Lower Limb Trauma:
Femur shaft;
Distal Femur
Ankle

Shalin Shah
Fellow in Paediatric Orthopaedics
Orthokids Clinic; BJ Wadia

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Pediatric Femur Fracture

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Demo and History

- **Femoral diaphyseal fractures** account for nearly 2 % of all bony injuries in children,

- The **most common** pediatric orthopedic injury requiring **hospitalization**.

- In the past treated with **immediate spica casting or a period of traction followed by casting.**

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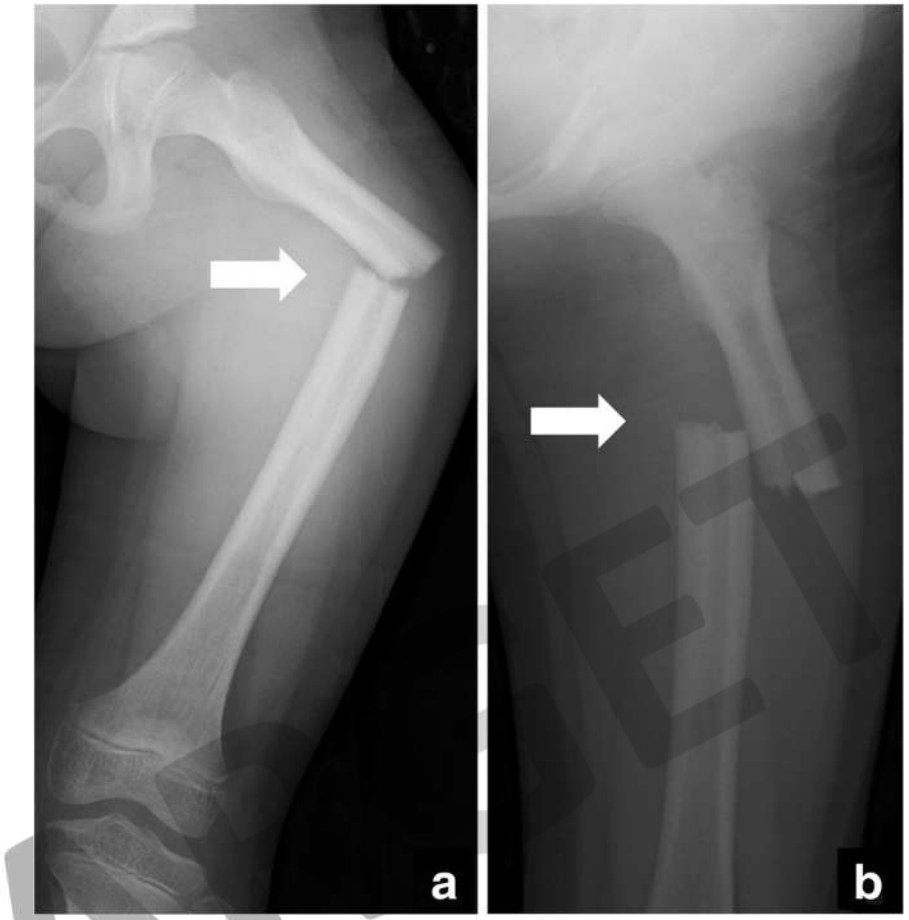

6 Year old with these fractures

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Now...

- Non school going, infants Pawlik and spica still the treatment of choice

- Sx used for older children

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Classifications

Characteristics of the fracture

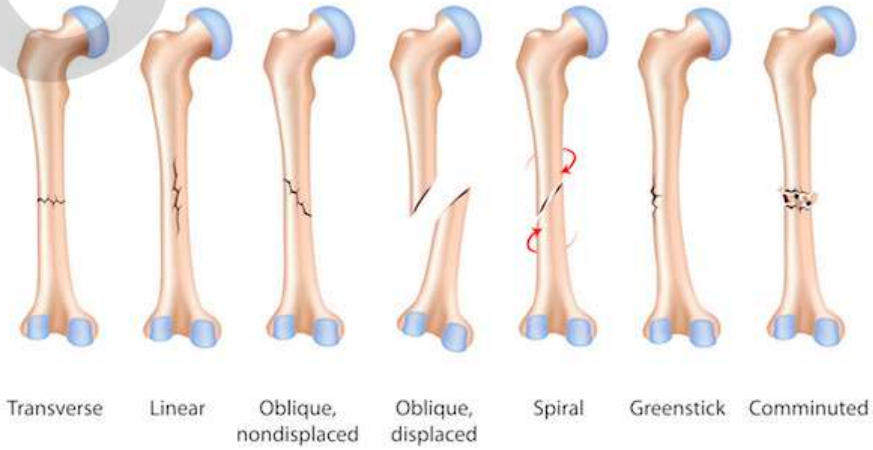
- transverse
- comminuted
- spiral
- Others

Location of the fracture

- proximal,
- middle, or
- distal third

Integrity of the soft-tissue envelope

- open vs. closed fracture



Transverse fracture has more likelihood of Non accidental trauma

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Most imp Classification:

Stability

- stable fractures (typically transverse or short oblique)
- unstable fractures (long spiral) (fracture length > 2x bone diameter at that level)

Age and Weight of child

- <6 months
- 6m to 4 years
- 4-11 years
- >11 years

- </> 50 Kg

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Age	Weight	Fracture Stability (Length Stable vs. Unstable*)	Treatment Options
< 6 mo	Any	Any	Pavlik harness Spica Cast
6 mo – 5 yrs	Any	Stable and Most unstable	Spica cast
	Any	Some unstable	90/90 traction à spica cast Flexible nails (controversial)
5 – 11 yrs.	< 49 kg	Stable	Flexible intramedullary nailing
	Any	Unstable	Submuscular bridge plate vs. External fixation
	> 49 kg	Any	Submuscular bridge plate vs. External fixation vs. Rigid trochanteric entry nail (in older children, but controversial)
> 11 yrs.	< 49 kg	Stable	Rigid trochanteric entry nail vs. Flexible intramedullary nailing
	> 49 kg	Any	Rigid trochanteric entry nail vs. submuscular plate
Special Situations			
Polytrauma or open fracture			Consider external fixation
Severe Comminution			External fixation vs. submuscular plating (consider use of rigid trochanteric entry nail in older kids)

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Length stable fractures have a transverse fracture pattern. Oblique and comminuted fracture patterns considered length unstable

Pawlik Harness application

The baby should be undressed.
A diaper/nappy and a single thin layer body garment can remain.

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Points

- < 6 months age
- More proximal the fracture higher the flexion
- Keep checking for femoral nerve palsy
- Keep for 2 weeks
- Do check for radiographic union

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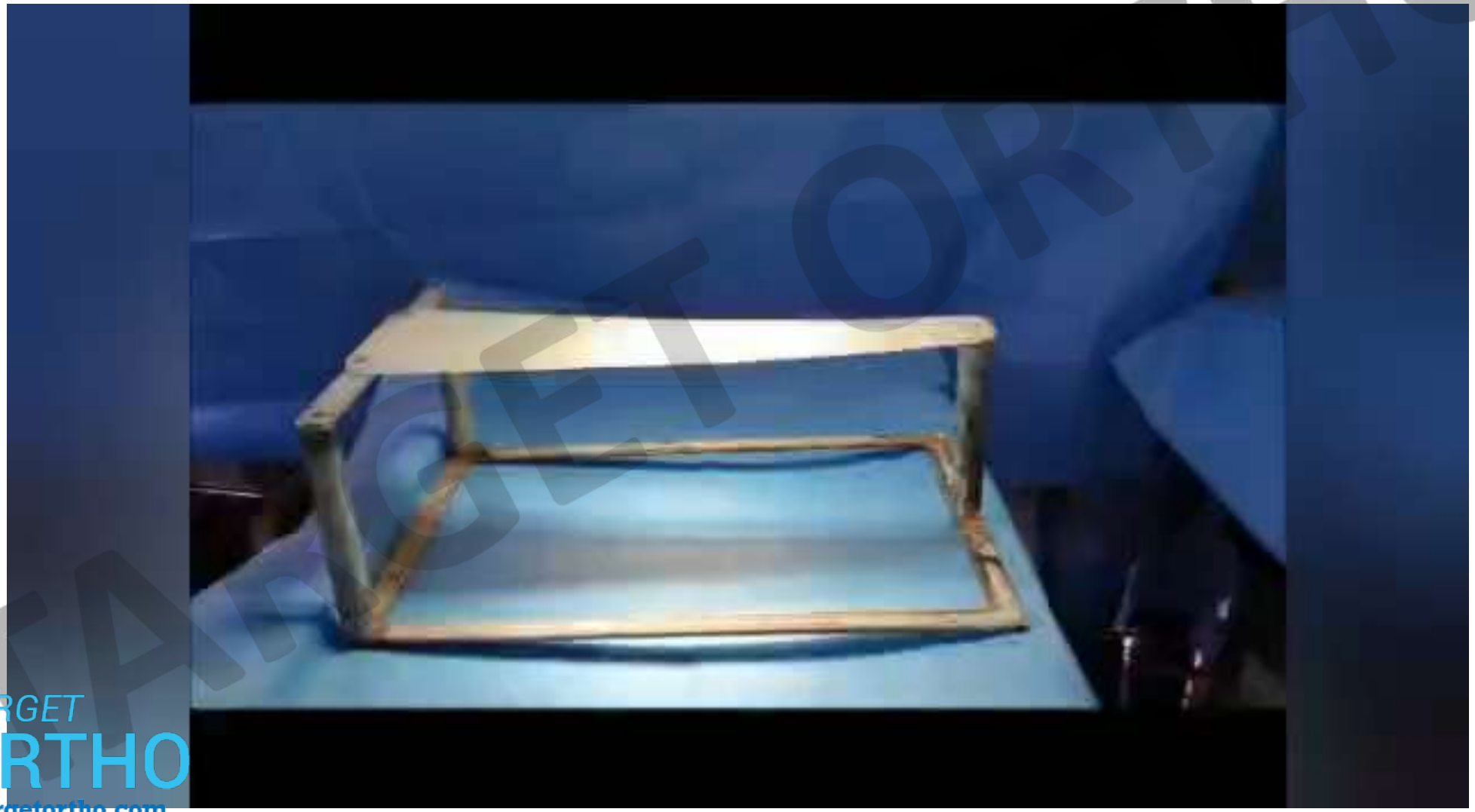
Hip spica application



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10y Boy, 45Kg weight

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Age	Weight	Fracture Stability (Length Stable vs. Unstable*)	Treatment Options
< 6 mo	Any	Any	Pavlik harness Spica Cast
6 mo – 5 yrs	Any	Stable and Most unstable	Spica cast
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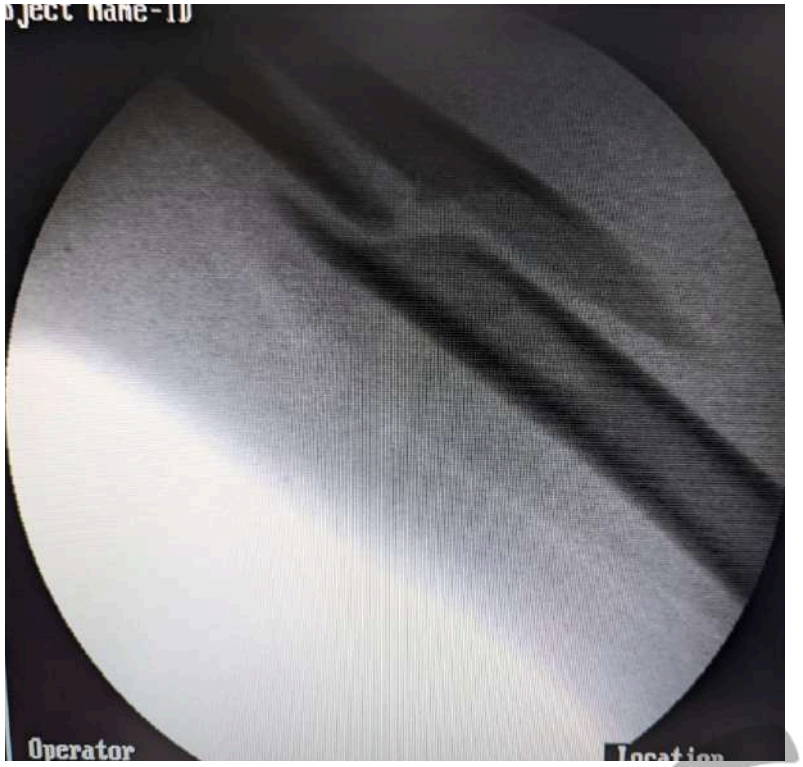

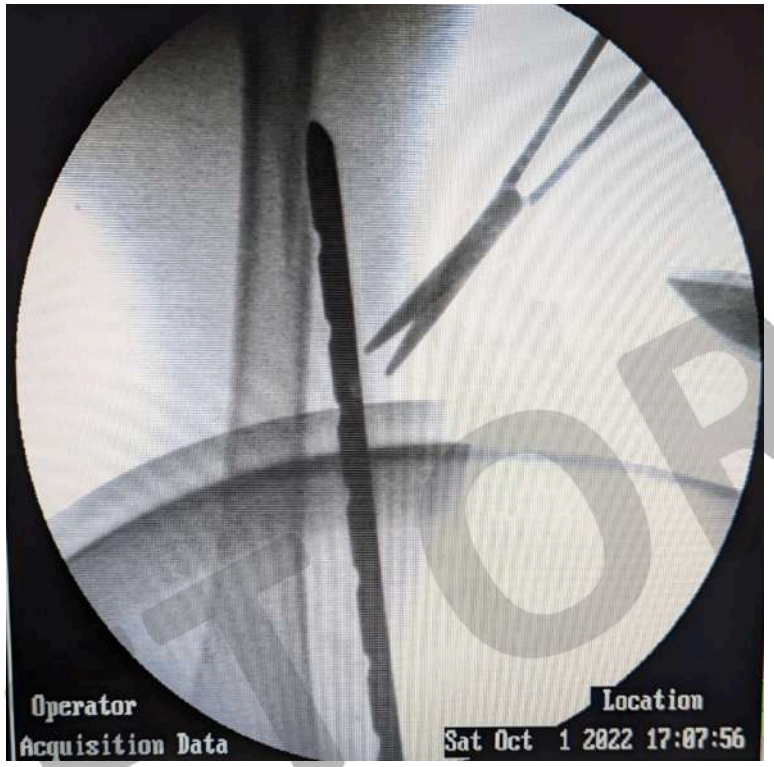

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Lateral view

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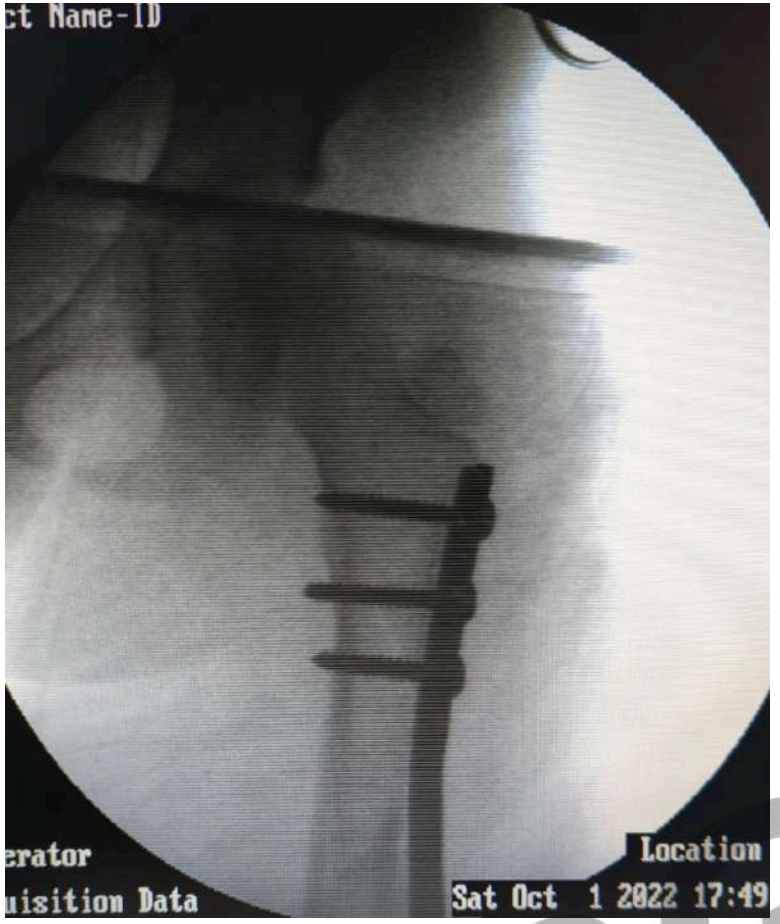

