Pediatric Fractures of the Foot

Nicholas Frane DO

Zucker/Hofstra School of Medicine Northwell Health

Disclosure

- Radiographic Images Courtesy of: Dr. Jon-Paul Dimauro M.D or Christopher D Souder, MD, unless otherwise specified

Overview

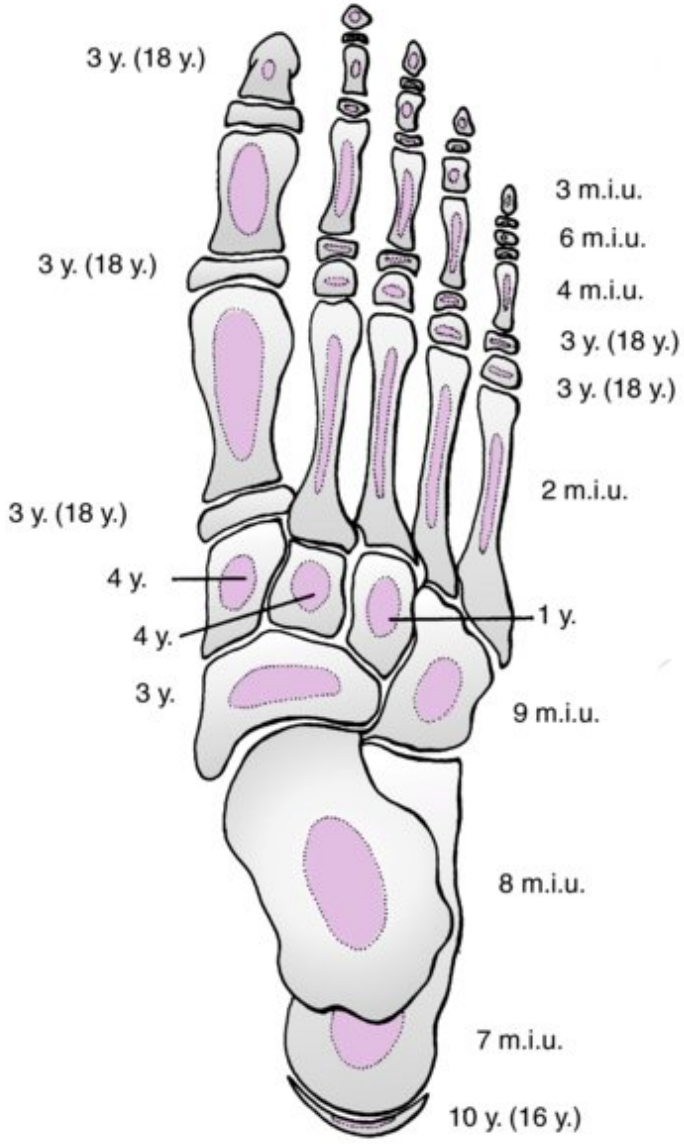
- Talar Fractures
- Calcaneal Fractures
- Metatarsal Fractures
- Phalangeal Fractures

Epidemiology

- <10% of fractures in children
- More common in adolescents and teenagers
- Pediatric foot
  - Cartilaginous →more elastic, absorptive, and flexible
    - As ossification occurs, injuries will more closely resemble adult patterns
- Incidence: 10.5/10,000 (Cooper et al 2004)
- Avg age of injury is 13 years
- M=F
- **Most treated with nonoperative management**

Pediatric Foot Anatomy

- Anatomic Subdivisions:
  - Hindfoot
    - Talus, Calcaneus
  - Midfoot
    - Navicular
    - Cuboid
    - Cuneiforms
  - Forefoot:
    - Metatarsals
    - Phalanges
- Variable number of sesamoids/accessory ossicles



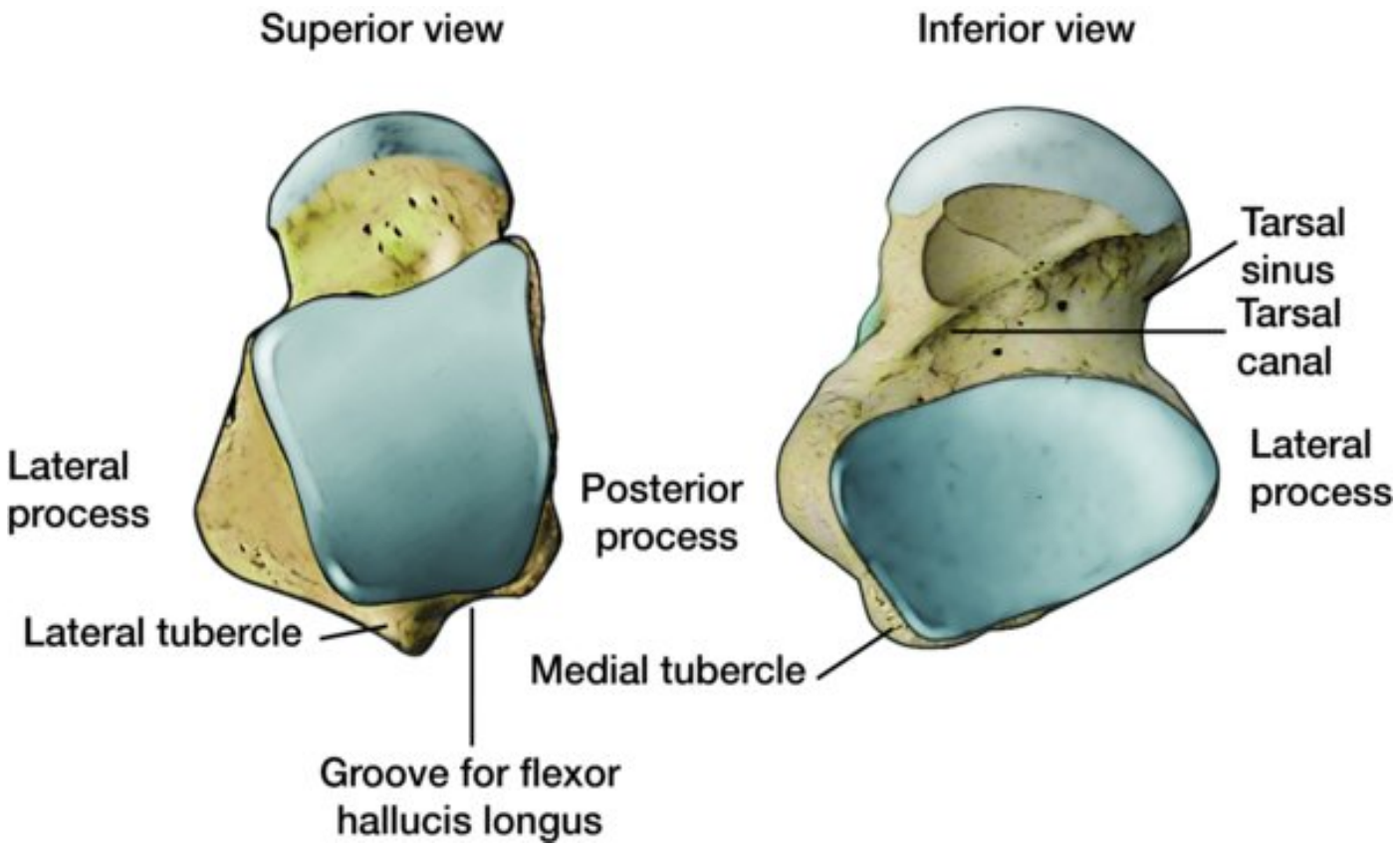
Rockwood and Wilkins' Fractures in Children, 9e, 2019

Talus Fractures

- Rare, incidence between .01% and .08%
- <2% of all pediatric foot fractures
- **Talar neck fractures most common**
- Tenuous blood supply
- MOI:
  - Direct trauma (object falls on foot)
  - Axial load with a dorsiflexed foot
- Majority treated with immobilization
- Adolescent fractures treated like fractures in adults
- Complication: AVN

Crawford AH. Fractures about the foot in children. A radiographic analysis. Cincinnati Children's Hospital, Cincinnati, OH

Talus Anatomy



Fracture Locations

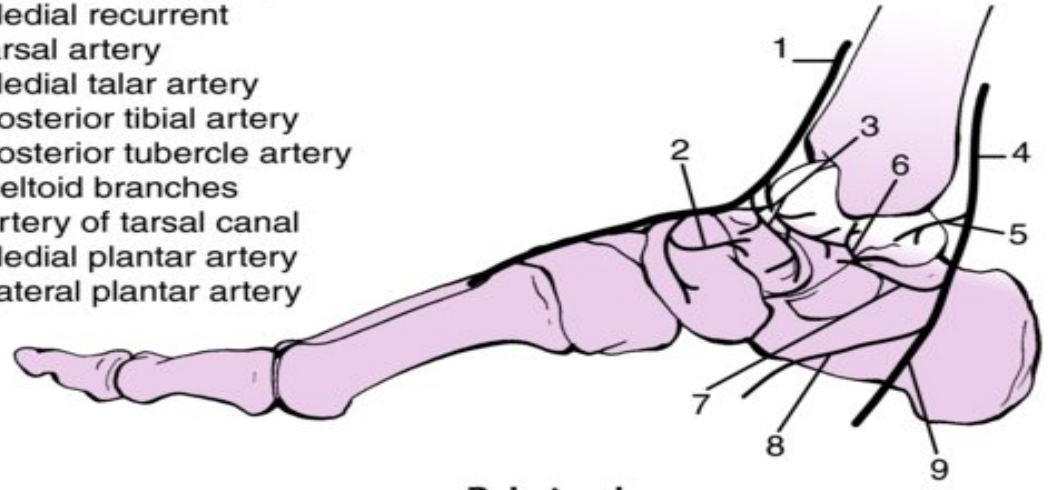
- **Neck**
- Body
- Medial Process
- Lateral Process

