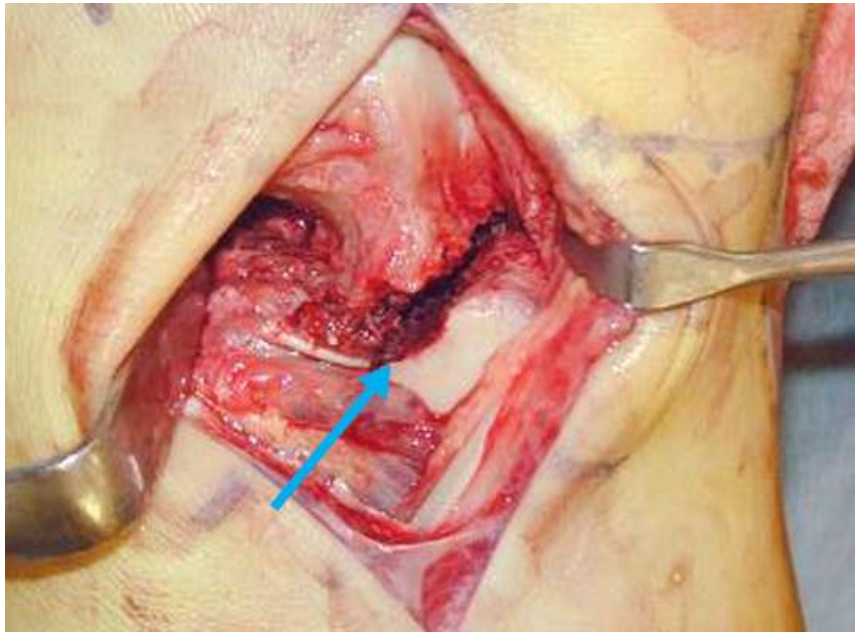
- Skin incision
- IV metatarsal
- Full thickness flaps



- extensor digitorum brevis

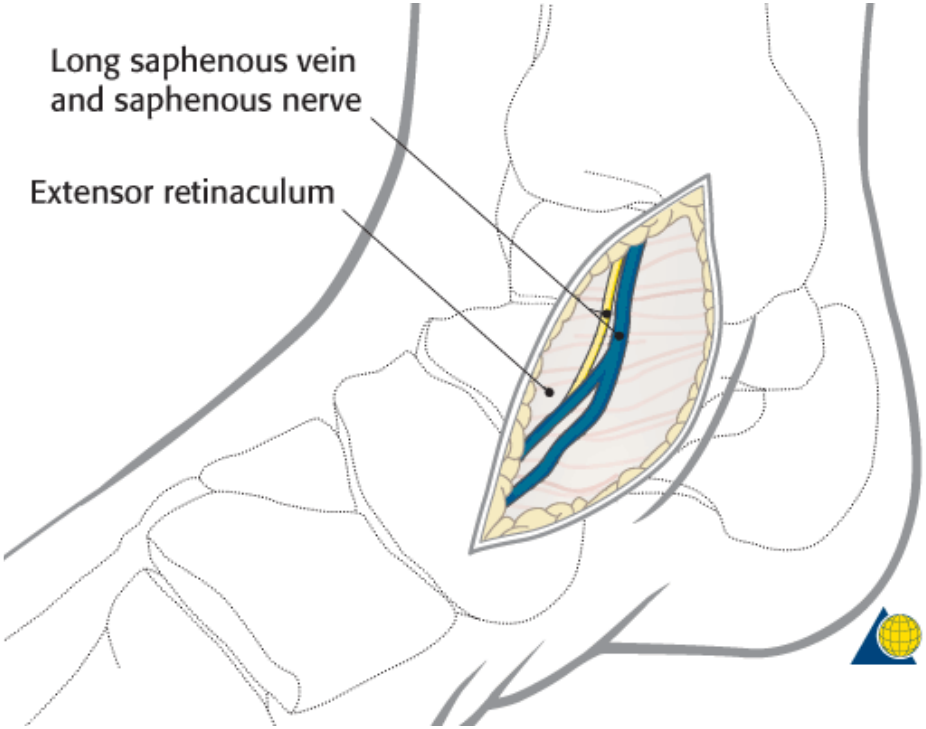


- Lateral talus &
- Subtalar joint

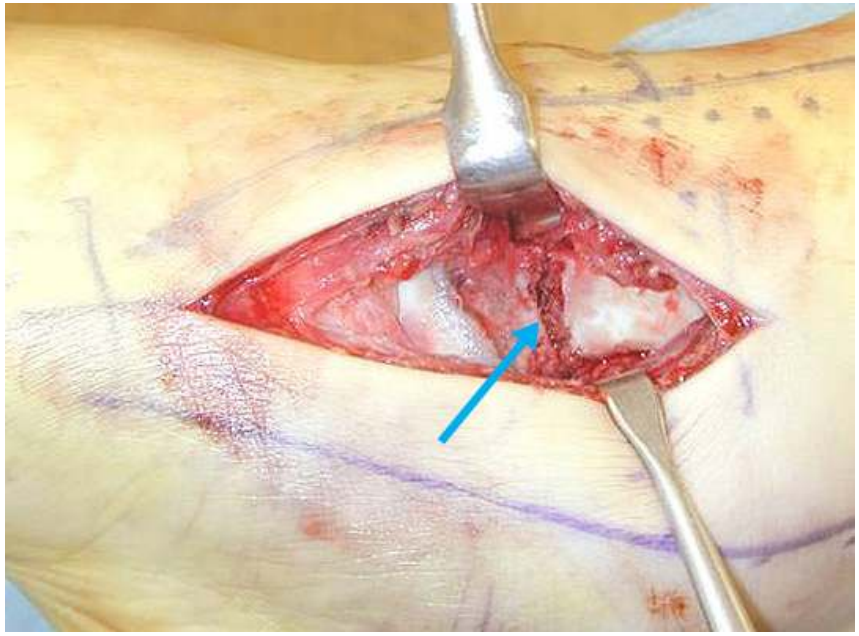


- lateral side of the neck comes under tension
- medial side under compression
- The fractures on the lateral side are simple
- medial side multifragmentary.

- Incision runs from the medial malleolus proximally to the base of the first metatarsal distally.

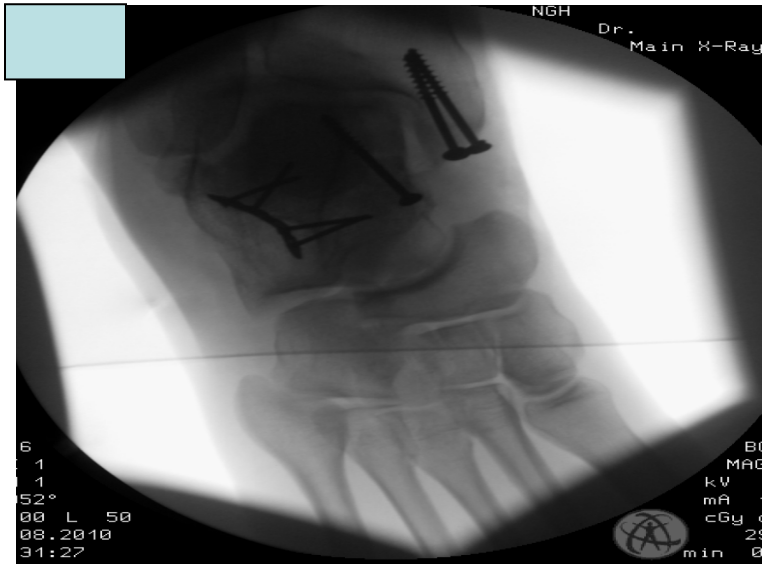


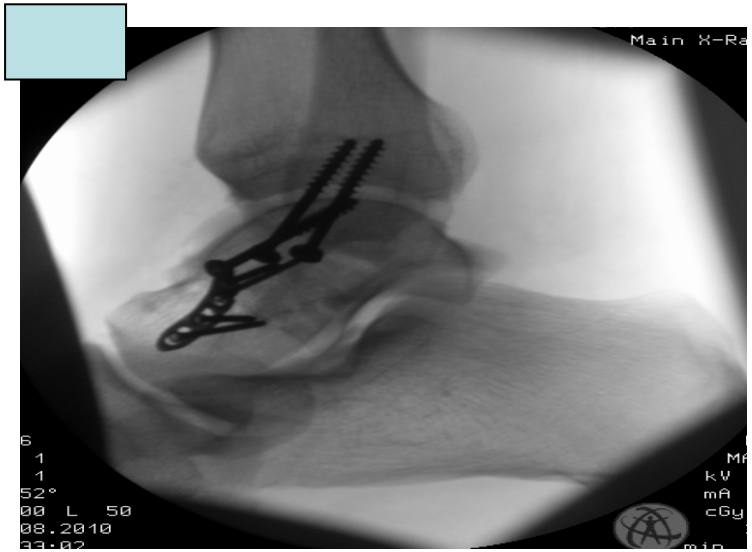
- important not to damage the deltoid branches
- which arise posteromedially
- and supply the medial two thirds of the talar body.

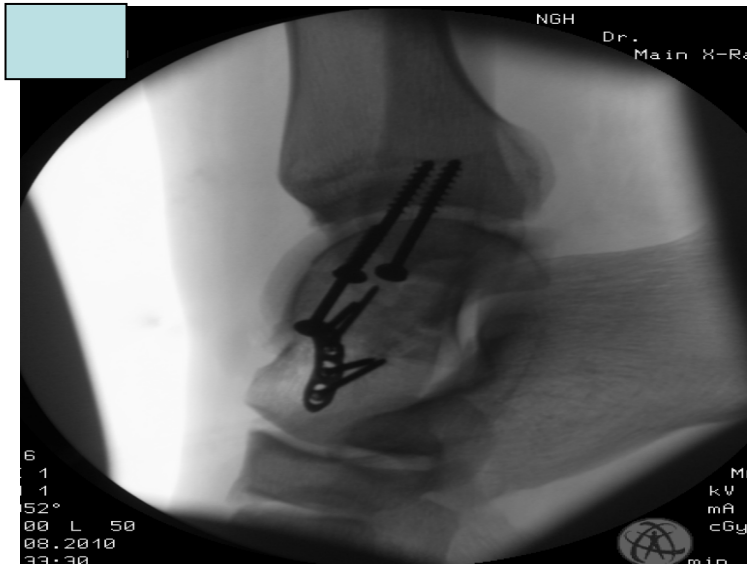


- Debridement of subtalar joint – allow reduction
- The fractures on the medial side are often multifragmentary
- Restoration of length, if the fracture is comminuted, depends on anatomic reduction of the lateral aspect of the talar neck.


NGH
Dr.
L 50
2010


NGH
Dr.
Main X-Ray
kV
mA
cGy
08.2010
31:27
min


Main X-Ra
kV
mA
cGy
52°
00 L 50
08.2010


NGH
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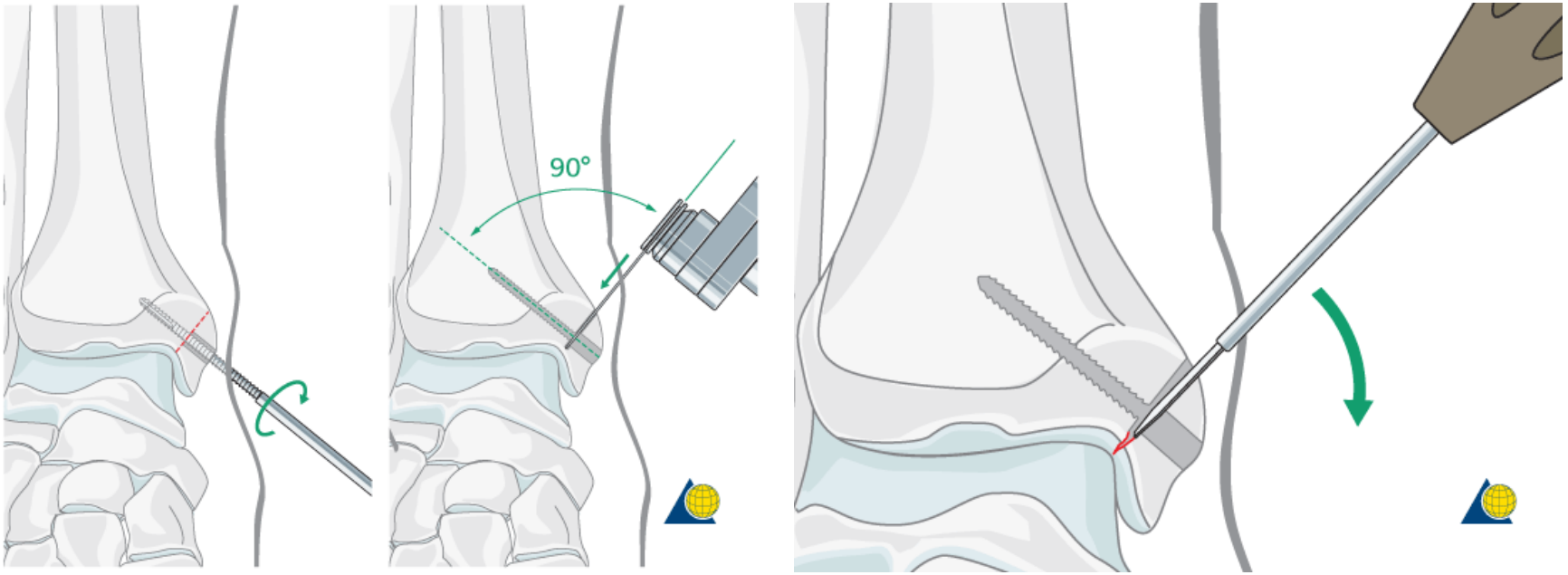
Main X-Ra
kV
mA
cGy
52°
00 L 50
08.2010


R


90°

Outcome

- Functional outcomes following displaced talar neck fractures. Sanders et al.,
- J Orthop Trauma, 2004:(18):265-70
- IV case series
- The incidence of secondary reconstructive surgery increased from 24% at 1 year to 48% at 10 years post injury
- Functional outcome varied
- most dependent upon the development of complications

Talar neck fractures: results and outcomes

J Bone Joint Surg Am, 2004:1616-24

- Case series 100 patients
- Xray evidence osteonecrosis 49% of these
- 37% demonstrated revascularisation of the talar dome without collapse
- osteonecrosis with collapse of the dome 31%
- Hawkins group-II fractures 39%
- Hawkins group-III fractures 64%

- No correlation could be identified between surgical delay and the development of osteonecrosis
- Osteonecrosis was associated with comminution of the talar neck ($p < 0.03$) and open fracture ($p < 0.05$)
- Patients with comminuted fractures also had worse functional outcome scores

Treatment of fracture dislocation of talus by primary tibiotalar arthrodesis (Blair fusion)

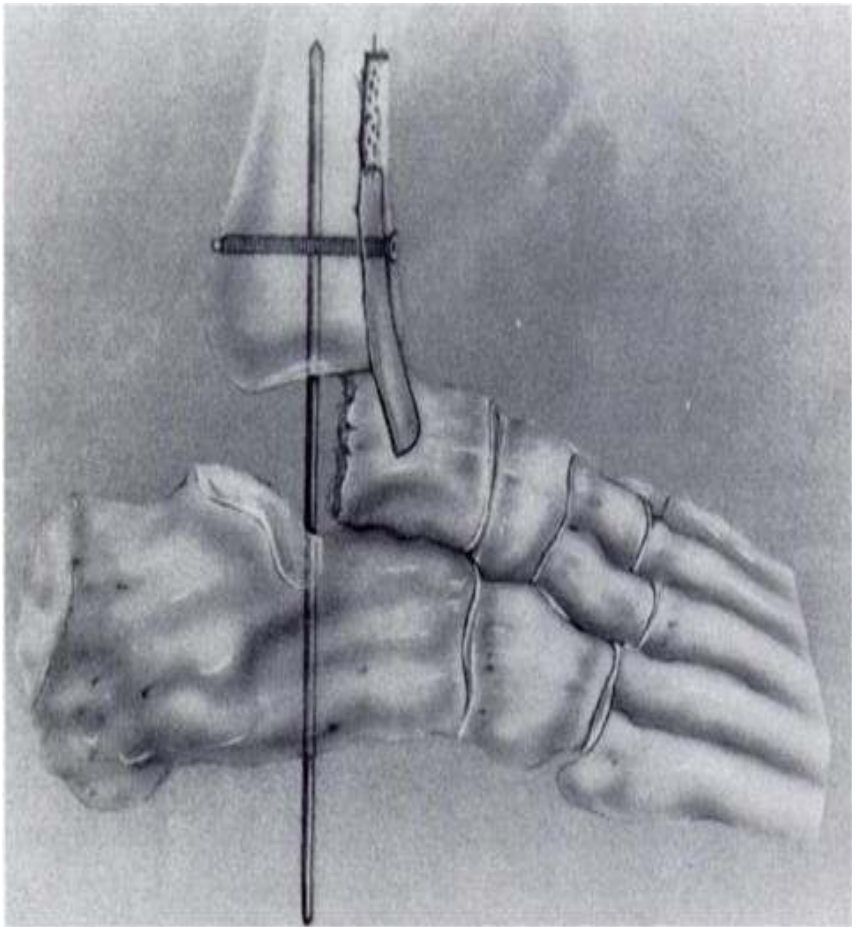
- Injury, 2005:(36):823-6 Shrivastava et al
- Case series 8 cases
  - good in six patients (75%)
  - fair in one (12.5%)
  - poor in one (12.5%)


Spin: -109
Tilt: 0


L


L

Blair Fusion



- Displaced talar fractures with late presentation are challenging to treat

Treatment of Hawkins type II fractures of talar neck by a vascularized cuboid pedicle bone graft and combined internal and external fixation: a preliminary report on nine cases