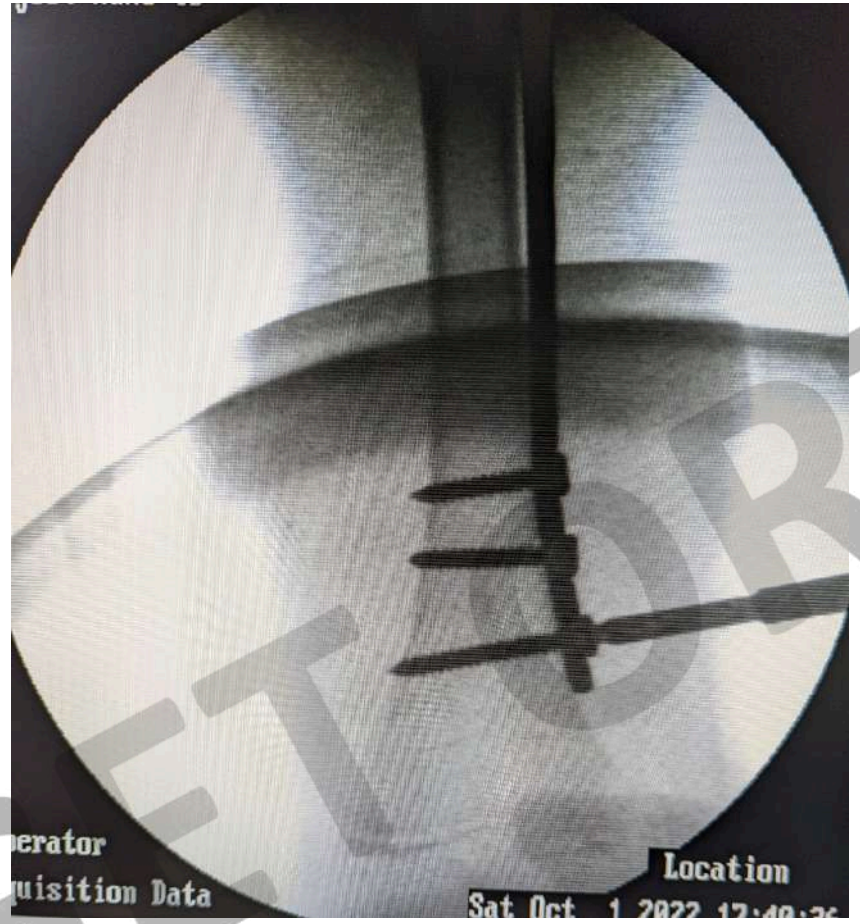

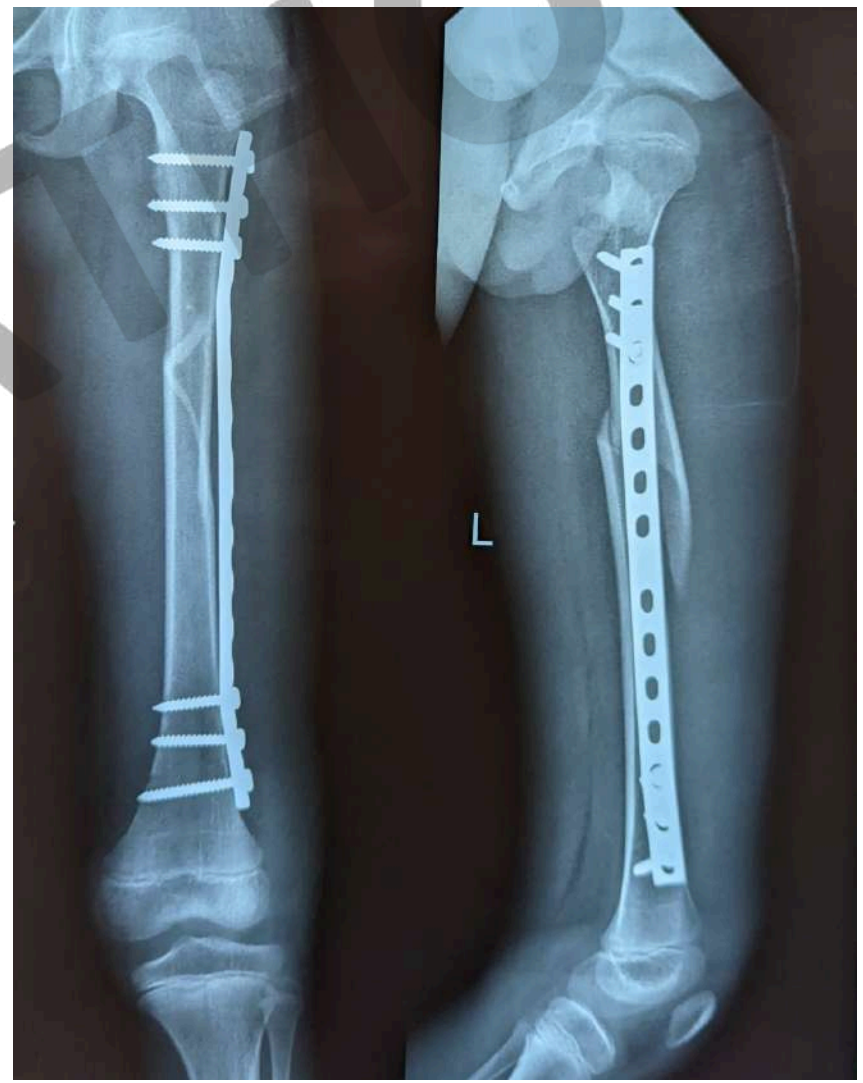

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12year boy, 52 kg

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Age	Weight	Fracture Stability (Length Stable vs. Unstable*)	Treatment Options
< 6 mo	Any	Any	Pavlik harness Spica Cast
6 mo – 5 yrs	Any	Stable and Most unstable	Spica cast
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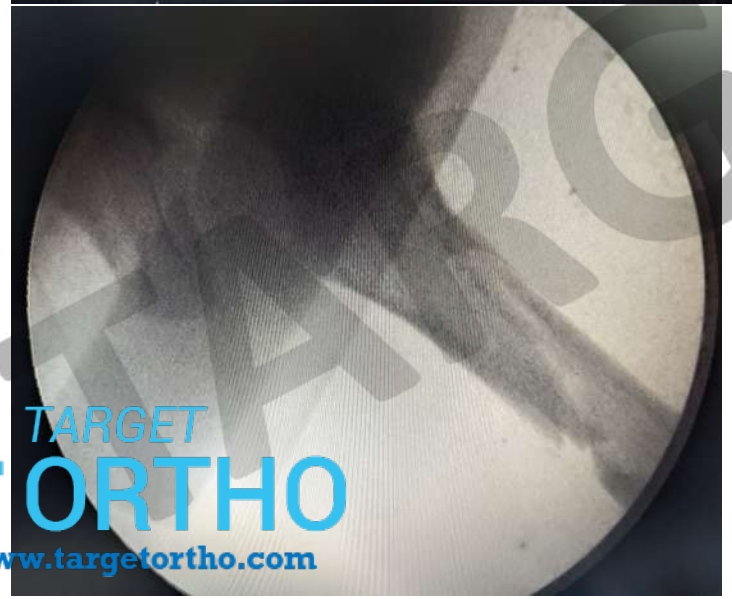

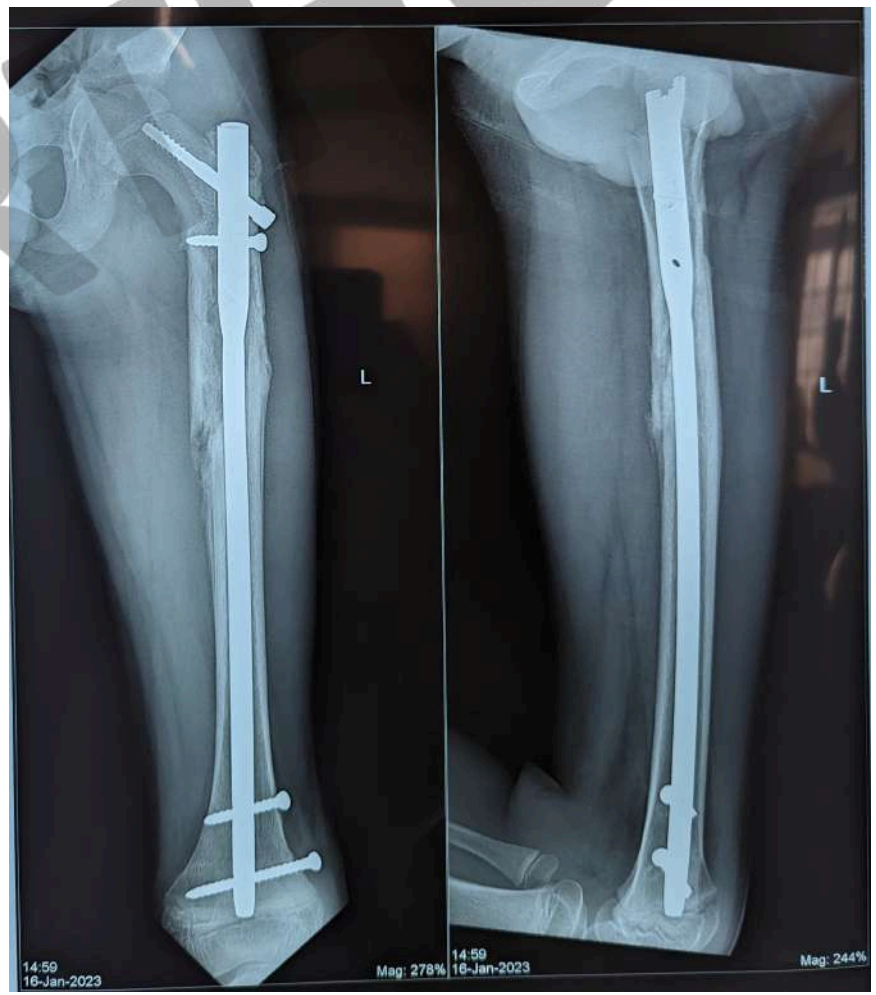

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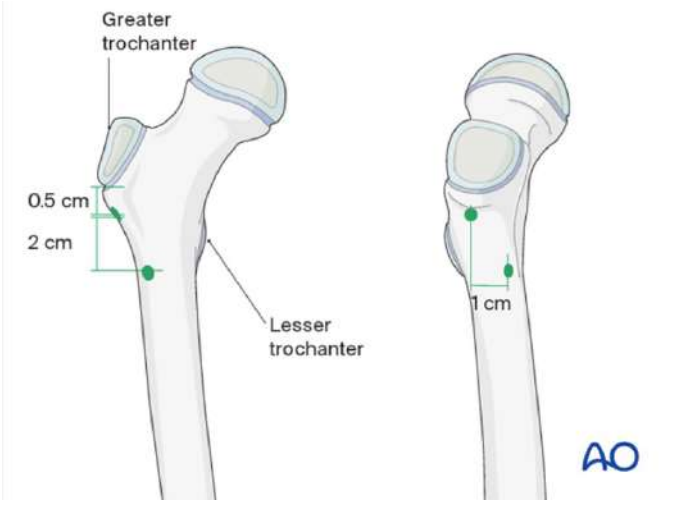
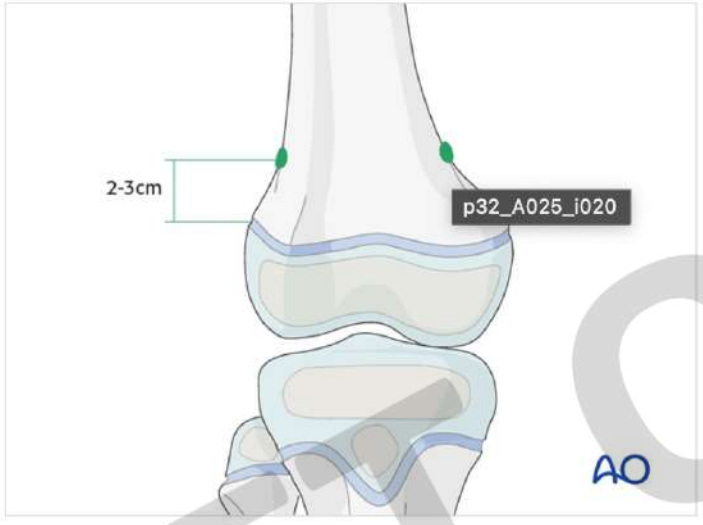
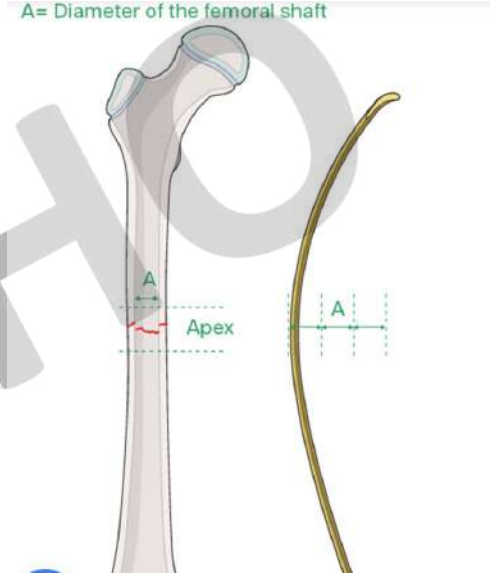
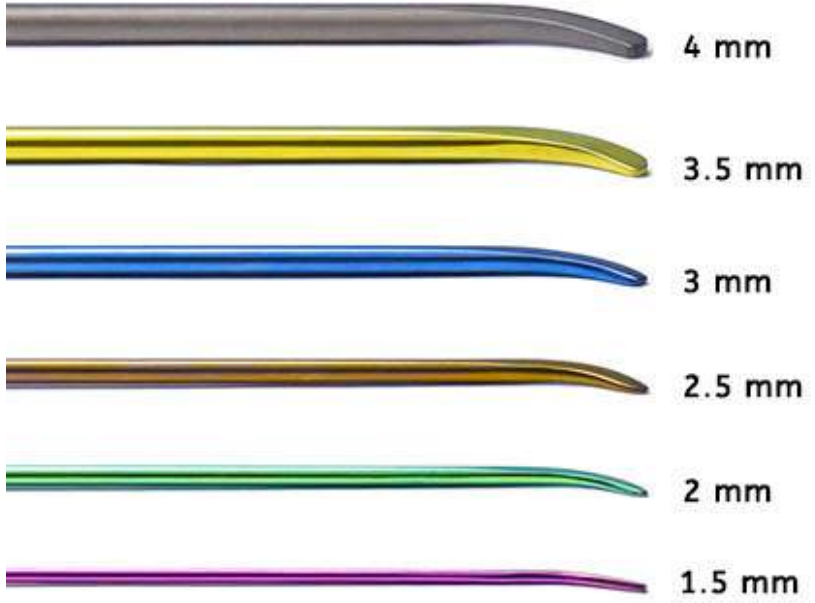
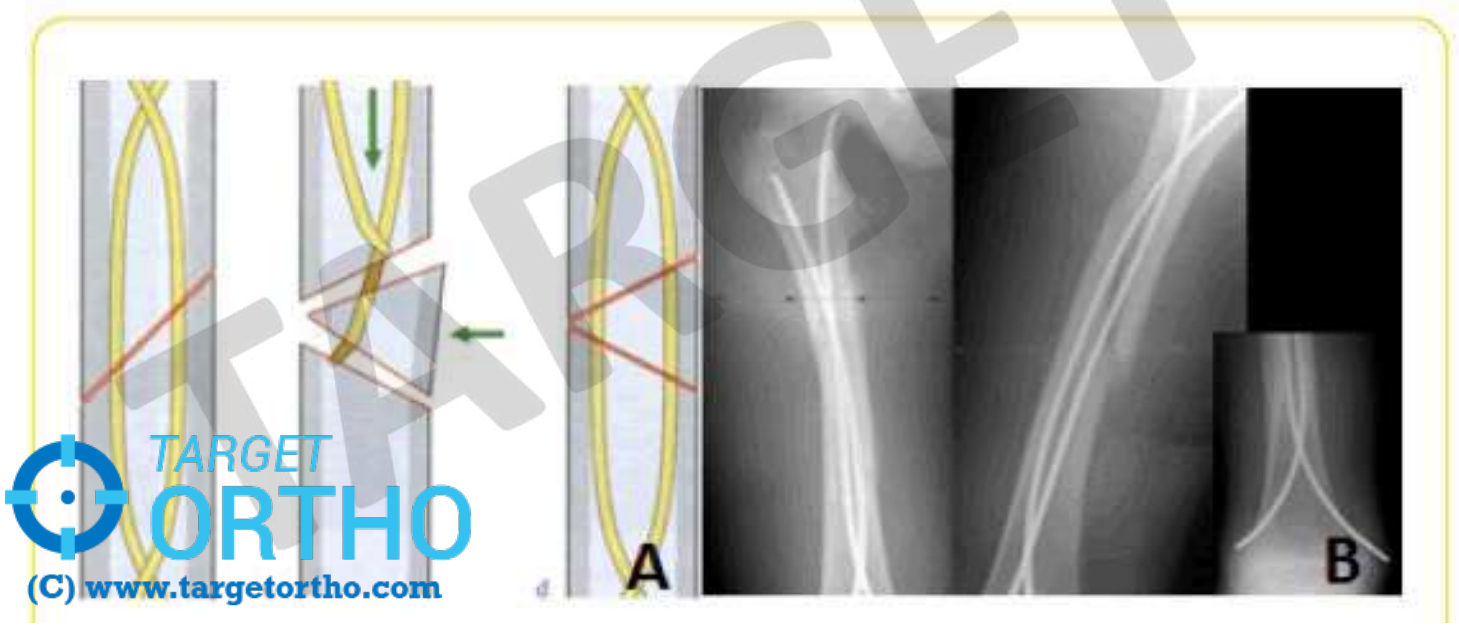
TENS Nailing











