PEDIATRIC LOWER LIMB INJURIES

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Pelvic injuries

- Pelvic fractures are sustained by high-energy mechanisms and require a comprehensive workup for concomitant injuries of the brain, abdominal viscera, and genitourinary system
- Pediatric pelvic ring injuries differ significantly from adult pelvic trauma with regards to injury pattern, treatment options, and outcomes

Pelvic injuries

- Standards of diagnostic care include Advanced Pediatric Life Support (APLS) protocol with an AP pelvis radiograph
- Commonly used classification systems include the Tile Classification and the Torode and Zieg Classification

- Avulsion injuries are a subset of pediatric pelvic fractures that occur in the adolescent population and are sustained by lower energy mechanisms.
- The unique anatomy of the immature pelvis predisposes to injury patterns, treatment options, and outcomes that significantly differ from adults.

- he intrapelvic viscera are not well protected and often sustain injury in the absence of pelvic fractures.(Gansslen, 2013)
- When a fracture does occur, there are a disproportionate number of single pelvic bone injuries due to the elastic biomechanical properties of the immature pelvis.

- The majority of fractures with < 2 cm displacement may be treated non-operatively
- Long-term complications include leg length discrepancy, pain from a displaced fracture, and growth disturbance due to injury of the triradiate cartilage

Avulsion injuries

- ischial avulsion (54%)
  - hamstrings and adductors
- AIIS avulsion (22%)
  - rectus femoris
- ASIS avulsion (19%)
  - sartorius
- pubic symphysis (3%)
  - abdominal muscles
- iliac crest (1%)
  - abdominal muscles
- lesser trochanter
  - iliopsoas

Classification

Tile Classification	
Type A	• Stable injuries (rotationally & vertically)
Type B	• Rotationally unstable • Vertically stable
Type C	• Unstable rotationally & vertically

Torode/Zieg Classification (pediatric pelvic ring)	
Type I	• Avulsion injuries
Type II	• Fractures of the iliac wing
Type III	• Fractures of the ring with no segmental instability
Type IV	• Fracture of the ring with segmental instability

Treatment

- Conservative
- Operative

Complications

- Death
- Physeal cartilage injury

  premature closure of triradiate cartilage/growth arrest .
- Leg length inequality
- Malunion/nonunion
- Neurovascular injury
- Hetertopic ossification
- Osteonecrosis
- Degenerative joint disease of the hip

Neck of femur fracture

- Rare injuries
- < 1% of all pediatric fractures

Why are they so important?

- Coxa vara
- Non union
- AVN

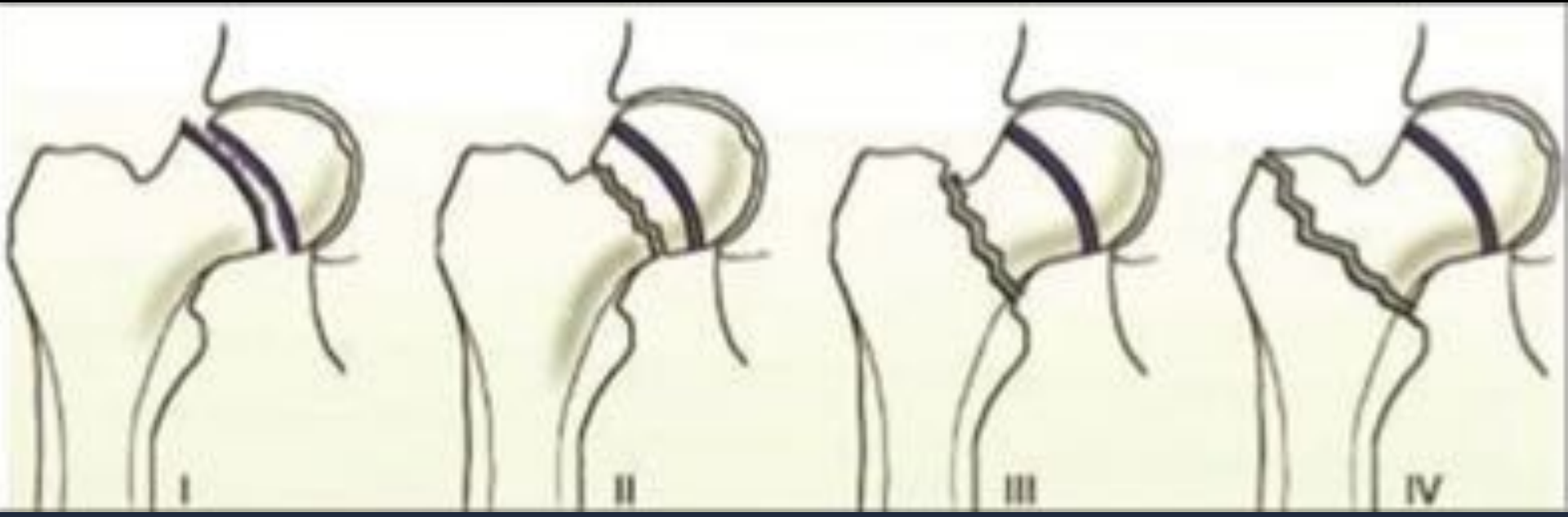
Mode of injury

- High energy trauma
- Motor vehicle accident
- Fall from height
- Pedestrian stuck by vehicle
- Child abuse

Classification: Delbet's

- Type I –transepiphyseal fractures
- Type II- transcervical fractures(45-50%)
- Type III- cervicotrochanteric fractures(35%)
- Type IV – intertrochanteric fractures

Delbet's classification



Pathology

- Its all about blood supply
- After age 3 physis blocks transmetaphyseal circulation
- This circulation returns after physis closure
- Main arterial blood supply is via lateral epiphyeal artery, a branch of the medial femoral circumflex artery.
- This means that femoral neck fractures are vascular emergencies.

Treatment

- Fully assess the child
- Reduce the fracture if there is going to be a delay

- Emergency surgery

Treatment

- Most of these kids needs internal fixation
- Most need spica for immobilzation
- Some need open reduction
- All pathologic fractures should be fixed

Complications

- General:

- Specific : AVN, non union , malunion, coxa vara, chondrolysis

AVN after femoral neck fractures

- Rates ranges from 0-92%
- Meta-analysis found rate 38% for type I, 28% for type II, 18% for type III and 5% for type IV fractures. (Moon 2006)
- Another recent study of 44 pts showed rates of 50%, 28%, 8% and 10% for #s type I to IV respectively.