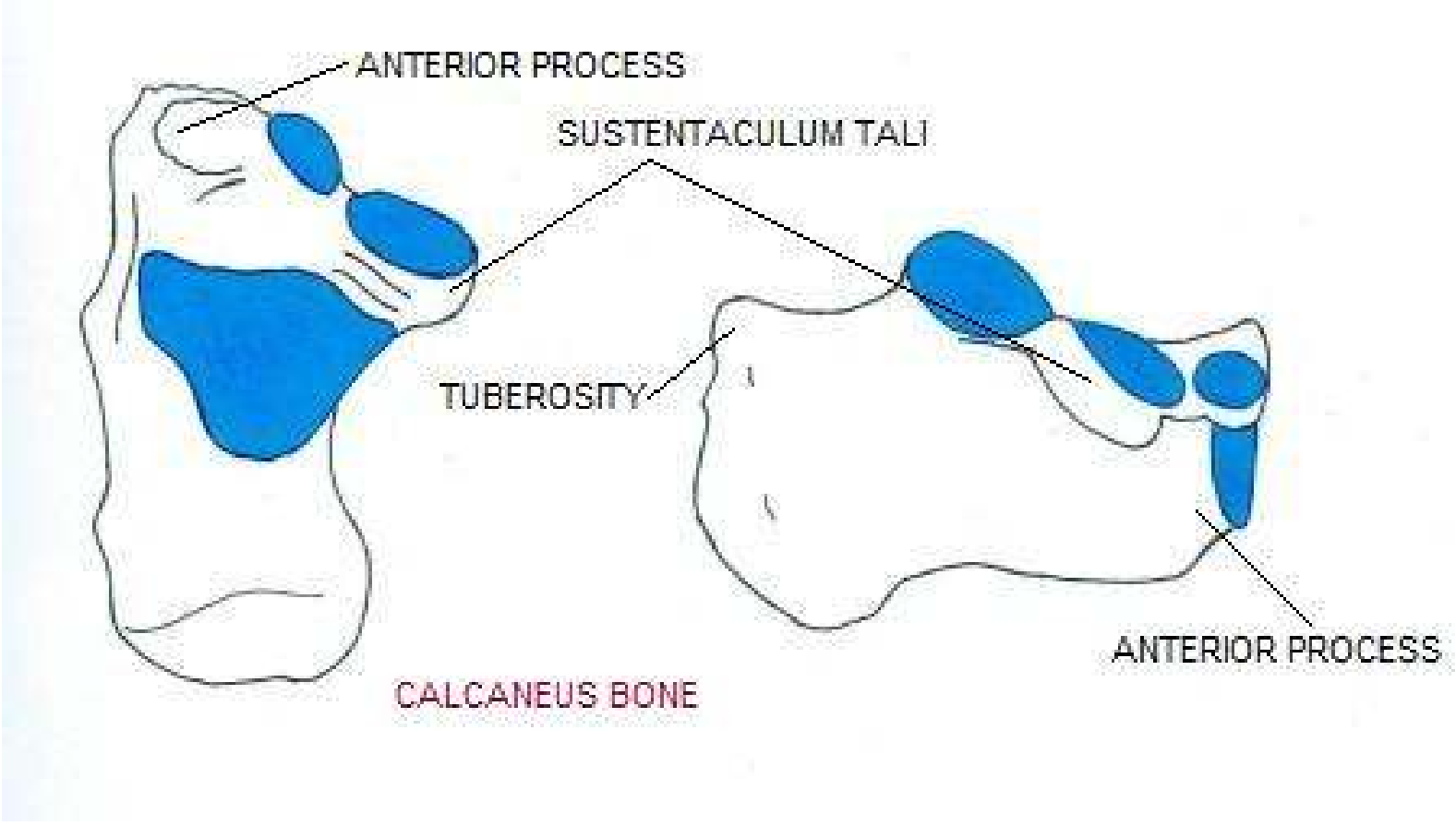
- J Trauma, 2010:(69):E1-5 Tang et al.,
  - Fractures healed uneventfully in all the patients with an mean time to union of 15.6 weeks
  - No avascular necrosis of the talus occurred

Calcaneal Fractures
Displaced intra-articular

Initial Managament

- ATLS
- Associated injuries
  - spine in 10%
  - contralateral calcaneus in 10%
- Elevation
- Ice/compression
- Evaluation

Anatomy

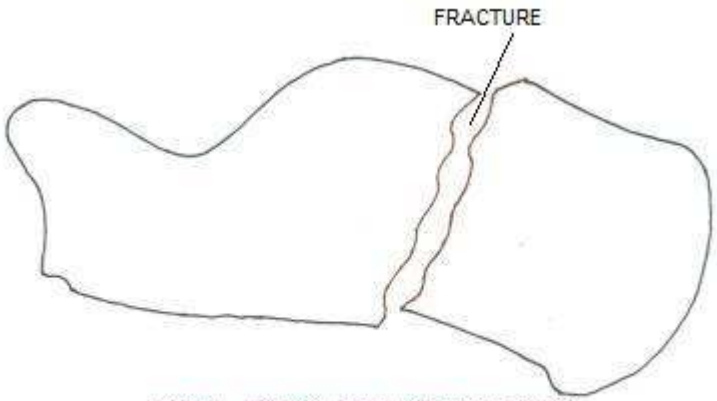

ANTERIOR PROCESS
SUSTENTACULUM TALI
TUBEROSITY
ANTERIOR PROCESS
CALCANEUS BONE

- 3 facets
- Various angles
- Articulations with talus, fibular and cuboid
- Tarsal sinus / canal

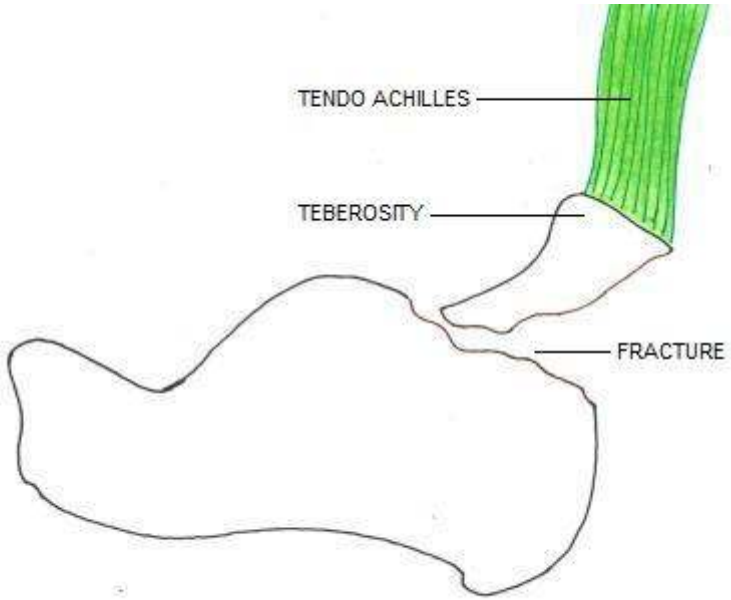
Classification

Extra-articular (25%)

- usually an avulsion injury of
  - anterior process by bifurcate ligament
  - sustentaculum tali
  - calcaneal tuberosity (Achilles tendon avulsion)



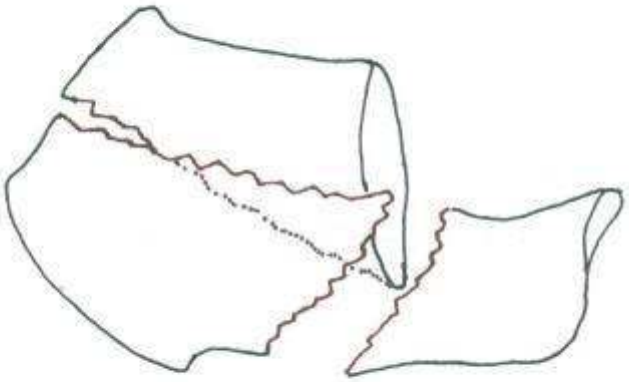
EXTRA - ARTICULAR FRACTURE OF BODY
NOT INVOLVING THE JOINT



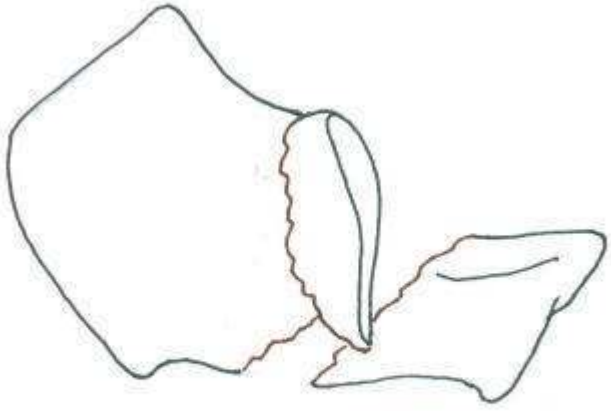
CALCANEUS TUBEROSITY FRACTURE

Intra-articular (75%)

- Essex-Lopresti classification
  - primary fx line runs obliquely through posterior facet forming two fragments
  - secondary fx line runs either
    - in axial plane beneath the facet and exits posteriorly in Tongue-type fx
    - just behind posterior facet in Joint depression fx

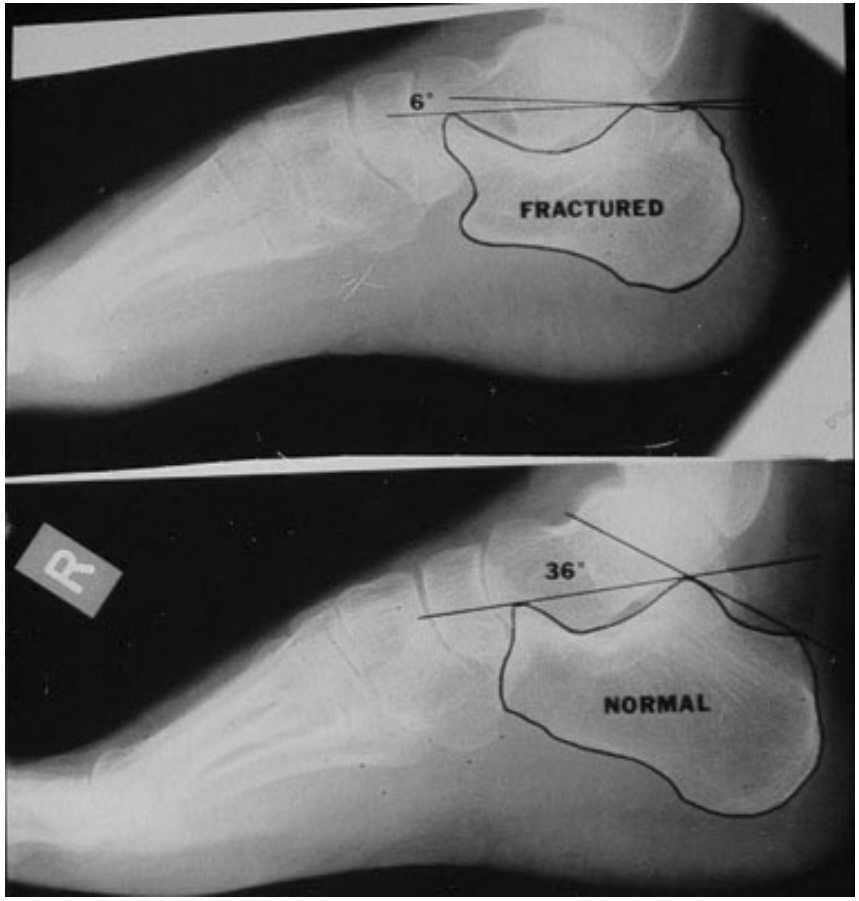


TONGUE TYPE OF CALCANEUS FRACTURE



JOINT DEPRESSION TYPE OF CALCANEUS FRACTURE

Radiology



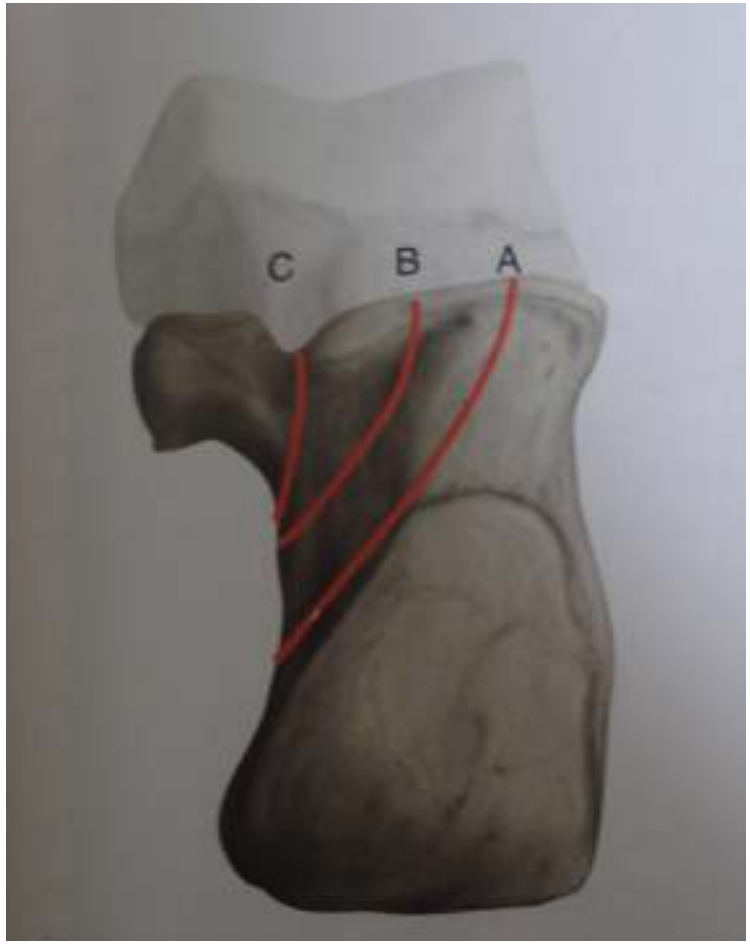
Sanders classification

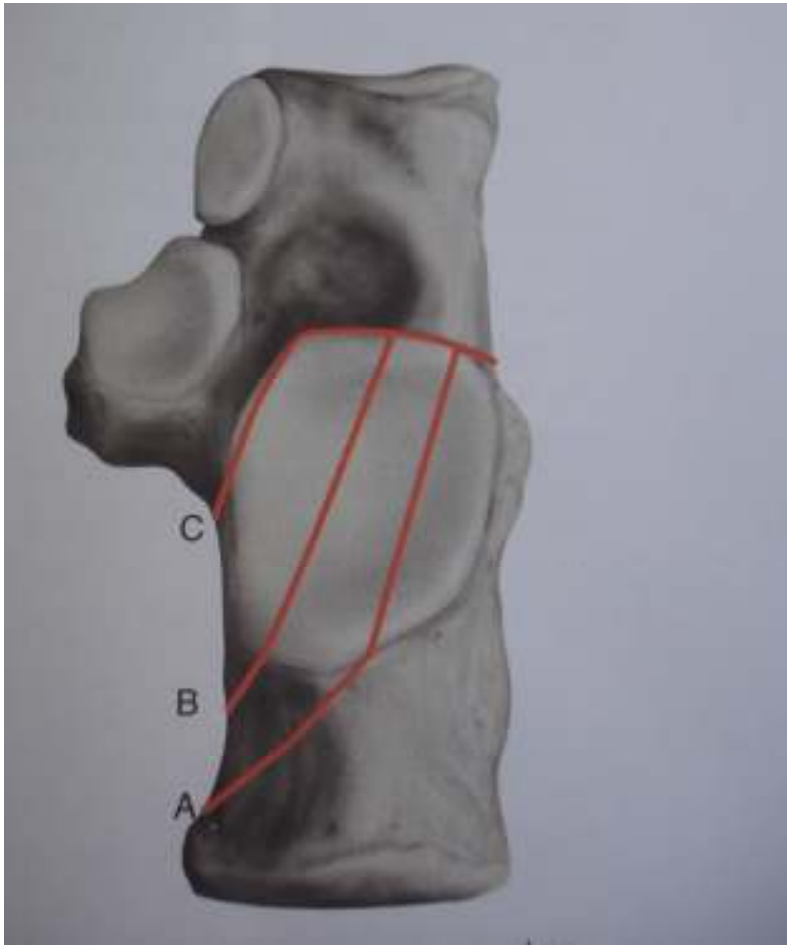
based on coronal CT image at level of posterior facet

- Type I - nondisplaced posterior facet (regardless number of fragments)
- Type II - one fx line in posterior facet (two fragments)
- Type III - two fx lines in posterior facet (three fragments)
- Type IV - three fx lines in posterior facet (four + fragments)

- extension into the calcaneocuboid joint occurs in 63%

CT





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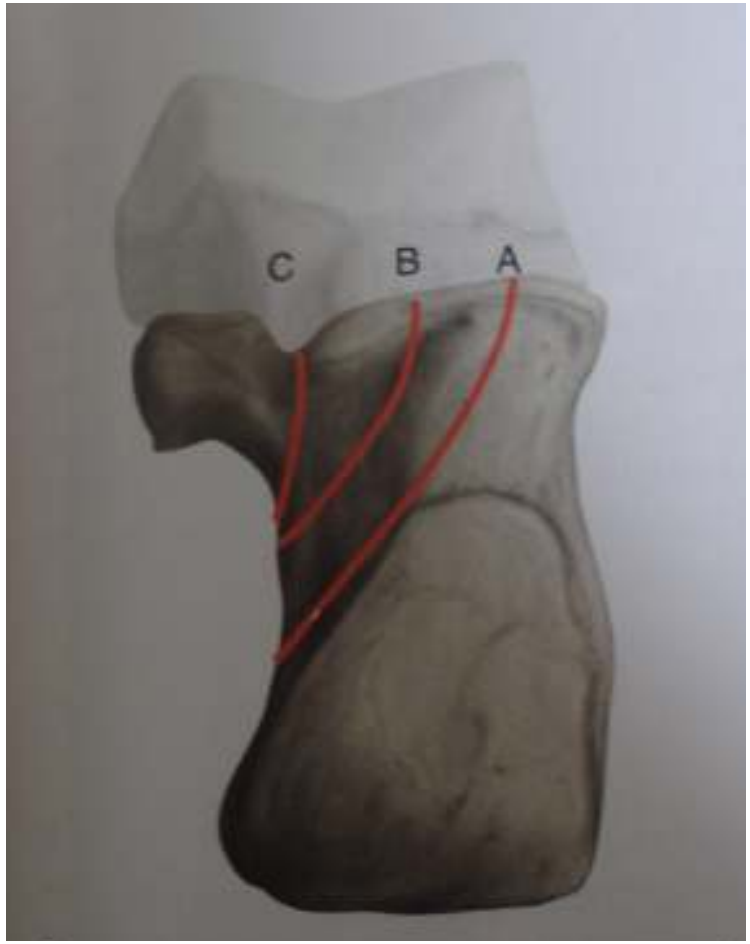
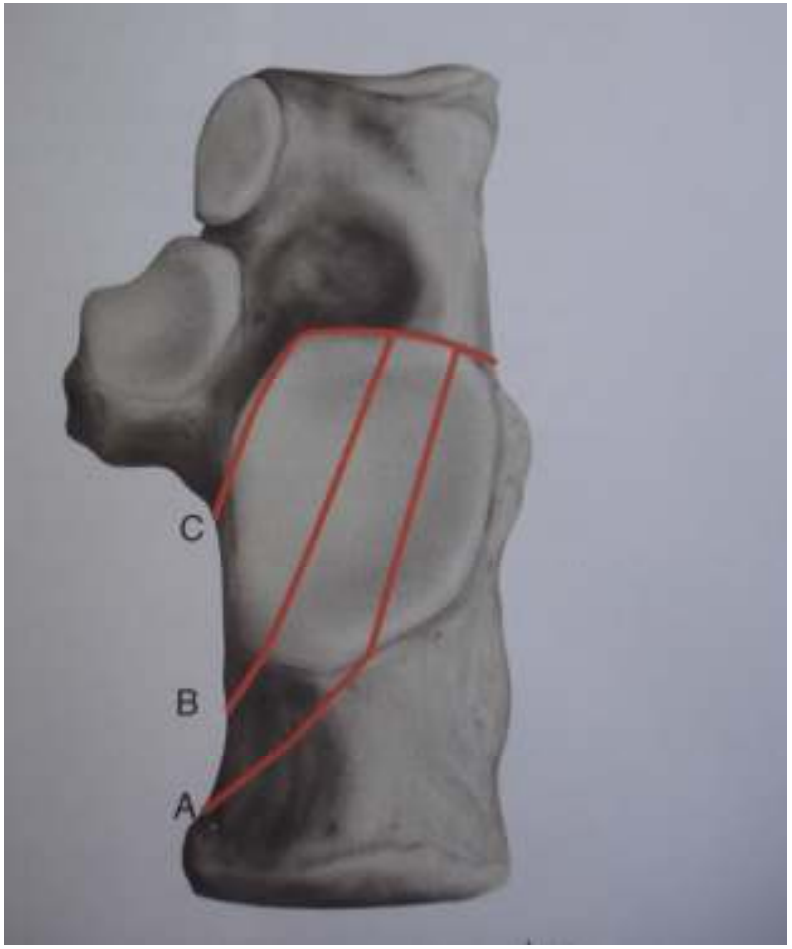
CT





