MRI-Arthroscopy Correlation: ACL

Disclosures

Cree Gaskin:
- Thieme Med Pub
  - Book Royalties
- Oxford Univ Press
  - Book Royalties

Mark Miller:
- Elsevier/LWW
  - Book Royalties
- MRC
  - Founder/Director

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  - Miller et al. Sports Medicine Conditions – Return to Play. Wolters Kluwer

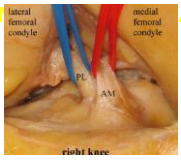
Overview

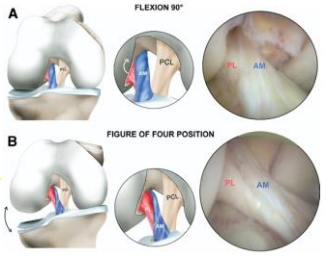
- Introduction
  - Anatomy of the ACL
  - MRI of the ACL
- Case 1: ACL & "Bone Bruise"
- Case 2: Pedi ACL
- Case 3: Revision ACL
- Case 4: ALL Augmentation
- Conclusion

Knee—ACL
Anatomy and Biomechanics

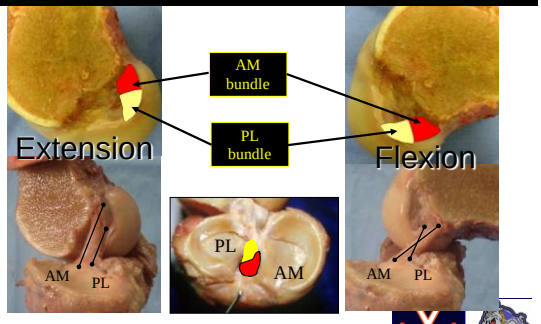
Tibia => LFC

- 33 mm x 11 mm
- 2 Bundles:
  - **AM** (tight in flexion)
  - **PL** (tight in extension)
- [illegible] A





Femoral Insertion Alignment Changes With Knee Flexion



ACL Arthroscopy

ACL Arthroscopy

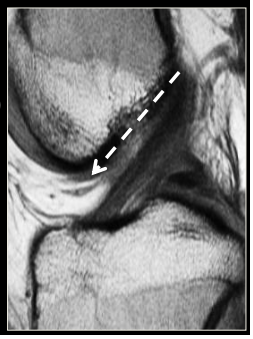
View from Anterolateral Portal

View from Anteromedial Portal

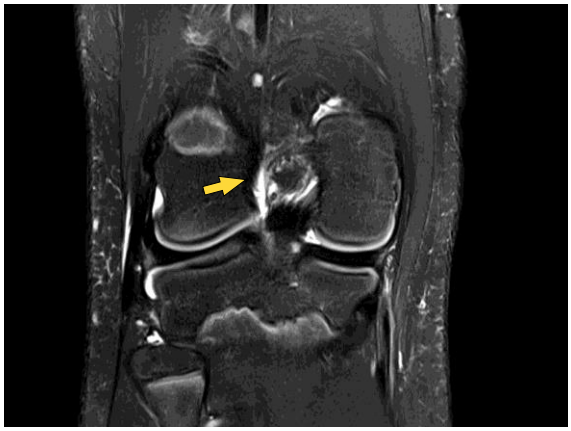
Normal ACL

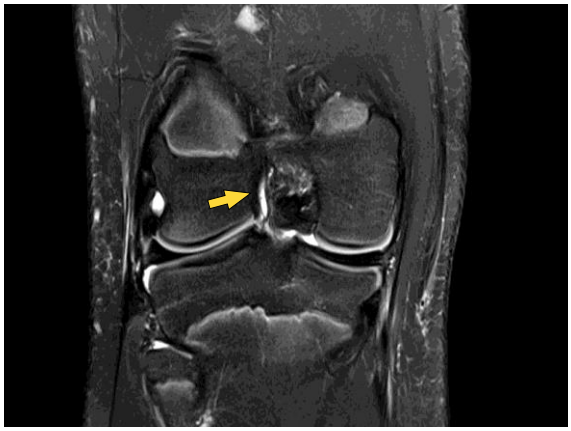
- Sagittal
  - Taut
  - Parallel
    - intercondylar roof
      (aka - Blumenstaat's line)
- Signal intensity
  - Low / intermediate
  - Striated

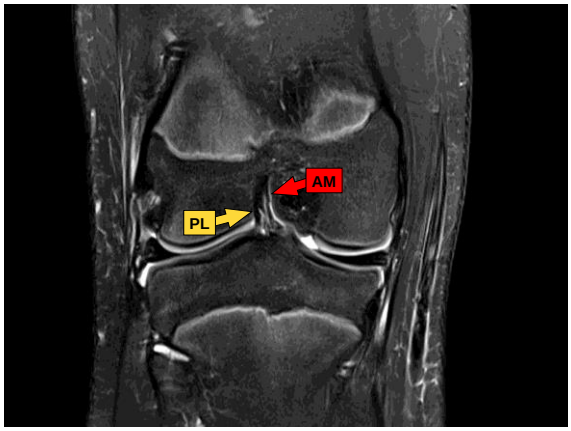
Evaluate in all planes

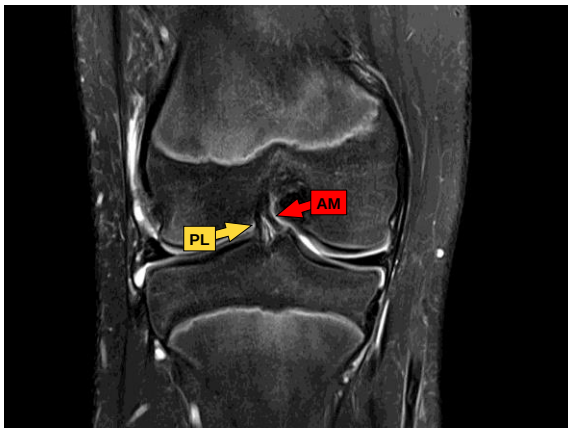



Coronal






AM
PL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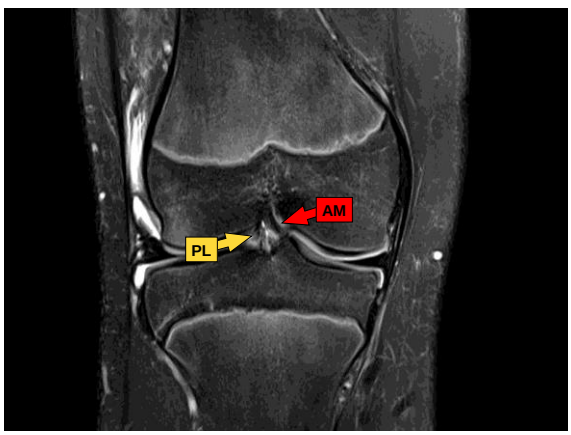
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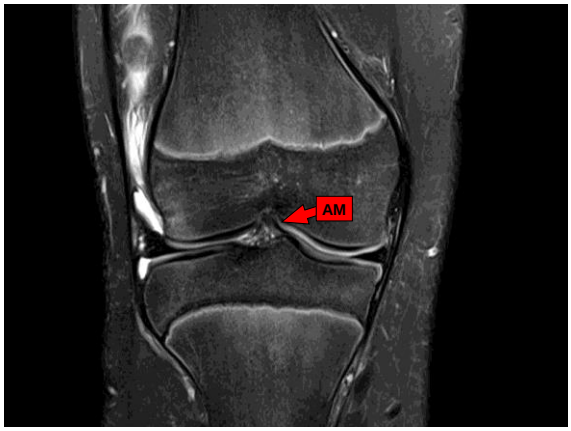
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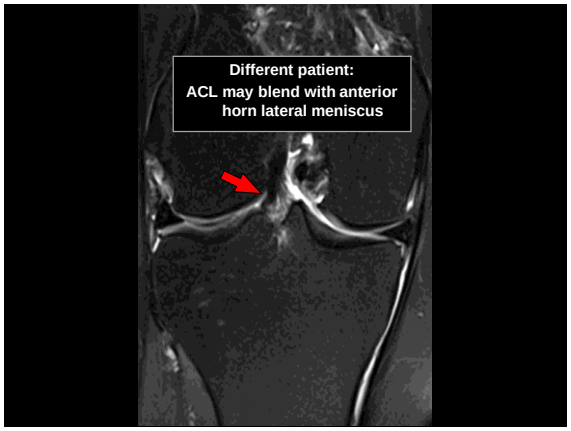
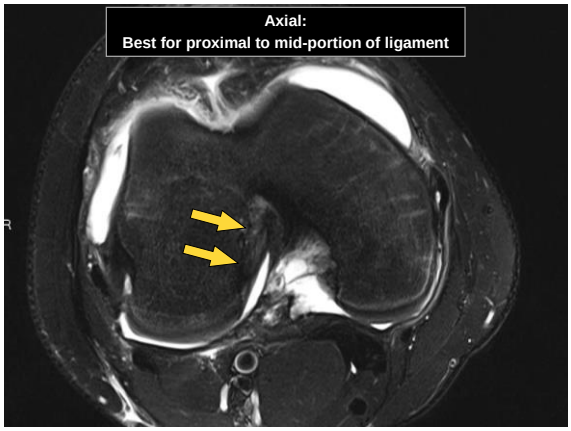
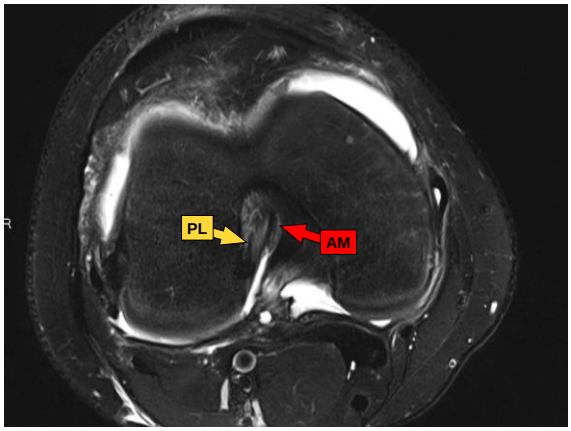

