DEPARTMENT OF MEDICAL IMAGING
UNIVERSITY OF TORONTO

MSK MRI
Knee: Cartilage and Bone

Joint Department of Medical Imaging
University Health Network, Mount Sinai and Women's College Hospitals

University of Toronto

MRI knee: Cartilage and Bone

Cartilage

- Imaging
- Lesions

Osteochondral lesions

Cartilage “repair”

Bone

- Contusions, Avulsions
- Stress/Insufficiency fractures

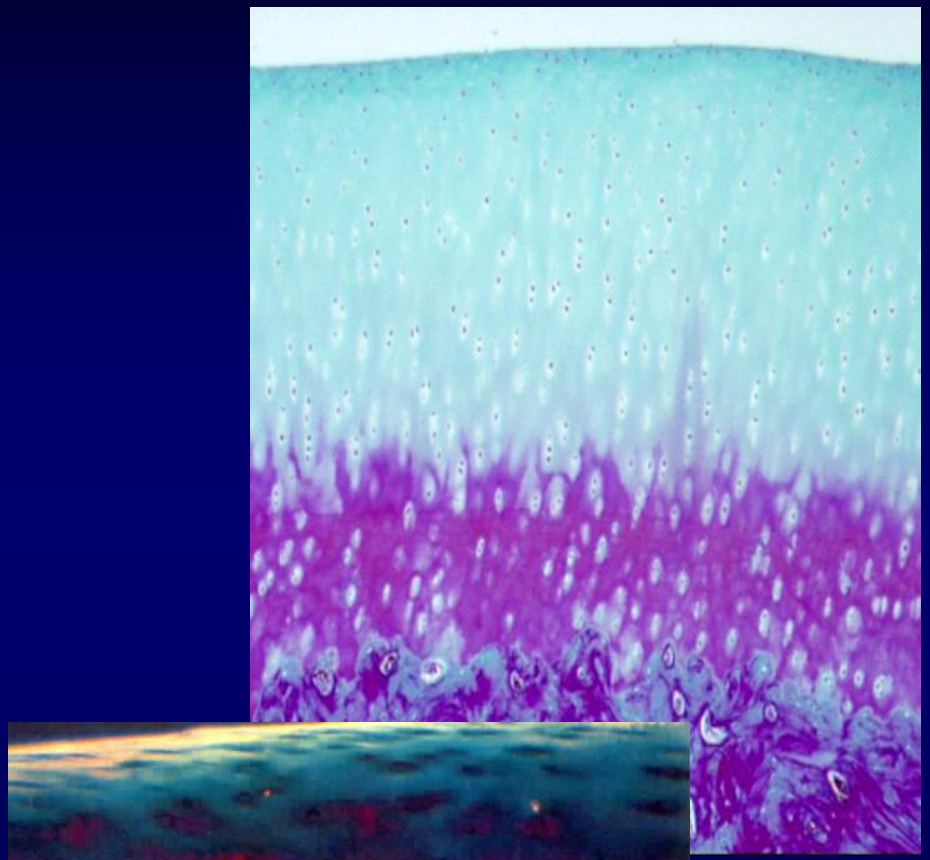
Articular Cartilage

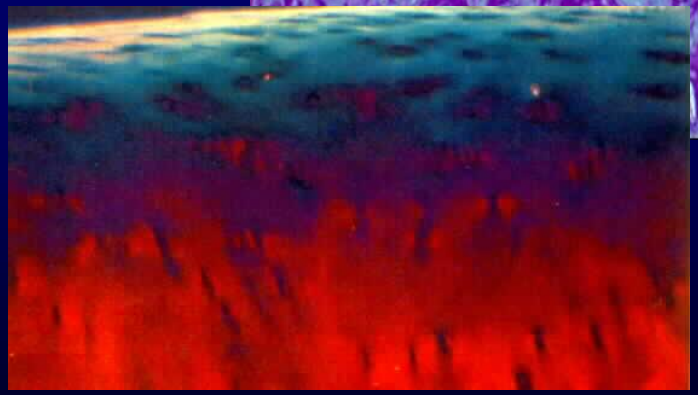
Highly specialized tissue

Complex ultrastructure

Biomechanically - essential

- Load distribution
- Low friction wt bearing surface





Numerous Pulse Sequences Advocated

- Clinical MR imaging assessment of cartilage

- Spin Echo (T1, PD, T2)
- GRE (2D, 3D)
- MR Arthrography (MRA)
- Magnetization Transfer Contrast (MTC)
- Fast (Turbo) Spin Echo
- Fat Suppression T1 Weighted Spoiled GRE

Fat Suppressed T1W SPGR

High spatial resolution – 3D

Excellent contrast

Cartilage(bright) + lesions

- Low signal intensity
- Contour defects

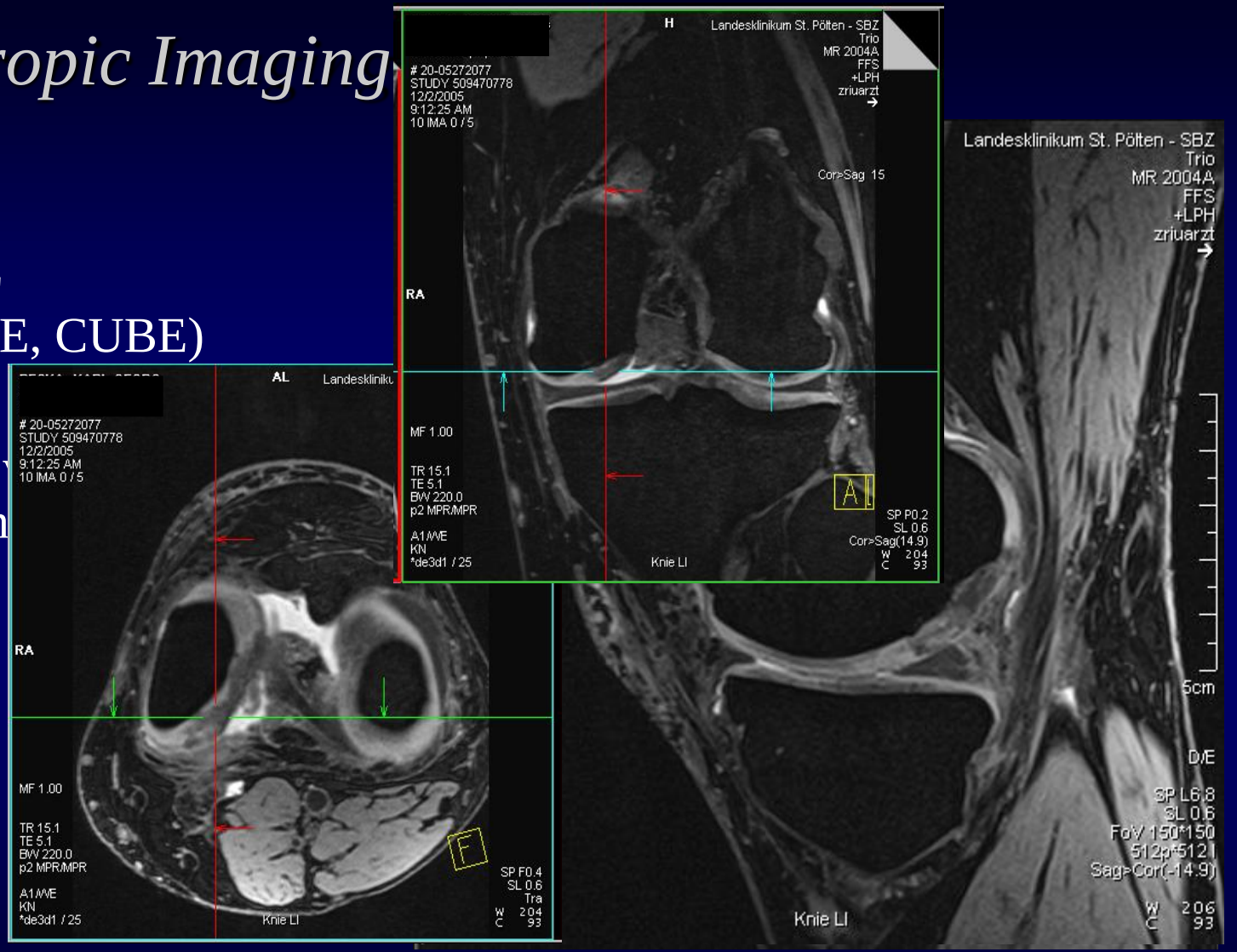
Min internal tissue contrast

Long imaging sequences

Rapid Isotropic Imaging

GRE, FSE/TSE
(SPACE, CUBE)

- Acquisition 3D
  isotropic imagin



Multiplanar recons -3D data set

3D DESS
0.6mm isotropic resolution, 5min scan time
MACI Cartilage Repair

Fast (Turbo) Spin-Echo

High spatial resolution

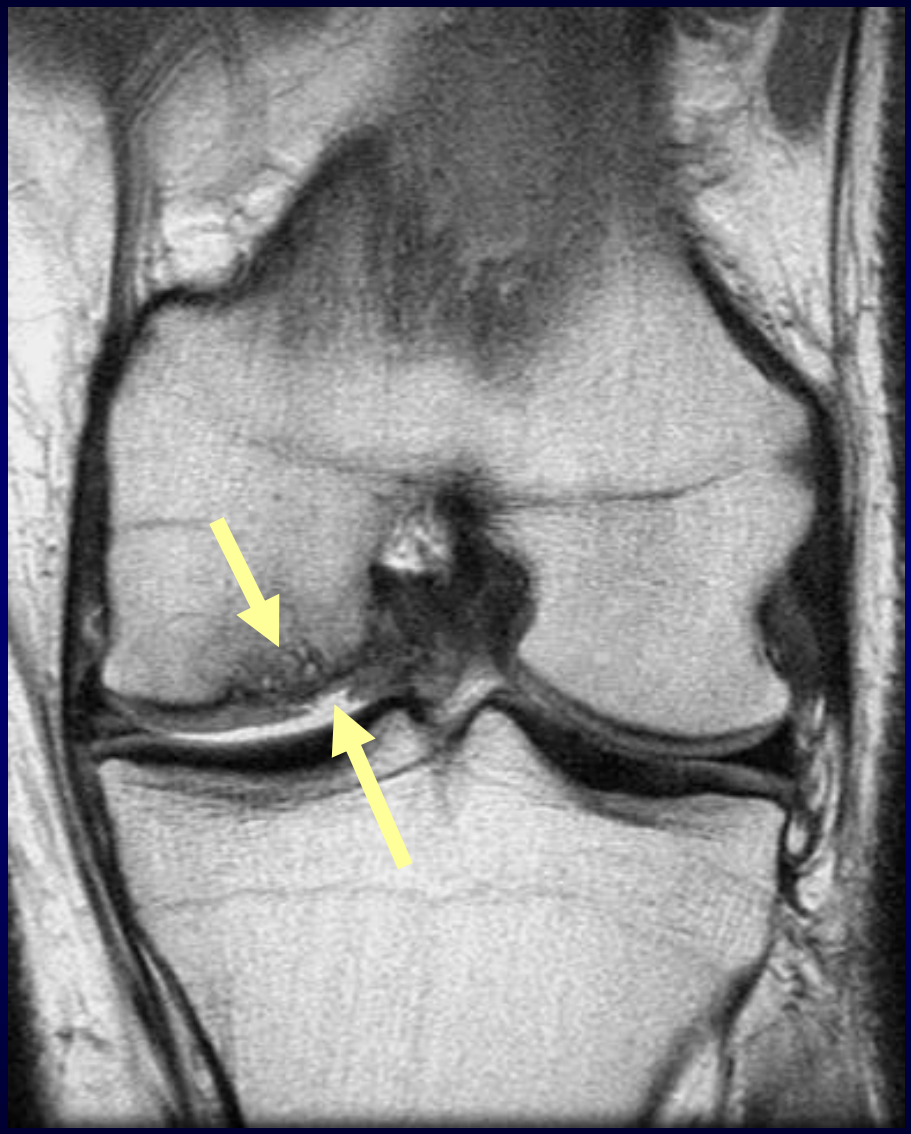
- Fast imaging times
  (512x256, 4-5 min)

Good contrast characteristics

Lesions, internal structure

- Intermediate/T2 W signal
- MT effect collagen

Lesions ↑ signal intensity



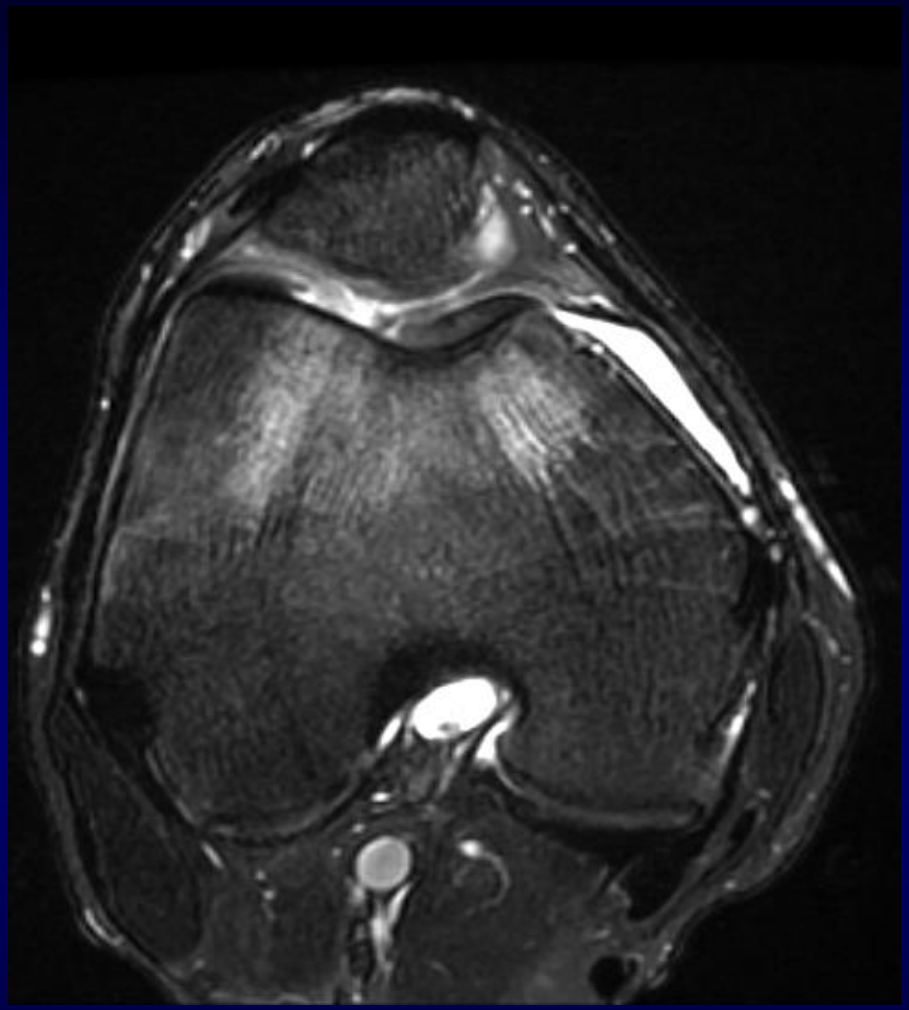
MR Imaging Evaluation Cartilage

	SENSITIVITY	SPECIFICITY
SPGR	75-93 %	93-99 %
FSE	87-94 %	94-99 %

- Disler et al. AJR 1996;167:127-132
- Recht et al. Radiology 1996;198:209-212
- Potter et al. JBJS 1998;80-A:1279-1287
- Bradella et al AJR 1999;172:1073-1080