Treatment Options

- Non-operative
  - Hindfoot stiff when immobilised
    - Elderly >60
    - Co-morbidities
    - Vascular insufficiency
    - Smokers
  - Early rom
    - Ice
    - Elevation
  - As long as no deformity

Wrinkle Test

Percutaneous

- Posterior joy-stick
- Where full approach not advisable
  - Skin,ST concerns
  - Elderly
  - Vascular
  - DM
  - No evidence

Operative Reduction

- Level II studies - Once ST settled

- Young better than old
- Female better than male
- Open #s better results with Sx
- Sanders II & III better with Sx
- Bohlers <0° x10 subtalar fusion (cf >15°)
- Sanders IV x5.5 fusion (cf Sanders II)
- Claimants x3 fusion
- No-op x6 fusion (cf ORIF)

Surgical Set Up

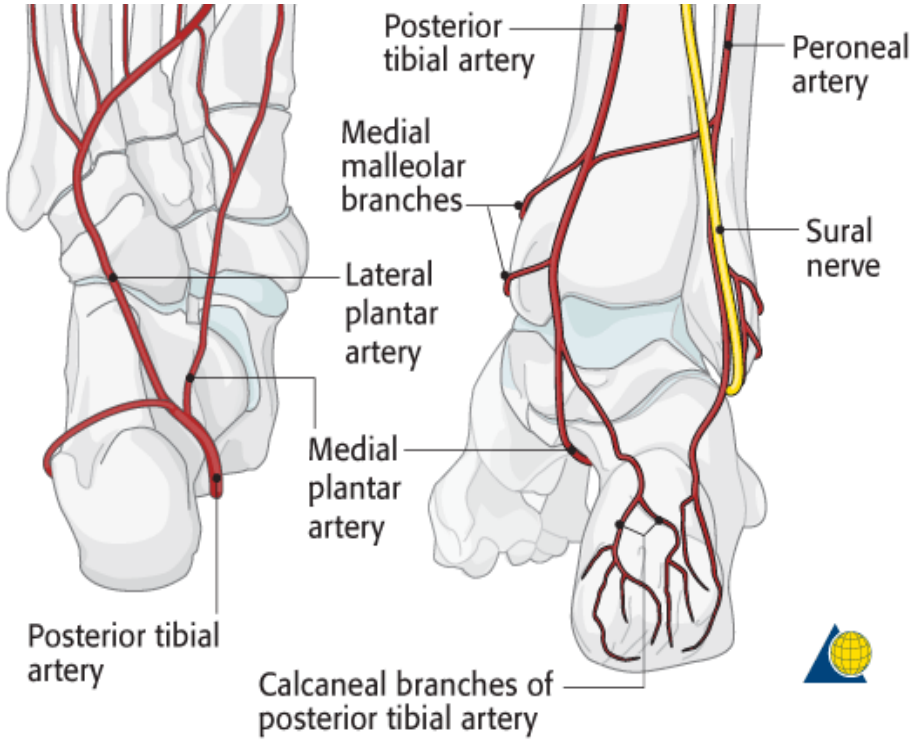
- Goals of surgery
  - restore congruity of subtalar joint
  - restore Bohler angle and calcaneal height
  - restore width
  - correct varus malalignment

  - Avoid complications!!

Surgical Set Up

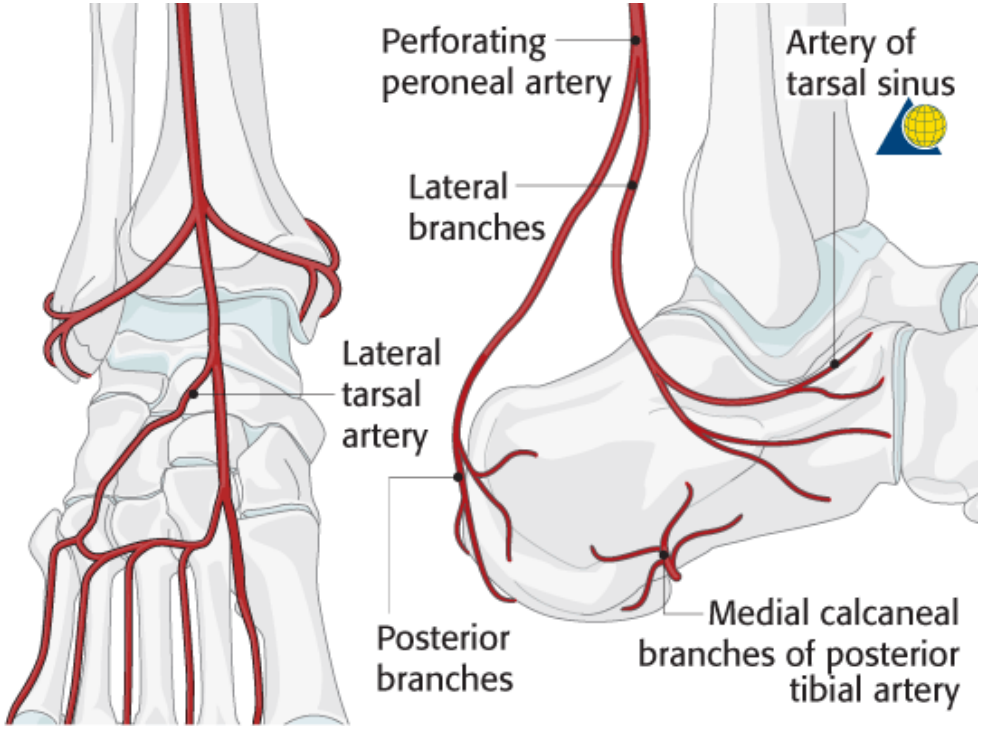
- Position
- Imaging
- Approach
- Reduction
- Closure
- Rehab

Blood Supply



- Perforating branches of the peroneal artery contribute to the vascularity of the lateral skin and soft tissue of the foot.
- Undermining of skin edges runs the risk of skin edge necrosis and therefore full-thickness flaps have to be developed to prevent this complication

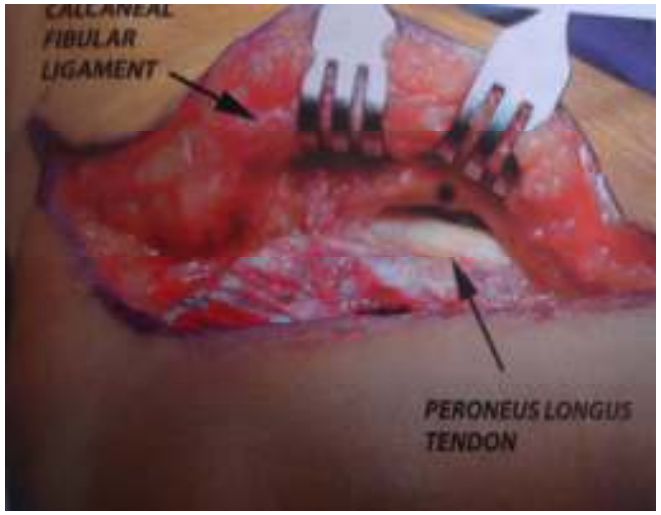
Blood Supply



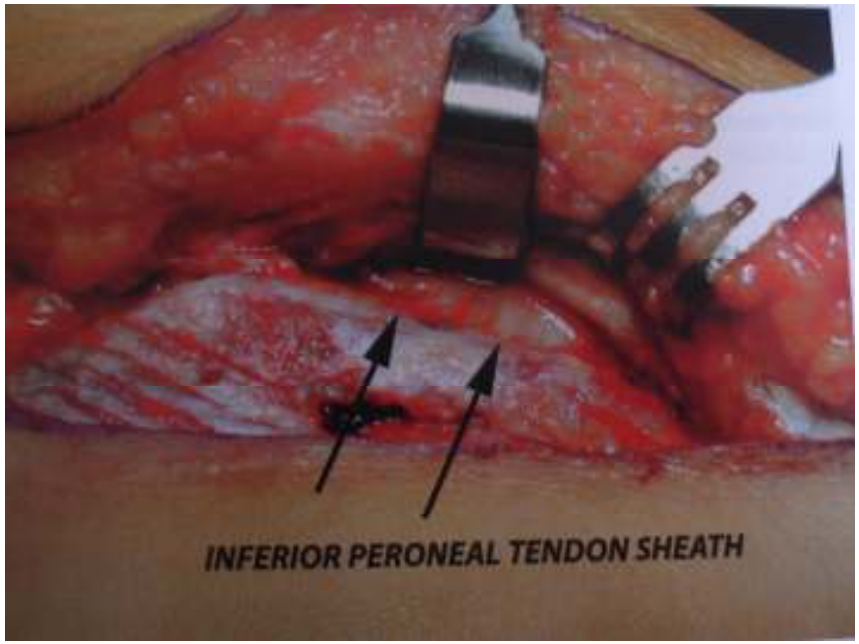
- The lateral calcaneal artery is responsible for the majority of the blood supply to the corner of the L-shaped flap of this approach
- The heel pad is mostly supplied from the posterior tibial artery branches medially.