Different patient:
ACL may blend with anterior horn lateral meniscus


Axial:
Best for proximal to mid-portion of ligament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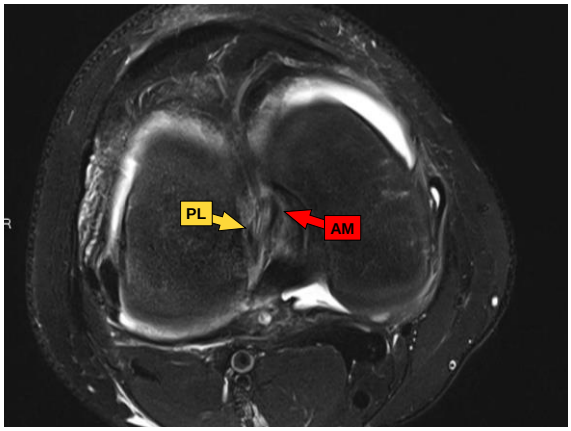
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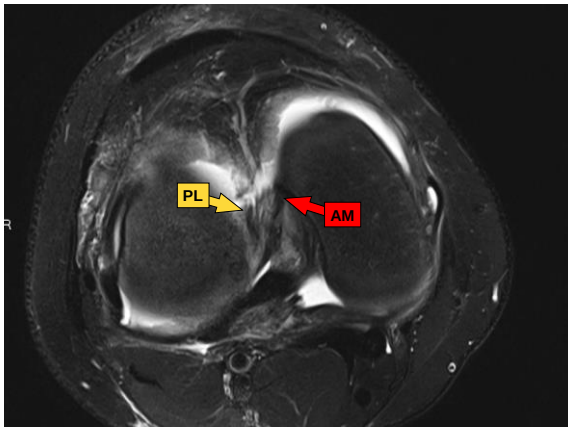
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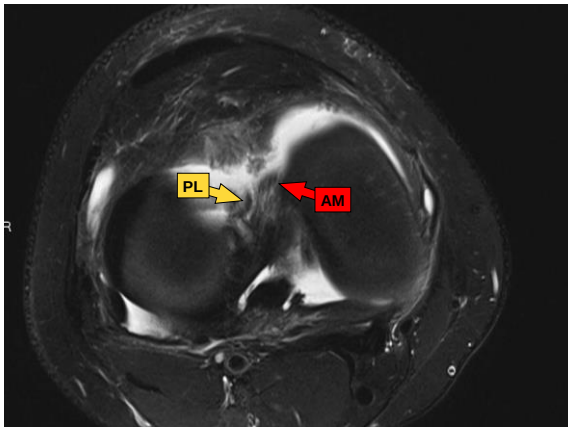
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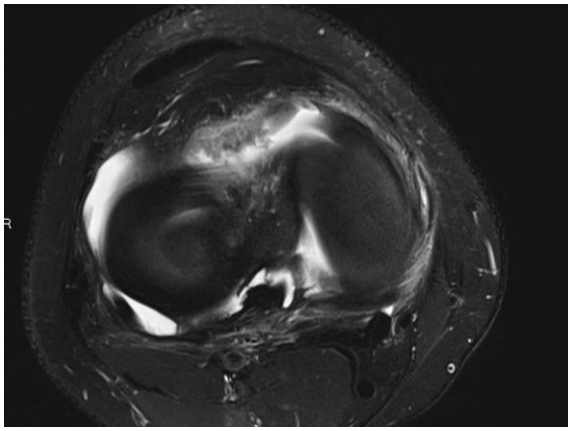


Case 1

HPI

- 17 yo M soccer player s/p **non-contact pivoting injury to L knee** during game 8 weeks prior
- Attempted to continue playing but had 2 **recurrent pivoting episodes**, most recently 5 days prior to presentation
- L knee swelling, pain, and **locking with incomplete extension** on most recent episode

Case 1

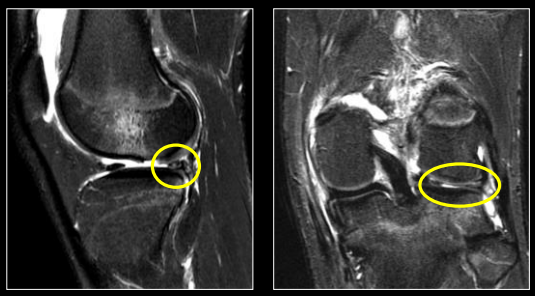
PE

- (+) effusion
- ROM 15-90
- (+) Lachman
- (+) lateral joint line tenderness

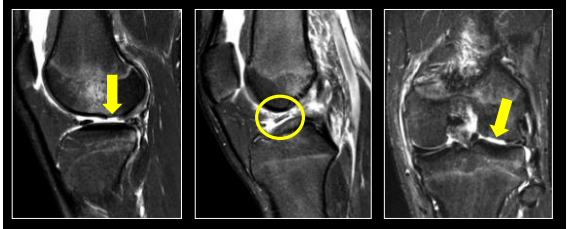
No XRs provided, brought in MRI from OSH performed after last instability episode

MRI – ACL Tear

MRI – Lateral Meniscus Tear



MRI – Chondral Defect/Loose Body



ACL: Complete Tear

Primary signs

- edematous mass
- “empty notch”
- irregular, horiz contour
- focal disruption

Case 1

Diagnosis

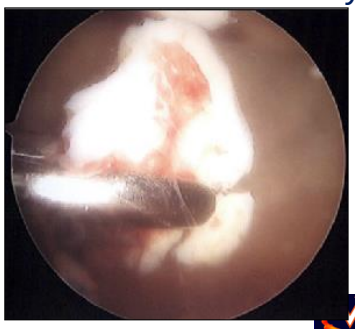
- Left knee ACL tear
- Left knee complex bucket-handle lateral meniscus tear
- Left knee lateral femoral condyle chondral fracture with loose body

Procedure

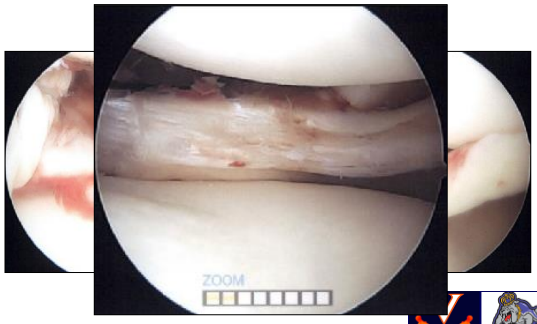
- Left knee ACL reconstruction with B-PT-B autograft
- Left knee PLM
- Left knee removal of loose body
- Left knee OATS to LFC

ACL Tear

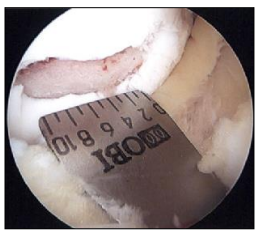
Removal of Loose Body

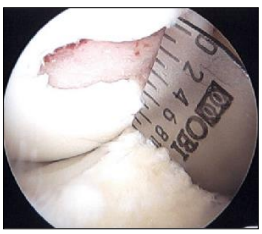


Lateral Meniscus Tear



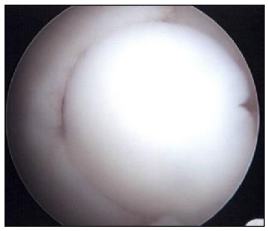
Chondral Defect





ACL Graft

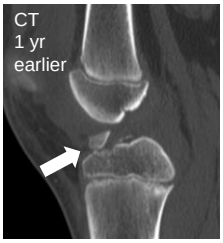
OATS Plugs



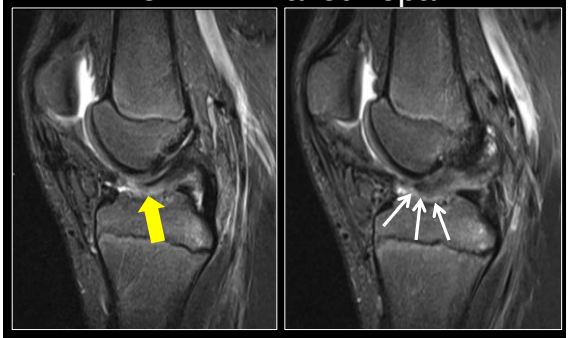
Case 2

HPI

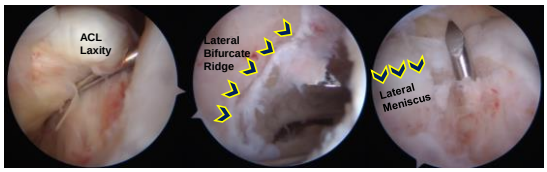
- 14 yo boy S/P attempted ACL eminence repair one year prior @ Outside Hospital.
- Recurrent instability
- 2+ Lachman
- + Pivot Shift



New MRI: failed repair

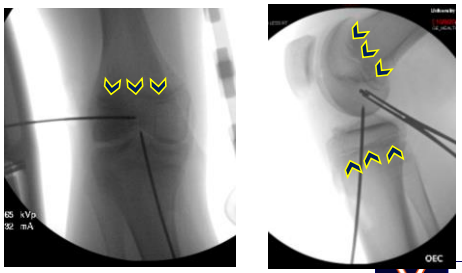


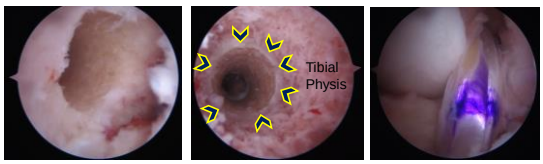
ACL Reconstruction



ACL Guide Pin Placement

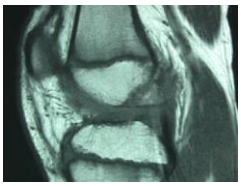
Femoral: Below Physis (All-Epiphyseal)
Tibial: Trans Physeal--Verticla





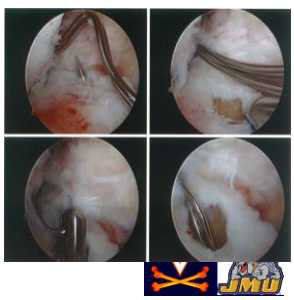
Case 2: Pediatric ACL Over-the-Top Case Example

- 11 year old boy with pivoting injury (football)
- Up to 12” growth remaining
- Failed non-operative management (recurrent instability)



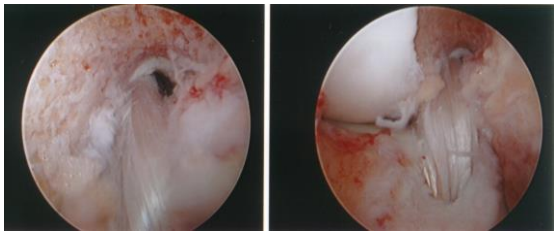
Pedi ACL Case

- 7-mm Central Vertical Tibial Tunnel
- 18-gauge looped wire passed from “over the top” and out the Tibial Tunnel



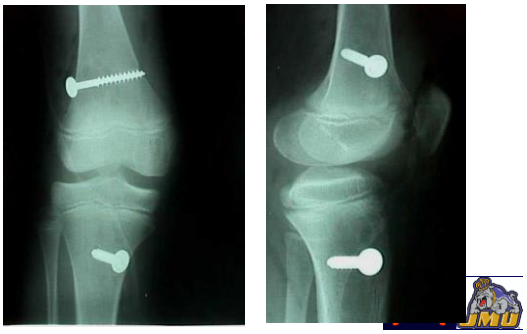
Pedi ACL Case

- ACL Hamstring Graft Placed “Over the Top”

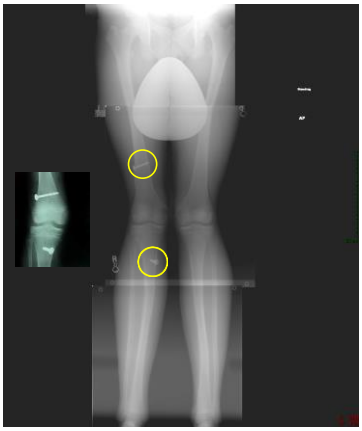


Pedi ACL Case

- Post-Operative Films



4 Year Follow-up



Adult Reconstruction

- Trans-Tibial
  - Less disruption of femoral physis
  - Non-anatomic
- Independent Drilling
  - Substantial risk to the physis*

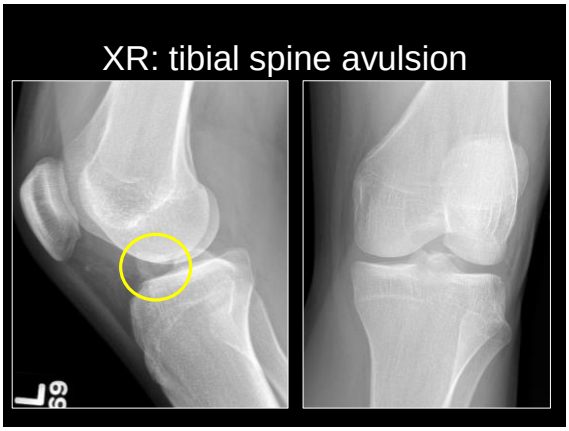
*Nelson J, Miller MD; JBJS-A 2011; 18:93 e53: 1-4

