

Pediatric Fractures of the Ankle

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Disclosure

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

Outline

- Epidemiology
- Anatomy
- Classification
- Assessment
- Treatment
- Outcomes

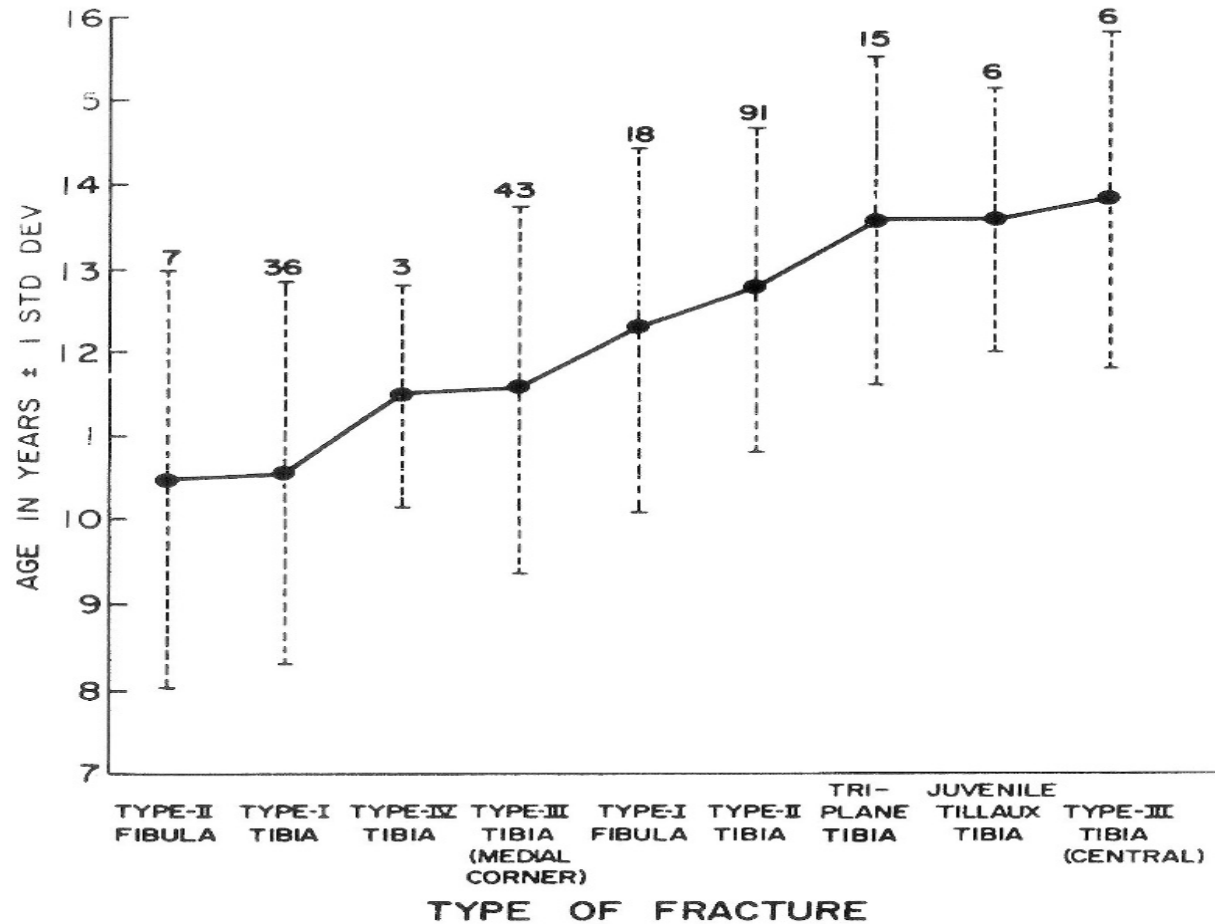
Epidemiology

- Distal tibial & fibular physeal injuries → 25%-38% of all physeal fractures
- Ankle is the 2nd most common site of physeal Injury in children
- Most common mechanism of injury → Sports
 - 58% of physeal ankle fractures occur during sports activities
- M>F
- Commonly seen in 8-15y/o



Hynes D, O'Brien T. Growth disturbance lines after injury of the distal tibial physis. Their significance in prognosis. *J Bone Joint Surg Br.* 1988;70:231–233
Zaricznyj B, Shattuck LJ, Mast TA, et al. Sports-related injuries in school-aged children. *Am J Sports Med.* 1980;8:318–324.

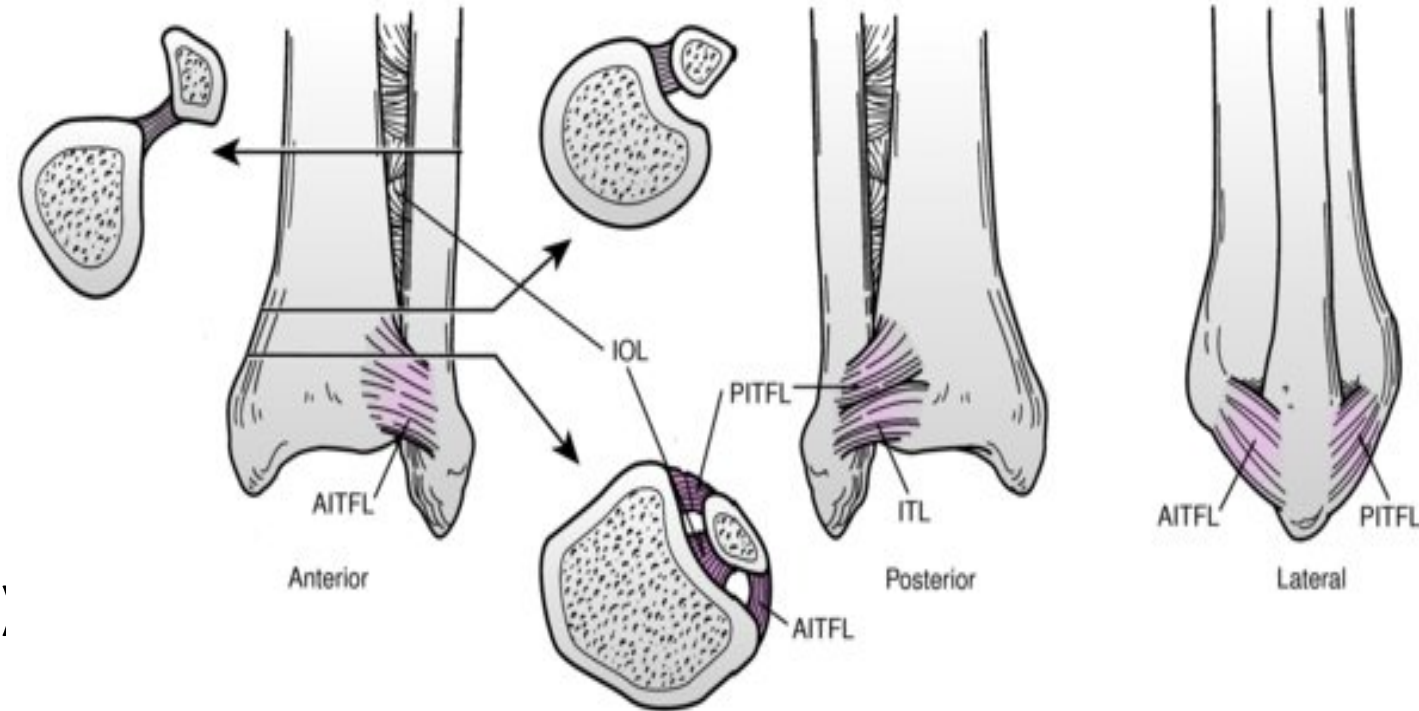
Epidemiology



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

Anatomy

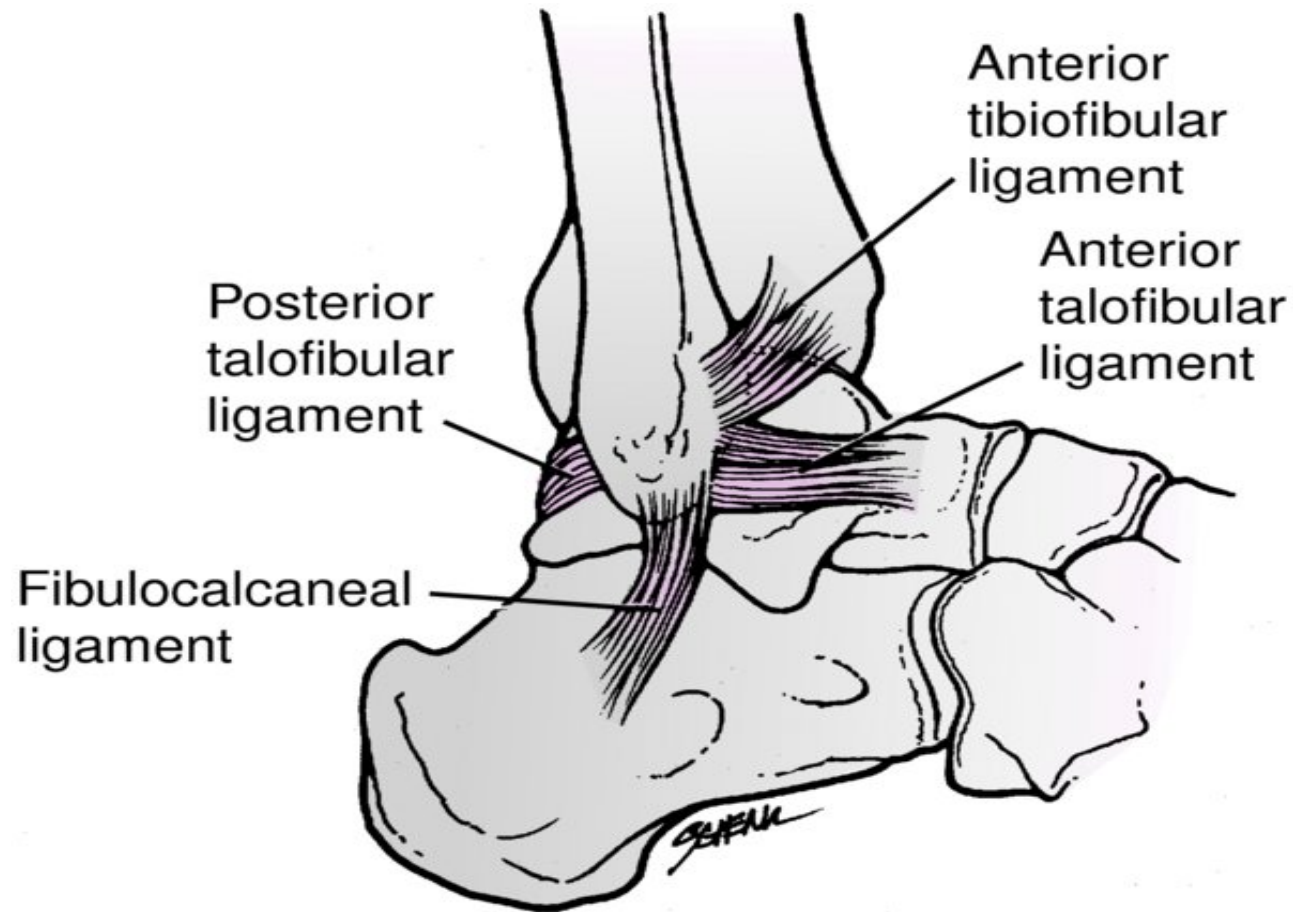
- Ligamentous structures attach distal to the physis
- Growth plate injury more likely than ligament failure secondary to tensile weakness in physis
- Syndesmosis
 - Anterior Tibio-fibular ligament (AITFL)
 - Posterior Inferior Tibio-fibular ligament (PITFL)
 - Inferior Transverse Ligament (ITL)
 - Interosseous Ligament (IOL)



