Calcaneal Fractures

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Objectives

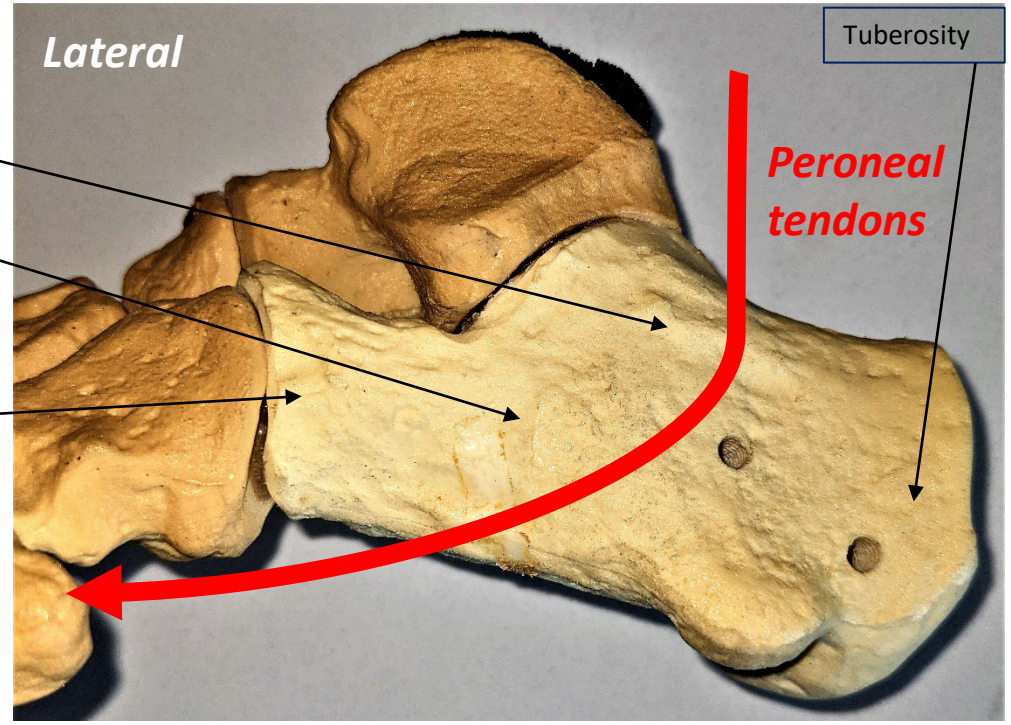
- **Describe the anatomy**
- **Understand initial clinical and radiographic assessment**
- **Describe the classification systems of calcaneal fractures**
- **Understand how patient, injury, and surgeon factors affect treatment recommendation**
- **Understand the goals and indications for operative treatment**
- **Describe potential adverse outcomes related to calcaneal fractures**

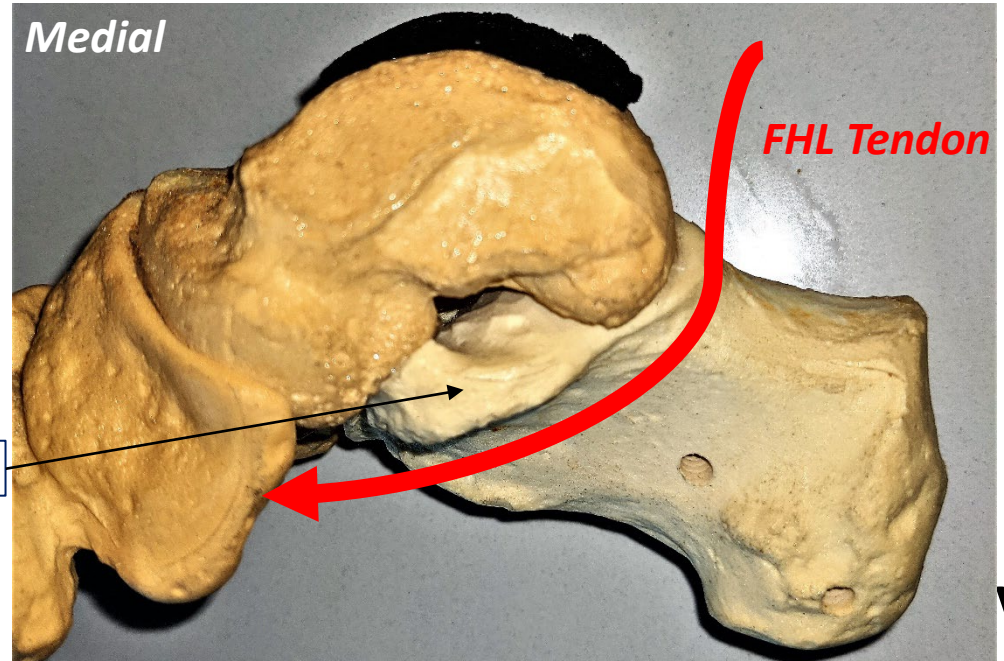
Introduction/Epidemiology

- Joseph-Francois Malgaigne described intra-articular fx patterns of the calcaneus in 1843
- Most commonly fractured tarsal bone (65%)
- Occurs more commonly in active working males (peak age 20 to 29)
- Most common mechanism is a fall from height or MVC
- 25- 50% of have associated injuries

Anatomy

- Tuberosity
  - Serves as attachment for Achilles tendon and plantar fascia
  - Has tubercles for CFL and peroneal tendons (both elevated during lateral approach)
- Anterior Process
  - Articulates with cuboid (CC joint)
  - Origin for extensor digitorum brevis muscle
- Sustentaculum tali
  - Supports middle facet of talus
  - Fulcrum for FHL tendon
  - Close relationship with posterior tibial vessels and terminal branches of tibial nerve





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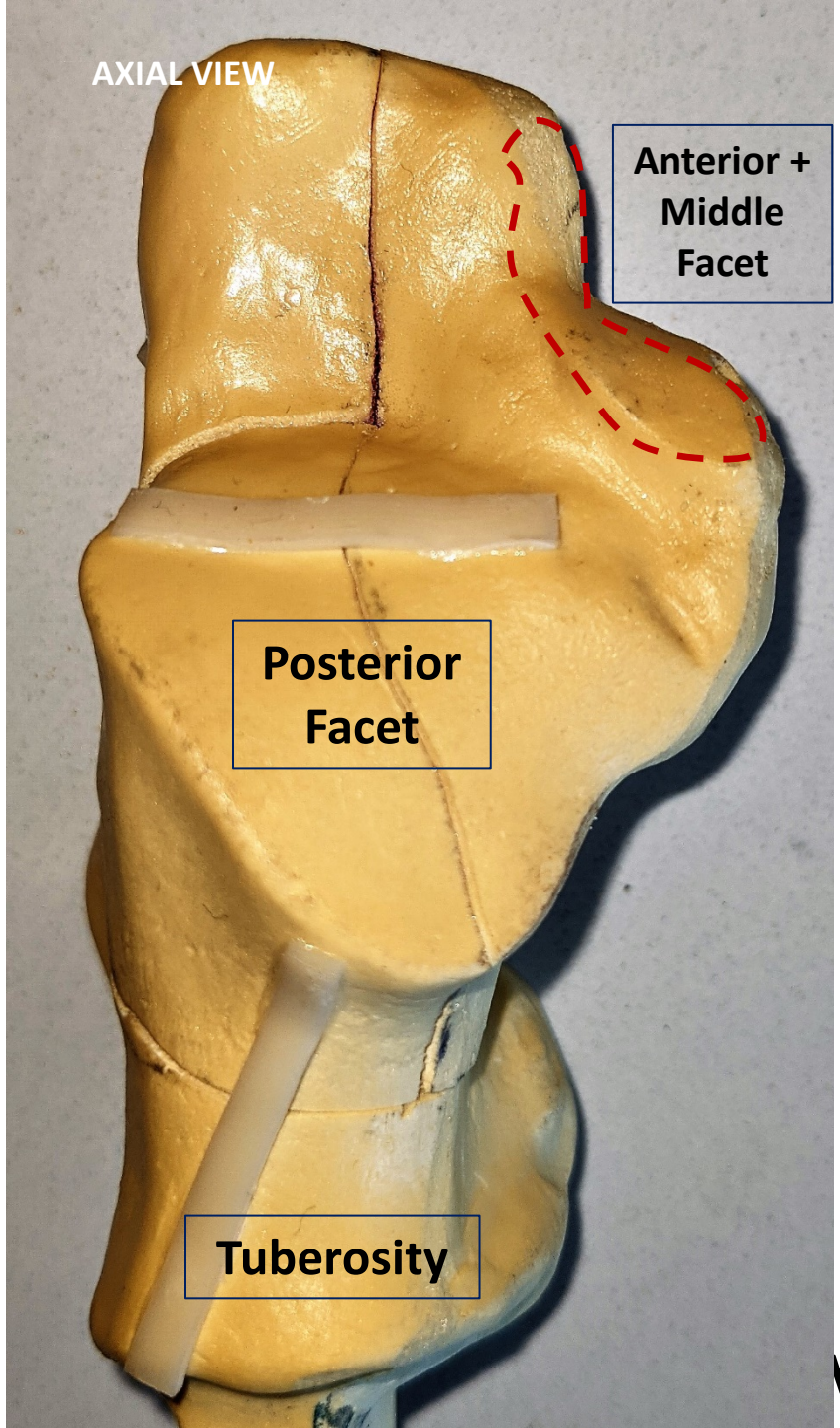
Anatomy

- Posterior Facet
  - supports the talar body

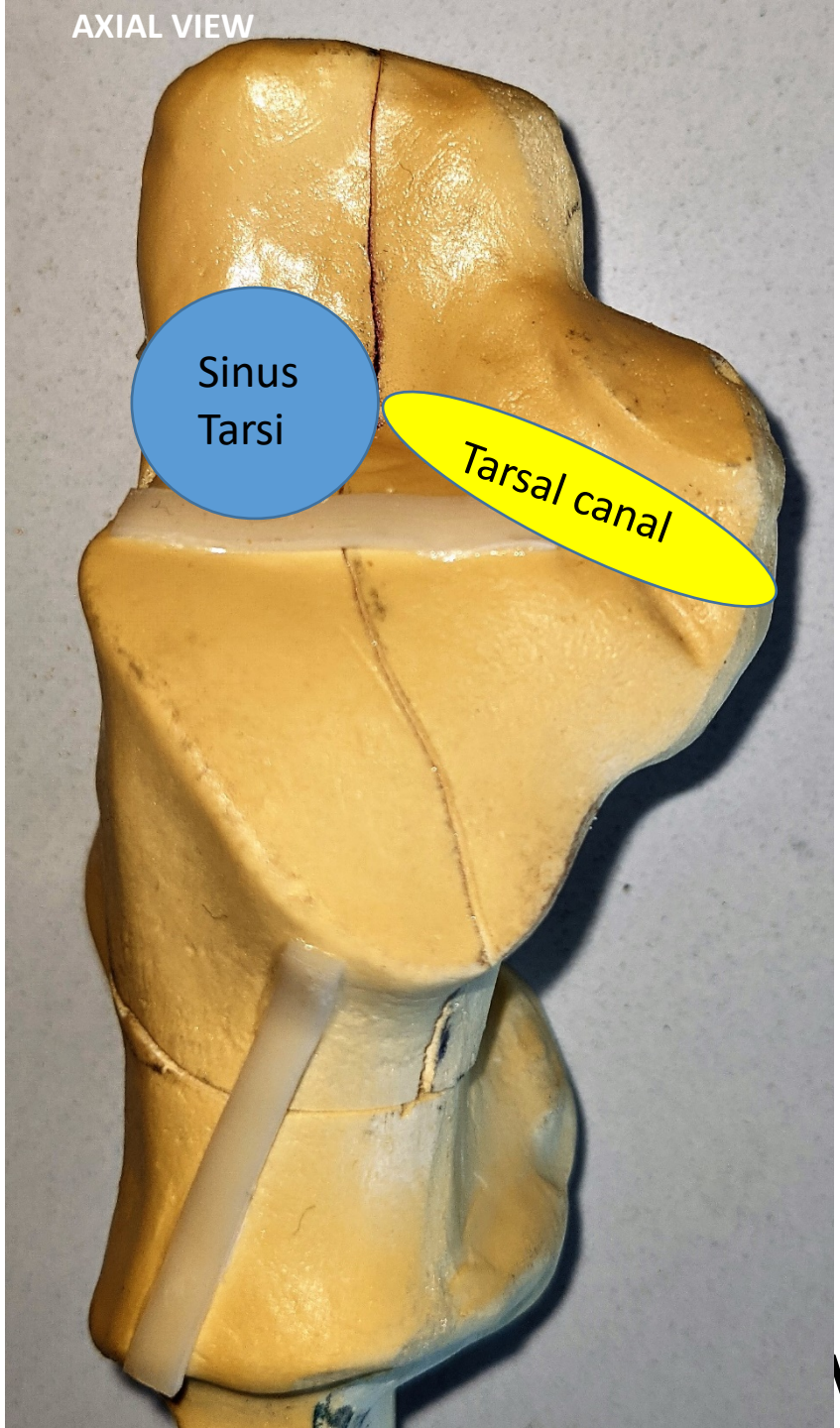
- Anterior and Middle Facets
  - Forms the sustentaculum tali
  - Called “constant fragment” because usually remains attached to the talus via the deltoid, interosseous ligament, and medial talocalcaneal ligament
  - Bears more weight per unit area than posterior facet