Superior and inferior views of the talus (stippling indicates the posterior and lateral processes)

Vascular anatomy of the Talus

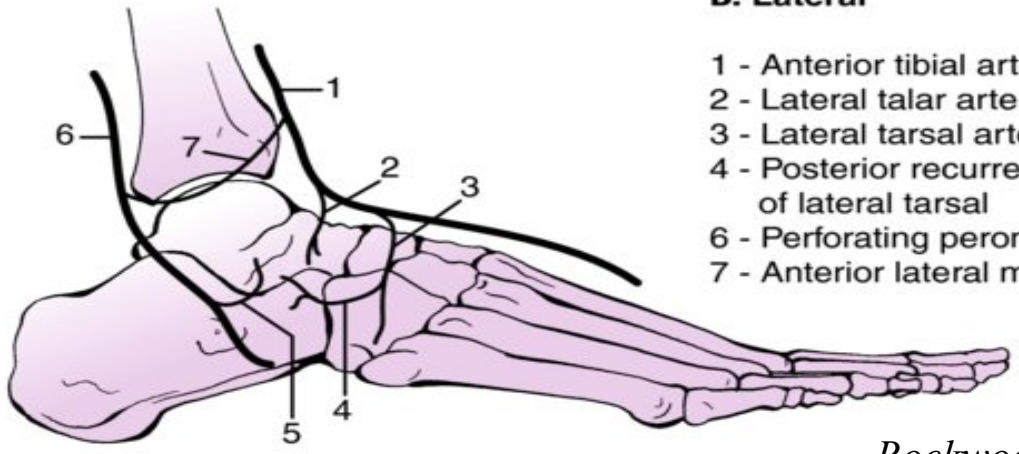
A. Medial

1 - Anterior tibial artery
2 - Medial recurrent tarsal artery
3 - Medial talar artery
4 - Posterior tibial artery
5 - Posterior tubercle artery
6 - Deltoid branches
7 - Artery of tarsal canal
8 - Medial plantar artery
9 - Lateral plantar artery



B. Lateral

1 - Anterior tibial artery
2 - Lateral talar artery
3 - Lateral tarsal artery
4 - Posterior recurrent branch of lateral tarsal
6 - Perforating peroneal artery
7 - Anterior lateral malleolar artery



Anastomosis in pediatric patients more evenly distributed amongst the contributing arteries

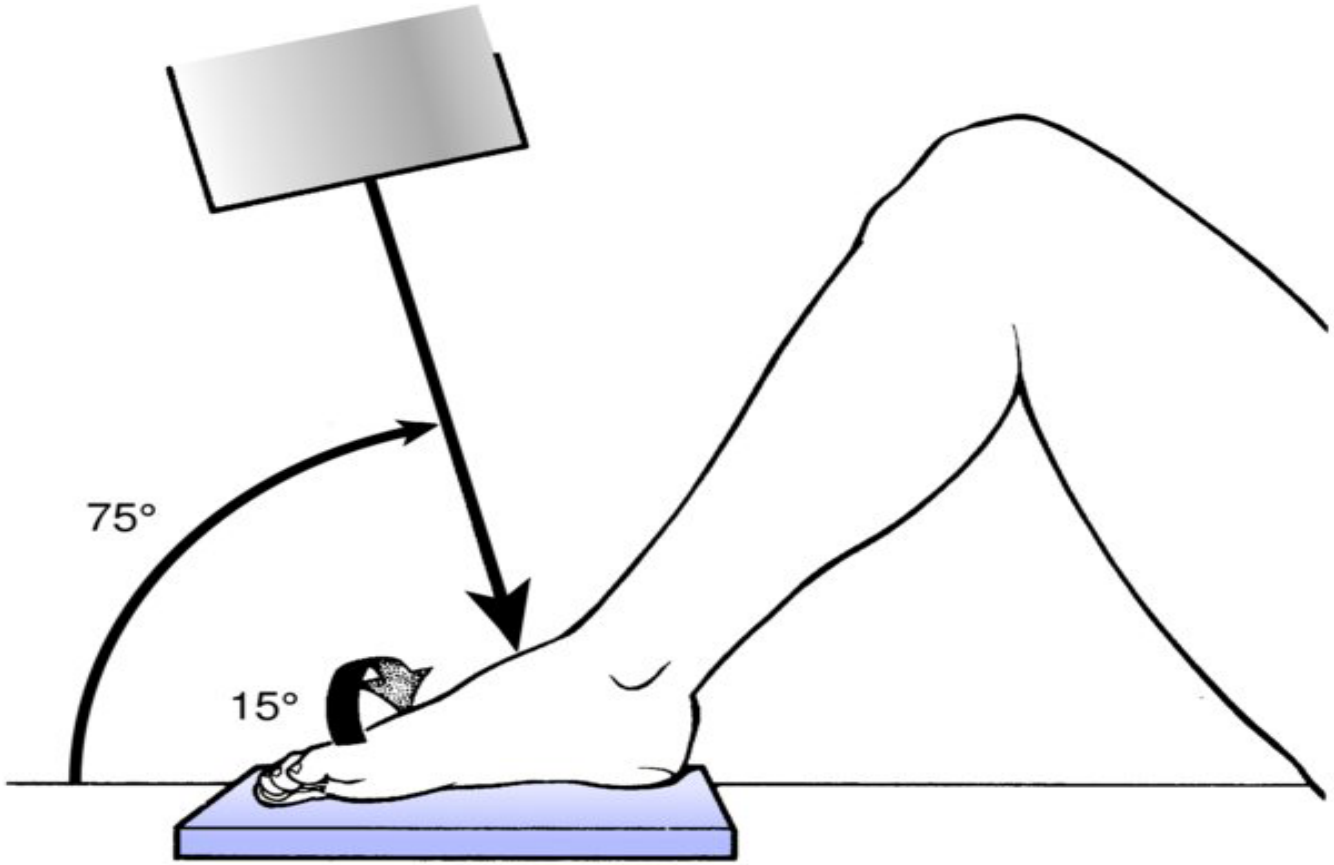
Rockwood and Green's Fractures in Adults, 9e, 2019

Imaging

- AP, lateral, oblique XR of foot & dedicated ankle
  - Canale-Kelly view
  - Talus largely cartilaginous until 2nd decade
- CT
  - Fracture plane, comminution, degree of displacement
  - Useful when pain prohibits appropriate radiographs
  - Preoperative planning
- MRI
  - Classifying osteochondral talus fractures
  - Evaluate AVN

Special Radiographs

- Canale and Kelly view of the foot
- The foot is pronated to 15° and the xray tube is angled 75° to the tabletop



Talar Neck Fractures

- Hawkins' Classification (same as in adults)
  - Type I: nondisplaced
  - Type II: displaced talar neck involving subtalar joint
  - Type III: displaced talar neck fractures involving ankle and subtalar joints
  - Type IV: displaced talar neck fractures involving ankle, subtalar and talonavicular joints
- <8, remodeling potential affords less than perfect reduction
- Outcome in patients <12 years old is favorable in most cases

Hawkins LG: Fractures of the neck of the talus. J Bone Joint Surg 52A:991–1002, 1970.
Canale ST, Kelly FB: Fractures of the neck of the talus, long term evaluation of seventy one cases. J Bone Joint Surg 60A:143–156, 1978.

Treatment of Talar Neck Fractures

Type	Description	Treatment	Blood Supply	ON Rate (%)
Type I	Nondisplaced fracture through talar neck (<5mm and 5 degrees).	6-8 weeks in cast, 4 weeks in CAM Walker.	Theoretical damage to only one vessel entering talar neck.	0–10
Type II	Displaced fracture with subtalar joint involvement.	Immediate closed reduction. A near anatomic reduction delays surgical treatment. If displaced K wires can be used to hold.	Two of three blood supply vessels lost: Neck vessel and one entering the tarsal canal.	20–50
Type III	Same as type II but with subluxation/dislocation of both the ankle and subtalar joint.	Direct to operating room for combined approach fixation w/ K wires vs Screws	All three sources of blood affected.	80–100
Type IV	Very Rare. Type III with talonavicular joint displacement.	Same	Not related to blood supply.	100