ACL Avulsion Repair
EMcD 2481546

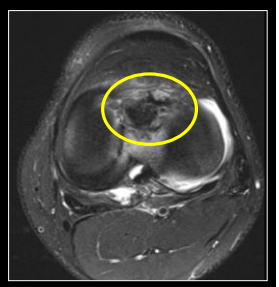
HPI: 19M with left knee pain, had a non-contact injury playing flag football and planted his foot on 9/12/14. He heard a pop and had immediate pain and swelling. Evaluated at ED, pain with WBAT, using crutches

Exam: 10° Loss of Extension; 2+ Lachman, + Pivot

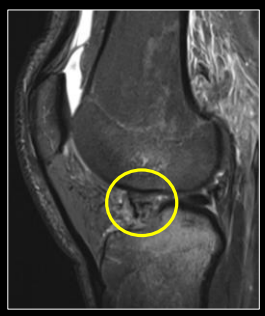
XR: tibial spine avulsion

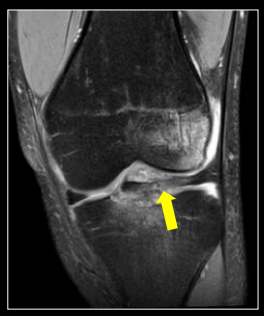


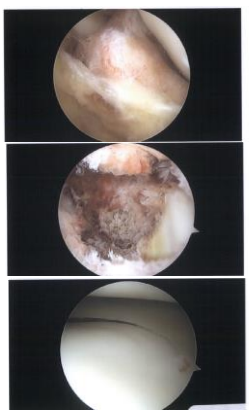
MRI: tibial spine avulsion

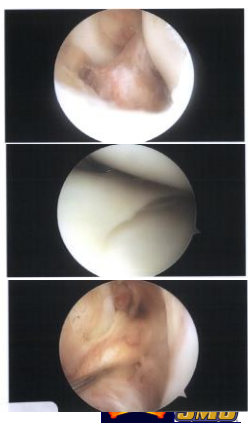


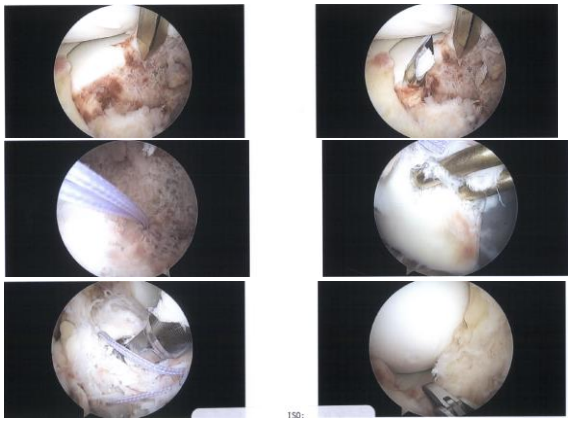
MRI: avulsion/AHLM root tear

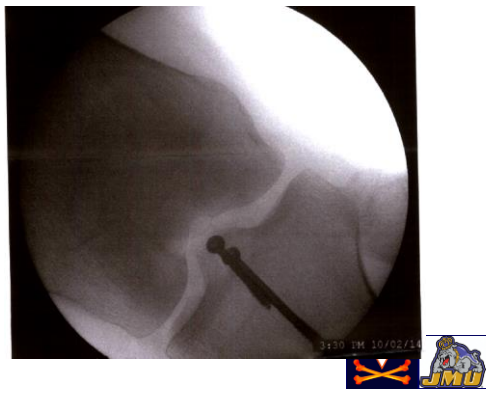


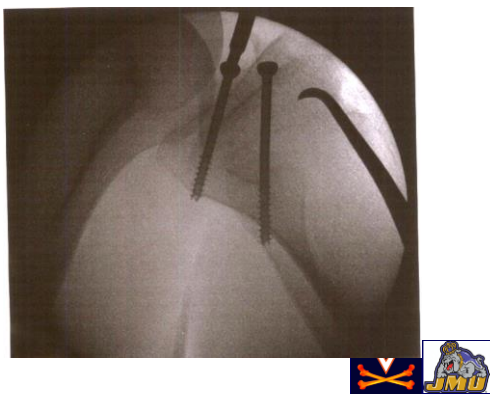













Case 3
Revision ACL Case

- 19yo Female S/P L ACL Revision x2
  - First ACL at age 15 BPTB T-T Allograft
    - Failed at 10 months—Soccer "injury"
  - Second ACL at age 16 BPTB T-T Allograft (again)
    - Failed again at 10 months—Soccer "injury"
  - Hardware removal and allograft bone grafting

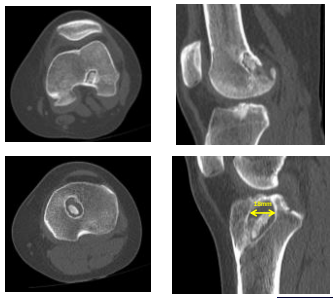
Revision ACL Case (Continued)

- On Presentation (4 months S/P bone grafting), patient (and parents) complained of recurrent instability and requested a second opinion
- Radiographs suggested tunnel osteolysis and vertical femoral tunnel placement

CT

Femoral Tunnel

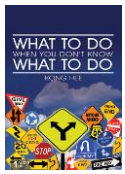
Tibial Tunnel



ACL Case 1 (Continued)

- Labs:
  - Knee Aspirate: 600 WBC, Gram Stain -, No Growth
  - Systemic Labs: WBC, ESR, CRP all Normal

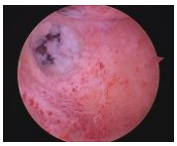
ACL Case 1
ARS Question 1



- What would you do next?
  - A. One Stage Revision ACL with Allograft
  - B. One Stage Revision ACL with Autograft
  - C. Two Stage Revision ACL—Allograft Bone Graft
  - D. Two Stage Revision ACL—Autograft Bone Graft

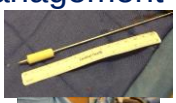
ACL Case 1 Management

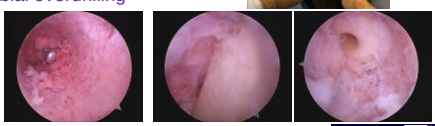
- Planned 2 stage Revision
- Tibia
  - Overdrilling (up to 18mm)
  - ICBG (“Sandwich” Technique)



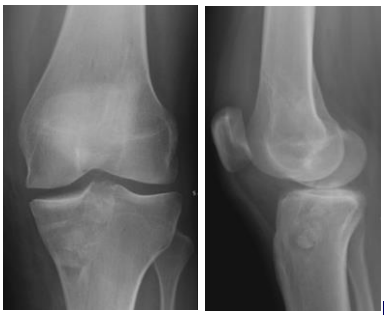
ACL Case 1 Management

- Planned 2 stage Revision
- Femur
  - Overdrilling (10 mm)
  - Allograft Cloward Dowel
    - Transtibial placement after tibial overdrilling

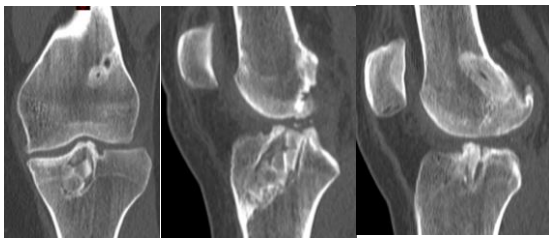




Revision ACL—Stage 1



CT—3 ½ months S/P Bone Grafting

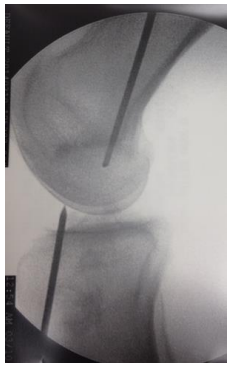


ACL Case 1
ARS Question 2

- What would you do next?
  - A. Wait for Bone Graft to further incorporate
  - B. Repeat Bone Grafting of Tibial Tunnel
  - C. Proceed with Revision ACL with Allograft
  - D. Proceed with Revision ACL with Autograft

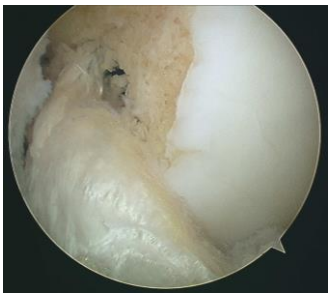
2nd Stage: ACL reconstruction

2nd Stage: ACL reconstruction



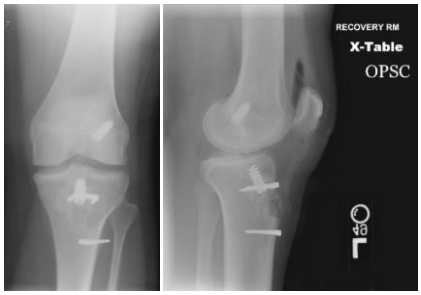
2nd Stage: ACL reconstruction

2nd Stage: ACL reconstruction



BPTB Autograft

2nd Stage: ACL reconstruction



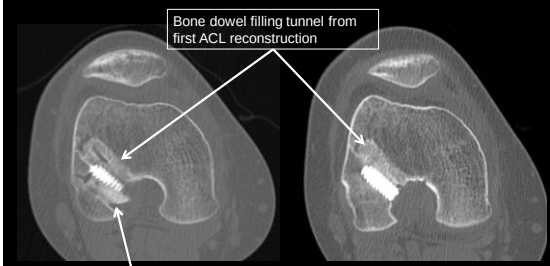
Revision ACL Plug Technique

Guide wire placed In old tibial tunnel. Drilled to 10 mm, 10 mm Dowel Placed, New Tunnel Placed Behind Old Tunnel

Cloward Plugs— Allograft Dowels used to fill in defects from hardware removal or tunnel osteolysis

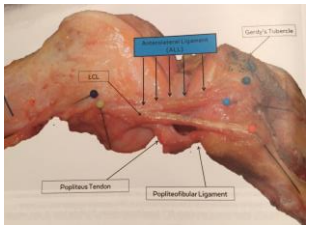
Battaglia T, Miller MD; *Arthroscopy* 2005; 21:767

CT: 5mos post ACL single stage revision with bone dowel



Anterolateral Ligament (ALL)

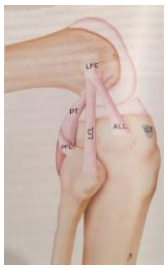
- Controversial
- Not really “New”
- What is it’s role?
- Europeans (Claes and others) recommend Repair/Reconstruction in Patients with:
  1. Segond Fx’s
  2. Huge Pivots
  3. Revisions

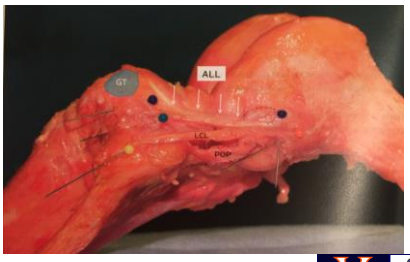


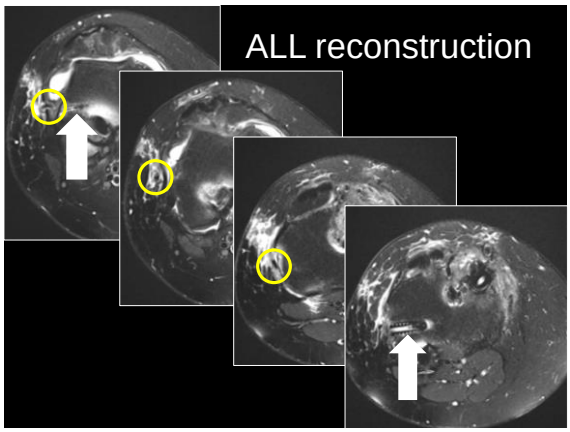
ACL: Complete Tear

Secondary signs

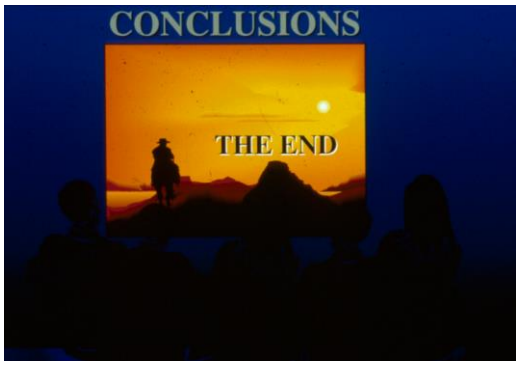
- ***bone contusions***
- ***“deep notch”***
- ***Segond fracture***