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

Anatomy

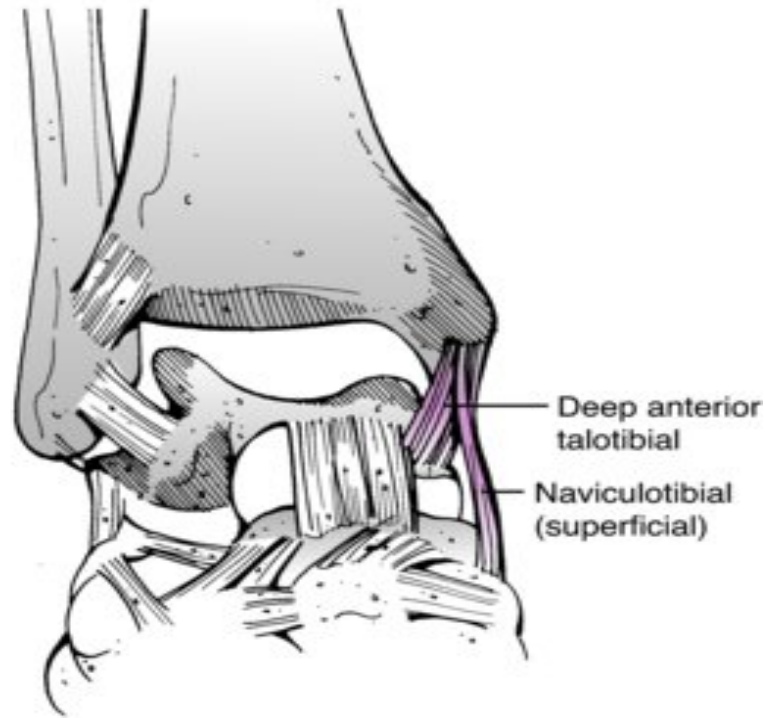
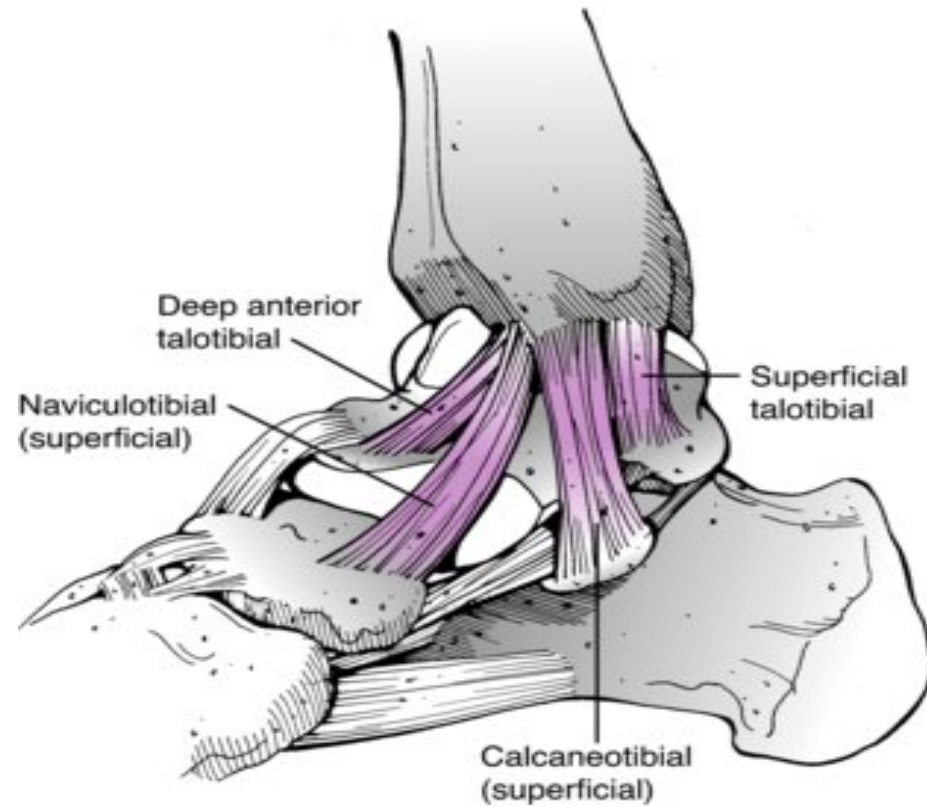
- Lateral Ligamentous Complex



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

Anatomy

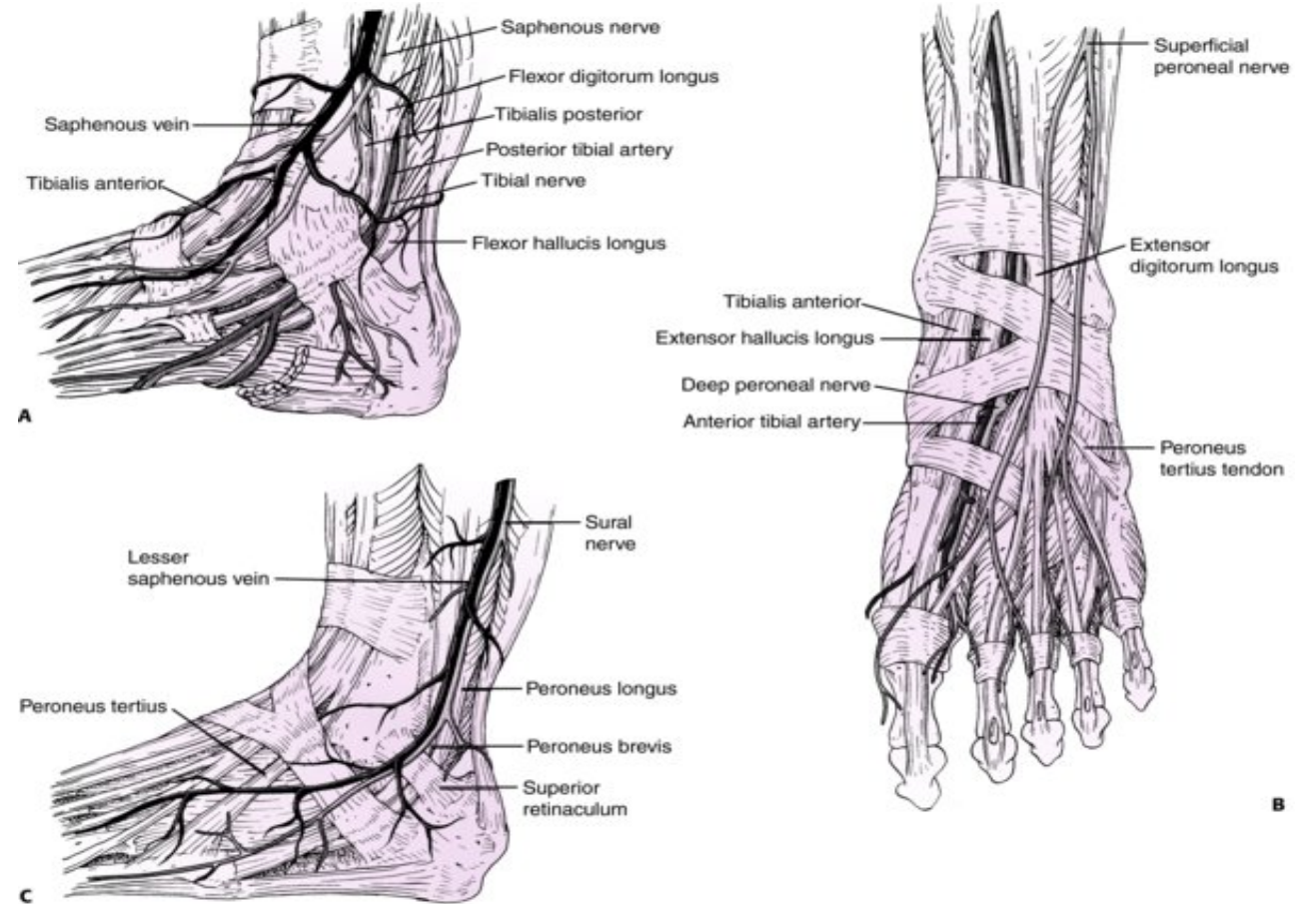
- Medial Ligamentous Structures



Anatomy

- **Structures crossing the Ankle Joint**

- A: Medial
- B: Anterior
- C: Lateral





Anatomy

- **Distal tibial ossification**
 - Appears 6-24 months
 - Medial Malleolus forms 7-8 years
 - Matures: 10 years
 - 20% from separate ossification center (*Os Tibial/subtibiale*)
 - Longitudinal growth ceases
 - 12 years in girls
 - 13 years in boys
 - Asymmetric fusion process
 - Central → medial → anterolateral



Anatomy

- **Distal fibular ossification**

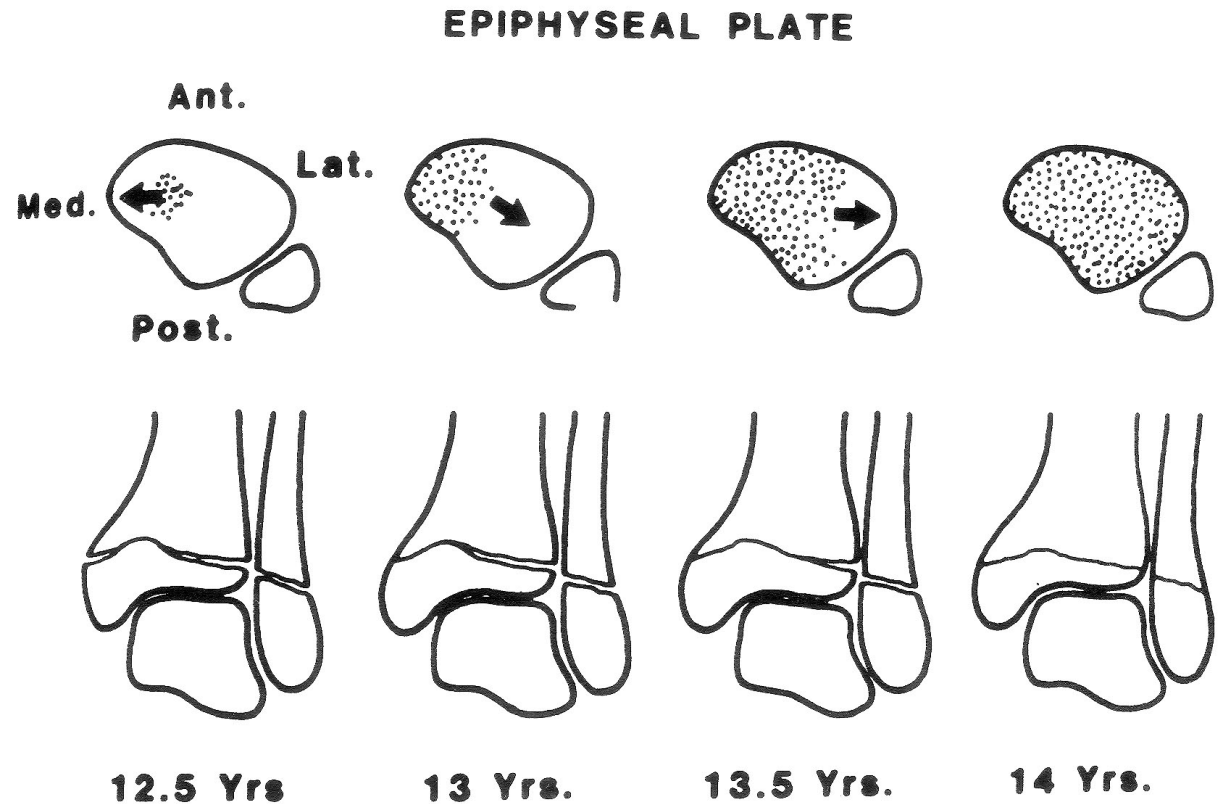
- Appears 9-24 months
- Fibular metaphysis at the level of tibial metaphysis initially
 - Moves distal to level of ankle joint with growth
- Closure follows distal tibial physis by 12-24 months
- *Os Subfibulare*
 - Lateral ossicle can be confused for fracture
 - Os demonstrates smooth, round borders



Distal Tibial Physeal Closure

- **Asynchronous fusion**

- Begins at tibial “hump” (central) and progresses:
 - Medial
 - Posteriorly
 - Anterolateral
- 18 months process
- Fused portion is an area of relative strength
 - Leads to transitional fracture patterns (Juvenile Tillaux & Triplane)



Presentation

- Tenderness
- Swelling
- Difficulty bearing weight
- History of trauma/injury
- Deformity
 - Compare to contralateral leg to assess rotational deformity
- Pain may be only presenting symptom



Do the Ottawa Ankle Rules work for Peds?