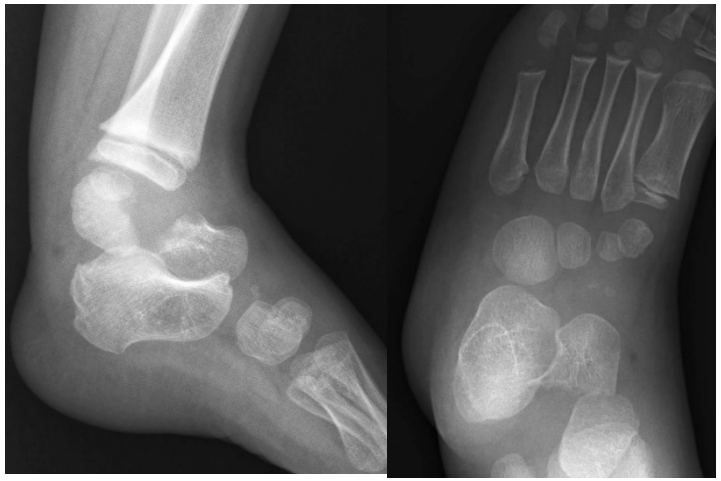
Adolescent with a displaced talar neck fracture with associated medial malleolar fracture


WT BEARING

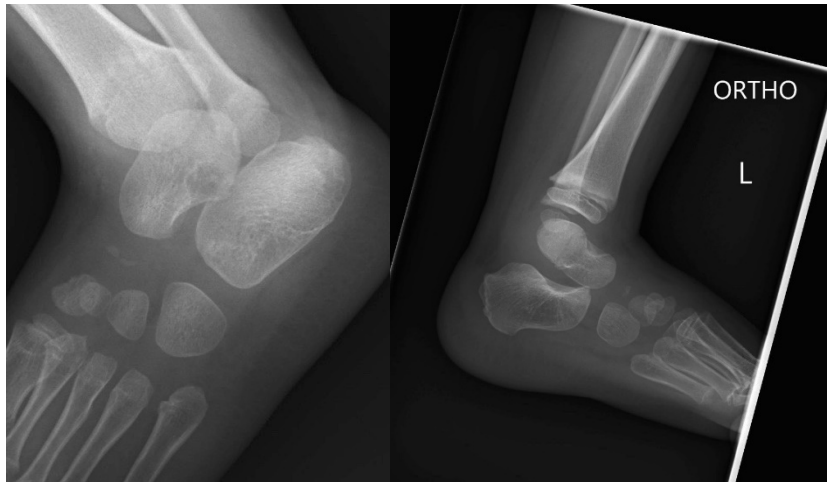

15y Sex: M

Talar AVN

Hawkins 3



CRC



AVN at 10m f/u

Hawkins Sign (A Good Sign)

- Resportion of subchondral bone at talar dome
- **Indicates adequate vascularity**
- May not be visualized in children
  - Mostly cartilaginous talus
- MRI or bone scan may be needed to evaluate for AVN

Osteochondral Talus Injuries

- Inversion/plantar flexion injury
  - Posteromedial lesion (more common)
- Eversion/dorsiflexion injury
  - Anterolateral lesion
- Consider if pain and swelling persist following ankle injury over 2 months
- MRI/MRI Arthrogram
- Lateral lesions are more often associated with trauma and more symptomatic than medial lesions

Osteochondral Talus Injuries

- Berndt and Harty Classification
  - Stage I lesions: nondisplaced
  - Stage II lesions: partially detached
  - Stage III lesions: detached but not displaced
  - Stage IV lesions: detached and displaced or rotated

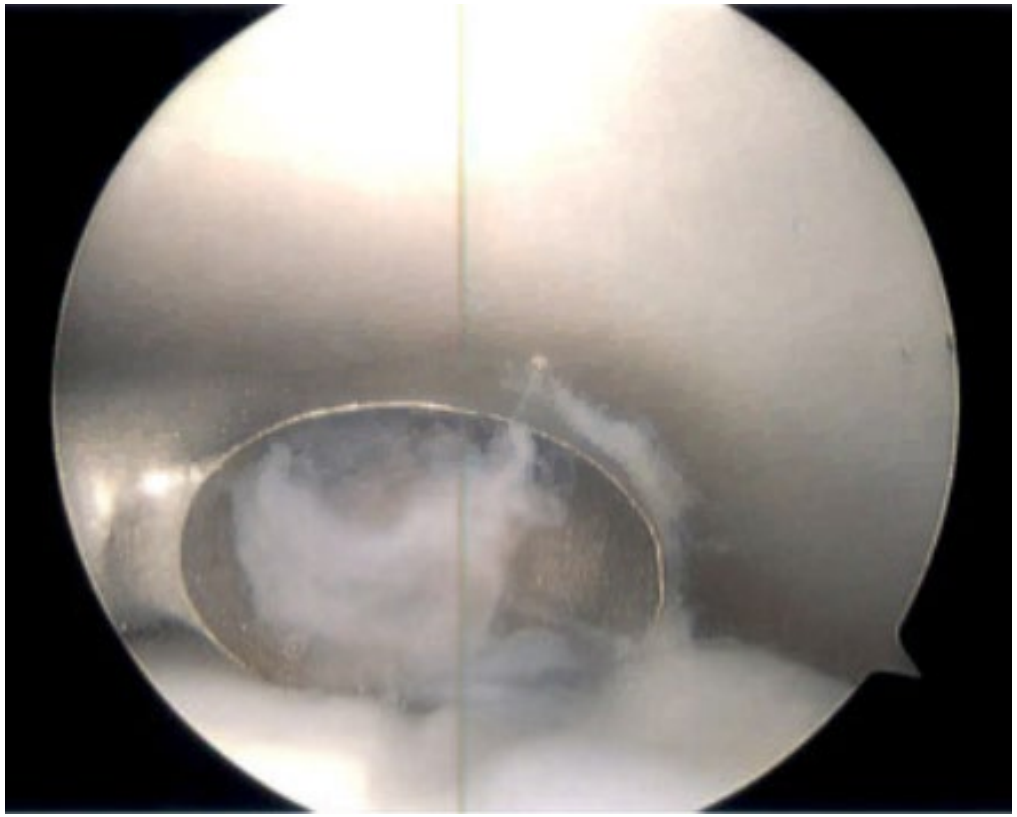
→ Short Leg Cast/Walking boot (Weeks 1-6)
ROM and activity modification (Weeks 7-12)

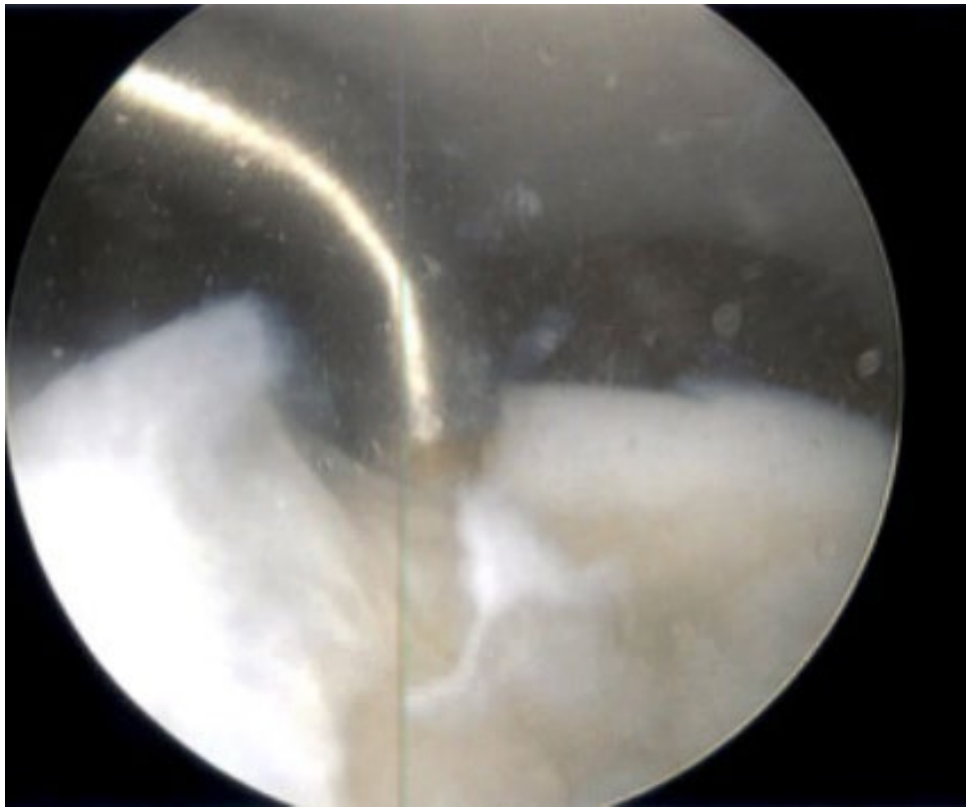
↓ If fail conservative treatment

→
- Drilling lesion (antegrade or retrograde)
- Curettage and Microfractures
- Internal Fixation w/ bioabsorbable implant
- Bone Graft and internal fixation

Berndt AL, Harty M: Transcondylar fractures (osteochondritis dissecans) of the talus. J Bone Joint Surg 41A:988–1020, 1959.

Talar Dome OCD Lesion, treated with arthroscopy and microfracture





Images Courtesy of: Dr. Adam Bitterman D.O.

Lateral Process of Talar Body Fractures

- "Snowboarders Fracture"
  - 13% of snowboarding foot/ankle injuries
- Initially missed in 40-50% of patients, mistaken for sprained ankle
  - Best viewed on ankle mortise film
- MOI: Dorsiflexion, Internal Rotation
  - Produces pain over ATFL

Hawkins LG. Fracture of the lateral process of the talus: a review of thirteen cases. J Bone Joint Surg Am 1965;47:1170–1175
Kirkpatrick et al. The snowboarder's foot and ankle. Am J Sports Med. 1998 Mar-Apr;26(2):271-7.