ALL Reconstruction



Conclusion

- Introduction
  - Anatomy of the ACL
  - MRI of the ACL
- Case 1: ACL & “Bone Bruise”
- Case 2: Pedi ACL
- Case 3: Revision ACL
- Case 4: ALL Augmentation
- Conclusion

Thank You

MRI – Arthroscopy Correlations of the Knee: Menisci

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Disclosures

Robert G Marx:

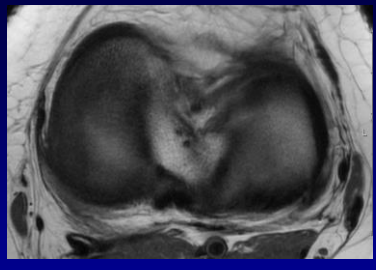
Books and copyrights:

- Marx, RG (Editor). *Revision ACL Reconstruction: Indications and Technique*. Springer. 273 pages. New York, 2013.
- Marx RG, Myklebust G, Boyle B. *The ACL Solution: Prevention and Recovery from Sports' Most Devastating Knee Injury.* Demos Health. 174 pages. New York, 2012.

Journal Editorship:

- Deputy Editor for Sports Medicine, The Journal of Bone & Joint Surgery
- Associate Editor for Evidence Based Orthopedics, The Journal of Bone & Joint Surgery
- Senior Associate Editor, The HSS Journal

Gabrielle Konin: No relevant financial disclosures.



- Semilunar (C–shaped)
  - Medial is more C-shaped and larger and lateral more rounded and smaller
- Divided into anterior and posterior horns and body
- Wedge shaped with biconcavity

Medial Meniscus

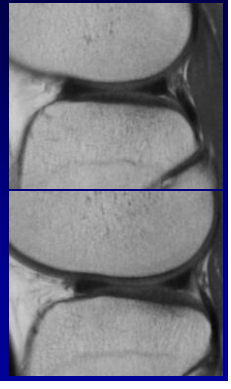
- Posterior horn is larger than anterior horn
- Non-mobile – more firmly attached to the joint capsule
- Meniscofemoral and meniscotibial (coronary) ligaments

Lateral Meniscus

- Anterior = Posterior Horn
- Fibers of ACL extend into anterior horn
- Posterior root attaches anterior to PCL
- Meniscofemoral ligaments – Humphrey & Wrisberg
- Popliteomeniscal fascicles

Lateral Meniscus

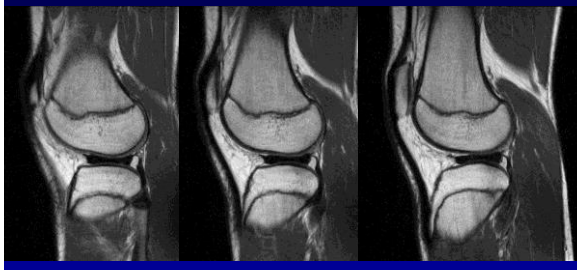
- Fascicles (2-3)
  - Meniscocapsular extension around popliteal hiatus
  - *Anteroinferior*: body LM to musculotendinous portion of popliteus – forms floor of hiatus
  - *Posterosuperior*: post horn LM to popliteus tendon – forms roof of popliteal hiatus
  - If ruptured, can render the LM hypermobile; pain and locking



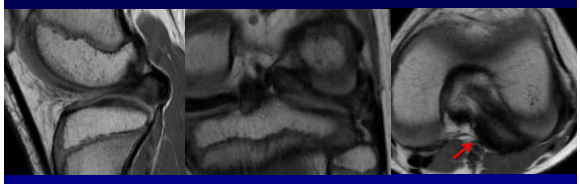
Discoid meniscus

- Watanabe classification: Complete, Incomplete* and Wrisberg variants
- Non-tapering of apex of meniscus
- Radial diameter > 13 mm
- Increased height >2mm than opp meniscus
- Predisposes to degeneration and tear
- Pain, clicking, mechanical locking

Discoid meniscus

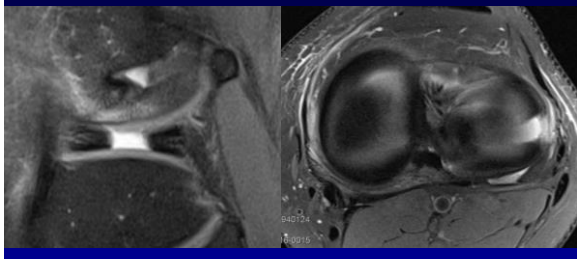


Discoid meniscus



8 year-old girl with posterior knee pain & clicking for a few years

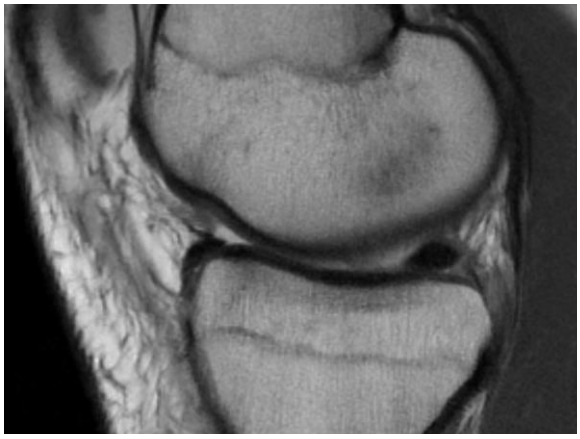
Radial tear

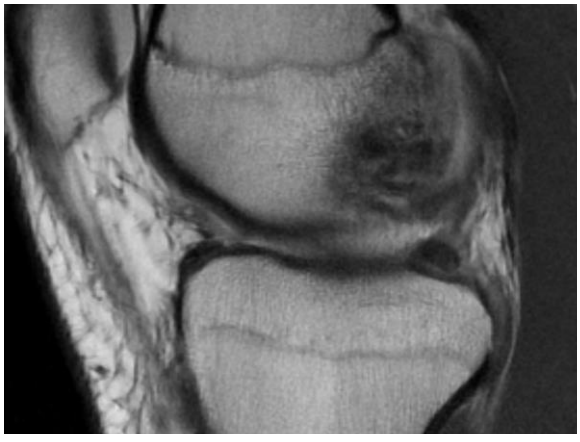


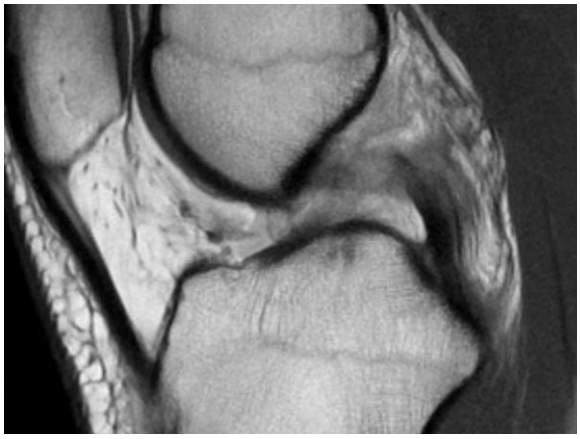
23 year old man s/p snowboarding injury

- Slight compression of the bone plate and overlying cartilage with subchondral edema and chondral shear anteriorly