Complications

- Coxa vara: should be very rare with good fixation and casting

- Non union: up to 10%

Summary

- Rare but tricky fractures
- Do them as emergencies
- Solid fixation and casts, don't
- Watch carefully for complications

Femur fractures

- Femur fracture in a child before walking age is suspicious for non-accidental trauma
- Most common femur fracture type in a child is closed, transverse, and non-comminuted
- Adolescents have adult-like mechanism for femur fracture (high energy) and associated injuries are common
- Treatment varies by age, weight, and fracture pattern

Classification

- Pattern
- Location
- Stability
- Whether fractures are open or closed

Treatment

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	go/go traction à spica cast Flexible nails (controversial)
5 – 11 yrs	< 49 kg	Stable	Flexible intramedullary nailing
	Any	Unstable	Submuscular bridge plate vs. External fixation

Treatment

> 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
[illegible]			External fixation vs. submuscular plating (consider use of rigid trochanteric entry nail in older kids)

Complications

- Limb length discrepancy
- Malrotation
- Surgical site infection

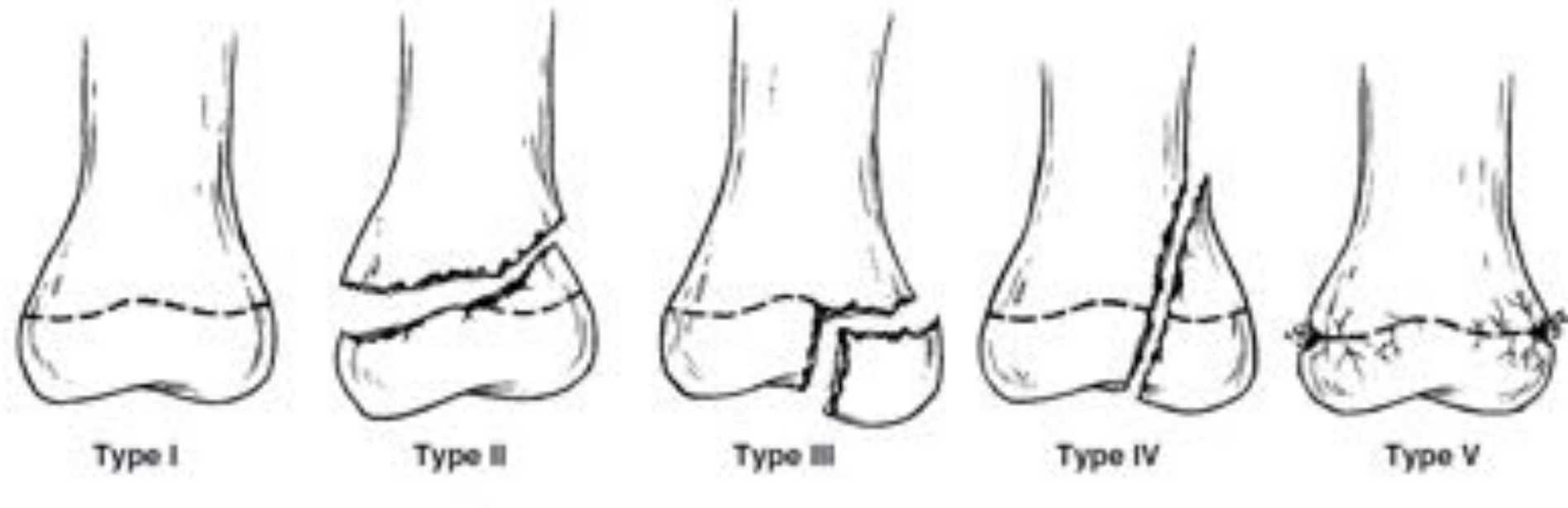
Acceptability creiteria

Table 2. Acceptable shortening and angulation measurements of femur fractures based on age

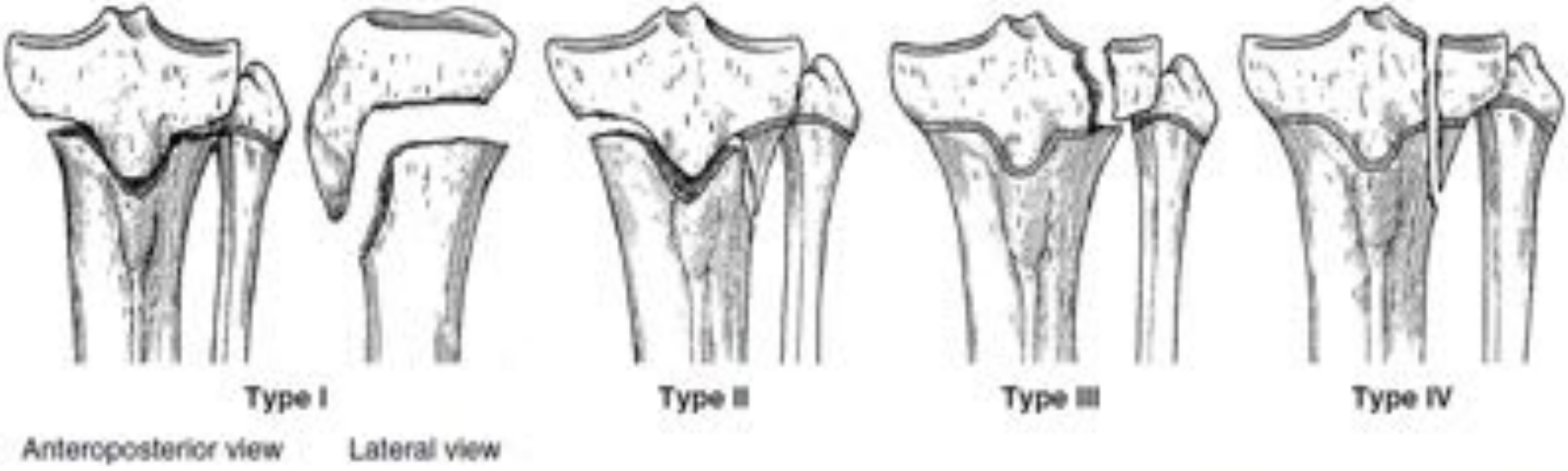
Age	Varus/Valgus (degrees)	Anterior/Posterior (degrees)	Shortening (mm)
Birth to 2 yr.	30	30	15
2 – 5 yr.	15	20	20
6 – 10 yr.	10	15	15
11 yr. to maturity	5	10	10

Adapted from Beaty JH and Kasser JR. Rockwood and Wilkins Fractures in Children. 7th Ed (Beaty JH. 2010 #133)