Lateral Process of Talar Body Fractures

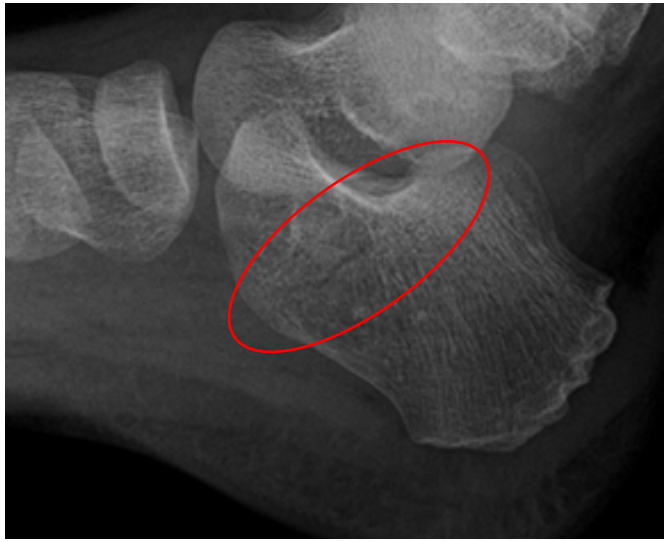
Treatment

- Nondisplaced fractures→6-8 weeks of NWB in a SLC
- Displaced fractures may require ORIF
  - ORIF if joint surface step-off >2-3mm
    - Cannulated or mini frag screw(s) from lateral to medial
    - Mini frag plates for communited or large fragments
- Nonunion has been reported when untreated

Flynn, J. M., In Skaggs, D. L., & In Waters, P. M. (2019). Rockwood & Wilkins' fractures in children.

Calcaneal Fractures

- Rare
  - 0.005% of fractures before 15 yo
- MOI: Falls
- Extra-articular fractures are more frequent
  - Approximately 65%
- Associated soft tissue or skeletal injuries present in 50%
  - Lacerations/open fractures in lawn mower injuries
  - Less common (5.4%) incidence of spinal fractures than in adults



Kay R, Tang C. Pediatric foot fractures: evaluation and treatment. *J Am Acad Orthop Surg*. 2001;9(5):308-19.

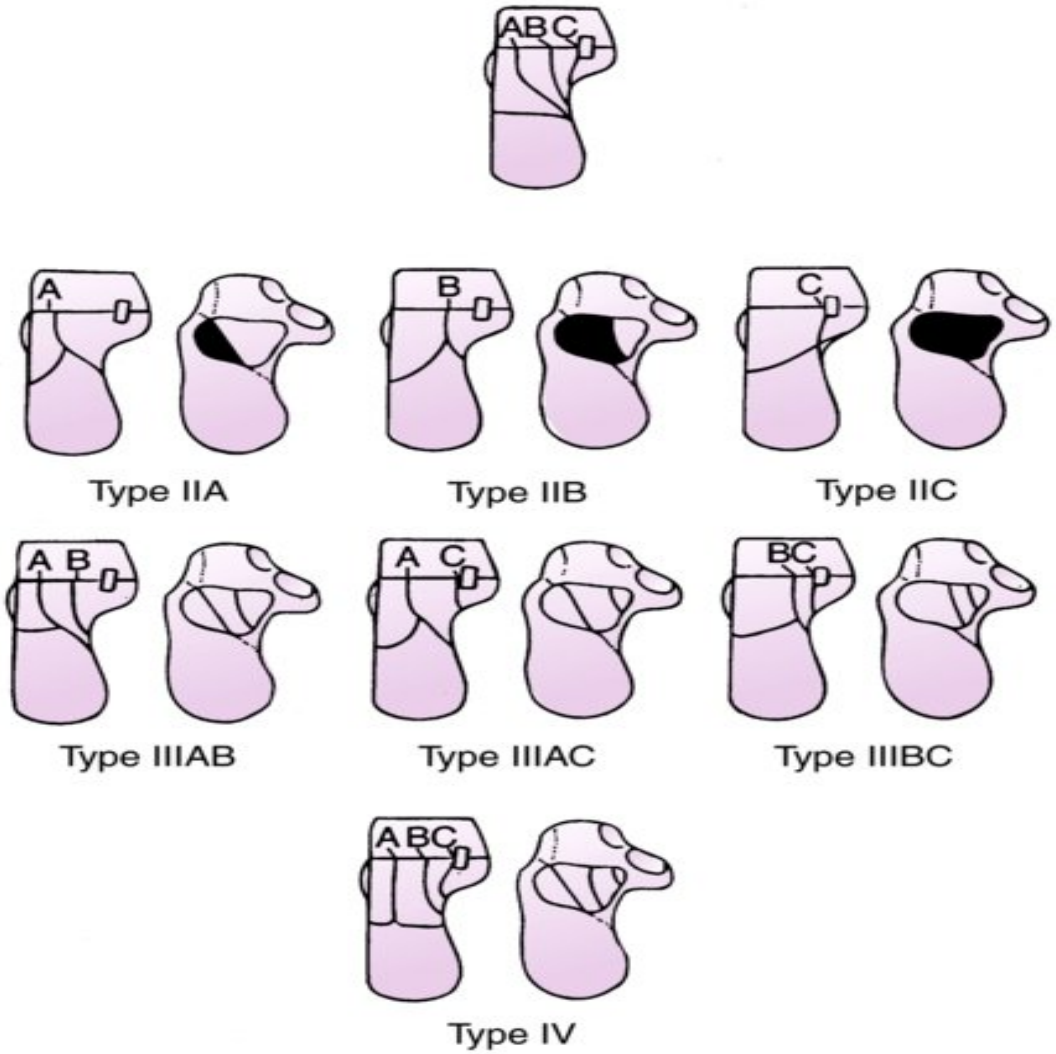
Calcaneal Fractures

- Can be nondisplaced and missed in young children
- Stress fractures:
  - Toddlers beginning to walk
  - Patients with cerebral spasticity
- Pain appreciated with squeezing the heel

Kay R, Tang C. Pediatric foot fractures: evaluation and treatment. *J Am Acad Orthop Surg*. 2001;9(5):308-19.

Classification

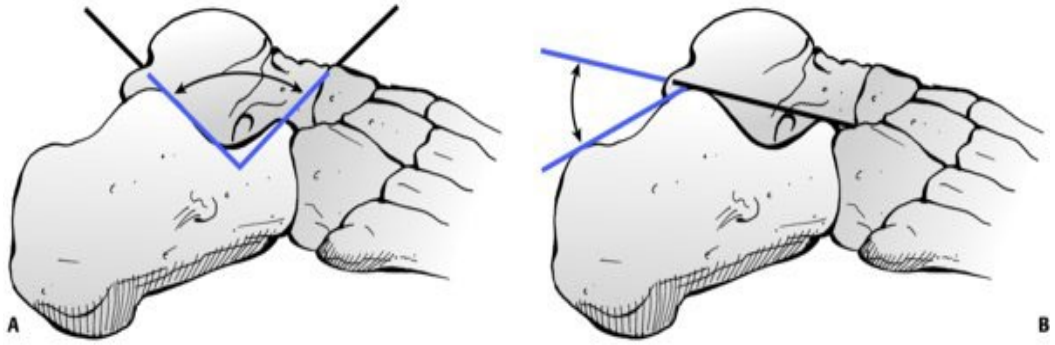
- Sanders Classification appropriate to use for adolescents
- CT-based classification of intra-articular fractures of the calcaneus



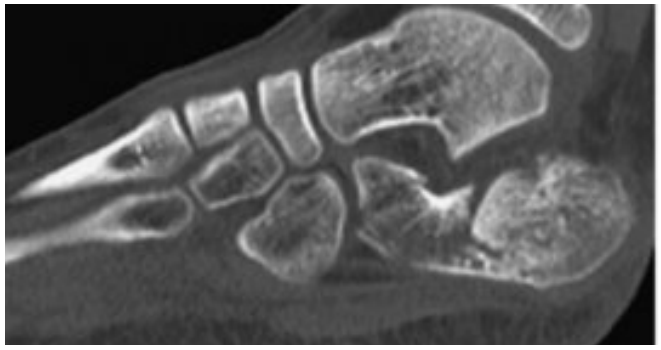
Sanders R. Intra-articular fractures of the calcaneus: present state of the art. *J Orthop Trauma*. 1992;6(2):252-265. doi:10.1097/00005131-199206000-00022

Imaging

- PA, Lateral, Axial Views
  - Bohler's Angle (B)
    - Normal 20-30 degrees
  - Crucial Angle of Gissane (A)
    - Normal: 95-105 degrees
- Child's calcaneus does not resemble that of an adult until after 10 yo
- CT to evaluate intraarticular extension
- MRI

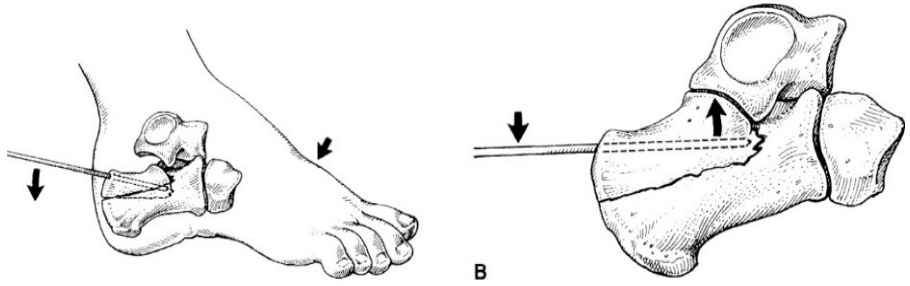


Anatomic angles for evaluation of fracture displacement and surgical reduction.