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DISTAL FEMUR PHYSEAL INJURIES:

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Distal Femoral Physeal Fractures

Characteristics:

- Rare: **2 %** of all injuries
- Peak incidence: Age 10-12 yrs.
- 6 times more incidence in Males
- Associated: High-Velocity Trauma / Sports

High Complication Rate

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High Complication Rate

- Growth arrest (30-40%)
- Compartment syndrome (1.2%)
- Neurovascular injury (2%)
- Ligament injury (8-35 %)

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Etiology

- Older children and adolescents
  High velocity trauma

- Neonates and infants
  Birth injury
  Child abuse

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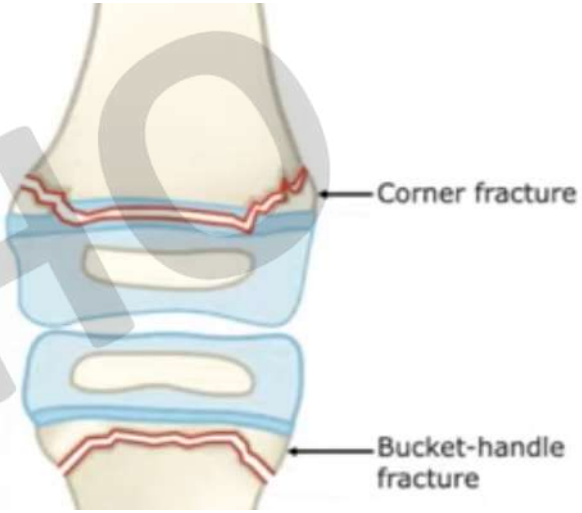
Be Careful During Evaluation



Metaphyseal Corner fractures :

NAI/NAT

Non Accidental Trauma

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Physis undulations

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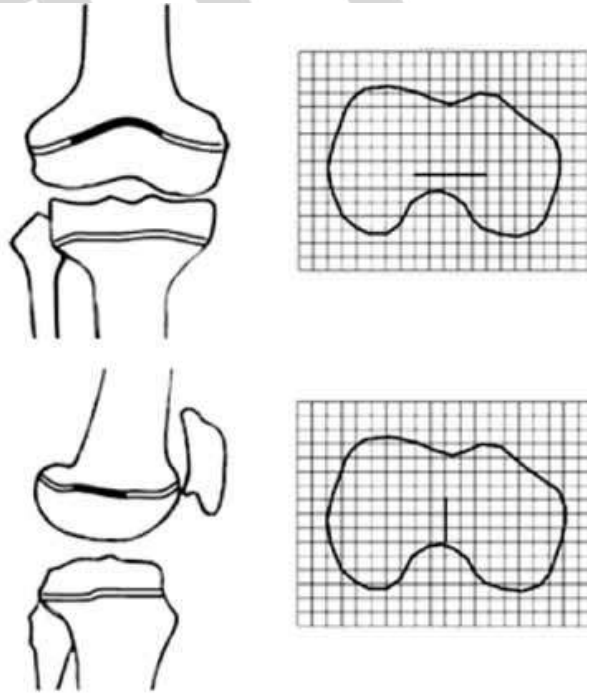
Distal Femur Physis Considerations

- Physeal closure girls avg 14, boys avg 16
- Undulating physis imparts stability, but also leads to more physeal damage
- Beware of NV injuries



- Physis contributes **70 %** to femoral growth & **37 %** Lower limb growth

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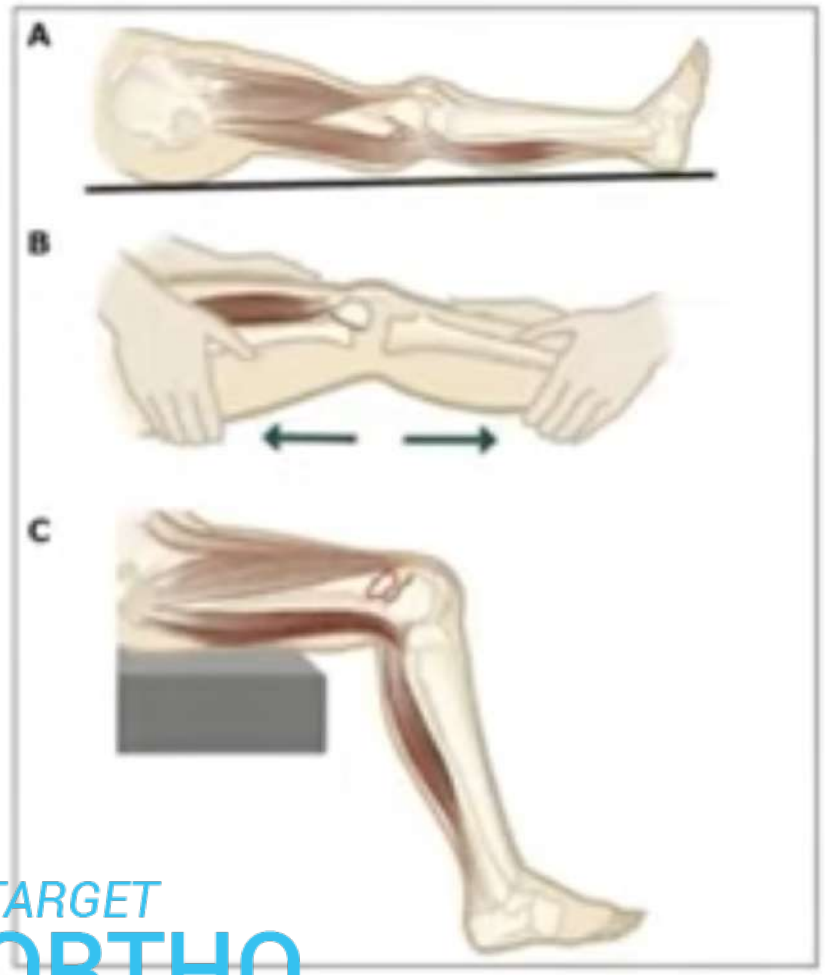
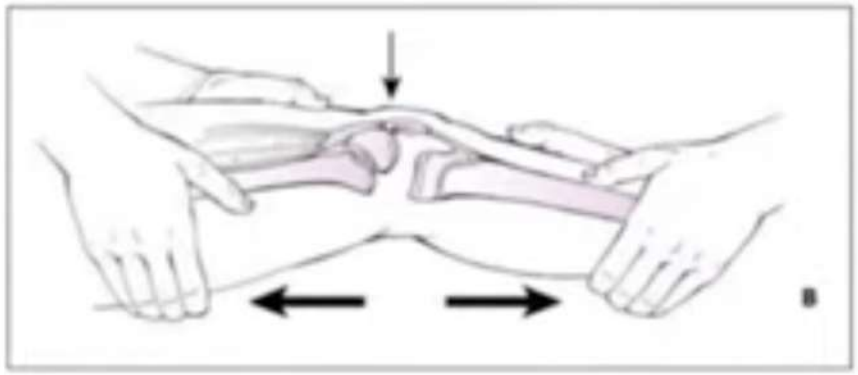
Reduction





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Case Ex:

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Type 1 SH Injury :

- Beware of entrapped periosteum
- SH1 – CR or open reduction if periosteum entrappe
- Cross wires, smooth big wires




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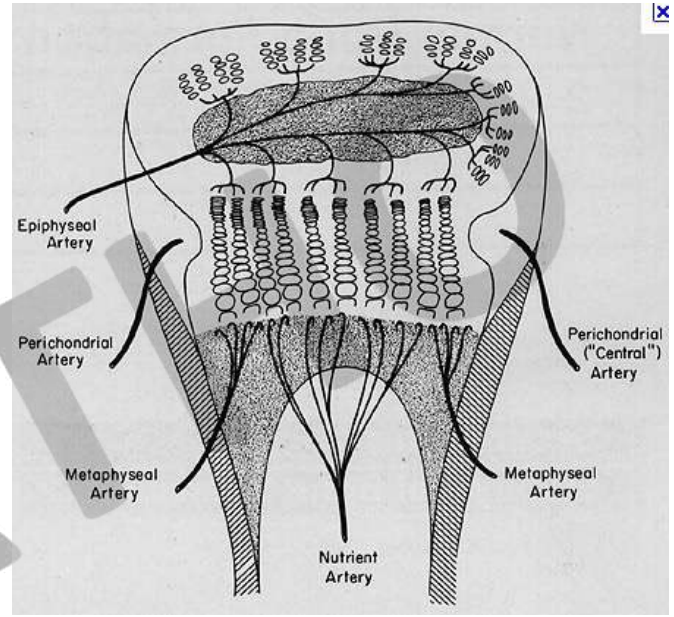
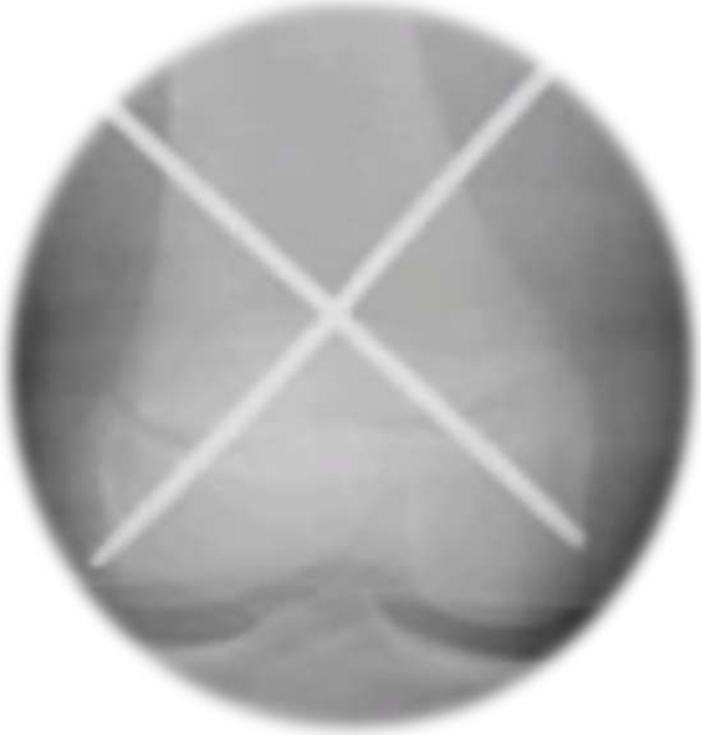
Pearls



- Smooth wires across physis
- 3-4 weeks: does not increase risk of growth arrest
- Risk of Septic knee with retrograde pins
- Antegrade fixation keeps pins out of the knee
- But avoid antegrade medial pin in <4 year
- Rapid healing: remove pins in 3-4 weeks



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What about CR + Casting !!!

- *Cast stabilisation may work in un-displaced fractures*
- *But, alone is unreliable, with a high rate of loss of reduction in the first 2 weeks and re-manipulation associated with a lower success rate*

~ Sepulveda et al EFORT Open rev (2022)

~ Duffy et al Eur. JOST (2021)

~ Duffy et al Eur. JOST (2021)

EFFORT Recommends :

Less than 5–6 years: 1.6-mm K-wires, in older children: 2.0-mm K-wires

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Physeal gap: Interposition

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- 8-year-old boy SH 2, sports injury, 11 pm, NV intact

- What will you do?
- CR/OR
- Maneuver
- How many attempts?
- Fixation?

