Pediatric Knee Injuries

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Disclaimer

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Objectives:

- **Highlight the importance of an anatomical reduction in physeal fractures to prevent growth arrest, malalignment, and leg length discrepancy**
- **Discuss fixation options that balance the need to maintain a reduction while respecting the biology of the physis**
- **Recognize injury patterns that are associated with neurovascular compromise**
- **Understand the differential diagnosis of acute knee effusion and strategies for managing intra-articular fractures in the pediatric knee**

Overview:

Extra-articular Injuries:

- **Distal Femoral Physeal Fractures**
- **Proximal Tibia Physeal Fractures**
- **Tibial Tubercle Fractures**

Intra-articular Injuries:

- **Tibial Eminence Fractures**
- **Patellar Sleeve Injuries**
- **Osteochondral Fractures**

Distal Femur Physeal Fractures

Distal Femoral Physeal Fractures

- **1898 - "Wagon-wheel injury" described by Poland**
  - **Often resulted in open injury w/ neurovascular compromise**
  - **High rate of popliteal ischemia and uncontrollable infection**

- **1952 - Aitken & Magill - series of distal femoral physeal fxs in football players**
  - **Noted high rate of leg length discrepancies and angular deformities**

- **Complex contour of physis makes it possible for shearing of the fracture line across several physeal zones (Brashear)**


Images courtesy of Chris Souder, MD

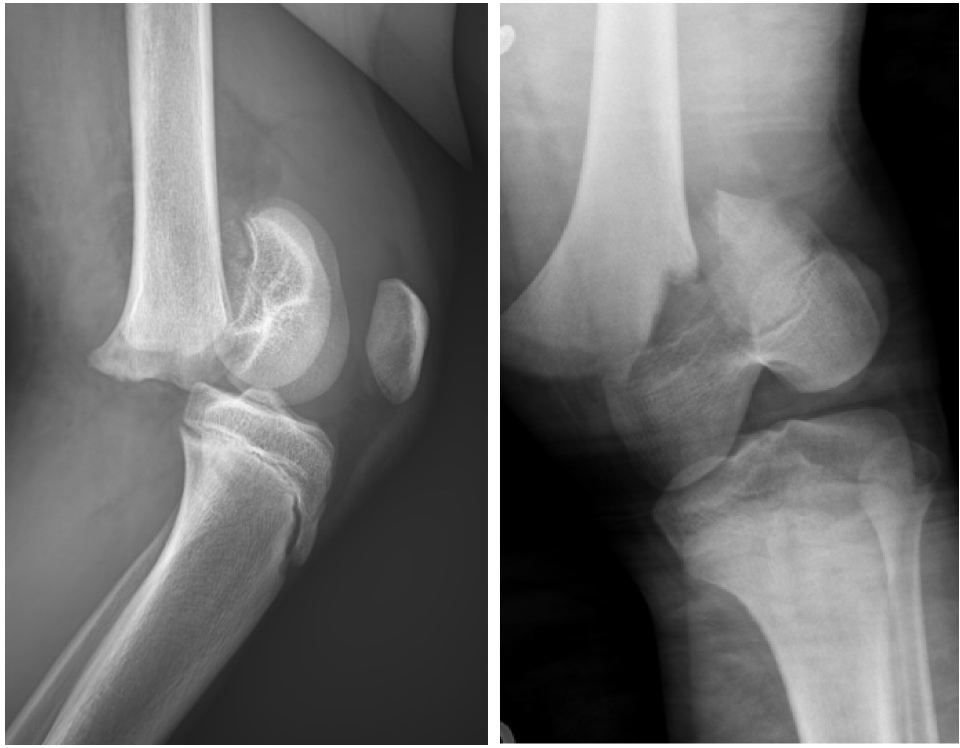
Epidemiology

- **Fracture Epidemiology**
  - **Rare injury (<1% of pediatric fractures)**
  - **Mechanism:**
    - **Often the result of high energy trauma in <11 y.o. (pedestrian struck or fall from a height)**
    - **Sports injuries in teens (2/3 of distal femoral fractures)**

- **Associated Injuries**
  - **Do not miss VASCULAR INJURY or TIBIAL/PERONEAL NERVE INJURY**
  - **Do not miss COMPARTMENT SYNDROME**

Mechanism of Injury

- Hyperextension → epiphysis displaced anteriorly, metaphysis displaced into popliteal fossa
  - Neurovascular injury
  - Reduction often unstable
  - Extreme knee flexion sometimes necessary to tighten anterior soft tissue hinge
- Varus-Valgus – due to adduction/abduction force
  - Periosteal hinge intact on concavity
  - Periosteum can be entrapped on convexity



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Anatomy

- **First physis to ossify, last long bone to fuse**
- **Contributes 70% growth of the femur, 37% growth of the lower extremity**
  - **Grows at rate of 9mm/year**

- **Medial and lateral collateral ligaments, as well as the anterior and posterior cruciate ligaments originate distal to femoral physis**
- **Physis fractures before ligaments tear**

Fractures of the distal femur and proximal tibial physis account for 2.2% of physeal fractures BUT they account for 51% of growth plate arrest[39]

Distal Femur: Anatomy

- **Both heads of gastrocnemius & plantaris originate just <u>proximal</u> to physis**
  - **Posterior epiphyseal displacement or angulation is uncommon**
  - **Ligament, rather than muscular pull more likely explains initial displacement at time of injury**

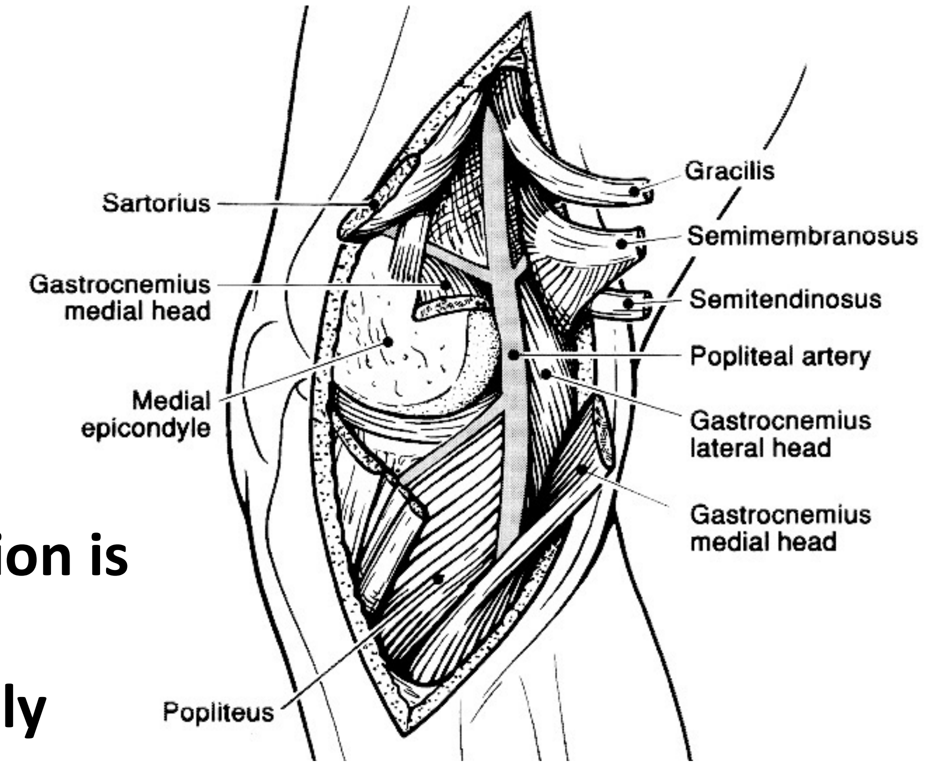


Image from Muscat, JO, Rogers W, Cruz, AB, Schenck RC. Arterial Injuries in Orthopaedics: The Posteromedial Approach for Vascular Control About the Knee. J Orthop Trauma. 1996;10(7):476-480

- **Sciatic nerve divides into peroneal and posterior tibial branches just <u>proximal</u> to the physis**
- **Popliteal artery is posterior at the level of the distal femur**
  - **Tethered at adductor hiatus proximally and soleus hiatus distally**
  - **Displaced fxs need surveillance of vascular injury**

Distal Femur: Exam

- **Effusion**
- **Ecchymosis of distal thigh and popliteal fossa within 72 hours**
- **Deformity**
  - **Varus/valgus – metaphyseal spike dimpling vastus medialis/lateralis**
  - **Anterior – patella prominence and fullness of popliteal fossa**
    - **Can feel for adductor tubercle to differentiate from knee dislocation**
- **Point tenderness along the physis & adductor tubercle**
  - **Tenderness medially at the physis can be a nondisplaced fracture**
    - **MCL injury is less likely**

Distal Femur: Exam

- **Motor and sensory**
  - **Peroneal and tibial nerves**
    - **Most common with varus displacement**
- **Vascular**
  - **Popliteal artery injury**
    - **Most common with anterior displacement**
    - **ABI testing**

$$ABI = \frac{\text{Ankle systolic BP}}{\text{Brachial systolic BP}} < 0.9$$

*** concerning for vascular injury**

- **MRI can detect nondisplaced fractures**
  - **Stress examination NO longer recommended due to risk of additional physeal injury**

image courtesy of Alfred Mansour, MD (2016 version)

Treatment

Goals:

Healing of the fracture in acceptable alignment

- Gentle reduction of the distal femoral physis
  - Reduce the risk of growth arrest
- Anatomic reduction of articular surface
  - Decrease likelihood of premature arthritis