- Normal function of the subtalar joint relies on restoration of the articular relationships of these joints



Anatomy

- Tarsal Canal and Tarsal Sinus
  - Funnel-shaped areas situated anterior to the posterior talocalcaneal joint and posterior to the talocalcaneonavicular joint
  - The larger tarsal sinus opens laterally, and tarsal canal extends medially, posterior to the sustentaculum tali



Anatomy

- Lateral calcaneal artery (LCA)
  - Terminal branch of peroneal artery
  - Dominant blood supply to the corner of the lateral extensile approach
- Lateral malleolar artery (LMA)
  - Branch of Anterior tibial artery
- Lateral tarsal artery (LTA)
  - Branch of Dorsalis Pedis

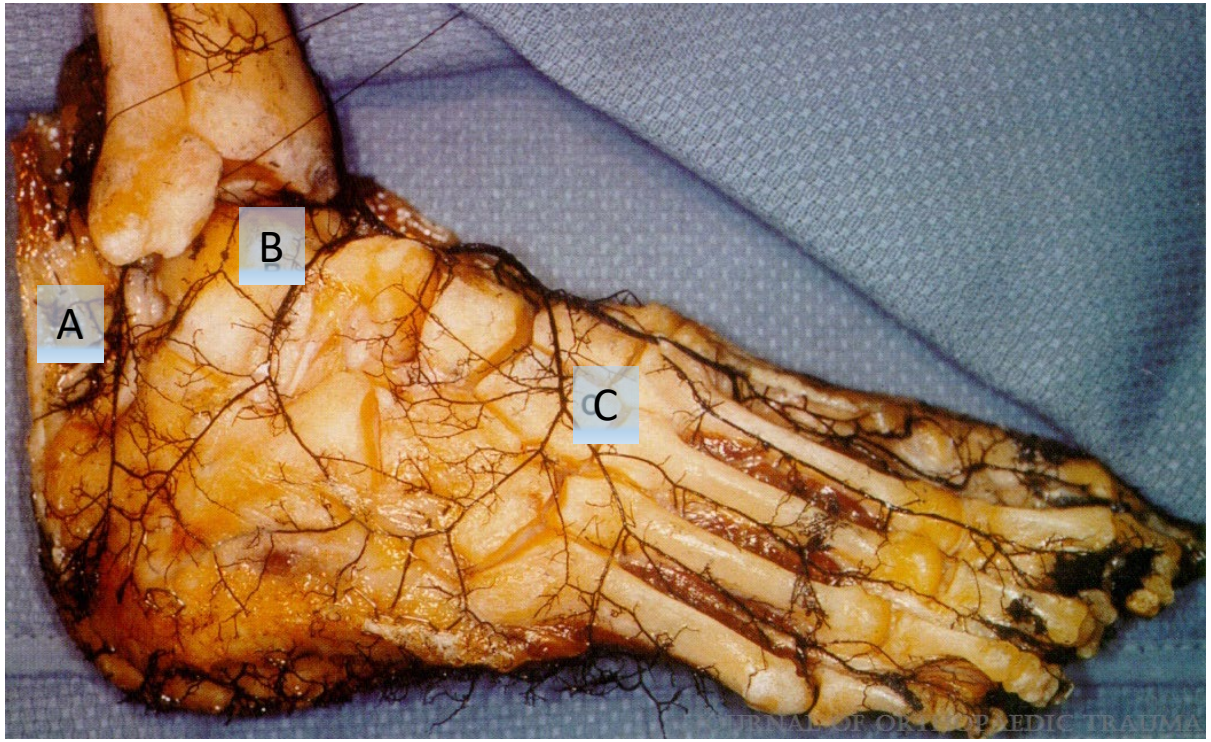


Photo of a chemically debrided specimen demonstrating the lateral calcaneal artery (A), the lateral malleolar artery (B), and the lateral tarsal artery (C).

Borrelli, Joseph Jr; Lashgari, Cyrus. Vascularity of the Lateral Calcaneal Flap: A Cadaveric Injection Study
Journal of Orthopaedic Trauma. 13(2):73-77, February 1999. (Fig1).

Anatomy

- Lateral calcaneal artery (LCA)
- Lateral malleolar artery (LMA)
- Lateral tarsal artery (LTA)

- Sural nerve and peroneal tendons at risk with lateral dissection

Tim White, Kate Bugler. Ankle Fractures.) In: Tornetta P, Ricci WM, eds. Rockwood and Green's Fractures in Adults, 9e. Philadelphia, PA. Wolters Kluwer Health, Inc; 2019. (Fig 64-6

Initial Assessment - History

- A thorough history is important to determine appropriate treatment
  - Pre-injury level of function/activity level
  - Occupation – desk work? laborer?
  - Habits - Smoker?
  - Medical comorbidities – diabetes? peripheral vascular disease?

- 25-50% with at least one associated injury
  - Thorough secondary evaluation is critical
    - 6-20% of patients with lumbar spine fracture
    - Up to 8% will have bilateral calcaneal fractures

Initial Assessment - Physical

- Note condition of skin
  - Fracture Blisters?
  - Threatened skin?
  - Open wounds?
- Detailed NV exam
- Associated injuries?
- Serial exams in the first hours after presentation to monitor for compartment syndrome

Initial Assessment - Physical

- Compartment syndrome following high-energy calcaneal fx estimated in 10-50%
- Clinical presentation - **pain out of proportion**, tense swelling, pain with passive stretch, sensory changes on plantar foot, and presence of blisters.
- Surgical decompression often complicated by wound dehiscence, infection, nerve injury, dry itchy skin, and chronic pain.
- Early cryotherapy and elevation may allow soft tissue swelling to stabilize, and alleviate pain in the acute period.

Initial Management

- Apply bulky splint in neutral dorsiflexion or slight equinus
- Period of soft tissue rest to allow for swelling to subside
  - Await return of skin wrinkling and resolution of blisters
- If skin at-risk e.g. tongue-type or tuberosity avulsion fracture, urgent surgery is indicated

Resolution of blisters and swelling prior to surgery. Note skin wrinkles

Radiographic Evaluation

- Initial plain radiographs (XR)
  - AP/Lateral/Oblique views of the foot
  - Mortise view of ankle
    - to r/o associated ankle pathology
  - Axial (Harris) view
- CT scan of the foot
- Consider plain radiographs of the lumbar spine and contralateral foot if warranted to rule out associated injuries

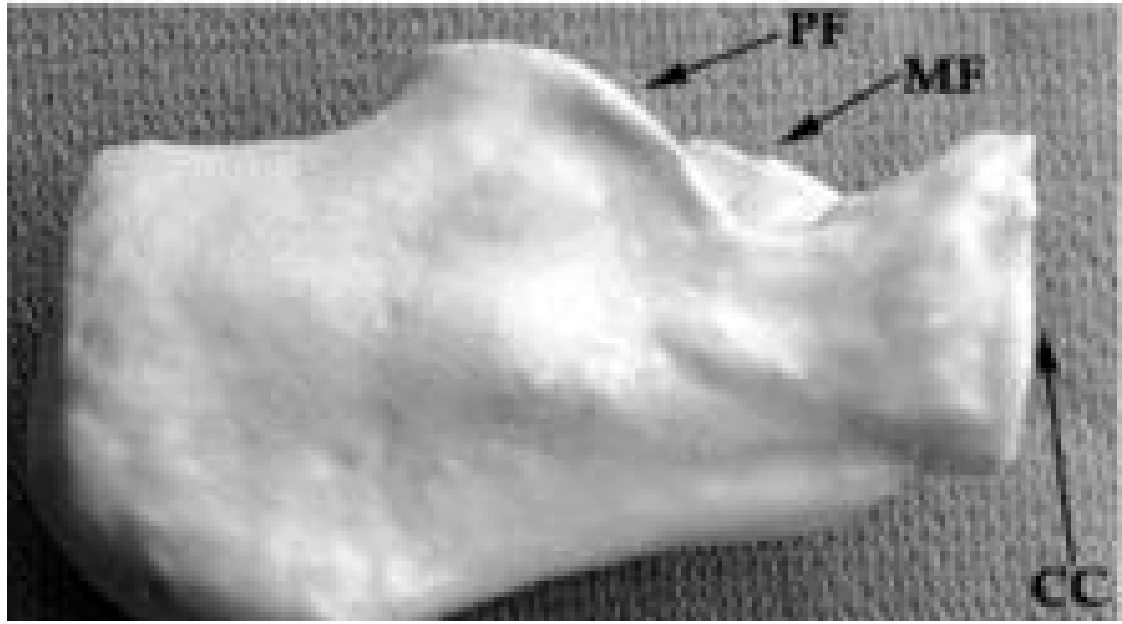
Intra-operative image of how Harris view is obtained.