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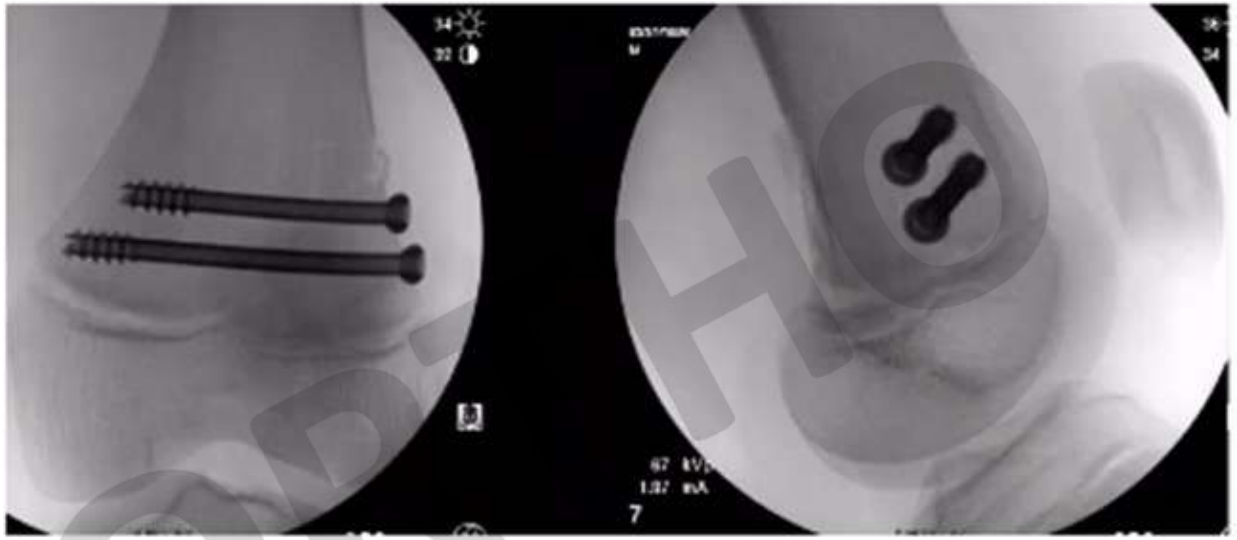
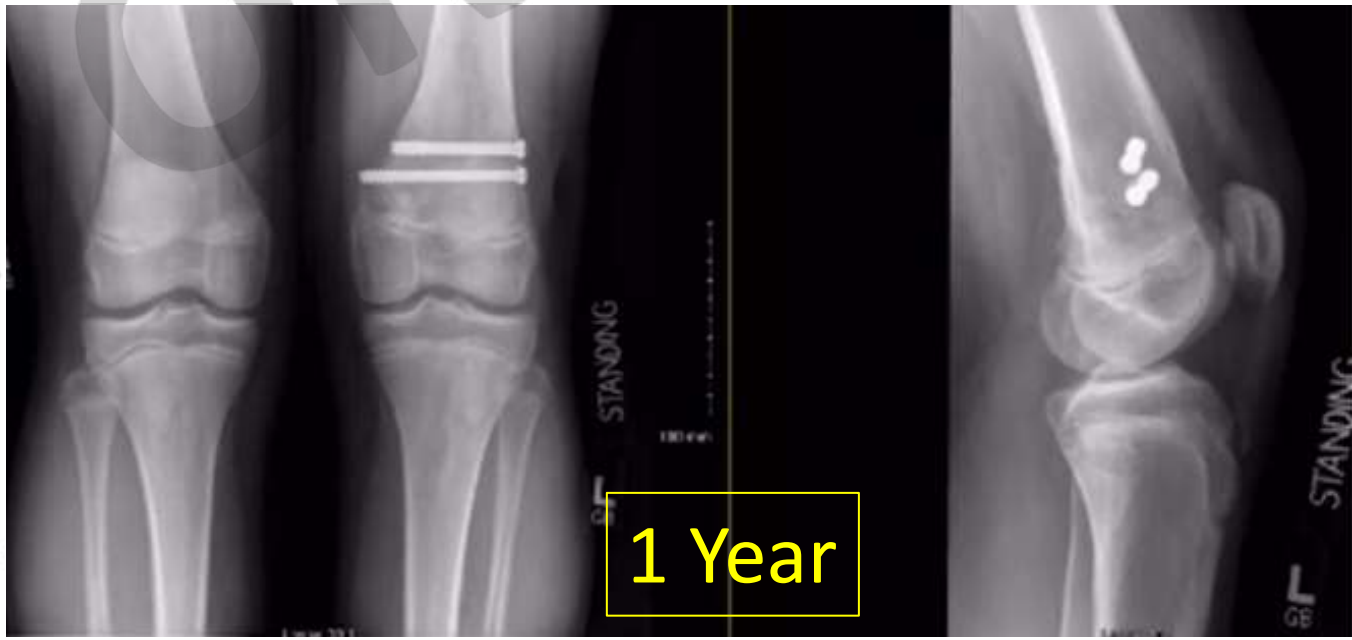
14 Y/M football injury





1 Year

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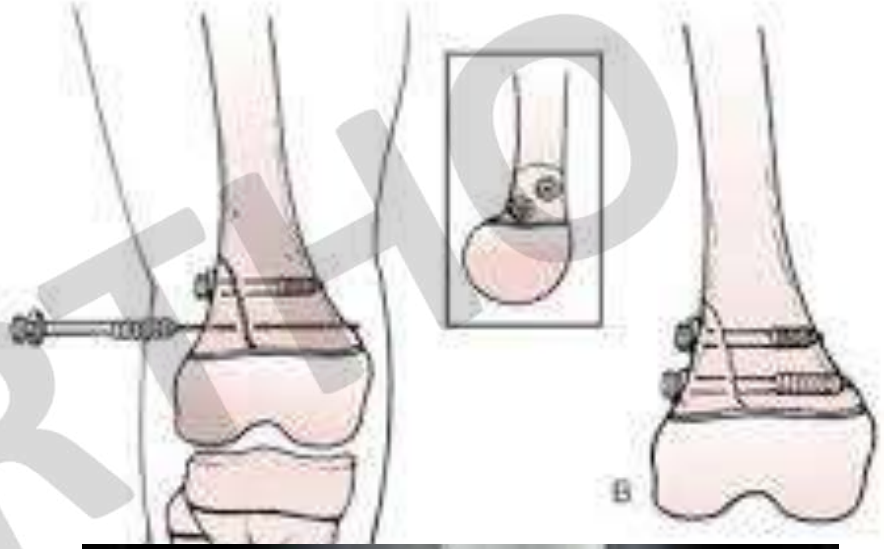
Pearls

- SH II: CR or open if periosteum entrapped
- Screws in Thurston holland fragment
- Try for 2 screws (4.5 CC)
- 1 close to physis and one more proximally.
- Use a washer for compression



~ Sepulveda et al EFORT Open rev (2022)

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European Journal of Orthopaedic Surgery & Traumatology (2021) 31:883–892
https://doi.org/10.1007/s00590-021-02933-1

GENERAL REVIEW

Check for updates

The clinical features, management options and complications of paediatric femoral fractures

Sean Duffy[1] · Yael Gelfer[2] · Alex Trompeter[2] · Anna Clarke[3] · Fergal Monsell[3]

Received: 24 December 2020 / Accepted: 8 March 2021 / Published online: 11 April 2021
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Surgical Management recommended: Displaced fractures
Internal fixation provides superior joint reconstruction and stability.
There is no good-quality evidence to identify the optimum management of these injuries

- *A physeal bar occurred in **31%** of patients with high-energy injuries*

  ***5%** in those with low-energy injuries*

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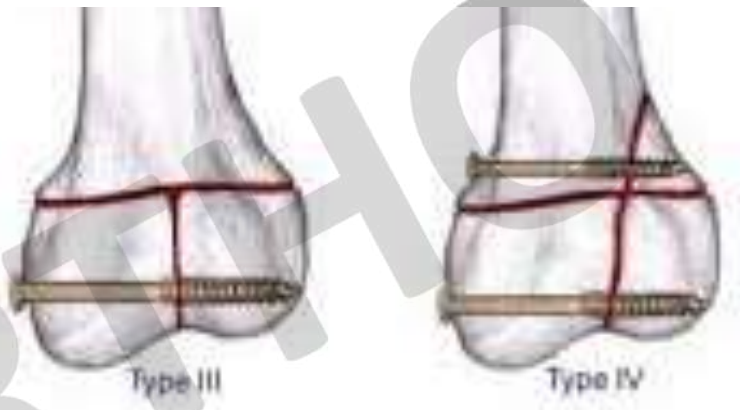
Type 3/4 Injury:



- SH III/IV
- Open anatomic reduction and screw fixation
- Cast after internal fixation
- Older treated like adult fractures

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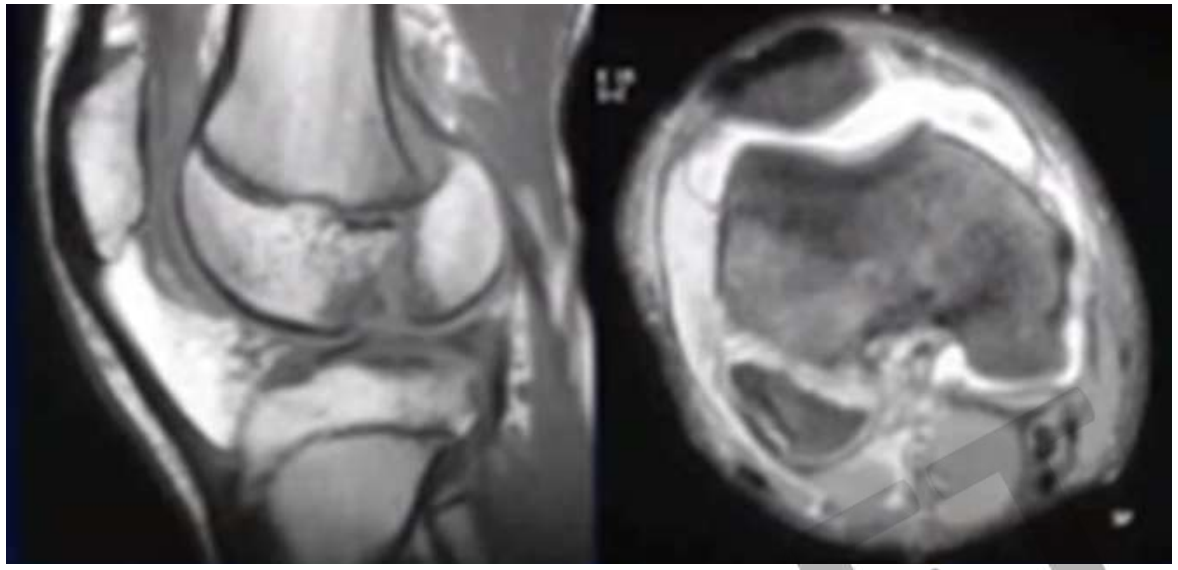

- Older children closure to maturity treat like adult trauma

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Beware

- Peroneal nerve :
- Avoid excessive traction or varus
- Vascular injury
- Knee joint instability- check once the fracture healed

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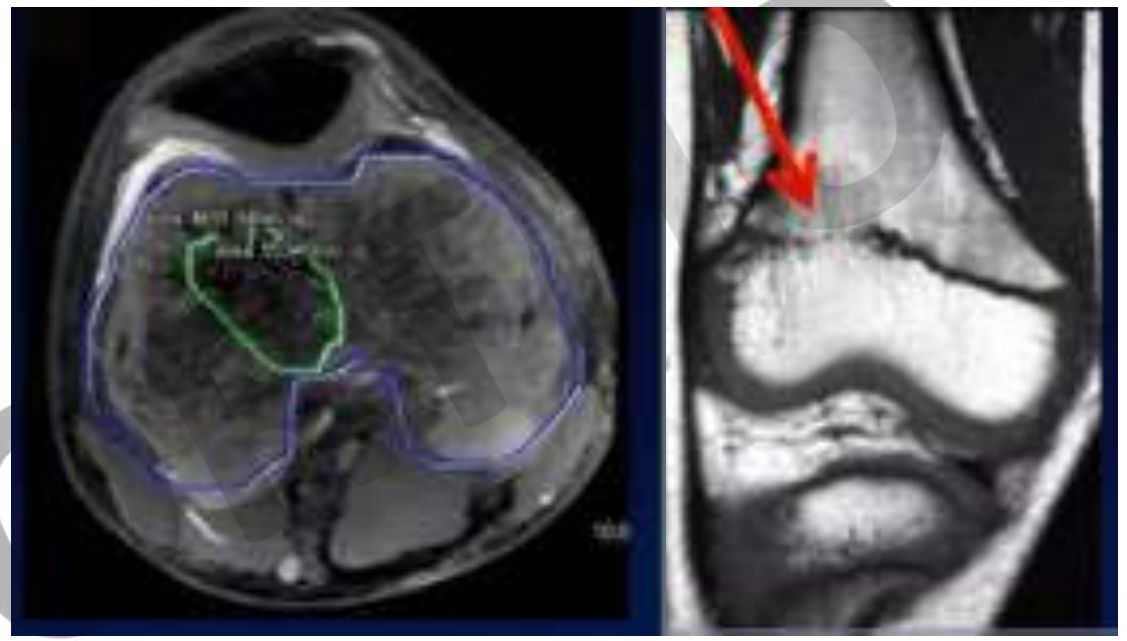
Growth Arrest Risk



- Growth arrest is very common:
- **25-50 %** after displaced fractures
- Remove all metal by 3-4 months
- MRI at 4-6 months after trauma to detect growth disturbances
- SPOILED GRADIENT – RECALL ECHO T1 SEQ
- High quality MRI to look at physis

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SUMMARY

- Decision making:

❖ Avoid CR and cast in displaced & higher-grade fractures

❖ Avoid multiple attempts at reduction

❖ Only indication for CR + cast:

Non-Displaced fractures, Stable SH1 Injury; Metaphyseal Fracture

❖ Displaced or unstable - Internal fixation

❖ Follow up till maturity for complications

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PAEDIATRIC ANKLE FRACTURES:

Transitional

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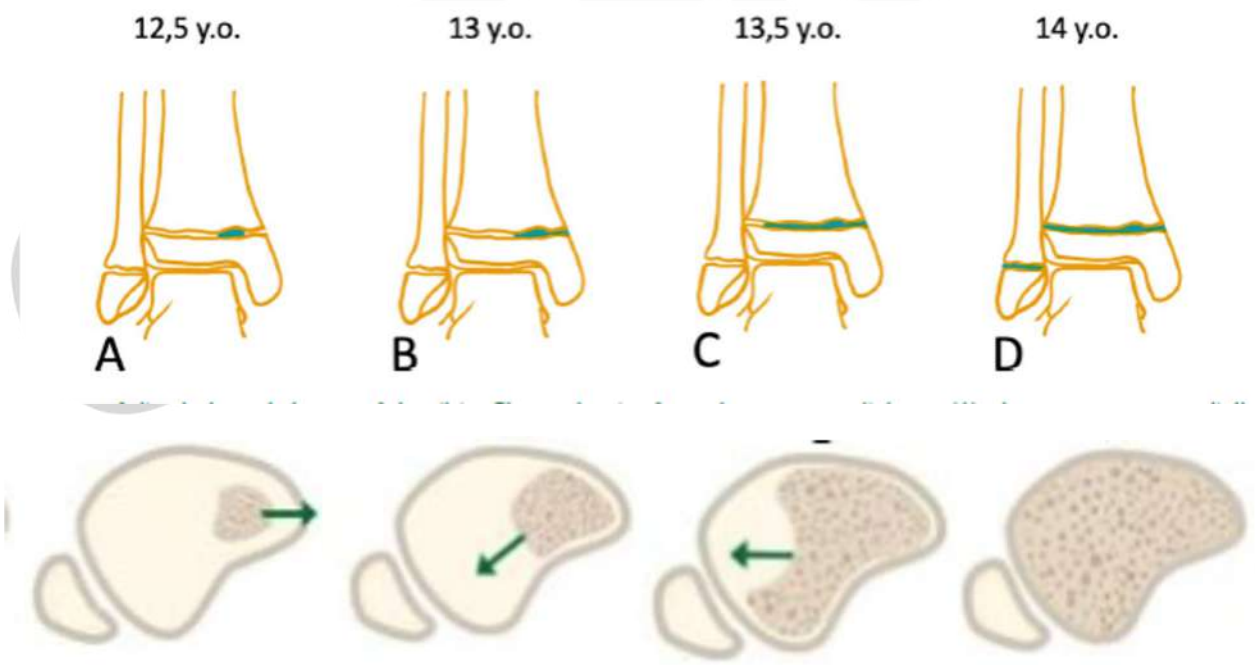
Introduction