Image courtesy of Chris Souder, MD

Treatment

- **Salter-Harris classification useful in description and treatment planning**
  - **Not strongly predictive of growth disturbance**

- **Direction and degree of displacement predict type and severity of complications (Arkader et al. JPO 2007)**

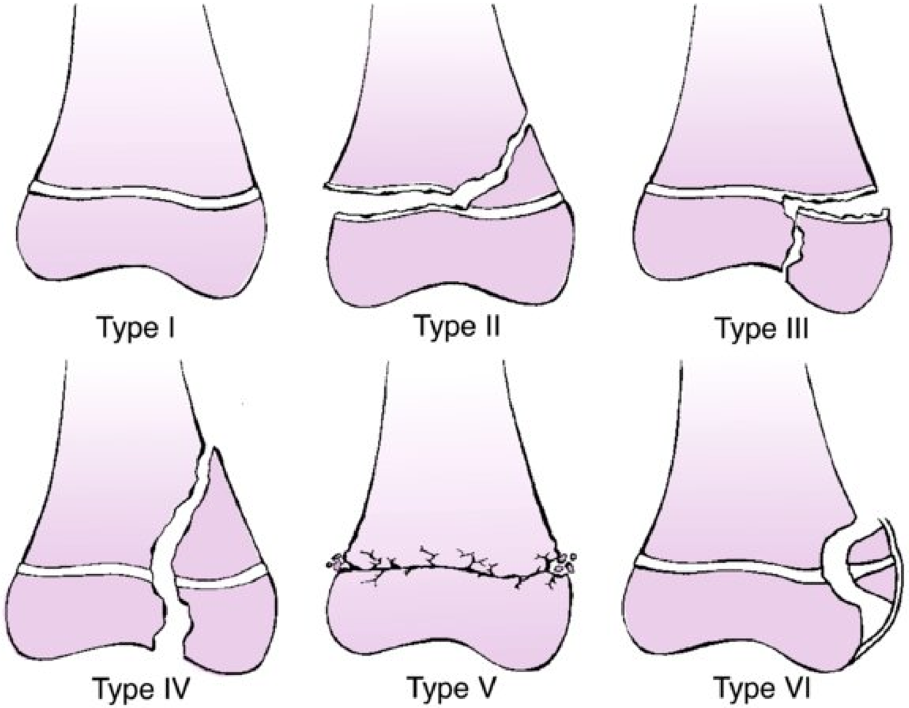


Image from R&W Fractures in Children 9th Ed. Figure 25-4

Reduction under Anesthesia

Intact tether of periosteum on the side of the epiphyseal displacement:
1) increase deformity slightly + traction
2) then realignment of angular deformity
- 90% traction, 10% leverage to avoid physeal injury

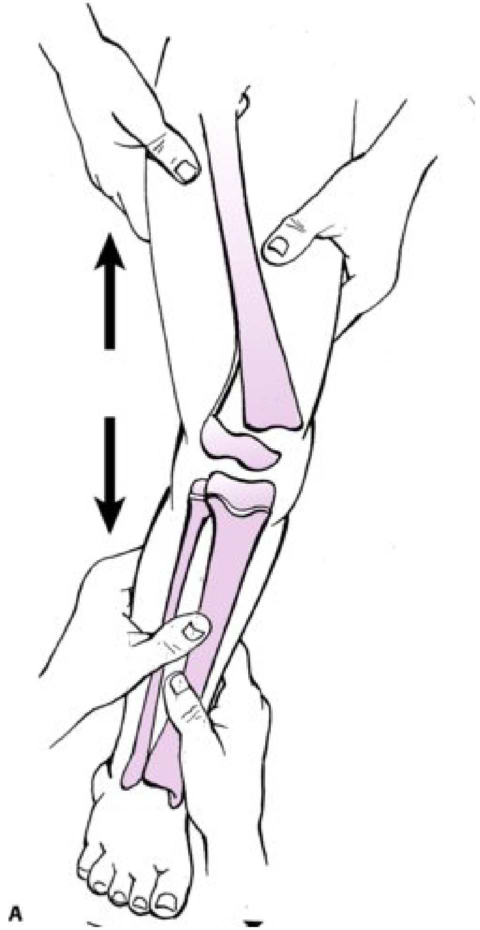


Image from R&W Fractures in Children 9th Ed. Figure 25-12A

Medial/Lateral Displacement:

- **Knee in extension, hip in slight flexion**
- **Assistant holds thigh**
- **Traction w/ 1 hand, palm placed at concavity of deformity for leverage**

Reduction under Anesthesia

Anterior Displacement:

- Traction to leg, hip flexed to 60
- Assistant holds thigh
- Longitudinal traction and downward pressure on epiphysis
- Knee is flexed to 45-90 degrees

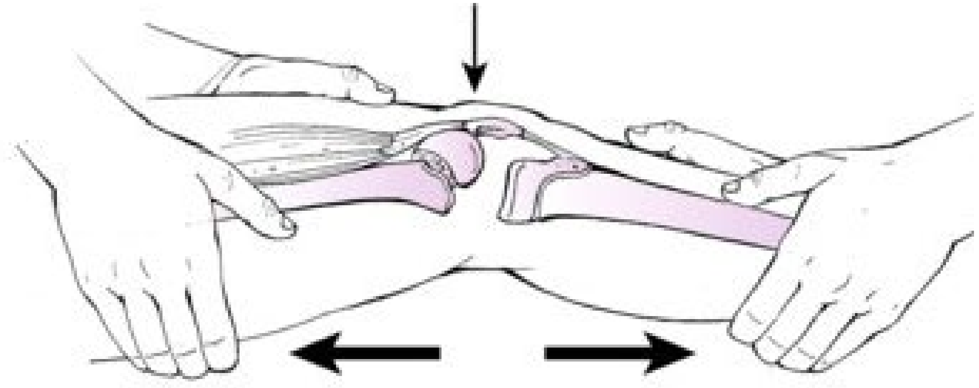


Image from R&W Fractures in Children 9th Ed. Figure 25-12B

*** Closed reduction can be performed up to 10 days after injury.**

Treatment

- Acceptable alignment for SH I & II
  - < 15-20 degrees in sagittal plane (Sharrard et al.)
  - < 5 degrees varus/valgus – does not remodel
- Anatomic reduction required for SH III & IV
  - CRPP vs ORIF
- Open treatment required for:
  - Open fractures
  - Entrapped tissues preventing reduction
  - Neurovascular injury

Image courtesy of Chris Souder, MD

Image courtesy of Greg Osgood, MD

Salter Harris I

- **Can be non-displaced or displaced**
  - **Nondisplaced fracture demonstrates TTP at the physis on exam**
  - **F/u radiographs demonstrate bony reaction**

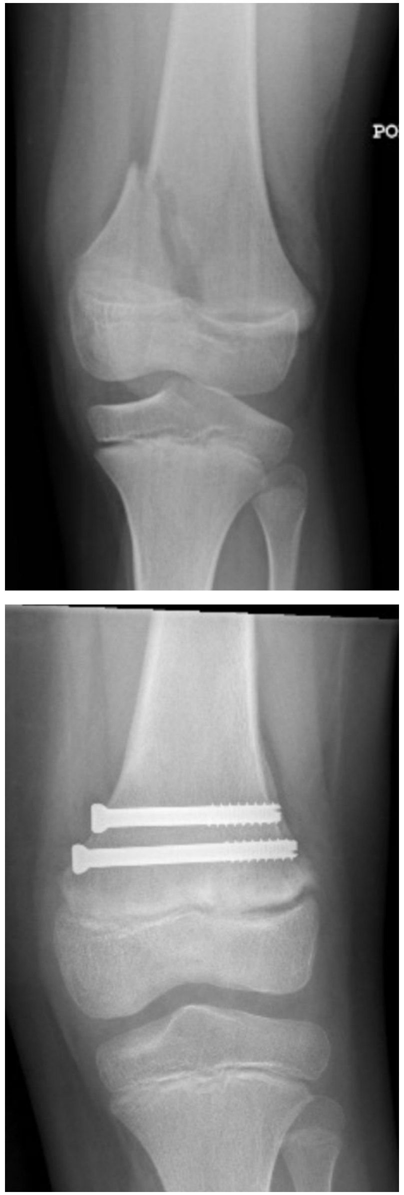
- **Tx:**
  - **long leg cast x 4 weeks if nondisplaced**
    - **LLC in 15-20 degrees flexion w/ 3-point mold**
      - **Thomson et al. – many displaced fractures lost reduction with cast immobilization – recommend internal fixation of all displaced fxs**
    - **Follow up XR in 1 week**
  - **CRPP for displaced fractures**
    - **Maintain pins and LLC x 4 weeks**

Images from R&W Fractures in Children 9th Ed. Figure 25-5(A,B)

Images from R&W Fractures in Children 9th Ed. Figure 25-5(C,D)

Salter Harris II

- **Most common type fracture type**
- **Displacement typically to side of Thurston Holland (TH) fragment**
- **Varus/valgus stress to reduce then percutaneous screws**
  - **Screw from TH fragment into intact metaphysis**
  - **Smooth wires used if TH fragment is small**
    - **Treated like a SH-1**
- **ORIF required if entrapped soft tissues block reduction**
  - **Opened on convexity**