Michel A. Taylor, Abdel Rahman Lawendy, David W. Sanders. Calcaneus Fractures. In: Tornetta P, Ricci WM, eds. Rockwood and Green's Fractures in Adults, 9e. Philadelphia, PA. Wolters Kluwer Health, Inc; 2019. (Fig 66-12)

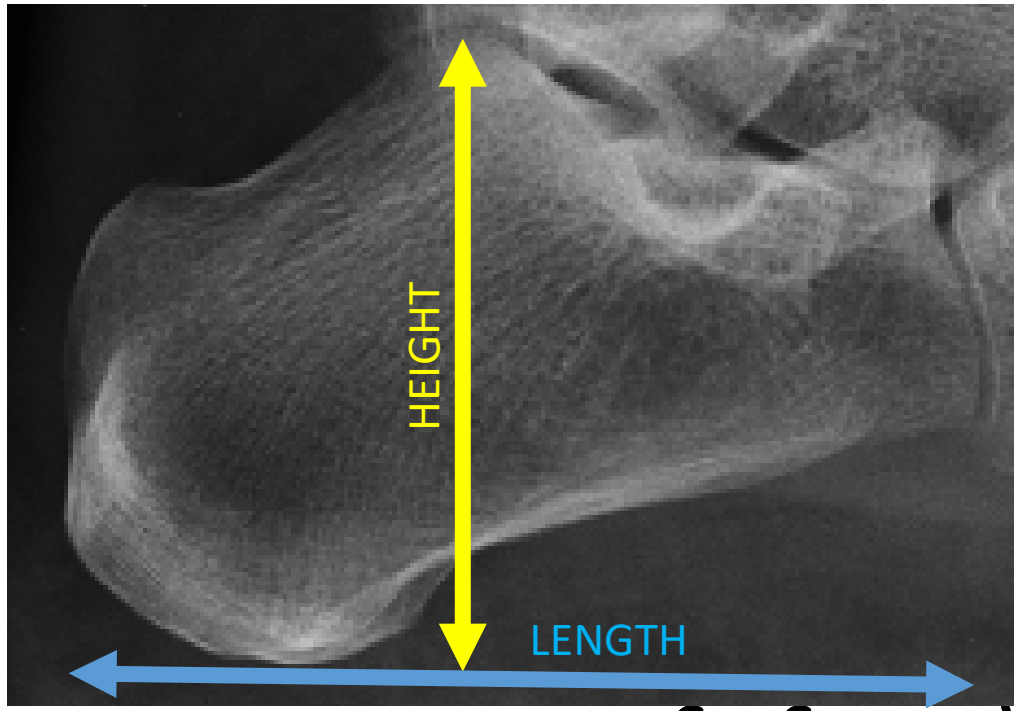
Lateral X-Ray

- Enables assessment of:
  - Posterior facet
  - Middle facet
  - Calcaneocuboid joint
  - Calcaneal length and height

- Can be used to classify the fracture as a joint depression or tongue type as described by Essex-Lopresti

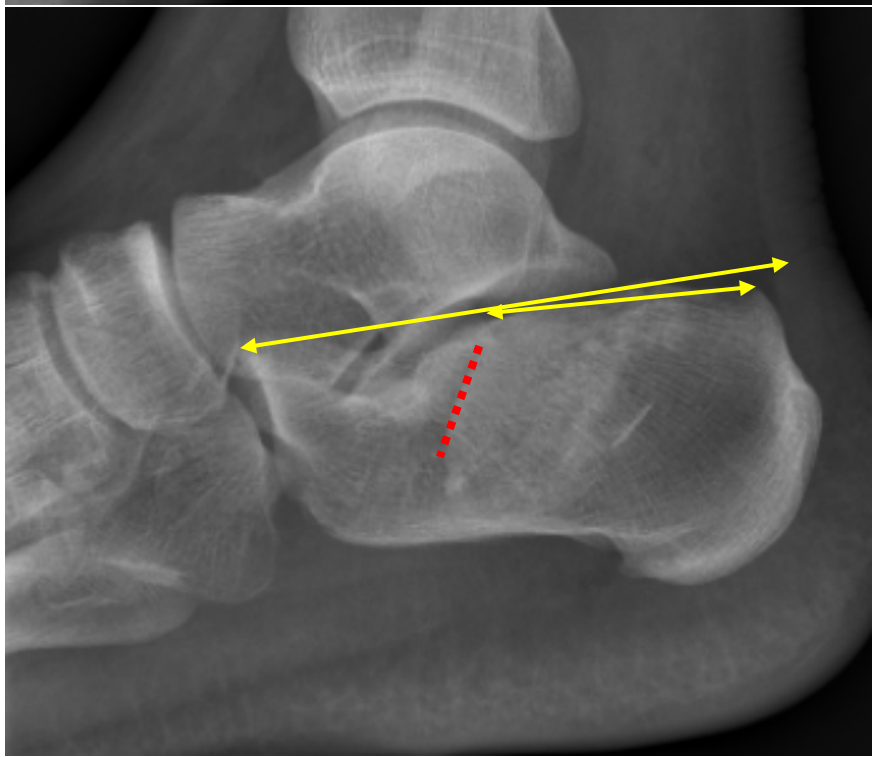


PF – Posterior Facet, MF – Middle Facet , CC - Calcaneocuboid



Lateral X-Ray

- Bohler’s Angle
  - line from highest point on anterior process to highest point on posterior facet and a line from this point to most superior point of calcaneal tuberosity.
  - *Normal 25-40^{o}*
  - Decreased angle indicates joint depression
  - Bohler's angle will only change if **entire** posterior facet is displaced



Lateral X-Ray

- Critical Angle of Gissane
  - formed by two cortical struts that join and intersect to form an obtuse angle
  - *Normal 120-145^{o}*
  - In an intra-articular fx involving the posterior facet, the lateral XR will typically show a loss of calcaneal height, depression and rotation of the posterior facet, and an **increase** in the critical angle of Gissane

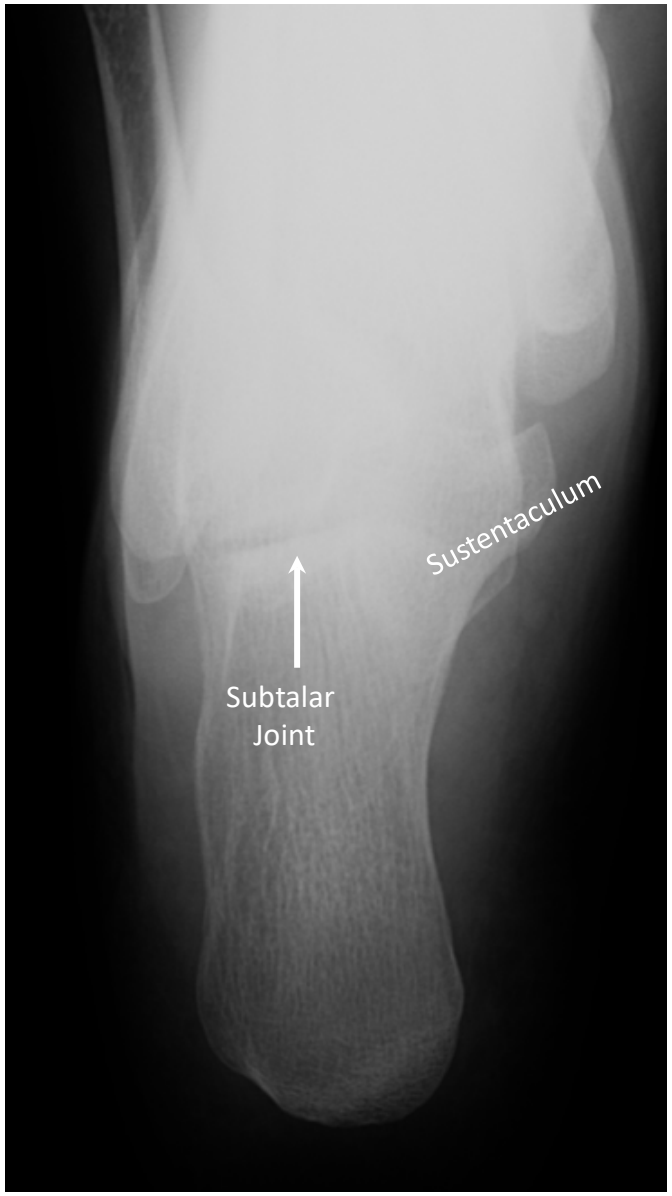
AP X-Ray

- Shows distal aspect of fracture line as it extends into the CC joint (up to 48% of cases)

- Can be useful to assess lateral wall defect, bulge, or blowout

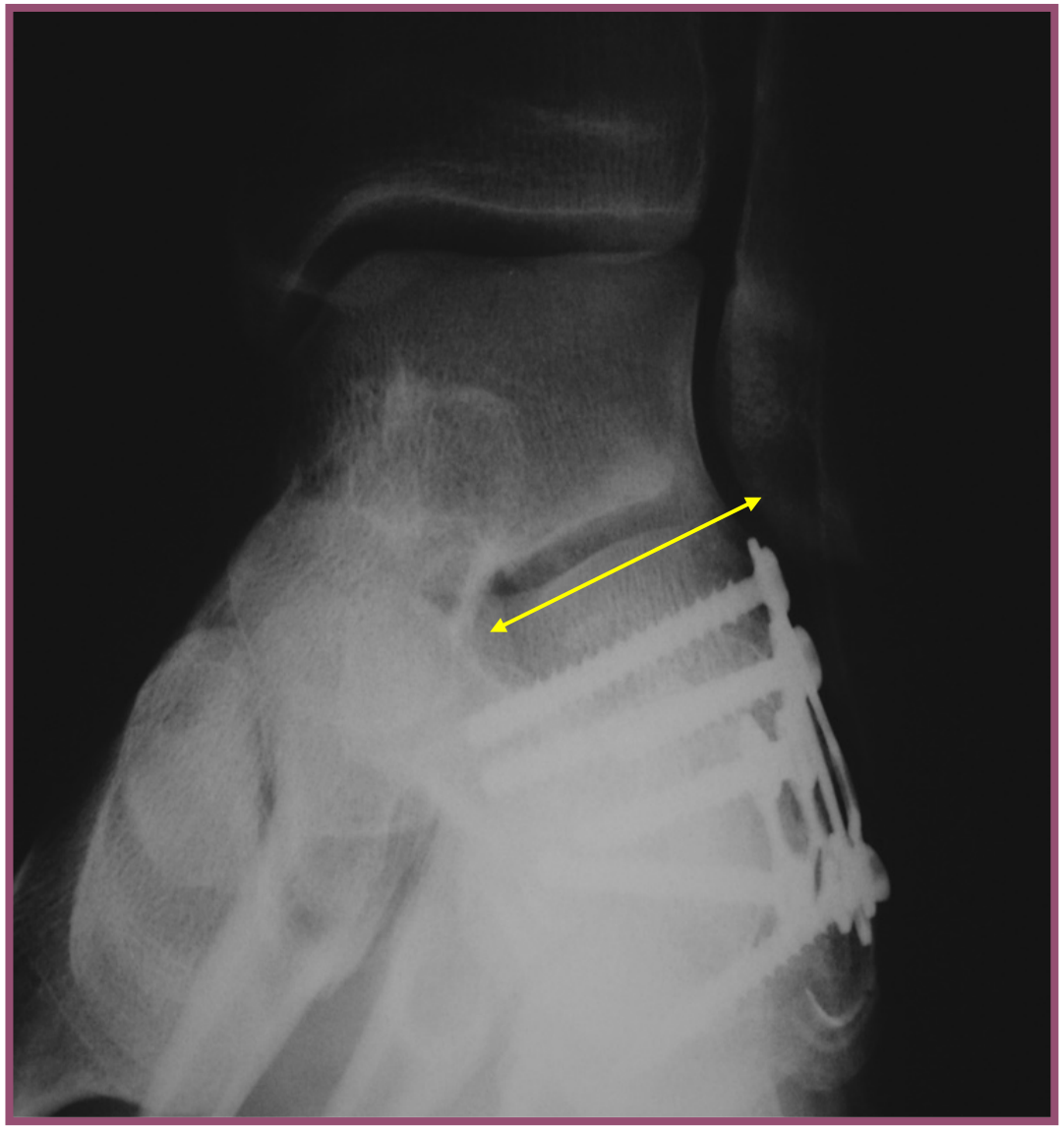
Axial (Harris Heel) View

- Can assess rotation of the sustentaculum
- Shows increase in calcaneal width
- Shows varus/valgus angulation of the tuberosity