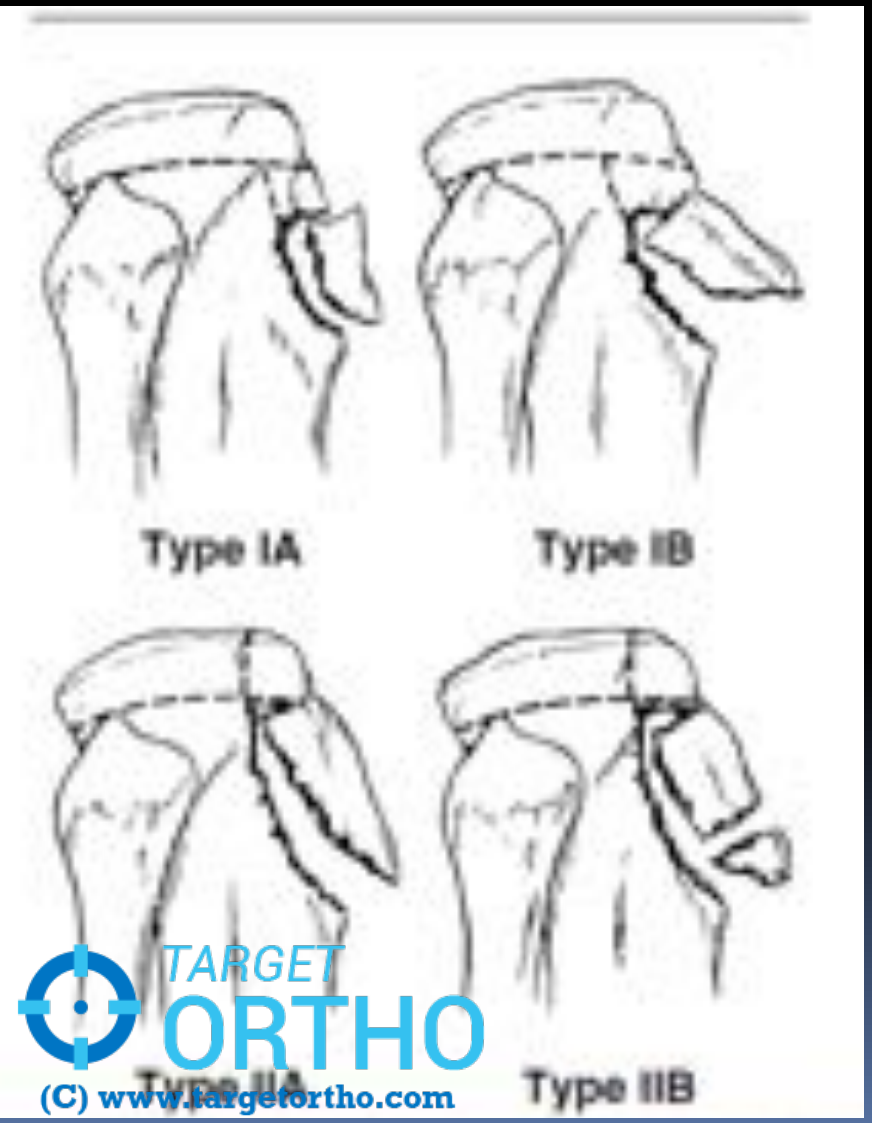
Distal femur fractures

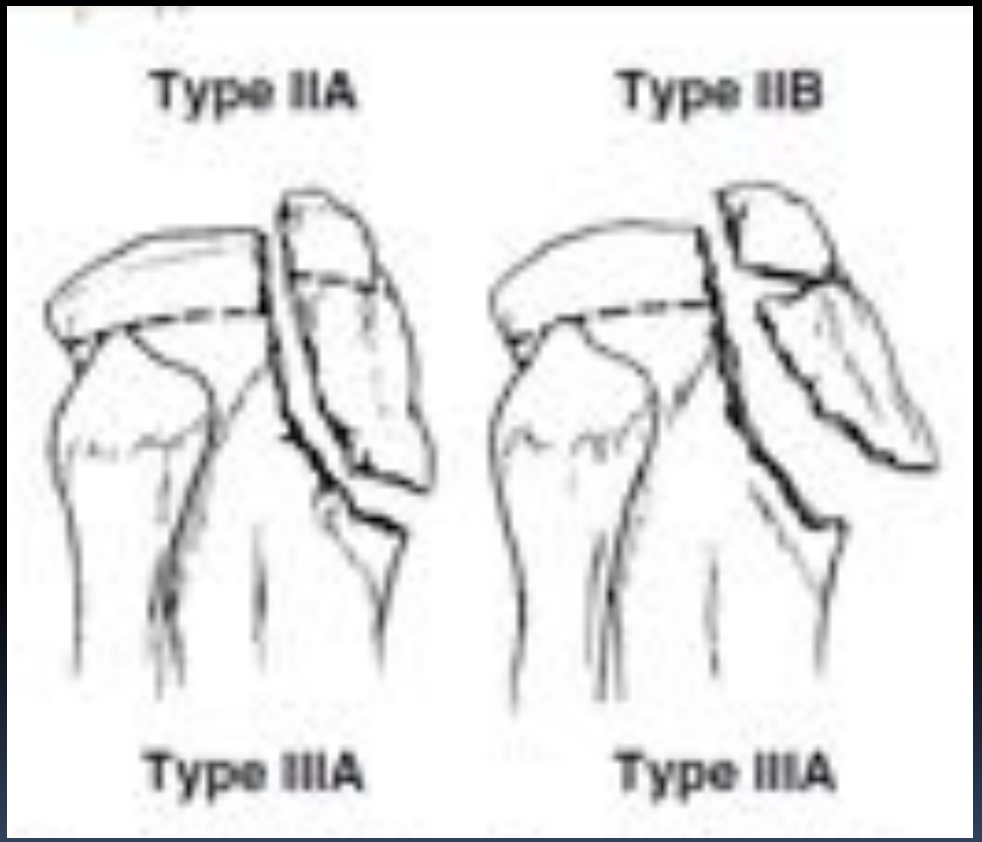


Proximal tibia fractures



Tibial tubercle fractures





Tibial spine fractures

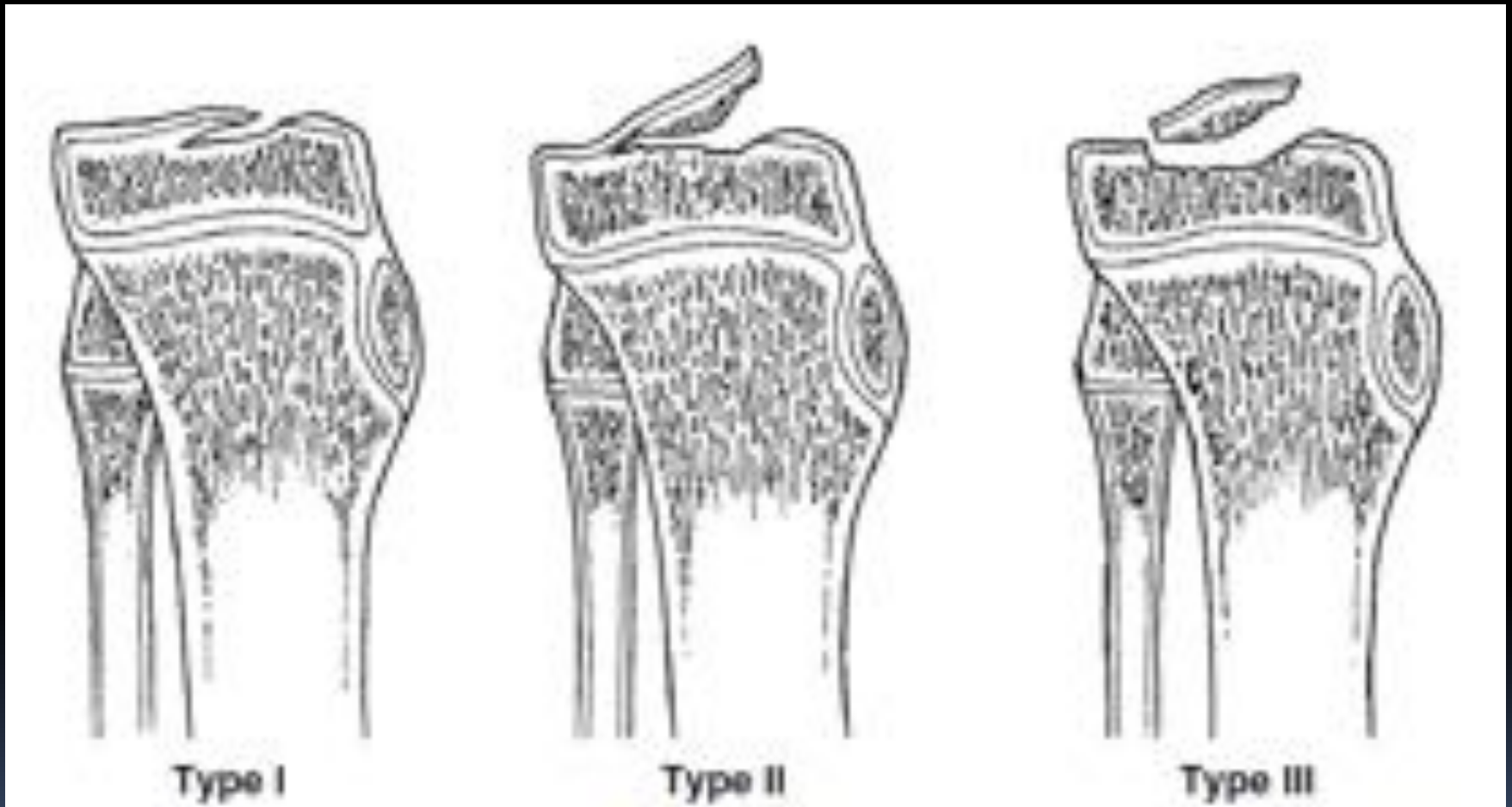
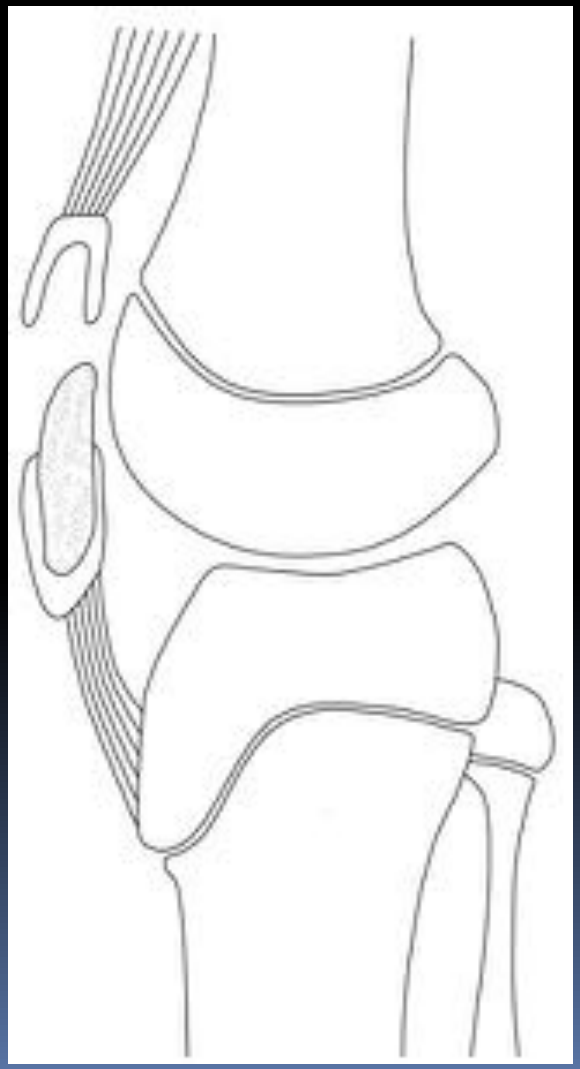


Figure 3. The Meyers and McKeever[9] classification for tibial spine fractures. (Adapted from Johnston DW, Wiens JT, Tolo VT: Fractures and dislocations around the knee, in Green NE, Swiontkowski MF (eds): *Skeletal Trauma in Children*. Philadelphia, PA: WB Saunders, 1994, vol 2, pp 369-396.)

Patella sleeve fractures

- are rare injuries seen in children between 8 and 12 years of age characterized by separation of the cartilage "sleeve" from the ossified patella.



Treatment

- Cylindical cast
- Orif with k wire and tension band wiring

Proximal tibia Meta-physeal

- Proximal Tibia Metaphyseal Fractures are fractures of the proximal tibia usually seen in children from 3 to 6 years of age.

- This fracture is significant for its tendency to develop a late valgus deformity, known as a Cozen's phenomenon, that must be monitored closely

Tibia

- Incidence: 15% of all pediatric fractures
- 39% of fractures occurs in mid diaphysis

Treatment

- Conservative : close reduction and long leg cast
- Operative : TENS/ PLATE

Foot injuries

- Subtalar dislocations and Lisfranc injuries are rare in children.
- Lisfranc injuries are frequently missed. Weight bearing radiographs are essential for evaluation of subtle injuries.
- Isolated fractures of the base of the 2nd metatarsal should alert practitioners to the presence of an injury to the Lisfranc complex.