Positioning

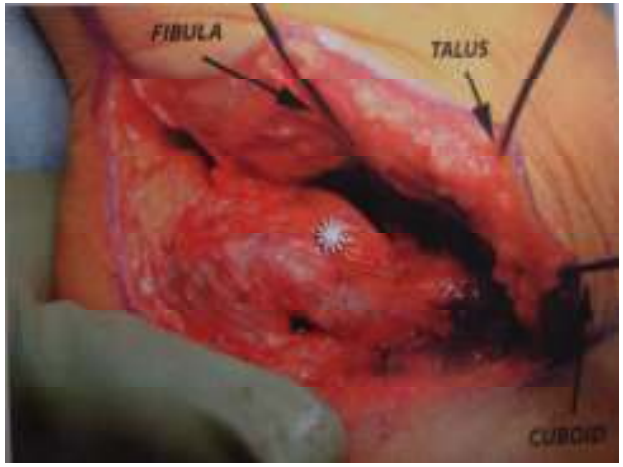
Approach



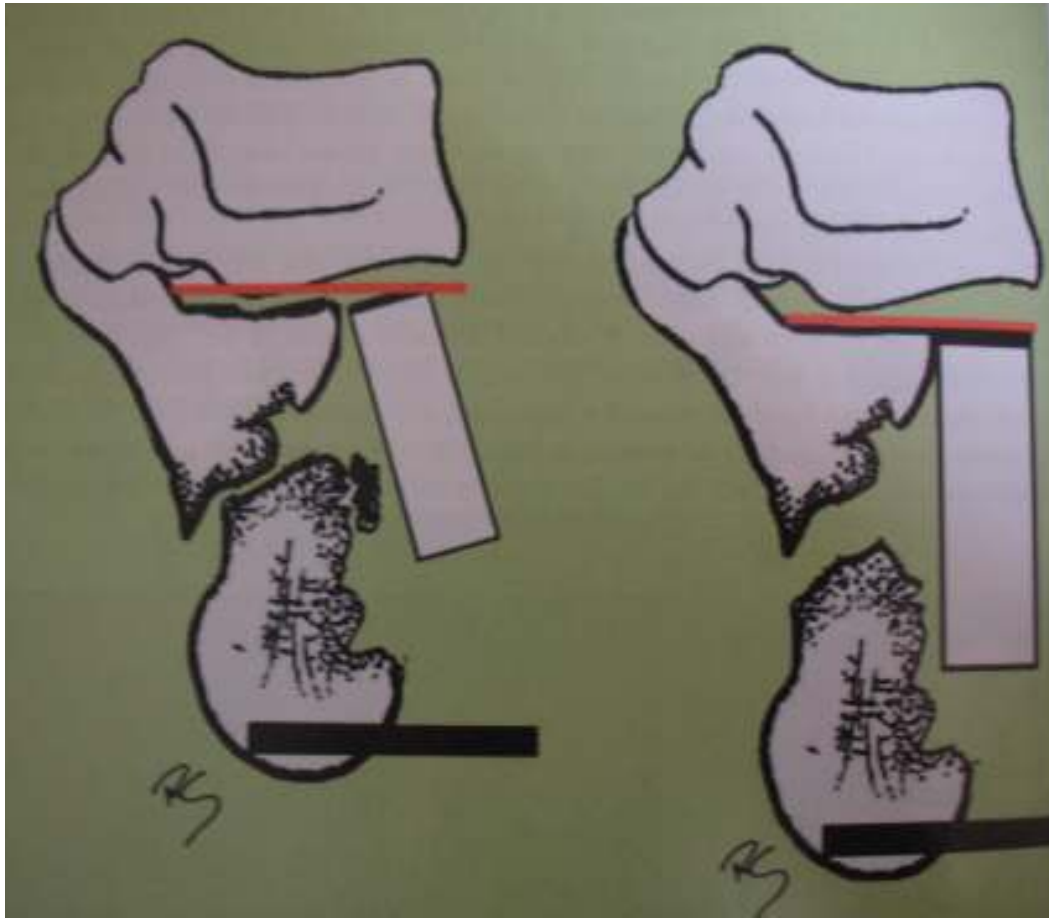
Approach


INFERIOR PERONEAL TENDON SHEATH

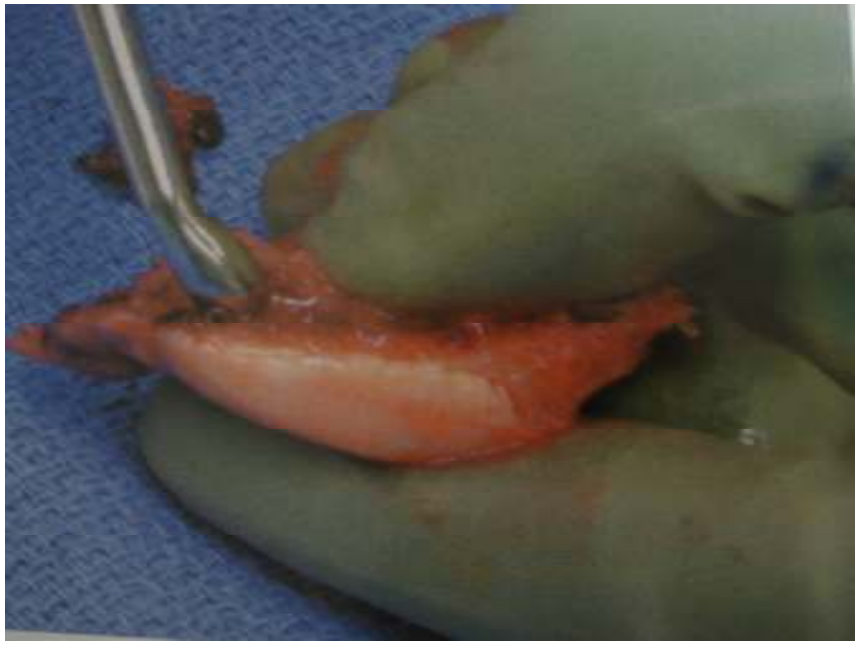

INFERIOR SHEATH
RESECTED FROM LATERAL WALL


FIBULA
TALUS
CUBOID

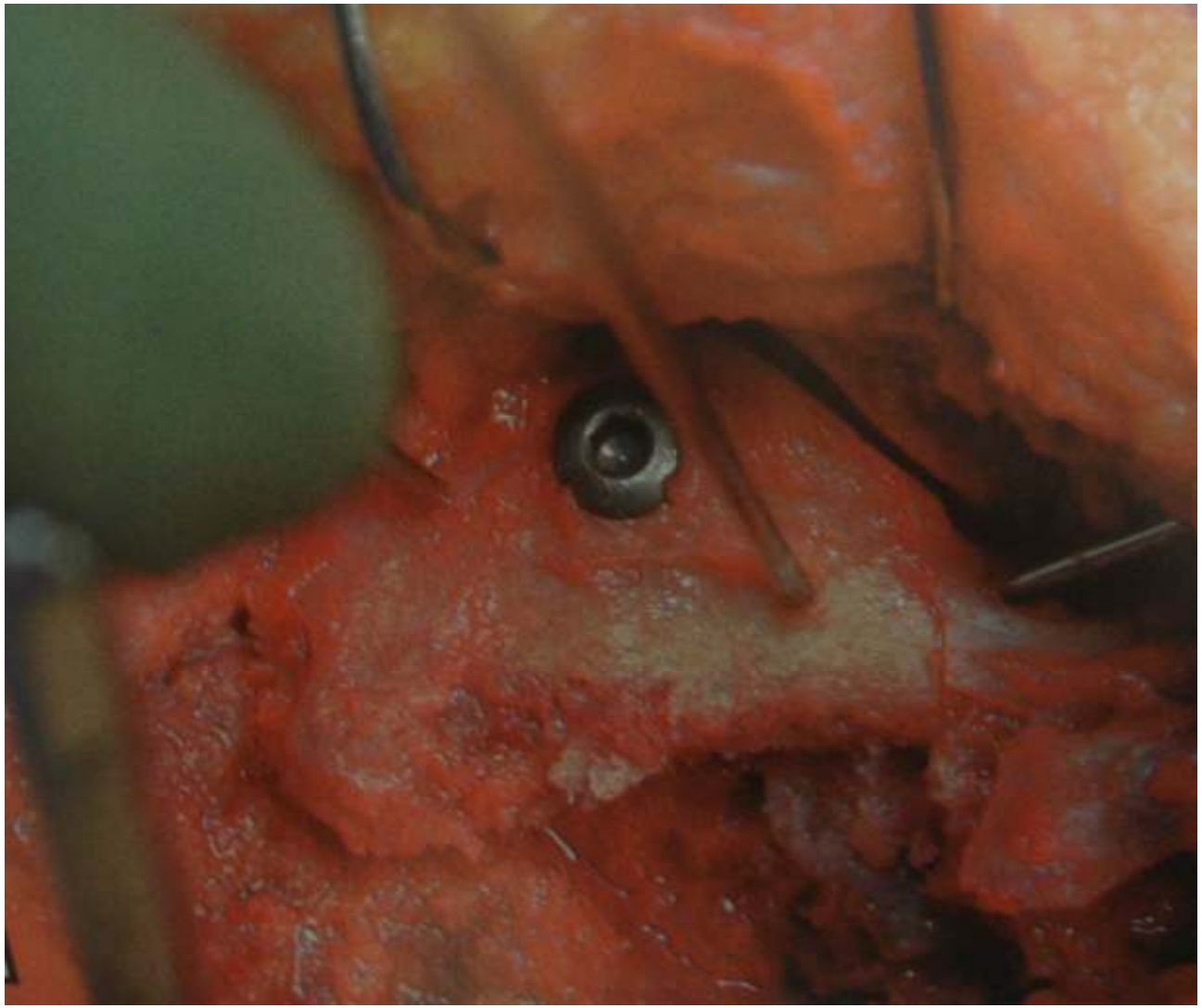
Reduction

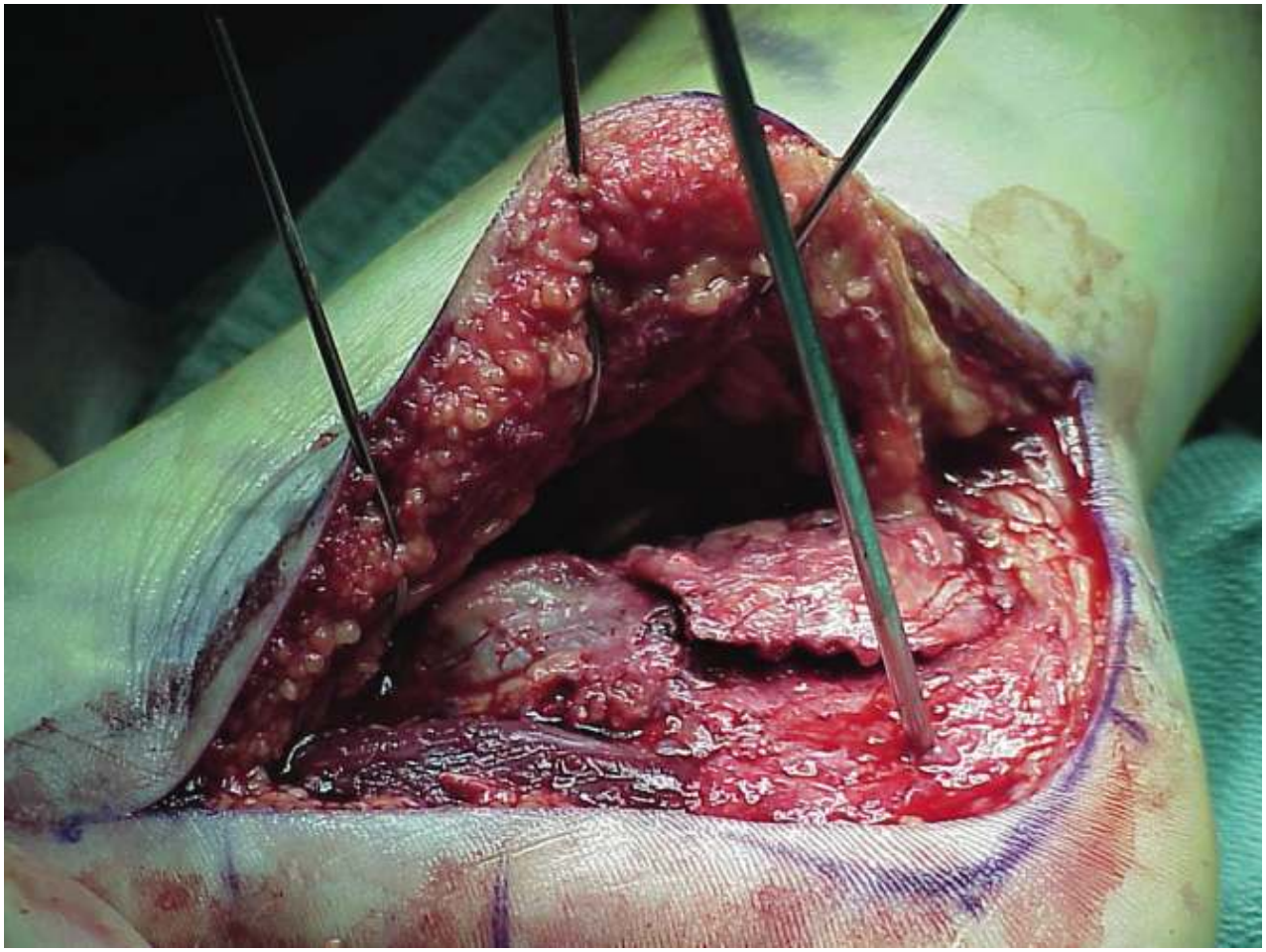


Reduction



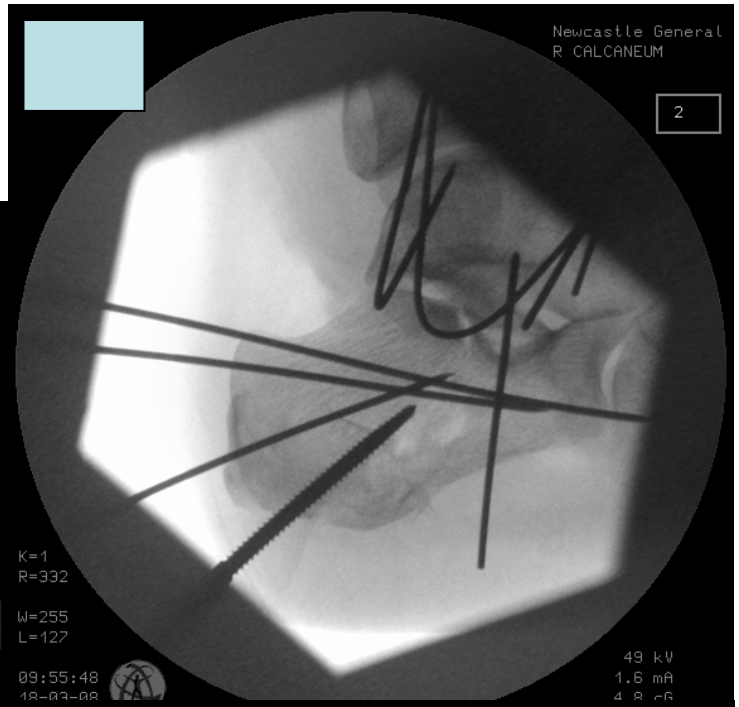
Articular Reduction

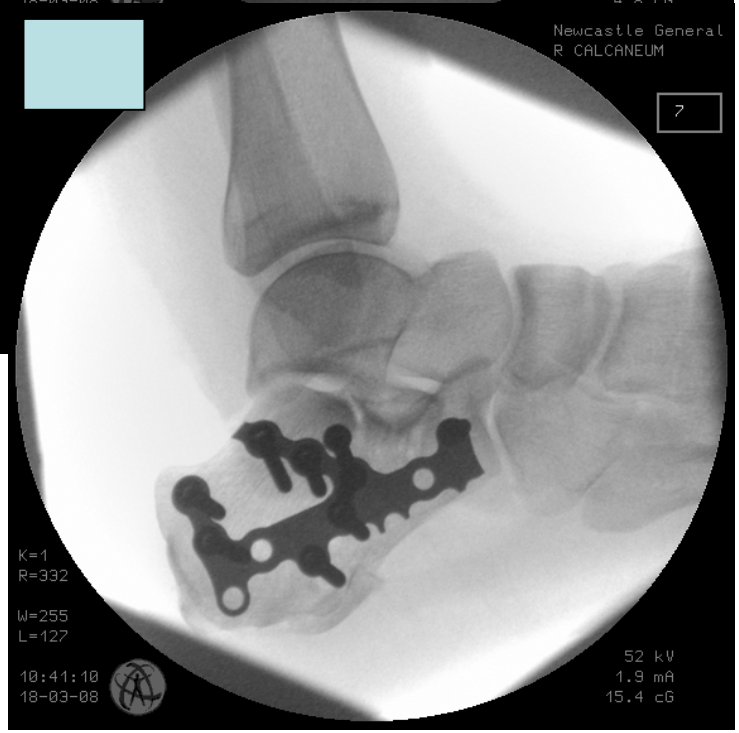


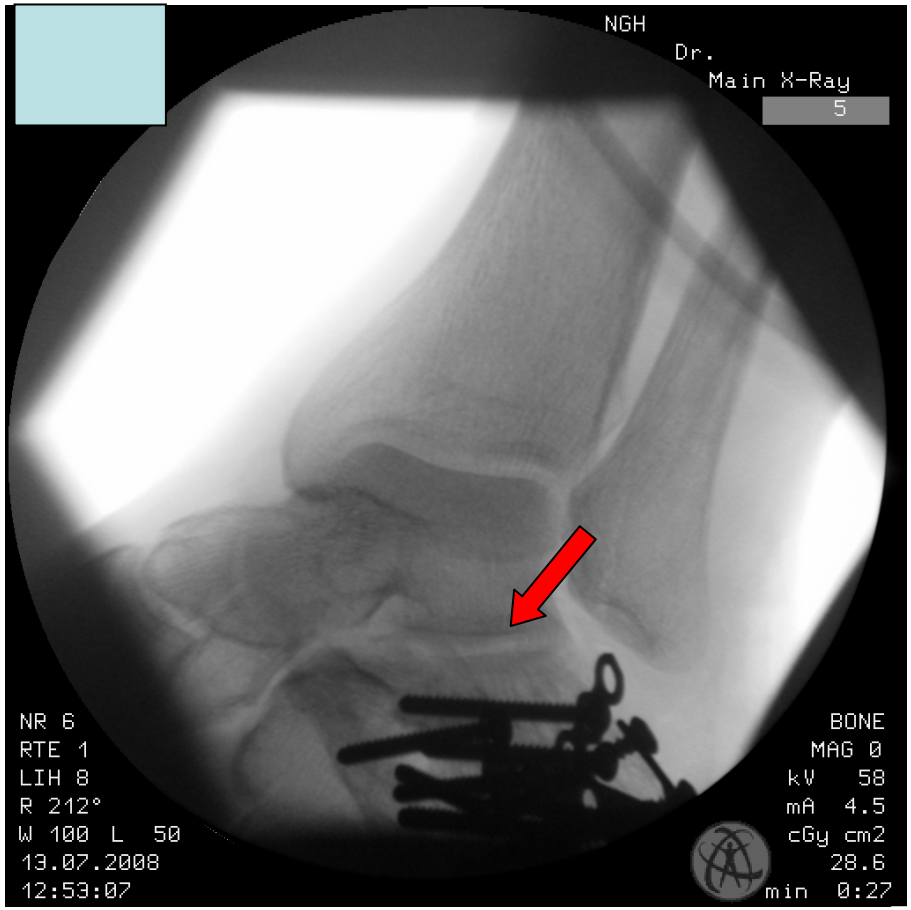


Imaging


Newcastle General
R CALCANEUM
1
K=1
R=332
W=255
L=127
09:53:14
18-03-08
43 kV
0.7 mA
3.7 cG


Newcastle General
R CALCANEUM
2
K=1
R=332
W=255
L=127
09:55:48
49 kV
1.6 mA


Newcastle General
R CALCANEUM
7
K=1
R=332
W=255
L=127
10:41:10
18-03-08
52 kV
1.9 mA
15.4 cG


NGH
Dr.
Main X-Ray
5
NR 6
RTE 1
LIH 8
R 212°
W 100 L 50
13.07.2008
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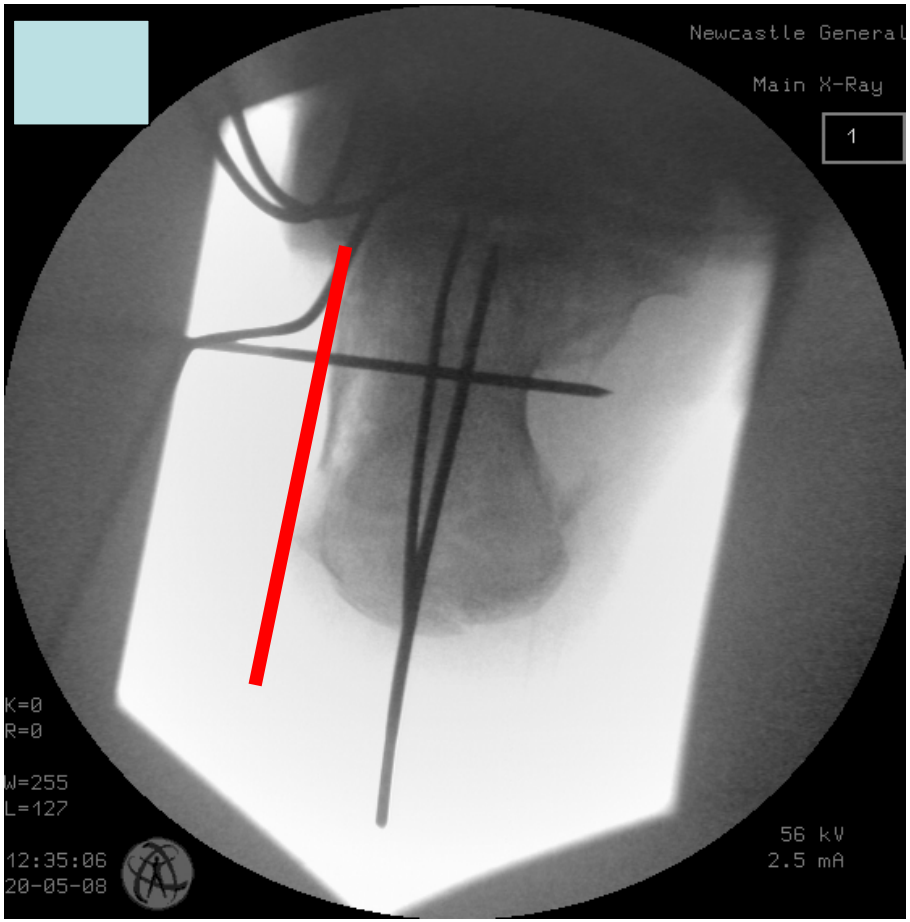
BONE
MAG 0
kV 58
mA 4.5
cGy cm2
28.6
min 0:27


Newcastle General
Main X-Ray
1
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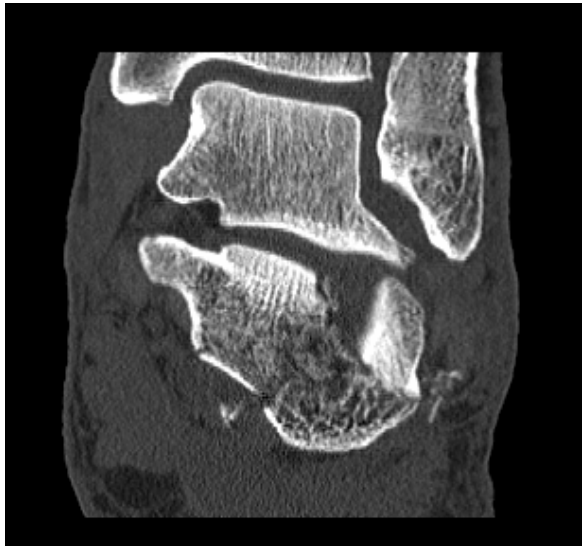
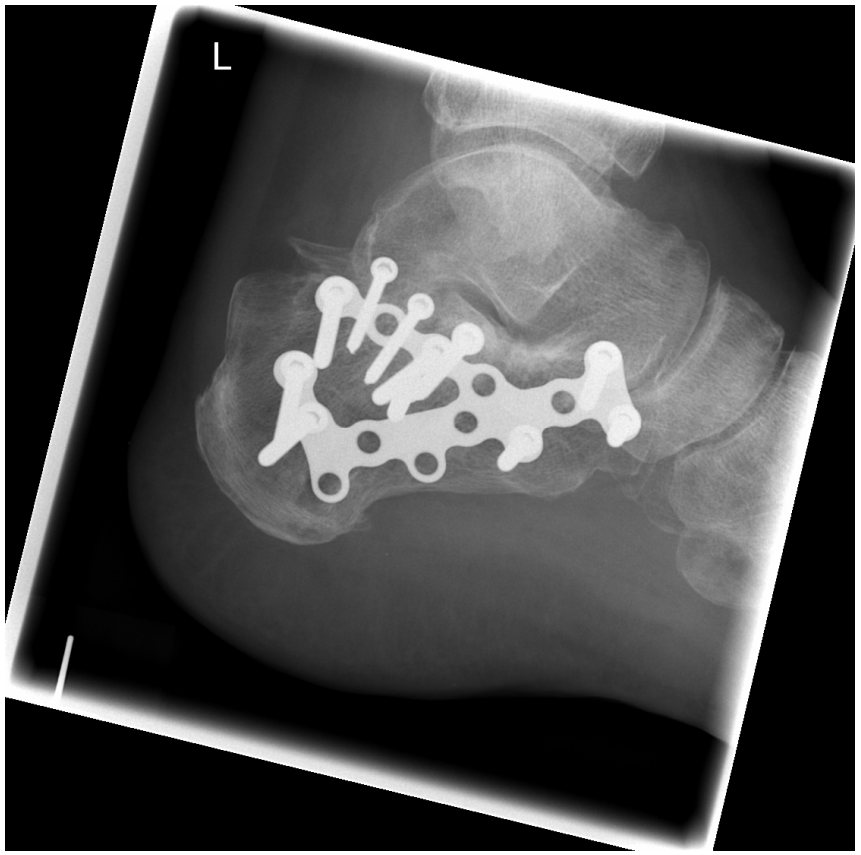
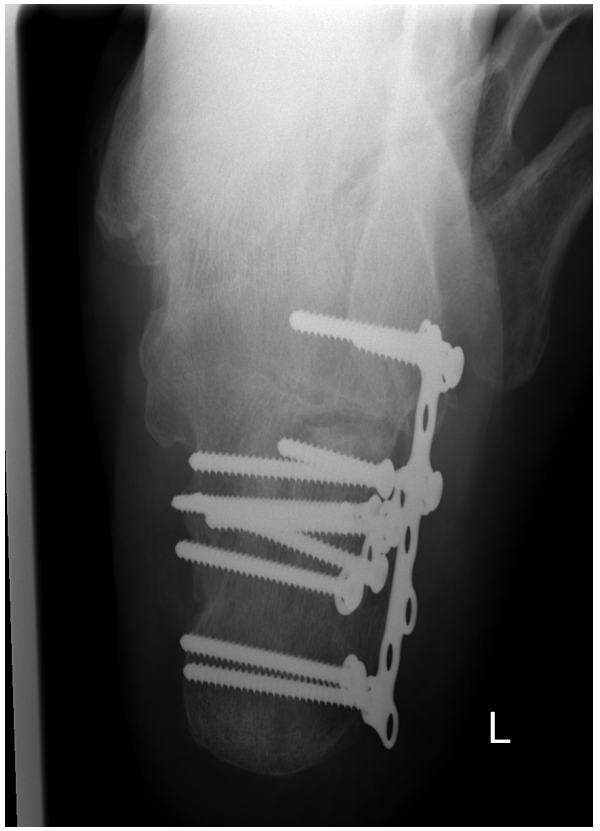
R=0
W=255
L=127
12:35:06
20-05-08
56 kV
2.5 mA

Closure

Case




L


L

Surgical Technique

Approach

- extensile lateral is most popular
-

- Technique
  - provisional fixation with Kirschner wires
  - reduction with low profile implants

- Postsurgical
  - Drain, dorsi-wedge splint
  - early supervised subtalar ROM exercises
  - NWB for ~12 weeks

Surgical Outcome

- Correlate with
  - number of intra-articular fragments
  - quality of articular reduction

- Factors associated with a poor outcome
    - (Howard et al, JOT 2003)
  - age > 50
  - obesity
  - manual labour
  - workers comp
  - smokers
  - bilateral calcaneal #x
  - vasculopathies
  - men do worse with surgery than women

Complications

- Wound complications (10-20%)
  - increase risk in smokers and diabetics
- Subtalar post-traumatic arthritis
- Compartment syndrome (10%)
  - results in clawing of the toes
- Heel deformities/malunion
- Osteomyolitis
- Amputation

An economic evaluation of operative compared with nonoperative management of displaced intra-articular calcaneal fractures JBJS Am, 2005(87):2741-9

- II
- Lower rate of ST fusion
- Shorter time off work
- More cost effective

Age

- Children
- <14yrs good results any treatment
- 15-17yrs better with operative
- Extra-articular treat non-operatively