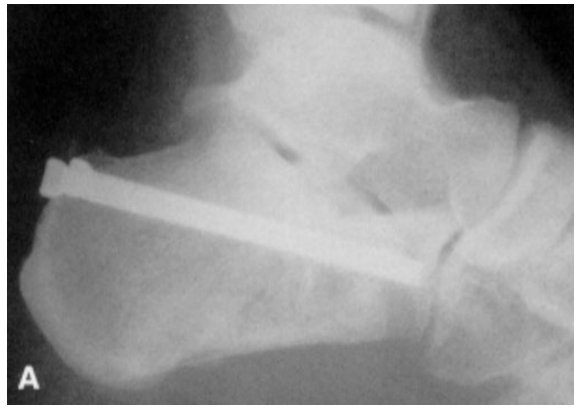


Treatment

- Extra-articular fractures can be treated with Cast for 6 weeks
- Tongue type fractures can be treated nonoperatively if posterior gap <1cm and not tenting the skin
  - Essex-Lopresti reduction if displaced
- Intraarticular fractures with displacement and joint depression
  - ORIF when soft tissues amenable



Tornetta P 3rd. The Essex-Lopresti reduction for calcaneal fractures revisited. J Orthop Trauma. 1998;12(7):469-73.



Brunet JA: Calcaneal fractures in children. Long-term results of treatment. J Bone Joint Surg 82B:211–216, 2000.
Inokuchi S, Usami N, Hiraishi E, Hashimoto T: Calcaneal fractures in children. J Pediatr Orthop 18:469–474, 1998.
Petit CJ, Lee BM, Kasser JR, et al. Operative treatment of intraarticular calcaneal fractures in the pediatric population. *J Pediatr Orthop*. 2007;27(8):856–862.

Axial “Harris” View of Calcaneus Fracture

- Demonstrates presence of heel varus displacement
- Sustentaculum tali is visualized

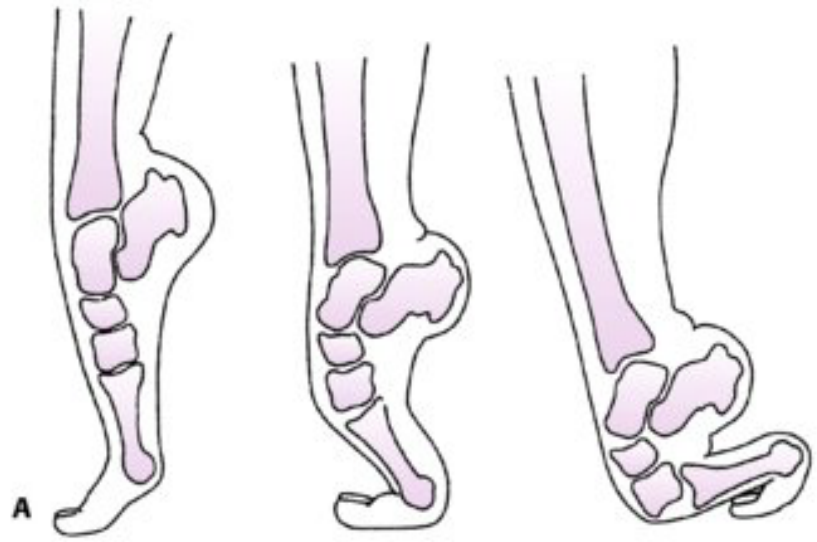
Complications

- Wound complications
  - Incidence lower in children than adults
- Complex Regional Pain Syndrome
- Peroneal Tendonitis/Dislocation

Pickle A, Benaroch TE, Guy P, et al. Clinical outcome of pediatric calcaneal fractures treated with open reduction and internal fixation. *J Pediatr Orthop*. 2004;24(2):178–180

Lisfranc Injuries

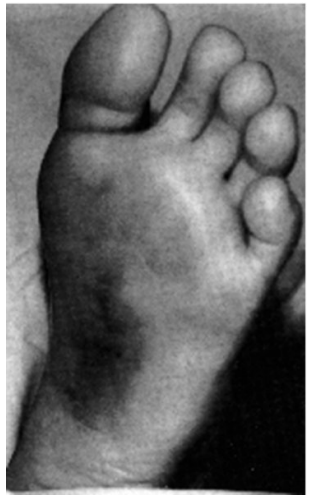
- Direct/indirect mechanisms of injury
- Represent significant force
  - Fracture of base of 2nd MT →increased suspicion for Lis Franc injury
    - Associated cuboid fx → pathognomonic for TMT injury

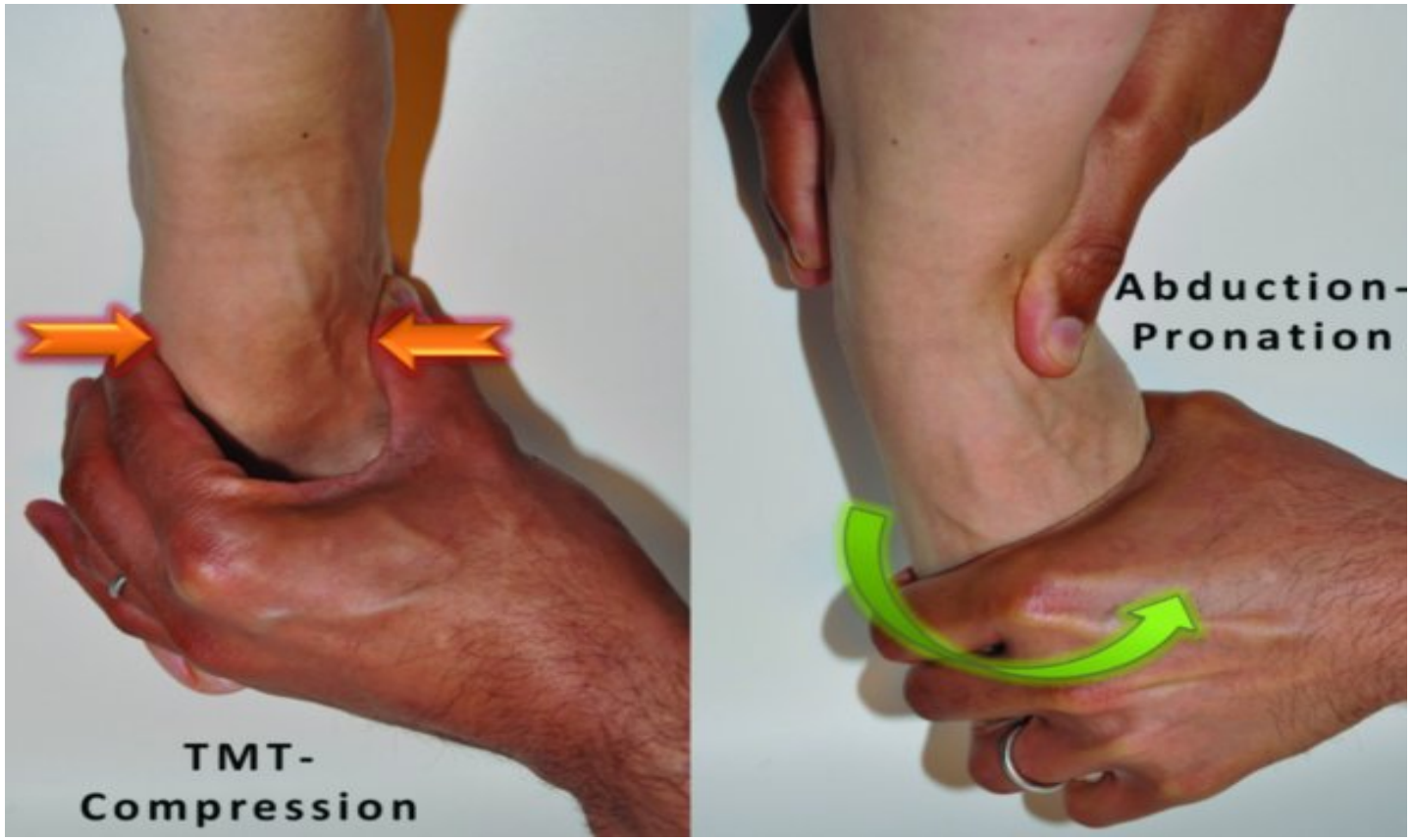


Rockwood and Wilkins' Fractures in Children, 9e, 2019

Lisfranc Injuries: Clinical Signs

- Plantar ecchymosis
- Inability to bear weight
- TMT Compression test
- Abduction Pronation test





Rockwood and Green's Fractures in Adults, 9e, 2019

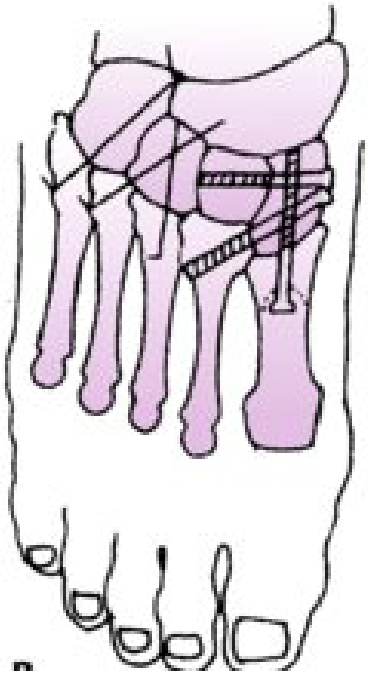
Crawford AH. Fractures about the foot in children: a radiographic analysis. The Children's Hospital Medical Center: Cincinnati.
Flynn, J. M., In Skaggs, D. L., & In Waters, P. M. (2019). Rockwood & Wilkins' fractures in children.