Foot injuries

- Lisfranc injuries range from purely ligamentous to severe fracture-dislocations of the forefoot.
- The tarsometatarsal joints have intrinsic stability due to the recessed base of the 2nd metatarsal and the "Roman arch" configuration of the middle three metatarsals as well as the Lisfranc ligament, which runs from the base of the 2nd metatarsal to the medial cuneiform.
- Diastasis frequently occurs between the 1st and 2nd metatarsals, but all 5 rays can be involved.

Hardcastle classification

- Type A: total incongruity of the entire metatarsal joint in a single plane

  Type B: partial incongruity of the joint caused by medial displacement of the first metatarsal or lateral displacement of the lateral metatarsals (most common in children)

  Type C: divergent pattern with the first metatarsal displaced medially and the lateral metatarsals displaced laterally

Compartment syndrome

- Children with tibia fractures, especially those sustained in motor vehicle accidents, are at risk for compartment syndrome.
- A recent report on compartment syndrome of the leg in children showed an average delay of 20.5 hours from injury to diagnosis, which may indicate slower development of compartment syndrome in children or difficulty in making the diagnosis

Compartment syndrome

- Tibial tubercle fractures are at increased risk due to potential associated injury of the recurrent anterior tibial artery (Pandya, 2012).

- close monitoring of children who present with high energy tibial shaft fractures or tibial tubercle fractures is recommednded.

Epiphyseal injuries around ankle

- 5% of all #
- 15-20% of all physeal injuries in children
- MC physeal injury in lower extremity

Epiphyseal injuries around ankle

- Ankle epiphyseal injury more frequently require surgical management than distal radius epiphyseal injuries
- Higher incidence in children with high BMI
- Basketball,football and scooters are the most common activites associated with these injuries

Pediatric Ankle anatomy

- Of all physeal injuries, # of the distal tibial physis have among the highest rates of complications including
- Premature physeal arrest
- Bar formation
- Angular deformity
- Articular incongruity

Pediatric Ankle anatomy

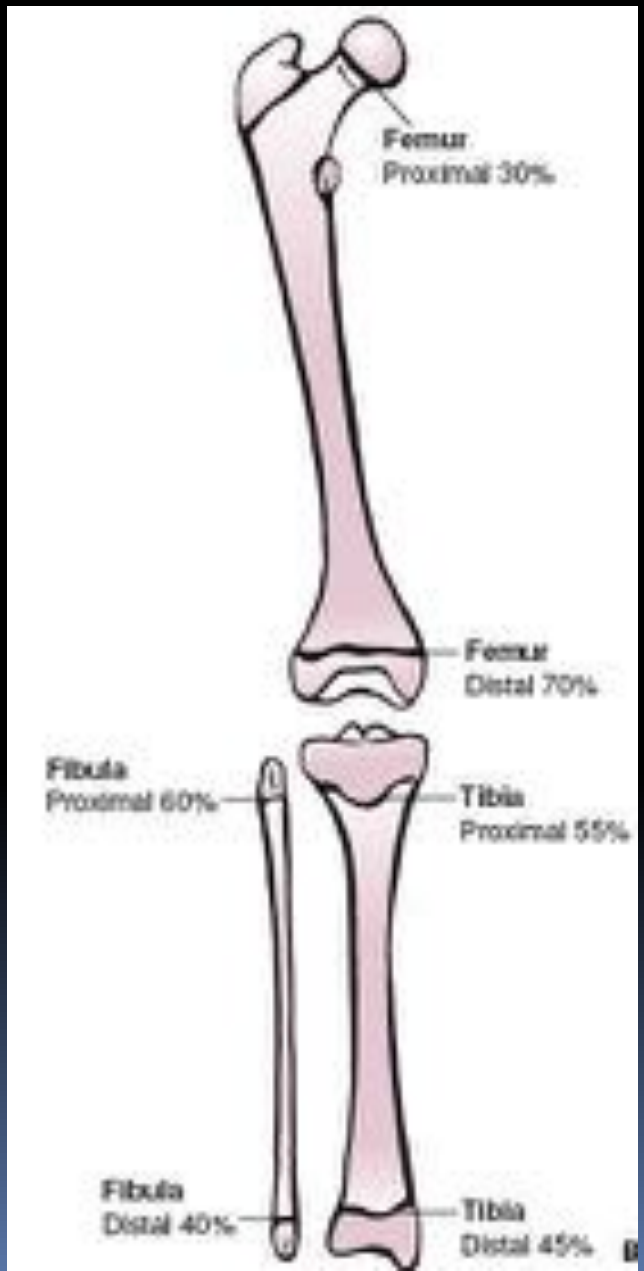
- Physis contains four zones
- Reserve zone
- Proliferative zone
- Hypertrophic zone
- Calcification zone

occurs through hypertrophic zone

which crosses the physis into epiphysis (SH type 3 & 4) may damage the resevre zone and thus are of higher risk of causing physeal growth disturbance.

Pediatric Ankle anatomy

- Distal tibia physis provides 40-50% of the growth of tibia & 17% of lower extremity
- 3-4 mm/year
- Till 7-9 years of age distal tibia growth occurs proportionately to the proximal tibia