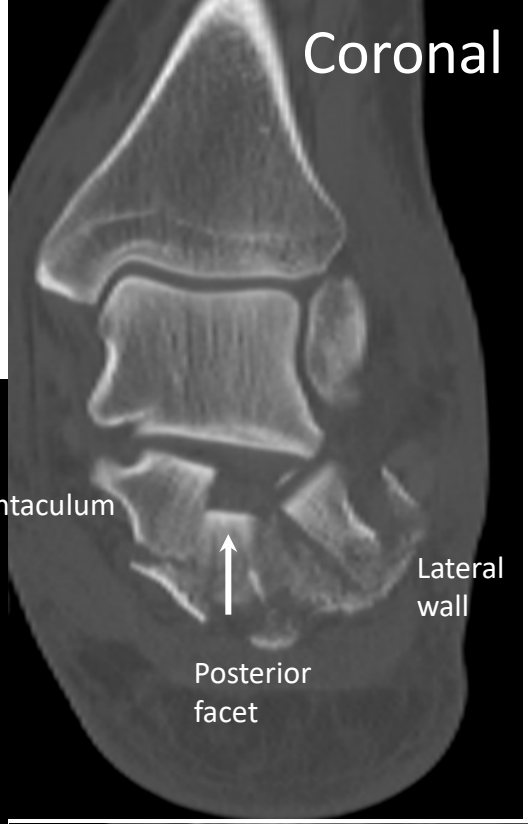
Broden's View

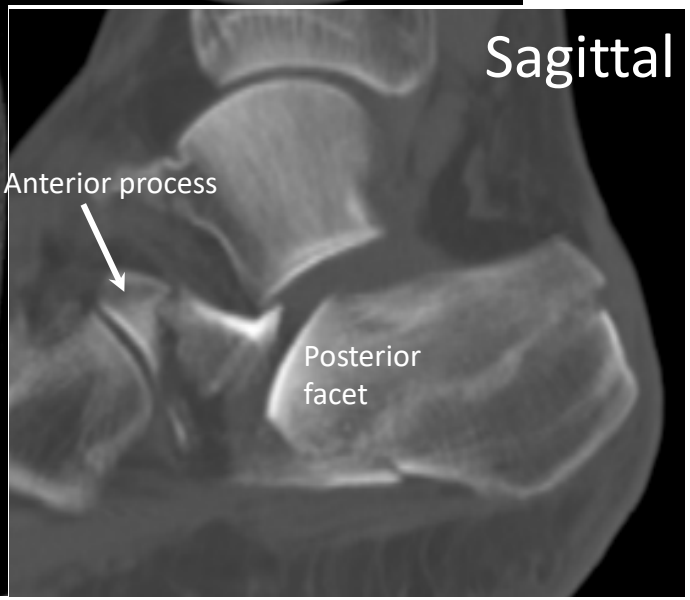
- Oblique radiograph of the hindfoot used intra-op to assess posterior facet
- IR foot 30-40 deg, aim beam at the angle of Gissane, and take four views angling the beam 40, 30, 20, 10 degrees cranial
- The sequential views are able to show the posterior articular facet moving from anterior to posterior and any associated fracture displacement, depression, or subluxation can be seen.



CT Scan

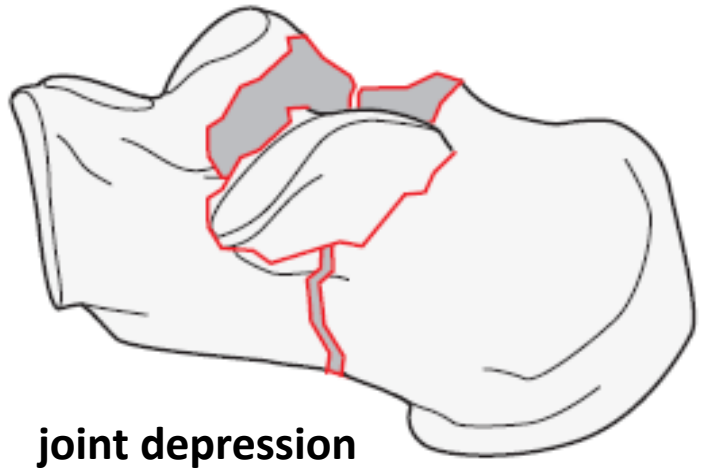
- *Technique: position the coronal plane perpendicular to the posterior facet of the calcaneus, 3mm cuts*
- Coronal: posterior facet, sustentaculum, lateral wall, fibula impingement
- Axial: CC joint involvement, posterior facet fracture lines, tuberosity displacement, lateral wall blowout
- Sagittal: posterior facet depression, anterior process involvement, tuberosity assessment



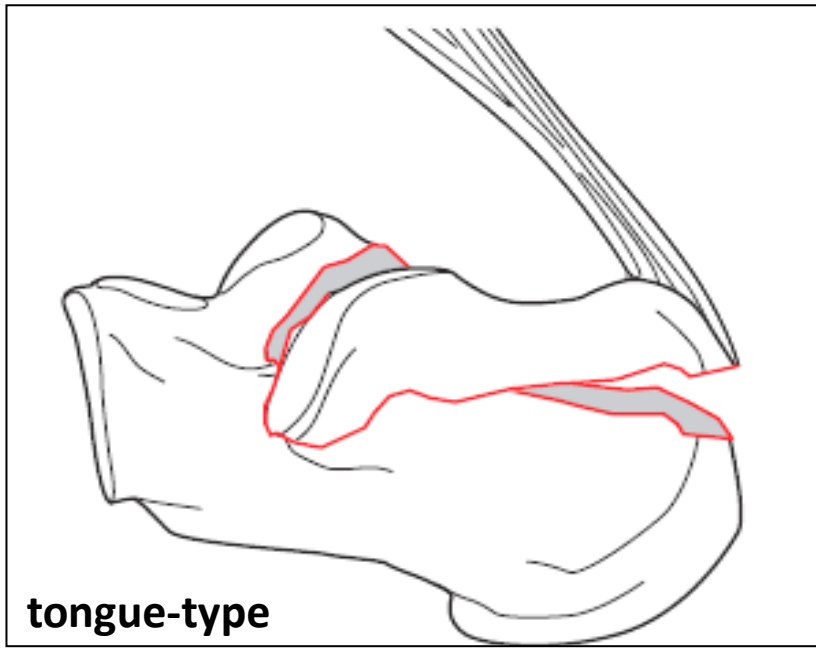


Classification – Essex-Lopresti

- Based on plain radiographs
- Two main fracture types:
  - intra-articular "**joint depression**": articular facet fragment is fractured and separate from the displaced tuberosity.
  - extra-articular "**tongue-type**": articular facet remains attached to the main tuberosity fragment
  - Can be surgical emergency due to skin compromise



joint depression



tongue-type

Meinberg E, Agel J, Roberts C, et al. Fracture and Dislocation Classification Compendium–2018, *Journal of Orthopaedic Trauma.* Volume 32: Number 1; Supplement, January 2018.

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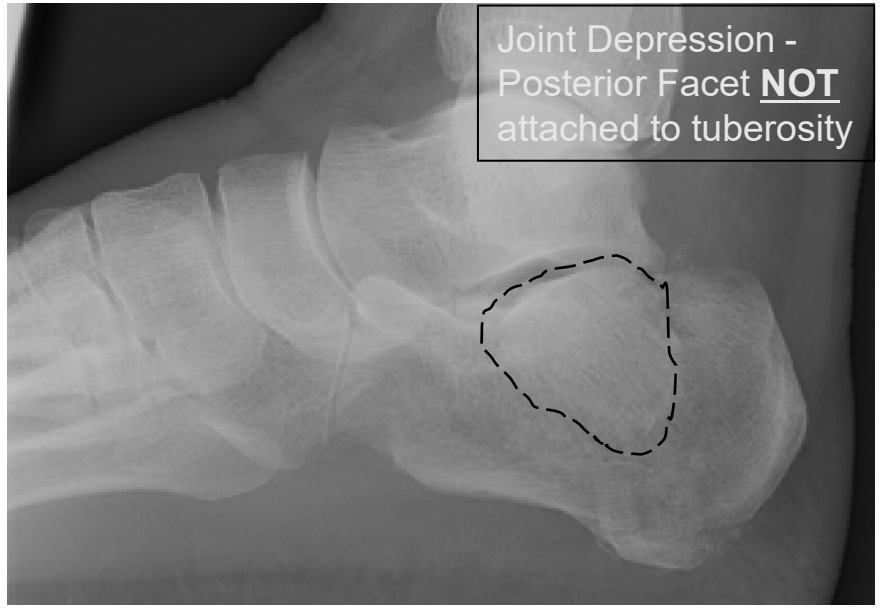
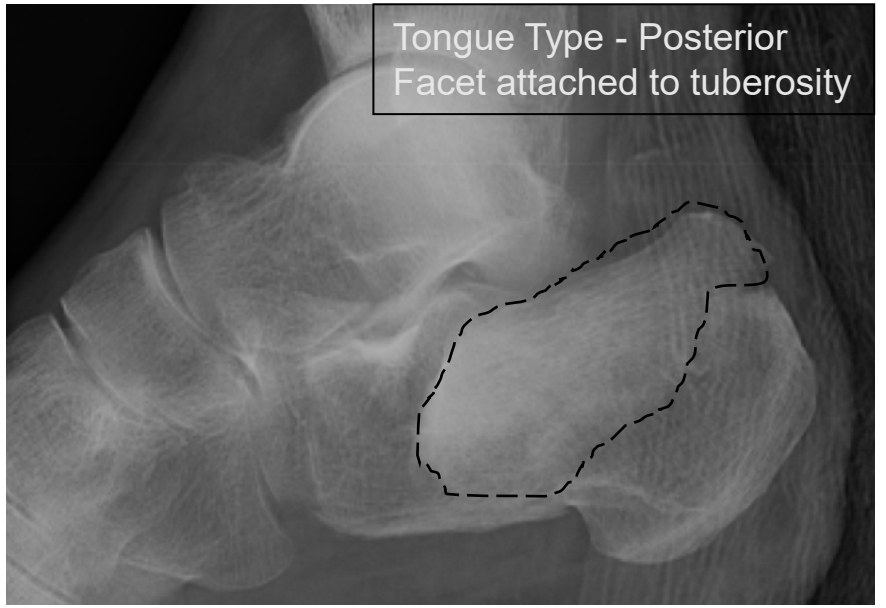
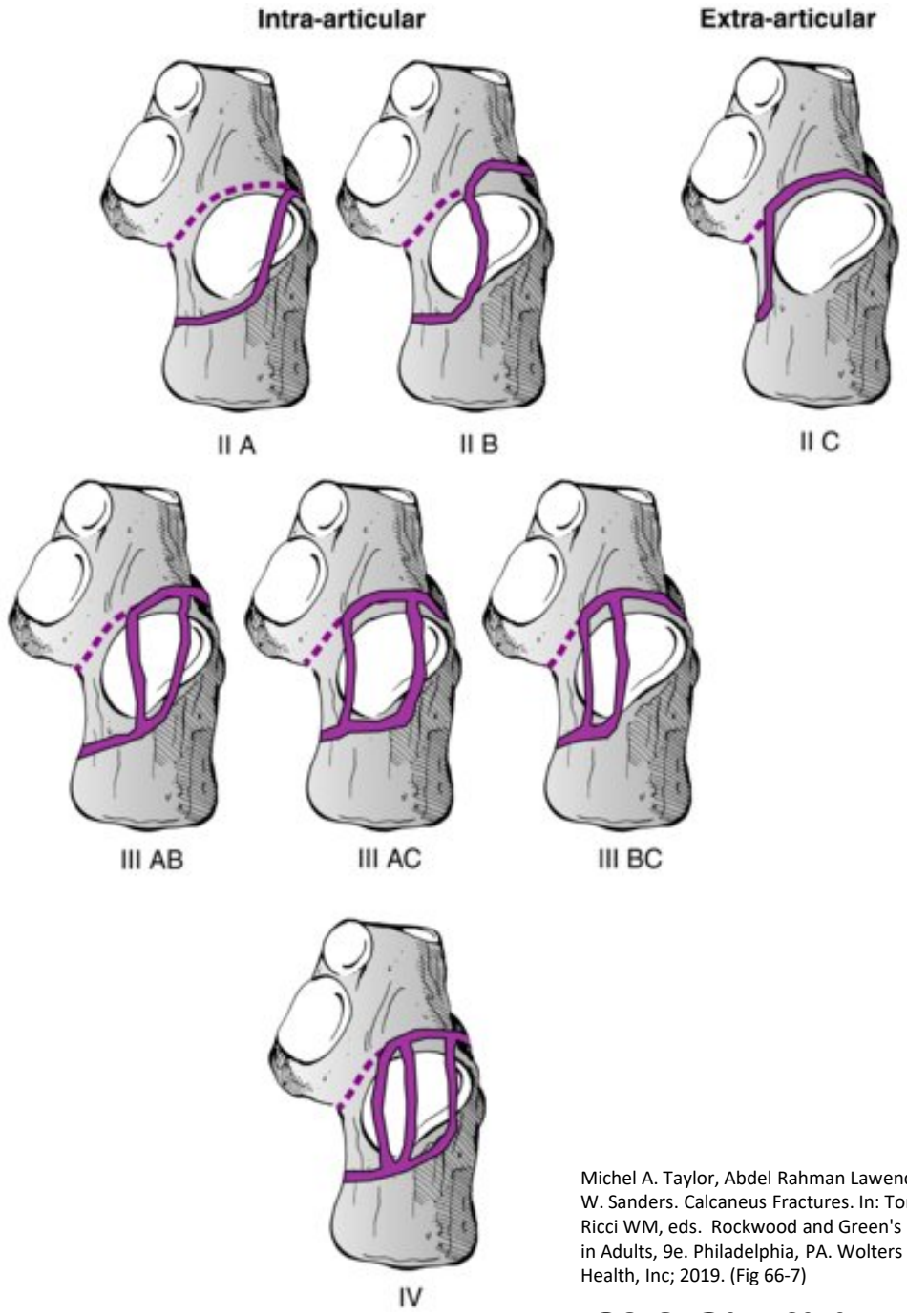