– 12-16 years: During the stage of transition from immature to mature skeleton: *Transitional fractures*

– 7-15% of all physeal fractures in adolescents

– Due to asymmetric closure of the distal tibial physis during 18 months period (central-medial-posterior-lateral)



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Mechanism of Injury

– External rotation of a supinated foot,

a common sports related injury

– 2 types

Juvenile Tillaux : Fracture involving only epiphysis

Triplane fracture: Extension into the metaphysis

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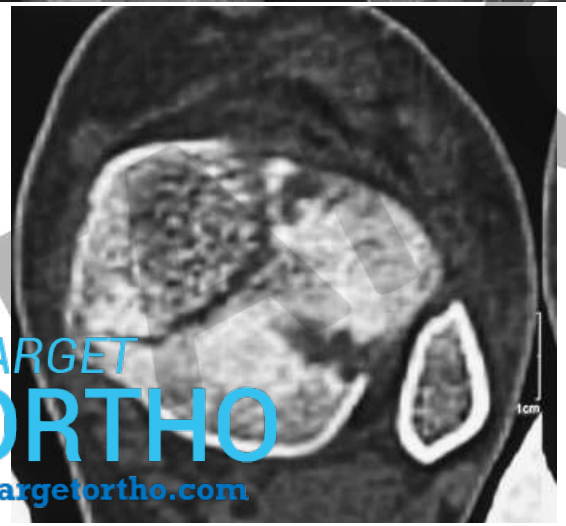

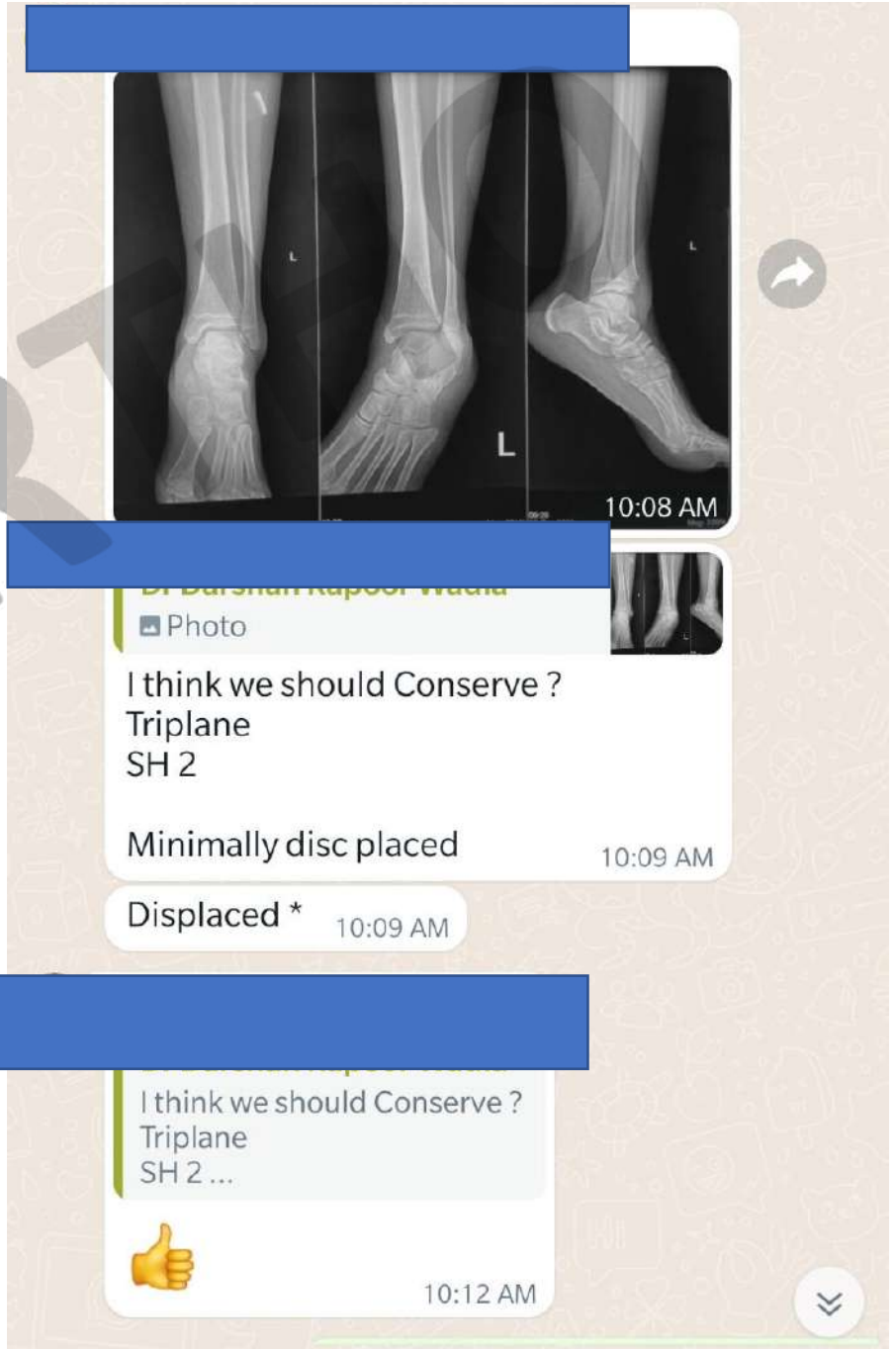

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Triplane Fracture

– Unique group of fractures appearing as

S-H type III fracture on AP and

S-H type II fracture on lateral X-ray

S-H type IV fractures as a whole

– 50% associated with fibula fracture

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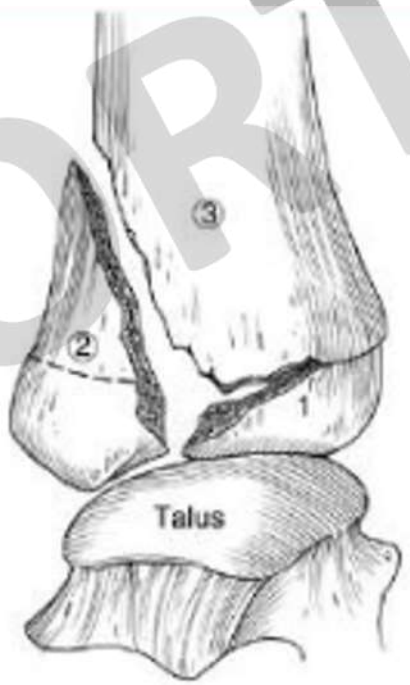
Three major fragments

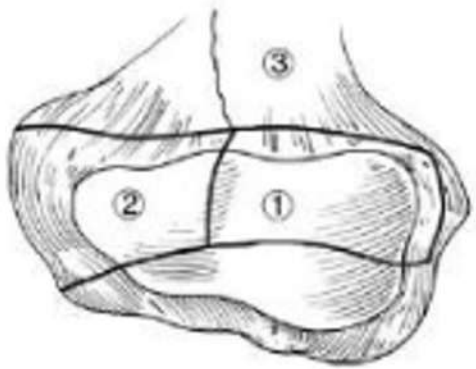
Three different planes

1.Anterolateral quadrant of distal tibia epiphysis

2.Medial and posterior portion of the epiphysis, in addition to posterior metaphyseal spike

3. Tibia metaphysis





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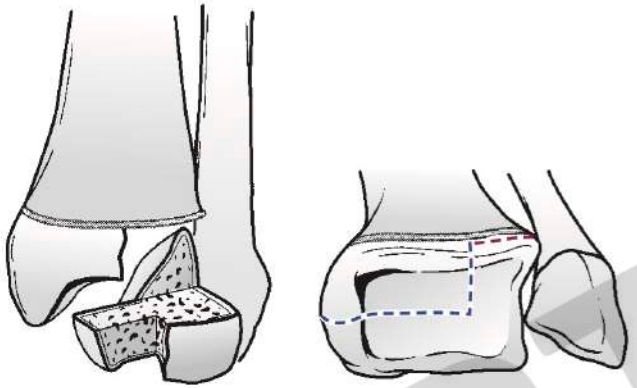
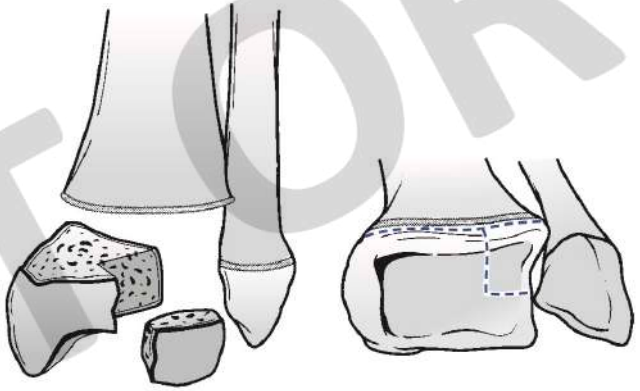
Classification

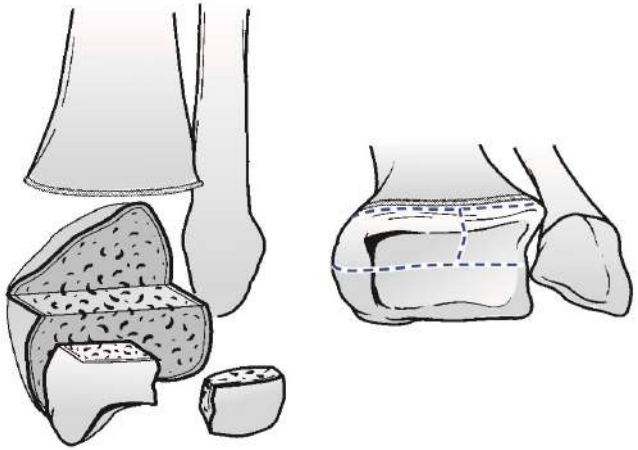
2 Part



3 Part



4 Part



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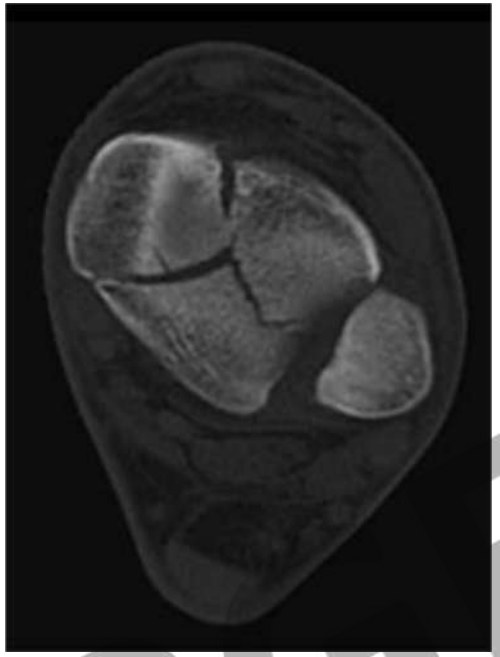
Diagnosis: *Classical 'Mercedes Benz' sign*



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Treatment: Non displaced, <2 mm displaced and extra-articular fractures

– CR under anaesthesia with axial traction on the ankle and internal rotation of the foot

– Immobilisation in NWB AK cast

– Serial follow up X-ray and CT scan is required for confirmation of reduction

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Treatment: >2 mm displaced fractures

– CR under anaesthesia and percutaneous screw fixation

– 4 mm screws from medial to lateral or anterior to posterior or both, based on the fracture pattern

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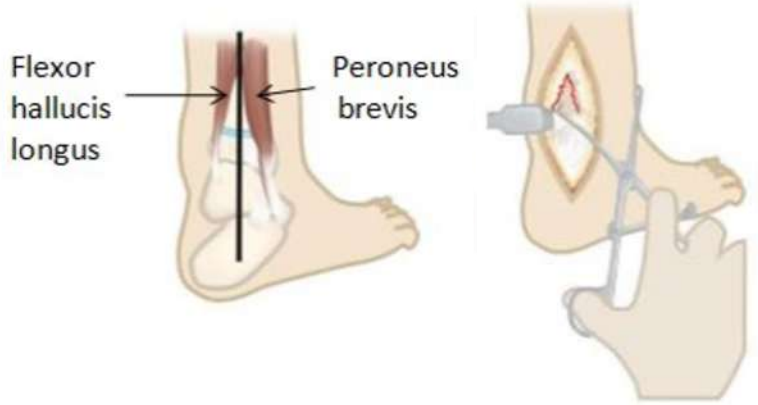
Open Reduction



– If closed reduction is not successful

– Lateral Triplane: Anterolateral approach

Medial Triplane : Anteromedial approach

– 3 or 4 part : Additional posterior exposure

– Associated fibula fracture: Difficult reduction

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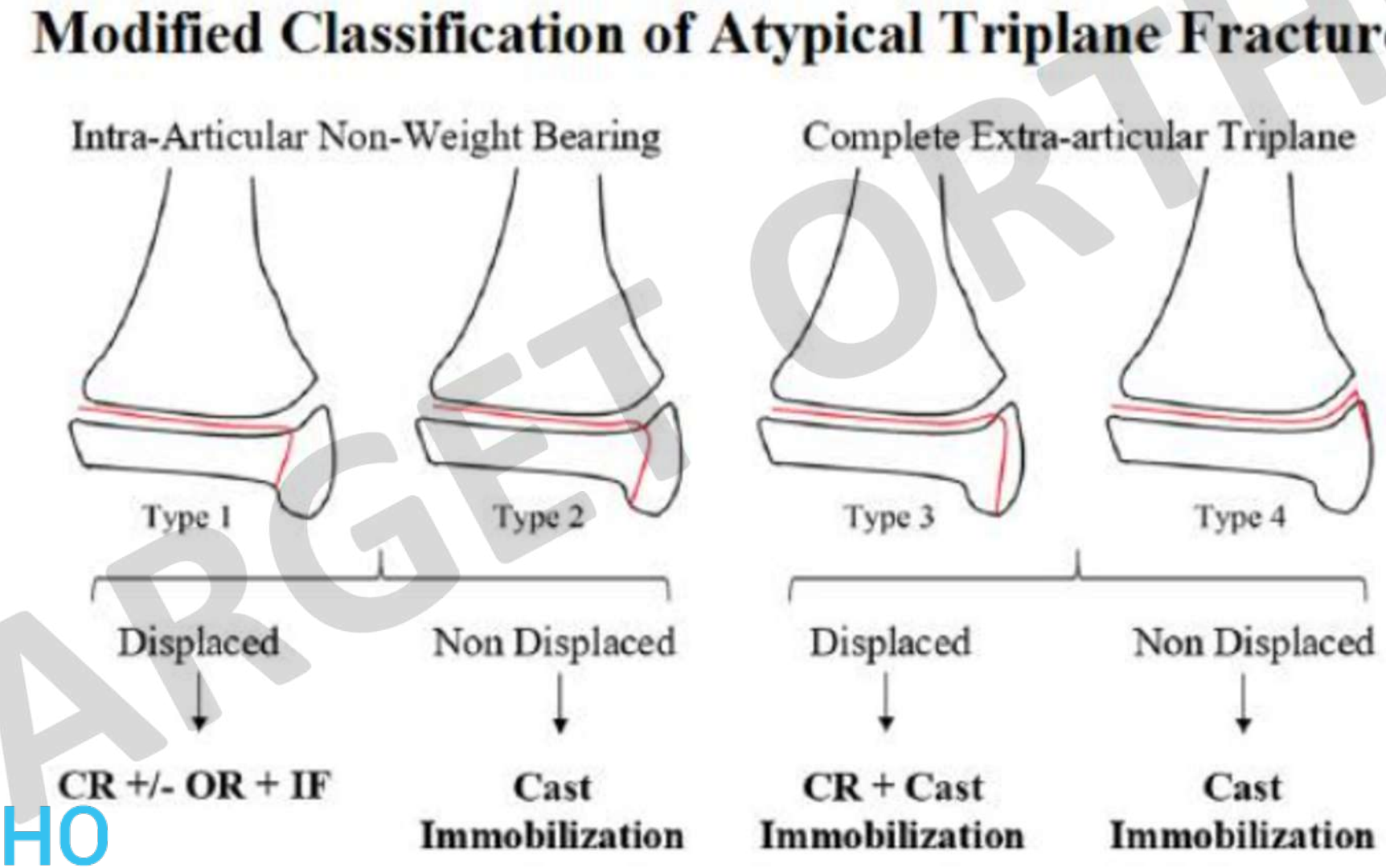
Treatment of Atypical Triplane Fractures