Pediatric Ankle anatomy

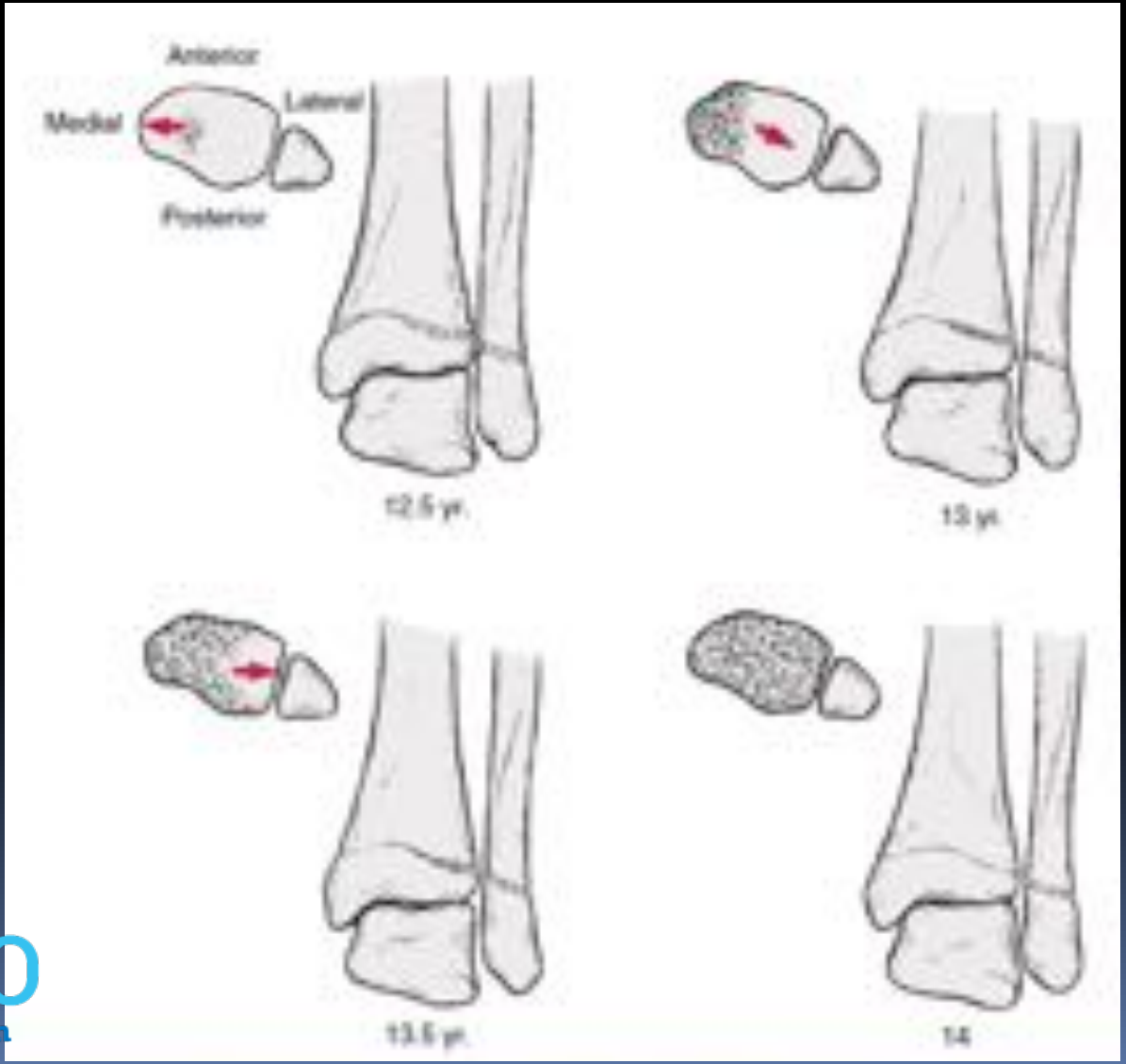
- During adolescence the proximal tibia growth becomes more rapid and distal tibia growth tapers off.

- Thus injury to the physis at early age can result in significant LLD.

Pediatric Ankle anatomy

- Distal tibia and fibular physeal closure occurs aroung 12-17 years in females and 15-20 in males

Tibial physis closure occurs slowly and eccentrically beginning around Poland's hump and then anteromedially, posteolaterally and finally anterolaterally



Pediatric Ankle anatomy

- Ligamentous structures in children are quite robust, whereas the physis is biomechanically vulnerable to shear and rotational forces.

- The distal fibula frequently has a secondary center of ossification which can mimic an avulsion #.

History AND CLINICAL EXAMINATION

- H/o twisting injury
- inability to bear weight,
- swelling,
- or deformity

- bony tenderness,

Radiograph

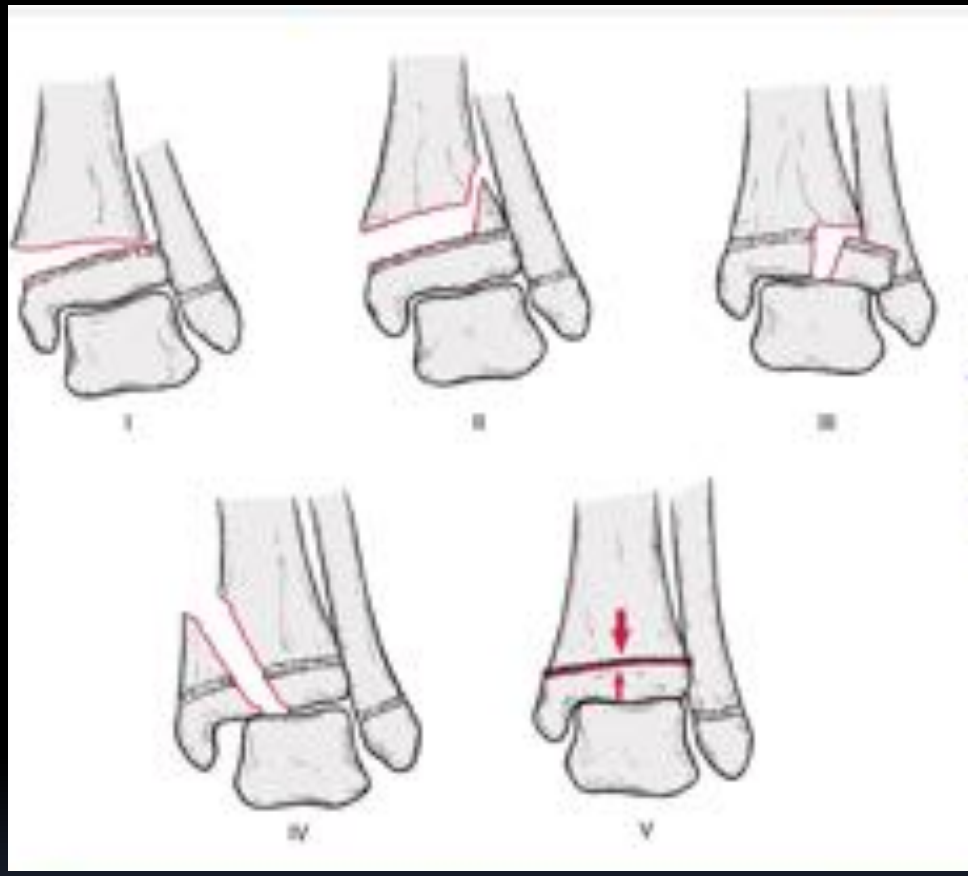
- Physeal widening
- Plafond and mortise should be carefully examined for evidence of an intraarticular # pattern such as tillaux or triplanar #.
- SH type II injury of distal fibula should be looked carefully