- Criteria:
 - **Pain near one or both of the malleoli plus (1):**
 - Inability to bear weight
 - Bone tenderness over posterior edge or the tip of either malleolus
- 2009 Meta-analysis conducted to determine accuracy in the pediatric population
 - Patients >5 years of age
- Missed fracture rate of 1.2%
 - Consistent with findings in adults
- X-Ray reduction rate of 24.8%
- *Suggests that Ottawa Ankle rules are applicable in the pediatric population*



Imaging

- Radiographs:
 - AP, LAT, Mortise
 - Joint above and below must be visualized
 - Tib-Fib film alone decreases quality of ankle views
- Stress radiographs: rarely recommended
- CT scan:
 - Articular and physeal involvement
 - Preoperative planning for triplane and Tillaux fractures
- MRI:
 - Detect occult fractures or growth plate injuries
 - Evaluate interposed soft tissue/periosteum
 - Mapping physeal bars



Imaging

Age specific variations:

- Incisura detectable:
 - Girls: 8 years
 - Boys: 11 years
- Tibiofibular overlap appears:
 - AP:
 - 5 years for boys/girls
 - Mortise:
 - Girls: 10 years
 - Boys: 16 years
- Medial clear space:
 - Normal averages 2-8mm
 - 23% children >6mm



Computed Tomography (CT)

- Allows precise determination of displacement
- Provides detailed information of fracture pattern
- Frequently alters fracture classification, identified displacement and treatment decisions
 - Increased likelihood of recommendation of surgical intervention in transitional ankle fractures
 - Displacement changed from $<2\text{mm}$ to $>2\text{mm}$ in 39% of triplane fractures
 - Orientation and/or number of screws changed in 41% of cases
- Associated with increased cost and radiation



Classification (Anatomic)

- Salter-Harris Classification

- I, II, III, IV, V
- High interobserver correlation
- Correlated with outcomes



Type I and II: Often amenable to closed tx; lower risk of physeal arrest

Type III and IV: More likely to require operative tx; higher risk of physeal arrest

Distal Fibula Fractures

- Typically Salter-Harris I or II fractures are most common
 - SH I Fractures: Average age 10 years
 - SH II Fractures: Average age 12 years
- Mechanism of Injury: Inversion of supinated Foot
 - Physis is weaker than ligaments



Distal Fibula Fractures

- Lateral soft tissue swelling
- Point tenderness
- Often equivocal radiographs
- Is it a SH I Distal Fibula Fracture vs. lateral ligamentous injury (sprain)?



Distal Fibula Fractures

- Sankar et al (JPO 2008)
 - 37 Children
 - All with Open Physes, Lateral Ankle Tenderness + Normal Films
 - 18%: Periosteal Bone Formation at 3 Weeks
- Boutis et al (JAMA Pediatr 2016)
 - 140 Children with Ankle Injuries - Prospectively Enrolled
 - All With Normal Films
 - 135 Underwent Ankle MRI
 - 3%: Salter Harris I Distal Fibula Fractures
 - 80%: Isolated Ligamentous Injuries

Distal Fibula Fractures: Treatment

- Nondisplaced
 - SLWC or walker boot for 3-4 weeks
- Displaced
 - Typically reduced with tibial reduction
 - Fibular treatment based on displacement, ankle mortise stability, and nature of tibia fracture
- Fixation
 - Smooth intramedullary or oblique k-wires
 - Occasionally, plate fixation required, especially if comminuted.



Distal Tibia Physeal Fractures

- Common are are of physeal injury
- SH-2 is the most common fracture pattern
- Rates of premature physeal closure vary from 20-50%



Classification (Mechanistic)

- **Dias-Tachdjian (1978)**

- **4 Types**

- Supination-inversion
- Pronation-eversion, external rotation (PEER)
- Supination-external rotation
- Supination-plantarflexion



A. Supination-inversion



B. Pronation-eversion external rotation



C. Supination-plantarflexion



D. Supination-external rotation

Supination inversion

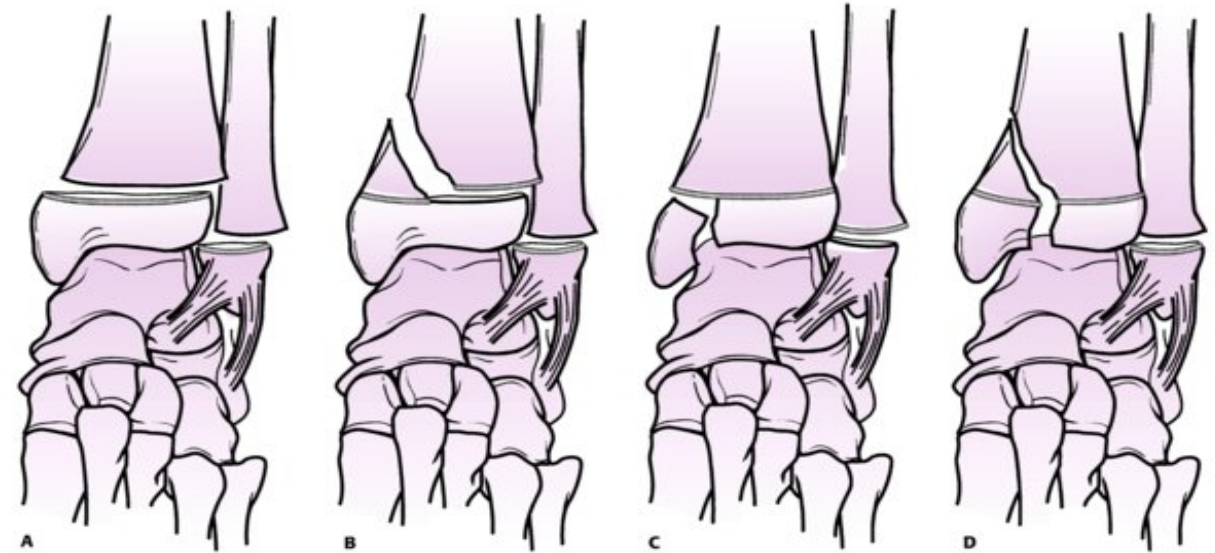
- **Grade 1:**

- Adduction or inversion force avulses fibula
- SH type I or II, rarely can be an epiphyseal fracture

- **Grade 2:**

- Further inversion → tibia fracture
- Compressive force to medial malleolus
- SH type III or IV

Variants of grade II supination–inversion injuries



A: SH type I fracture of the distal tibia and fibula.

B: SH type I fracture of the fibula, type II tibial fracture.

C: SH type I fibular fracture, type III tibial fracture.

D: SH type I fibular fracture, type IV tibial fracture.

Supination inversion

- *McFarland Fracture*
- Higher likelihood of nonunion
 - Intra-articular fracture
- Delayed union not uncommon
 - Late displacement can occur
- **Growth arrest most common in this pattern**
 - Up to 40-50%
 - *Adequacy of reduction is only predictive factor of physeal arrest*

Harris line
angled
downward to
physis



Physeal bar



Pronation-eversion, external-rotation

- Tibial SH I/II fracture pattern
 - Thurston-Holland fragment posterolateral
- Transverse fibula fracture
 - Can be a greenstick fracture
- **Soft tissue interposition is common**
 - Medial periosteum
 - Post/Ant Tib
- Premature physeal closure is common





Supination-External Rotation

- **Grade 1:**
 - External rotational force
 - SH type II tibia fracture
 - Thurston Holland fragment visible on AP Xray
 - Differentiates from Supination-plantarflexion
 - Tibial epiphysis displaces posterolaterally
 - Similar to Supination-plantarflexion
- **Grade 2:**
 - Spiral fx distal fibula metaphysis
 - Anteroinferior to posterosuperior
- **Complications:**
 - External rotation deformity can occur due to incomplete reduction



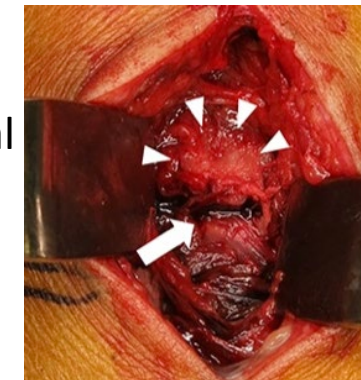
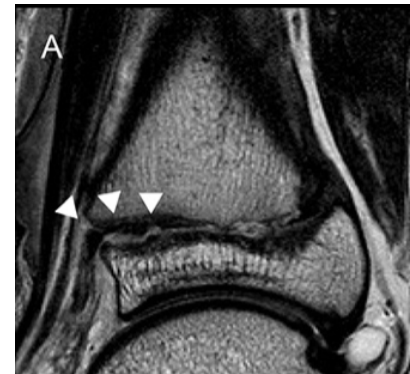
Dias-Tachdjian Supination-Plantarflexion

- Plantarflexion force leads to posterior displacement of epiphysis
 - SH type I/II Tibia fracture
 - Posterior based Thurston-Holland not seen on AP X-Ray
- Complications:
 - Interposed soft tissue is common
 - Anterior periosteum
 - Premature physeal closure

Physeal gap

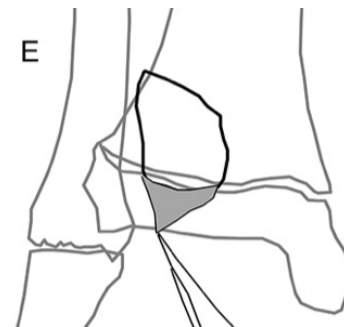


Entrapped periosteum



Arrow heads—metaphyseal donor site of periosteum

Arrow—entrapped periosteum



Distal Tibia Fractures: Treatment

- Location of fracture
- Amount of displacement
- Age of child (how much growth remains)
 - Distal tibia physis contributes:
 - 3-4 mm growth per year
 - 35-45% of overall tibial length
- Follow up X-rays for 6-12 months to evaluate for physeal closure



Treatment Options

Fracture	Options	Pros	Cons
Distal tibia physis	Above-knee vs. below-knee cast	Below-knee casts may allow for less knee stiffness and muscle atrophy of the thigh	For fractures with potential for displacement, the below-knee cast may increase the risk of displacement.
	Local anesthesia with sedation vs. general anesthesia (closed reduction of fractures)	Local anesthesia techniques combined with sedation in the ER may be less expensive, and allow for early reduction	Guidelines for sedation techniques must follow guidelines established by the American Society of Anesthesiologists, and adequate facilities and personnel may not be available in all emergency rooms.
	Minimally invasive approaches (including arthroscopic assistance) vs. traditional open surgical exposures	Arthroscopic-assisted procedures may allow for smaller incisions, and better assessment of articular reductions than open exposures	Additional equipment and OR staffing requirements for arthroscopy are necessary. Surgeon experience with arthroscopy may be more limited.
	Bioabsorbable vs. metal implants	Bioabsorbable devices do not require removal, and subsequent imaging studies (CT, MRI) are not affected by these implants	First-generation implants have a higher risk of local inflammation, and the quality of fixation may be less secure.