16 year-old girl with medial knee pain following soccer injury







Radial Tear at Tibial Root

Radial Tear at Tibial Root

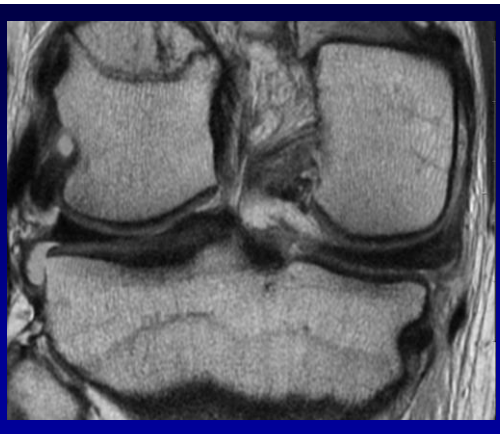
Radial Tear at Tibial Root

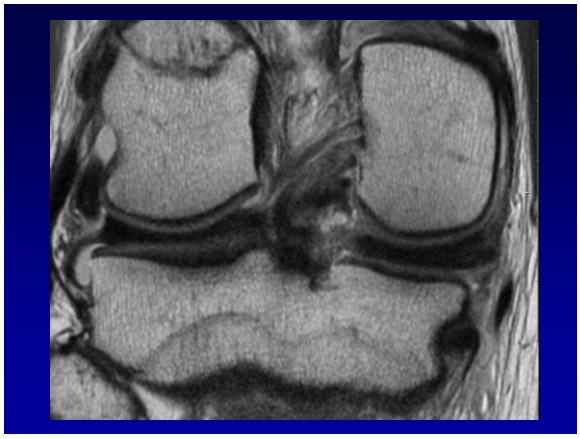
Radial Tear at Tibial Root

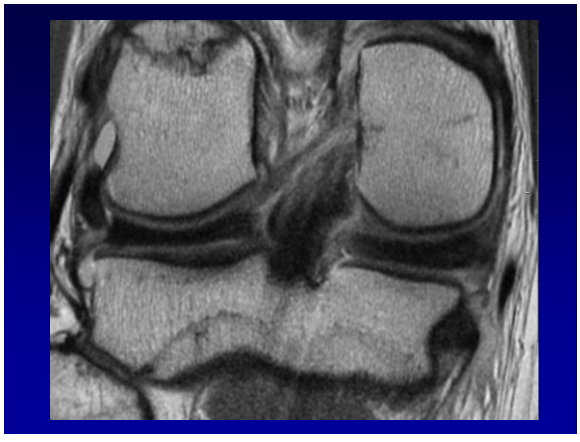
Radial Tear at Tibial Root

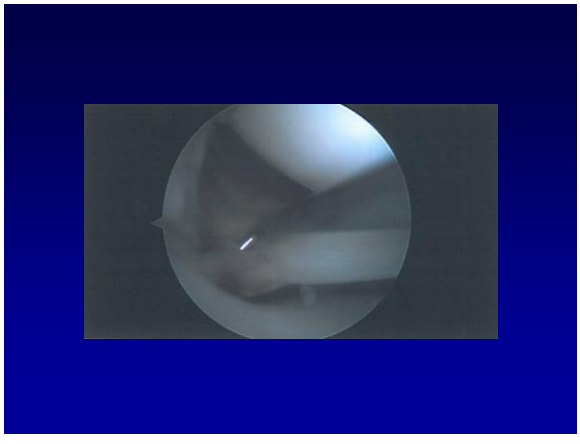
Radial Tear at Tibial Root

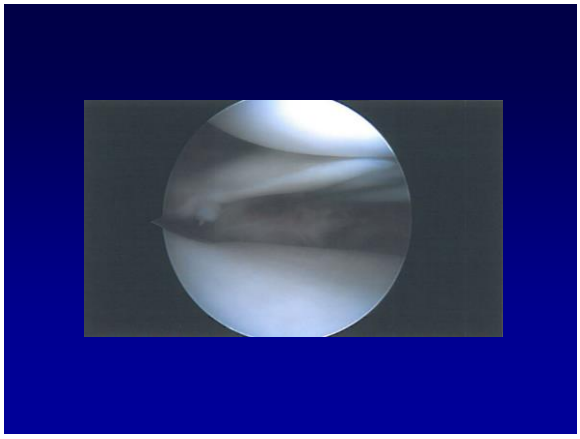
Radial Tear at Tibial Root

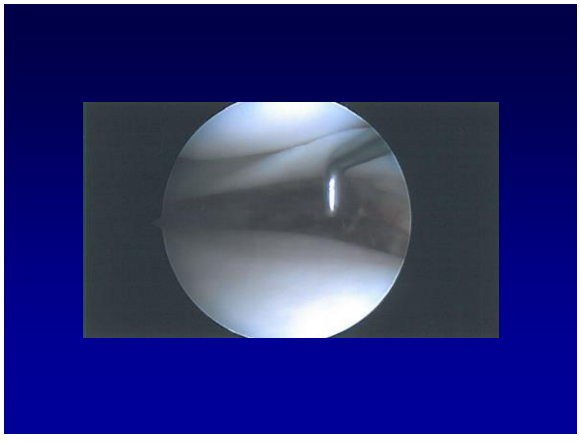


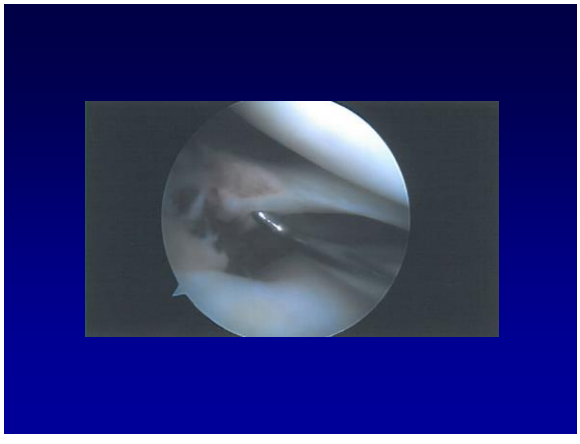


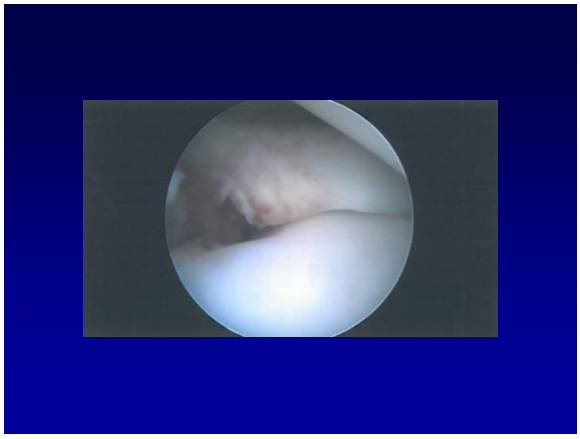


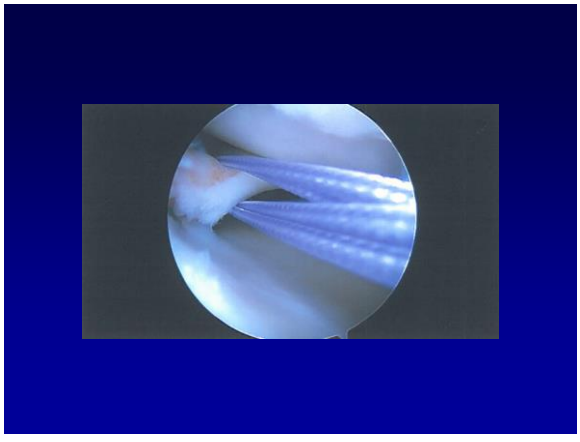


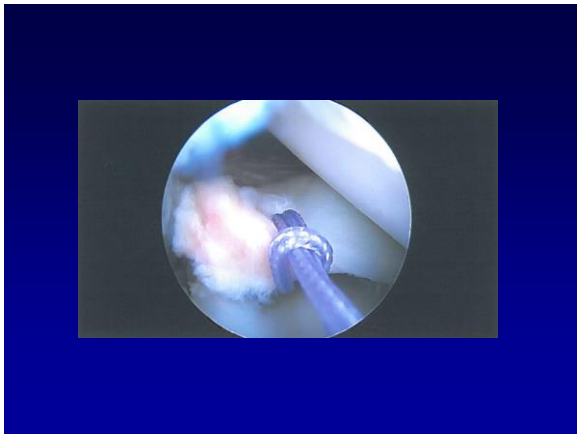


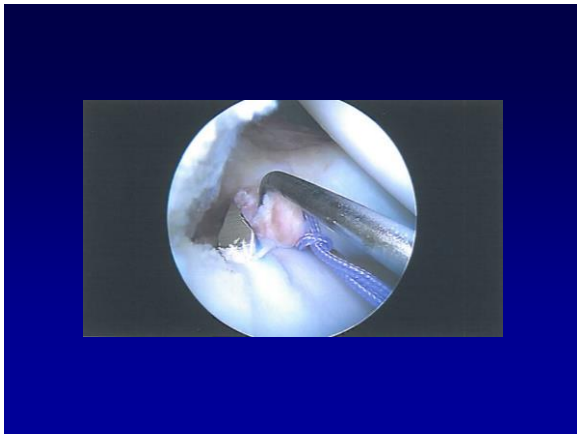


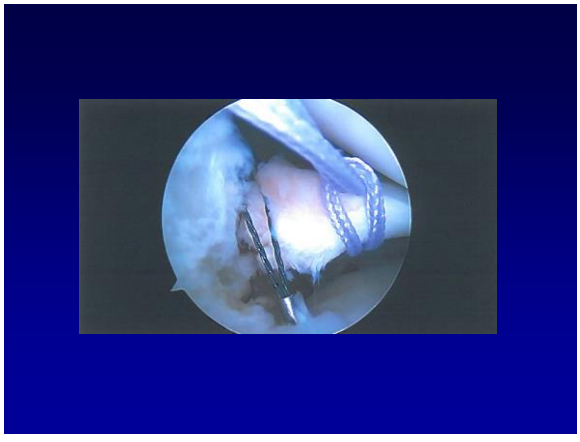


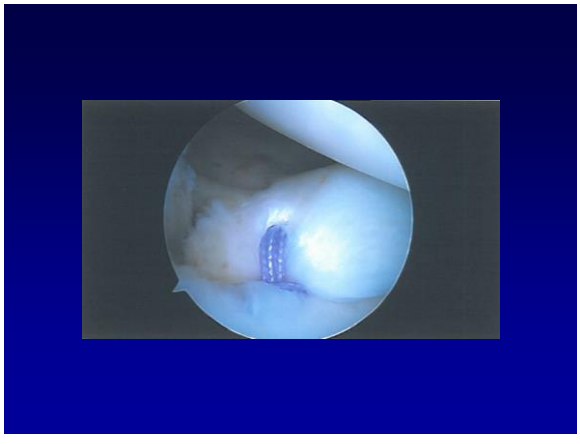


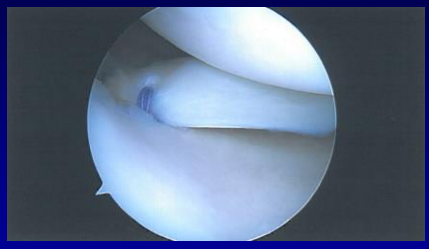






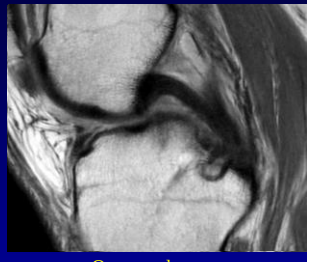






47 year-old female with medial knee pain. Prior history of meniscal root re-attachment.

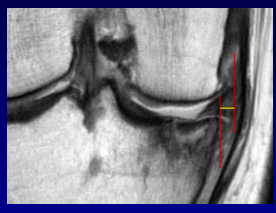
Radial tear



One year later

- Radial split at the post horn root junction MM. “Ghost sign”
- Subacute subchondral medial plateau fracture with mild bone plate depression and focal area of devitalized bone

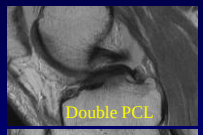
Meniscal extrusion

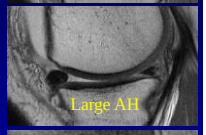


- Measured from outer meniscal edge to proximal tibial margin
- Medial > 3 mm. Lateral > 1mm
- Meniscal extrusion is 4 times more common medially

Bucket handle

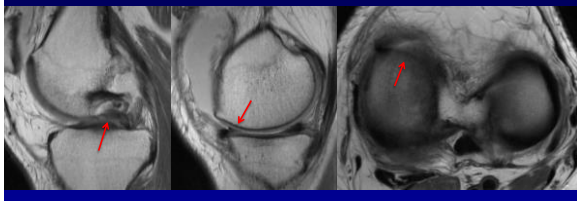
- Circumferential longitudinal vertical tear w/ displacement of free internal fragment into intercondylar notch
- MM > LM
- MRI Signs
  - Double PCL
  - Double delta (lateral)
  - Large AH
  - Fragment in notch
  - Absent bow tie
  - Disproportionate horns

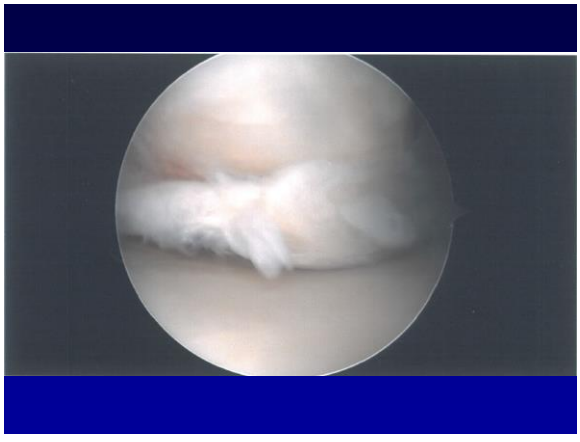


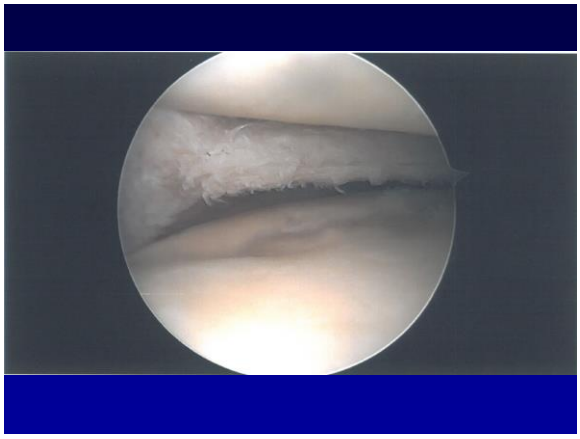


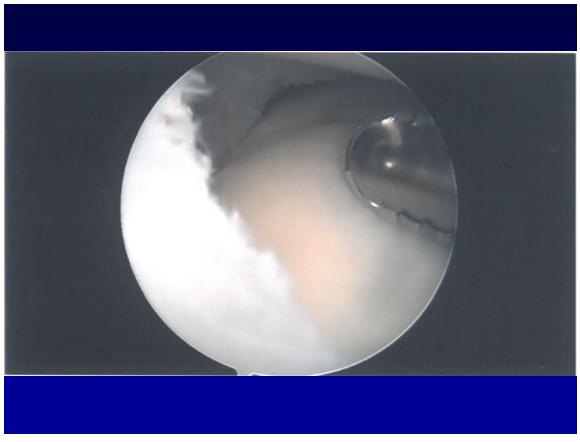
48 year-old man with medial knee pain. Twisting injury a few months ago, heard a "crack".