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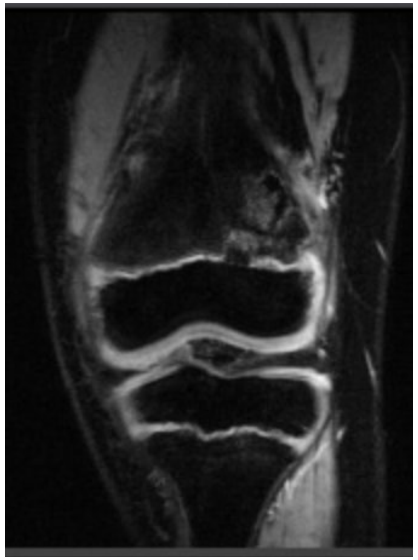
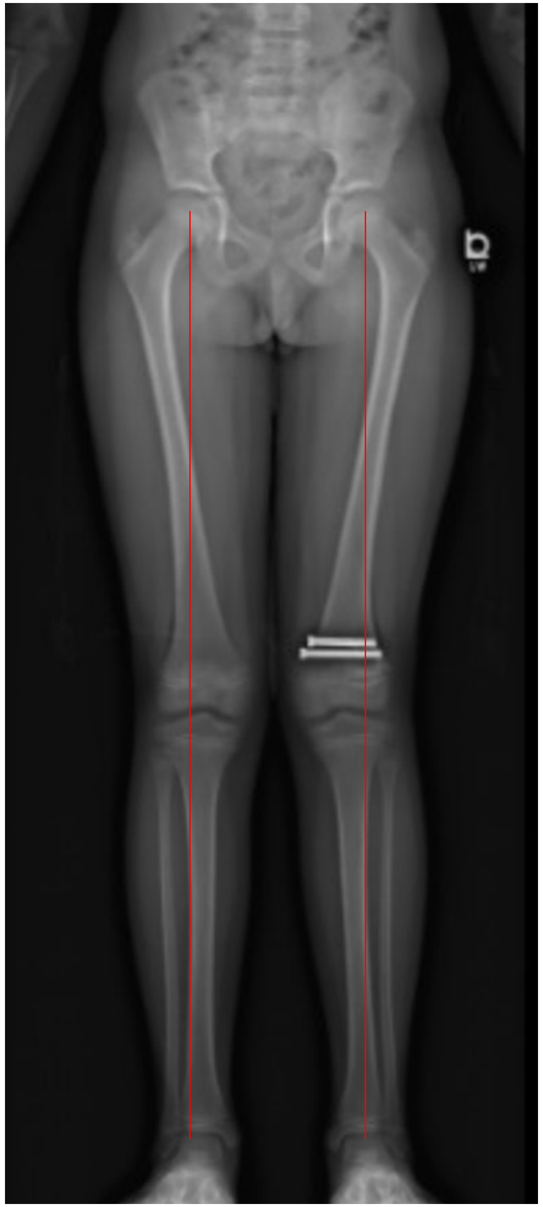
Salter Harris II

- **Tendency to produce premature physeal closure (~30-50%)**
  - **Riseborough et al: 11/25 pts closed prematurely resulting in >2.4cm LLD**
  - **Growth arrest related to the <u>severity</u> of displacement (Stephens et al.)**
  - **Signs of premature closure typically evident within 6 months of injury**
- **Angular deformity more common**
  - **Metaphyseal fragment physis spared**





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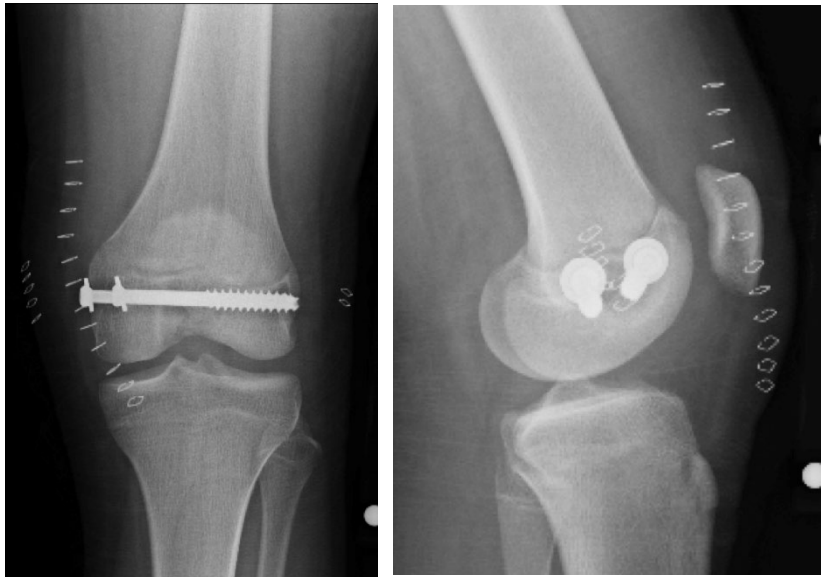
Salter Harris III

- **Tends to occur as physis is closing (decreased risk of LLD)**
  - **Typically involves the medial physis and MFC**
- **Medial femoral condyle fracture results from valgus force**
  - **MCL attachment leads to epiphyseal avulsion**
  - **Can be associated with cruciate ligament injury**
- **Tx: ORIF w/ transepiphyseal screws**
  - **Anatomic reduction of articular surface**

Image courtesy of Chris Souder, MD



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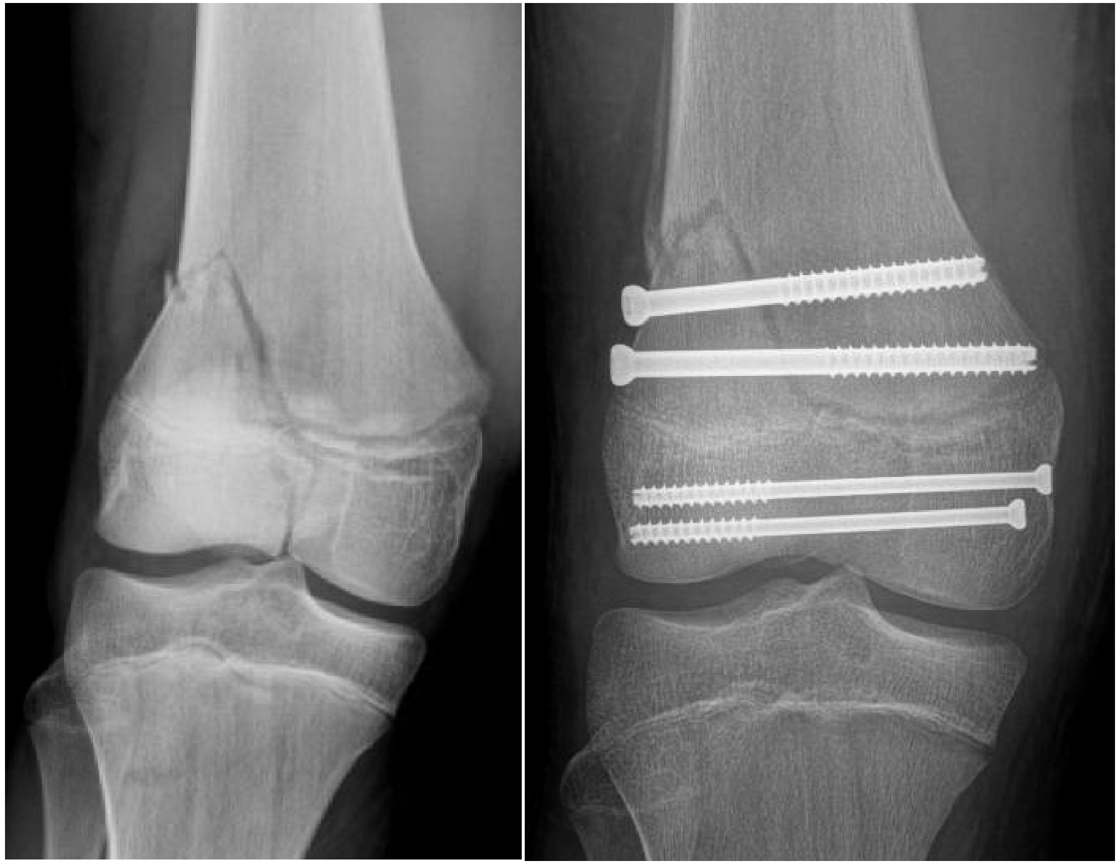
Salter Harris IV

- **Uncommon injury**
- **Anatomic reduction necessary**
  - **Possibly decrease risk of physeal arrest**
  - **Restores the joint surface**
- **Highest risk for partial growth arrest**
- **Tx: ORIF w/ cannulated screws avoiding physis**



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Distal Femur: Early Complications

- **Recurrent physeal displacement**
- **Knee ligament injury (37%)**
  - **14/29 patients w/ physeal injury and associated ligament instability (Bertin and Goble)**
  - **SH3 associated with ACL tears (Brone and Wroble)**
- **Neurovascular injury**
  - **Peroneal nerve (3%)**
  - **Popliteal artery (1%)**

Distal Femur: Late Complications

- **Physeal arrest (~30-50%)**
  - **Partial arrest**
    - **Angular deformity**
    - **Most common**
  - **Complete arrest**
    - **Leg length discrepancy**
  - **Usually evident by 6 months post injury**