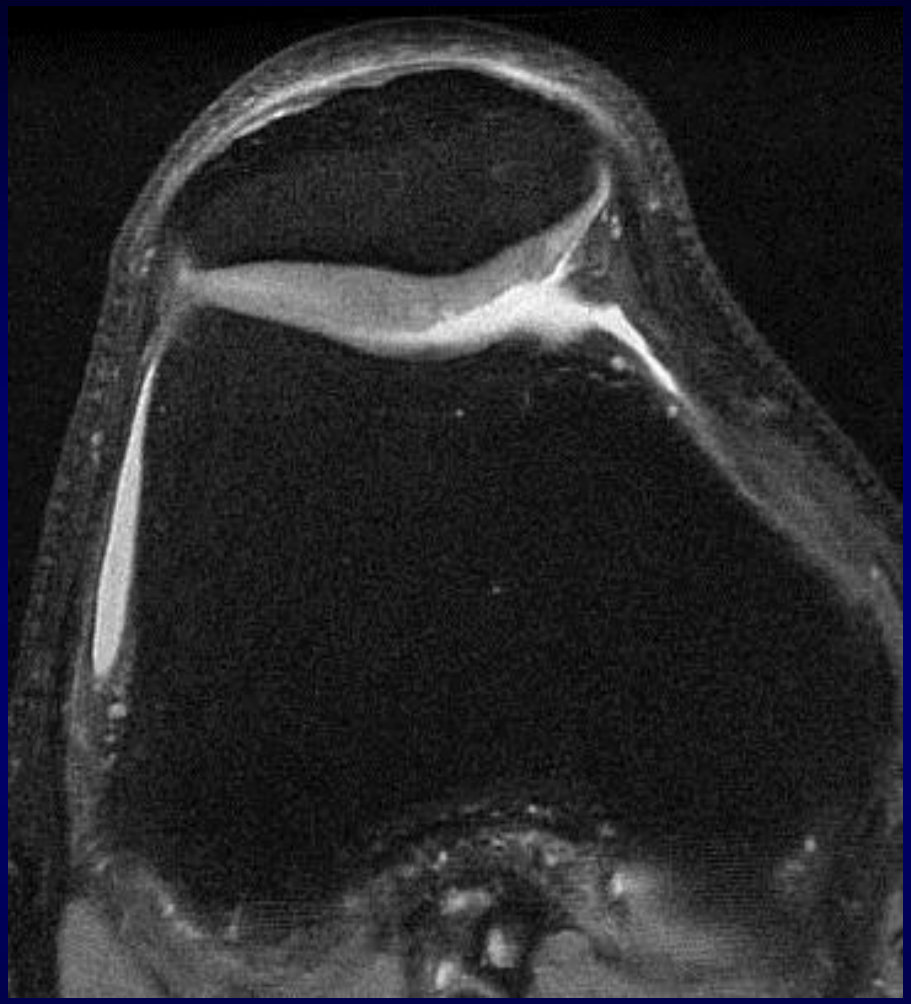
Quad

8 Ch



1.5T

3T



FSE, 4000/15, ETL 8, +32kHz, FOV14cm, 3mm, 512x384, Fat Sat

Articular Cartilage Damage

Degenerative

- Aging/Osteoarthritis

Traumatic

- Chondral/Osteochondral injury

Degenerative Osteoarthritis

- Most common form arthritis

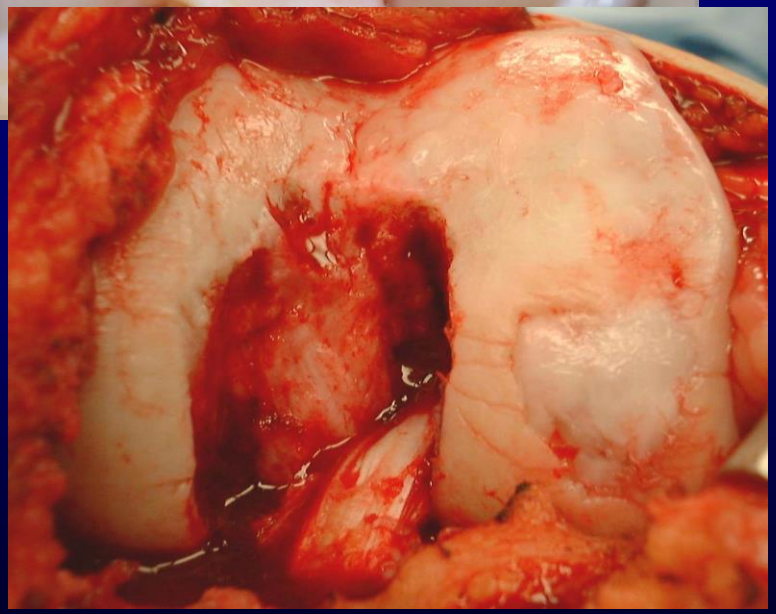
  ~10% of the general population

- Insidious, slowly progressive condition

- Major - disability worldwide

  ↑ incidence - aging population

Economic perspective $65 billion in US
(CDC, 1999)

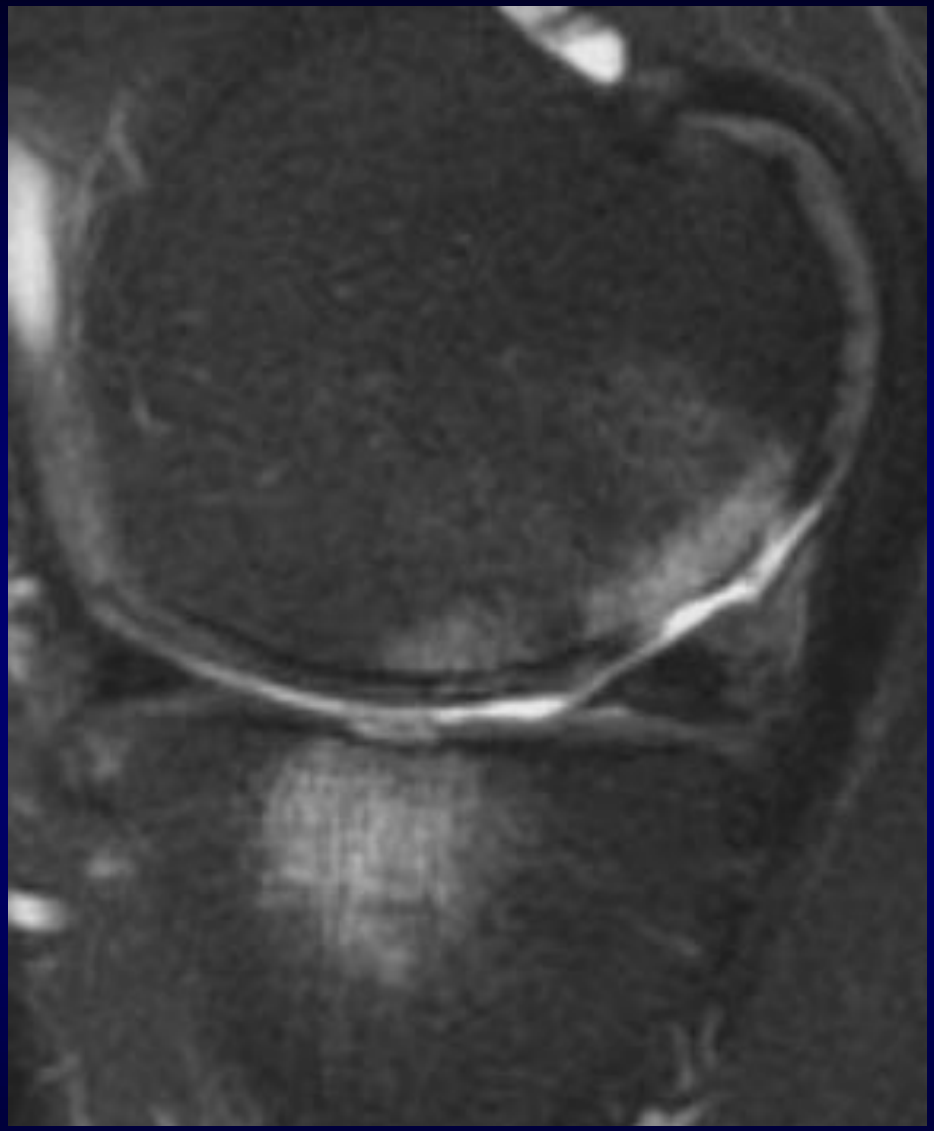


Major advances OA - early detection/diagnosis disease - MR Imaging

MR imaging features OA

- Obtusely marginated lesions
- Diffuse cartilage thinning
- Multiple kissing defects - varying size and depth

  - Typical locations
    - Medial TibioFemoral
    - Patellofemoral
  - Abnormal biomechanical stress/trauma



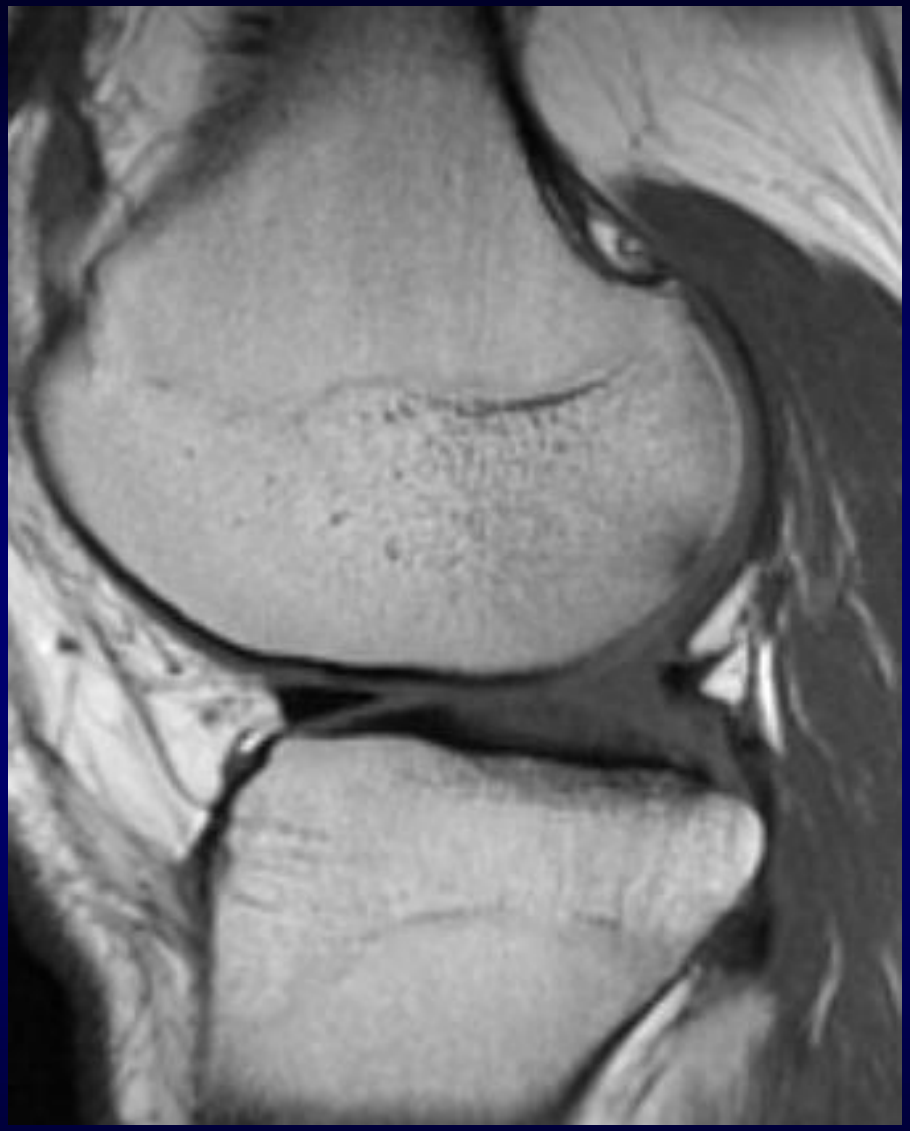
Mensicectomy - etiologic factor osteoarthritis

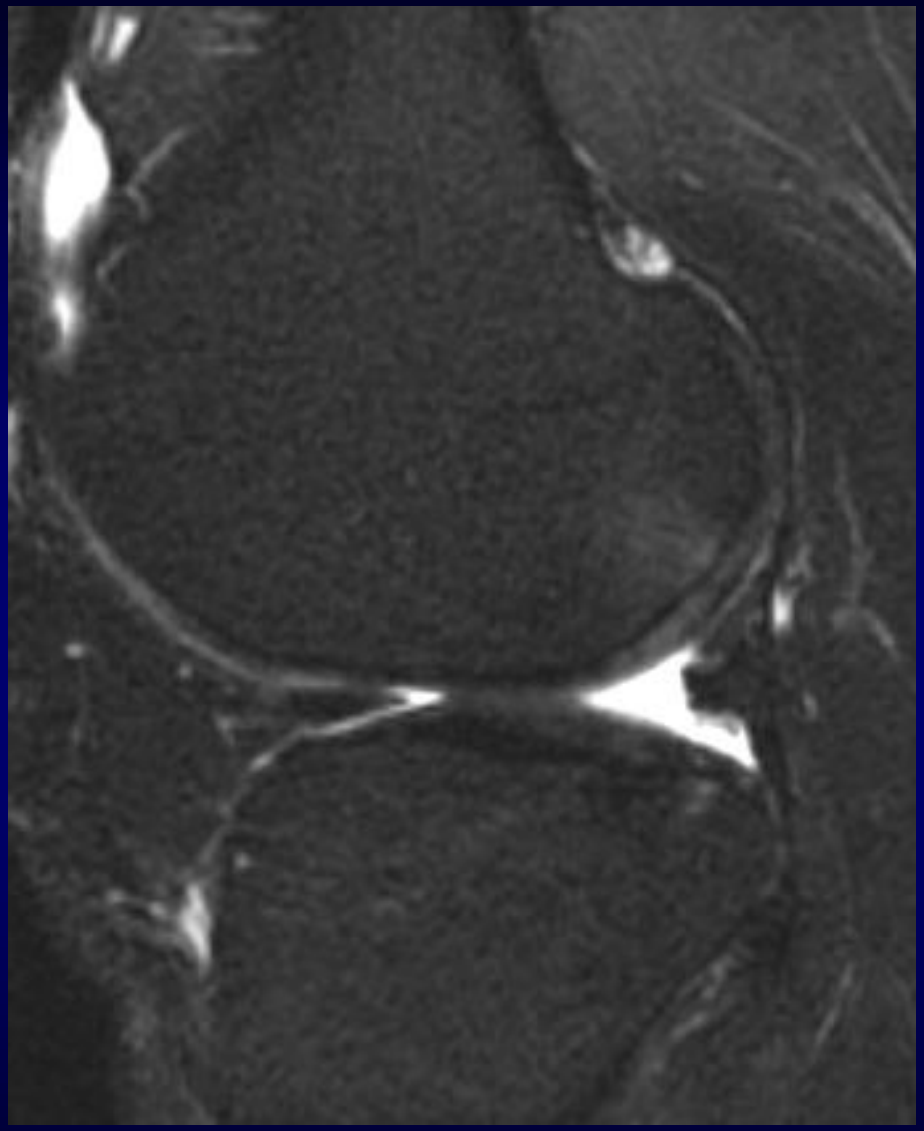
Amount OA $\leftrightarrow$ Amount meniscus removed