Bucket handle









Flap tear with displacement

Flap tear with displacement

- Important to recognize because gutters can be difficult to visualize at arthroscopy

35 year-old woman with history of subtotal lateral meniscectomy and subsequent meniscal allograft.

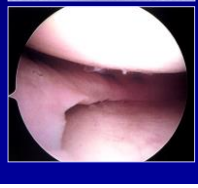
Meniscal Allograft Transplantation

- The allograft bone slot is incorporated
- Mild extrusion of the body segment
- Satisfactory position of the horns
- No meniscal split

Meniscal Allograft Transplantation

Why implant an allograft?

- "Arthroprotection"
  - Decrease contact stress on articular cartilage
- Pain relief
- Restore normal / near normal kinematics



Thank you

HOSPITAL FOR SPECIAL SURGERY
WHERE THE WORLD COMES TO GET BACK IN THE GAME

David Geffen School of Medicine | UCLA Health

MRI -Arthroscopy Correlations: Cartilage

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David Geffen School of Medicine | UCLA Health

Disclosures

- Frank A. Petrigliano, MD:
  - Speaker - Biomet
  - Research Support – Musculoskeletal Transplant Foundation
  - Honoraria – Musculoskeletal Transplant Foundation
  - Committee Member – AOSSM Research Committee
- Benjamin D. Levine, MD:
  - None

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Imaging Hyaline Cartilage

Quantitative MRI Techniques

David Geffen School of Medicine

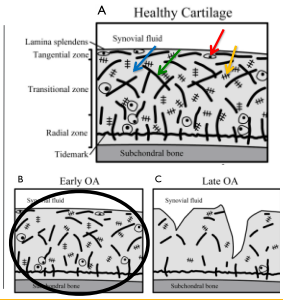
UCLA Health

Hyaline Cartilage

Physiology

- Water (65-85%)
- Chondrocytes (4%)
- Type II Collagen (15-20%)
- Proteoglycans (PGs) (3-10%)
  - Protein core glycosaminoglycans (GAGs)

Biophysical structure



Matzat SJ et al. *Quant Imaging Med Surg* 2013;3(3): 162-174

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Quantitative MRI of Cartilage

- dGEMRIC
- T1rho Mapping
- T2 Mapping
- Sodium MRI

- Ultrashort TE
- gagCEST
- DWI

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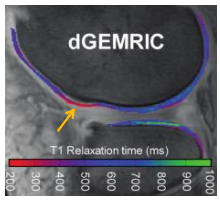
dGEMRIC

- Utilizes the fixed charge density (FCD) in cartilage to indirectly measure GAG content
- Requires intravenous contrast, exercise, and delay between injection and image acquisition
- Long scan times and contrast risk



Bittersohl B, et al. *Invest Radiol* 2010;45:538-42.

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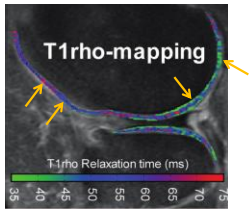
T1rho Mapping

- Non invasive measure of GAG content
- Inverse relation between T1rho relaxation time and PG/GAG content
- T1rho increases with age
- Potential tissue heating risk from the high RF power required



Matzat SJ et al. *Quant Imaging Med Surg* 2013;3(3):162-174

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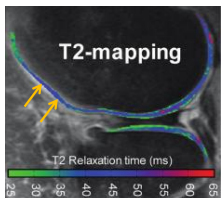
T2 Mapping

- Measures water content in cartilage
- Indirect assessment of collagen content and orientation
- May also be sensitive to PG content
- Susceptible to magic angle, rendering inaccuracies
- PG depletion occurs prior to collagen matrix degradation



Mosher TJ, et al. *Semin Musculoskelet Radiol* 2004;8:355-68.

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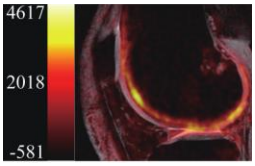
Sodium MRI

- Sodium cations are attracted to negatively charged GAGs
- Difficult to generate MR signal with Na ions
- Need high magnetic field strength with special coils
- Long scan times



Matzat SJ et al. *Quant Imaging Med Surg* 2013;3(3):162-174

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Case #1

- 30-year-old man with a acute on chronic left knee pain following an traumatic basketball injury
- PE
  - Substantial effusion, TTP LJTL
  - ROM 20 – 90 degrees
  - Stable ligament exam
  - Neutral alignment

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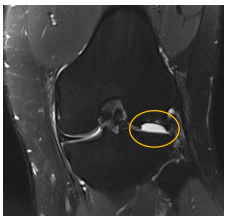
MRI



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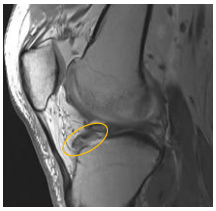
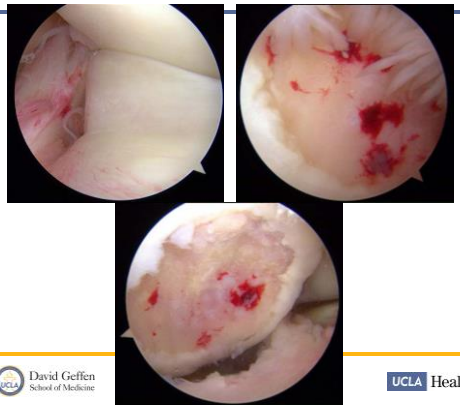
MRI



Treatment?

- Lesion Qualities
  - Etiology
    - Trauma
    - AVN
    - OCD
  - Location
  - Grade
  - Size
  - Character
    - Chondral vs. Osteochondral
- Patient Qualities
  - Age
  - Demand (High v. Low)
  - BMI (>30)
  - Expectations
  - Alignment
  - Meniscal Status
  - Knee Stability

Current Treatment Options in the USA

Treatment	Repair Tissue	Fill	Durability
Marrow Stimulation	Fibrocartilage	Partial	2-3 Years
Autologous OATS	Hyaline Cartilage	Near total	3-5 Years
ACI	Hyaline-like Fibrocartilage	Partial to near total	2-5 Years
Osteochondral Allograft	Hyaline Cartilage	Near total	5-10 Years
Particulated Juvenile Allograft	Hyaline-like Fibrocartilage	Partial to near total	UNKNOWN

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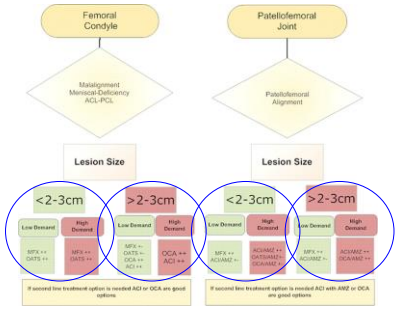

Brian J. Cole et al. J Bone Joint Surg Am 2009;91:1778-1790

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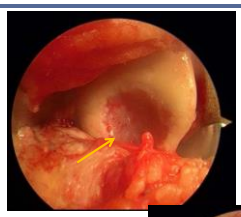
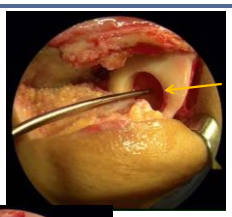
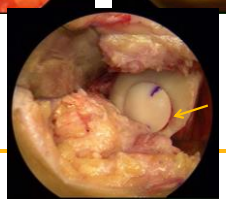




Persistent lateral compartment pain despite adequate rehabilitation



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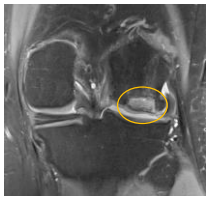
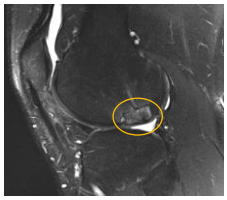
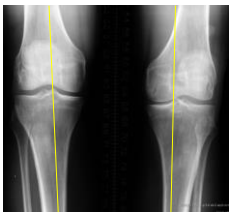
Post-op MRI

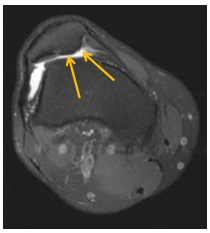
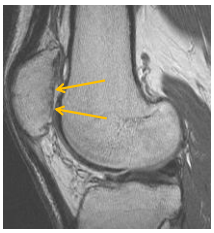
Companion Case


Case #2

- 24-year-old male with a chief complaint of chronic knee pain. History of recurrent patellar dislocations. Pt complains of pain and intermittent buckling/catching of his right knee as well as clicking of his right knee.
- PE
  - 0-130
  - Stable knee exam
  - + Patellar grind
  - Lateral patellar tilt
  - Positive J sign
  - TT-TG = 15 mm

MRI

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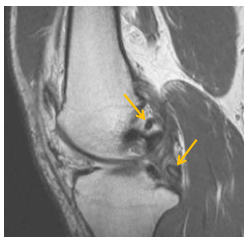
MRI

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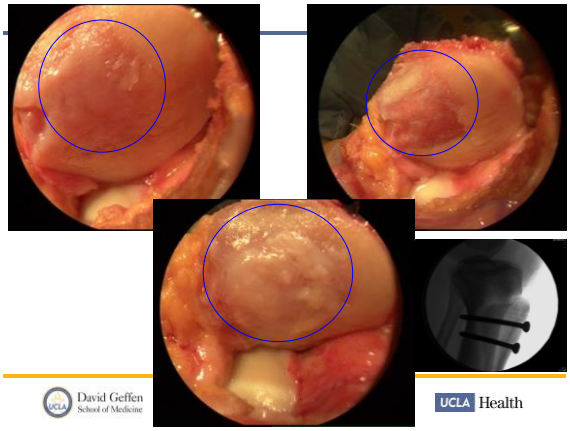

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Case # 3

- 30-year-old male with ACL, PMM, MFC OCD treated initially with ACLR, partial meniscectomy, and microfracture and subsequent debridement one year later.
- Pain with running and pivoting localized to medial compartment of knee
- PE:
  - ROM 0-135
  - TTP MFC
  - Stable Knee exam

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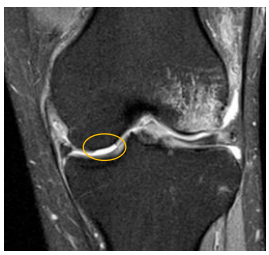
MRI



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MRI 2013


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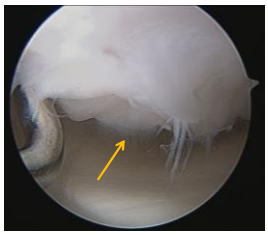

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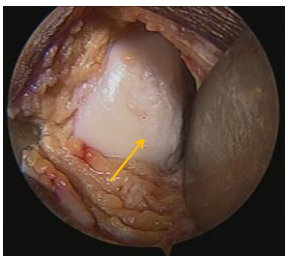


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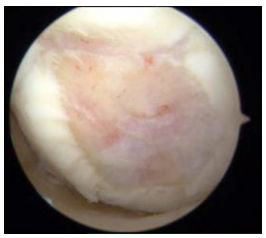
Post-op Course

- Did well for about a year
- Moderate medial knee pain and catching/clicking sensation
- PE:
  - Trace effusion
  - 0-130
  - TTP over the MFC with click on flexion
  - Stable ligament exam
- Repeat MRI

MRI 2015





Keys to successful cartilage surgery

- Understand the basic physiology of cartilage repair & healing with each approach
- Clarify relevant diagnoses stringent indications
- Manage patient expectations
- Attention to surgical detail and rehabilitation
- Do the surgery with which you are most comfortable

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Patellofemoral Instability

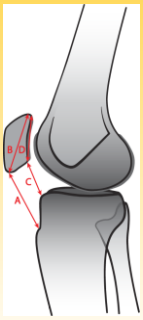
Jutta Ellerman, MD
Associate Professor
Department of Radiology
University of Minnesota

Marc Tompkins, MD
Assistant Professor
Department of Orthopaedic Surgery
University of Minnesota/TRIA Orthopaedic Center

We have no conflicts to declare.