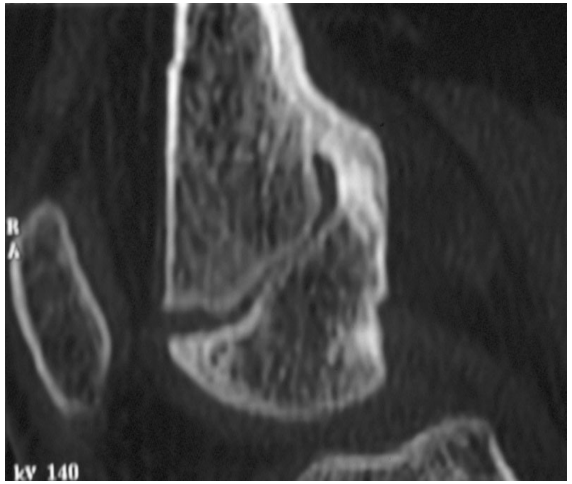


Image courtesy of Chris Souder, MD

Classification:	Growth Disturbance:
SH 1	36%
SH 2	58%
SH 3	49%
SH 4	64%

Displacement:	Growth Disturbance:
Non-displaced	31%
Displaced	65%

Basener et al. JOT 2009

Smooth pins across physis not statistically associated w/ growth arrest

Garrett et al. BJJ 2011


Image courtesy of Greg Osgood, MD

Distal Femur: Late Complications

- **Stiffness**
- **Quadriceps weakness**
- **Persistent knee instability**
  - **Must perform ligamentous examination after fixation**

Proximal Tibia Physeal Fractures

Proximal Tibia Physeal Fractures

- **Rare injury (0.8% of physeal fractures)**
  - **Inherent stability by surrounding structures: fibula (laterally), superficial MCL (medially), semimembranosus (posteromedially), tibial tubercle (anteriorly)**
  - **Epiphysis typically displaces anterior, anteromedial, or anterolateral**
  - **Rare posterior displacement results in epiphysis and tubercle moving as unit**

- **Fuses ~ 15 years (posteriorly → anteriorly)**
- **Contributes 6mm growth/year**

Image courtesy of Greg Osgood, MD

Mechanism

- **Varus/Valgus → occurs near maturity**
  - **Apex medial implies partial tear of superficial MCL**
- **Flexion injury – boys age 15-16 during jumping**
  - **Early closure → results in genu recurvatum deformity**
  - **Pes anserinus or periosteum may be entrapped**
  - **Transition between tibial physeal separation and tibial tubercle fx**
- **Hyperextension – risk of vascular injury and compartment syndrome**

image courtesy of Alfred Mansour, MD (2016 version)

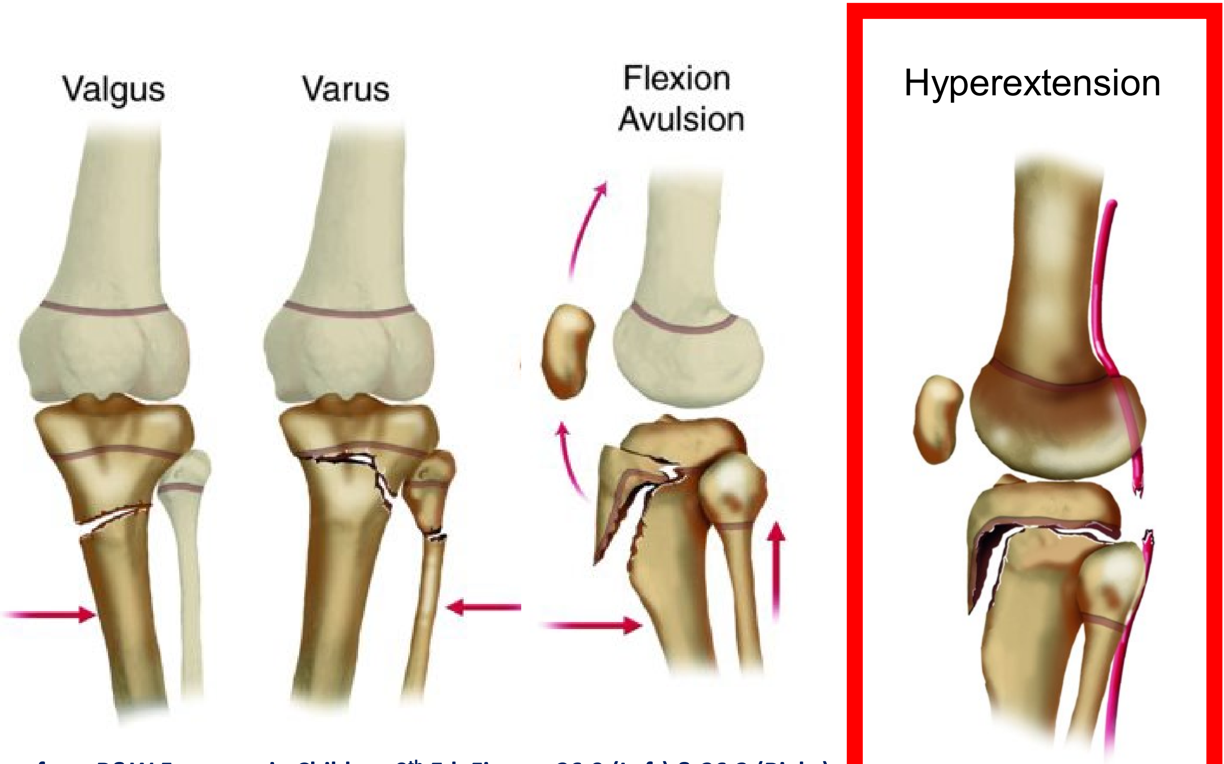


Image from R&W Fractures in Children 9th Ed. Figures 26-9 (Left) & 26-3 (Right)

Classification

SH 1

- 50% nondisplaced
- Medial or posterior physeal widening
- Associated proximal fibula physeal injury

SH 2

- 30% nondisplaced
- Displacement typically medial w/ metaphyseal spike laterally – valgus deformity

SH3

- Most common is vertical fracture through lateral epiphysis
- Associated with MCL injury

SH 4

- Can involve medial or lateral plateau

SH5

- Rare, usually made in retrospect after progressive angulation or LLD

Images courtesy of Greg Osgood, MD

Treatment

- **Closed reduction and long leg cast in stable fracture patterns**
  - **Not common**
- **CRPP**
  - **Most common technique**
- **Screw fixation if metaphyseal fragment is large**

Lovejoy SA, Mehlman, CT. The Community Orthopaedic Surgeon Taking Trauma Call: Pediatric Tibia Fracture Pearls and Pitfalls. *J Orthop Trauma*. 2017;31:22-26.

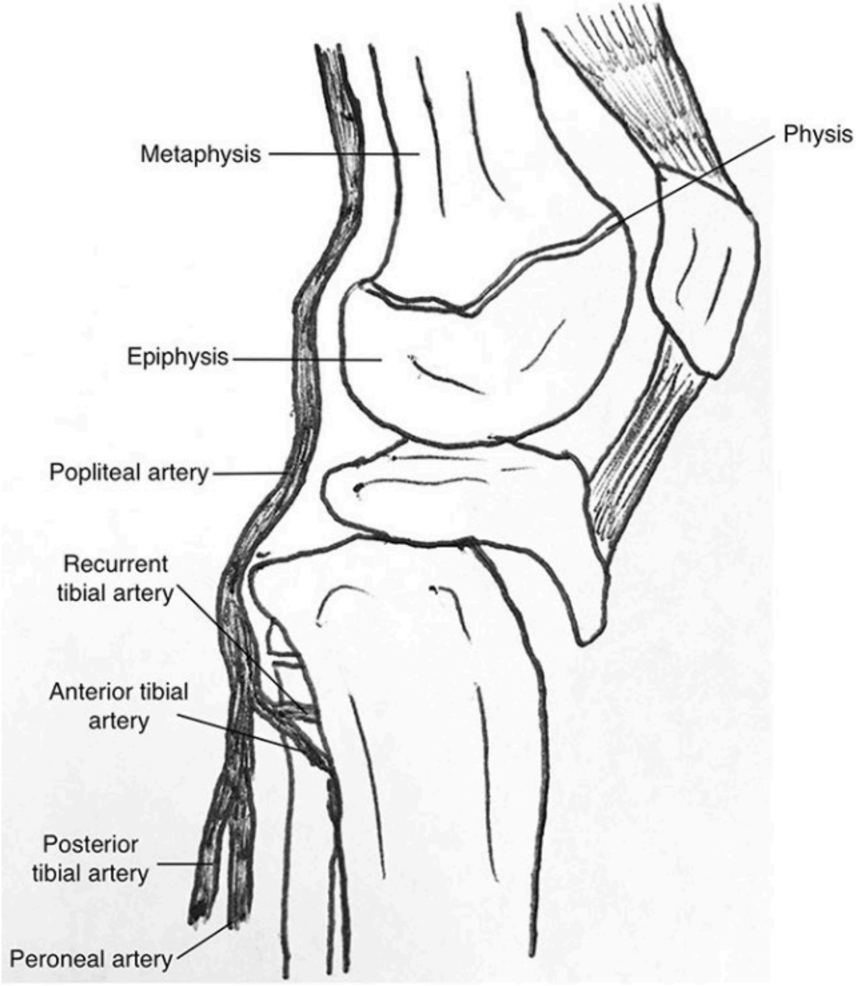
Complications

- **Physeal disturbance**
  - **Most common complication**
    - **25% incidence**
  - **Shortening or angulation**
    - **Recurvatum is common**
- **Popliteal artery injury**
  - **10% incidence (Gautier, 1998)**
- **Peroneal nerve palsy**
  - **Spontaneous recovery is typical**
- **Knee ligament instability (40% in SH3 & 4)**
  - **5/15 concomitant avulsion of ACL (Poulsen, 1989)**
  - **SH3 fx associated with MCL tears**

Images courtesy of Chris Souder, MD

Vascular Injury

- **Popliteal artery injury (10%)[20]**
  - **Tethered near posterior surface of proximal tibial epiphysis by geniculate branches and trifurcation**
    - **Proximal tibial artery passes under soleus hiatus**
    - **Anterior tibial artery travels above proximal border of interosseous membrane**



Lovejoy SA, Mehlman, CT. The Community Orthopaedic Surgeon Taking Trauma Call: Pediatric Tibia Fracture Pearls and Pitfalls. *J Orthop Trauma*. 2017;31:22-26.