- Ceccarelli et al., FAI 2000, 21: 825-832

Case


RT
*


L
*

Bilateral Injuries

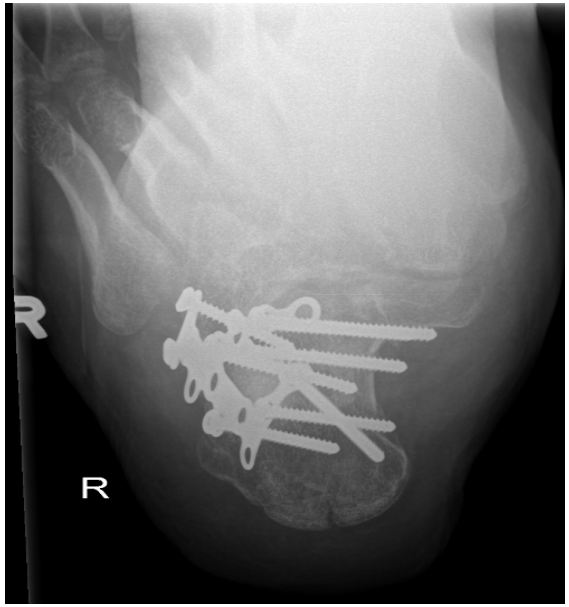
- Less successful outcomes
- Gait & occupation compromised

- Dooley et al., Foot Ankle Int 2004 (25):47-52


L


R


L


R
R

Subtalar Fusion

- Sanders IV early fusion Vs ORIF
- No difference

- Late fusion similar results to early ORIF
  - Csizy et al., JOT 2003, 17:106-112

- Subtalar fusion after displaced intra-articular calcaneal fractures:does initial operative treatment matter?
- Radnay/Clare/Sanders
- JBJS Am, 2010(92 suppl) 32-43
- Cohort III

- Better function

- Fewer wound complications

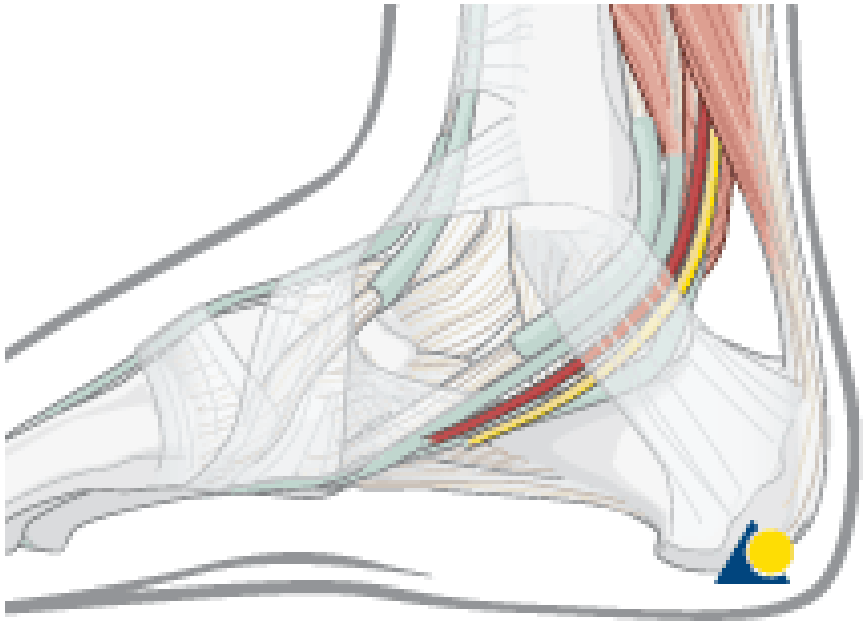
  – Ass with ST fusion following ORIF as initial treatment

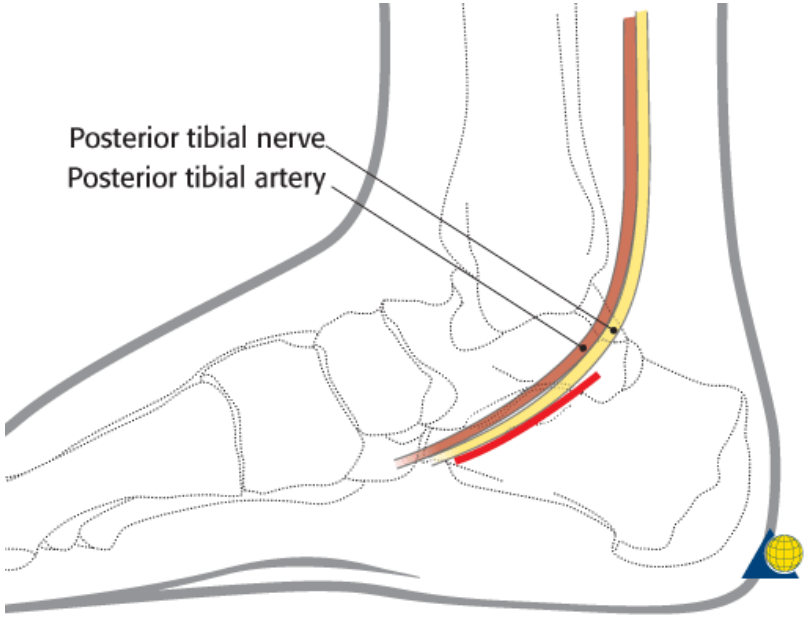
Conclusion

- Not for occasional surgeon!
  - (refer appropriately)
  - JBJS Am 2008 (90) 1013-21 – Poeze et al.,
  - “The relationship between the outcome of operatively treated cal #s & institutional # load”

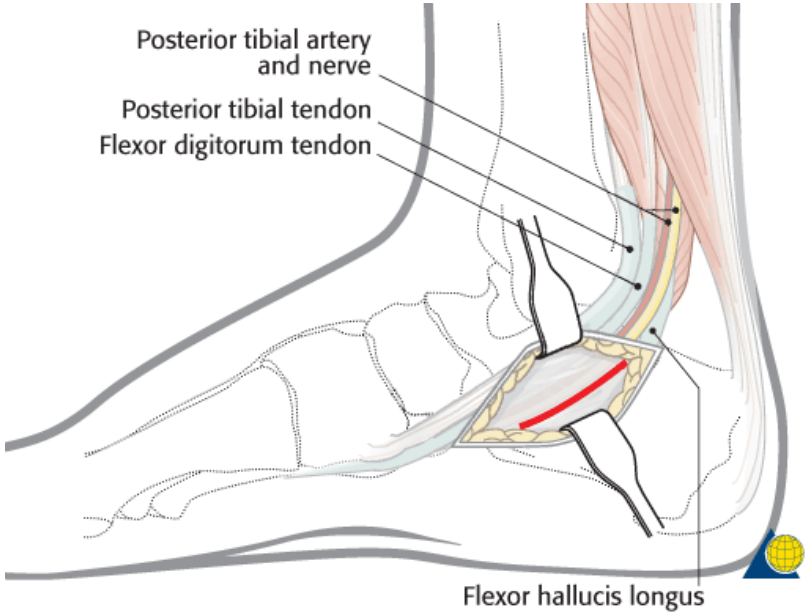
- ORIF Rx of choice
  - As long as complications minimised
  - Review patient characteristics

Medial Approach

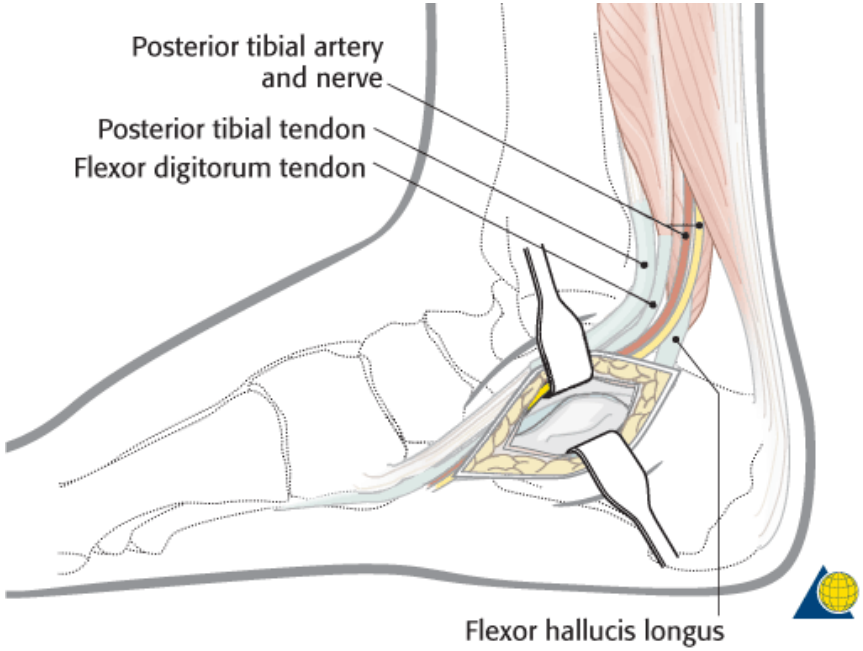




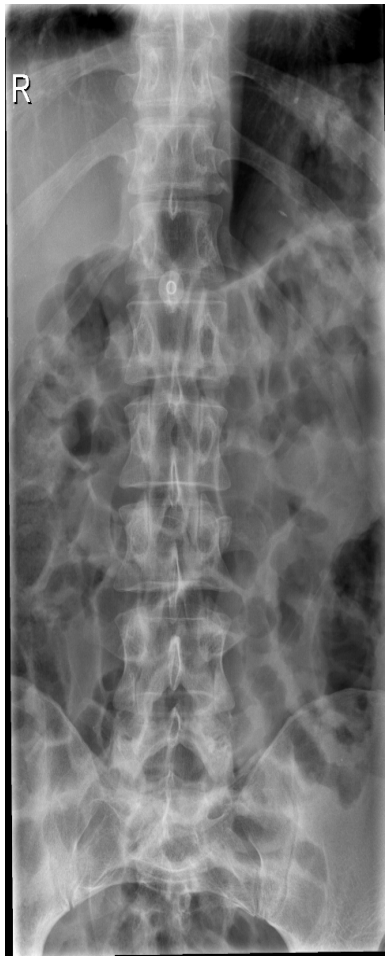
2 cm beneath the medial malleolus and 2 cm proximal to the navicular



- Interval between
- posterior tibial nerve
- flexor hallucis tendon, which is retracted distally
- You must incise the retinaculum and feel for the bump which is the sustentaculum. It is immediately above the flexor hallucis tendon.


Posterior tibial artery
and nerve
Posterior tibial tendon
Flexor digitorum tendon
Flexor hallucis longus


R

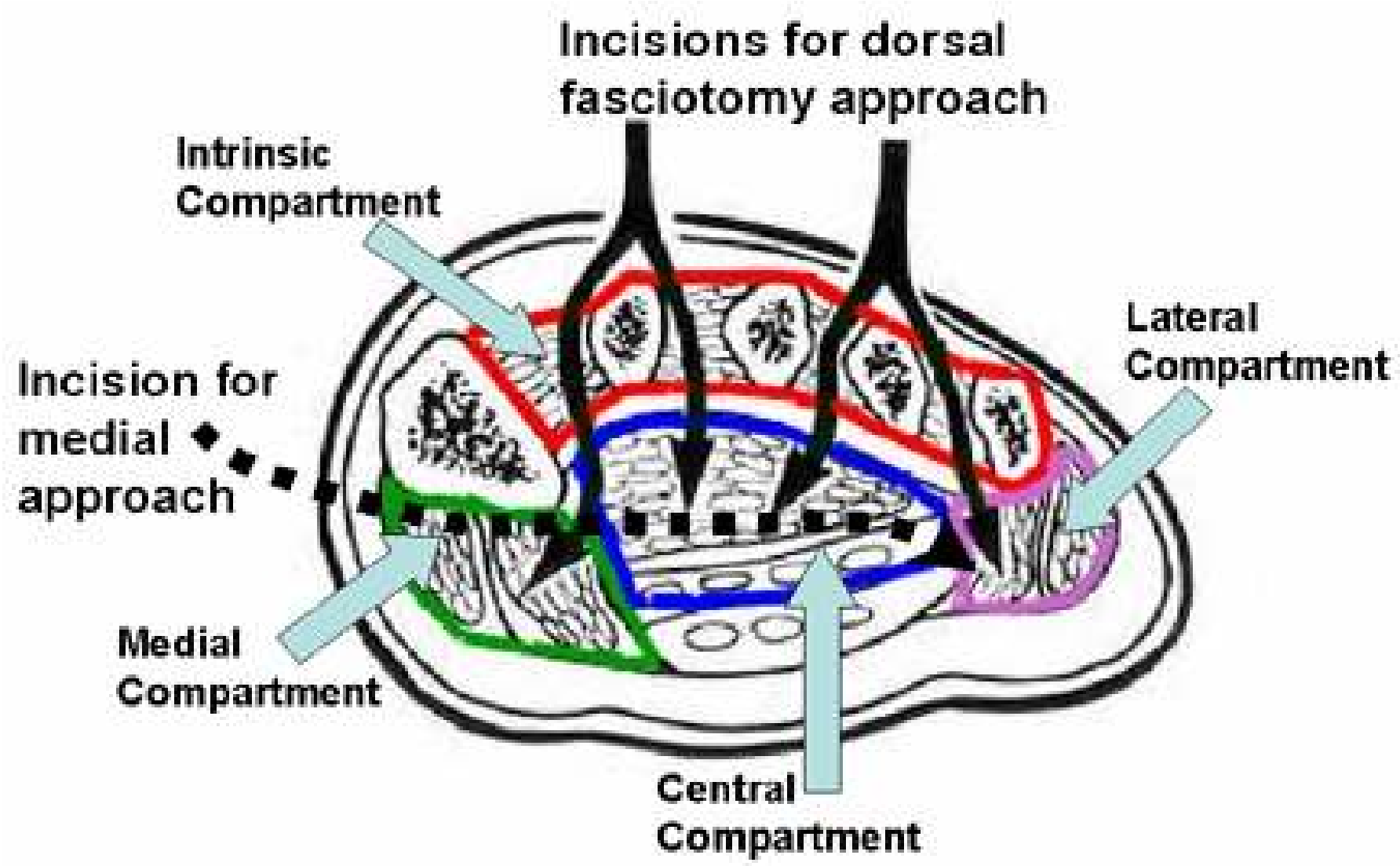

R


L


L

Compartment Syndrome of the Foot

- 10% of calcaneal fractures
- 41% of crush injuries of the foot.
- no classic signs in the foot.
- Pain on passive stretch and diminished pulses are not consistent physical findings.
- Tense tissue bulging may be the most reliable finding.
- high index of suspicion.
- Absolute pressures > 30 mm Hg or pressures less than 20 mm Hg below the diastolic blood pressure requires decompression.


Incisions for dorsal fasciotomy approach
Intrinsic Compartment
Incision for medial approach
Lateral Compartment
Medial Compartment
Central Compartment