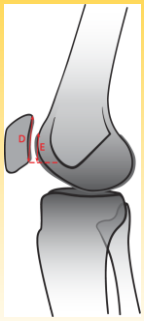
Patella Height

- Caton Deschamps Index
  - C/D
- Insall Salvati Ratio
  - A/B

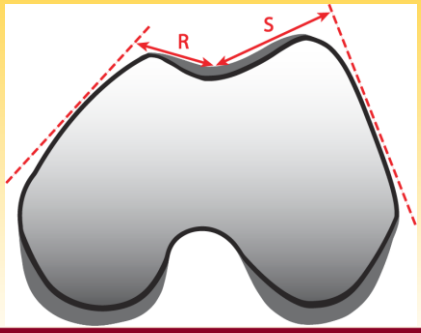


Patella Height :
Patella Trochlear Index (PTI)

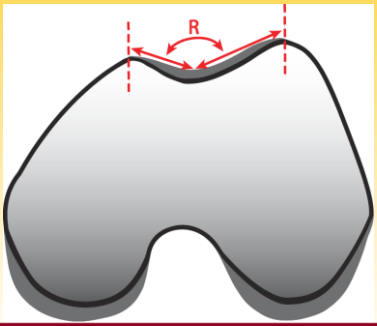
- E/D



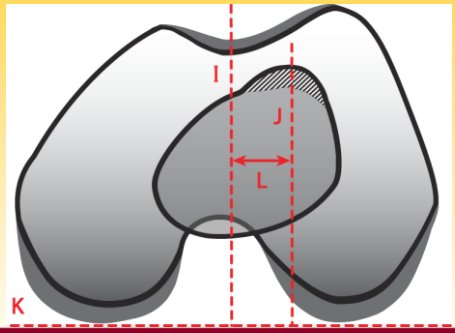
Facet Asymmetry (Medial/Lateral)

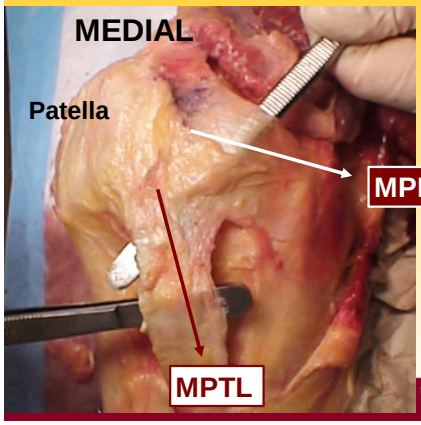


Sulcus Angle



Tibial Tubercle Trochlear Groove Distance





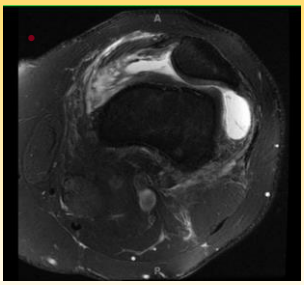
Courtesy Liza Arendt, MD

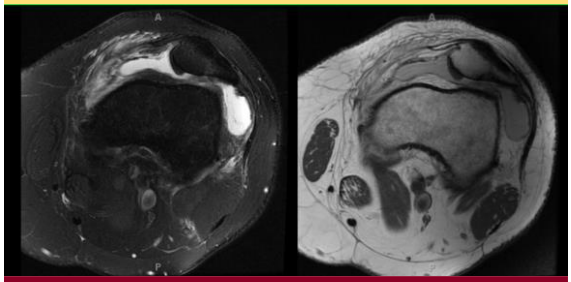
Case 1

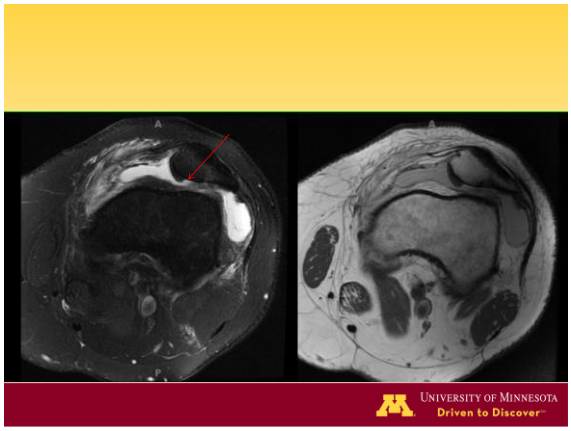
- HX:
- 18 y/o offensive lineman for high school football team
- First injured 2 y/a
  - Valgus force & patellar dislocation
- Reinjured playing football
  - Valgus force and re-dislocation

Case 1

- Exam:
- 2-3Q lateral patellar translation with soft endpoint
- Patellar apprehension
- Medial patellar TTP
- Mild J sign
- Tight lateral retinaculum



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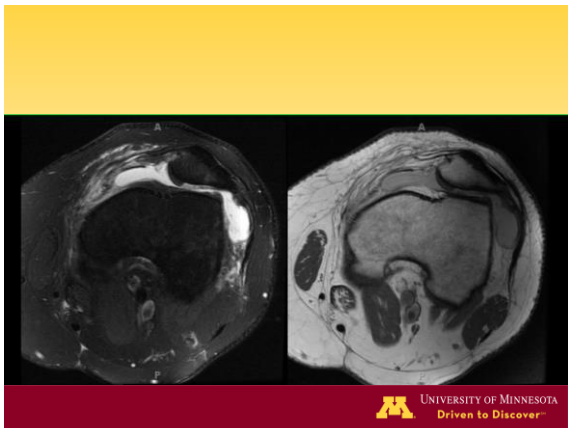
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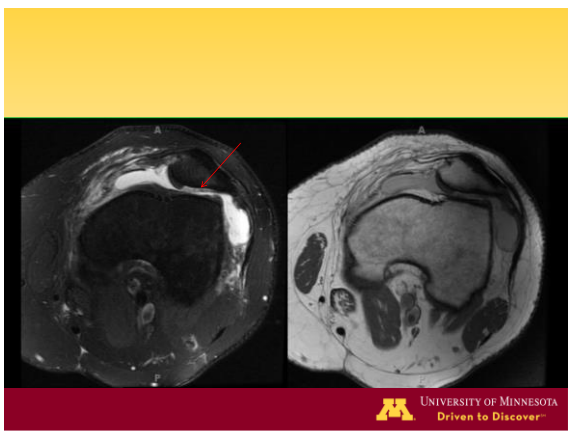
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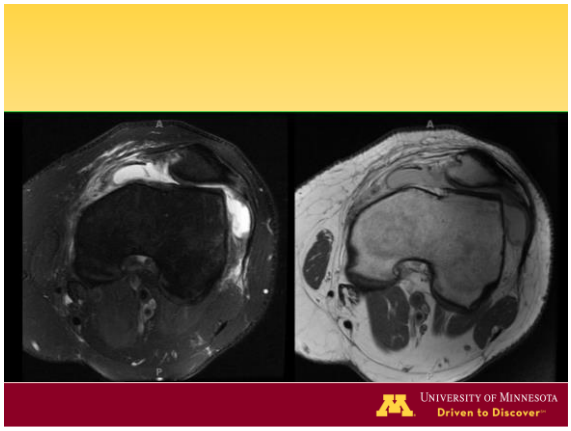
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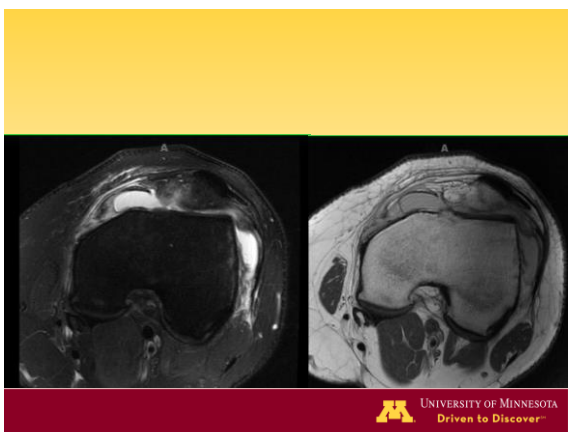
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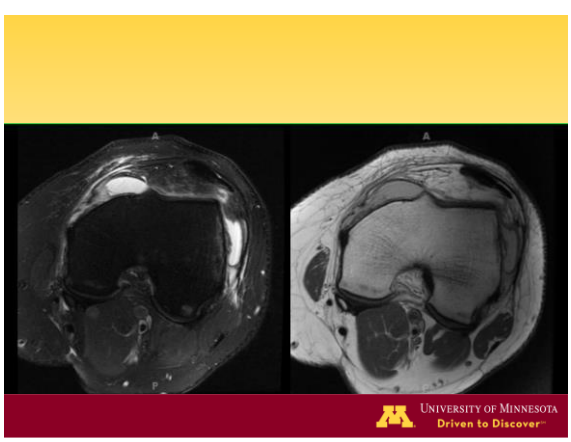
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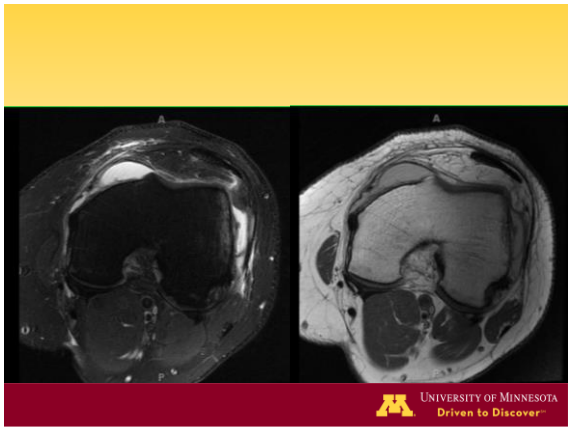
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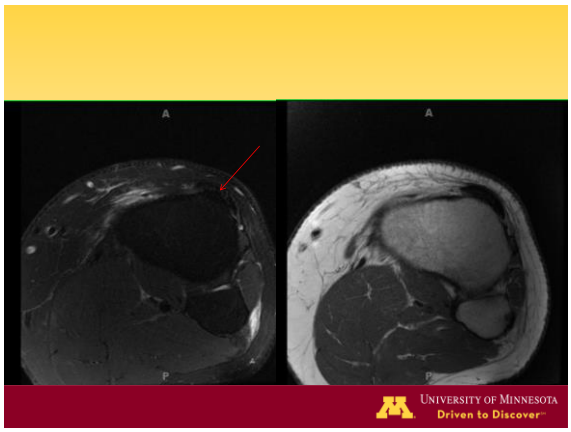
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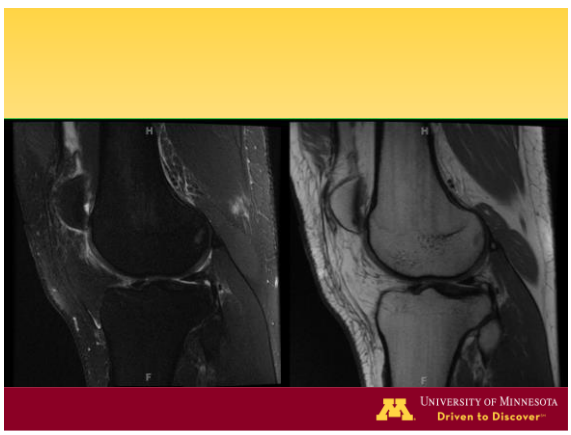
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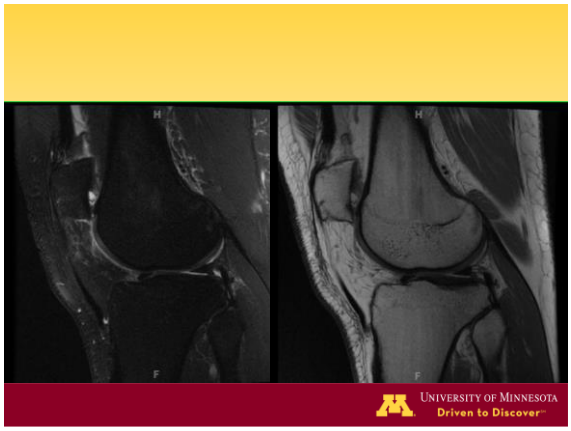
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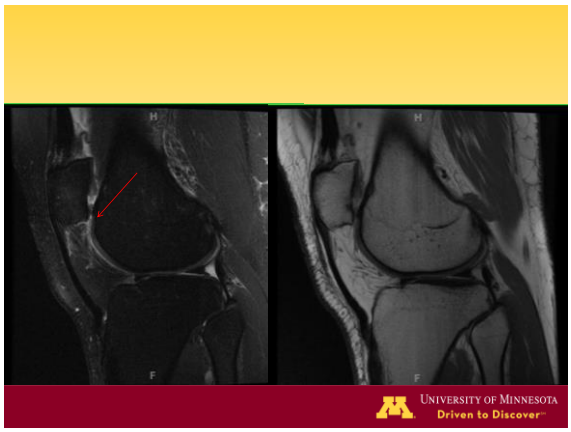
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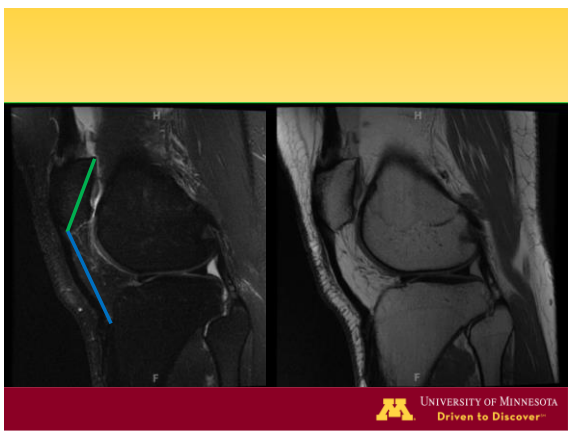
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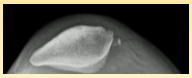
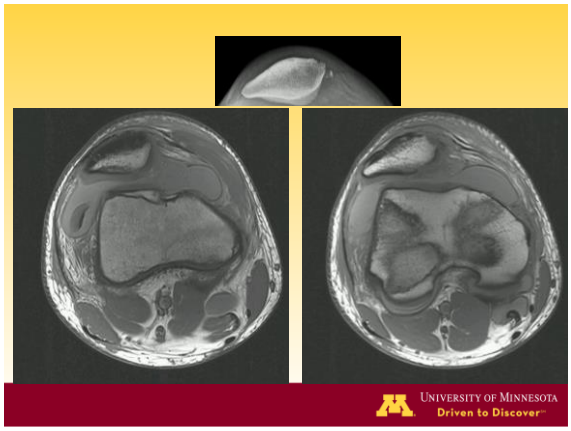
Case 2