Major principle meniscal surgery

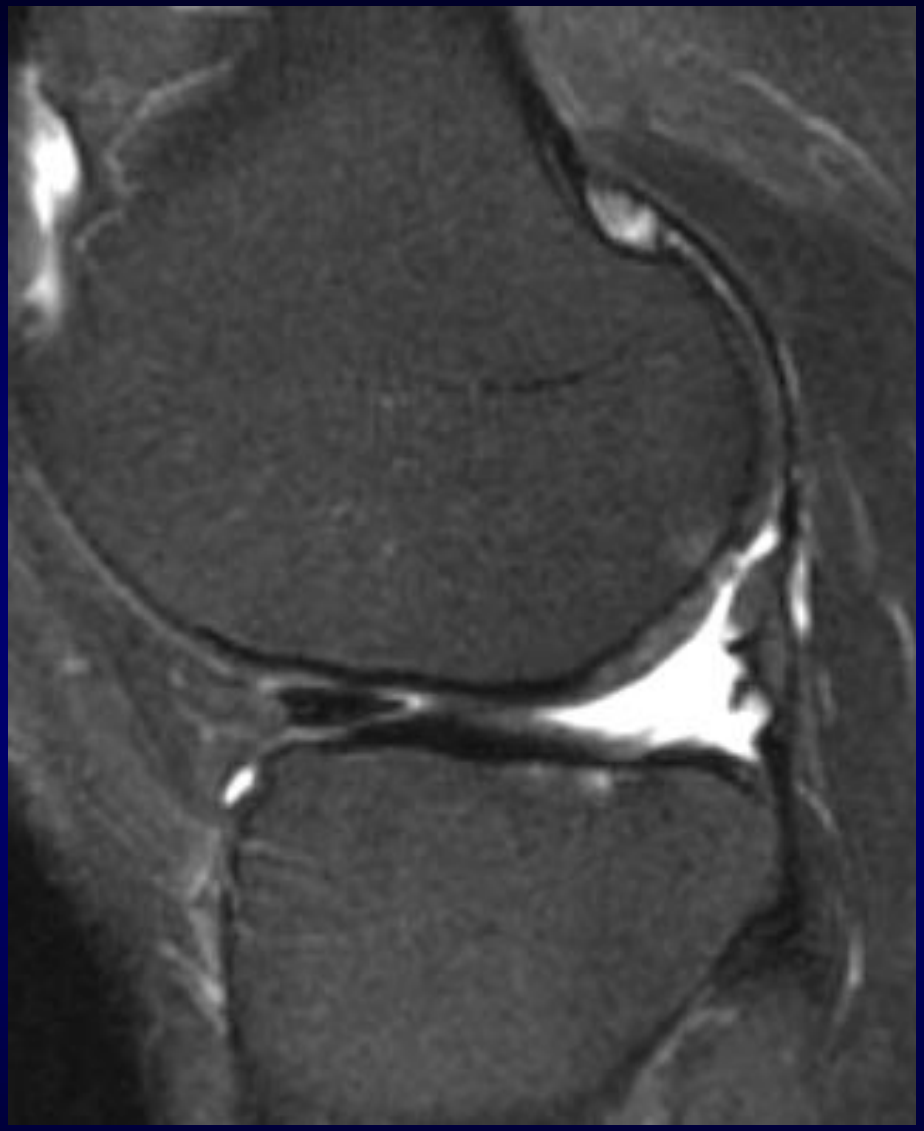
- Preservation as much meniscal tissue as possible

Fairbanks TJ. J Bone Joint Surg [Br] 1948; 30:664
Cox JS, et al. Clin Orthop Rel Res 1975: 10:178

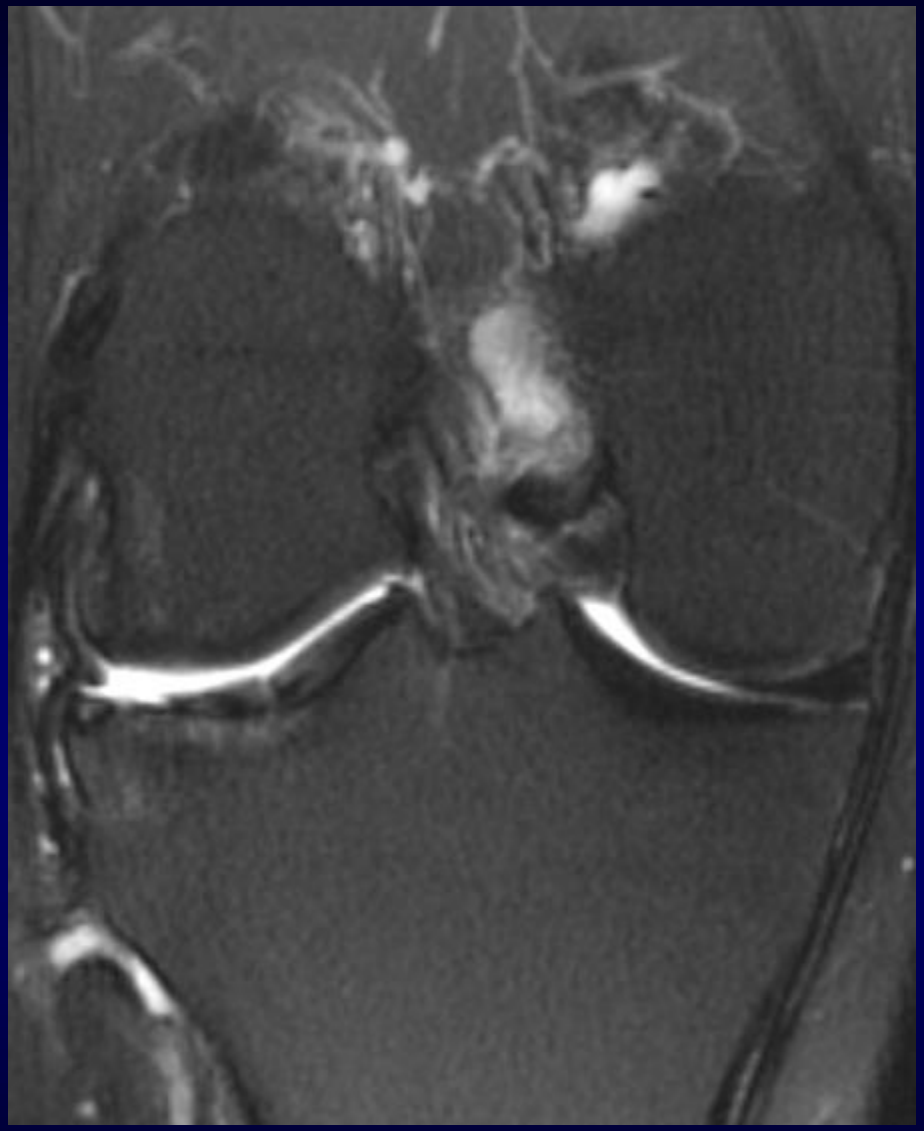




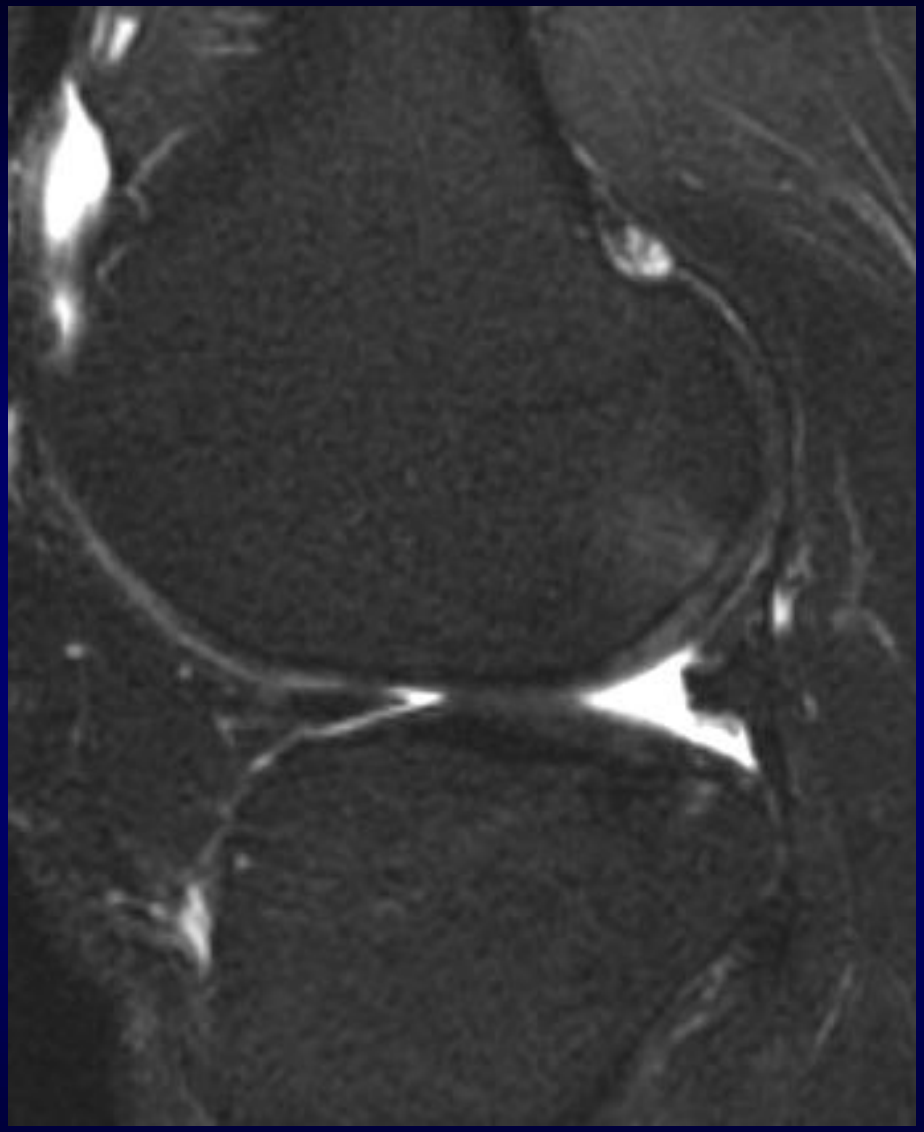
Baseline exam: 1 year postop



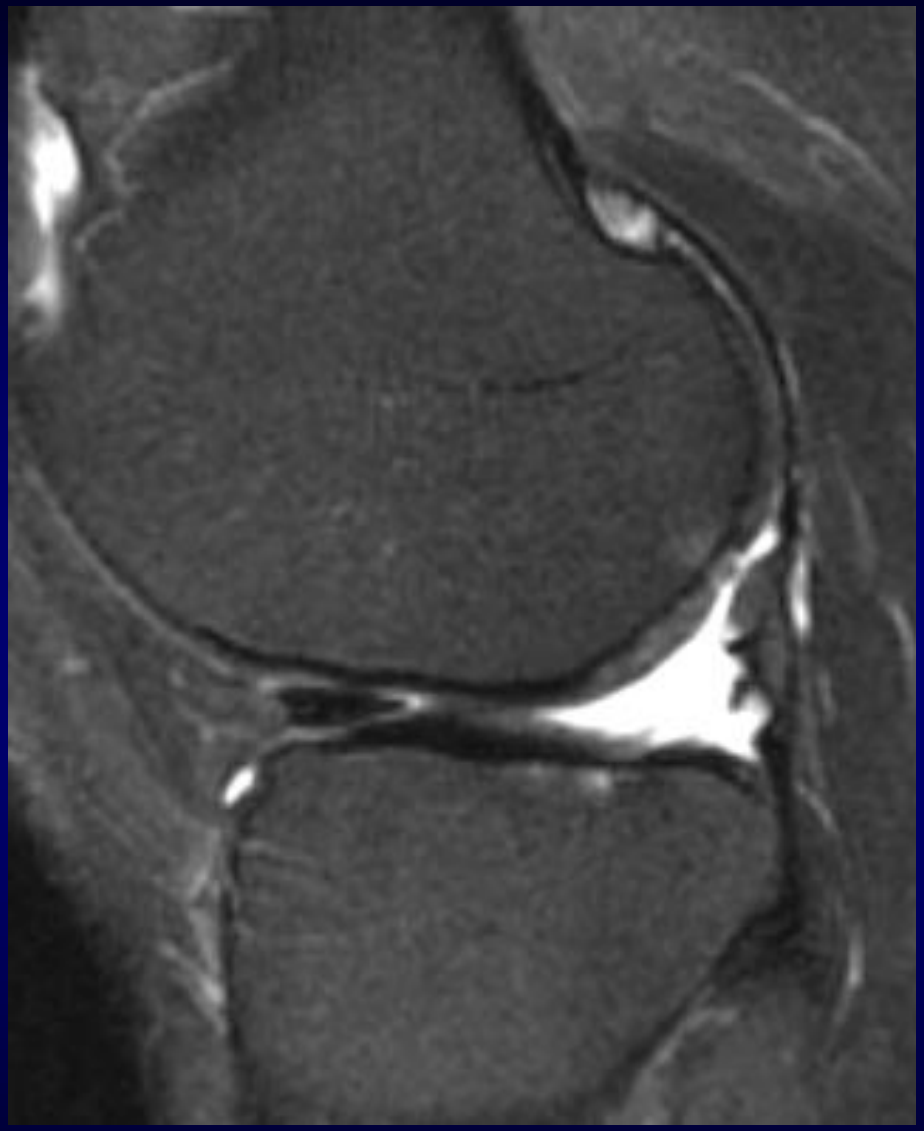
Follow-up exam: 2 years postop



Follow-up exam: 2 years postop



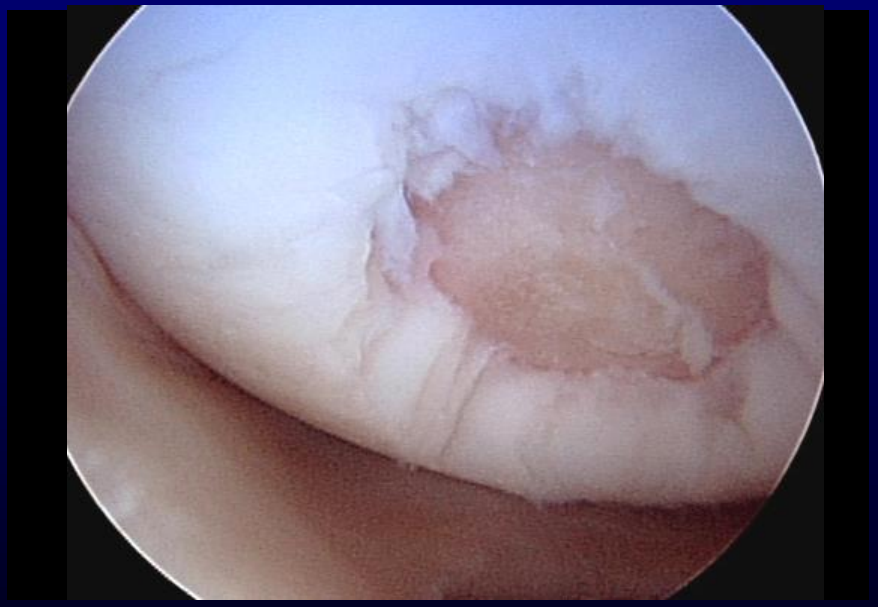
1 year postop



2 years postop

Traumatic Chondral Injury

- Defects often solitary
- Can be variable in size
- Acutely angled margins
- Partial vs Full Thickness
  purely chondral or
  osteochondral