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Prognosis

– Tillaux Fracture: Good outcome

Low risk of growth arrest

– Triplane Fracture: Early arthritis due to joint malalignment

Close follow up for growth arrest and angular deformity

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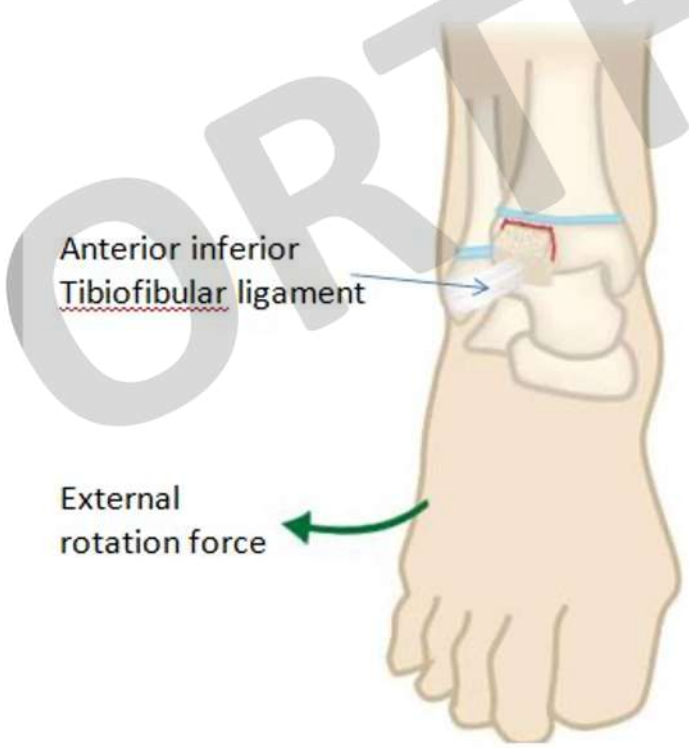
Tillaux Fracture

Avulsion of anterior inferior tibiofibular ligament:

S- H type III fracture involving anterolateral distal tibia



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Diagnosis

– Best seen on Mortise view

– CT: Evaluation of fracture displacement

Surgical planning

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Treatment: Non displaced /< 2 mm displaced fractures

NWB AK cast with knee in 30° flexion and foot in neutral / internal rotation

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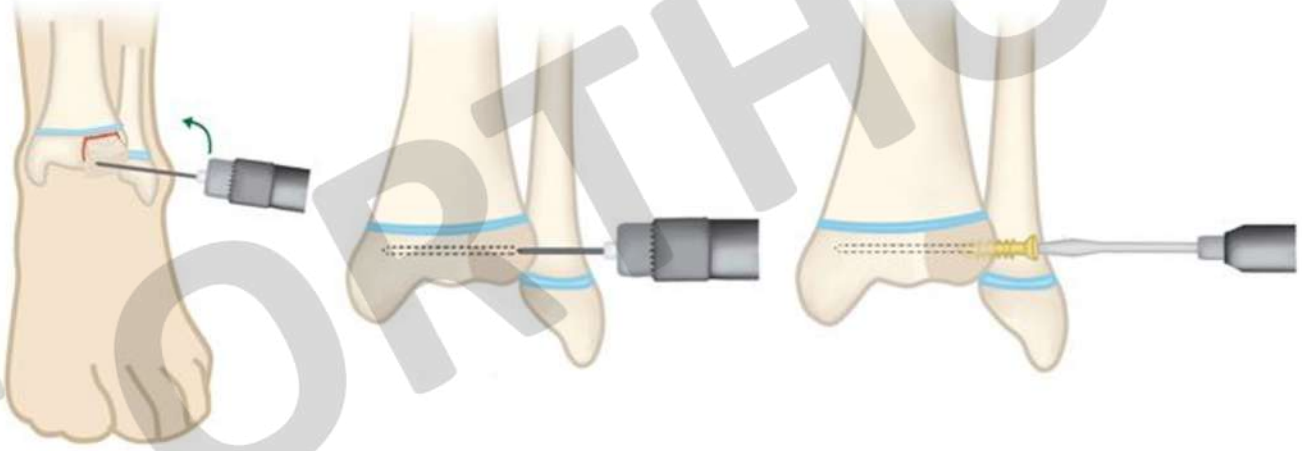
Treatment: >2 mm displaced fractures

– Closed reduction by internal rotation of foot and manual pressure over anterolateral tibia

– Arthrography confirmation

– Percutaneous K wire or screw fixation for providing stability



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Indication for Open Reduction

– Failure of closed reduction

– Anterior approach: interval between EDL and EHL

– Fixation with 4 mm compression screw if large fragment

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To Summarise…

– Tillaux and Triplane are special ankle fractures in adolescents… Transitional fractures

– CT scan helpful in evaluation of fracture displacement & planning of treatment

– Goal of treatment : Restoration of articular alignment

– Good result if correct treatment protocol followed

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Paediatric ankle physeal injuries

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DOMINANT WAY OF THINKING

Ankle Fractures-Anatomic classification

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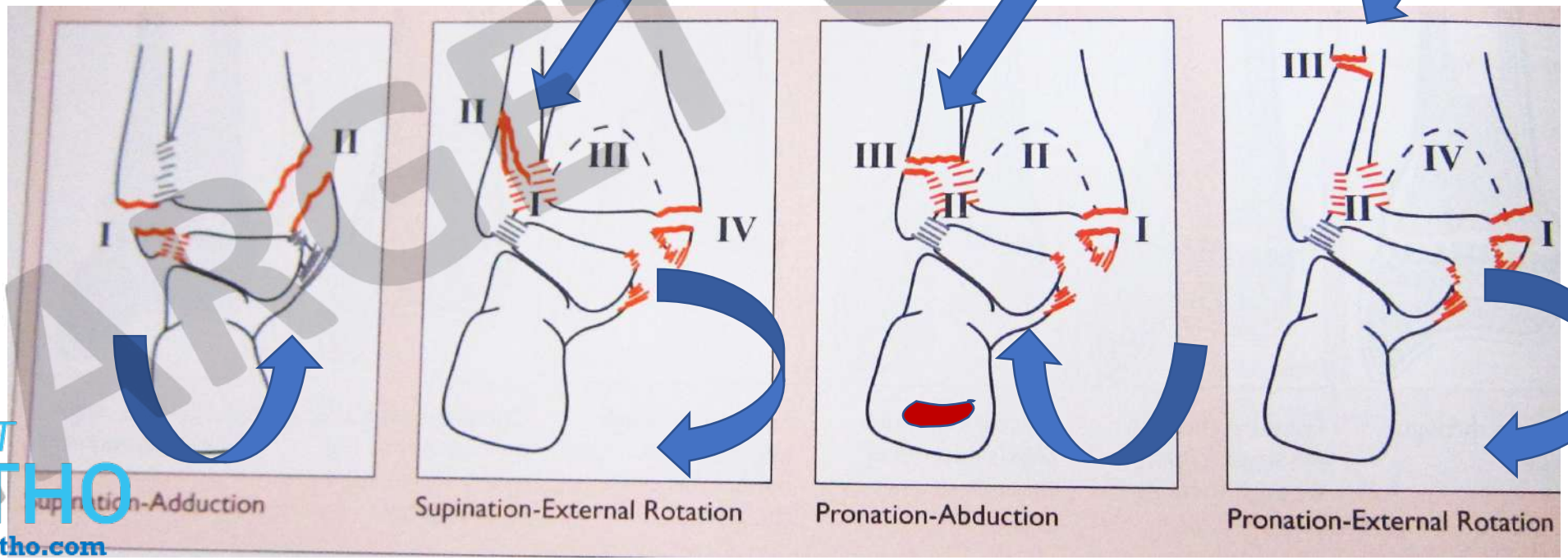
Ankle Fractures

BUT ANKLE FRACTURES ARE A LITTLE DIFFERENT

Different stages of the injuries
(DIAS – TACHJIAN)



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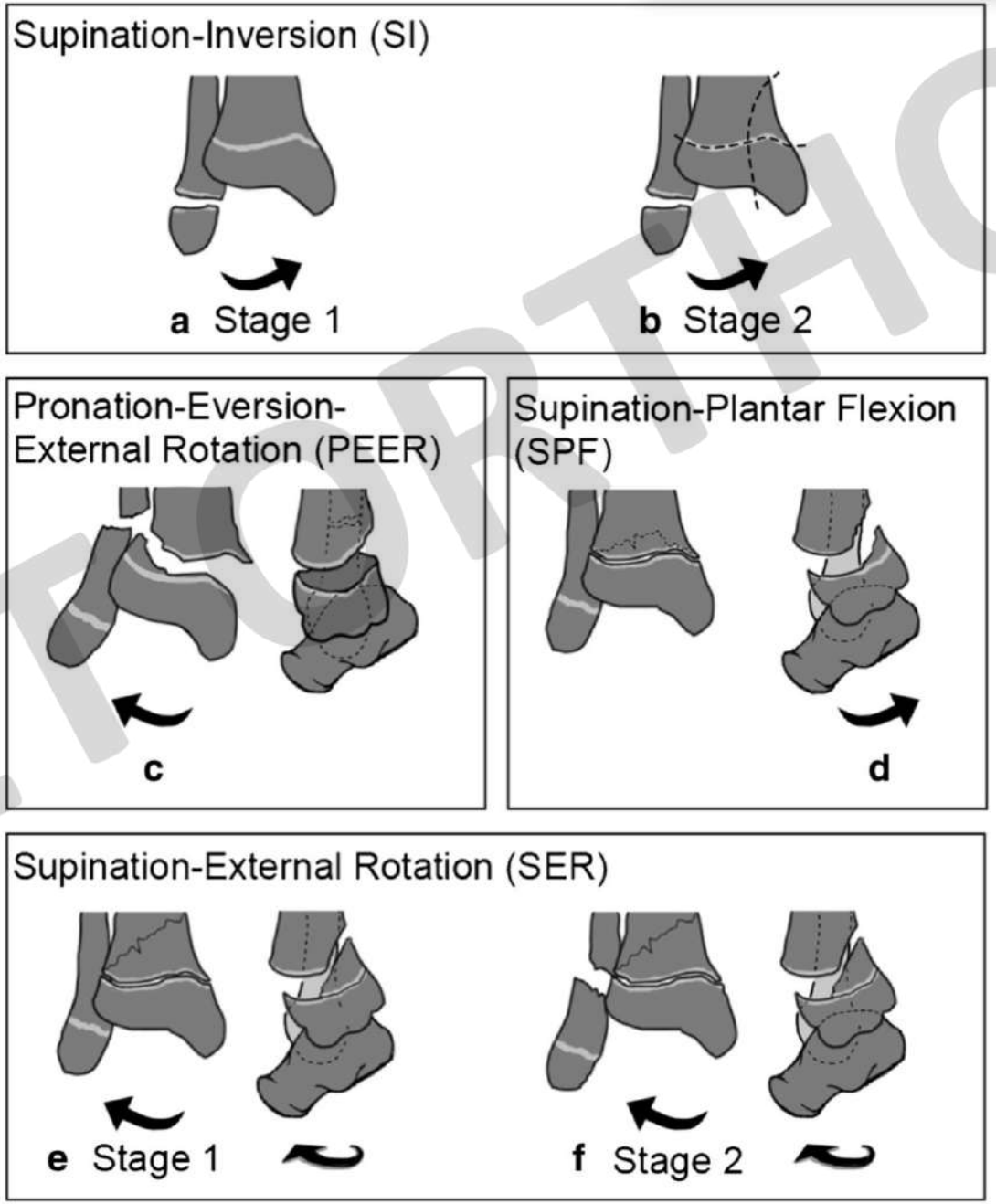

Fig. 2 Dias-Tachdjian classification of pediatric ankle fracture with respect to the physis and the mechanism of injury. (**a**, **b**) Supination-inversion pattern includes Salter-Harris (SH) type I distal fibular fracture in stage 1 injury with the addition of *medial* distal tibial fracture (SH type I-IV) in stage 2 injury. (**c**) Pronation-eversion external rotation injury demonstrates SH type II fracture of the *lateral* distal tibia with distal fibular *diaphyseal* fracture. (**d**) Supination-plantar flexion injury reveals SH type II fracture of the *posterior* distal tibia. (**e**, **f**) Supination-external rotation injury includes *spiral* SH type II fracture of the distal tibia in stage 1 with the addition of spiral fracture of the distal fibular *metadiaphysis* in stage 2