Tibial Tubercle Fractures

Tibial Tubercle Fractures

- < 1% of all epiphyseal fractures
- Occurs almost exclusively in adolescent males during jumping activities
  - Explosive quad contraction during jumping
  - Rapid passive knee flexion against contracting quad while landing

- Fracture pattern depends on amount of physeal closure and degree of knee flexion at time of injury[42]
  - Physis closes posterior → anterior
  - > 30 degrees of flexion results in SH3 of proximal tibial physis[23]

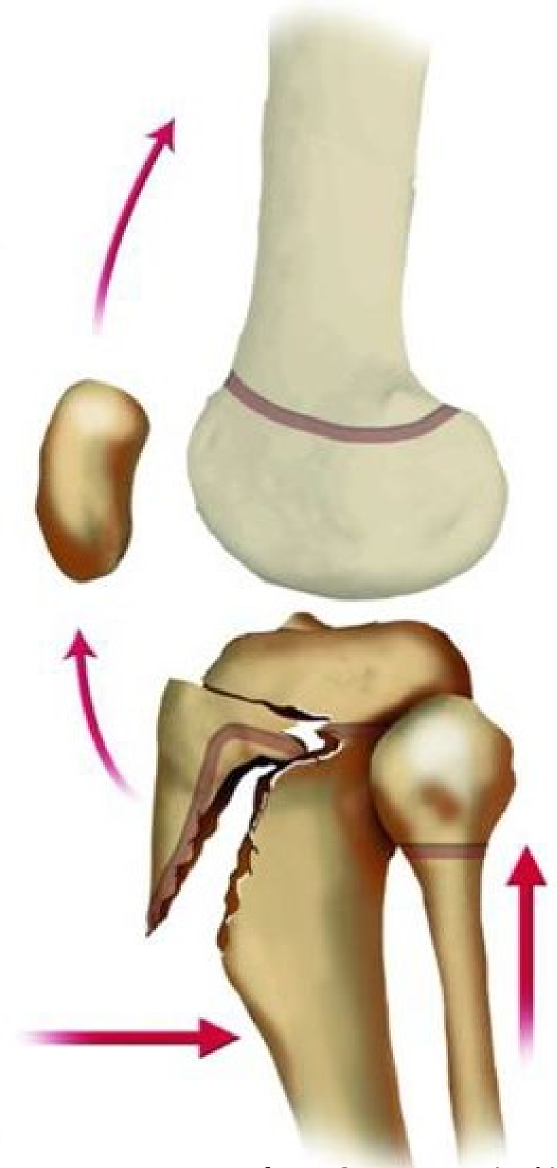


Image from R&W Fractures in Children 9th Ed. Figure 26-2

Tibial Tubercle: Exam

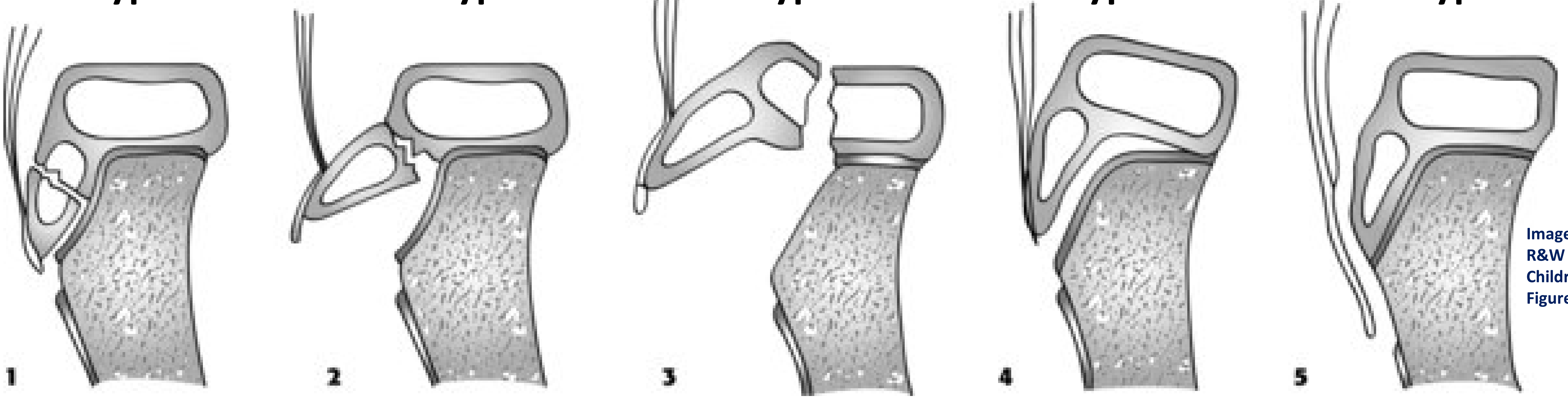
- **Inability to fully extend knee**
- **Anterior knee pain**
- **Effusion, hemarthrosis**
- **Skin tenting**
- **Patella alta**

- **Must evaluate for compartment swelling**
  - **Pulses, palpate compartments, stretch testing of anterior compartment musculature**

Image from R&W Fractures in Children 9th Ed. Figure 26-8

Tibial Tubercle: Modified Ogden Classification

Type 1 **Type 2** **Type 3** **Type 4** **Type 5**



Images from R&W Fractures in Children 9th Ed. Figure 26-11

Type 1	Type 2	Type 3	Type 4	Type 5
Involves apophysis only	Involves apophysis and epiphysis **without** intra-articular extension	Involves apophysis and epiphysis **with** intra-articular extension	Fracture of entire proximal tibial physis	Pure patellar avulsion injury

- **Degree of displacement depends on severity of injury to adjacent soft tissue attachments (Ogden et al)**

Treatment

- **Extend leg to reduce**
- **Splint and admit for observation**
  - **Increased risk of compartment syndrome**
    - **Risk of bleeding from anterior tibial recurrent artery**

- **Non-operative treatment**
  - **Minimally displaced fractures**
  - **Long leg cast in full extension x 4-6 weeks**

images courtesy of Alfred Mansour, MD (2016 version)

Treatment

- **Surgical fixation**
  - **Open reduction with internal fixation**
    - **Allows removal of large periosteal flap**
      - **Anatomic reduction**
    - **Inspect joint through fracture site ensure meniscus is not entrapped**
    - **Knee extension reduces the fracture**
    - **Screw fixation most commonly used**
      - **Smooth k-wires in young children**
        - **Tension band suture can be used to reinforce repair**
    - **Consider prophylactic anterior compartment fasciotomy**