Lisfranc Injuries: Imaging

- Radiographs
  - AP, Lateral, Oblique
    - Weightbearing when subtle injury is suspected
    - Contralateral comparison views allow detection of subtle widening
  - Lateral border of 1st MT and medial cuneiform should line up
  - Medial border of 2nd MT and intermediate cuneiform should line up
  - Distance between base of 2nd MT and medial cuneiform should be **less than 2mm in children >6 years of age**
- CT/MRI can helpful in suspected cases with normal XR to identify ligamentous involvement

Lisfranc Injuries

- Treatment **- requires anatomic reduction**
  - Treat soft tissues first with elevation
  - Non-displaced → SLC x 4-6 weeks
  - Displaced
    - Closed reduction ± pinning can be useful in young children
    - ORIF with screws in older children/adolescents
    - Suture button fixation can be used for ligamentous injuries
    - *Keystone is base of 2nd MT to medial cuneiform*
  - Compartment syndrome can occur



Rockwood and Green's Fractures in Adults, 9e, 2019

Lis Franc Injuries: Case Example

Injury

Contralateral (normal)

Suture button fixation—internal ligament brace

Metatarsal Fractures

- Account for 60-70% of pediatric foot fractures
- 1st metatarsal most common (<5yo)
  - Physis located on proximal end
  - ”Bunk bed injury”
- 5th metatarsal most common (>10yo)
- 2nd metatarsal prone to stress fractures from repetitive trauma (2nd decade)
  - “March Fractures”

Crawford AH. Fractures about the foot in children: a radiographic analysis. The Children’s Hospital Medical Center: Cincinnati.
Flynn, J. M., In Skaggs, D. L., & In Waters, P. M. (2019). Rockwood & Wilkins' fractures in children.

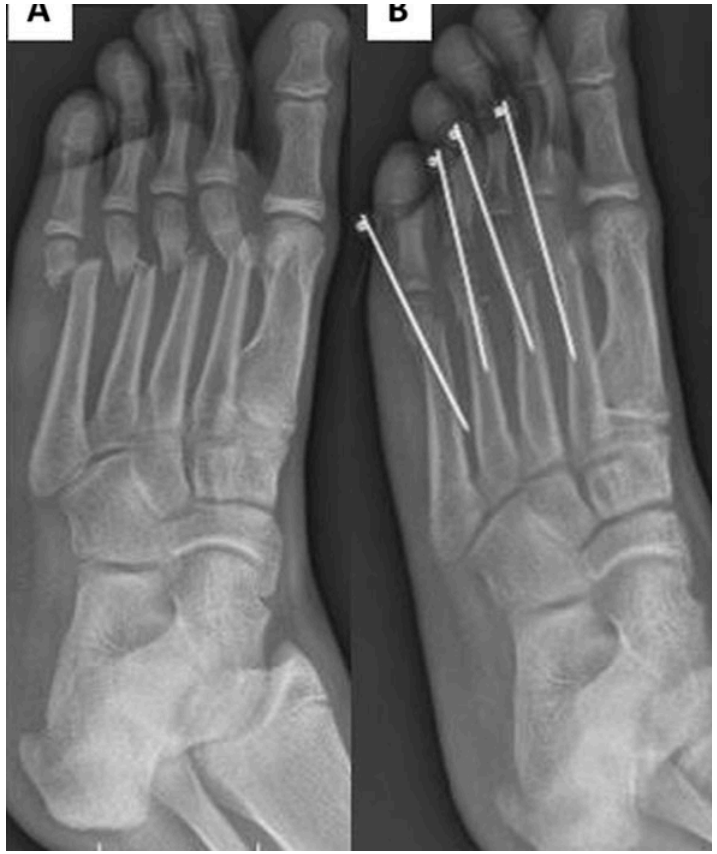
Metatarsal Fractures

- MOI: Direct trauma, torsional stress, sports
  - <5 years old most commonly associated with a fall from height
    - "Bunkbed injury" with base of 1st metatarsal buckle fracture
  - >5 years old most likely results from sporting injury
- Metatarsal base fractures produce concern for Lis Franc disruption

Crawford AH. Fractures about the foot in children: a radiographic analysis. The Children's Hospital Medical Center: Cincinnati.
Flynn, J. M., In Skaggs, D. L., & In Waters, P. M. (2019). Rockwood & Wilkins' fractures in children.

Treatment

- Closed Reduction:
  - Completely displaced fracture
  - >20 degrees angulation
  - Significant dorsal/plantar angulation is not well tolerated
  - Below knee walking cast x 3-6 weeks
- CRPP
  - Unstable reductions



Owen RJT, Hickey FG, Finlay DB: A study of metatarsal fractures in children. Injury 1995;26:537-538
Flynn, J. M., In Skaggs, D. L., & In Waters, P. M. (2019). Rockwood & Wilkins' fractures in children.

Treatment

- Surgical Treatment
  - Retrograde pinning→1-2 K-wires in distal fragment exiting plantar skin
  - IM pinning
  - ORIF
  - Short Leg Non weight bearing cast, remove pins at 4-6 weeks
- Absolute indications
  - Open fracture, associated compartment syndrome, nonunion, or displaced articular fracture
- Relative
  - Adolescents
  - Multiple metatarsal fractures
  - Significant (75% shaft width) translation
- 15% delayed union rate

Owen RJT, Hickey FG, Finlay DB: A study of metatarsal fractures in children. Injury 1995;26:537-538
Flynn, J. M., In Skaggs, D. L., & In Waters, P. M. (2019). Rockwood & Wilkins' fractures in children.

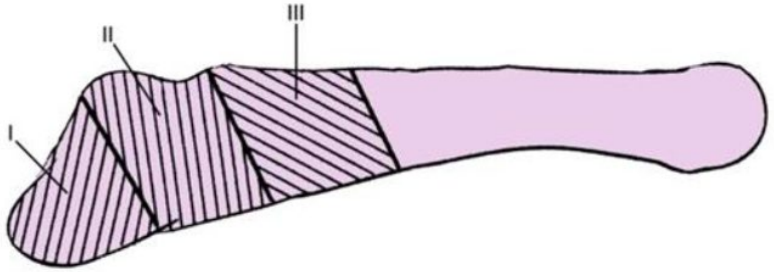
Adolescent female with multiple metatarsal fractures and proximal phalanx fracture of the hallux

5th Metatarsal Fractures

- Types of fractures:
  1. Apophyseal avulsions (involving either part or all of the variably ossified apophysis)
  2. Apophyseal stress fractures (Iselin disease)
  3. Tuberosity avulsion fractures
  4. Jones-type fractures through the metaphyseal-diaphyseal water-shaded area (typically a transverse fracture extending into the common articular facet of the fourth and fifth metatarsals)
  5. Acute diaphyseal fractures
  6. Stress fractures of the diaphysis

Mencio, Gregory A, Marc F. Swiontkowski, and Neil E. Green. Green's Skeletal Trauma in Children
Lawrence SJ. Technique tip: local bone grafting technique for Jones fracture management with intramedullary screw fixation. *Foot Ankle Int*. 2004;25:920–921

5th Metatarsal Base Fractures



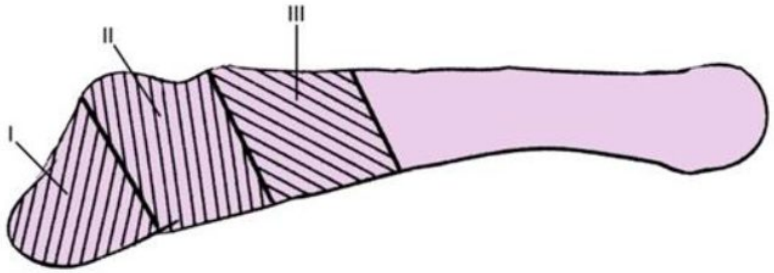
- Most common pediatric metatarsal fracture
  - 50% of all metatarsal fractures
- Apophysis is often misdiagnosed as a fracture
  - Os vesalianum appears by age 9 years
    - Unites with the metaphysis between ages 12 and 15 years
- Apophysis runs parallel to metatarsal
  - Fractures are perpendicular

Fracture→thin arrow
Apophysis→thick arrow

5th Metatarsal Base Fractures

- Zone I
  - Most commonly an avulsion injury
  - Protected weightbearing for 4-6 weeks
  - Radiographic healing lags behind clinical healing
- Zone II
  - Jones type fractures
  - Most commonly in adolescents
  - Acute injuries do will with non-operative treatment
  - Chronic injuries often require IM screw fixation
- Zone III
  - Typically stress fractures
  - Require prolonged immobilization
  - Occasionally require IM screw fixation ± bone grafting

Rockwood and Wilkins' Fractures in Children, 9e, 2019



Parikh SN, Mehlman CT. The Community Orthopaedic Surgeon Taking Trauma Call: Pediatric Ankle Fracture Pearls and Pitfalls. *J Orthop Trauma*. 2017;31 Suppl 6:S27-S31.