- Hx/Exam:

- 15 y/o M
- Non contact injury following spin move playing football
- First injury to the knee
- + effusion, global patellar tenderness, & patellar apprehension

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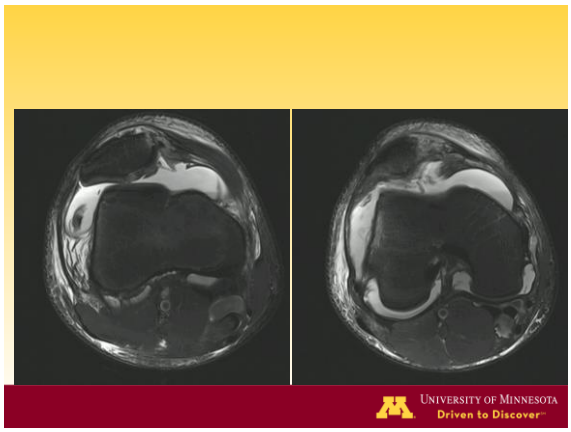
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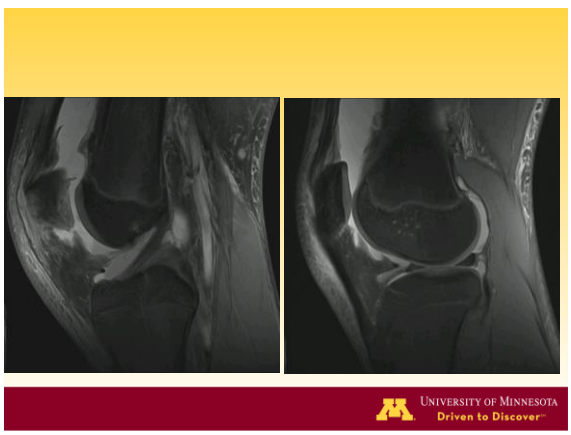
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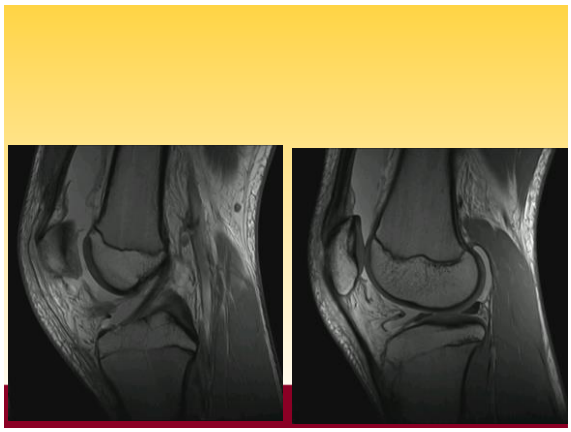


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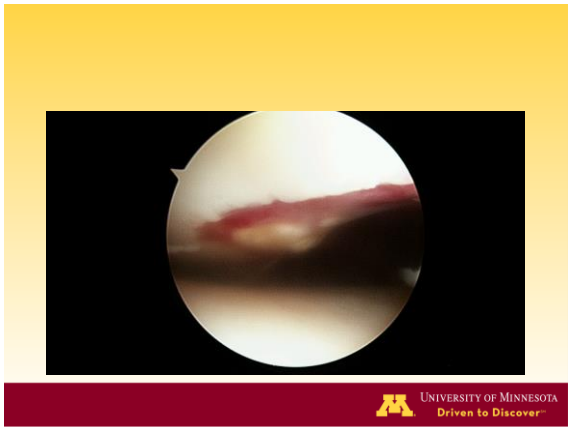
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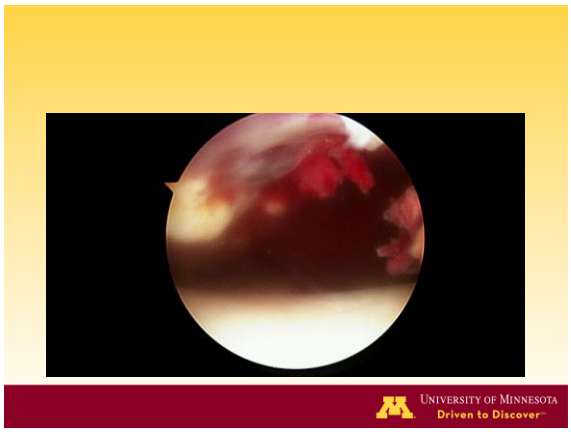
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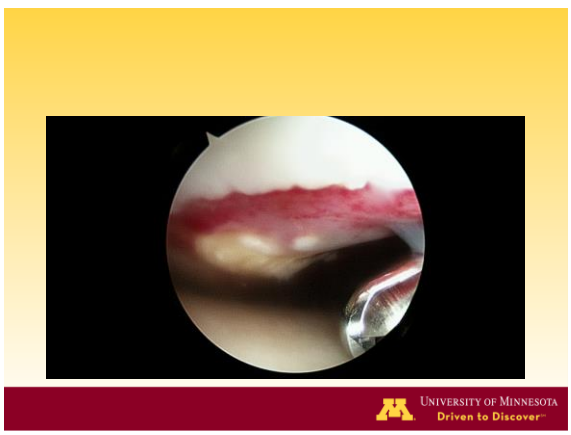
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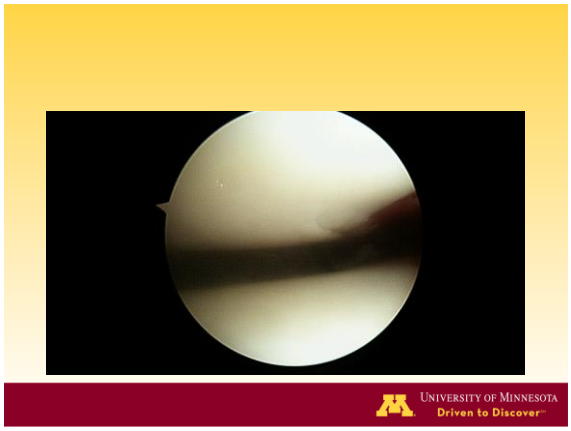
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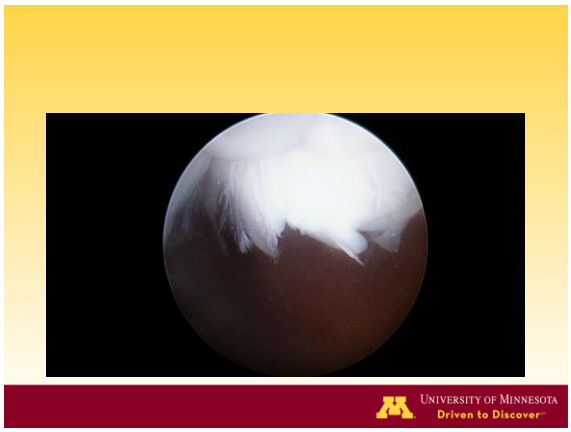
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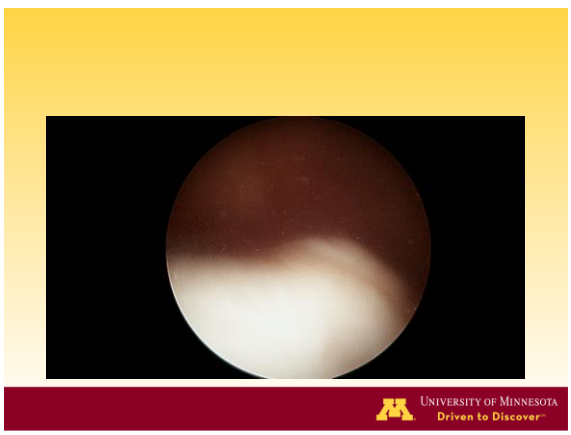
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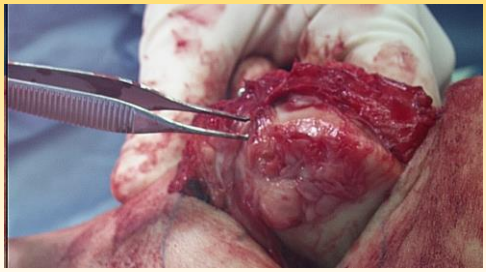

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