Classification – Sanders

- Based on the coronal CT scan
- Divided into four types (I-IV) indicating number of posterior facet fragments
  - Type I = all undisplaced fx, regardless of number of fracture lines.
- Letters describe the location of the primary fx lines from lateral to medial
  - extra-articular fracture classified as IIC
- Demonstrated to have good therapeutic and prognostic value *(Launder et al, FAI 2006)*



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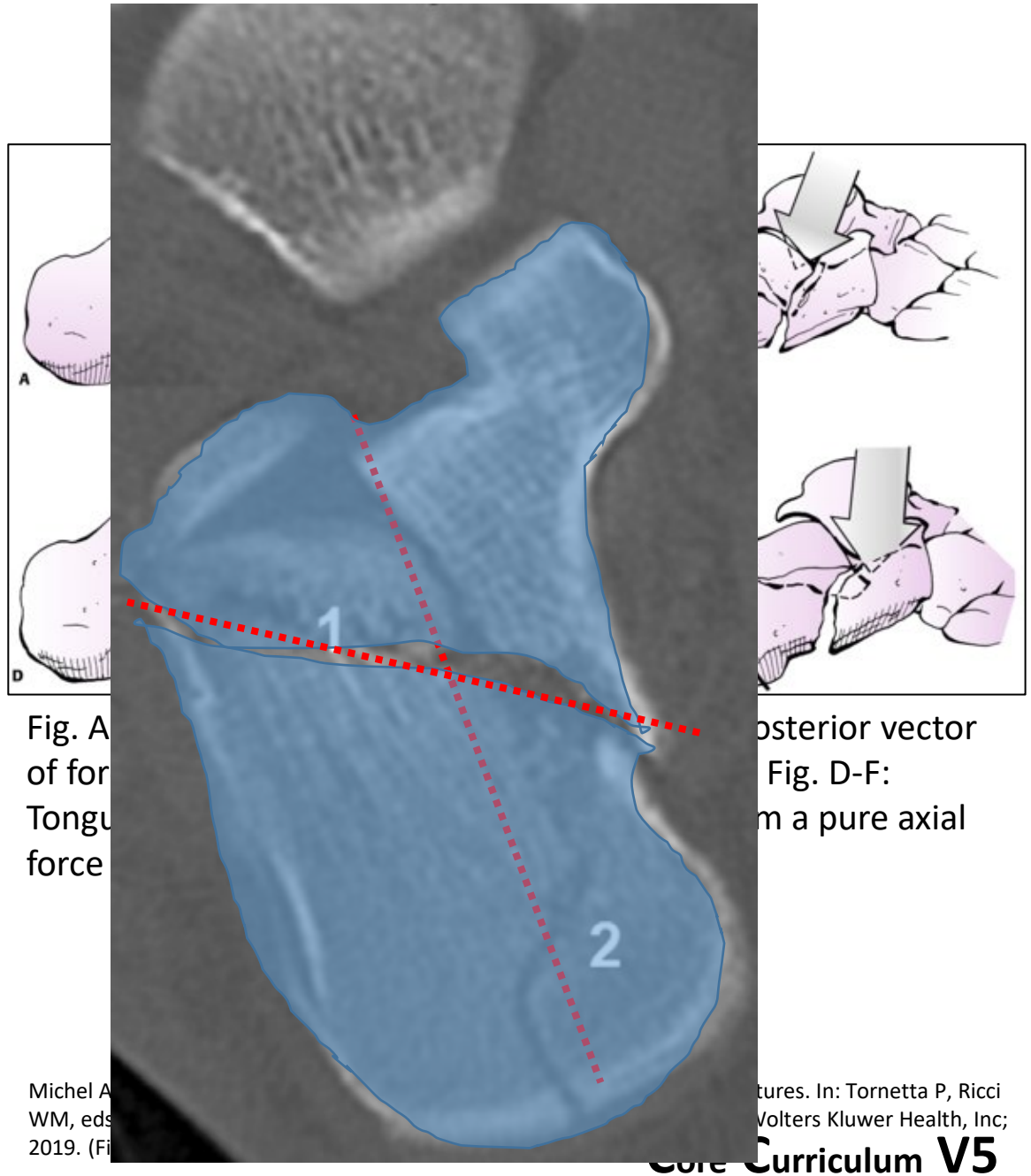
V5

Pathoanatomy

- Intra-articular fx result from axial load
- Lateral process of talus is driven into “angle of Gissane” creating **primary fx line** from anterolateral to posteromedial
  - Fx Location depends on hindfoot position
    - valgus = lateral fx line; varus = medial fx
- **Secondary fx line** depends on direction of force
  - Posterior force = joint depression variant
  - Pure axial force = tongue type variant



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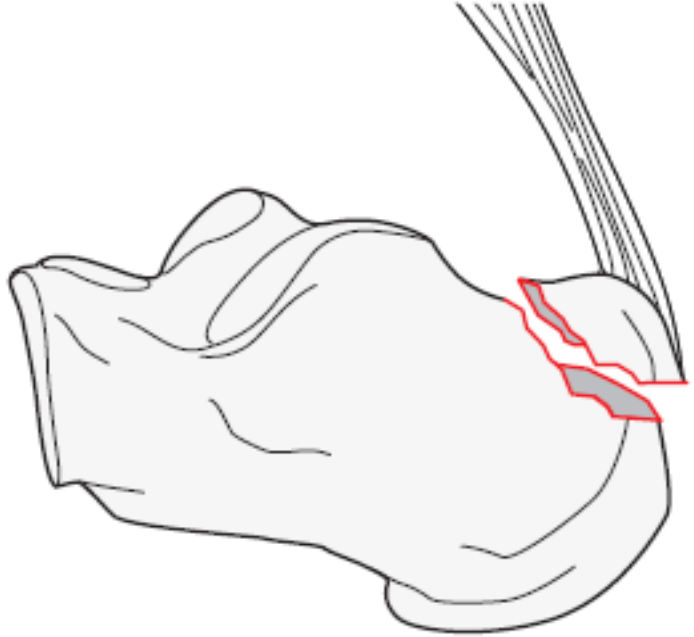
Pathoanatomy

- **Posterior calcaneal tuberosity avulsion fractures** are a subset of extra-articular calcaneus fxs
- Calcaneal bone strength ↓ with age
  - peak incidence: women in 7th decade
- Mechanism - violent pull from the gastrocnemius-soleus complex coupled with forced dorsiflexion
- Posterior skin at severe risk



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Pathoanatomy

- **Anterior process fractures** happen in isolation or as extension of an intra-articular fracture
- anterior process contributes to anterior facet and CC.
- Proposed mechanisms:
  - forced hindfoot dorsiflexion and eversion with compression of the anterior process between the cuboid and the talus
  - sudden ankle inversion w/ plantarflexed foot.
- Most do well with conservative management
- Large (>25% CC joint with displacement) → ORIF

Indications for Non-Operative Treatment

- Nondisplaced intra-articular or extra-articular fractures
- Minimally displaced (<1 cm) extra-articular fractures
- Anterior process fractures <25% CC joint involvement
- Other Treatment considerations:
  - Patient factors
  - Injury factors
  - Surgeon factors

Treatment Considerations – Patient Factors

Patient Age:

- *Essex-Lopresti (BrJS 1952)* – 40% of pt >50 with unacceptable outcome
- *Herscovici et. al (JBJS 2005)* – 4/37 major complications in pt>65 yo; outcomes correlated more with presence of comorbidities than age
- *Gaskill et al (JBJS 2010*) - Outcomes in pt >50 yo comparable to younger patients if no prohibitive comorbidities

Medical Comorbidities:

- Consider less invasive management in the presence of:
  - Insulin Dependent Diabetes, Peripheral Vascular Disease
  - Neuropathy, Organic Brain Disease
  - ESRD, CHF

Treatment Considerations – Patient Factors

Social Factors:

- Drug/Alcohol Abuse
- Unable to cooperate with NWB/PWB
- Smoking
  - 70% complication rate in smokers vs 15% in nonsmokers *(Assous et al, Injury 2001)*
  - 3X rate of deep infection *(Soni et al, FAS 2014)*

Worker's Compensation:

- after removing pts on WC, outcomes better in some groups of surgically treated patients *(Buckley et al, JBJS 2002)*

Treatment Considerations – Injury Factors

Higher degree of soft tissue injury:

- Open Calcaneus Fractures (*Mehta et al, JOT 2010)*
  - rate of wound complications (19% to 67%)
  - rate of osteomyelitis (10% to 33%)

Higher degree of osseous injury:

- Sanders Type IV more likely to be fused than Type II; 25% at 2 years (*Buckley et al, JBJS 2002)*
- Böhler angle on presentation <0° 10x more likely to require secondary subtalar fusion than >15° (*Csizy et al, JOT 2003)*