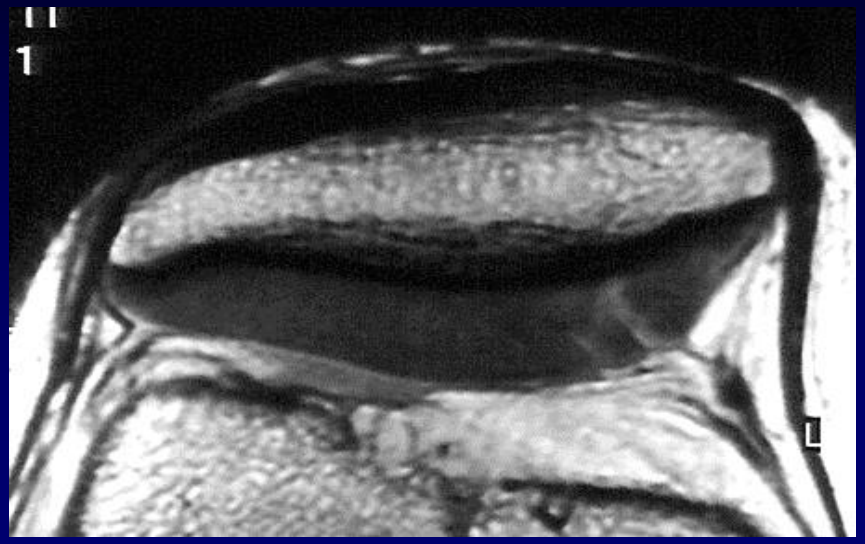
Traumatic Chondral Injury

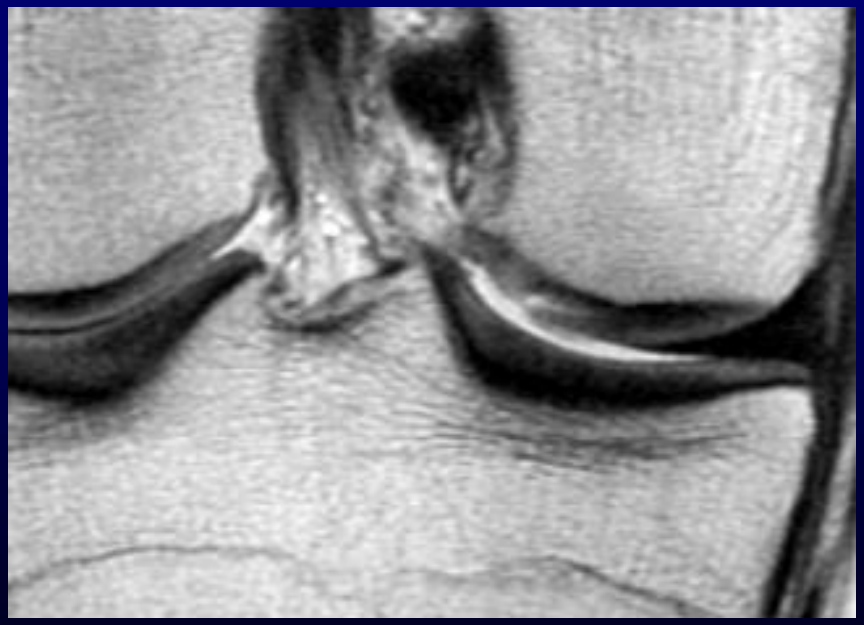
Adults

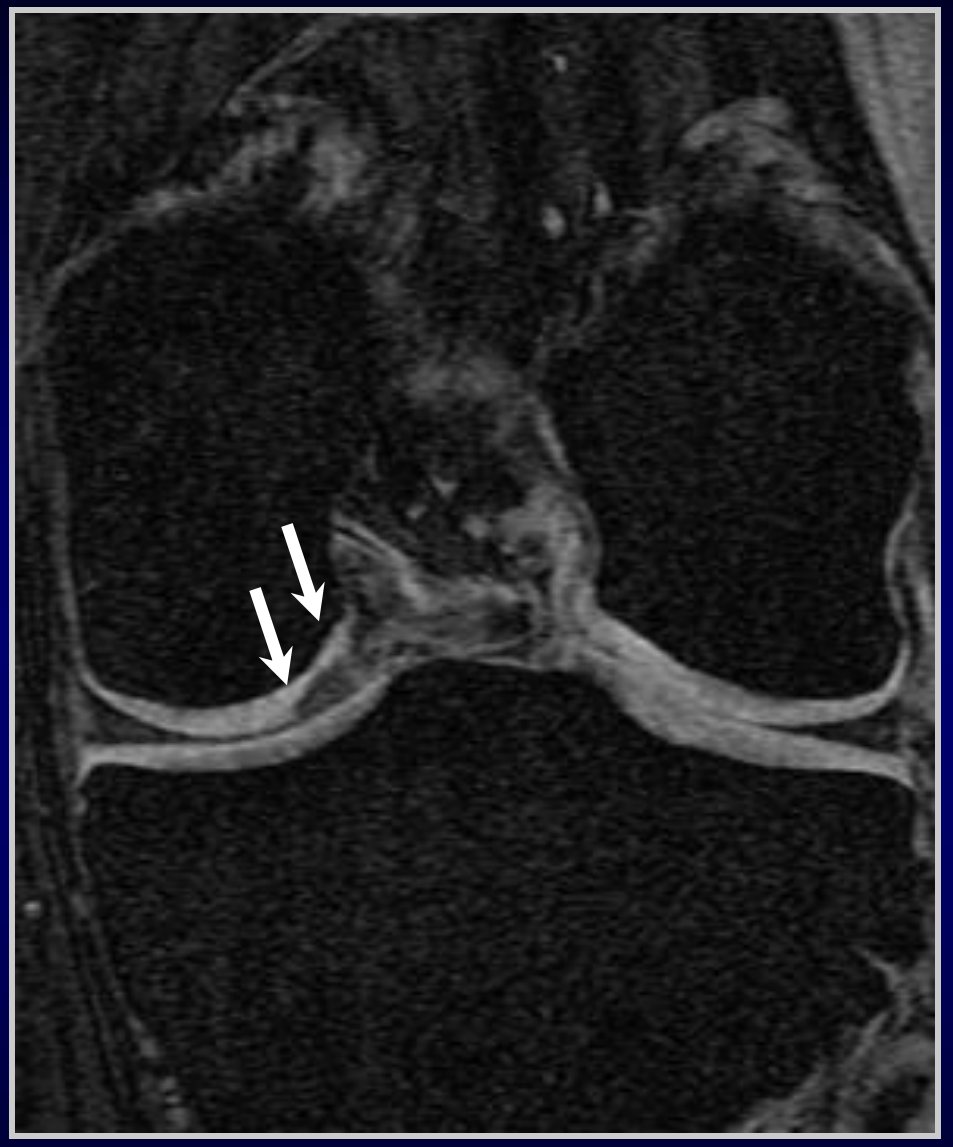
- Tidemark zone (cart/bone)
- Weak link – wt bearing cart

Rotary / Shearing forces

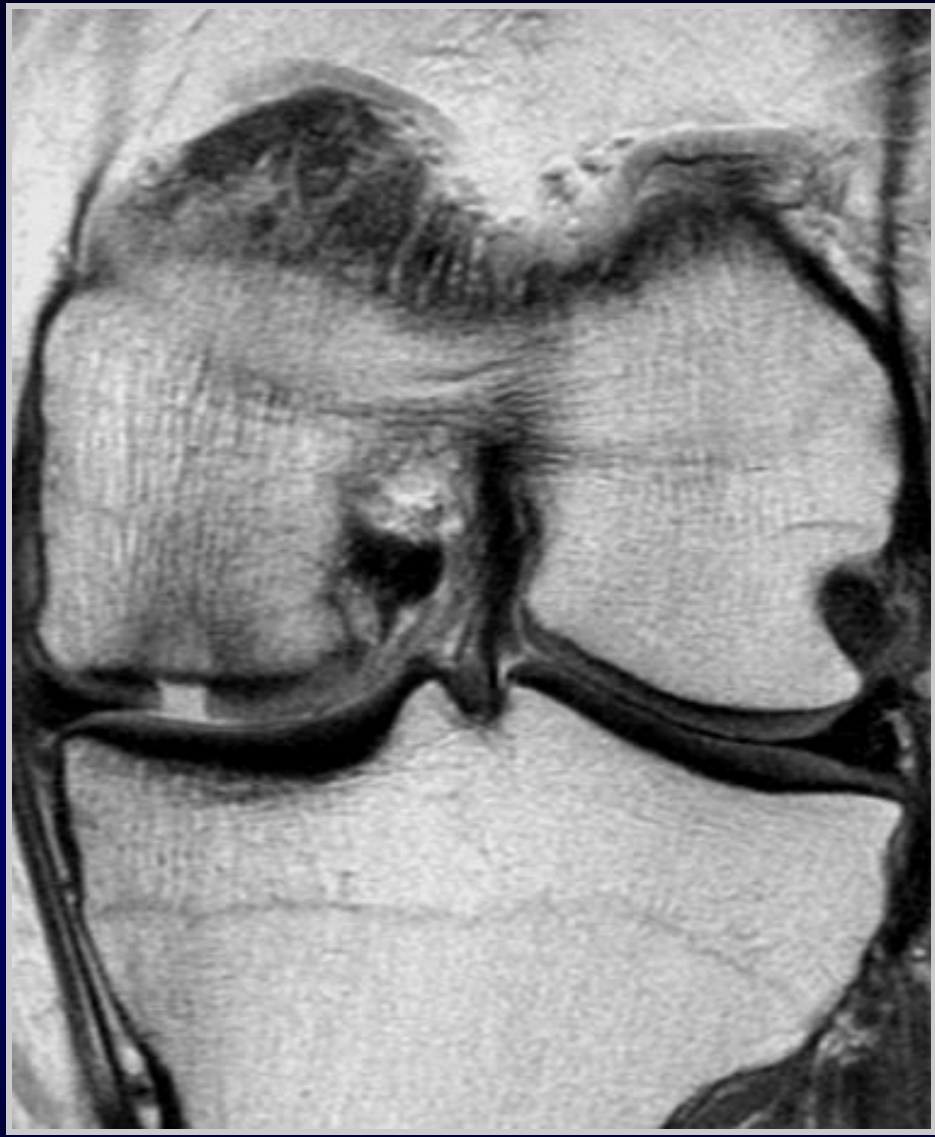
- Fissures
- Flap Tears
- Delamination
- Focal Defects







Partial Thickness – Chondral Injuries

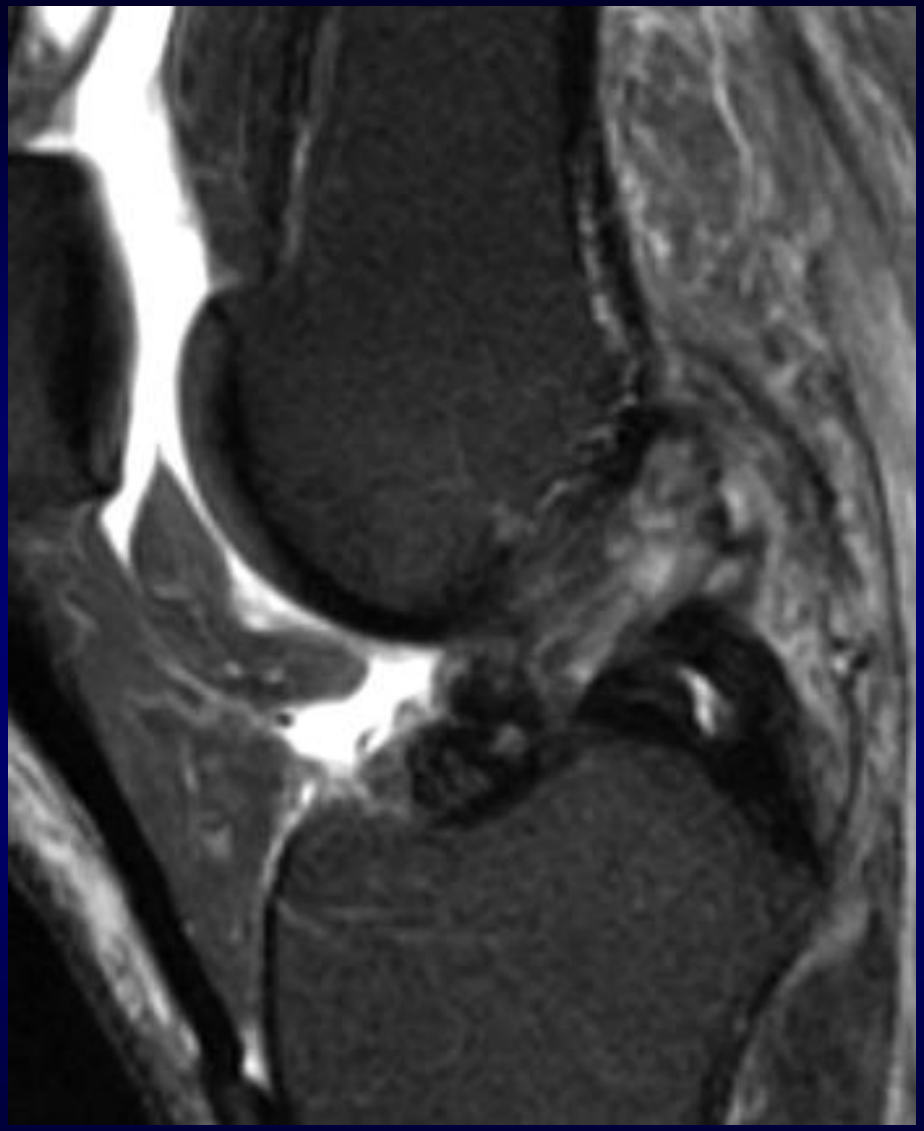


Full Thickness – Acute Chondral Injuries

* Underlying Marrow Edema

Full Thickness – Acute Chondral Injury
Displaced Chondral Fragment

Full Thickness – Acute Chondral Injury
Displaced Chondral Fragment



Complete ACL Tear – Repeated Pivot Injuries

Complete ACL Tear – Repeated Pivot Injuries – Cartilage and Meniscal

Description of lesions

type of lesion

location and severity

reproducible and acceptable to referring surgeons

Numerous classification systems proposed

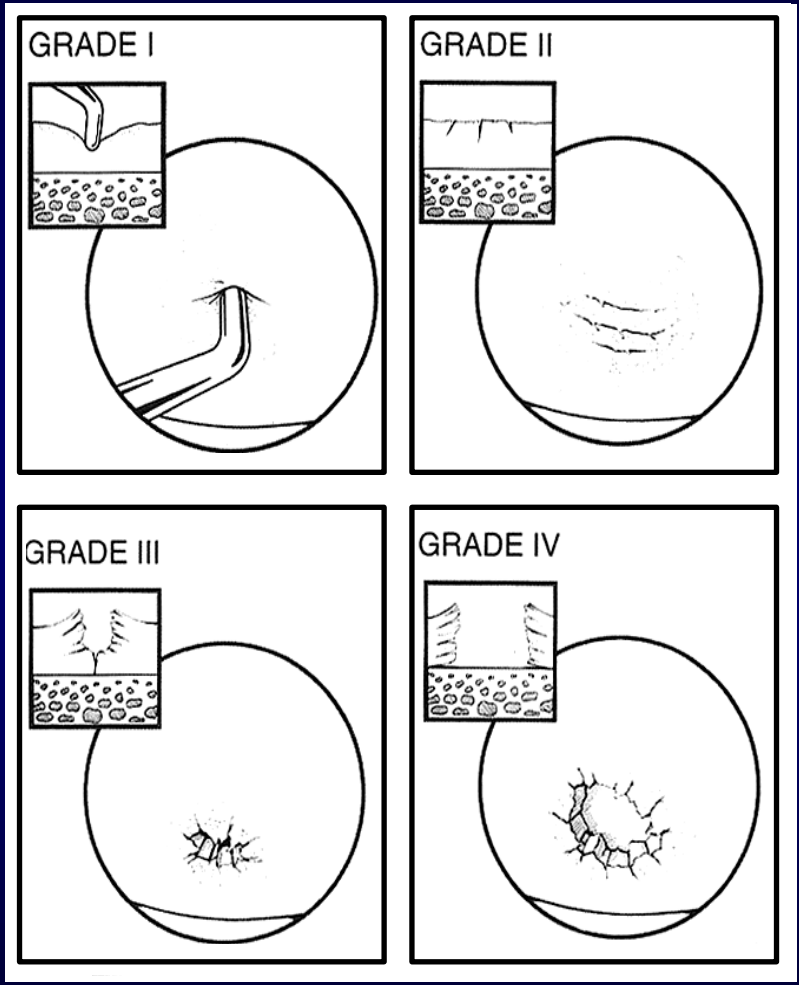
Staging / Grading cartilage lesions

Histology, Surgical, Imaging - Radiographs, MRI

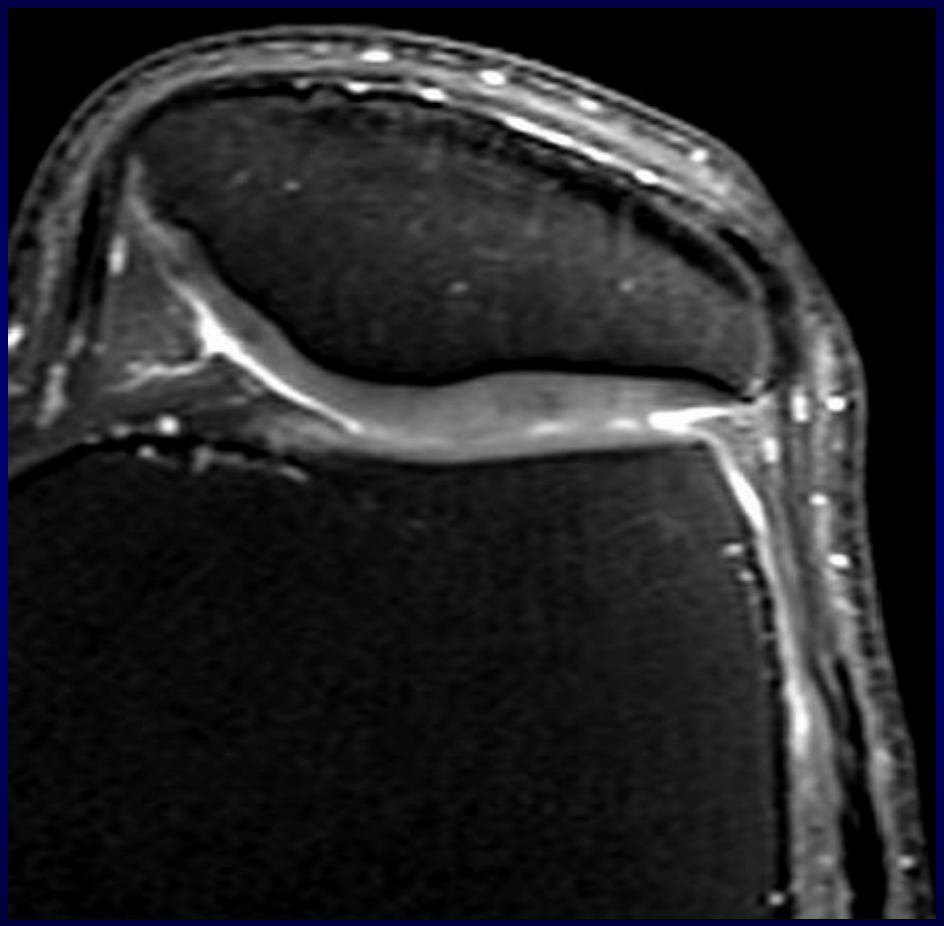
- WORMS (Whole Organ MR Scoring 2003)
- ICRS (Surgical 2000)
- Noyes (Surgical 1989)
- Outerbridge (Surgical 1961, Modified 1985)