Nonoperative Treatment

Indications	Contraindications
<ul style="list-style-type: none">• Nondisplaced, stable fracture patterns• Stable, minimally displaced fractures	<ul style="list-style-type: none">• Significant intra-articular displacement or step off of articular surface, more than 2 mm• Unstable fracture patterns• Significant fracture displacement

- SLC for 4 weeks
 - Weightbearing is restricted for initial 2 weeks
- Additional immobilization is based on amount of healing present

Closed Reduction and Casting (CRC)

- Indicated for closed, displaced SH-1 and SH-2 fractures
- OR vs ER sedation
- Technique
 - Axial traction → reverse the deforming force
 - Long leg cast with foot inverted/everted appropriately to hold reduction
 - Knee flexed 30-90°



Operative Indications

- Open fractures or injuries with severe soft tissue injury
- Displacement of the articular surface (>2mm)
- Unable to obtain or maintain acceptable reduction





Treatment

- Controversies
 - Acceptable alignment is not well-defined
 - Significant remodeling of the distal tibia is not always reliable
 - Acceptable physeal gapping
 - Some studies suggest a physeal gap $>3\text{mm}$ \rightarrow increased risk of premature physeal closure (PPC)
 - Open reduction did not decrease rates of PPC
 - Interposed soft-tissue removal
 - Unclear if the presence of a periosteal flap is associated with an increased rate of PPC

Injury



Post-reduction



Deformity at 4y f/u





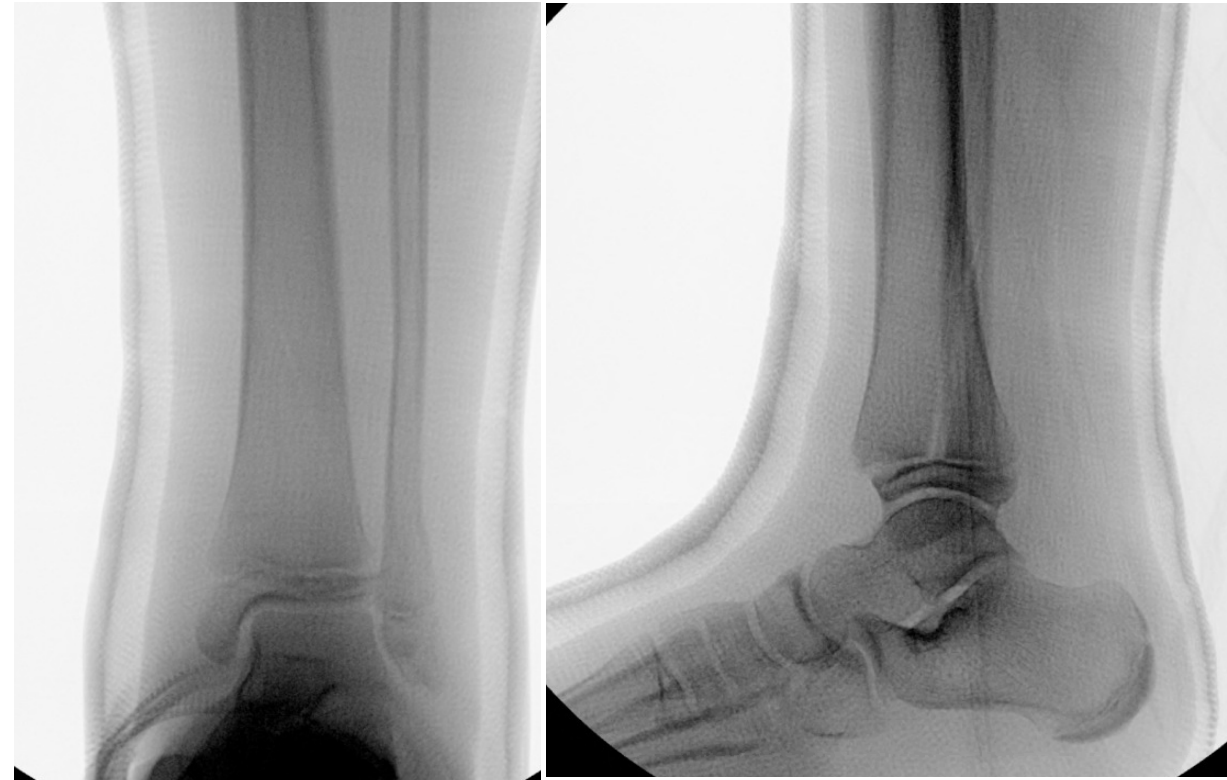
SH I/II Distal Tibia Fractures: Treatment

- Most common fracture type
- Nondisplaced fractures
 - Short leg case for 3-4 weeks
- Displaced fractures
 - Closed reduction and casting
 - LLC for 2-3 weeks,
 - Followed by SLWC cast for 3 weeks
 - If acceptable reduction is unable to be obtained/maintained
 - ORIF if Thurston-Holland (TH) fragment is large enough
 - Smooth, transphyseal K wires if TH is small





No rotation seen



Treated with CRC

*Note: Anterior physeal gapping > 3 mm s/p reduction may indicate entrapped periosteum

Treatment

- Closed reduction and above knee casting
 - Transitioned to below knee walking cast or boot after 3-4 weeks
- If unstable, smooth pin fixation may be needed (removed after 2-4 weeks)
- Screw fixation can be used if Thurston-Holland fragment is large enough