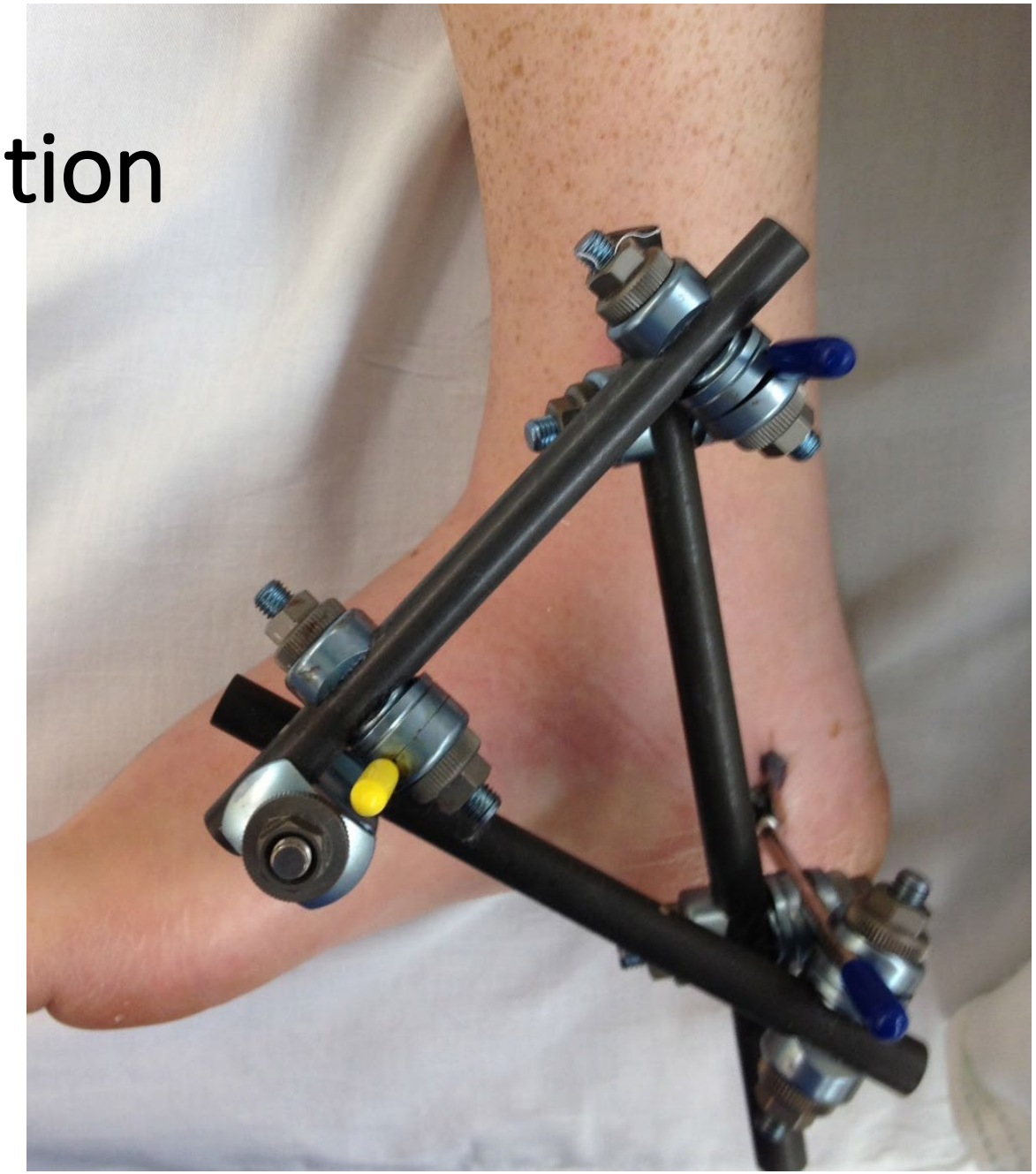
Treatment Considerations – Injury Factors

- Significant learning curve
- Challenging fracture to treat operatively
- Surgical Complications may be worse than nonoperative treatment
- Consideration for care by “experts” or specialty centers

(Court-Brown et al, Injury 2009), (Schepers et al, JFAS 2013)

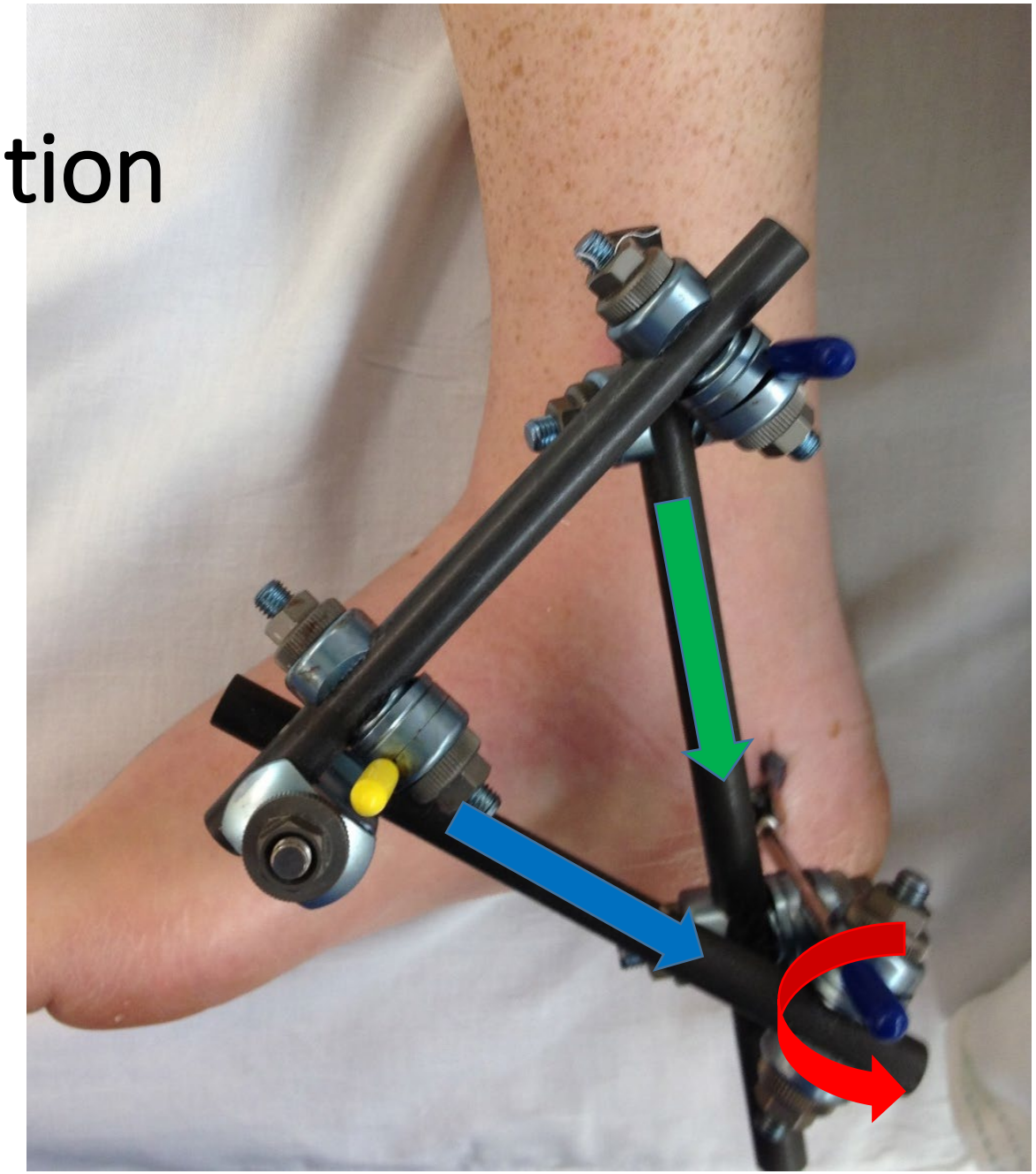
Technique - External Fixation

- Medial frame can be placed temporarily to preserve lateral soft tissues for exposure after soft tissues heal
- Can also be definitive treatment to get overall morphology (height, length, remove varus)
  - subsequent limited exposures can be done laterally for articular reduction/fusion



Technique - External Fixation

- Place Shanz pins:
  - Medial cuneiform to middle of lateral cuneiform
  - Medial distal tibia
  - Medial calcaneal tuberosity
- Reduce Tuberosity:
  - Height
  - Length
  - Translation
  - Angulation



Goals of Operative Treatment

Restoration of Anatomy

- Articular congruency – minimize arthritis
- Calcaneal morphology
  - Restore Width
    - allow for shoe wear
    - minimize sub-fibular impingement
  - Restore height for ankle function
    - anterior ankle impingement from dorsiflexed talus
  - Restore length for foot alignment
    - Lever arm for propulsive gait through the gastrocnemius-soleus
    - Post-traumatic pes planus

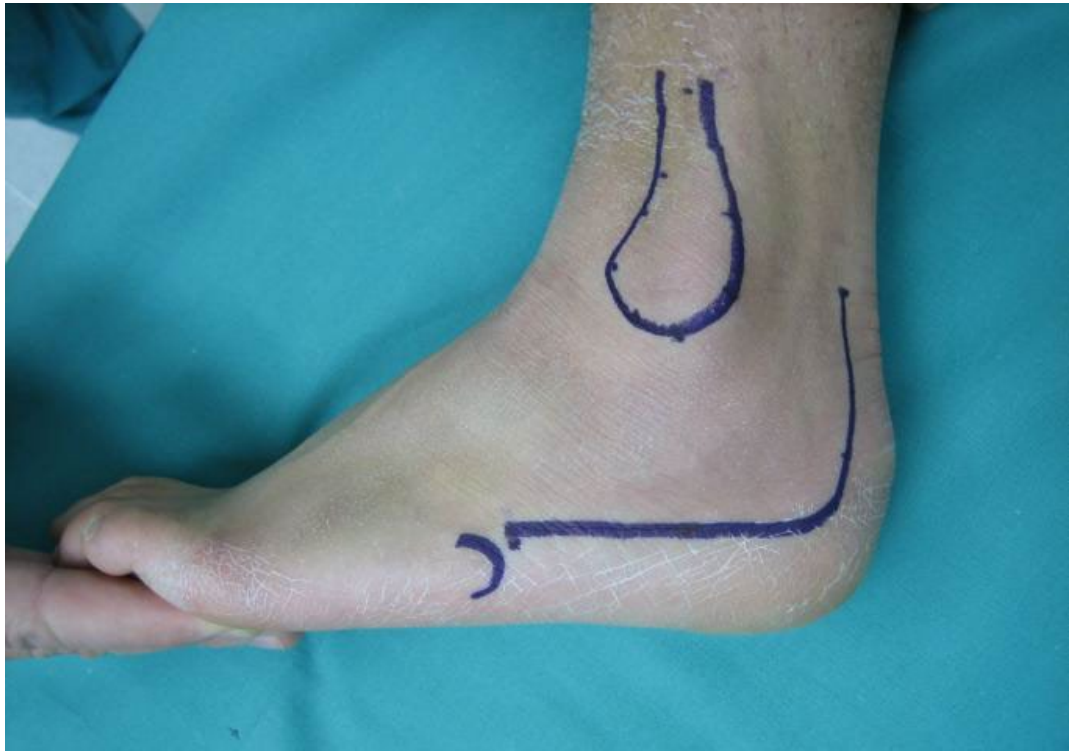
Surgical Approaches - Extensile Lateral

Pros:

- Visualization of entire lateral calcaneus
- Good view of posterior facet
- Direct reduction of ant. process + tuberosity
- Easy to address lateral wall “blow-out”
- Stable fixation with lateral plate

Cons:

- Increased risk of wound healing problems



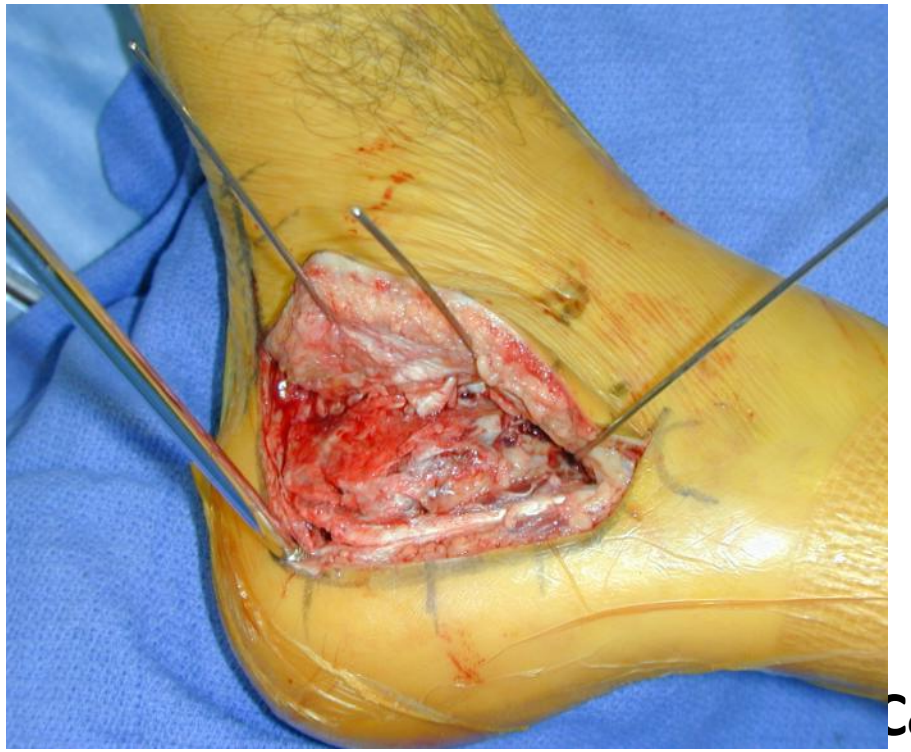
Technique - Extensile Lateral

Positioning

- Lateral on a beanbag
- Blankets or foam ramp as platform for operative limb
- Ensure adequate external rotation of hip for Broden's and Harris views
- C-ARM comes in at an angle from the foot of the bed

Technique

- Full thickness sub-periosteal flap
- Care not to damage sural nerve
- Elevate calcaneofibular ligament and peroneal tendons w/ flap
- “No touch” technique for flap retraction with wires in fibula, talar neck and cuboid
  - *Not all surgeons advocate use of wires for flap retraction*

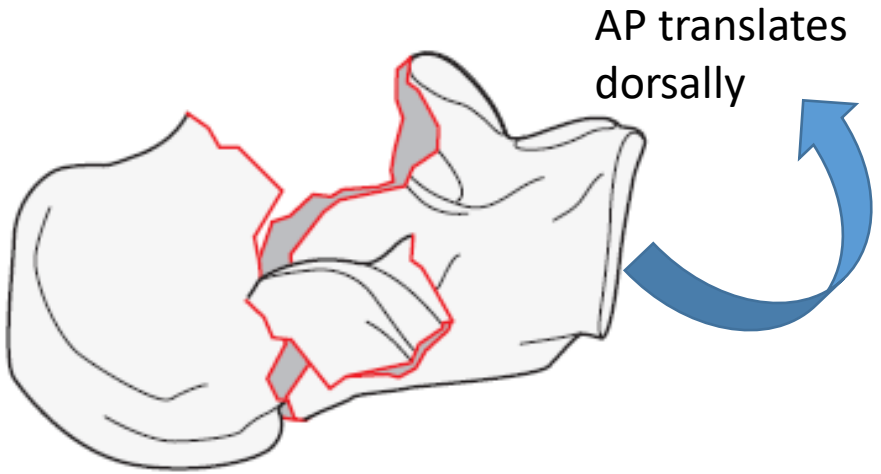


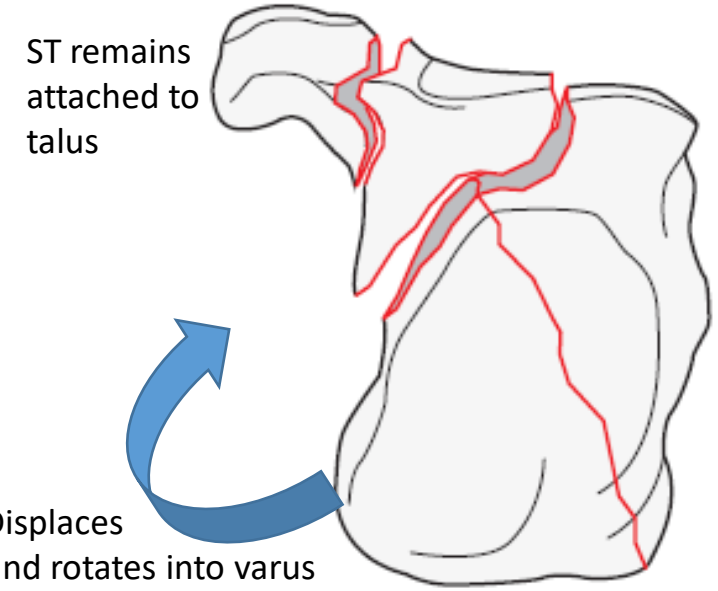
Technique - Reduction

Significant variability in the fx pattern of intra-articular calcaneal fx

BUT there are consistent features:

- The sustentaculum typically remains attached to the talus
- The anterior process translates dorsally
- The tuberosity translates laterally, displaces superiorly (pull of Achilles), rotates into varus, and shortens into the fracture



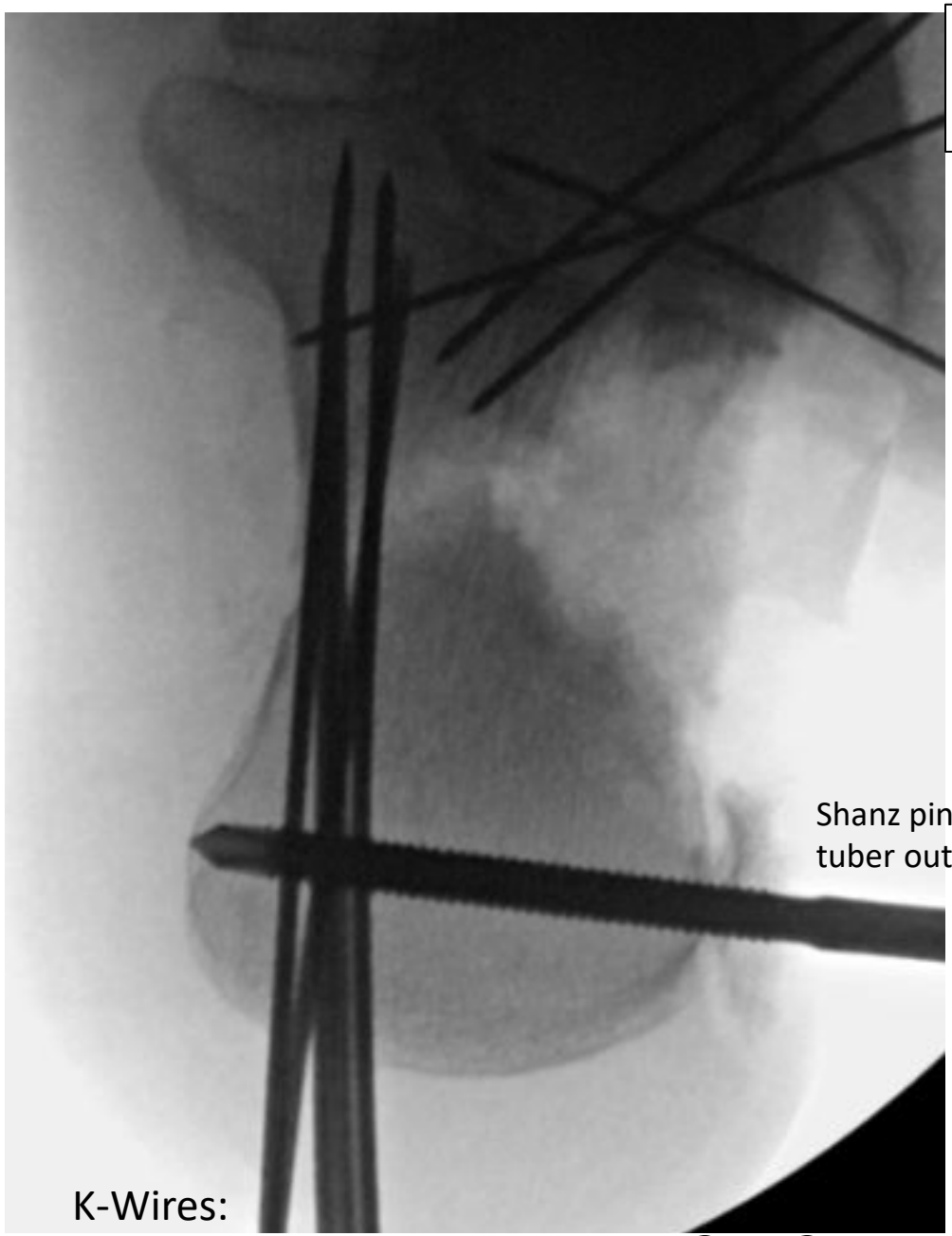


Meinberg E, Agel J, Roberts C, et al. Fraction and Dislocation Classification Compendium–2018, *Journal of Orthopaedic Trauma.* Volume 32: Number 1; Supplement, January 2018.

V5

Technique - Reduction

- Lateral wall is reflected
- Reduction proceeds from anterior to posterior typically
  - Anterior process to sustentaculum
  - Tuberosity is levered out of varus
  - Reduce tuberosity to the sustentaculum



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  - Tuberosity is levered out of varus
  - Reduce tuberosity to the sustentaculum
  - **Reduce lateral posterior facet joint fragments to sustentaculum and to talar facet above**

Michel A. Taylor, Abdel Rahman Lawendy, David W. Sanders. Calcaneus Fractures. In: Tornetta P, Ricci WM, eds. Rockwood and Green's Fractures in Adults, 9e. Philadelphia, PA. Wolters Kluwer Health, Inc; 2019. (Fig 66-16)

Technique - Plating

- Plate(s) is then applied. Serves as a washer for the screws, to compress the lateral wall, and acts to resist the deforming varus forces.