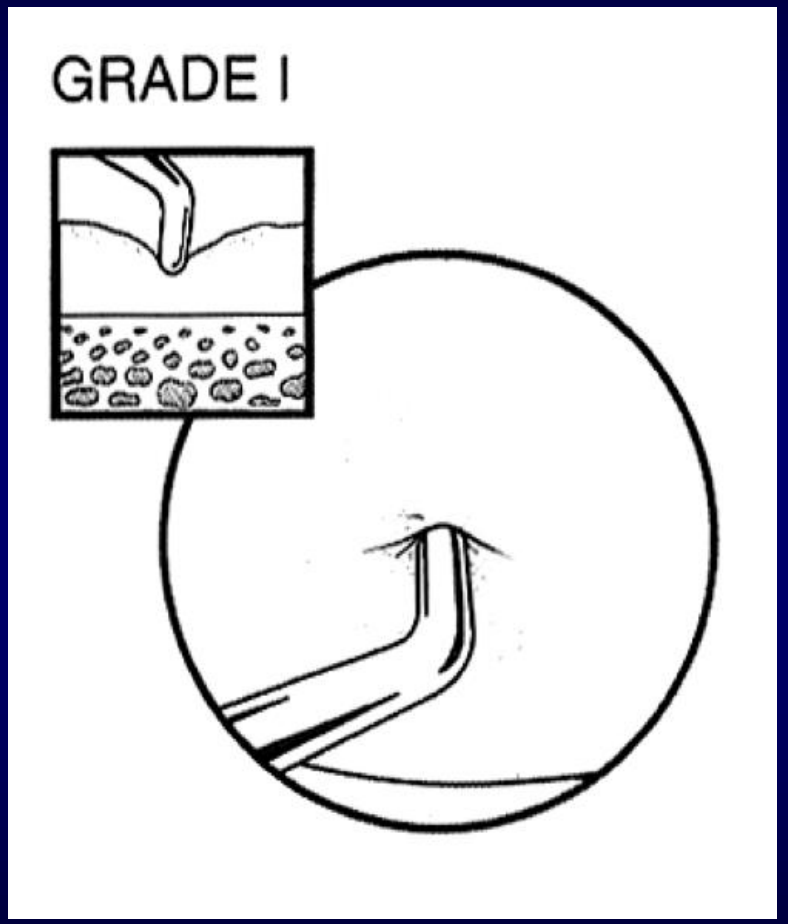
Grading/Severity: Outerbridge classification

- Softening and swelling
- Less than half thickness
- Full thickness
- Erosion to subchondral bone



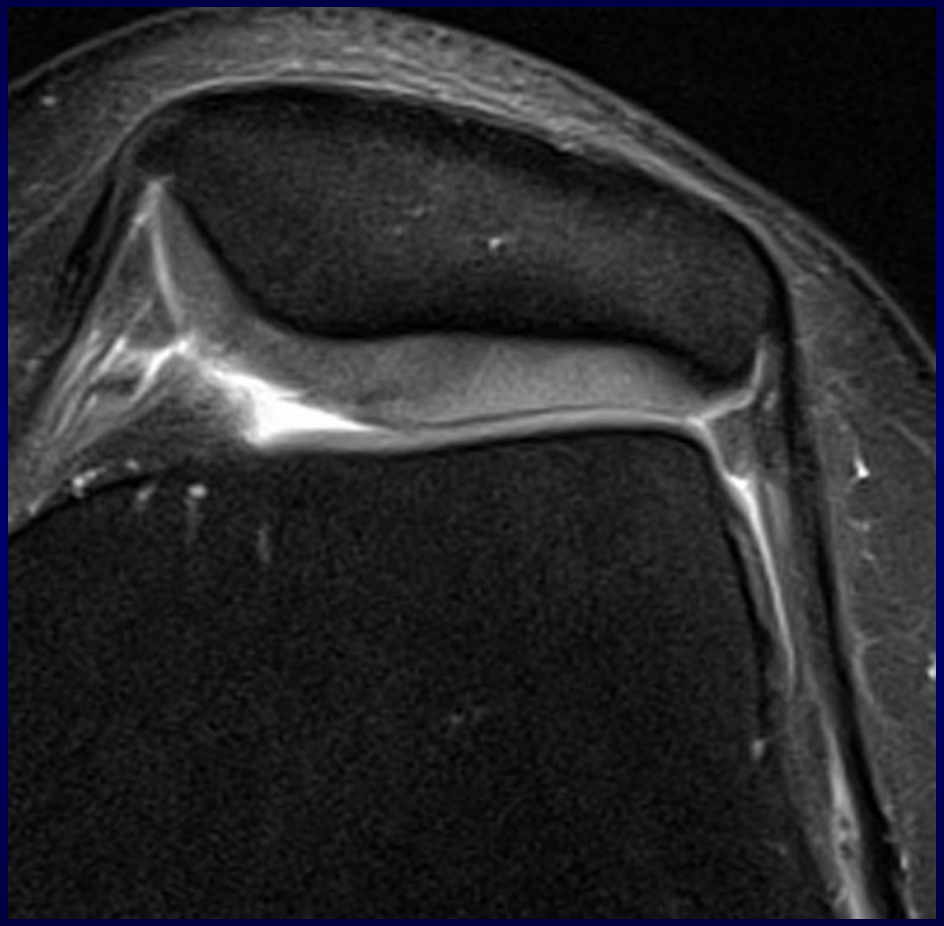
Grade I: softening and swelling

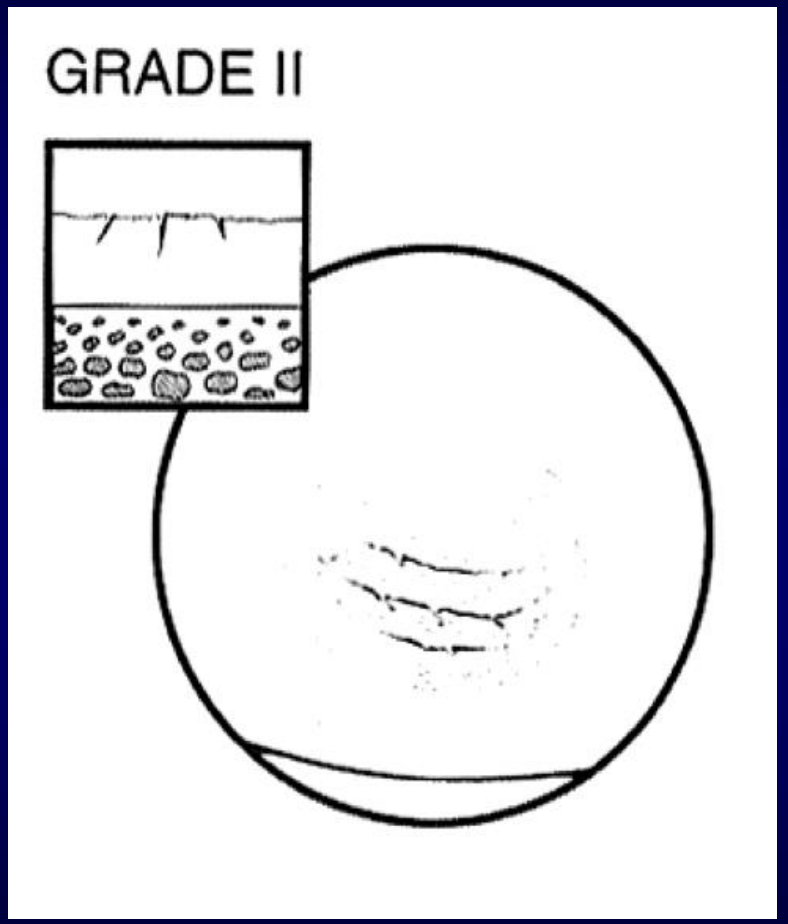




“abnormal cartilage without obvious erosion or fissure”

Grade II: partial thickness

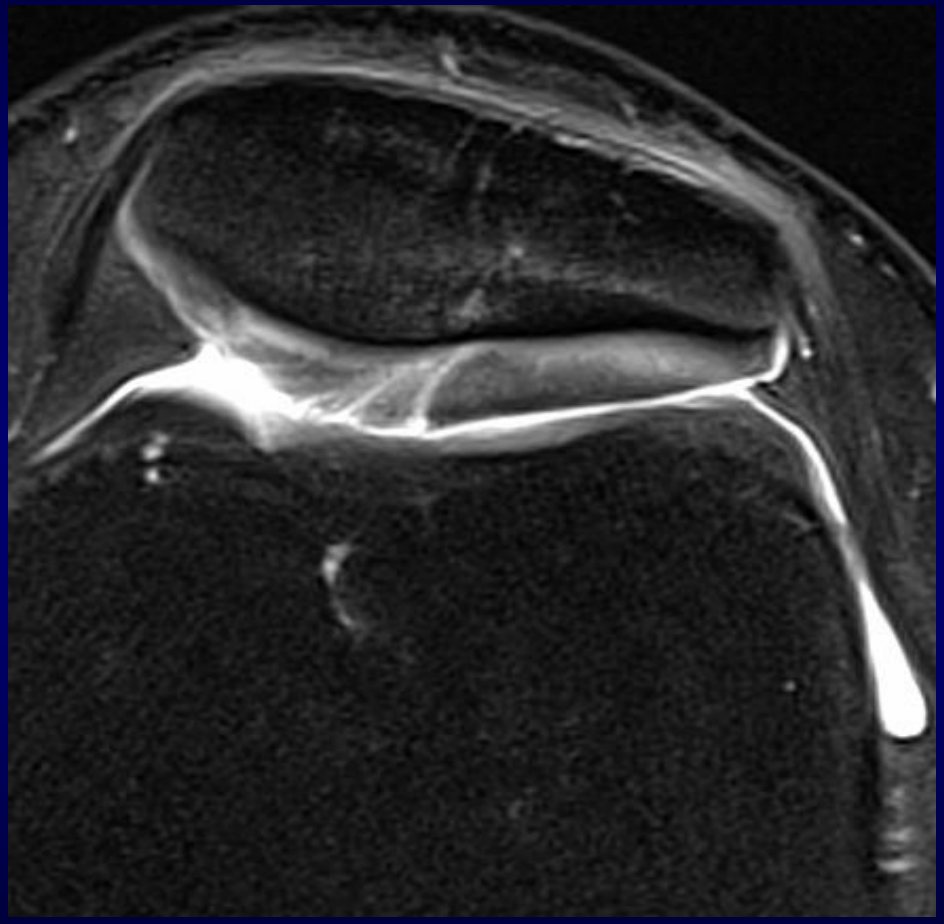


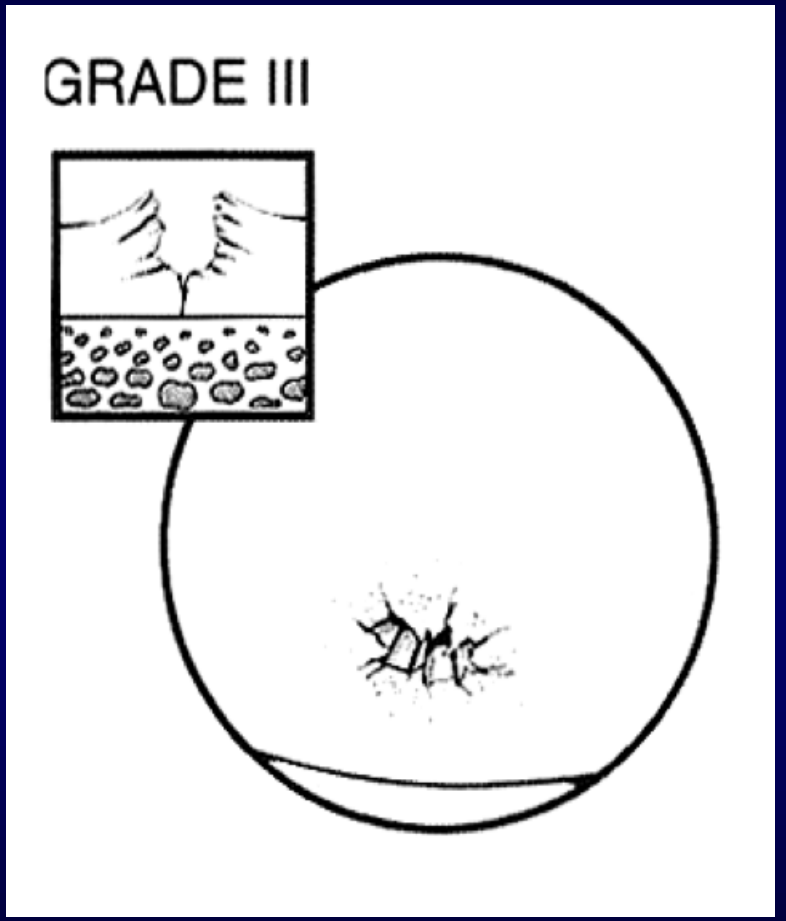


“fissure or erosion involving less than ½ thickness”