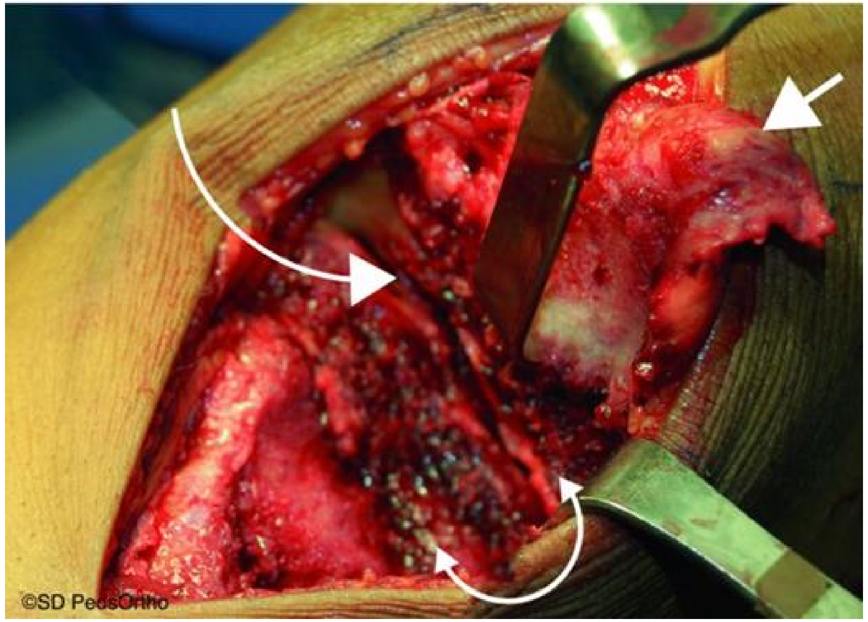


Image from R&W Fractures in Children 9th Ed. Figure 26-18

Image courtesy of Chris Souder, MD

Image courtesy of Chris Souder, MD

Treatment

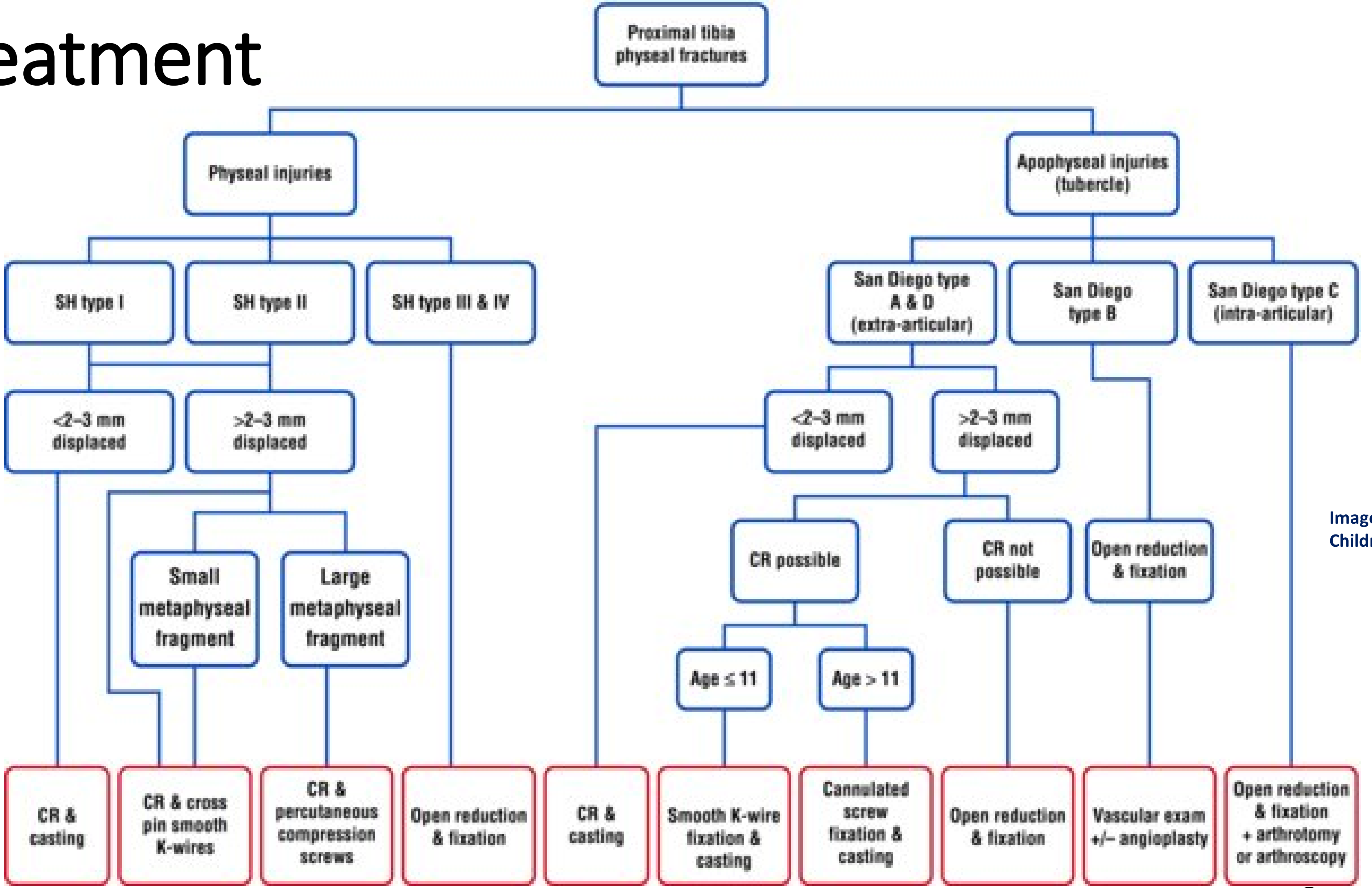


Image from R&W Fractures in Children 9th Ed. Algorithm 26-1

Complications

- **Compartment syndrome**
  - **Risk of bleeding from anterior tibial recurrent artery**
    - **Near base of tubercle**

- **Low rate of tendon avulsion (2%), meniscal tear (2%), & cruciate ligament laxity (1%) (Pretell-Mazzini et al, JPO 2016)**

Intra-articular Knee Injuries

Intra-articular Knee Injuries

Differential diagnosis for acute hemarthrosis within 2 hours of injury includes:[13]

- **Tibial eminence fracture**
- **Patellofemoral dislocation**
- **Osteochondral fracture**
  - **Typically associated with a PF dislocation**
- **Cruciate ligament rupture**
- **Peripheral meniscal tear**

Tibial Eminence Fractures

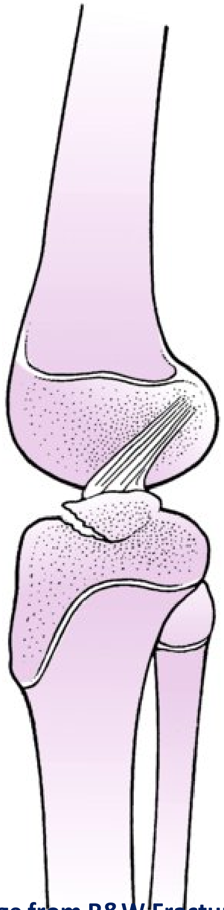


Image from R&W Fractures in Children 9th Ed. Figure 27-9

- **Most commonly caused by bike accidents & athletic injuries (Meyers & McKeever JBJS 1959)**
- **Chondroepiphyseal avulsion of ACL**
  - **Incompletely ossified tibial spine weaker to tensile strength than ACL**
- **Mechanism: forced valgus and external rotation of tibia**

<u>Associated injuries:</u>

- **37% associated meniscal injury[15]**
  - **Increased incidence with age, Tanner stage & pubescence**
  - **90% involved lateral meniscus**
    - Anterior horn remains attached to tibial spine fragment[28]
    - Collateral ligament injury uncommon

Lovejoy SA, Mehlman, CT. The Community Orthopaedic Surgeon Taking Trauma Call: Pediatric Tibia Fracture Pearls and Pitfalls. *J Orthop Trauma*.2017;31:22-26.

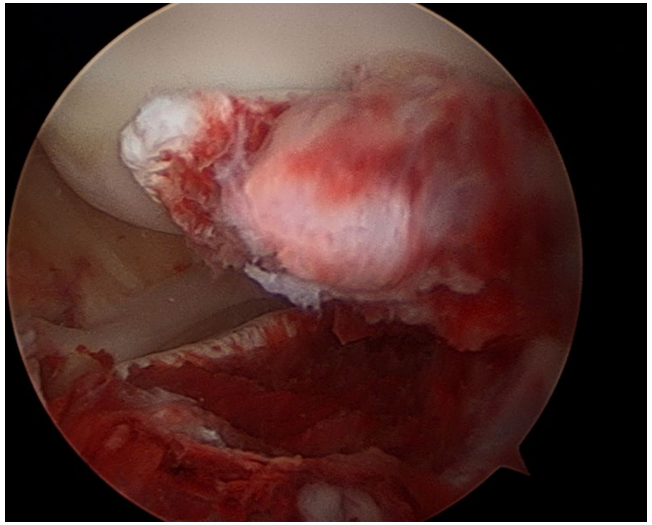


Image courtesy of Chris Souder, MD

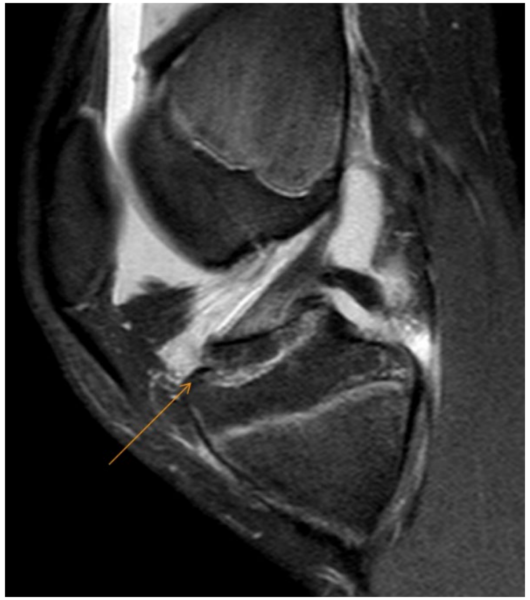
Tibial Eminence: Evaluation

Lateral imaging helps determine:

- **Fracture classification**
- **Amount of displacement**
- **Size of fragment**
- **Degree of comminution**
- **Status of physis**
- **Entrapped soft-tissue**

MRI may be helpful to assess concomitant injuries (Ishibashi et al, CORR 2005)