External Rotation deformity
--must be reversed during
closed reduction



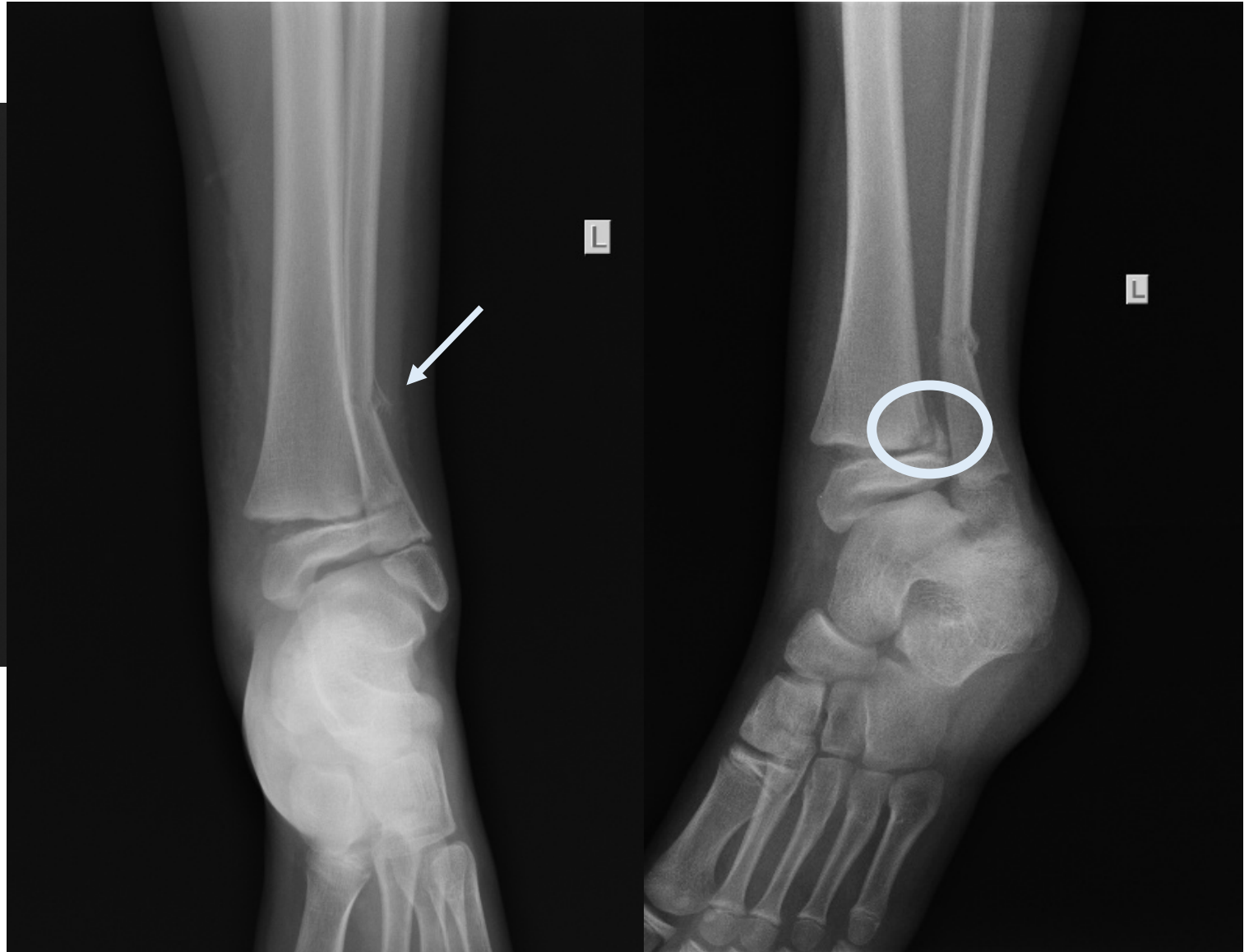
Closed reduction and casting in OR



9 M, fall off scooter

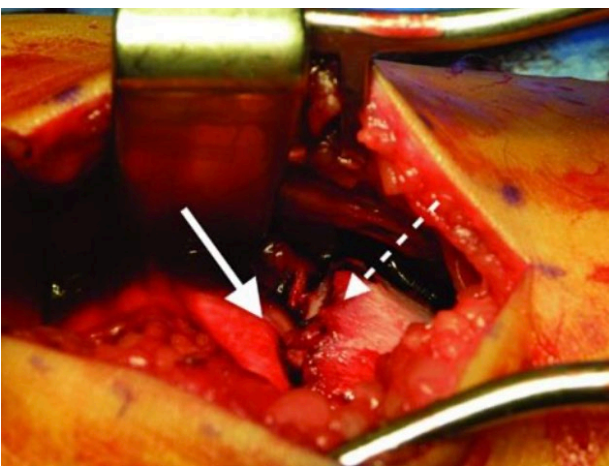


Small TH fragment not amenable to screw fixation

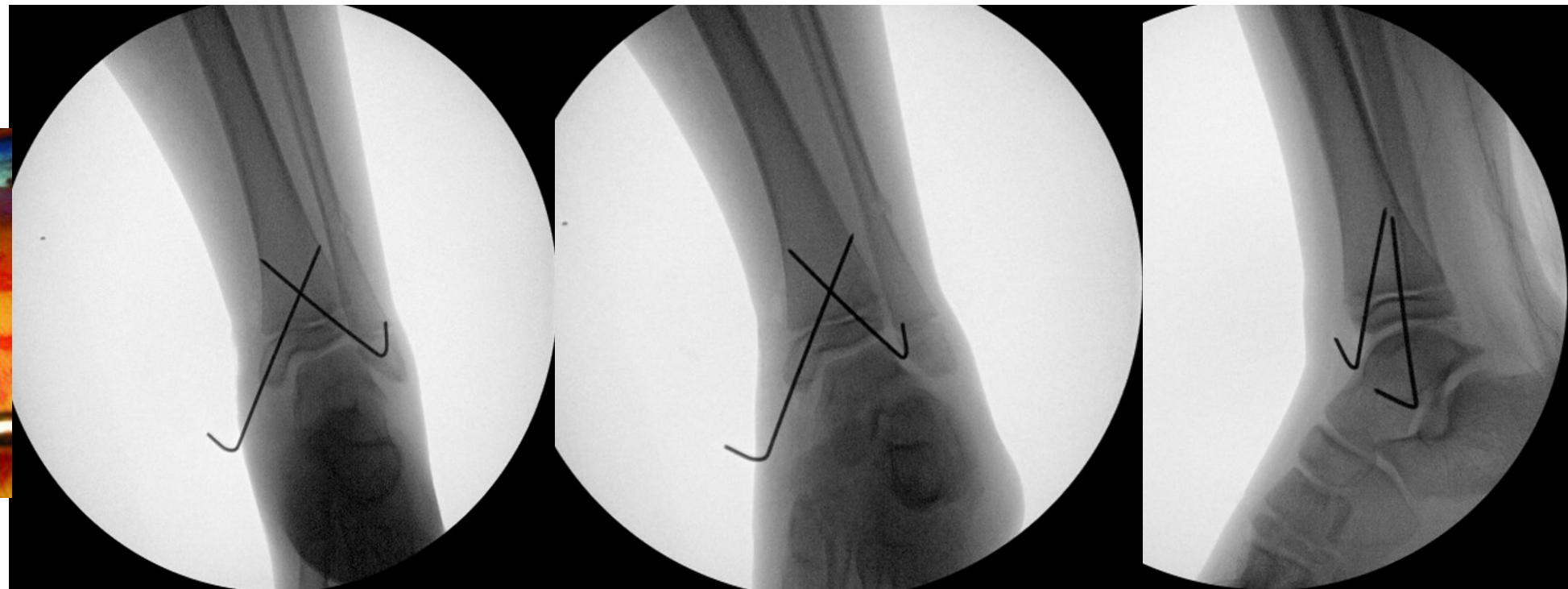




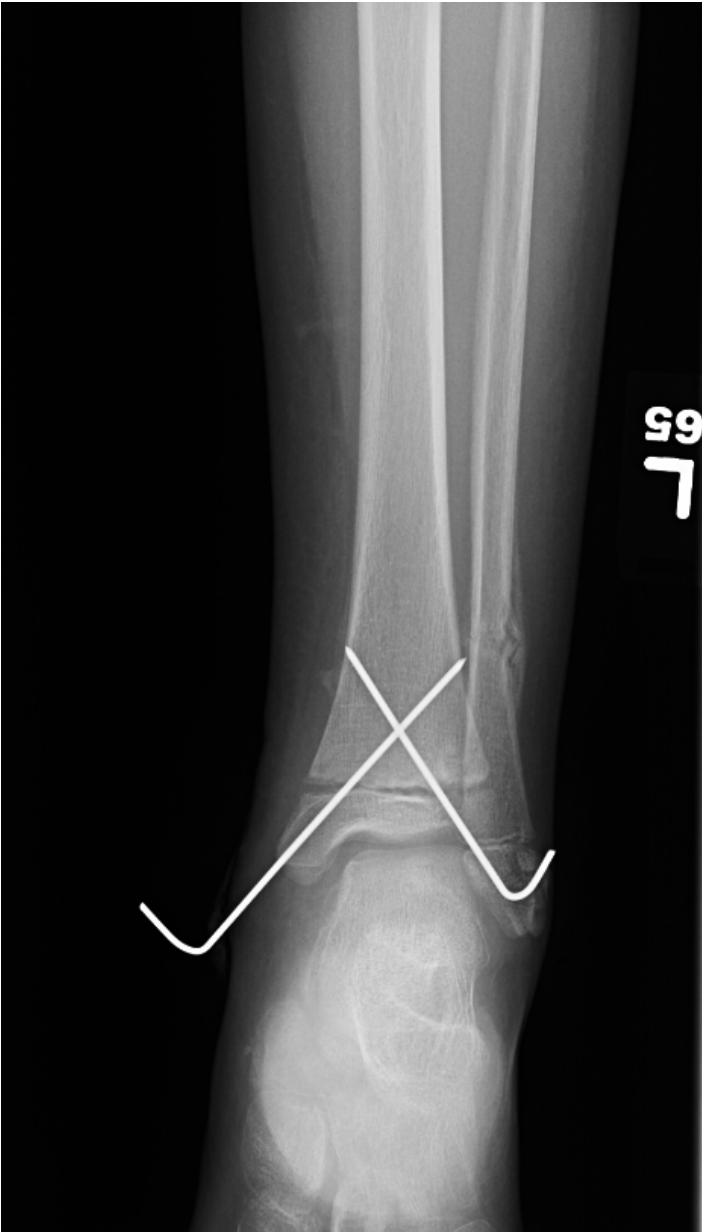
Unacceptable alignment after reduction



Entrapped periosteum medially (solid arrow)



Periosteum removal allowed anatomic reduction.
Reduction stabilized with smooth k-wires



3 month follow-up



14 y/o M with fall from skateboard



Attempted closed reduction



Entrapped bone fragment removed posteriorly
Entrapped periosteum removed anteriorly



Large TH fragment allowed screw fixation

SH III/IV Distal Tibia Fractures: Treatment

- SH III/IV fractures typically involve medial malleolus
 - Higher risk for developing partial growth arrest and varus deformity
- **Articular surface MUST be aligned**
- **Physis MUST be aligned**
- Nondisplaced fractures (<2mm)
 - LLC x 4-6 weeks
 - May transition to SLWC at 3-4 weeks
 - Require close f/u to identify interval displacement
 - Consider CT after cast placement to accurately assess displacement



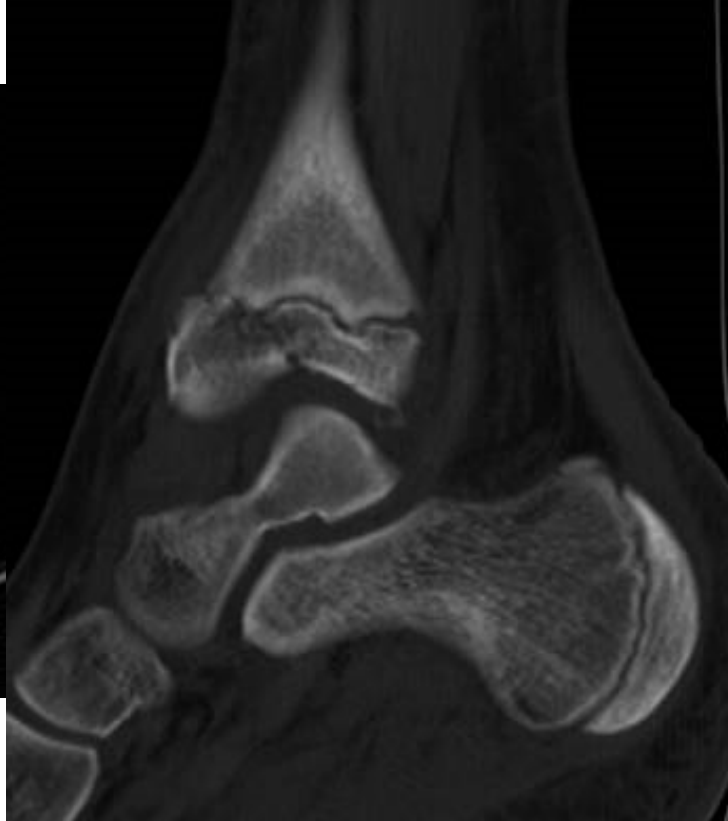
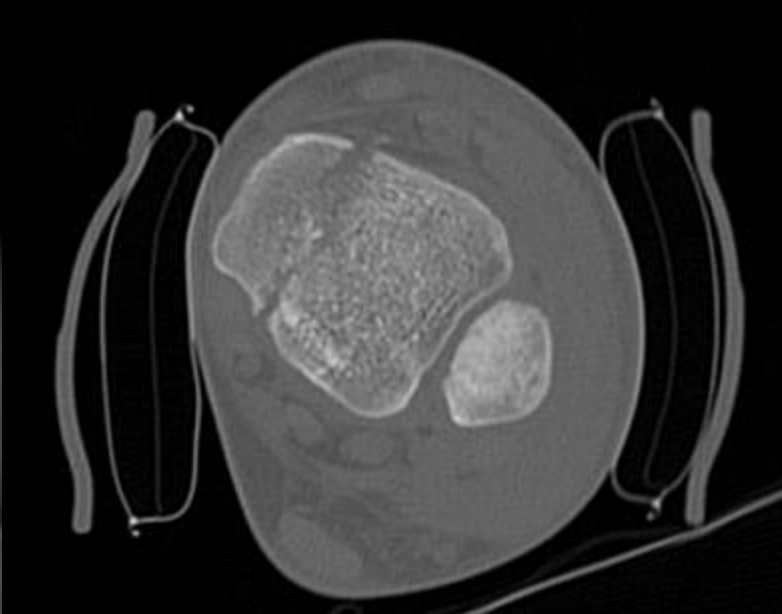
SH III/IV Distal Tibia Fractures: Treatment

- Displaced Fractures (>2mm)
 - Closed reduction under anesthesia can be attempted
 - If unable to reduce then open reduction may be needed
 - ORIF typically required
 - All epiphyseal fixation parallel to growth plate (Screws or K-wires)
 - Avoid screws crossing physis if possible
 - LLC needed 3-4 weeks before transition to walking cast or boot for additional 2-3 weeks
 - Follow for growth arrest
 - Rates are possibly decreased with ORIF









Intraarticular step off

ORIF—all epiphyseal cannulated screws



Healed at 10 week follow up



Medial Malleolus Fracture Outcomes

- Abbott et al (POSNA 2015)
 - 42 pediatric medial malleolus fractures with > 3 months follow-up
 - 52% developed a physeal bar
 - 27% were Diagnosed > 6 Months from Injury
 - SH classification and amount of displacement not predictive of bar formation
 - **Adequacy of reduction = only predictive factor of bar formation**