Radioraph

- Role of CT
- Most comm
  triplanar fr

Fracture classification

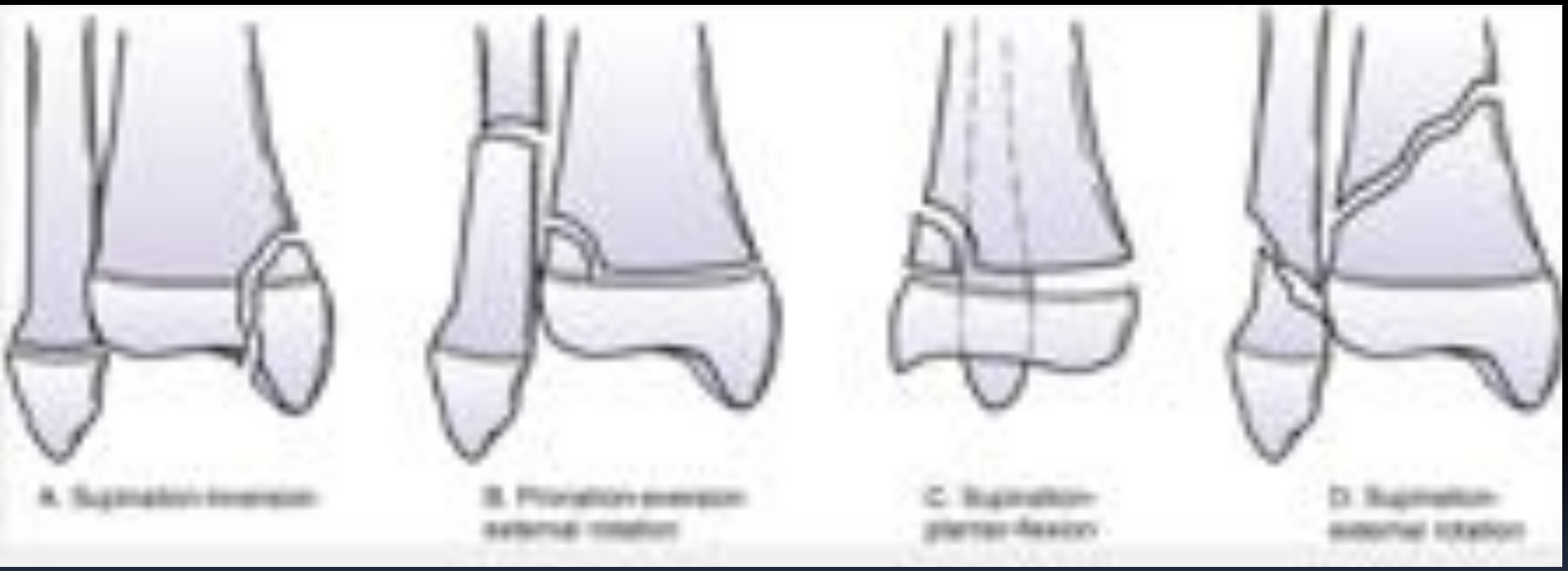
Salter harris



- Type II MC(32-40%)
- SH III(25%)
- SH IV (upto25%)
- SH I(3-15%)
- SH V(<1%)

- Salter-Harris Type VI has also been proposed as an open fracture with partial physis loss.

The Dias- Tachdjian

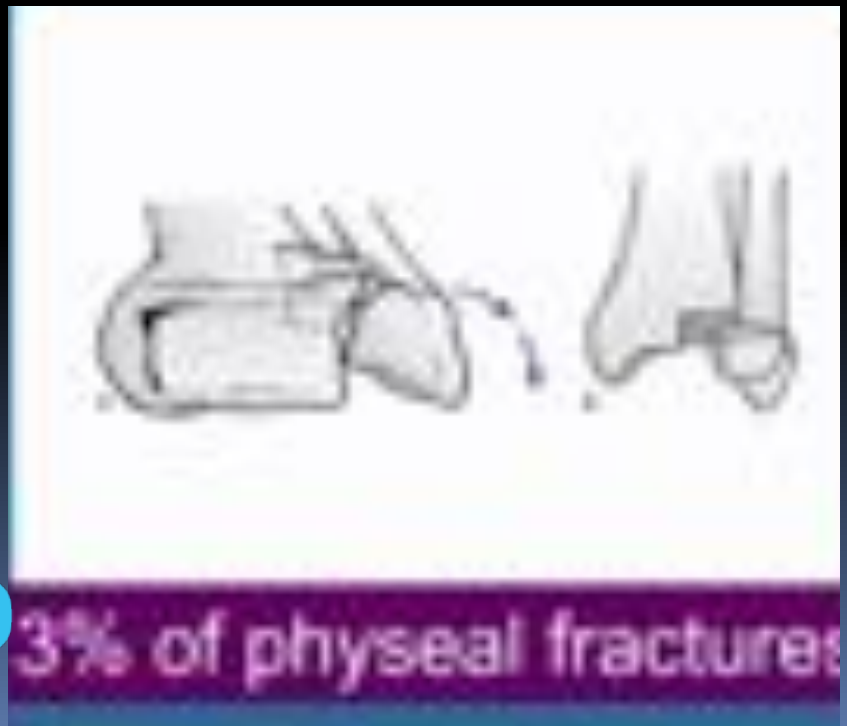


Transitional fractures

- Pts B/w age 12 and 15 years of age with closing physes are susceptible to specific distal tibial fracture patterns.