Outerbridge classification
Grade 2 medial femoral condyle

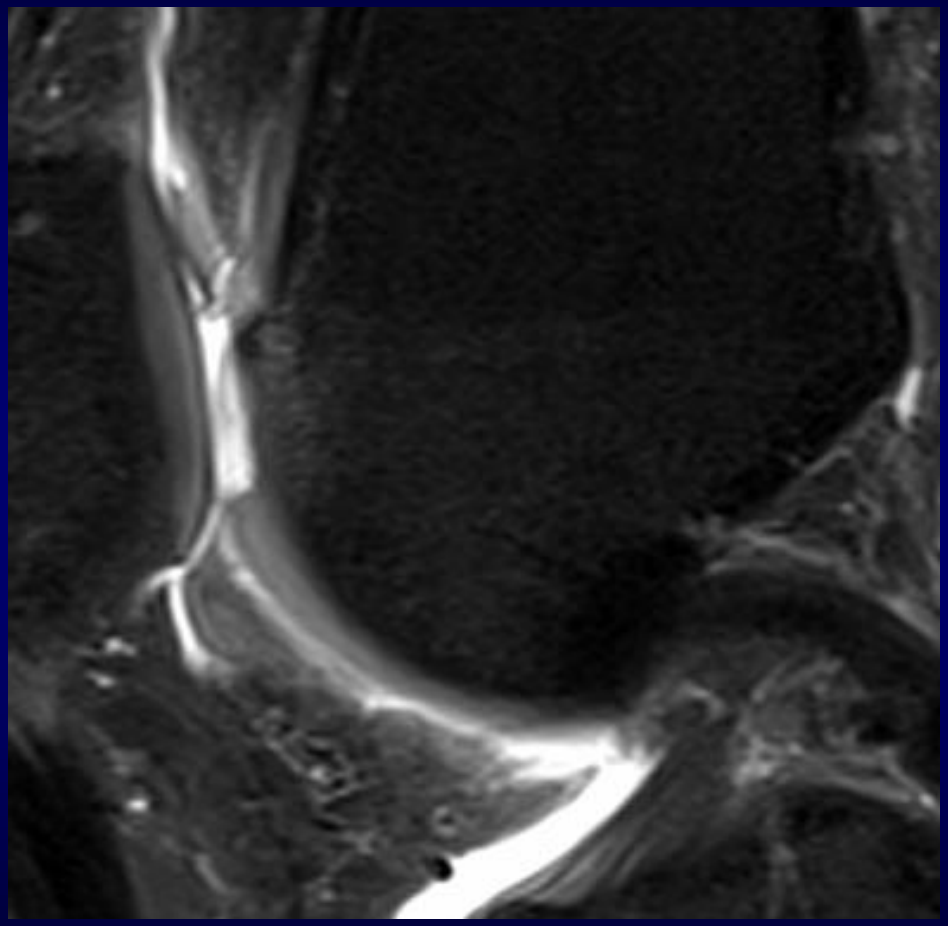
Grade III: full thickness fissure

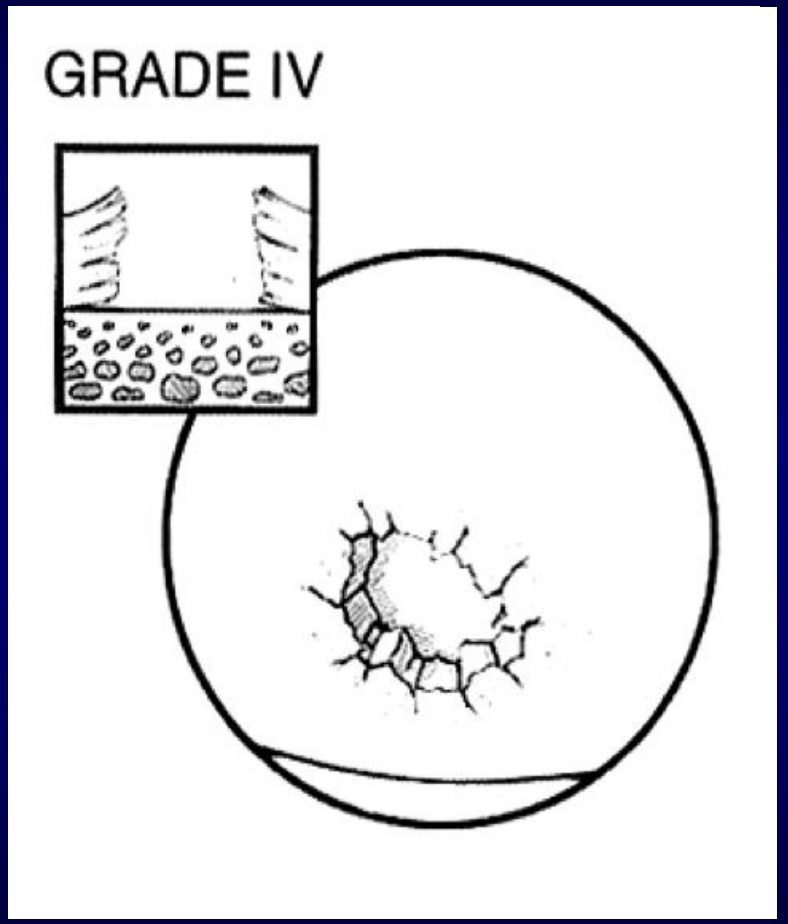




“full thickness defect or fissure”

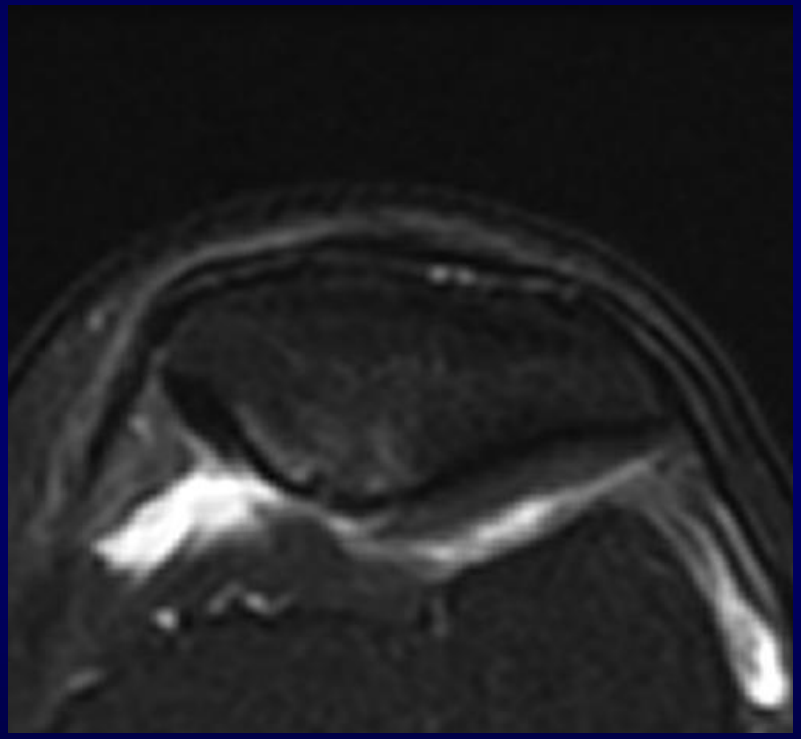
Grade IV

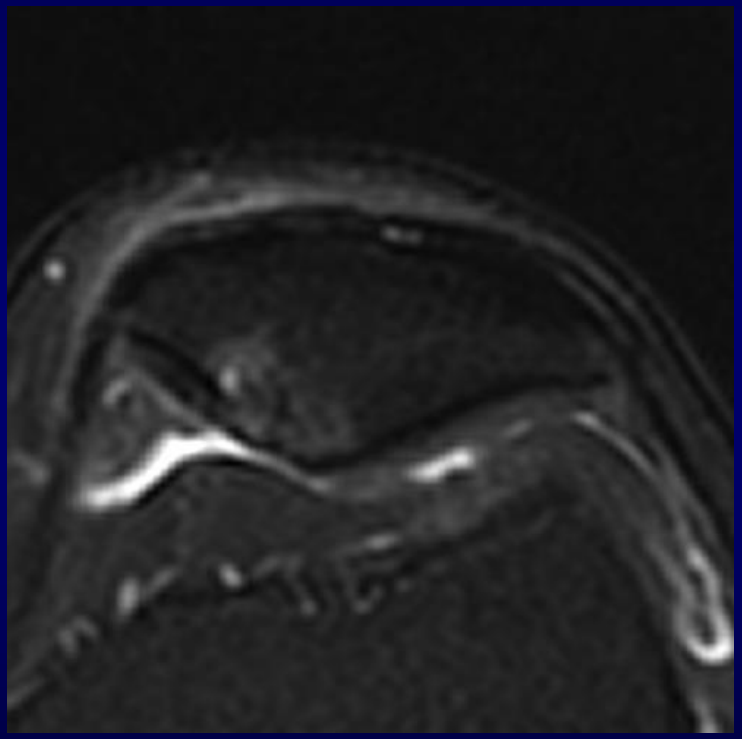




“chondral defect with subchondral changes”

Outerbridge classification
Grade 4 apex and medial facet patella





Osteochondral Injury / OCD

Injury cartilage + underlying subchondral bone

- In situ — Overlying cartilage intact
- Partially detached — Cartilage partially disrupted
- Completely detached — Cartilage completely disrupted

- MRI - NB information; lesion size, status of overlying cartilage and subchondral bone, edema or cysts, possible loose bodies

- Osteochondritis Dissecans - common young adults and children. repetitive microtraumatic impact loading

Osteochondritis Dissecans

- 2 discrete forms – clinical outcome / instability

Juvenile OCD (open growth plates)

- high rate healing - spontaneous healing >50% of cases

Adult OCD (closed physes)

- greater propensity for instability → intervention

Instability

- adults – rim ↑T2, or interface cysts
- children – inner ↑T2 + outer ↓T2, breaks subchondral plate, cysts - multiple / large (>5mm)

Osteochondral Injury / OCD

The presence of :

- a high T2 signal intensity rim
- cysts surrounding an OCD lesion
- a high T2 signal intensity fracture line extending through the articular cartilage overlying an OCD lesion
- a fluid-filled osteochondral defect

are signs of instability in patients with ***adult*** OCD of the knee

Osteochondral Injury / OCD

The most useful secondary MR imaging findings for distinguishing between stable and unstable juvenile OCD lesions with a high T2 signal intensity rim are:

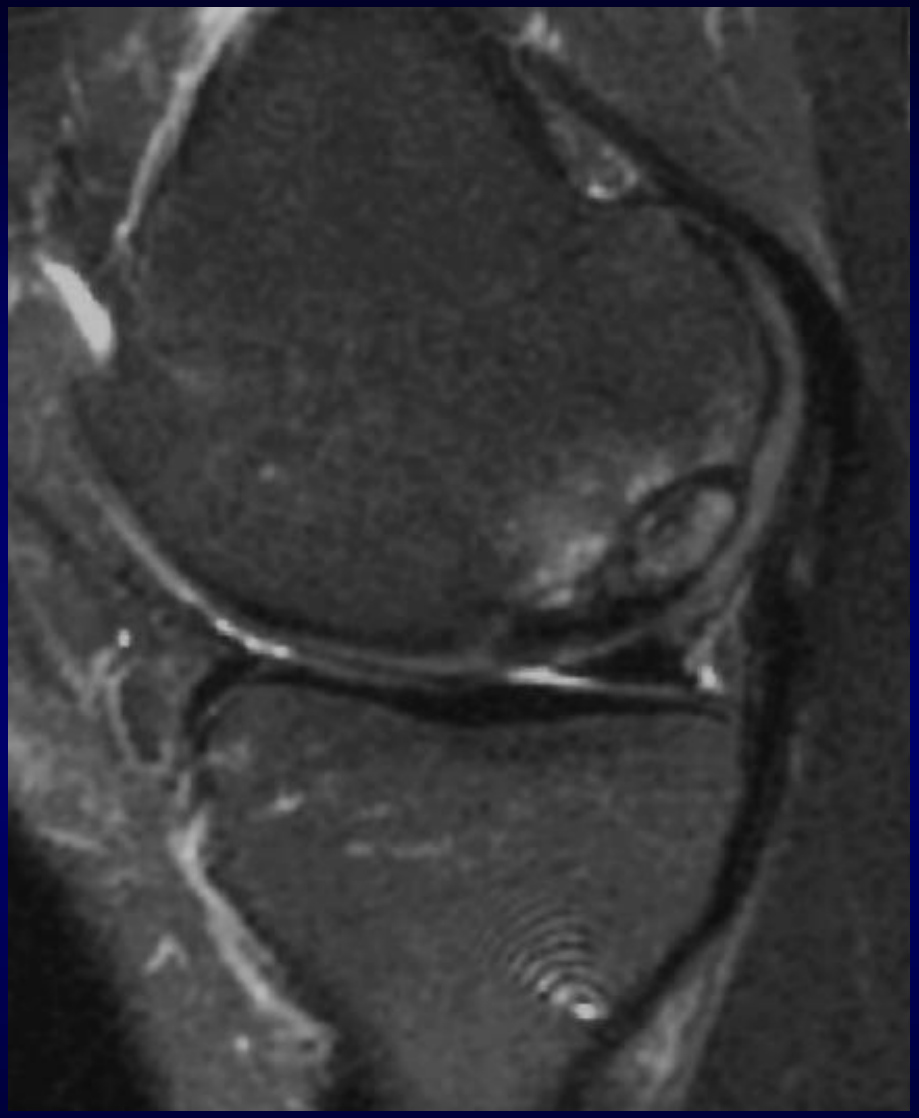
- a rim of fluid signal intensity
- multiple breaks in the subchondral bone plate on T2-weighted MR images
- a second outer rim of low T2 signal intensity

Osteochondral Injury / OCD

A high T2 signal intensity rim surrounding a juvenile OCD lesion indicates instability only if :

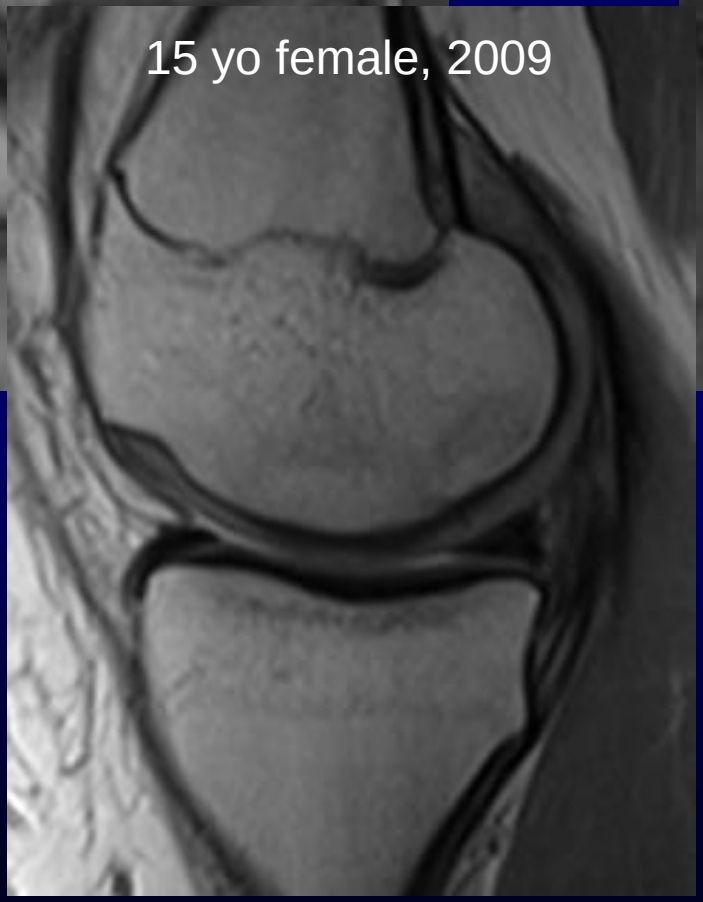
- it has the same signal intensity as adjacent joint fluid
- is surrounded by a second outer rim of low T2 signal intensity or
- is accompanied by multiple breaks in the subchondral bone plate on T2-weighted MR images.