Interosseous or Intrinsic compartment

4 intrinsic muscles between the 1st & 5th metatarsals

Medial compartment

abductor hallicus

flexor hallicus brevis

Central or calcaneal compartment

flexor digitorum brevis

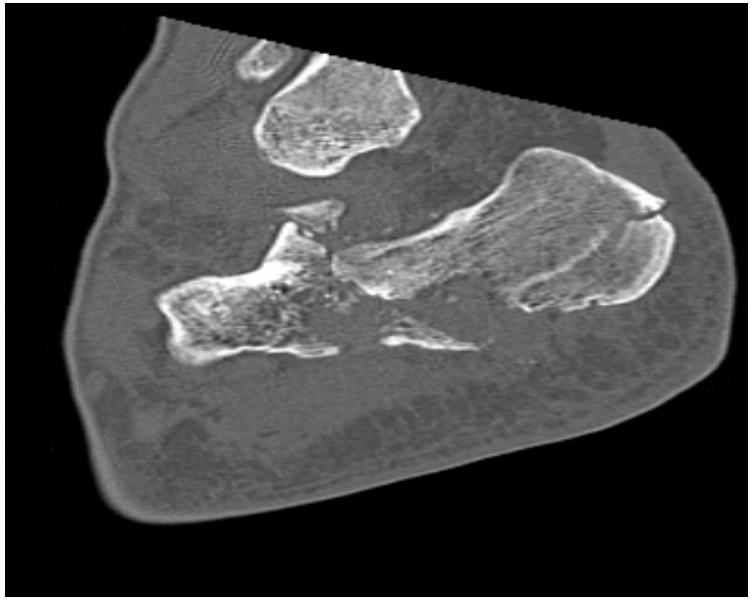
quadratus plantae

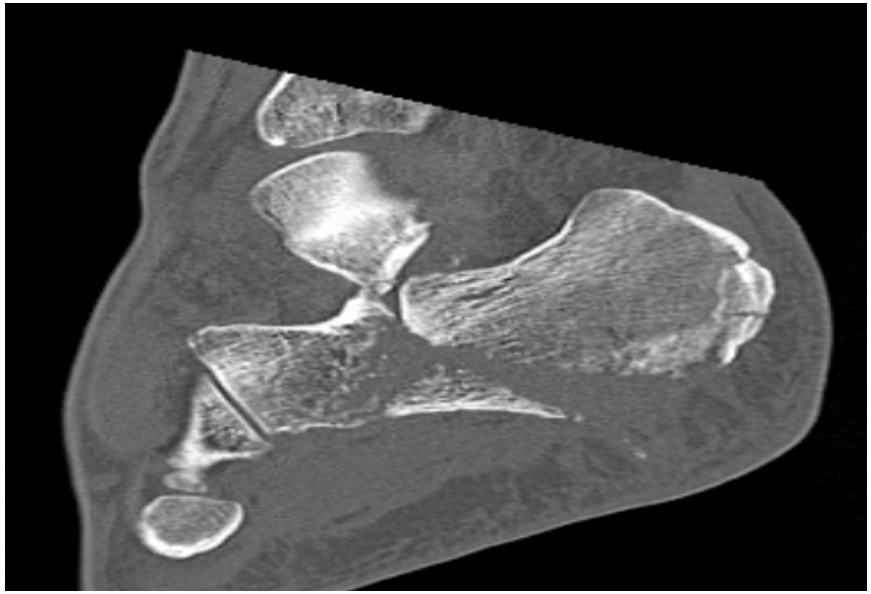
adductor hallicus

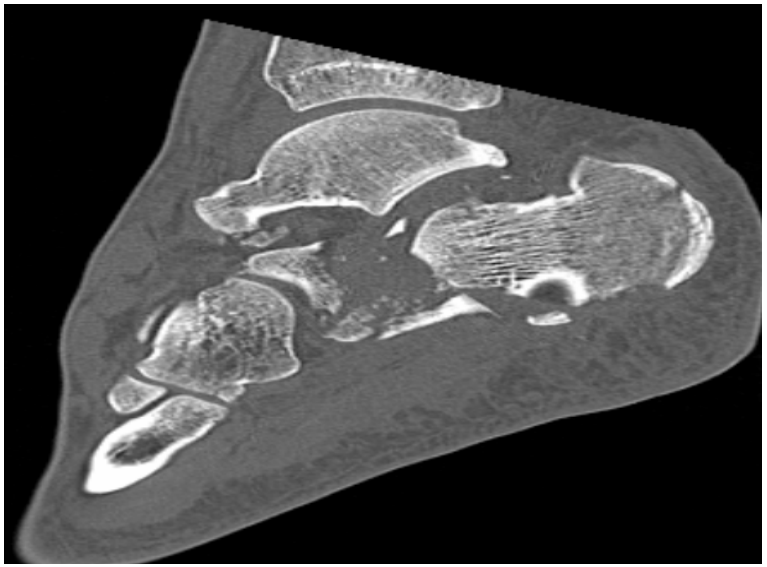
Lateral compartment

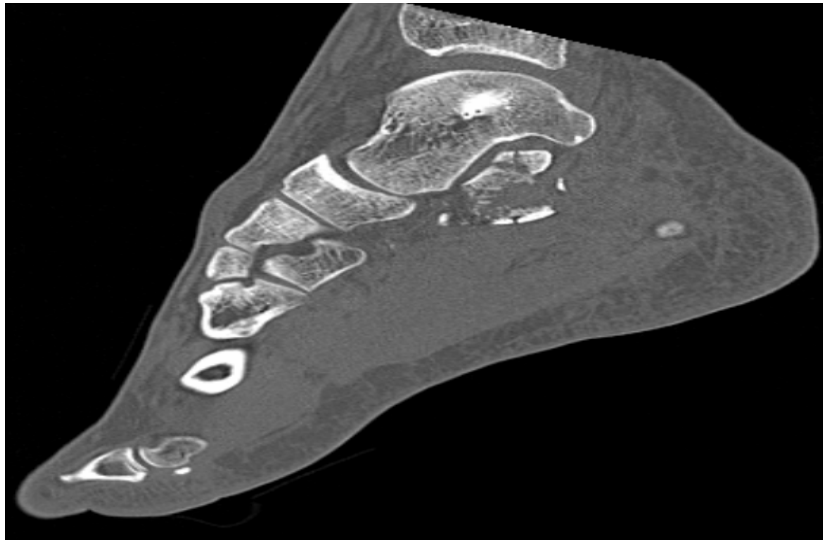
flexor digiti minimi brevis

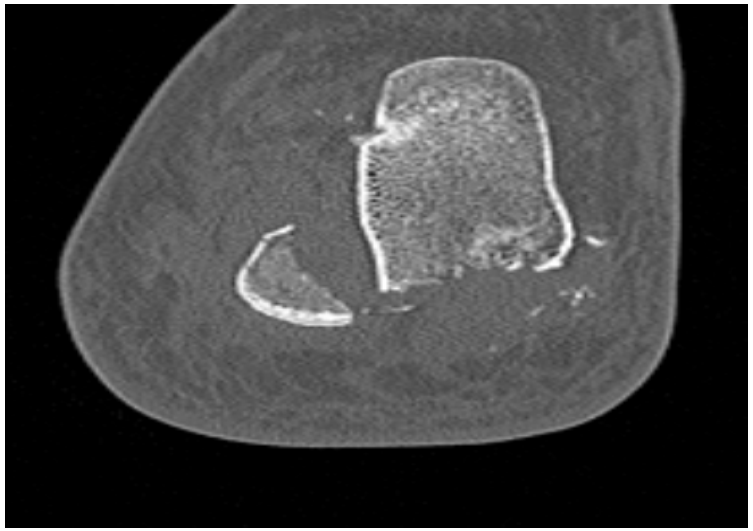
abductor digiti minimi

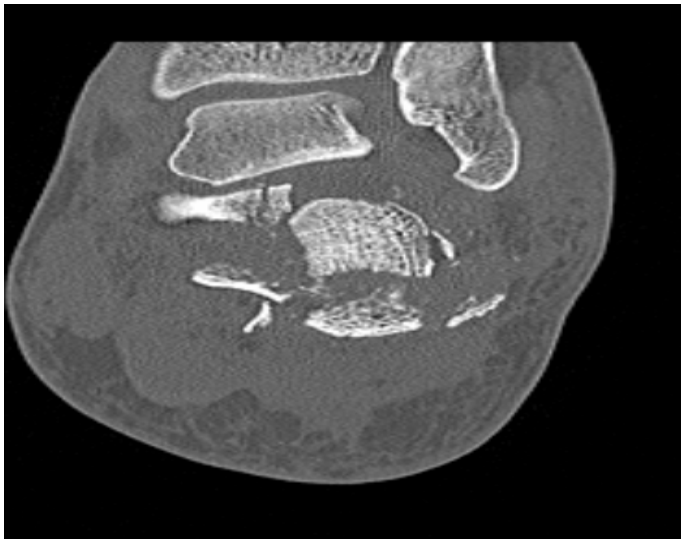


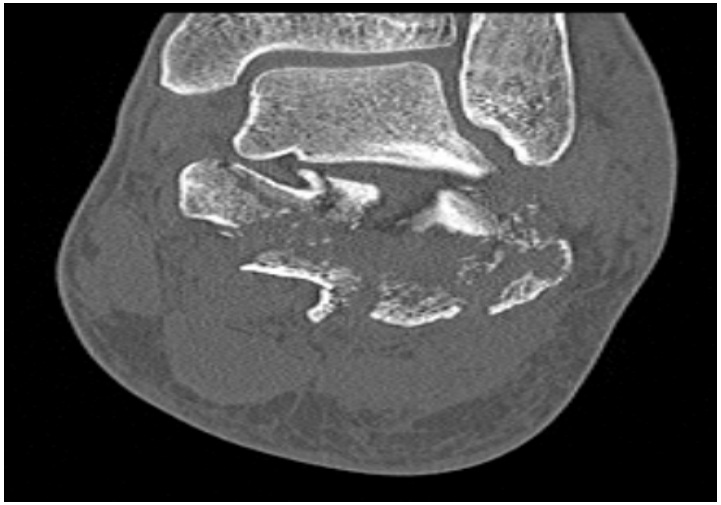


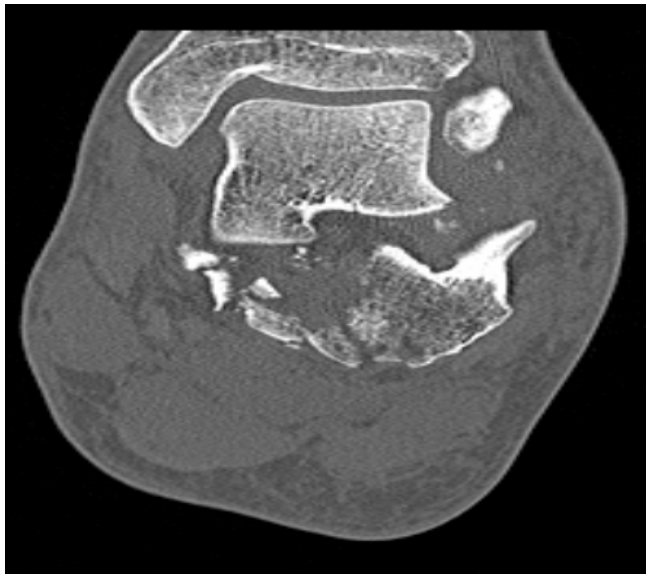


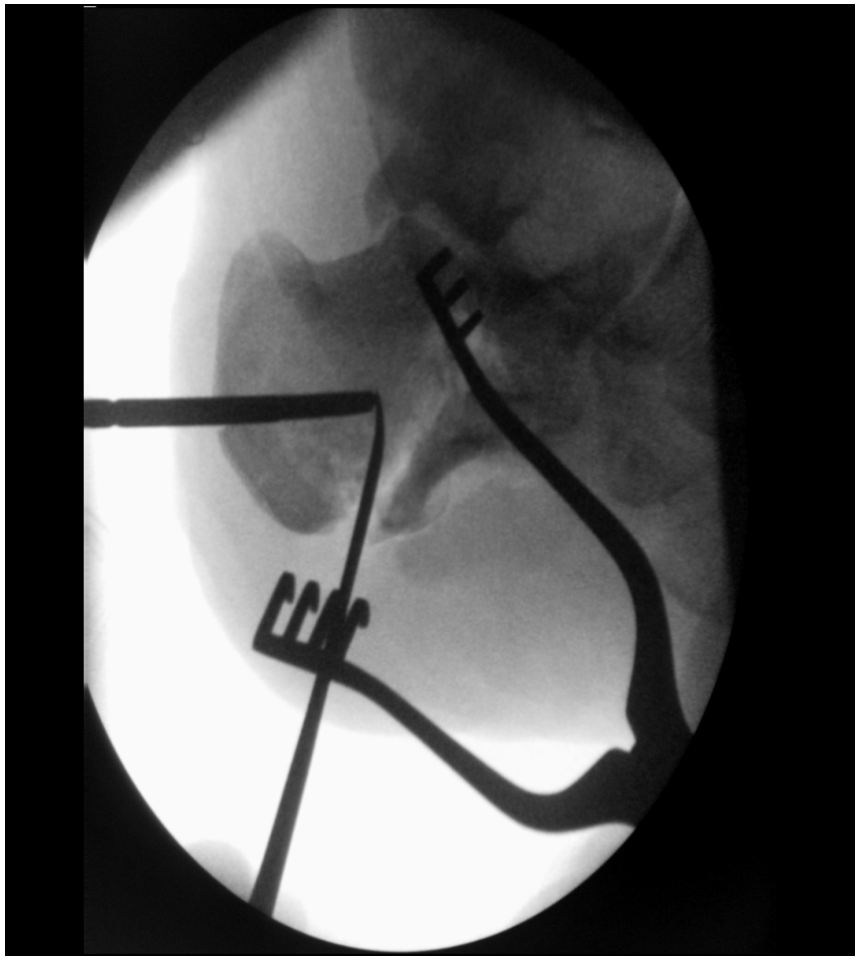


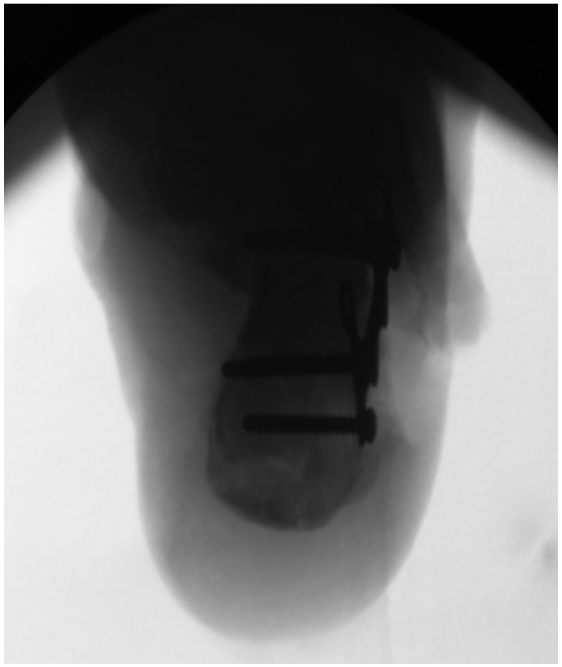


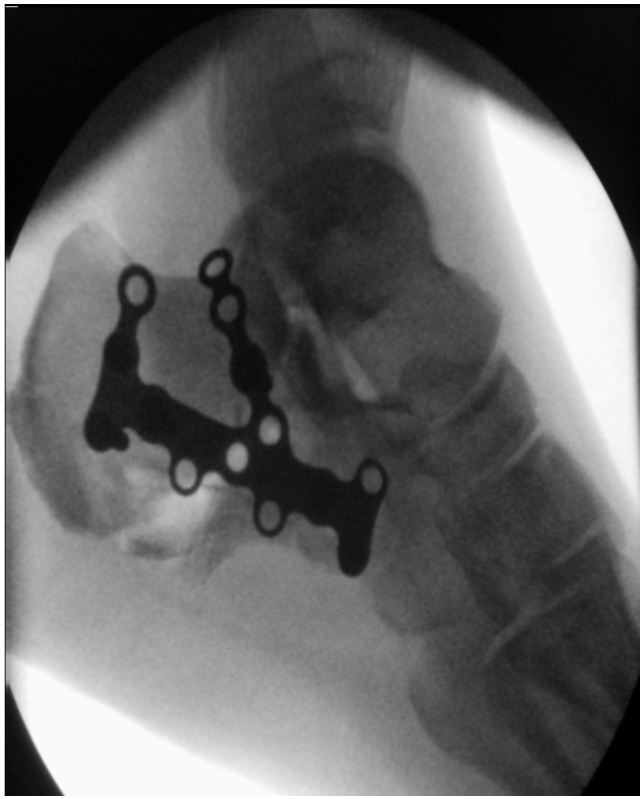


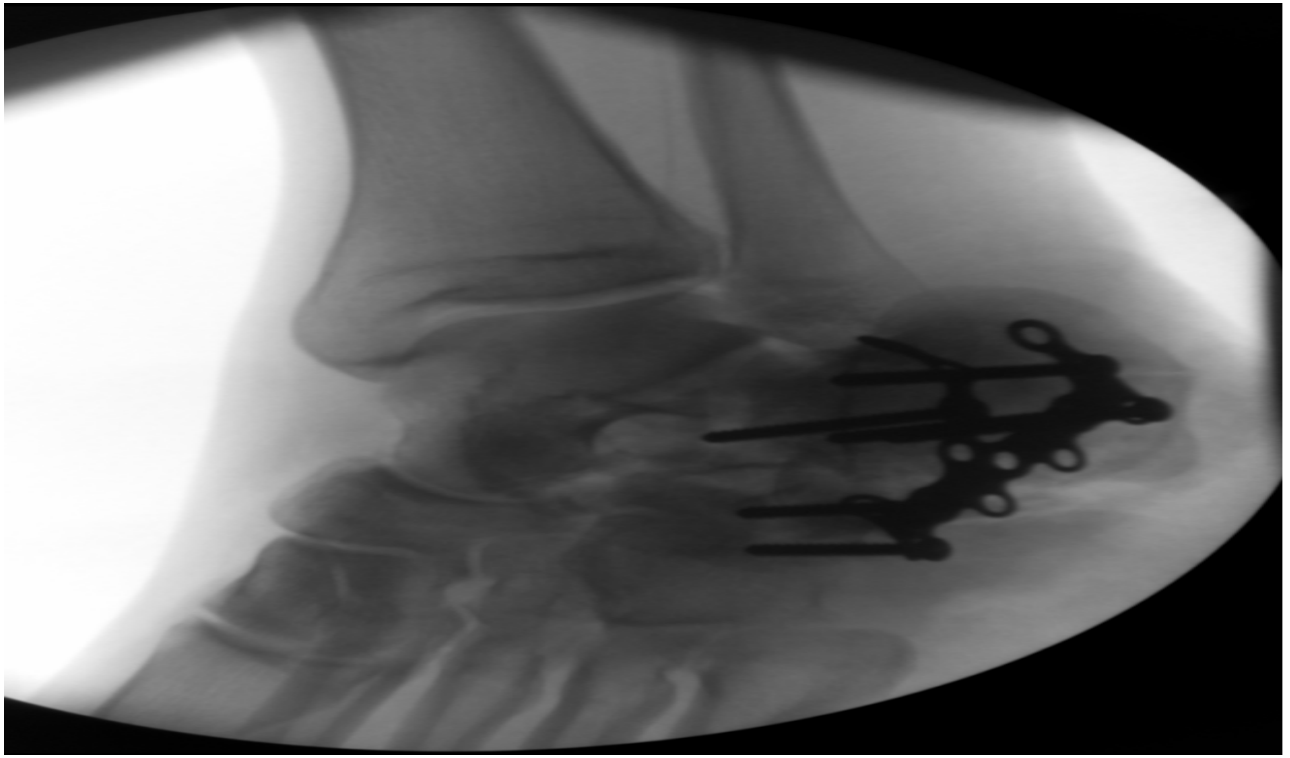




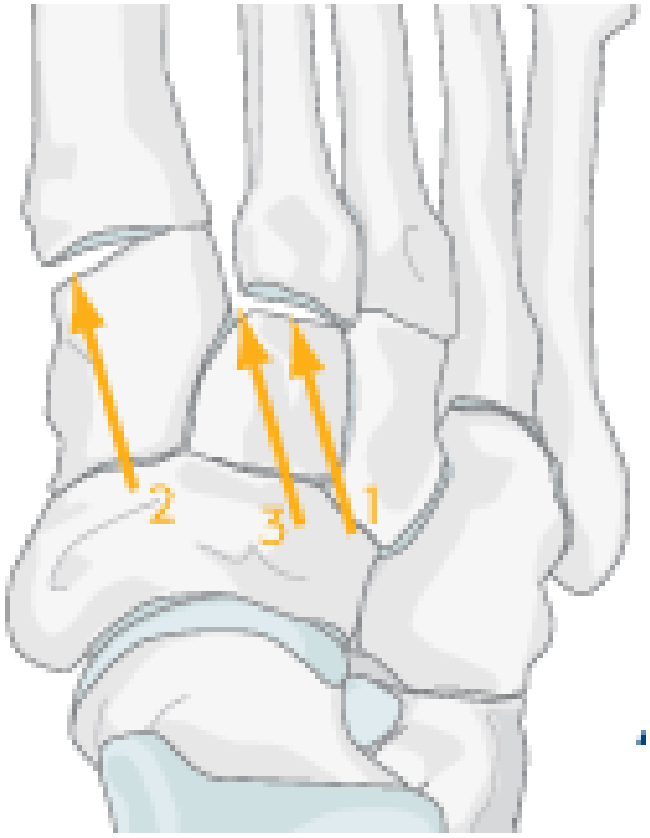




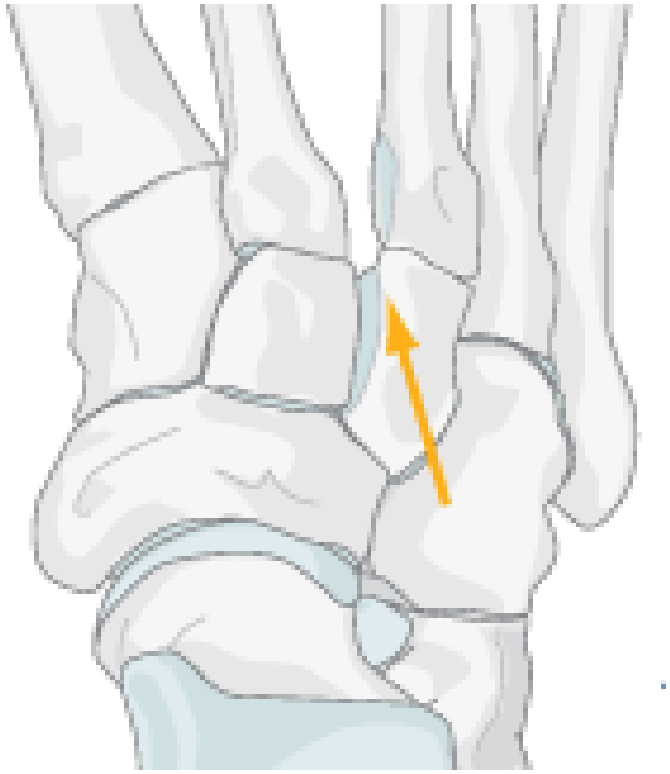




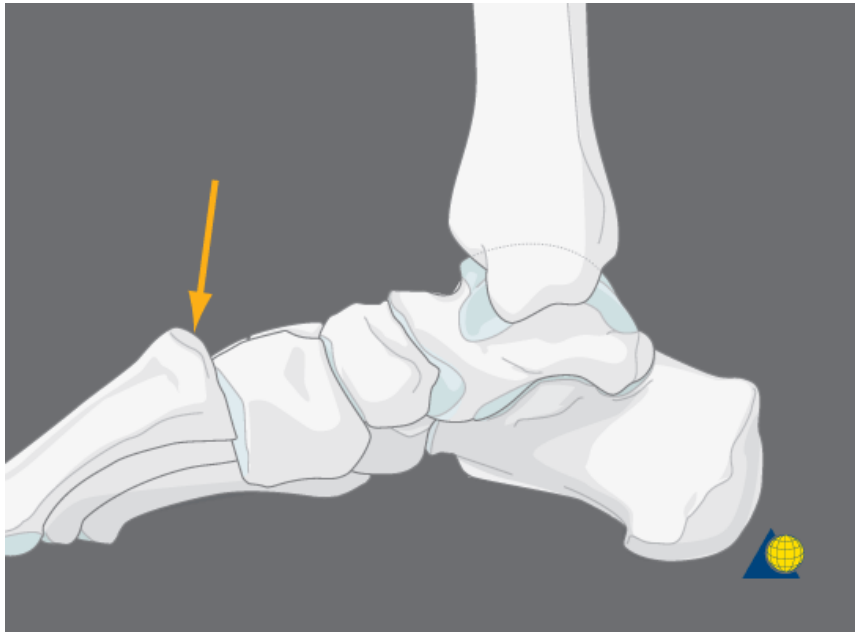
Lisfranc



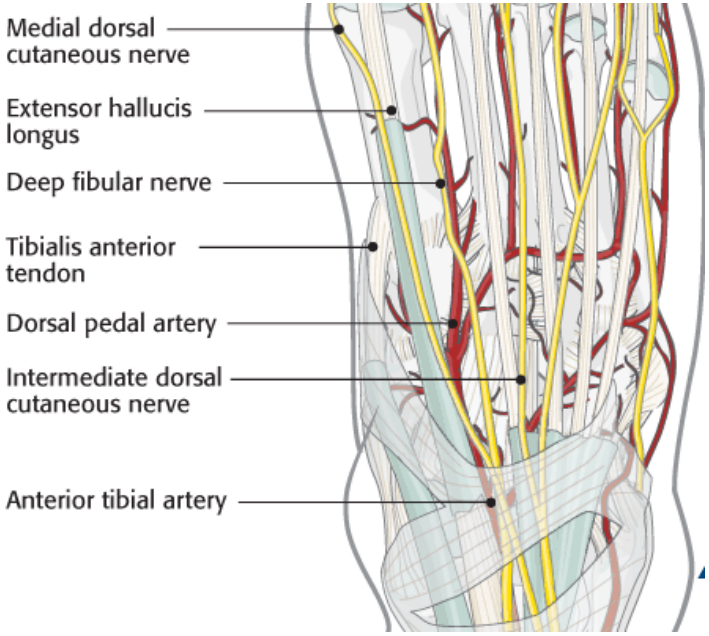
- 1 Lateral displacement of 2nd metatarsal on intermediate cuneiform
- 2 TMT 1 disruption
- 3 Gap between 1st and 2nd metatarsal