Parallel Harris growth lines



Right side with converging Harris growth lines

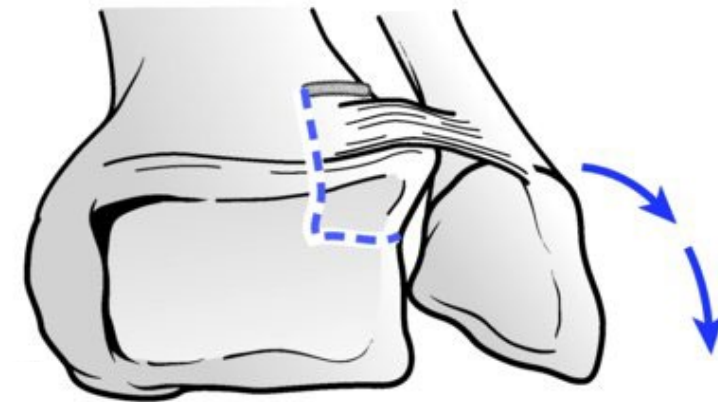


Transitional Ankle Fractures

Juvenile Tillaux Fractures

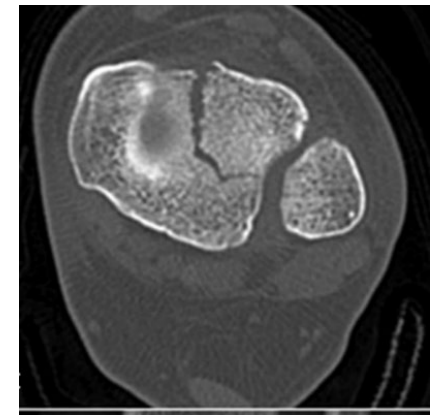
- **Juvenile Tillaux Fracture**

- SH-III fracture of anterolateral tibial epiphysis
 - Chaput tubercle
- Mechanism: external rotation with avulsion via the AITFL
- Intra-articular fracture
- May be associated with ipsilateral tibial shaft fractures



Juvenile Tillaux Fractures: Treatment

- Nondisplaced fractures
 - <2mm
 - Treated with LLC vs SLC x 4-6 weeks
 - Must follow closely to monitor for interval displacement
 - CT scan allows most accurate assessment of intra-articular displacement

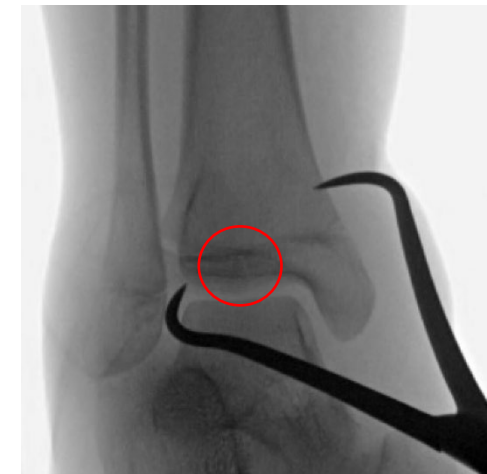


Juvenile Tillaux Fractures: Treatment

- Displaced fractures
 - Closed Reduction and Cast is occasionally successful
 - Internal rotation used to reduce fracture
 - LLC to hold reduction
 - Close follow up required
 - Percutaneous vs open reduction with screw fixation
 - Most common treatment
 - Superficial peroneal nerve at risk



Percutaneous reduction



Tillaux Fracture Treatment: ORIF

- Exposure: Anterior Approach
- Reduction
 - Mobilize Fragment and debride hematoma
 - Reduce Articular Surface Anatomically
 - Reduction Clamps or Dental Pick to Hold Reduction
- Fixation
 - 3.5 mm or 4.0 mm partially-threaded cannulated screw \pm washer
 - Screw placed lateral to medial from fragment
 - Separate percutaneous incision is occasionally required
 - Screw Must Not Violate Joint
 - Can commonly cross physis when closing



OTA Video Library Tillaux Fracture Video

- <https://otaonline.org/video-library/45036/procedures-and-techniques/multimedia/16776663/tillaux>
- Cannulated screw from anterolateral tibial epiphyseal fragment into intact tibia
- Physis is most commonly closing and therefore can be crossed
 - Screw aimed superior and posteromedial is positioned against the vector of displacement



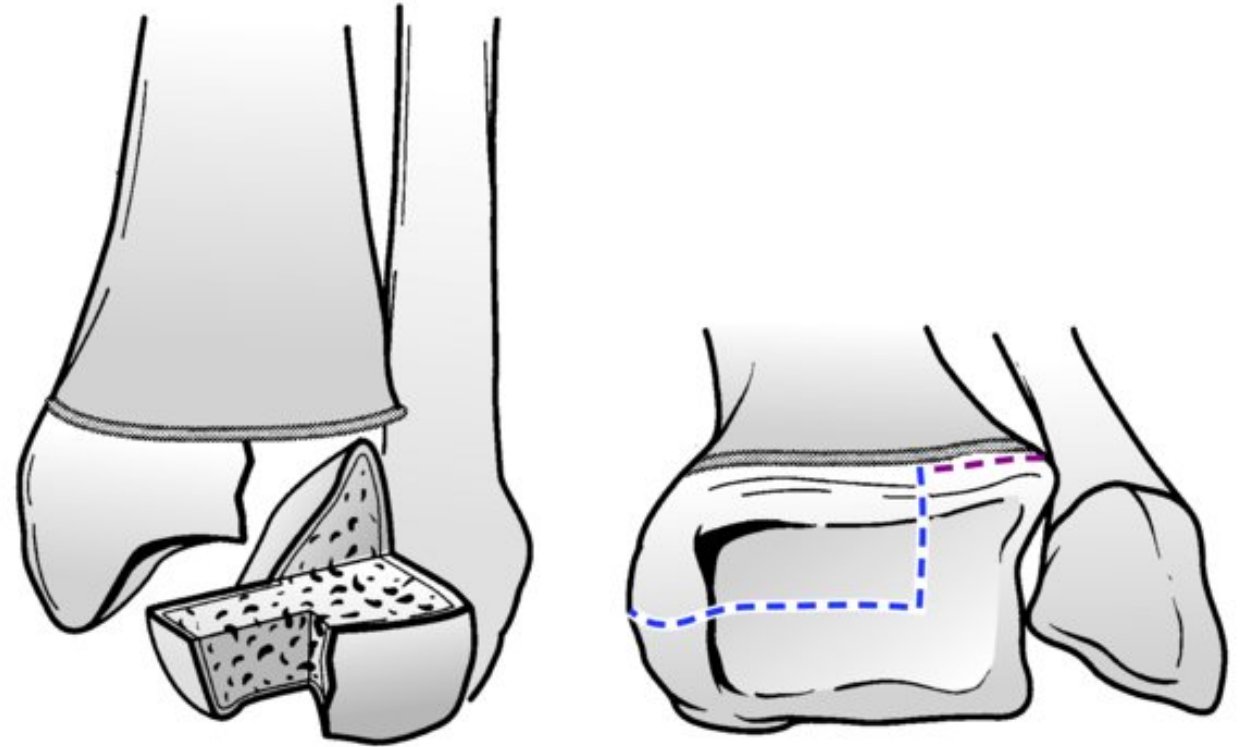
Triplane Fracture

- Typically 1 – 1.5 years younger than Tillaux fracture patients
- Secondary to asymmetric distal tibial physis closure
- Mechanism of injury → rotational force
- **Three Planes**
 - Sagittal: Epiphysis
 - Horizontal: Physis
 - Coronal: Metaphysis
- CT scan after attempted closed reduction
 - Helpful to determine displacement and plan screw placement



Classification

Author	Two-Part	Three-Part	Four-Part
McNealy et al	14	5	0
Ertl et al	4	11	0
Rapariz et al	12	23	0
El-Karef et al	12	6	3
Brown et al	43	8	0
Total	85/141 (60%)	52/141 (38%)	3/141 (2%)



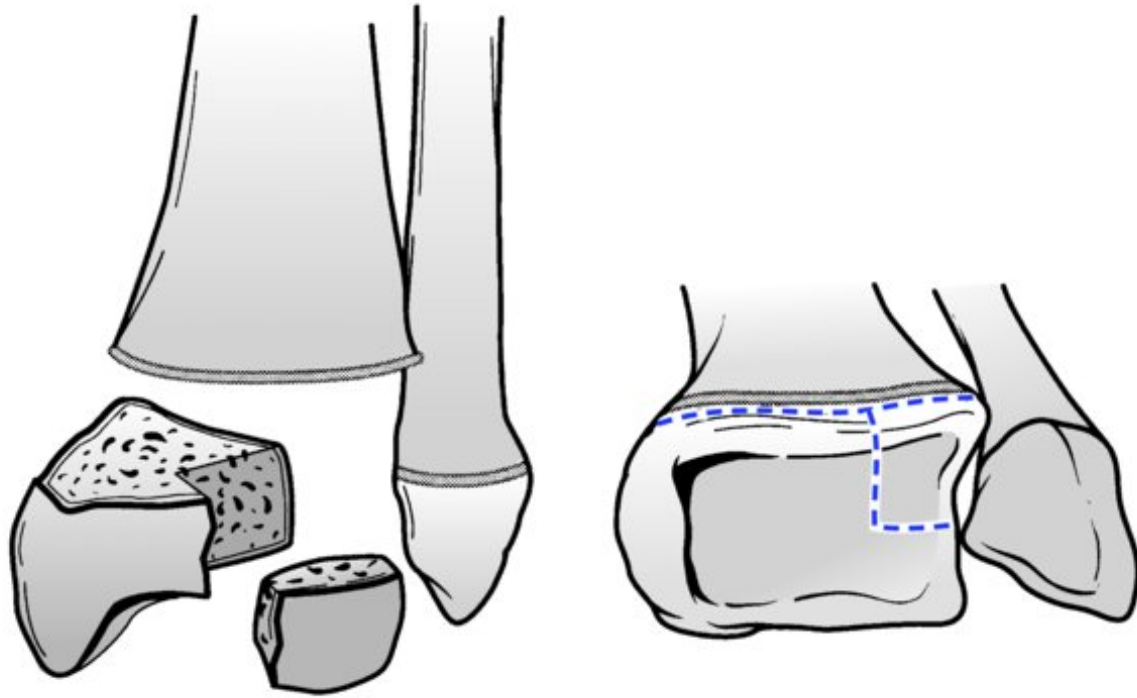
Two Part lateral triplane fracture

Large posterolateral epiphyseal fragment with its posterior metaphyseal fragment. The anterior portion of the medial malleolus remains intact

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

- McNealy GA, Rogers LF, Hernandez R, et al. Injuries of the distal tibial epiphysis: systematic radiographic evaluation. *AJR Am J Roentgenol.* 1982;138:683–689.
- Ertl JP, Barrack RL, Alexander AH, Van Buecken K. Triplane fracture of the distal tibial epiphysis: long-term follow-up. *J Bone Joint Surg Am.* 1988;70:967–976.
- Rapariz JM, Ocete G, Gonzalez-Herranz P, et al. Distal tibial triplane fractures: long-term follow-up. *J Pediatr Orthop.* 1996;16:113–118.
- El-Karef E, Sadek HI, Nairn DS, et al. Triplane fracture of the distal tibia. *Injury.* 2000;31:729–736.
- Brown SD, Kasser JR, Zvrakowski D, et al. Analysis of 51 tibial triplane fractures using CT with multiplanar reconstruction. *AJR Am J Roentgenol.* 2004;183:1489–1495