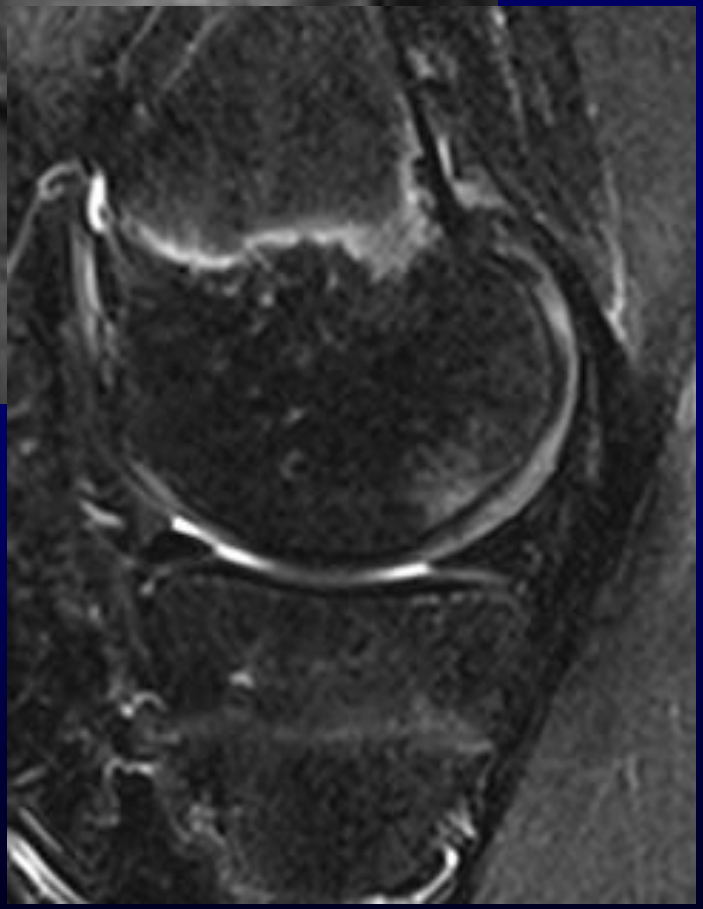
Cysts surrounding a juvenile OCD lesion indicate instability only if they are multiple or large in size.



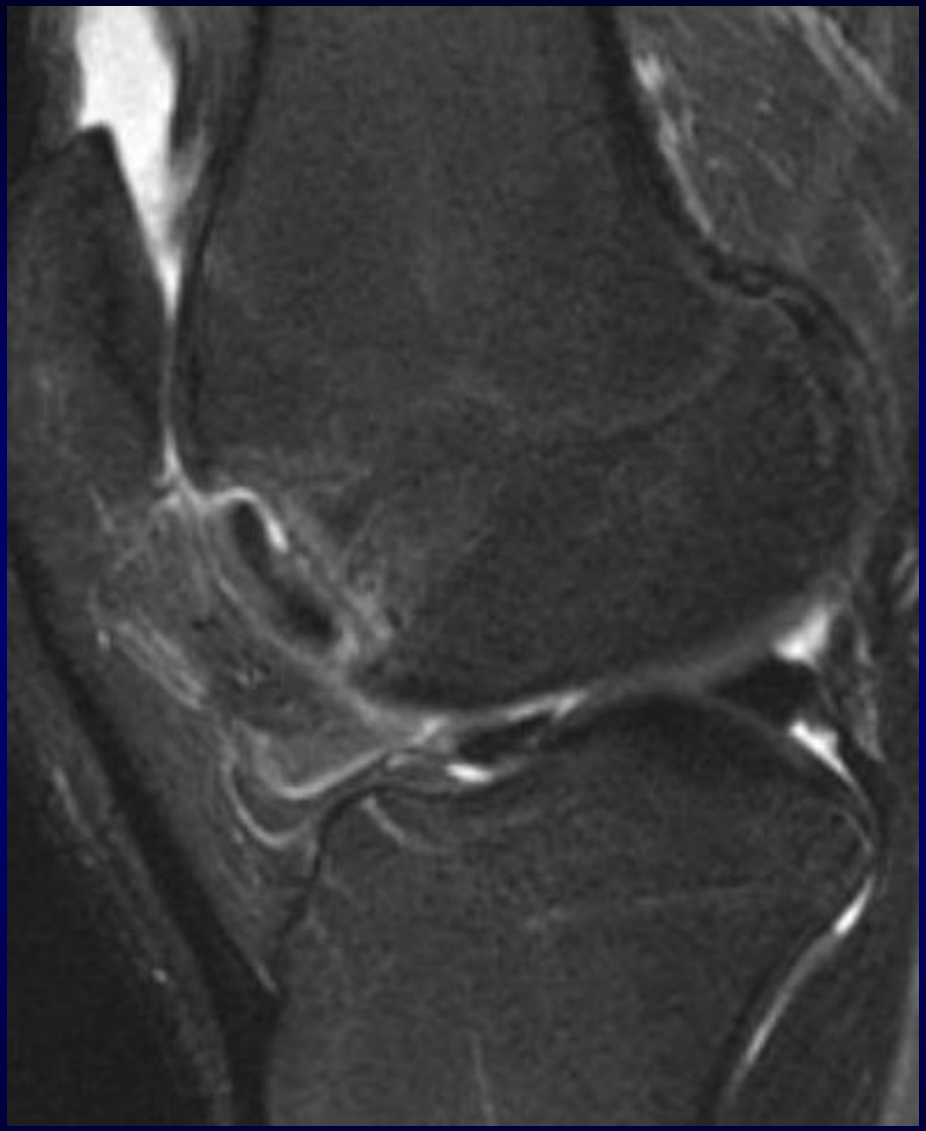
Osteochondral Injuries – Overlying Cartilage Intact
“In Situ” - Stable


10 yo female, 2004

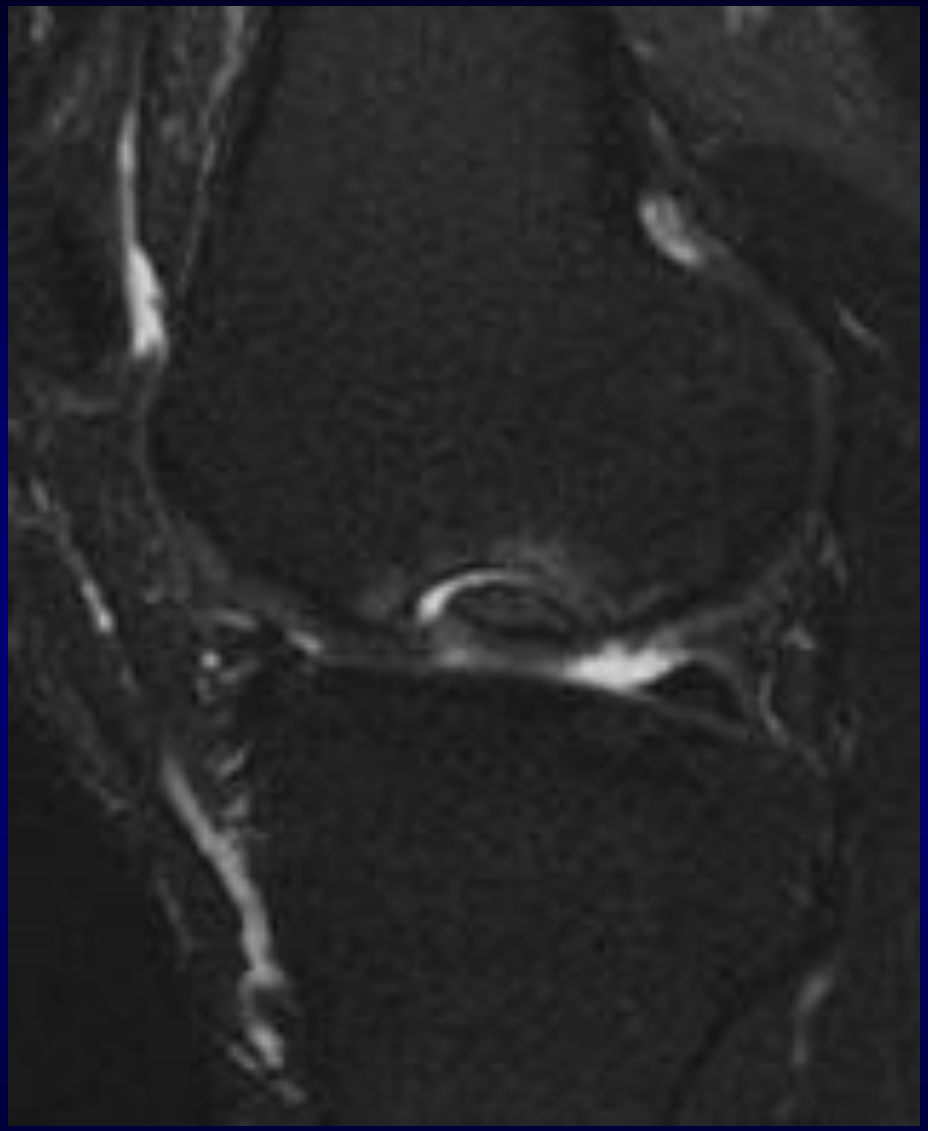

15 yo female, 2009

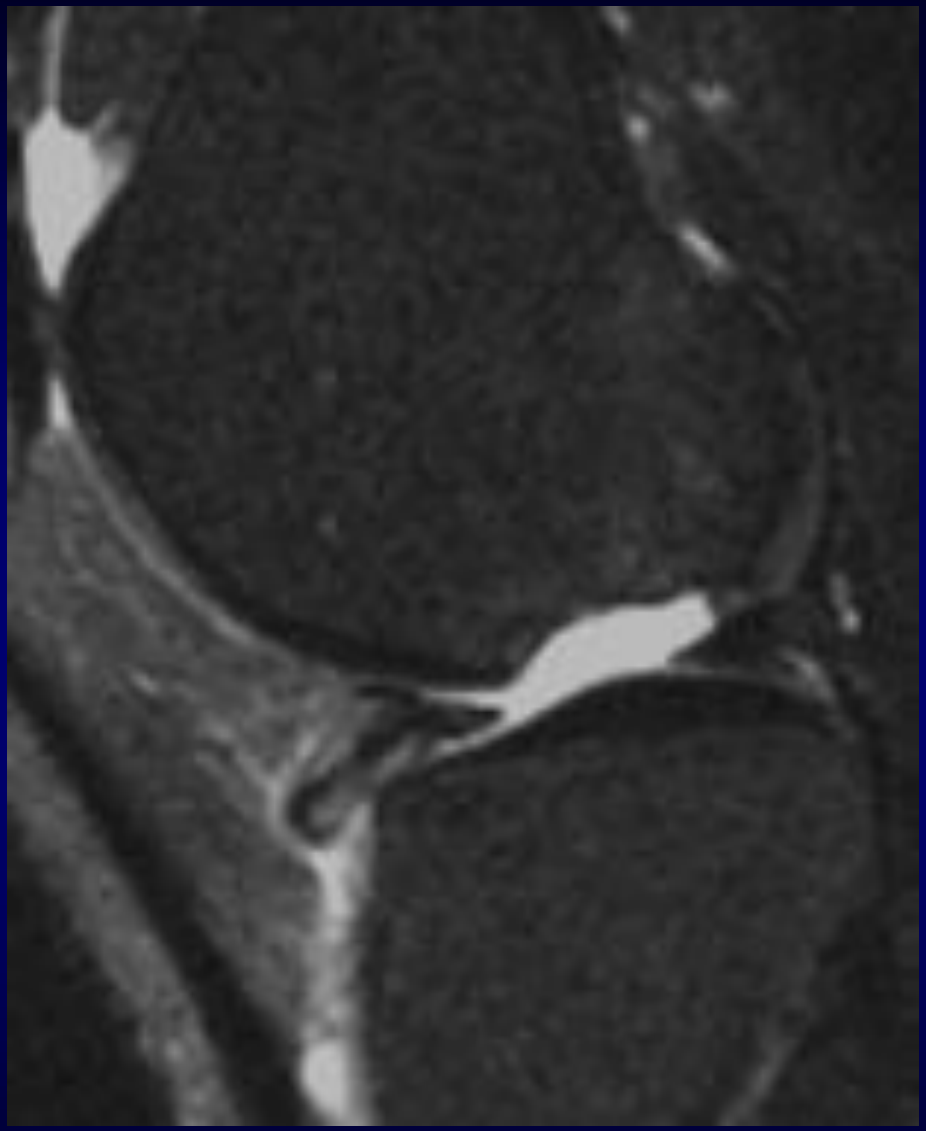


Osteochondral Injury –Partial disruption Cartilage
“Partially Detached” - Loose In-Situ



Osteochondral Injury – Complete Disruption Cartilage
“Completely Detached” - Loose





Osteochondral Injuries – Complete Disruption Cartilage

“Completely Detached” - Displaced

Chondral / Osteochondral Lesions

What can be done

Unstable osteochondral lesion (acute/subacute)

- Surgical fixation

Chondral Lesions - ?

Surgical Repair Procedures - Cartilage

Marrow Stimulation Techniques

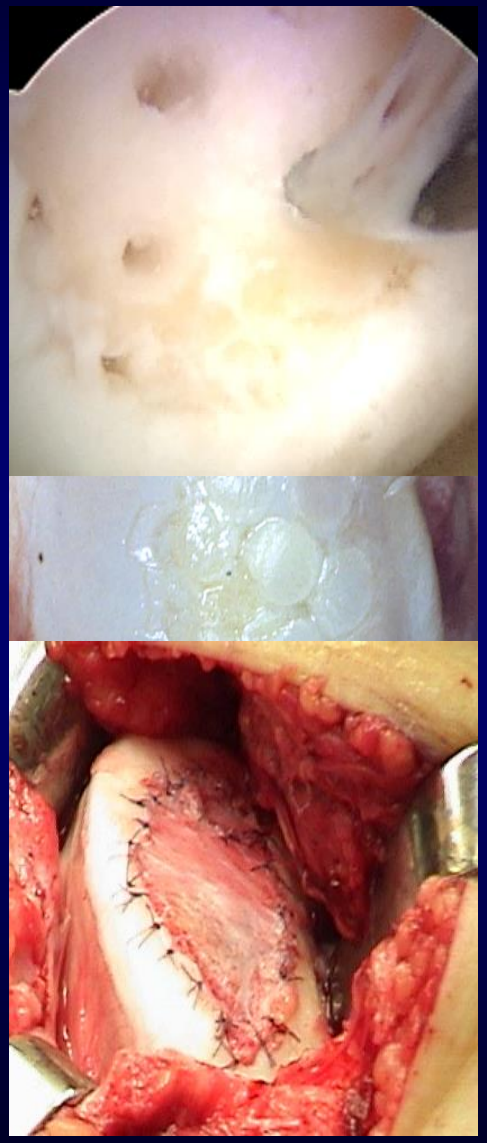
- Abrasion, Drilling, Microfracture

Osteochondral Transplantation

- Autologous transplants (OAT, Mosiacplasty)
- Allograft transplantation

Autologous Chondrocyte Transplantation

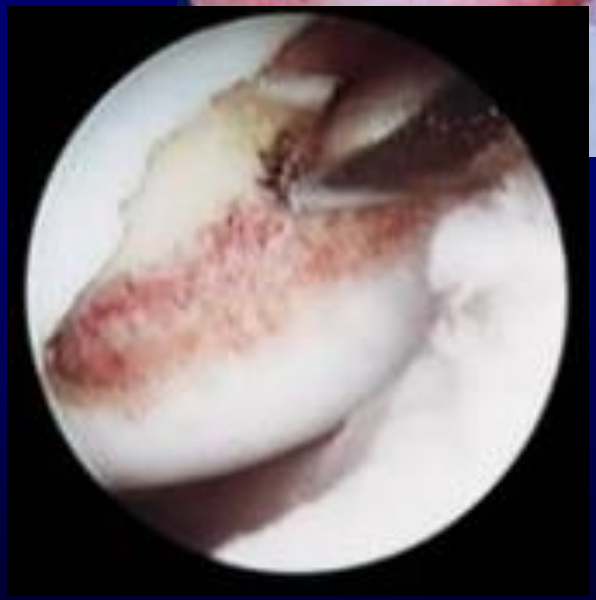
- Autologous chondrocyte implantation (ACI)
- Matrix assisted chondrocyte implantation (MACI)