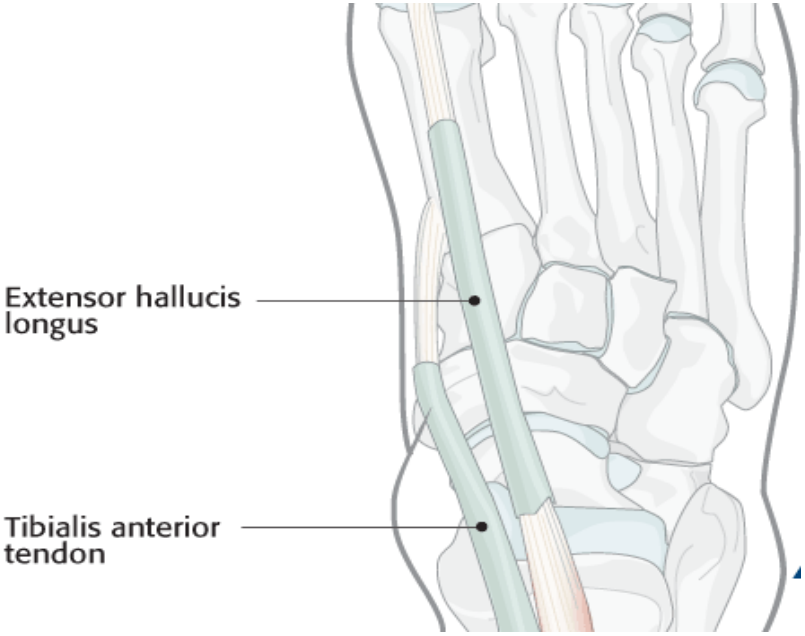


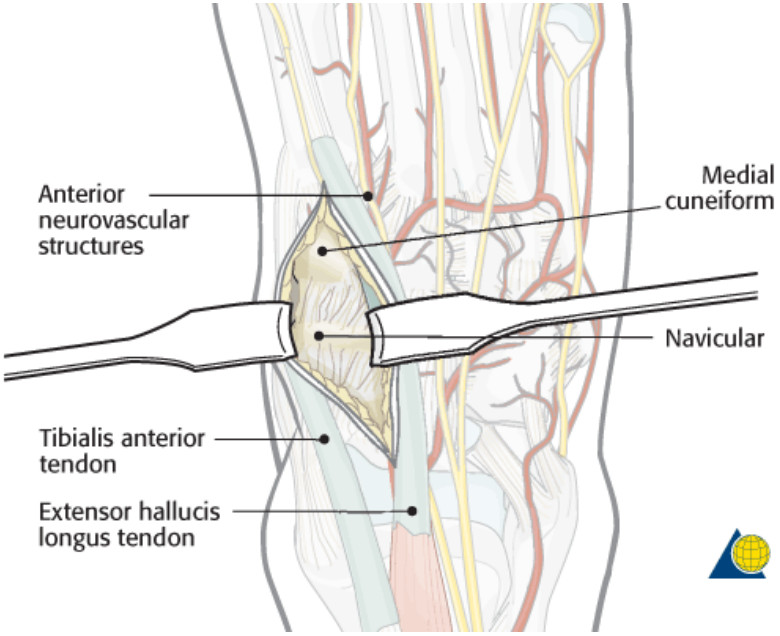
- Lateral displacement of 3rd metatarsal on lateral cuneiform



- Dorsal displacement of the metatarsal bases above the level of the cuneiforms is abnormal and indicates a Lisfranc injury


Medial dorsal cutaneous nerve
Extensor hallucis longus
Deep fibular nerve
Tibialis anterior tendon
Dorsal pedal artery
Intermediate dorsal cutaneous nerve
Anterior tibial artery

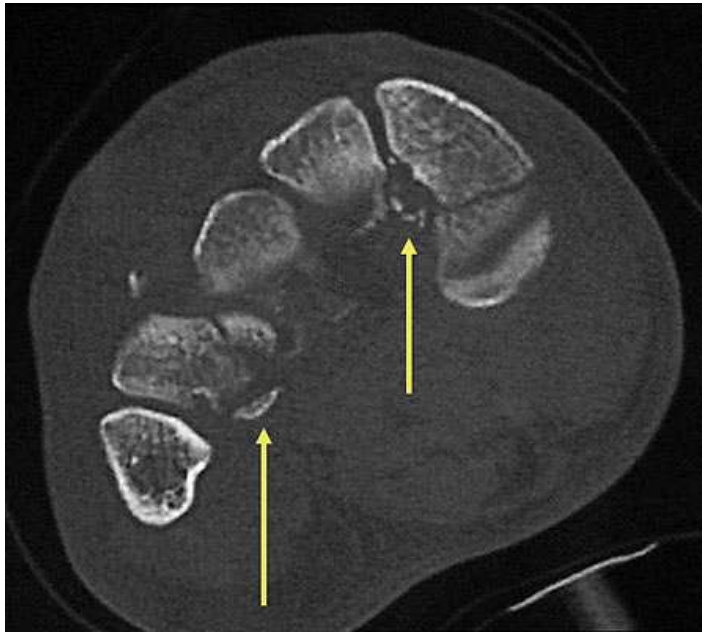

Extensor hallucis longus
Tibialis anterior tendon

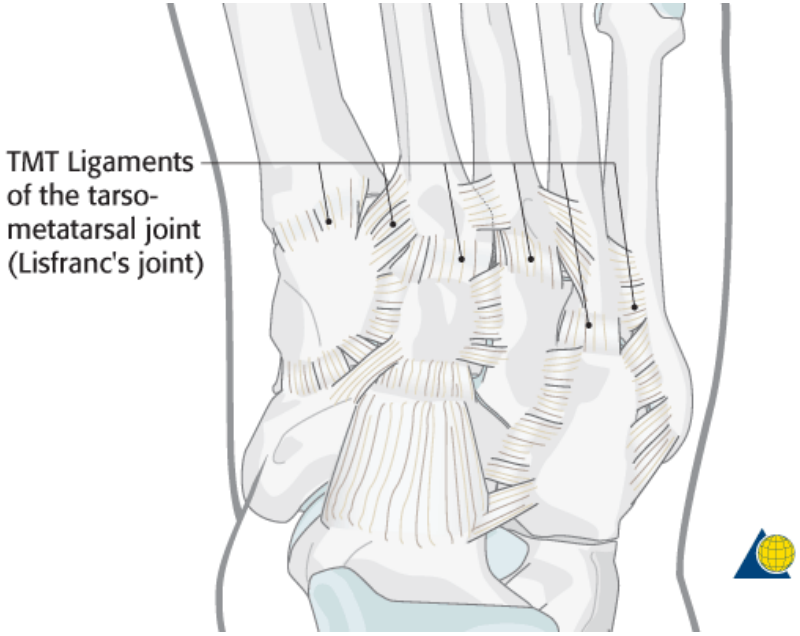

Anterior
neurovascular
structures
Medial
cuneiform
Navicular
Tibialis anterior
tendon
Extensor hallucis
longus tendon

Diagnosis

- Suspicious of history
- Clinical exam/bruising
- Radiographs
- Stress views
- CT/MRI

- Stress x-ray



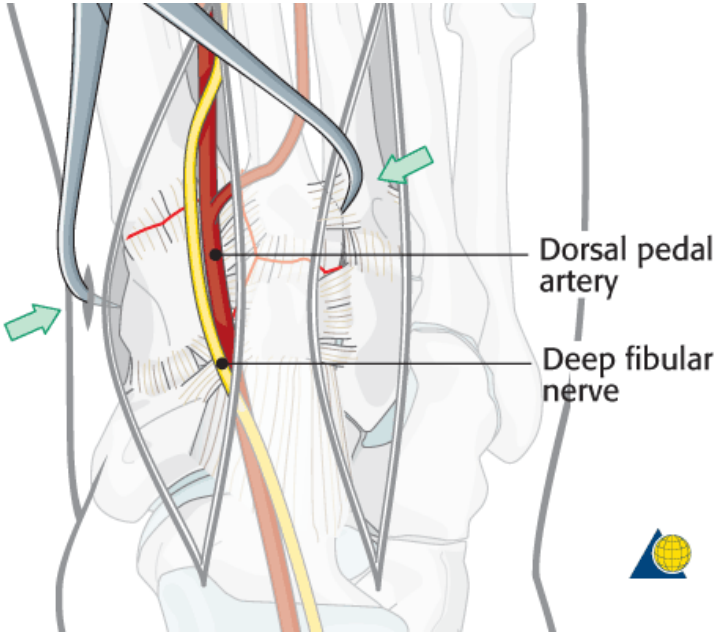

TMT Ligaments
of the tarso-
metatarsal joint
(Lisfranc's joint)

Approach

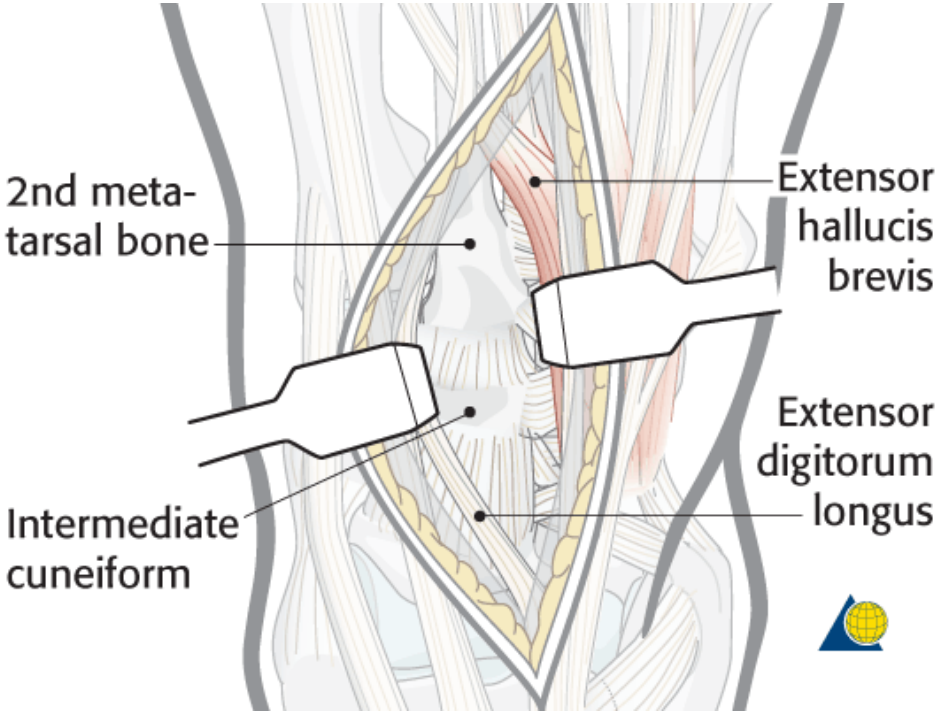
- **Dorsal double parallel and medial mini approach**
- never be undermine

- Dorsomedial incision over the TMT area (EHL & EHB)
- access to the first TMT and the medial base of the 2nd TMT

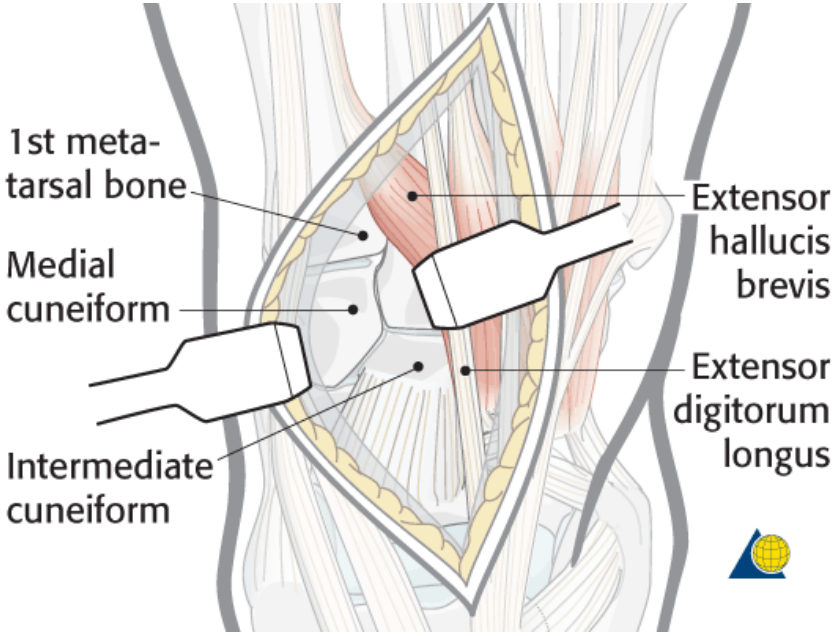
- Dorsolateral incision roughly in line with the IVth metatarsal
- A skin bridge as wide as possible should be maintained. But, as long as the area between the incisions is not undermined, the skin bridge is not compromised.

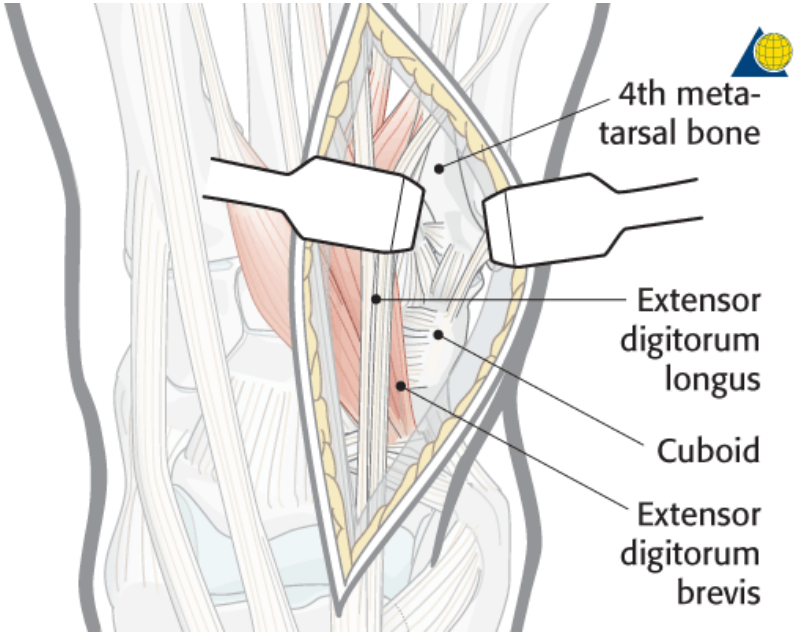


- **Access**
- The dorsomedial full-thickness incision allows access to the 1st TMT and medial area of the 2nd TMT
- The dorsolateral full-thickness incision allows access to the lateral area of the second TMT
- Work back and forth to reduce and fix the 2nd TMT taking care not to undermine the middle area between the incisions
- Care should be taken not to disturb the neurovascular bundle between the incisions in the flap
- The joints can be distracted with a bone spreader allowing access to soft-tissue interposition and bony fragments. These can be debrided and removed to allow perfect reduction of the base of the 2nd MT into the "keystone" corner of the TMT joint

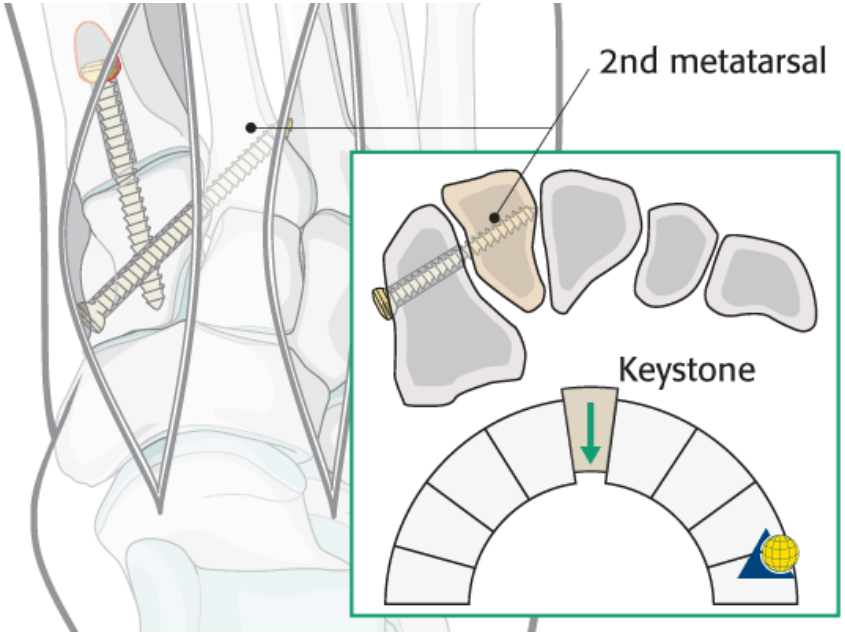


- **Alternative incision**
- An alternative approach is the extensile dorsal salvage incision (EDSI/Zwipp)
- The EDSI is useful in extreme injuries (combined foot and leg injuries)
- It starts at the base of the second toe and runs straight up the foot to the ankle, and if needed it can be extended proximally along the anterior compartment of the leg.
- In the foot, it can be used for decompression as well as approach for ORIF.