Images Courtesy of: Dr. Adam Bitterman D.O.

Images Courtesy of: Dr. Adam Bitterman D.O.

Pediatric Phalangeal Fractures

- 18% of children's foot fractures
  - Proximal Phalanx > Middle Phalanx > Distal Phalanx
- MOI: Direct trauma, barefoot stubbing
- Look for a break in the skin
  - Base of nail avulsion with distal phalanx fractures→open fracture

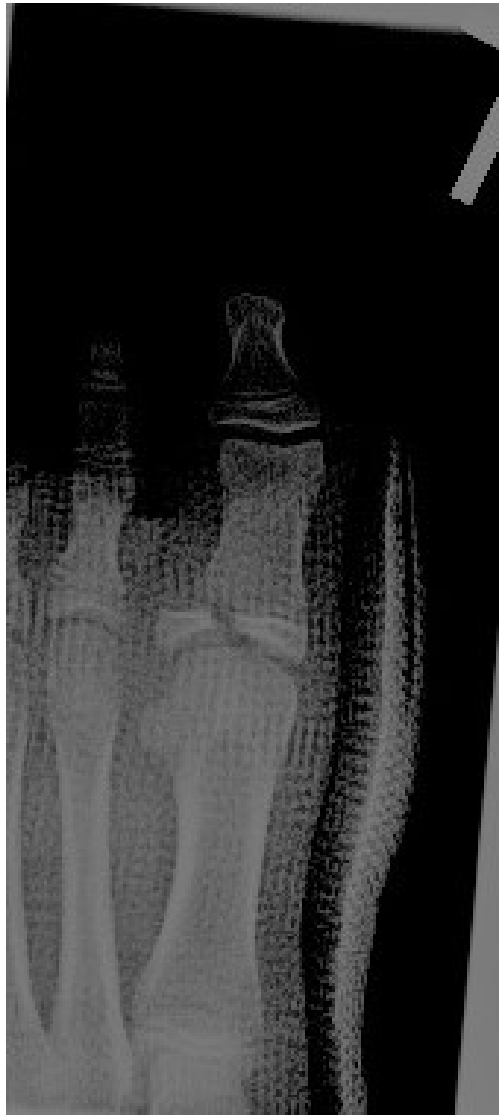
Crawford AH. Fractures about the foot in children: a radiographic analysis. The Children's Hospital Medical Center: Cincinnati.
Flynn, J. M., In Skaggs, D. L., & In Waters, P. M. (2019). Rockwood & Wilkins' fractures in children.

Pediatric Phalangeal Fractures

- Treatment
  - Traction, closed reduction, buddy taping, hard sole shoe
- Open injures require I&D/IV antibiotic
  - Pin if reduction is unstable
  - Meticulous nailbed repair if disrupted
- Intra-articular fractures
  - Anatomic reduction and pinning
  - Indications:
    - >30% of articular surface involved
    - Displacement >2mm

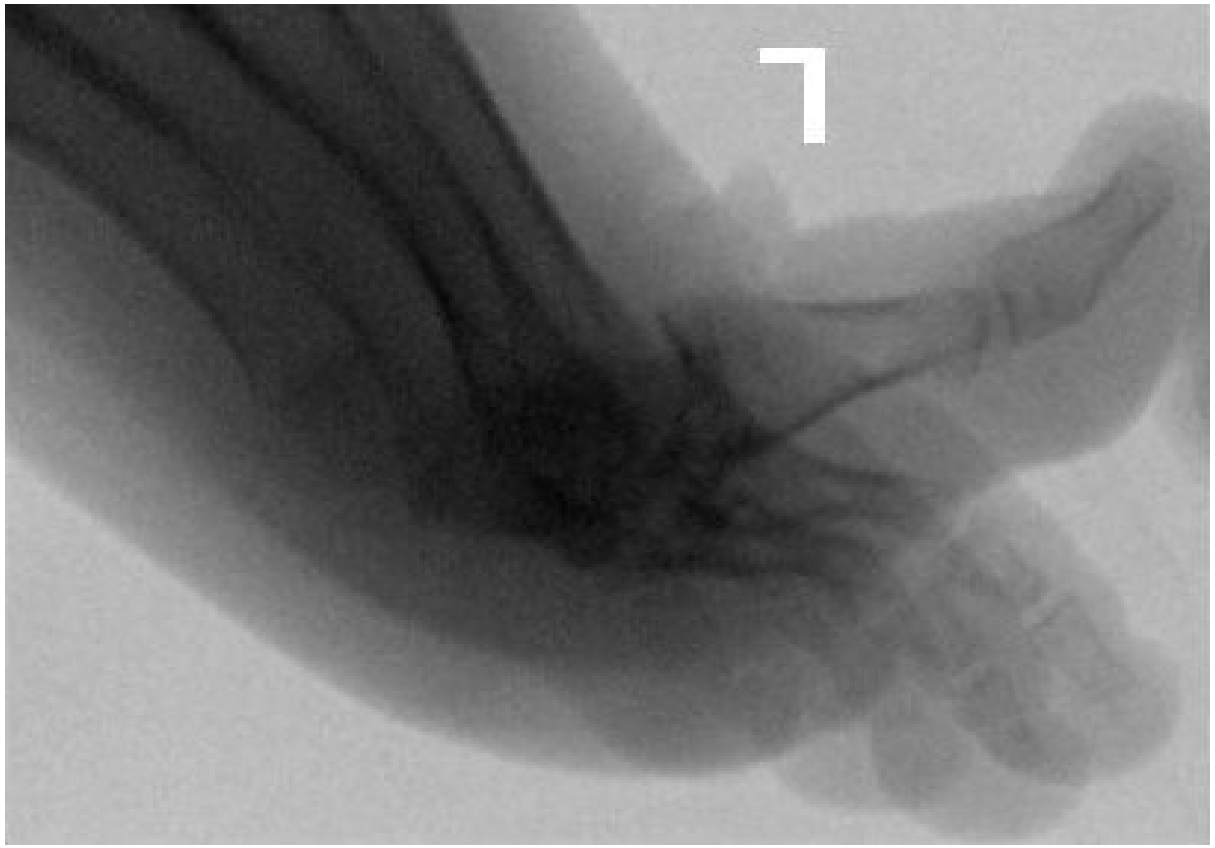
Crawford AH. Fractures about the foot in children: a radiographic analysis. The Children's Hospital Medical Center: Cincinnati.
Flynn, J. M., In Skaggs, D. L., & In Waters, P. M. (2019). Rockwood & Wilkins' fractures in children.

Proximal Phalanx SHIII Fracture 11 yo F



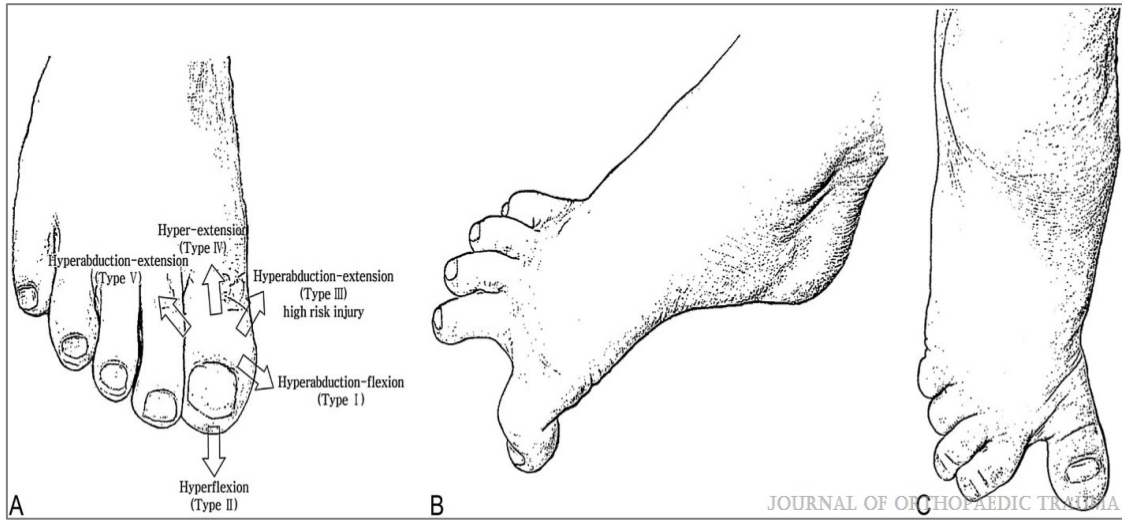
Loss of reduction 1 weeks into conservative management