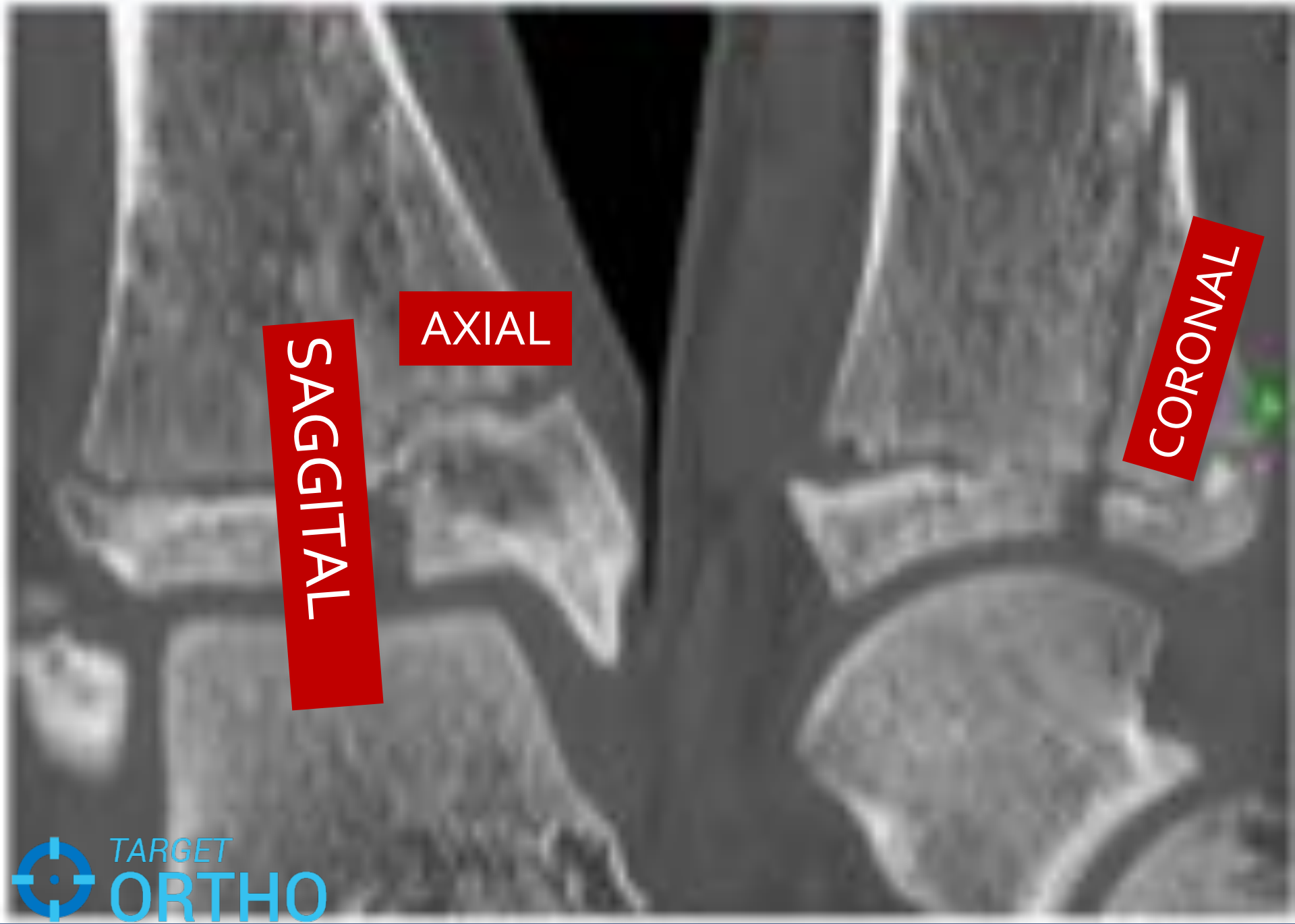
TRANSITIONAL FRACTURES

- Tillaux – SH type III injury , avulsion of anterolateral distal tibia epiphyses at the insertion site of anterior tibiofibular ligament.



Triplane fractures

- 3 dimensional SH type IV injury.
- Classical ones are lateral and medial
- AP SH type III
- On lat SH type II



Treatment

- Aims are to minimize angular deformity
- LLD,
- to avoid post traumatic arthritis
- and to achieve normal ankle motion.

- Articular step-off should be <1-2mm

Treatment

- In growing children efforts should be made to achieve anatomic reduction of the physes to facilitate normal physeal growth.

- Repeated or delayed manipulation should be avoided

Treatment

- Undisplaced fracture CASt
- Simple displaced fracture can be treated with CR & pop cast
- Unstable fracture patterns might require percutaneous fixation and pop cast

Close reduction

- Gentle
- To circumvent physeal damage, the reduction should be 75% traction and 25% manipulation
- Restoration of the congruency of both the articular surface and the physis is essential if it has been disrupted, especially in young children.

Close reduction

- No definite degree of angulation can be called acceptable in children's fractures.
- In general, greater angular deformity can be tolerated in the upper extremity than in the lower extremity,

Close reduction

- more valgus deformity can be tolerated than varus deformity,
- And more flexion deformity can be tolerated than extension deformity
- The undulating contour of the physes must be borne in mind.

Close reduction

- The risk of growth arrest also has been linked to the accuracy of reduction

Close reduction

- Barmada et al (80) reviewed their experience with 44 Salter-Harris I and II fractures.
- They found that in patients with less than 3 mm of residual physeal widening after closed reduction, a diagnosis of premature partial growth arrest could be made in 17% at follow-up.
- In patients with more than 3 mm of residual physeal widening, the frequency increased to 60% .
- Based on their findings, they recommended open reduction and removal of entrapped periosteum for residual physeal widening of more than 3 mm.

Internal fixation

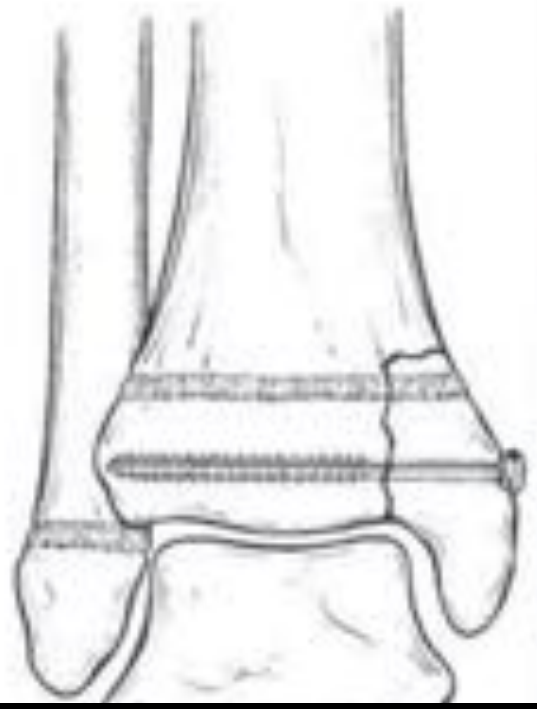
- Internal fixation should be adequate for rigid fixation,
- but not more than necessary,
- and should be easily removable.

Internal fixation

- Smooth rather than threaded pins should be used,
- and the physis should be avoided if possible
- pins should parallel the physis in the epiphysis and metaphysis.

Internal fixation

- Smooth oblique pins should be inserted across the physis only if satisfactory internal fixation cannot be achieved with transverse fixation



Internal fixation

- Joint congruity is critical
- Rule of 2s : IA displacement of <2mm or <2mm displacement of the physis in achild with 2 year of growth remaining

Open reduction

- Bright recommended careful resection for about 1 cm on either side of the physis to prevent the formation of a bony bridge between the epiphysis and metaphysis.

- Periosteum interposed in the fracture site has been implicated in the formation of bony bars

Treatment: transitional

- Restore joint congruity
- IA> physeal
- Minimal physeal growth remaining

Most are nearing skeletal maturity = fixation can cross the physis because growth arrest will not be clinically significant

Treatment

- CR may be successful for SH type I and II
- Displaced SH type III and IV benefit from anatomic reduction, internal fixation and restoration of joint congruity.

complications

- Premature physeal arrest
- OA

TARGET ORTHO

Thanx for your kind attention