1st meta-
tarsal bone
Medial
cuneiform
Intermediate
cuneiform
Extensor
hallucis
brevis
Extensor
digitorum
longus


4th meta-
tarsal bone
Extensor
digitorum
longus
Cuboid
Extensor
digitorum
brevis

Fixation




R
R


NGH
Dr.
Main X-Ra
NR 1
RTE 1
LIH 8
R 0°
J 100 L 50
26.12.2008
19:17:13
kV
mA
cGy
min


NGH
Dr.
Main X-Ray
L 50
2008
29
BONE
MAG 0
kV 59
mA 4.9
cGy cm2
18.4
min 0:30


R
STANDING


R


R
STANDING
STANDING
R

Primary ORIF compared with delayed corrective arthrodesis in the treatment of tarsometatarsal (Lisfranc) fracture dislocation

- J Bone Joint Surg Br, 2008:(90):1499-506 Rammelt e al., III
- Primary ORIF of Lisfranc fracture-dislocations leads to improved functional results
- earlier return to work
- greater patient satisfaction than secondary corrective arthrodesis
- which remains a useful salvage procedure.

- **Treatment of primarily ligamentous Lisfranc joint injuries: primary arthrodesis compared with open reduction and internal fixation. A prospective, randomized study**
- J Bone Joint Surg Am, 2006:(88):514-20
- Ly & Coetzee RTC

- Anatomic initial reduction was obtained in 18 ORIF patients and 20 arthrodesis patients

- Mean AOFAS Midfoot score was 68.6 points in the ORIF group and 88 points in the arthrodesis group at two years ($P < .005$)

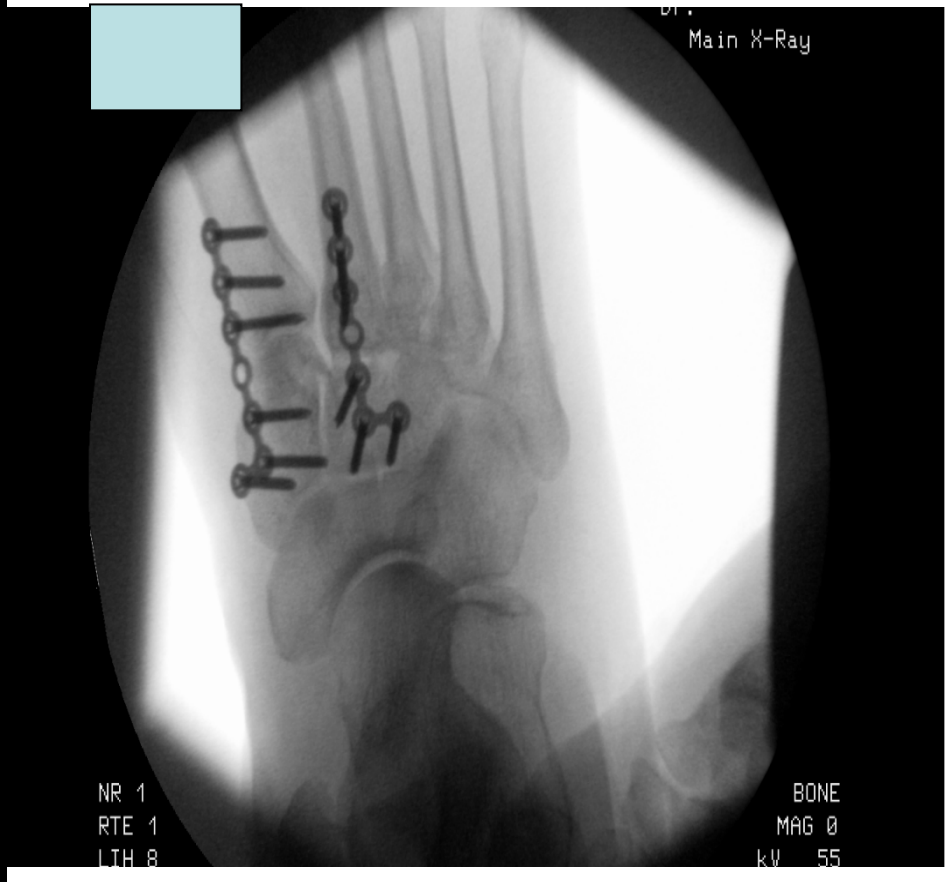
- Persistent pain with development of deformity or osteoarthrosis was found in five ORIF patients who were eventually treated with arthrodesis

- Postoperative level of activities was 65% of their preinjury level for the ORIF patients and 92% of their preinjury level for the primary arthrodesis patients ($P < .005$)


R

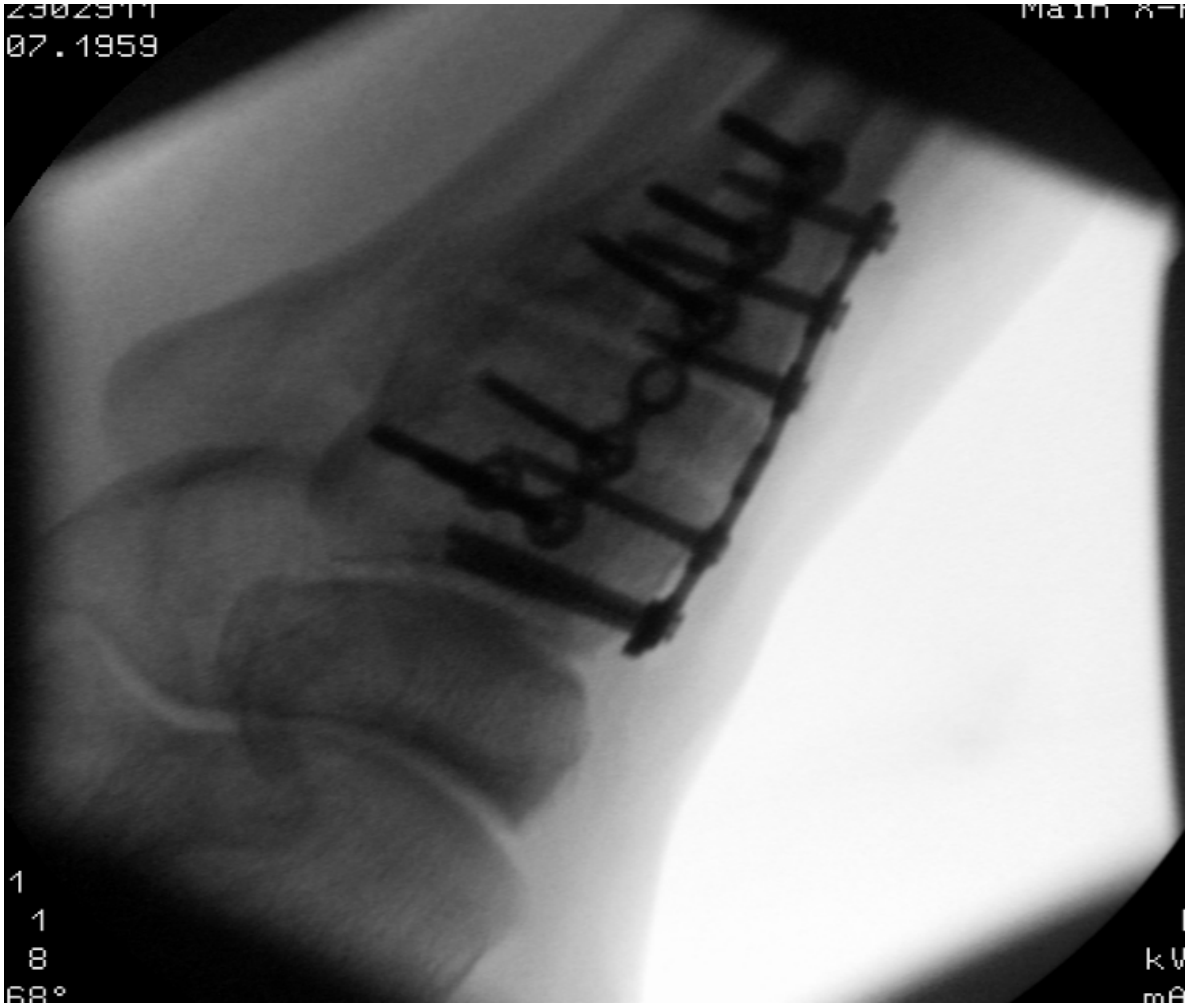

R


19:36:39
30.04.2009
W 100 L 50
R 0°
LIH 8
RTE 1
NR 1
BONE
MAG 0
kV 53
mA 3.4
cGy cm2
10.8
min 0:24

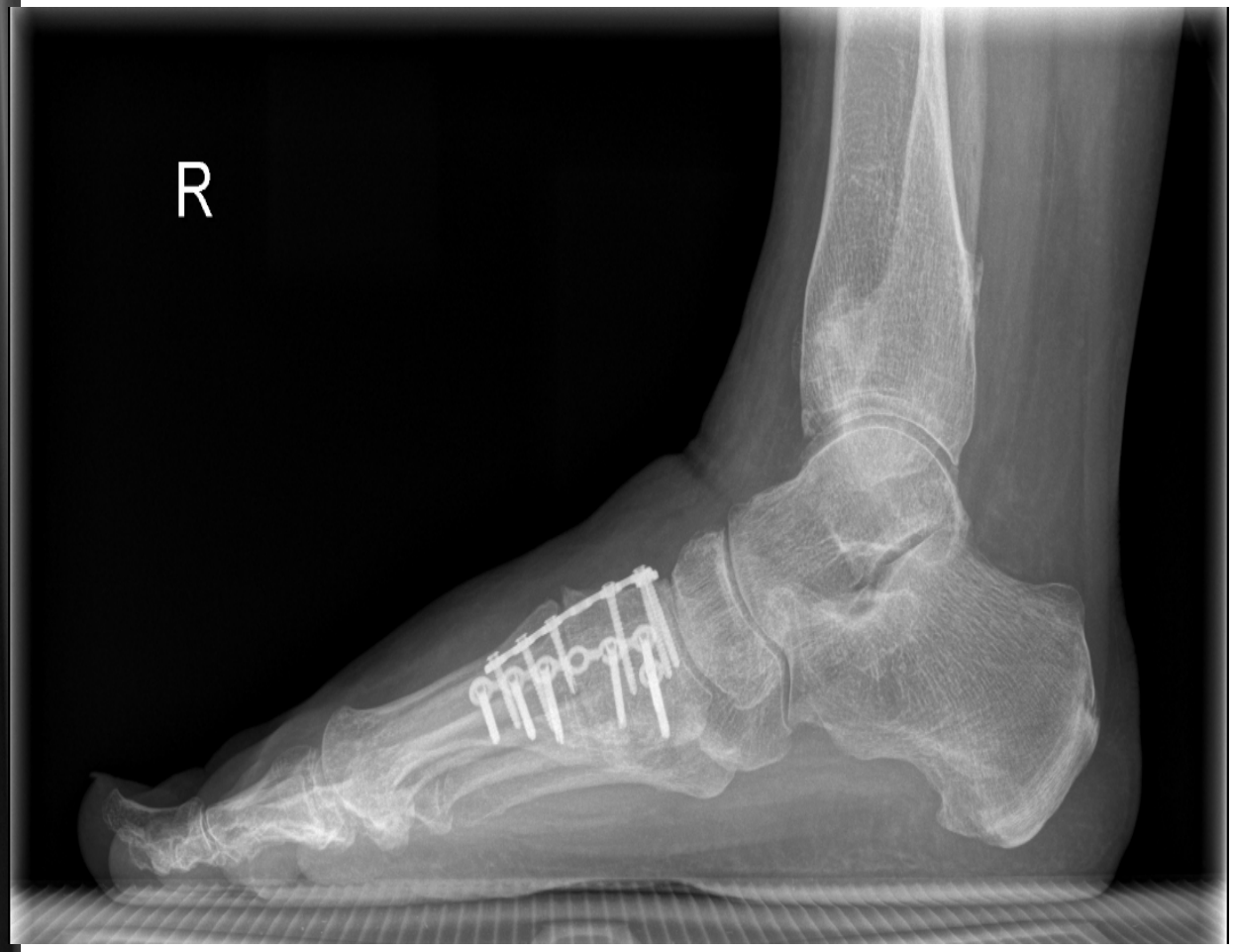

Main X-Ray
NR 1
RTE 1
BONE
MAG 0
kV 55


NGH
Dr.
Main X-Ray
1
1
8
68°
00 L 50
04.2009
30:58
BC
MAG
kV
mA
cGy
min

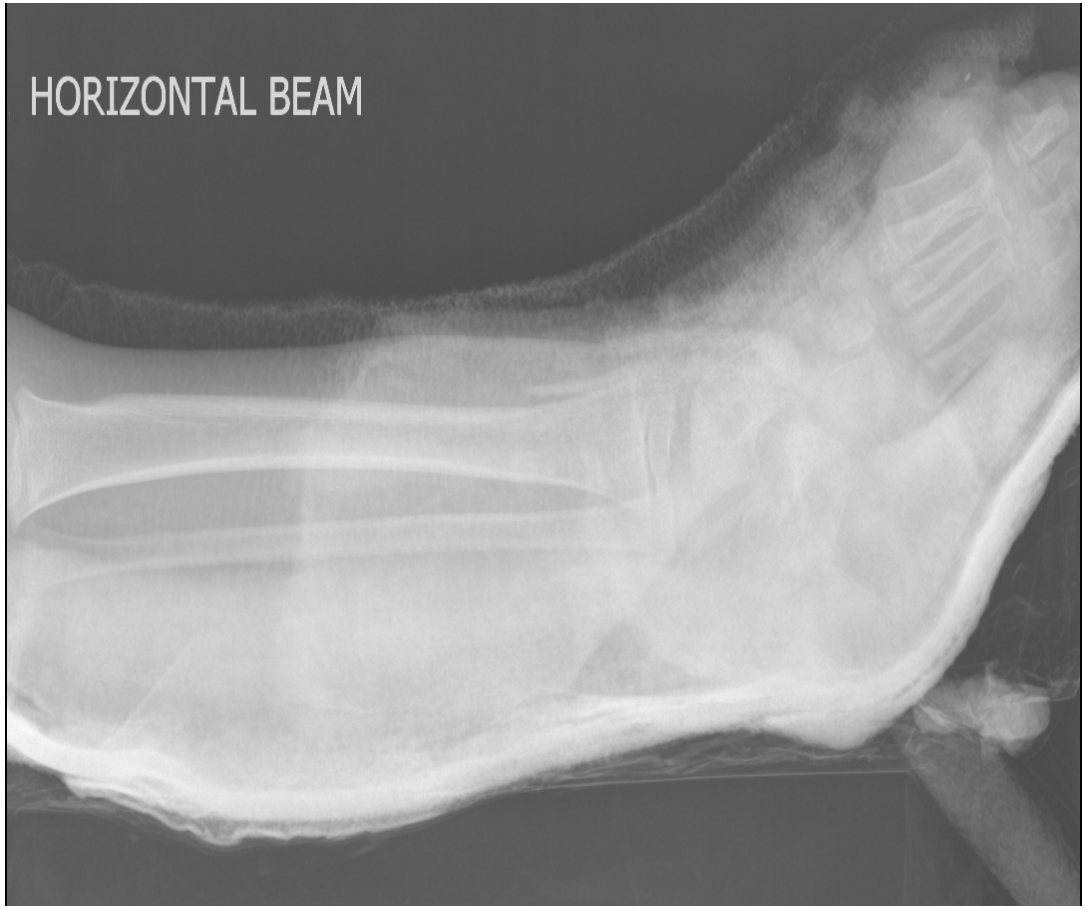

Main X-R
NR 1
RTE 1
LIH 8
R 168°
kV
mA

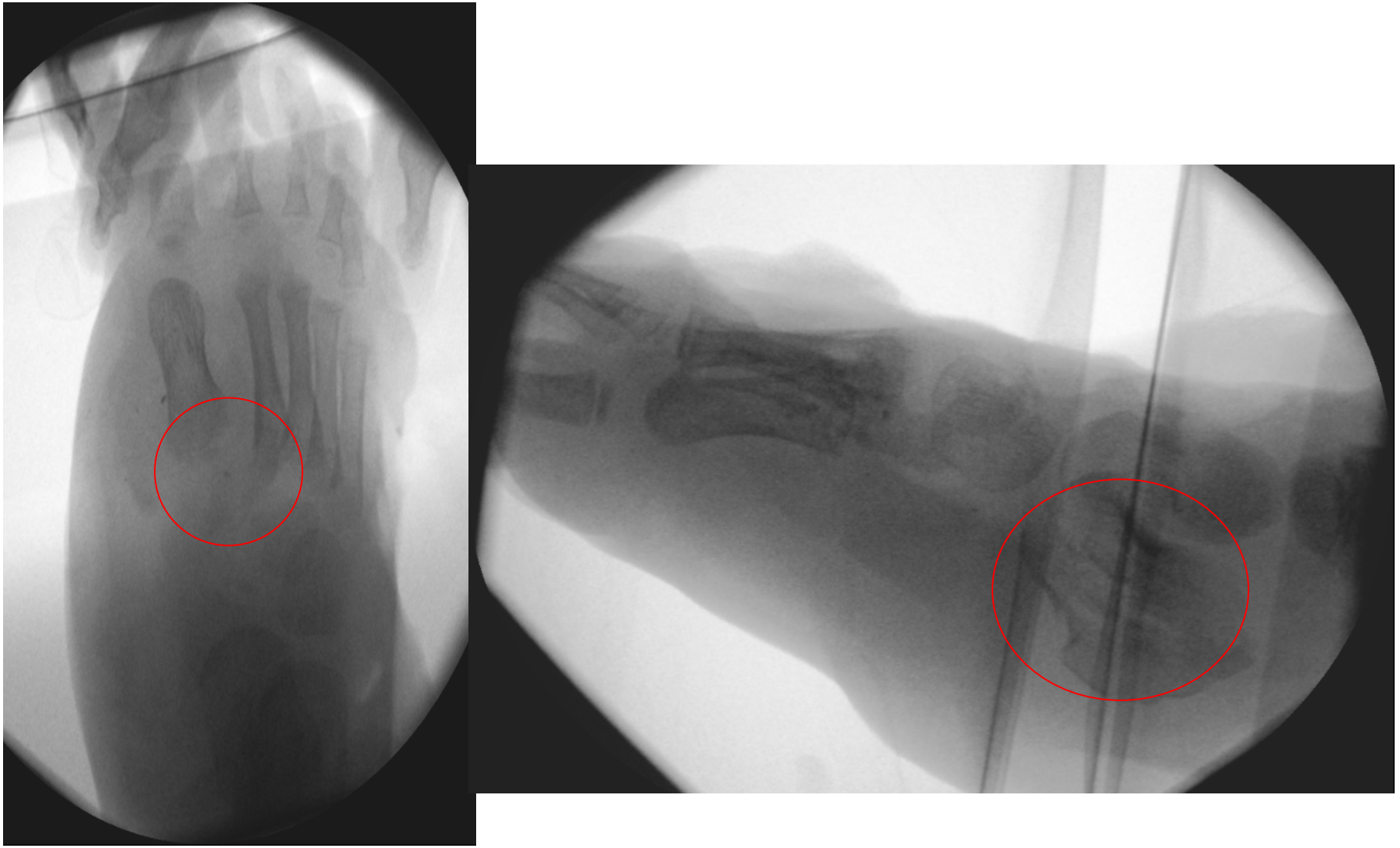

07.1959
1
1
8
68°


RT STANDING


R

Degloving






R


R