Image from R&W Fractures in Children 9th Ed. Figure 27-5



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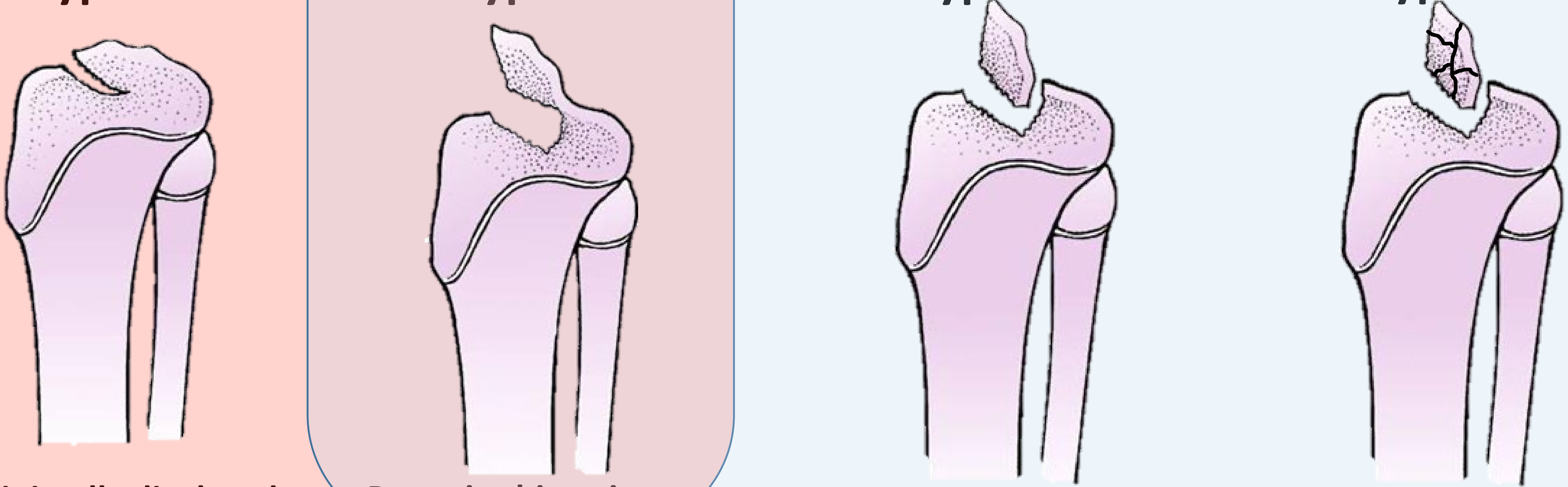
Myers & McKeever Classification

*Modification by Zaricznyi

Closed reduction + Long leg casting

Open vs arthroscopic reduction and internal fixation

Type 1 | **Type 2** | **Type 3** | **Type 4***



Minimally displaced | Posterior hinge intact | Complete separation | Comminuted

Image adapted from R&W Fractures in Children 9th Ed. Figure 27-4

Treatment: Type I & II

- Knee aspiration & reduction in extension
- If < 3mm of displacement – long leg cast in 10° flexion x 4 to 6 weeks, followed by hinged brace
- If >3mm of displacement or block to extension – open vs arthroscopic reduction +/- internal fixation
- Meniscus may block anatomic reduction
  - Kocher et al. entrapment of anterior horn of medical meniscus, lateral meniscus or intermeniscal ligament in 26% of type II fractures and 65% of type III (Kocher et al, AJSM 2003)
  - Entrapment may cause knee pain after fracture healing (Chandler et al, Athroscopy 1995)

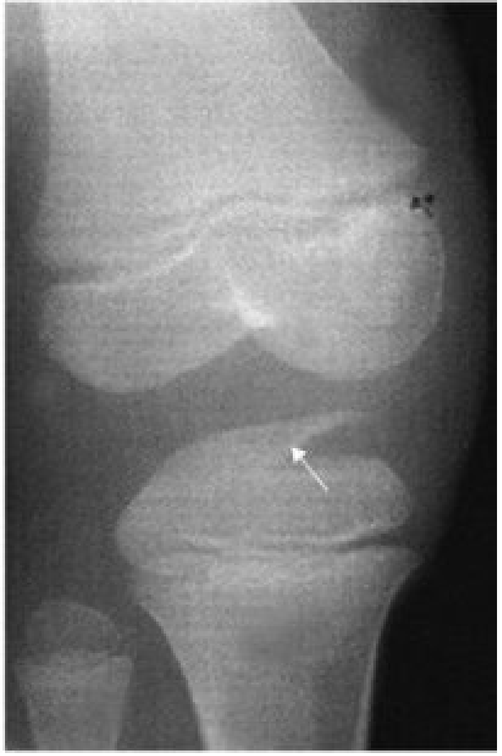


Image from R&W Fractures in Children 9th Ed. Figure 27-5

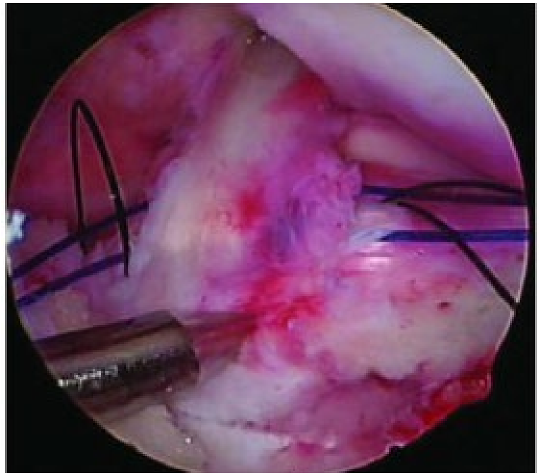


Image from R&W Fractures in Children 9th Ed. Figure 27-11E

Treatment: Type III & IV

- **Open or arthroscopic reduction**
- **Fixation options include:**
  - **Transosseous suture, screw, K-wire, suture anchor**
    - **Similar strength between bioabsorbable and metallic screw[30], and nonabsorbable vs absorbable suture[27]**
    - **Increased strength with suture fixation over internal fixation[8 & 14]**
    - **Inconsistent strength with suture fixation[3]**
- **For Type IV fractures suture fixation is preferred**

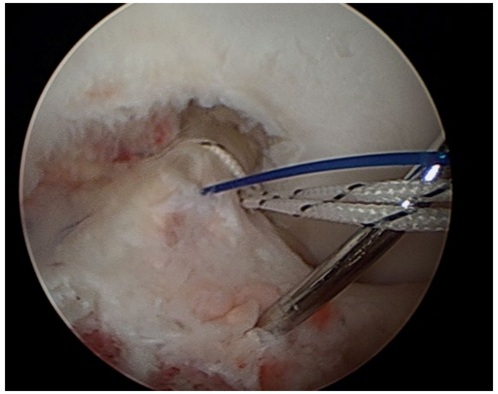


Image courtesy of Chris Souder, MD

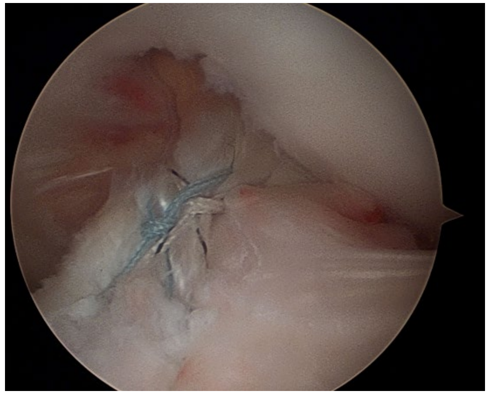


Image courtesy of Chris Souder, MD

Images from R&W Fractures in Children 9th Ed. Figure 27-12B (right) & 27-12D (left)

Complications

- **Loss of extension (60%)**
- **Arthrofibrosis (10%)**[48]
  - **Early motion minimizes risk**
- **Residual knee laxity**
  - **Common occurrence**
  - **Rarely symptomatic**
- **Nonunion**
- **Malunion**
  - **May cause mechanical impingement in extension**[17]
  - **Growth disturbance**
  - **Due to hardware crossing proximal tibial physis resulting in recurvatum deformity or shortening**[33]

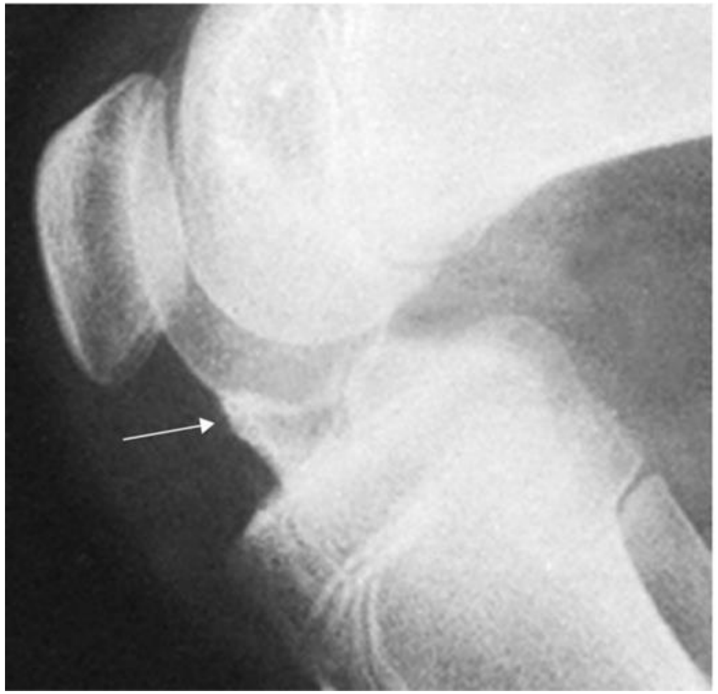


Image from R&W Fractures in Children 9th Ed. Figure 27-13

Osteochondral Fractures

- **Associated with acute patellar dislocation (19-50%)[34]**
  - **Either dislocation or relocation of patella can cause fracture**
  - **Less common for chronic dislocations due to soft tissue laxity**

- **Most common locations: inferior medial patellar facet, lateral aspect of lateral femoral condyle**