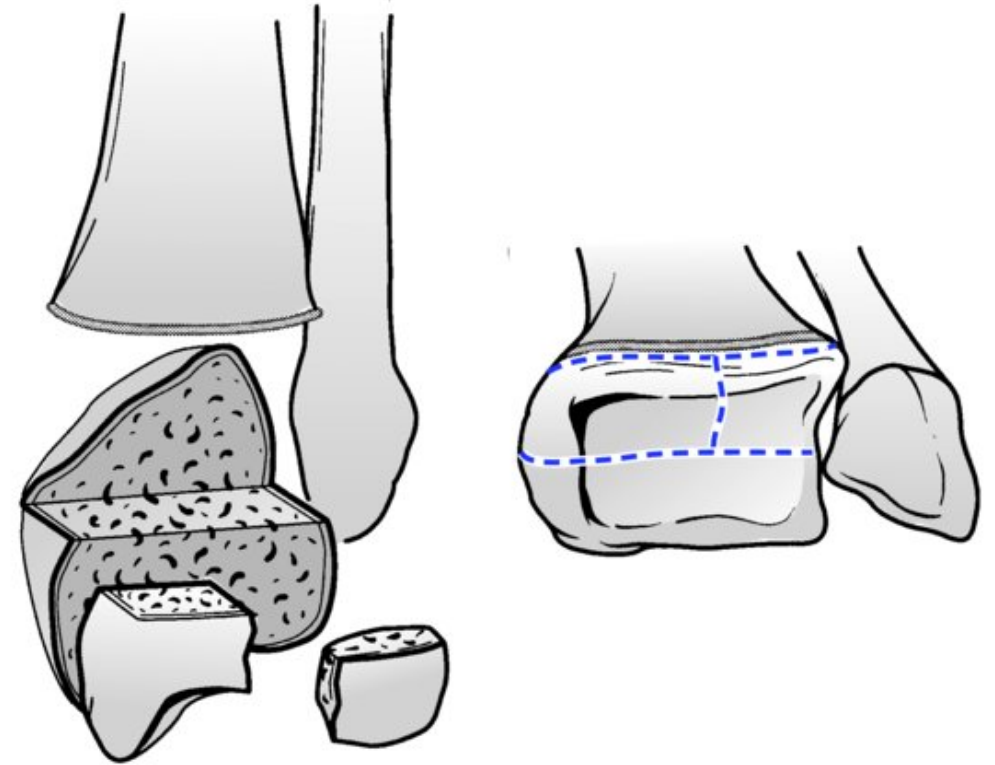
Classification



Three Part lateral triplane fracture

Large epiphyseal fragment with its metaphyseal component and the smaller anterolateral epiphyseal fragment.

**separate Tillaux fragment*



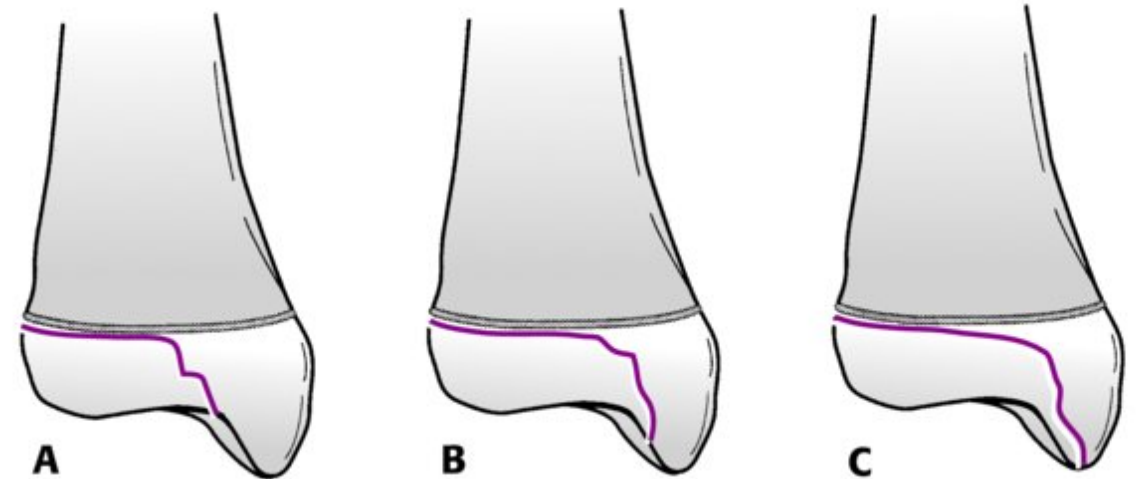
Four Part lateral triplane fracture

Large posterior epiphyseal fragment with its posterior metaphyseal fragment. The anterior portion of the epiphysis is split into 2 pieces

**separate Tillaux fragment & medial malleolus fragment*

Intramalleolar Triplane Variant

- Type I:
 - Intramalleolar, intra-articular fracture at the junction of the tibial plafond and the medial malleolus.
- Type II:
 - Intramalleolar, intra-articular fracture outside the weight-bearing zone of the tibial plafond.
- Type III:
 - Intramalleolar, extra-articular fracture

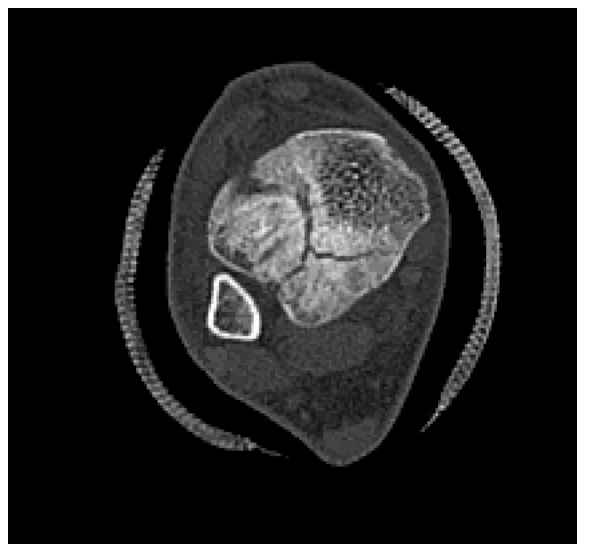




Triplane Fractures: Treatment

- Non-displaced fractures
 - Non weight bearing cast 3-4 wks (SLC vs LLC)
 - Transition to SLWC cast x 3-4 wks
 - CT scan to confirm acceptable joint reduction
 - Monitor in cast to assure no displacement
 - F/u x-rays every 6-12 months for 2 to 3 yrs to assess for growth arrest
 - Growth arrest not as concerning because growth plate is typically closing

“Mercedes sign”





Triplane Fractures: Treatment

- Displaced fractures (>2 mm)
 - Anatomic reduction required
 - CRC can be attempted
 - Long leg cast with 30° of knee flexion
 - Internal rotation of foot
 - ORIF
 - Cannulated 3.5/4.0mm screws used to fix each part
- Postop: Non-weight bearing cast 4-6 weeks,
 - Transition to walker boot or SLWC x 3-4 weeks



Triplane Fracture Treatment: ORIF

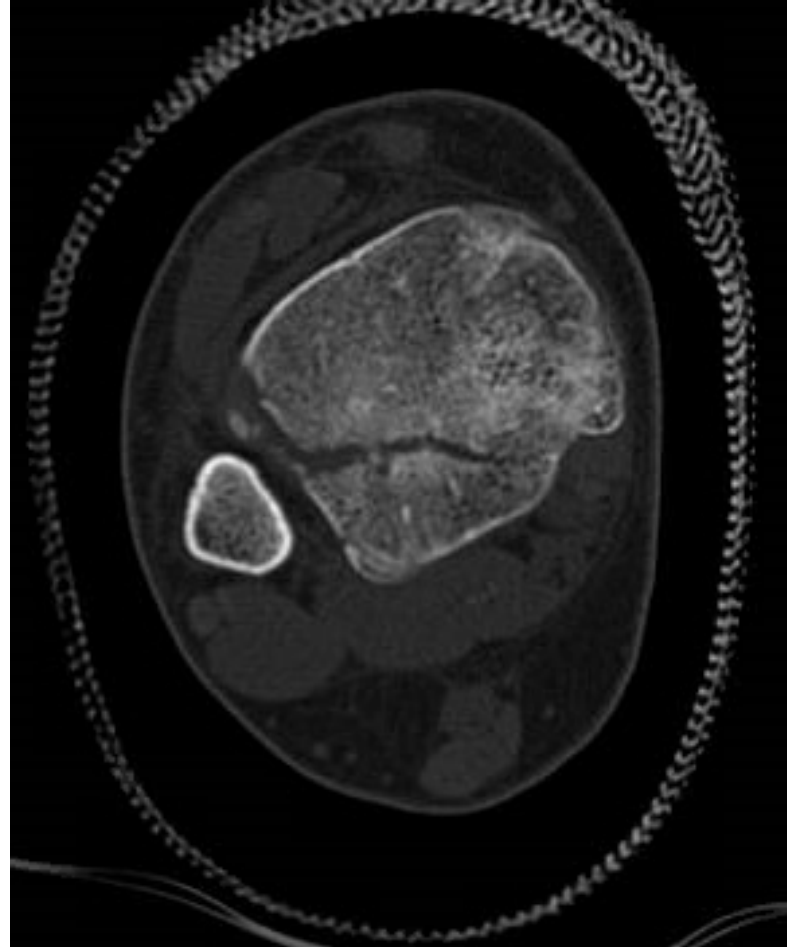
- SH II Component (2-part) / SH-IV Component (3- & 4-part)
 - Often amenable to closed manipulation
 - If closed manipulation fails: Posterolateral/posteromedial approach and clamp reduction
 - Fixate fragment in 3- & 4-part fractures
 - Fixation used in 2-part fractures if not stable
- SH III Component
 - Anterior approach (similar to Tillaux fracture)
 - Mobilize fragment, remove soft tissue impeding reduction
 - Reduce articular surface anatomically
 - Reduction forceps or dental pick to hold reduction
- Fixation
 - Partially threaded canulated screws \pm washer (3.5 mm or 4.0 mm)
 - Direction of screw based on fracture location
 - Can usually be performed percutaneously
 - Avoid crossing the physis in young patients

3-part Triplane ORIF



13 yo female fell down flight of stairs





2-part Triplane fracture



Transitional Fractures: Outcomes

- Lurie et al (JBJS 2020)
 - Retrospective review comparing operative and nonoperative cases
 - 2-5 mm of intra-articular displacement after closed reduction
 - Patients treated non operatively with gap <2.5mm had significantly higher SANE Sports score than those >2.5mm gap
- Predictors of negative functional outcomes:
 - Non operative treatment
 - Larger gap after closed reduction
 - Presence of complication
- **Conclusion: Surgical treatment of gaps >2.5mm most likely produces greatest functional benefit**