LOOK AT THE FIBULA FRACTURE

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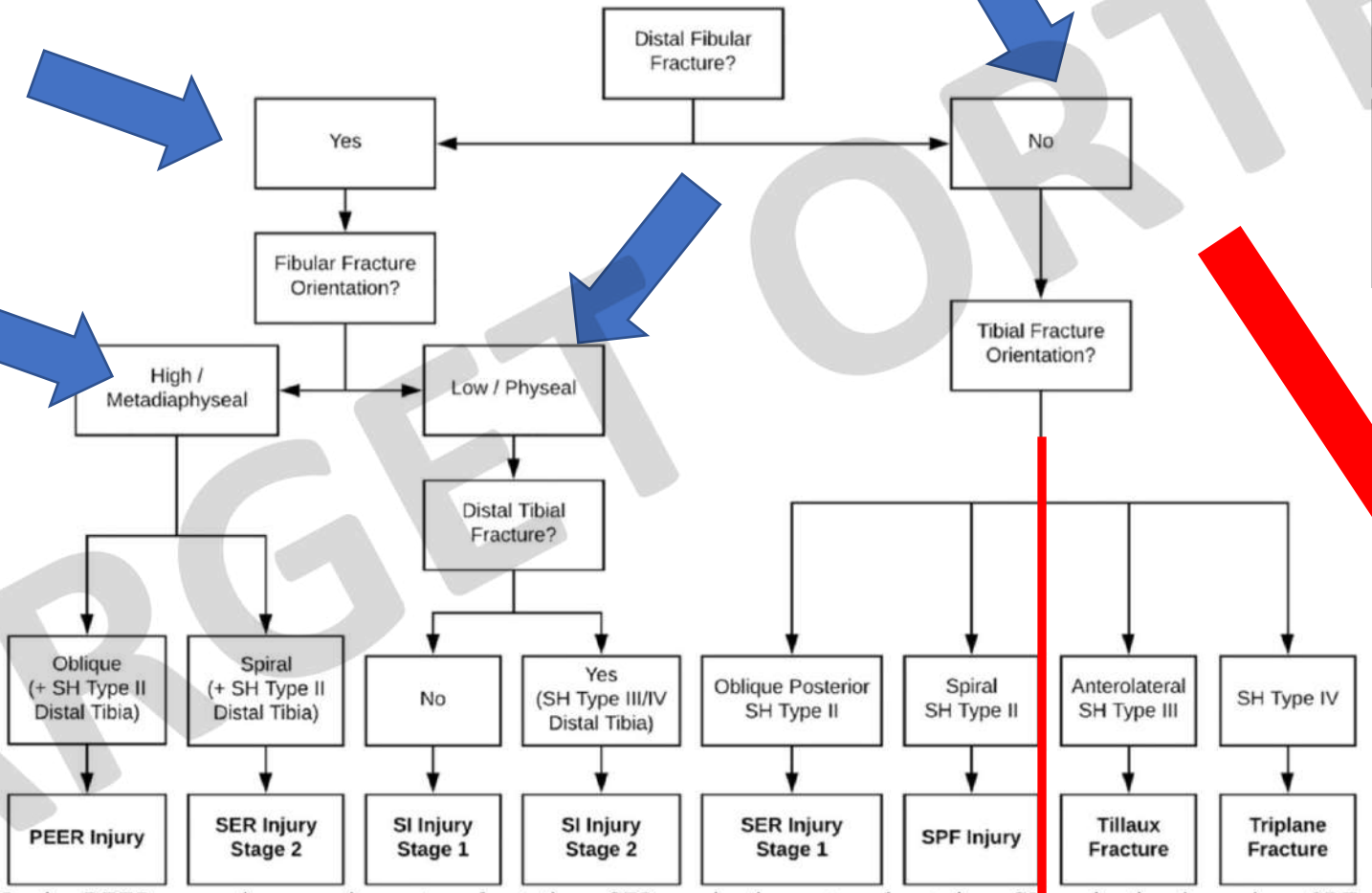
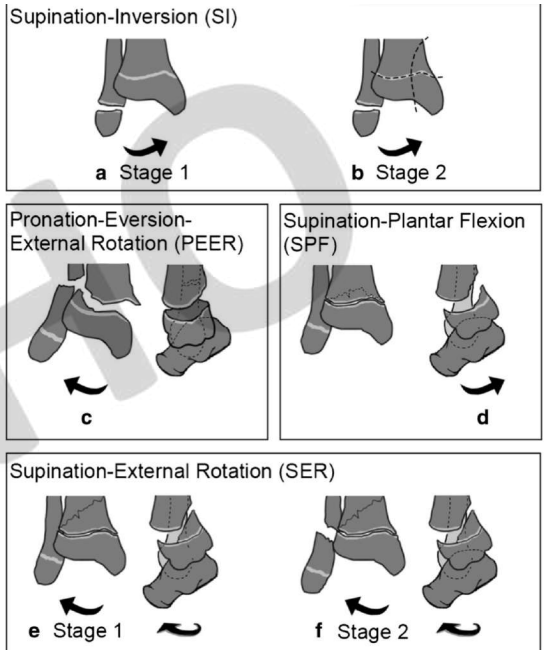
Table 2 Simplified algorithm for Dias-Tachdjian classification of pediatric ankle fractures



SH, Salter-Harris; *PEER*, pronation-eversion external rotation; *SER*, supination-external rotation; *SI*, supination-inversion; *SPF*, supination-plantar flexion



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10y Female ankle trauma

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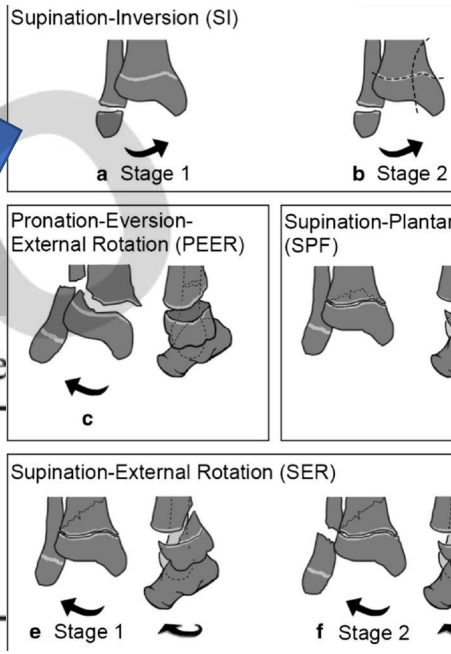

Table 1 Dias-Tachdjian classification of pediatric ankle fractures with associated Salter-Harris components and treatme

Dias-Tachdjian	Salter-Harris		Treatment
	Tibia	Fibula	
SI stage 1	n/a	Type 1	Short leg cast for 3–4 weeks
SI stage 2	Type 3/4	Type 1	Possible ORIF of medial distal tibia
PEER	Type 2	Metadia	Closed reduction (may require lateral incision to disengage lateral tibial metaphyseal fragme
SER stage 1	Type 2	n/a	Close reduction or possible tibial trans metaphyseal fixation
SER stage 2	Type 2	Metadia	Close reduction or possible tibial trans metaphyseal fixation
SPF	Type 2	n/a	Long leg cast 4–6 weeks (may require anteromedial incision to disengage periosteal fragmer
Tillaux	Type 3	n/a	Short or long cast if nondisplaced; ORIF if > 2 mm displacement on CT
Triplane	Type 4	n/a	Short or long cast if nondisplaced; ORIF if > 2 mm displacement on CT

SI, supination-inversion; *PEER*, pronation-eversion external rotation; *SER*, supination-external rotation; *SPF*, supination-plantar flexion; *metad* metadiaphyseal

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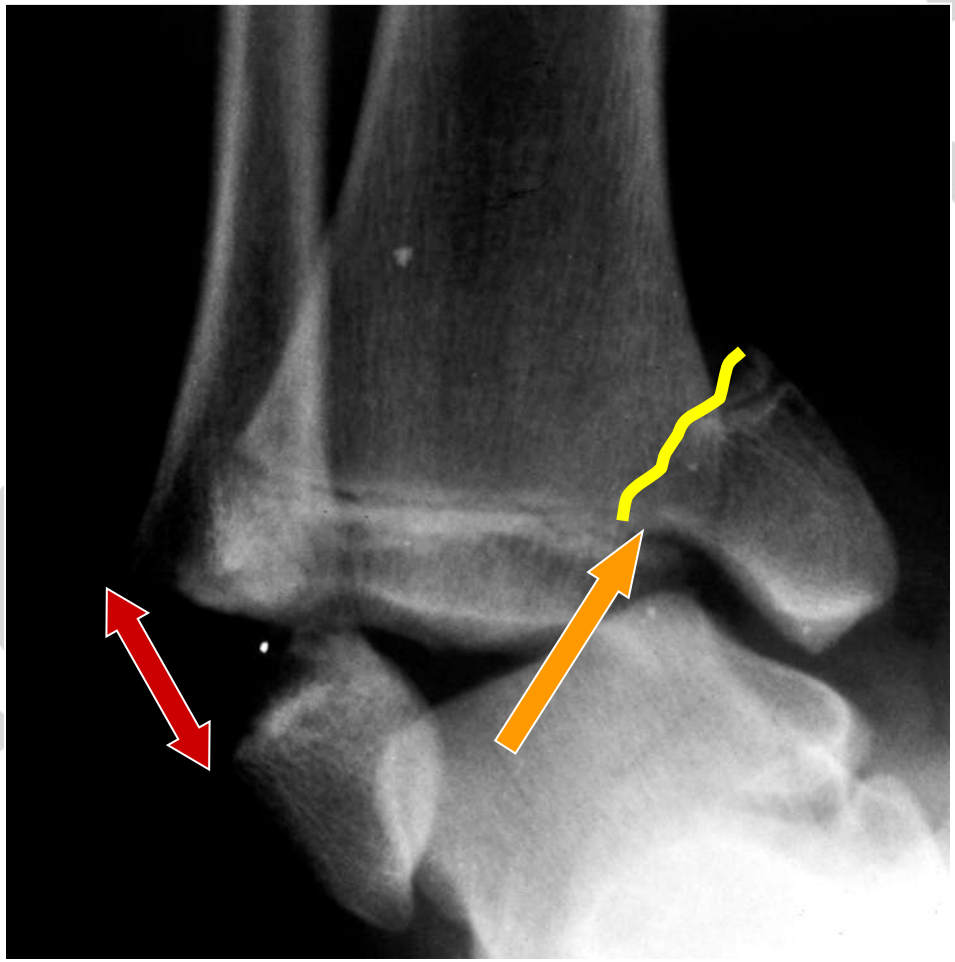
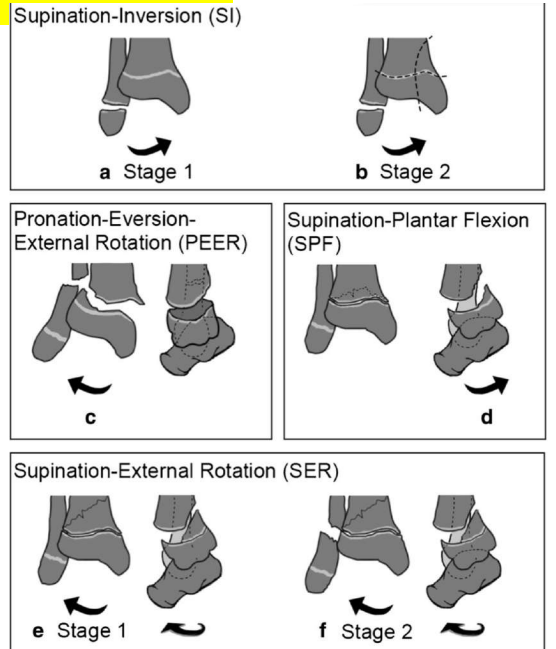
What is significant about Stage II injuries ?

Avulsion fibular physis



S-H III or IV medial malleous



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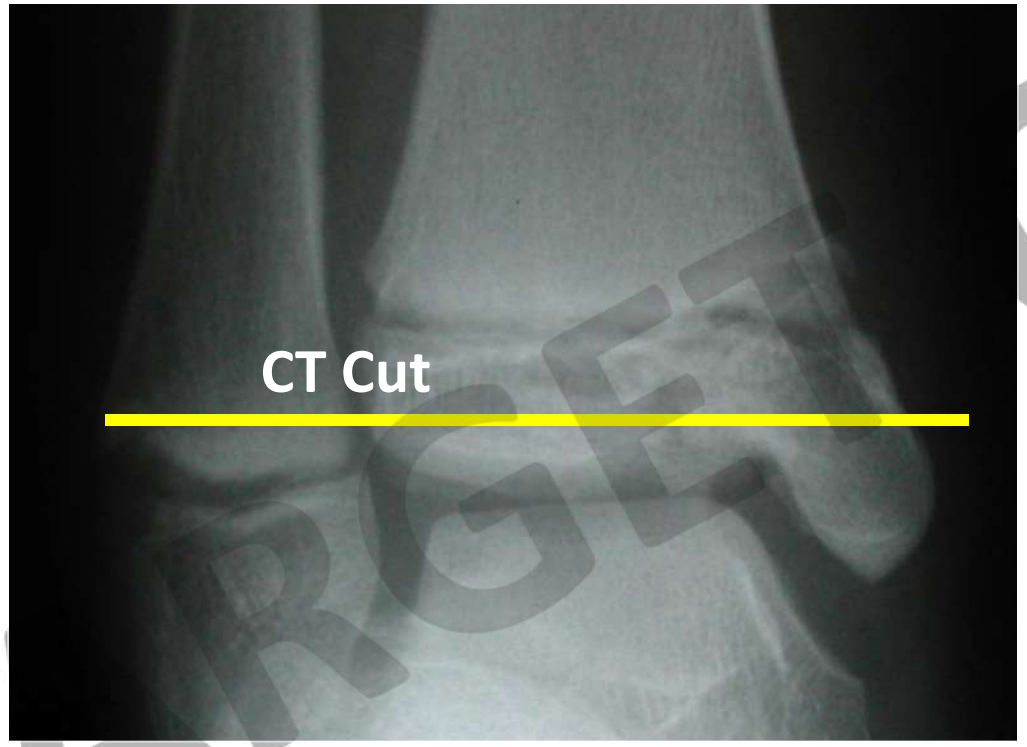

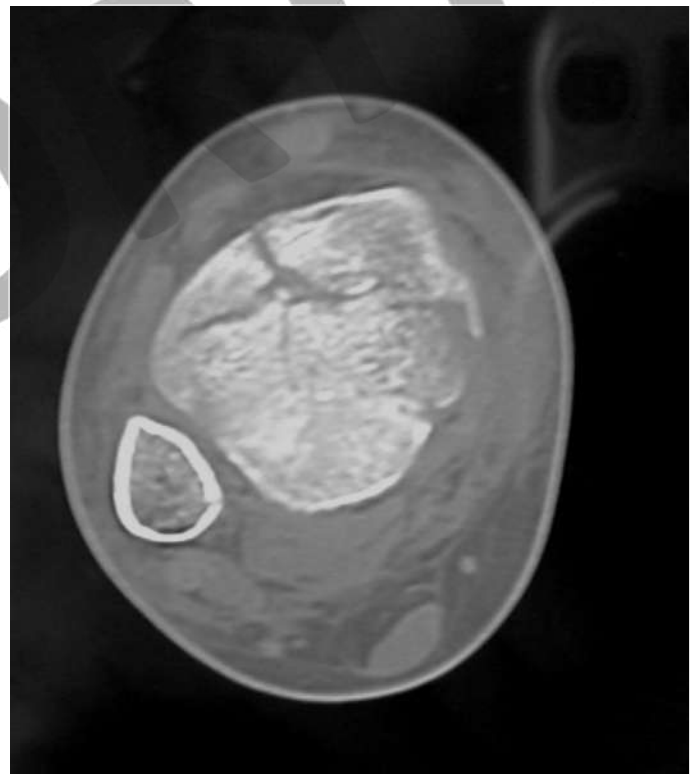

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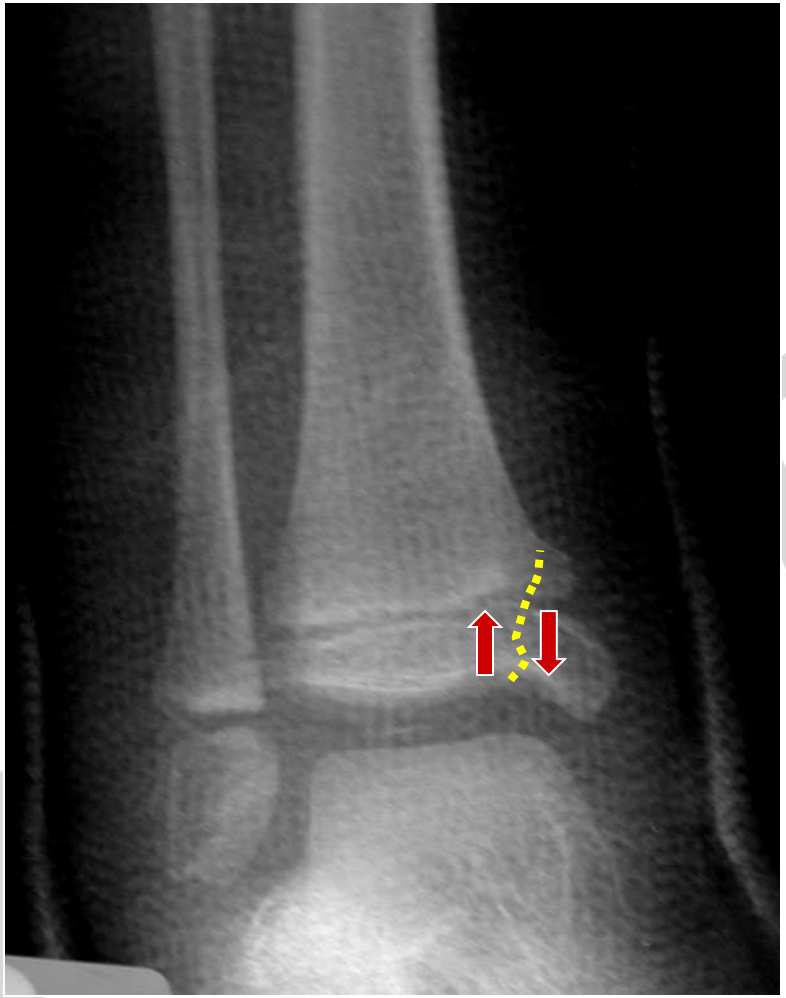
S I Secondly, you have to maintain the reduction.