L



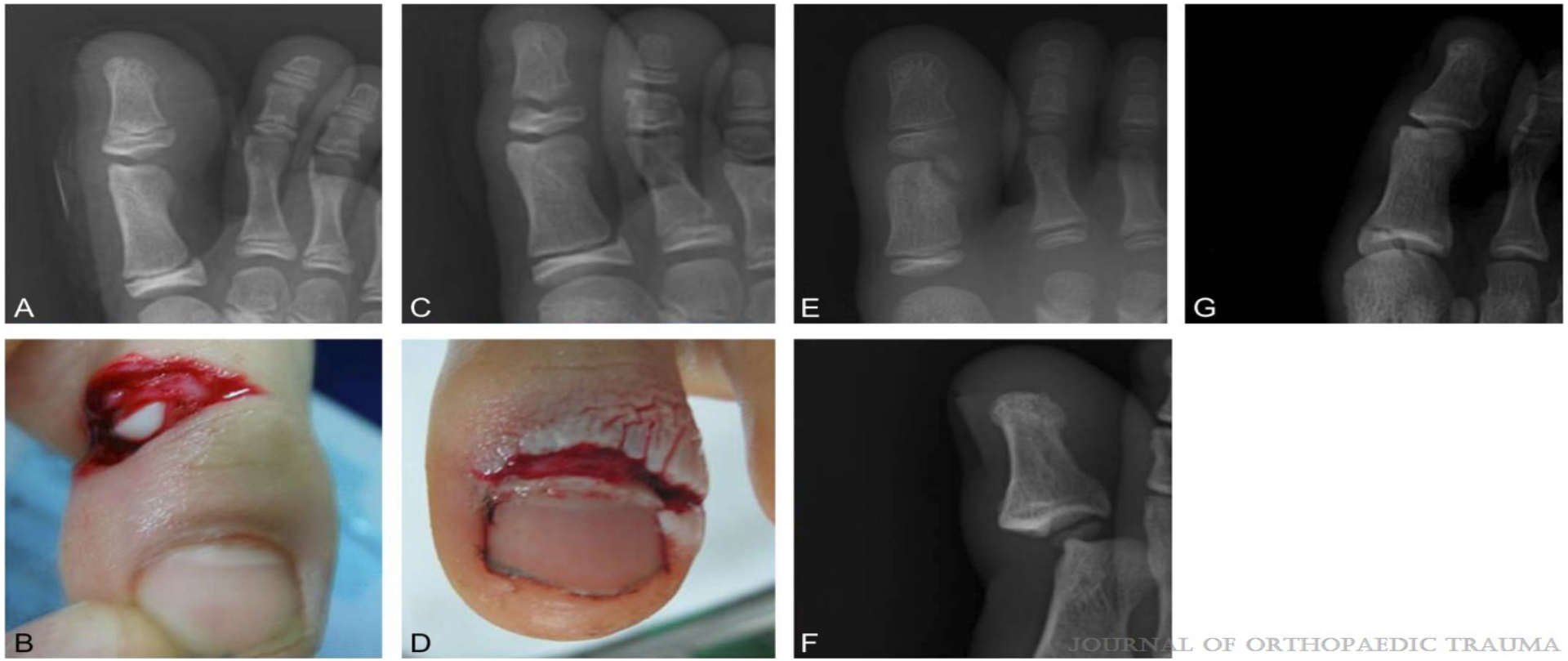
Barefoot Stubbing Injuries to the Great Toe in Children

- High prevalence of hallux injuries from barefoot sports and activities in children
- Open injuries at risk for osteomyelitis
- HAbd-F, HF, HE, and HE-Add are associated with great outcomes
- **The HAbd-E group showed the worst prognosis**



A, Classification of great toe barefoot sports injury mechanisms.
B, The figure shows hyperabduction–flexion injury to the great toe (type I injury mechanism).
C, The figure shows hyperabduction–extension injury to the great toe (type III injury mechanism).

Park DY, et al. Barefoot Stubbing Injuries to the Great Toe in Children: A New Classification by Injury Mechanism. J Orthop Trauma. 2013;27(11):651-655.



- Conclusions:
  - Lateral condyle avulsion fractures of the proximal phalanx should be regarded as a high-risk sign for nonunion
  - Propose aggressive approach for this group
  - Minimally displaced fragments may benefit from open reduction and pinning.

A. Type I (HAbd-F) injury, showing reduction of an open proximal interphalangeal dislocation.
B. Type I (HAbd-F) injury, showing typical dorsolateral wound of an open interphalangeal dislocation.
C. Type II (HF) injury showing mallet toe-like Salter-Harris type I distal phalanx fracture.
D. Type II (HF) injury showing an open wound on the eponychium.
E. Type III (HAbd-E) injury showing avulsion fracture of the lateral volar condyle of the proximal phalanx.
F. Type IV (HE) injury showing dorsal interphalangeal dislocation.
G. Type V (HE-Add) injury showing medial proximal phalanx base fracture.

Park DY, et al. Barefoot Stubbing Injuries to the Great Toe in Children: A New Classification by Injury Mechanism. J Orthop Trauma. 2013;27(11):651-655.

Summary

- Fractures of the Pediatric Foot are infrequently described in the literature
- The majority of these injuries can be managed conservatively with immobilization and follow up
- Fractures in adolescents are treated similar to adults
- Operative indications should be kept in mind as complications can occur

References

Brunet JA: Calcaneal fractures in children. Long-term results of treatment. J Bone Joint Surg 82B:211–216, 2000.

Canale ST, Kelly FB: Fractures of the neck of the talus, long term evaluation of seventy one cases. J Bone Joint Surg 60A:143–156, 1978

Crawford AH. Fractures about the foot in children. A radiographic analysis. Cincinnati Children's Hospital, Cincinnati, OH.

Hawkins LG: Fractures of the neck of the talus. J Bone Joint Surg 52A:991–1002, 1970.

Hawkins LG. Fracture of the lateral process of the talus: a review of thirteen cases. J Bone Joint Surg Am 1965;47:1170–1175

Inokuchi S, Usami N, Hiraishi E, Hashimoto T: Calcaneal fractures in children. J Pediatr Orthop 18:469–474, 1998.

Kay R, Tang C. Pediatric foot fractures: evaluation and treatment. *J Am Acad Orthop Surg*. 2001;9(5):308-19

Kirkpatrick DP, Hunter RE, Janes PC, Mastrangelo J, Nicholas RA. The snowboarder's foot and ankle. Am J Sports Med. 1998 Mar-Apr;26(2):271-7. doi: 10.1177/03635465980260021901. PMID: 9548123

References

Lawrence SJ. Technique tip: local bone grafting technique for Jones fracture management with intramedullary screw fixation. *Foot Ankle Int*. 2004;25:920–921

Parikh SN, Mehlman CT. The Community Orthopaedic Surgeon Taking Trauma Call: Pediatric Ankle Fracture Pearls and Pitfalls. *J Orthop Trauma*. 2017;31 Suppl 6:S27-S31. doi:10.1097/BOT.0000000000001014

Park, Do Y. MD, Han, Kyeong J, Han, Seung H, Cho, Jae H. Barefoot Stubbing Injuries to the Great Toe in Children: A New Classification by Injury Mechanism, Journal of Orthopaedic Trauma: November 2013 - Volume 27 - Issue 11 - p 651-655. doi: 10.1097/BOT.0b013e31828e5d39

Petit CJ, Lee BM, Kasser JR, et al. Operative treatment of intraarticular calcaneal fractures in the pediatric population. *J Pediatr Orthop*. 2007;27(8):856–862

Pickle A, Benaroch TE, Guy P, et al. Clinical outcome of pediatric calcaneal fractures treated with open reduction and internal fixation. *J Pediatr Orthop*. 2004;24(2):178–180

References

Sanders R. Intraarticular fractures of the calcaneus: Present state of the art. *J Orthop Trauma*. 1992;6(2):252–265

Tornetta, Paul III The Essex-Lopresti Reduction for Calcaneal Fractures Revisited, Journal of Orthopaedic Trauma: September 1998 - Volume 12 - Issue 7 - p 469-473

Waters, Peter M, David L. Skaggs, John M. Flynn, and Charles M. Court-Brown. *Rockwood and Wilkins' Fractures in Children*. Philadelphia: Wolters Kluwer, 2020

Zaricznyj B, Shattuck LJ, Mast TA, et al. Sports-related injuries in school-aged children. *Am J Sports Med.* 1980;8:318–324.

Figures used with permission from Roy W. Sanders and John P. Ketz. Chapter 65: Fractures and Dislocations of the Talus. In: Tornetta P, Ricci WM, eds. Rockwood and Green's Fractures in Adults, 9e. Philadelphia, PA. Wolters Kluwer Health, Inc; 2019
Michel A. Taylor, Abdel Rahman Lawendy, and David W. Sanders. Chapter 66: Calcaneus Fractures. In: Tornetta P, Ricci WM, eds. Rockwood and Green's Fractures in Adults, 9e. Philadelphia, PA. Wolters Kluwer Health, Inc; 2019
Thomas A. Schildhauer and Martin F. Hoffman. Chapter 67: Fractures and Dislocations of the Midfoot and Forefoot. In: Tornetta P, Ricci WM, eds. Rockwood and Green's Fractures in Adults, 9e. Philadelphia, PA. Wolters Kluwer Health, Inc; 2019