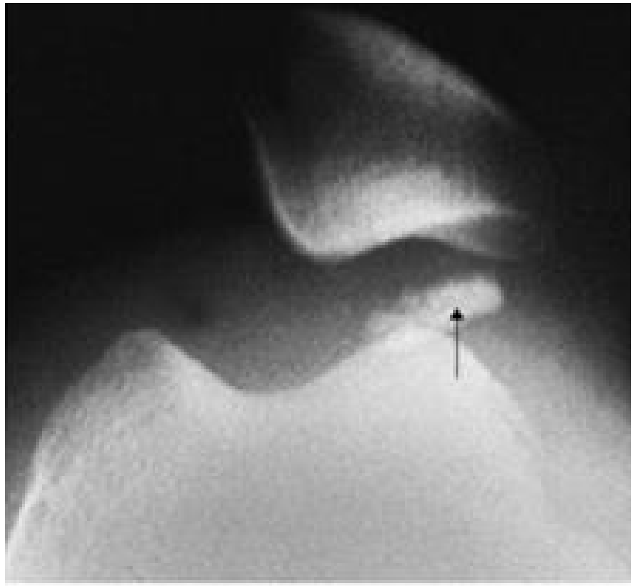


Image from R&W Fractures in Children 9th Ed. Figure 27-15B

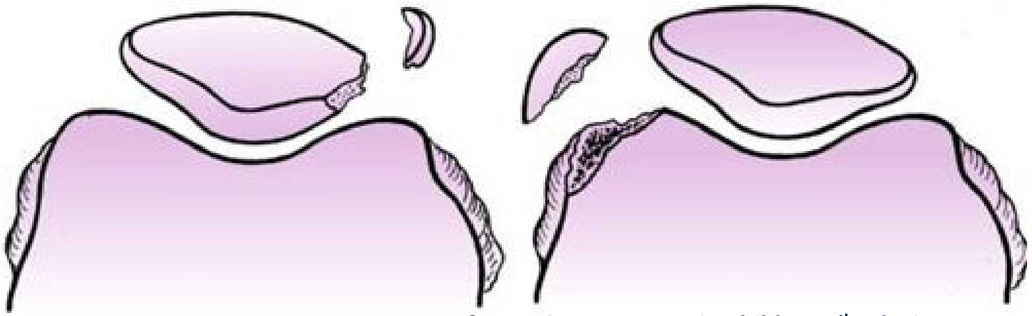


Image from R&W Fractures in Children 9th Ed. Figure 27-14

Mechanism:

1) direct blow to knee with shearing force to LFC or MFC

2) flexion rotation injury internal rotation of tibia on a fixed foot w/ quad contraction

Osteochondral Fractures

- **Shear stress in juvenile joint → forces transmitted to subchondral bone by interdigitating cartilage resulting in failure at porous trabecular bone interface[16]**
  - **Fragments often contain subchondral bone and are visible on XR**
  - **XR fail to detect fragment in 36% of cases[30]**

- **MRI helpful in diagnosis of the injury**
  - **Can also aid in differentiating osteochondral versus chondral-only fragments**

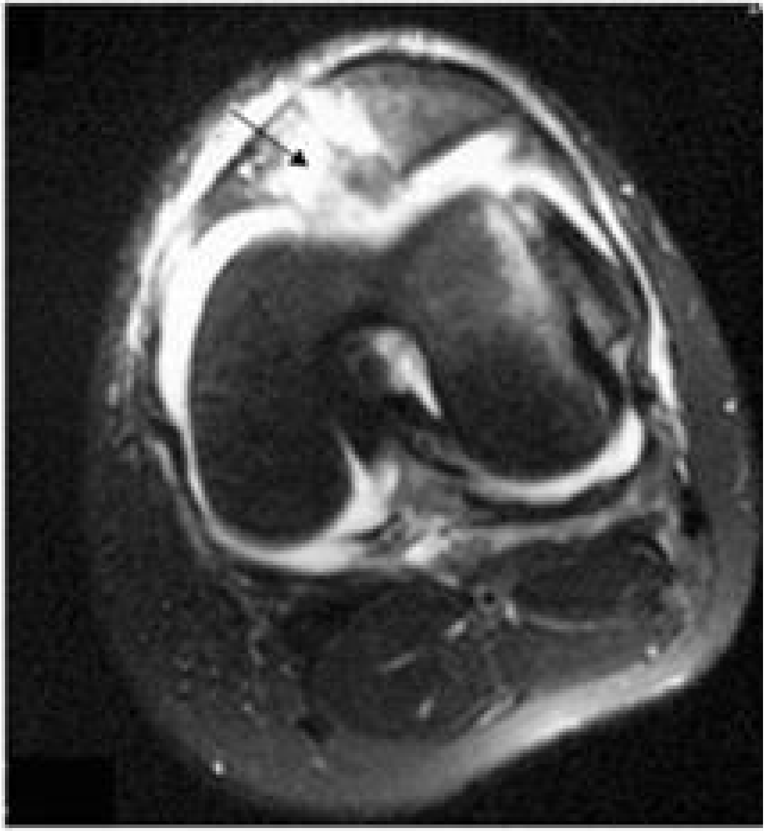


Image from R&W Fractures in Children 9th Ed. Figure 27-17B

Treatment

Based on:

- **Patient age & activity level**
- **Size, location & viability of fragment**
- **Degree of surrounding injury**

Fixation indicated for:

- **Large pieces**
- **Sufficient bone attached**
- **Central weightbearing fragments**

- Small fragment (< 5mm)
- Chronic loose body
- Poor subchondral bone
- Non-weight bearing area
- Potential to cause mechanical symptoms

REMOVAL OF LOOSE BODIES

- Large fragment (>5mm)
- Acute fracture (< 6 weeks)
- Adequate subchondral bone
- Weight bearing surface

FRAGMENT FIXATION

+/- Medial patellofemoral ligament repair, proximal medial retinacular repair, lateral retinacular release

Adapted from R&W Fractures in Children 9th Ed. Algorithm 27-2

Complications

- **Arthrofibrosis**
  - **Treat with aggressive therapy & dynamic splinting during first 3-4 mo. (Pace et al., JPO 2018)**
- **Loss of fixation/nonunion**
- **Osteoarthritis**
  - **Excision of large weightbearing fragments predictably leads to degenerative changes (Anderson et al., AJSM 1997)**
- **Repeat patellar dislocation**
  - **Controversial whether concomitant MPFL repair decreases risk of recurrent instability**

Patella Fractures

- **Patella ossifies at 3-5 years of life**
- **Injury is rare because patella mostly cartilaginous and has greater mobility than adults**
- **Avulsion fractures are more common in children than adults**

Mechanism:

- **Eccentric quadriceps contraction**
- **Direct blow**
  - **Results in comminuted pattern**

Image courtesy of Alfred Mansour, MD (2016 version)

Examination

- Painful, swollen knee
- Inability to extend knee
- Hemarthrosis
- Patella alta
- Palpable defect at affected patellar pole
- Apprehension test may be positive if fracture secondary to patellar dislocation

- Sagittal plane fractures best seen on sunrise view
- Comparison views of contralateral side may be helpful
  - Sleeve fractures – may only contain small subchondral fragment

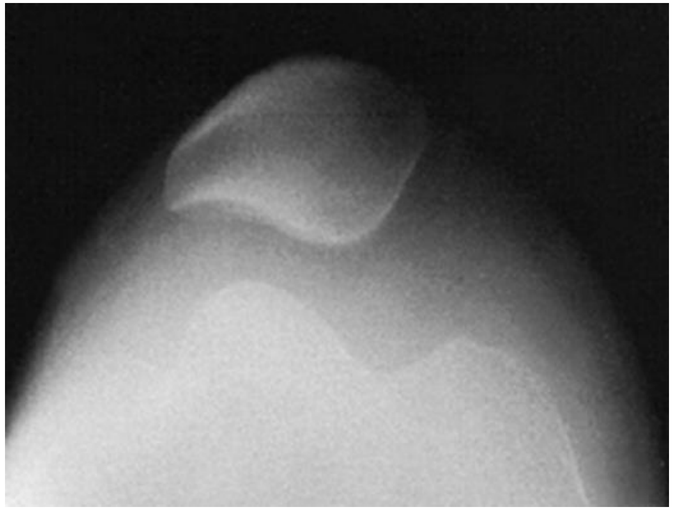


Image courtesy of Greg Osgood, MD

Classification (Grogan JPO 1990)

Primary Osseous Fractures

Avulsion Fractures:

- NO significant avulsion of cartilage
- Superior, inferior, medial (often w/ acute patellar dislocation), lateral (chronic stress from repetitive pull of vastus lateralis)

Sleeve Fractures:

- Avulsion of pole of patella WITH a large potion of articular cartilage
  - Cartilage, retinaculum, and periosteum may be involved
- Typically occur at inferior or superior poles

Image courtesy of Alfred Mansour, MD (2016 version)

Image courtesy of Greg Osgood, MD (2011 version)

Treatment

Closed treatment with long leg casting

Indications:

1. Extensor mechanism intact
2. < 2-3mm of articular displacement

Left: image courtesy of Alfred Mansour, MD (2016 version)

Right: image courtesy of Greg Osgood, MD

Open reduction and internal fixation:

- AO tension band, cerclage wire/ nonabsorbable suture, interfragmentary screws
  - Sutures alone sufficient for sleeve fractures
- Recommended to repair retinaculum
- Splint for 4-6 weeks

Summary

- **Extra-articular knee injuries require an anatomical reduction to prevent physeal arrest, malalignment, and leg length discrepancy**
- **Fixation must be adequate to prevent loss of reduction while respecting the biology of the physis**
  - **Postoperative supplemental splint/cast may be necessary**
- **Understand the differential diagnosis of acute knee effusion and strategies for managing intra-articular fractures in the pediatric knee**

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