Stage II



There are vertical shear forces acting at the fracture site.

what is needed?

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How are these shear forces best neutralized ?

Need compressive forces

Trans-Epiphyseal Screw (Percutaneous)

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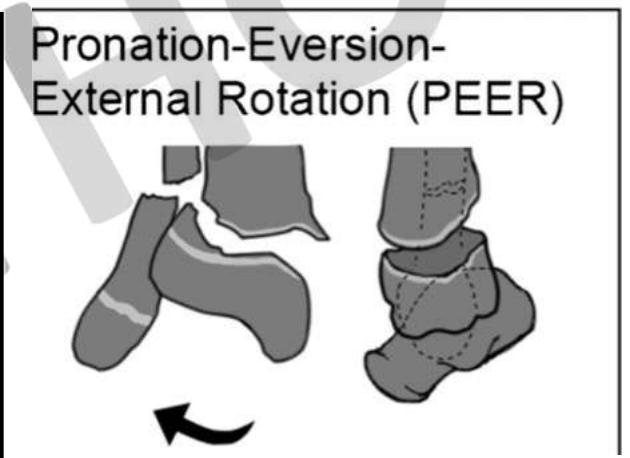
aastha - chord

Pronation Eversion External Rotation

What is the pathology associated with this fracture pattern?



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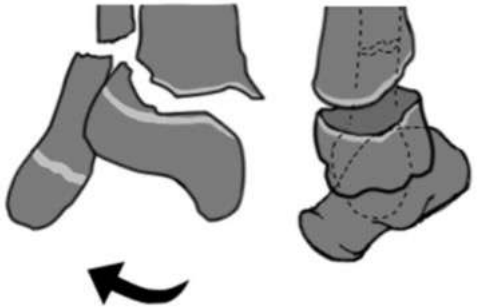
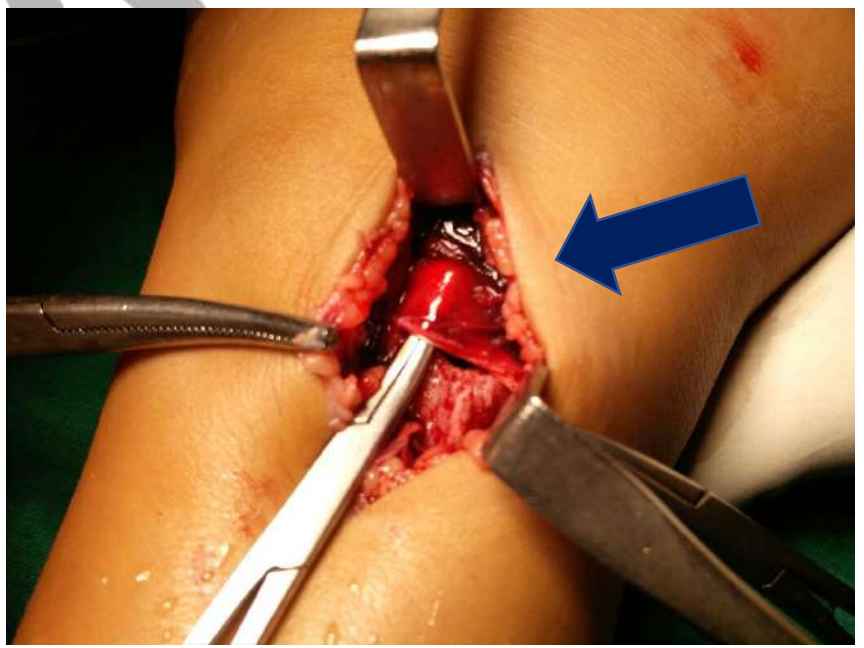
Pronation-Eversion-
External Rotation (PEER)





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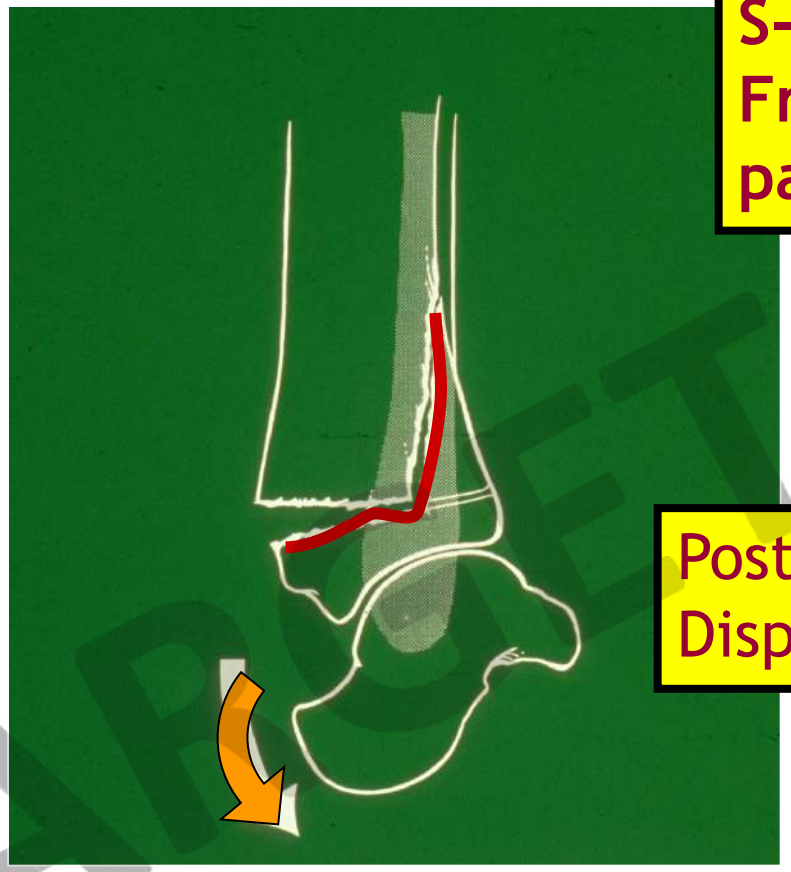
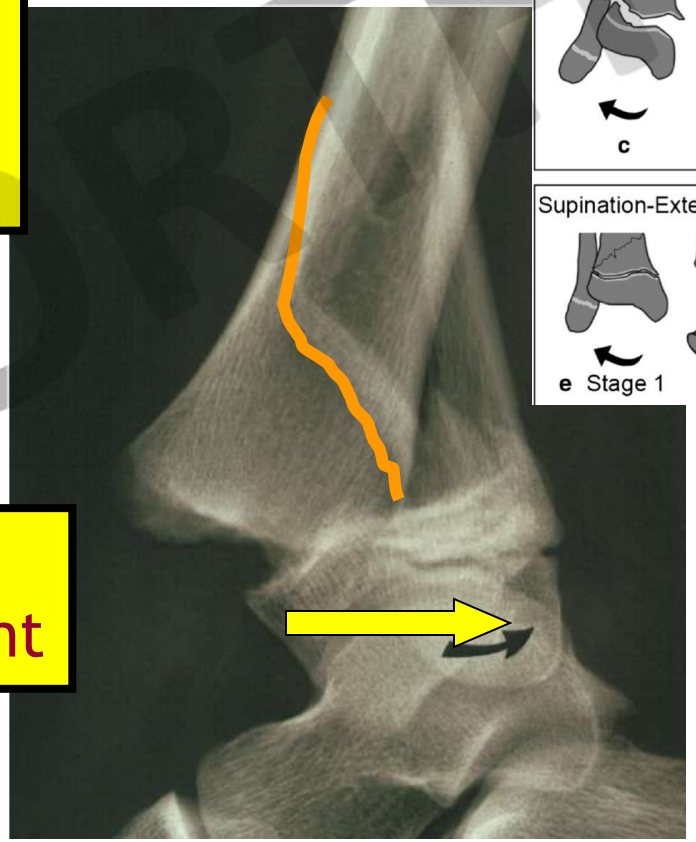
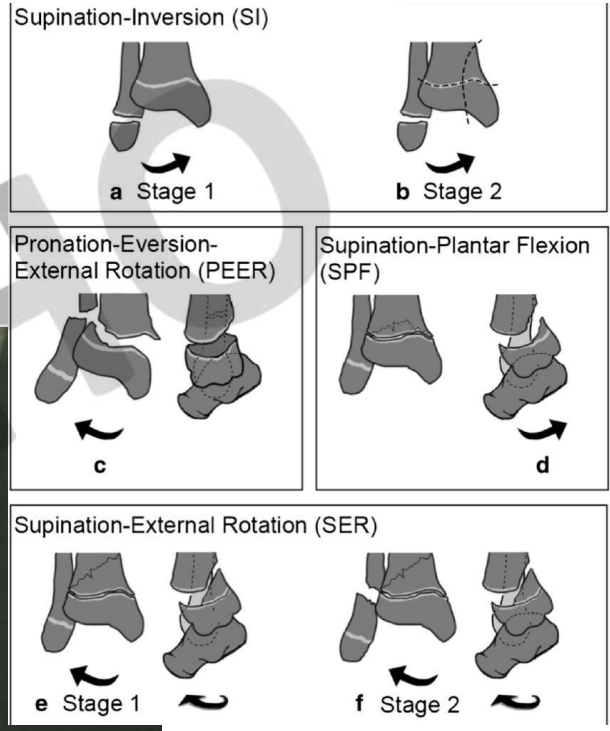
Supination Plantar Flexion



S-H I or II Fracture pattern

Posterior Displacement





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SPF

How are most of these fractures treated?

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SER

Post Reduction

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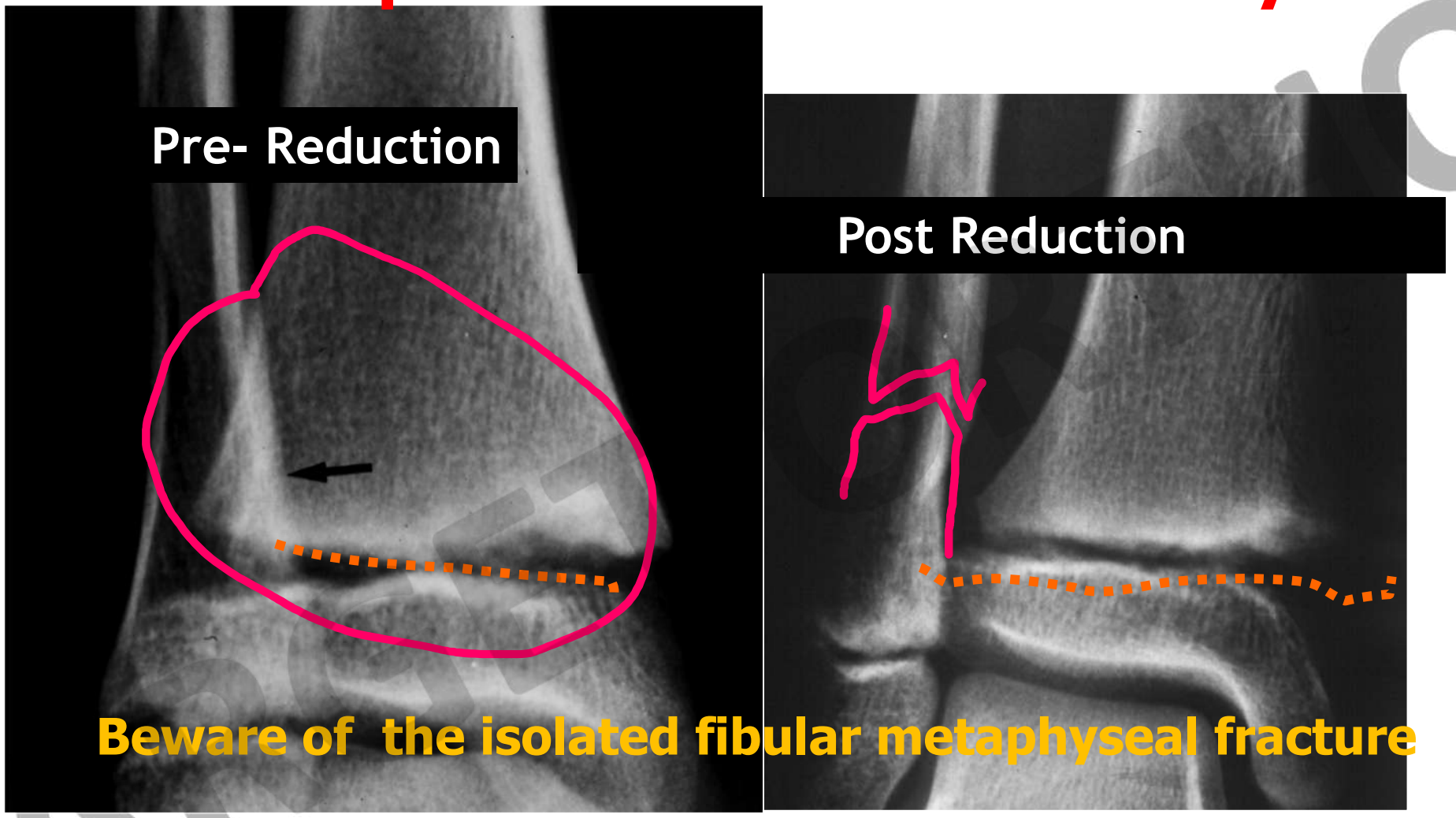
SER

Comparison views tell the story



Cannot really make out the distal tibial physeal injury

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Take Home:

1. Predict the type of injury by looking at the fibula
2. Presumption that SH type 1 and type 2 are simpler injuries is wrong
3. Need open reduction very frequently
4. Removal of interposed tissues
5. High level of awareness
6. CT/ MRI

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