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Best bone for fixation:

- Subchondral posterior facet
- Subchondral angle of Gissane
- Subchondral CC joint
- Sustentaculum
- Tuberosity near Achilles insertion

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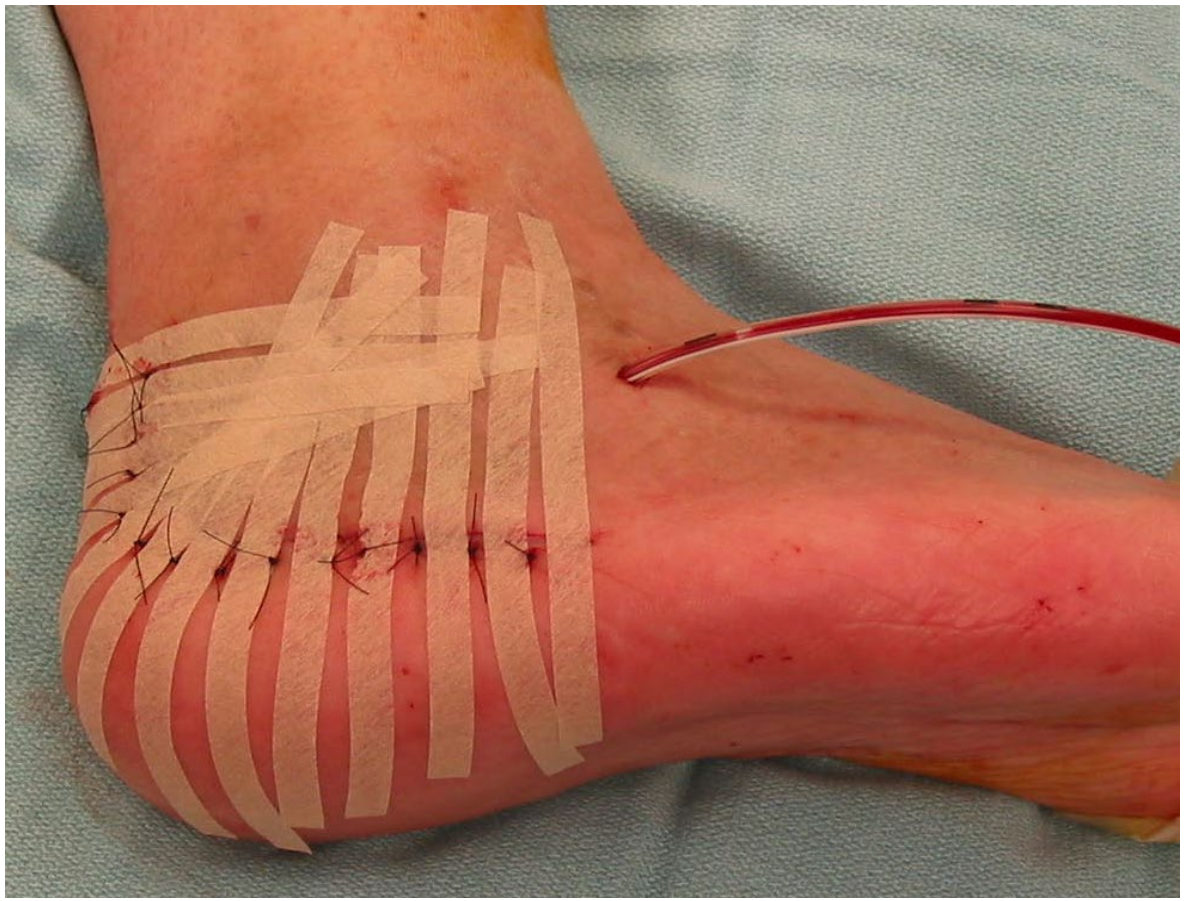
Technique - Closure

- Careful soft tissue handling is critical
- Place all periosteal subcutaneous sutures
- Reduce flap to apex



Surgical Approaches - Sinus Tarsi

Pros:

- Lower risk of wound complications
- Operate earlier (fracture mobile)
- Good view of posterior facet
- Direct reduction of anterior process

Cons:

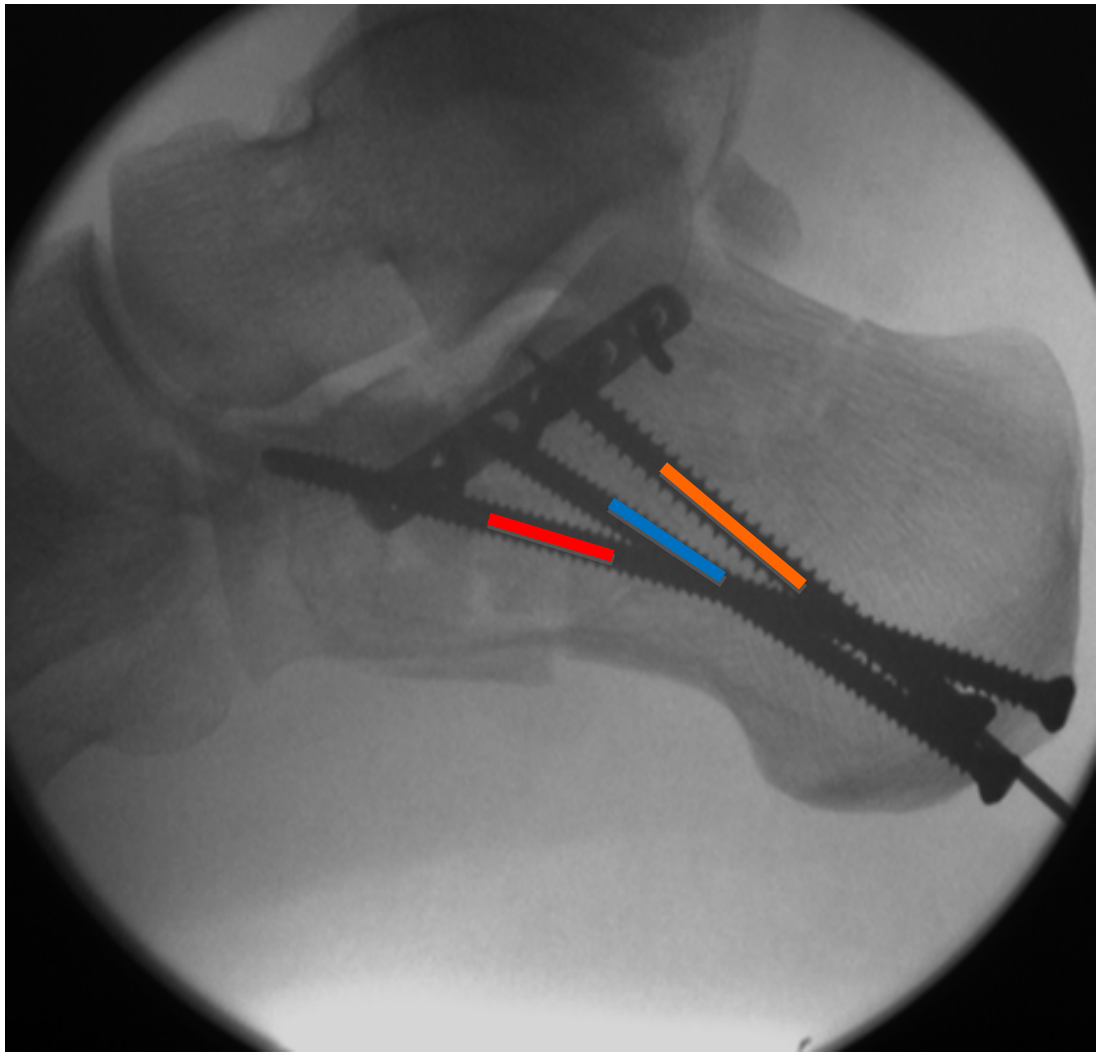
- Indirect reduction of tuberosity
- Harder to address lateral wall blowout
- Limited fixation options

Technique - Sinus Tarsi

- 2- to 4-cm incision from the tip of the fibula to base of the fourth metatarsal .
- EDB is retracted cephalad to permit visualization of posterior facet
- Schantz pin is placed through a stab incision in the posteroinferior calcaneal tuberosity from lateral to medial to allow for tuberosity manipulation
- Hold reduction with K-Wires. Fixation can be done with cannulated or solid screws

Technique - Sinus Tarsi

- Small screws to compress articular Fx +/- small plate to span angle of Gissane
- Medial Wall Screw
  - Into sustentaculum
- "Articular Support Screw"/ "Kickstand" Screw
  - Support depressed articular fragment
- Lateral Column Screw
  - Into anterior process



Technique - Percutaneous Reduction and Fixation

Percutaneous Reduction and Fixation of Displaced Intraarticular Calcaneal Fracture ☆

John L. Marsh, Phinit Phisitkul

This video demonstrates a percutaneous technique in the reduction and fixation of a case with a tongue type fracture with intraarticular comminution.

Consideration – Primary Subtalar Arthrodesis

- Two roles for subtalar arthrodesis:
  - *Late*: to manage post traumatic arthritis, ankle impingement, correct deformity
  - *Acute*: to manage fractures with severe comminution and/or cartilage damage

- Sanders IV fx do worse clinically, and have higher rates of late fusion
  - In the 2002 Buckley RCT, **25% of <u>ALL</u> Sanders IV patients go on to ST fusion within 2 years.**

Primary Subtalar Arthrodesis for the Treatment of Comminuted Calcaneal Fractures

FAI 1996

Barbara D. Buch, M.D., Mark S. Myerson, M.D., and Stuart D. Miller, M.D.

- 108 patients with 112 calcaneal treated b/w 1989 – 1992
- **15% (16 pts) w/ ORIF (to restore height and width) and primary ST arthrodesis**
- 14 patients (12 males and 2 females; mean age, 40 years) were available for f/u at a mean time of 26 months after surgery
- Of the 12 patients employed before the injury, 11 returned to their original occupations at a mean time of 8.8 months after injury
- The mean AOFAS score 72.4

Open Reduction and Internal Fixation Compared With ORIF and Primary Subtalar Arthrodesis for Treatment of Sanders Type IV Calcaneal Fractures: A Randomized Multicenter Trial

Richard Buckley, MD, FRCS, Ross Leighton, MD, FRCSC, David Sanders, MD, FRCSC,

JOT 2014

- 31 pts with 31 Sanders IV calcaneal fractures (4 centers)
- 17 patients received lateral approach for ORIF. 14 with ORIF + PSTA
- From 2004 to 2011, 26 patients were followed for a minimum of 2 years (81% f/u)
  - 1 ORIF patient needed secondary fusion (1/17)
- No statistical difference was found between the results for ORIF, compared with ORIF + PSTA (SF-36, AOFAS 64 vs 62, VAS)
  - Possibility of Type 2 error (Underpowered study)

Authors Conclusions: "ORIF + PSTA however, should be considered for patients with Sanders type IV fractures, and the health care system as they heal at a much more rapid rate, and will not require additional surgery. This must be considered, as the choice of treatment may have profound economic effects on the patient."

- (Healing based on time to Weight bearing --10wks in ORIF vs 6 wks in PSTA)

Subtalar Fusion After Displaced Intra-Articular Calcaneal Fractures: Does Initial Operative Treatment Matter?

By Craig S. Radnay, MD, MPH, Michael P. Clare, MD, and Roy W. Sanders, MD

JBJS 2010

- 69 pts w/ 75 DIACF underwent subtalar arthrodesis for post-traumatic arthritis.
  - Group A – 34 pts (36 fx) initially managed ORIF at an average of 22.6 months later.
  - Group B - 35 pts (39 fx) initially managed nonoperatively
- There were three nonunions per group.
- Group A had less wound complications and significantly higher Maryland Foot Scores (90.8 vs 79.1; $p < 0.0001$) and AOFAS ankle-hindfoot scores (87.1 vs 73.8; $p < 0.0001$) than did Group B.

Authors conclusions: "Initial open reduction and internal fixation restores calcaneal shape, alignment, and height, which facilitates the fusion procedure and establishes an opportunity to create a better long-term functional result."

Summary

- Calcaneus fractures can be extremely debilitating injuries
- Thorough radiographic assessment needed
- Operative indications must be carefully considered – with particular attention to patient, injury and surgeon factors
- Host and injury factors affect choice of surgical approaches
- Remember, do no harm.

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