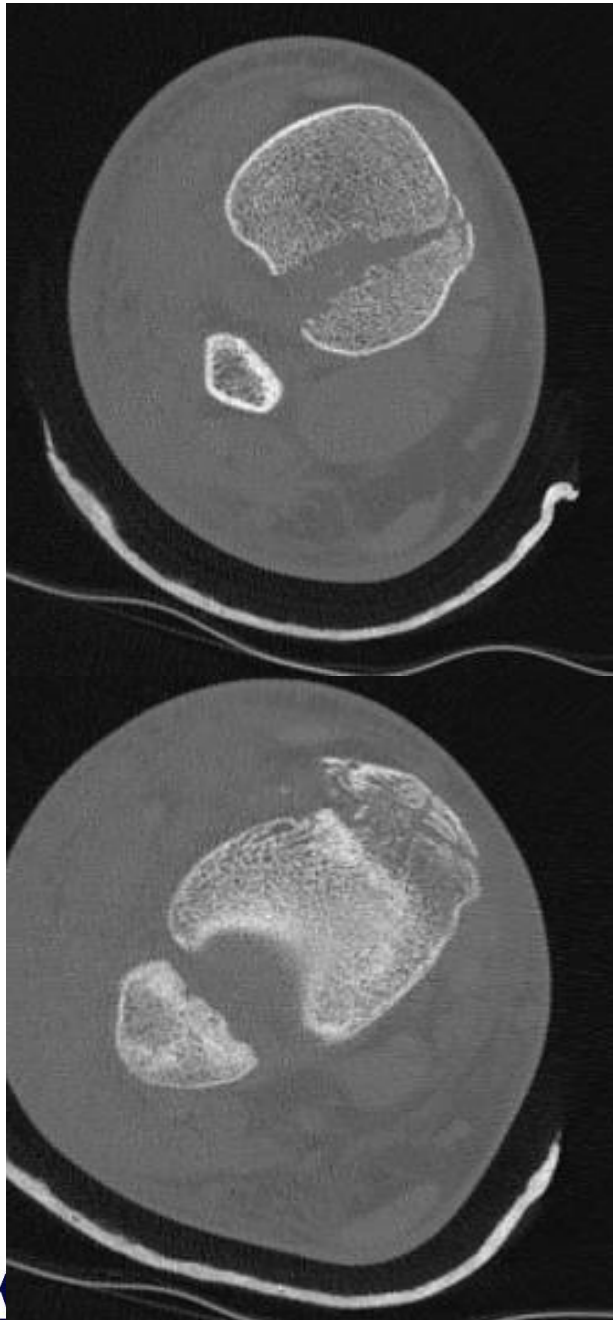


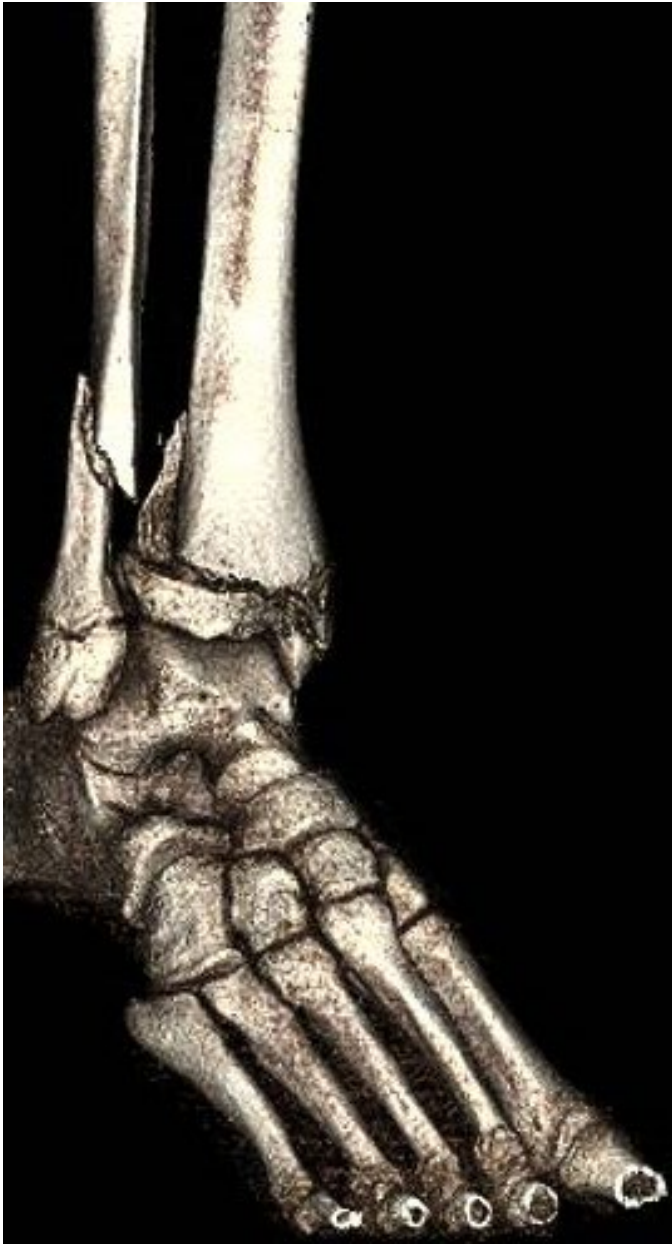
Outcomes

- Anticipate full return to activities in 3-4 months
 - Full, painfree ankle range of motion
 - Return of strength and proprioception
 - Most can return with help of a home exercise program
- Routine screw removal is controversial
 - 2005 cadaveric study demonstrated
 - Increased peak contact pressures and total force at the joint
 - Both decreased with screw removal
- Growth arrest not as concerning because growth plate is typically closing

14 yo Male: Intramalleolar Triplane Variant









6 month follow up





Adolescent Pilon Fracture

- **Fracture of tibial plafond**
 - Articular
 - Physeal
 - +/- Talar and fibular involvement
 - >5mm displacement
- **Classification (Letts et al 2001)**
 - Type I fractures have minimal comminution and no physeal displacement
 - Type II fractures have marked comminution and less than 5 mm of physeal displacement
 - Type III fractures have marked comminution and more than 5 mm of physeal displacement





High energy distal tibia fracture/subluxation 11 year old female in MVC



One Year Follow Up





Implant Options for Pediatric Ankle Fractures

- Smooth K-wires
- Small fragment cortical and cancellous screws
- 3- and 4-mm cannulated screws
- Bioabsorbable Implants
- External Fixation



Ankle joint biomechanics following transepiphyseal screw fixation of the distal tibia

- Cadaveric Study on 2 pediatric (2 years old) and 7 adult (mean 70.4 years old) Limbs
- Tested in loading
- Screw in: Significant increase in peak contact pressure / total force compared with control
- Screw Removal: Decreased force and peak pressure values
- Results not significantly different in pediatric limbs secondary to small sample size
- Do screws need to be removed? Remains controversial



Complications of Ankle Fractures

- Growth Arrest
 - Most common
 - Highest in SH3 & SH4
 - Medial malleolus
- Arthritis
- Malunion
- Delayed/nonunion
- AVN distal tibial epiphysis (rare)
- Synostosis



Premature physeal closure following distal tibia physeal fractures: a new radiographic predictor

- 92 fractures reviewed with 1 year follow up
- 27.2% had premature physeal closure (PPC)
 - SH III/IV, Medial Malleolar type: 38% PPC
 - SH I/II: 36% PPC
 - Triplane: 21%
 - Tillaux: 0%
- Initial displacement, number of reduction attempts, treatment method didn't affect incidence of PPC
- Residual physeal gap (>3mm) following reduction for SH I and II fractures increased incidence of PPC 60%
- No gap decreased to 17%
- Conclusion: for SH I and II fractures, residual fx gap may represent entrapped periosteum and lead to higher incidence of PPC



Salter-Harris II Fractures of the Distal Tibia: Does Surgical Management Reduce the Risk of Premature Physeal Closure?

- 96 pts, average 12.6 years old, evaluated PPC and secondary procedure (epiphysiodesis, osteotomy, ect)
- Group 1 (N=14)
 - 29% PPC; 7% subsequent procedure
- Group 2 (N=33)
 - 33% PPC; 15% had a second procedure
- Group 3 (N=11)
 - 46 PPC; 18% had a second procedure
- Group 4 (N=38)
 - 55% PPC; 23% had a second procedure
- No difference PPC or secondary surgery between groups
- No difference in PPC based on age, sex, MOI, time to treatment, initial displacement, number of reduction attempts, and operative treatment

Group	Displacement (post reduction)	Treatment
1	<2mm	NWB LLC
2	2-4mm	NWB LLC
3	2-4mm	ORIF, removal of soft tissue if entrapped
4	>4mm	ORIF, removal of soft tissue if entrapped

References

Barmada A, Gaynor T, Mubarak SJ. Premature physeal closure following distal tibia physeal fractures: a new radiographic predictor. *J Pediatr Orthop*. 2003 Nov-Dec;23(6):733-9. doi: 10.1097/00004694-200311000-00010

Brown SD, Kasser JR, Zvrakowski D, et al. Analysis of 51 tibial triplane fractures using CT with multiplanar reconstruction. *AJR Am J Roentgenol*. 2004;183:1489–1495.

Charlton, Michael, et al. Ankle joint biomechanics following transepiphyseal screw fixation of the distal tibia. *Journal of Pediatric Orthopaedics* 25.5 (2005): 635-640

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

Dowling S, Spooner CH, Liang Y, et al. Accuracy of Ottawa Ankle Rules to exclude fractures of the ankle and midfoot in children: a meta-analysis. *Acad Emerg Med*. 2009;16:277–287

El-Karef E, Sadek HI, Nairn DS, et al. Triplane fracture of the distal tibia. *Injury*. 2000;31:729–736.

References

Ertl JP, Barrack RL, Alexander AH, Van Buecken K. Triplane fracture of the distal tibial epiphysis: long-term follow-up. *J Bone Joint Surg Am.* 1988;70:967–976.

Hynes D, O'Brien T. Growth disturbance lines after injury of the distal tibial physis. Their significance in prognosis. *J Bone Joint Surg Br.* 1988;70:231–233

Letts M, Davidson D, McCaffrey M. The adolescent pilon fracture: management and outcome. *J Pediatr Orthop.* 2001;21:20–26.

Lurie B, Van Rysselberghe N, Pennock AT, Upasani VV. Functional Outcomes of Tillaux and Triplane Fractures with 2 to 5 Millimeters of Intra-Articular Gap. *J Bone Joint Surg Am.* 2020;102(8):679-686. doi:10.2106/JBJS.19.01170

McNealy GA, Rogers LF, Hernandez R, et al. Injuries of the distal tibial epiphysis: systematic radiographic evaluation. *AJR Am J Roentgenol.* 1982;138:683–689.

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

References

Rapariz JM, Ocete G, Gonzalez-Herranz P, et al. Distal tibial triplane fractures: long-term follow-up. *J Pediatr Orthop*. 1996;16:113– 118.

Rockwood, Charles A, David P. Green, Paul Tornetta, William M. Ricci, Robert F. Ostrum, Margaret M. McQueen, Michael D. McKee, and Charles M. Court-Brown. *Rockwood and Green's Fractures in Adults: Volume 2.* , 2020.

Russo, Franco BA; Moor, Molly A. MPH; Mubarak, Scott J. MD; Pennock, Andrew T. MD Salter-Harris II Fractures of the Distal Tibia: Does Surgical Management Reduce the Risk of Premature Physeal Closure?, *Journal of Pediatric Orthopaedics*. Doi: 10.1097/BPO.0b013e3182880279

Spiegel P, et al. Epiphyseal fractures of the distal ends of the tibia and fibula. *J Bone Joint Surg Am*. 1978;60(8):1046-50

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. Print

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

References

Figures used with permission from Tim White and Kate Bugler. Chapter 64: Ankle Fractures. In: Tornetta P, Ricci WM, eds. Rockwood and Green's Fractures in Adults, 9e. Philadelphia, PA. Wolters Kluwer Health, Inc; 2019

Kevin G. Shea and Steven L. Frick. Chapter 29: Ankle Fractures. In: Waters PM, Skaggs DL and Flynn JM, eds. Rockwood and Wilkins' Fractures in Children, 9e. Philadelphia, PA. Wolters Kluwer Health, Inc; 2019