Marrow stimulation techniques

Abrasion arthroplasty
Subchondral drilling
Microfracture

Small lesions < $4cm^2$



- Penetration - subchondral bone

- Defect fill with fibrocartilaginous repair tissue

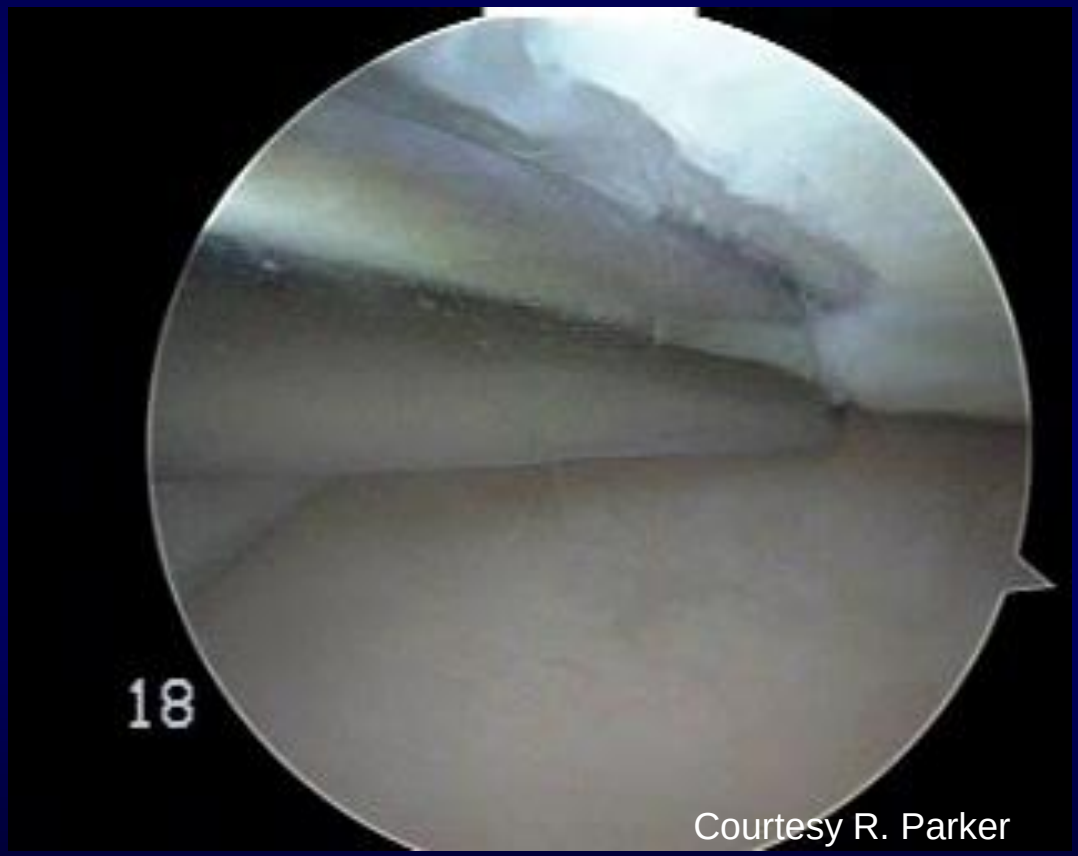
Microfracture

Most widespread of repair techniques

Debridement defect

Use Pick or Awl - multiple penetrations (3 -4 per cm2) subchondral bone

Promote subchondral bleeding - Formation Fibrin Clot



Courtesy R. Parker

Traumatic OCD

Traumatic OCD - Microfracture

MR Imaging - Microfracture

Initial (< 6-12 mos)

- Sl heterogeneous repair tissue thinner adjacent cartilage
- Marrow (edema) signal Δs

Maturation repair tissue (1-2 yrs)

- ↑ thickness repair tissue

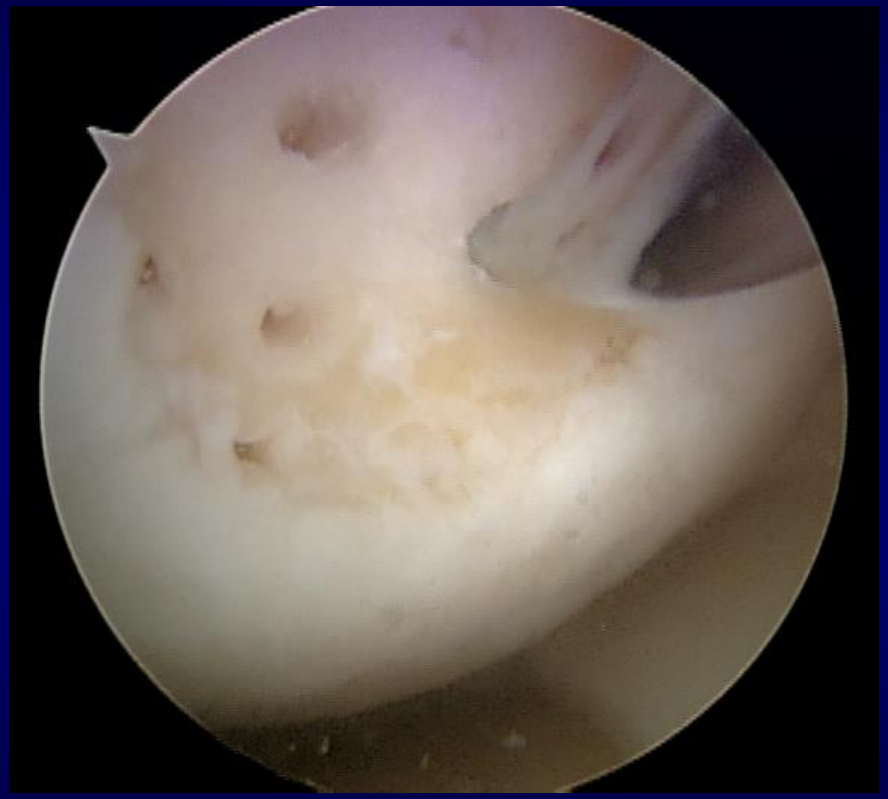

2 mos postop


7 mos postop

Compared to other repair techniques

Microfracture

Technically uncomplicated
Single stage procedure
Basic arthroscopic equipment



- Equivalent clinical results - ACI
- Similar histology repair tissue
  - outcome ≠ quality tissue

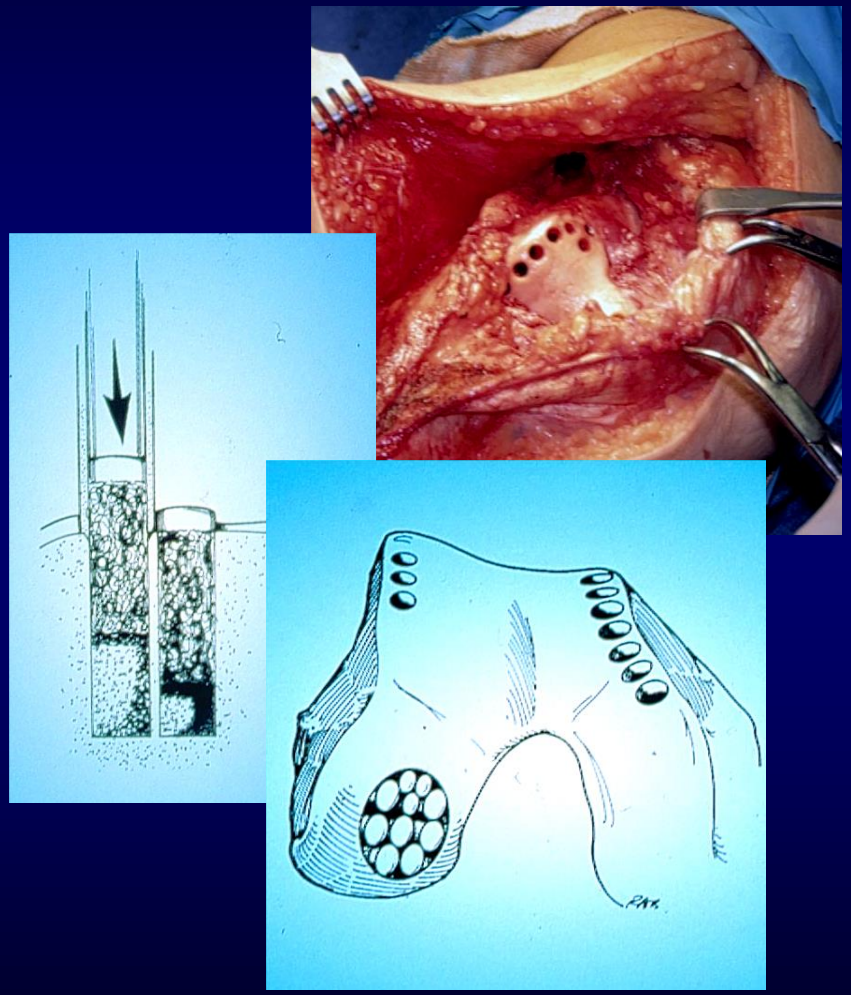
Knutsen G, et al. JBJS [Am] 2004; 86-A (3), 455

Osteochondral Autograft Transplantation

OAT
Mosaicplasty

Small lesions < 4 cm^2

- Autologous transplantation
  Osteochondral plug(s)
- Resurfacing – defects



Osteochondral Autograft Transplantation

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Small lesions < 4 cm^2

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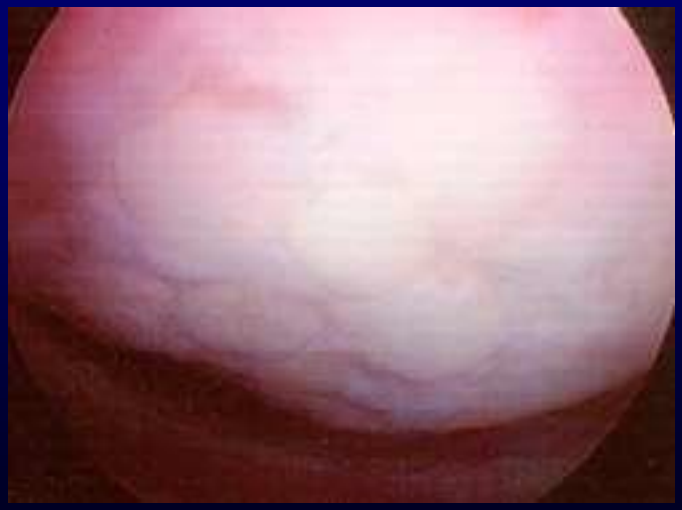
  Osteochondral plug(s)
- Resurfacing – defects

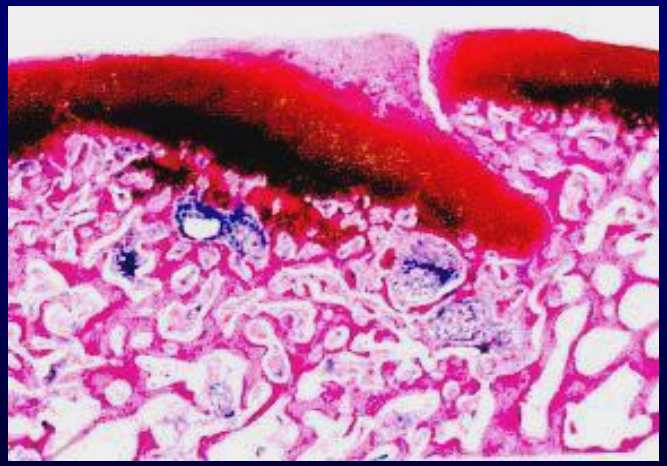


Graft congruity – primary goal/challenge

positioning graft cartilage - flush surrounding articular surface

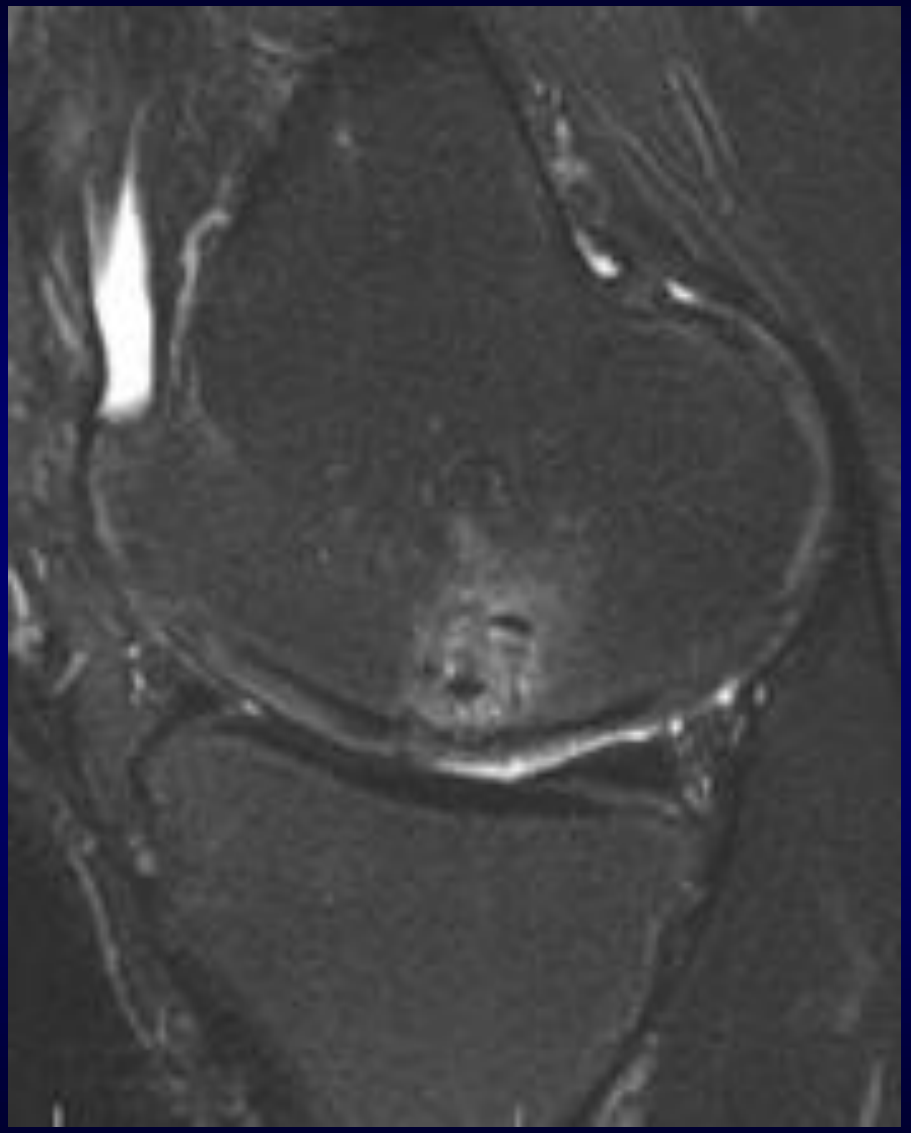
- Predeterminate procedural success

  T. Schiel, DVSc Thesis, Guelph 1998



- Incongruity
  - Technical difficulties
  - Graft subsidence / motion

Defect fill/ articular congruence



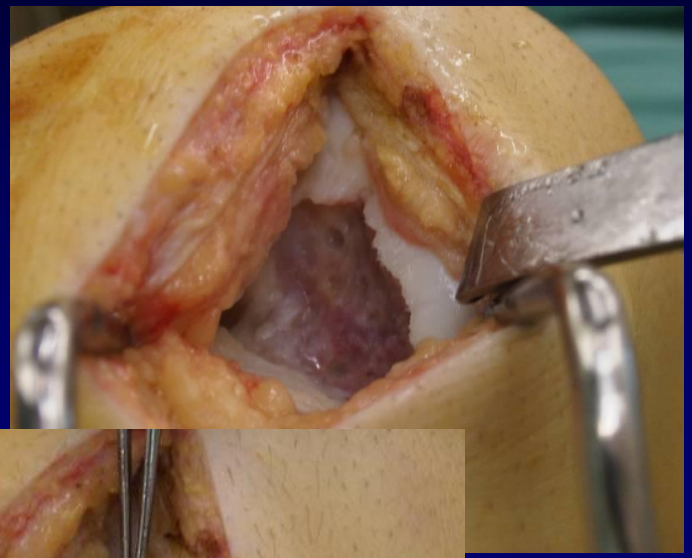

Courtesy M. Recht

Osteochondral Allograft Transplantation

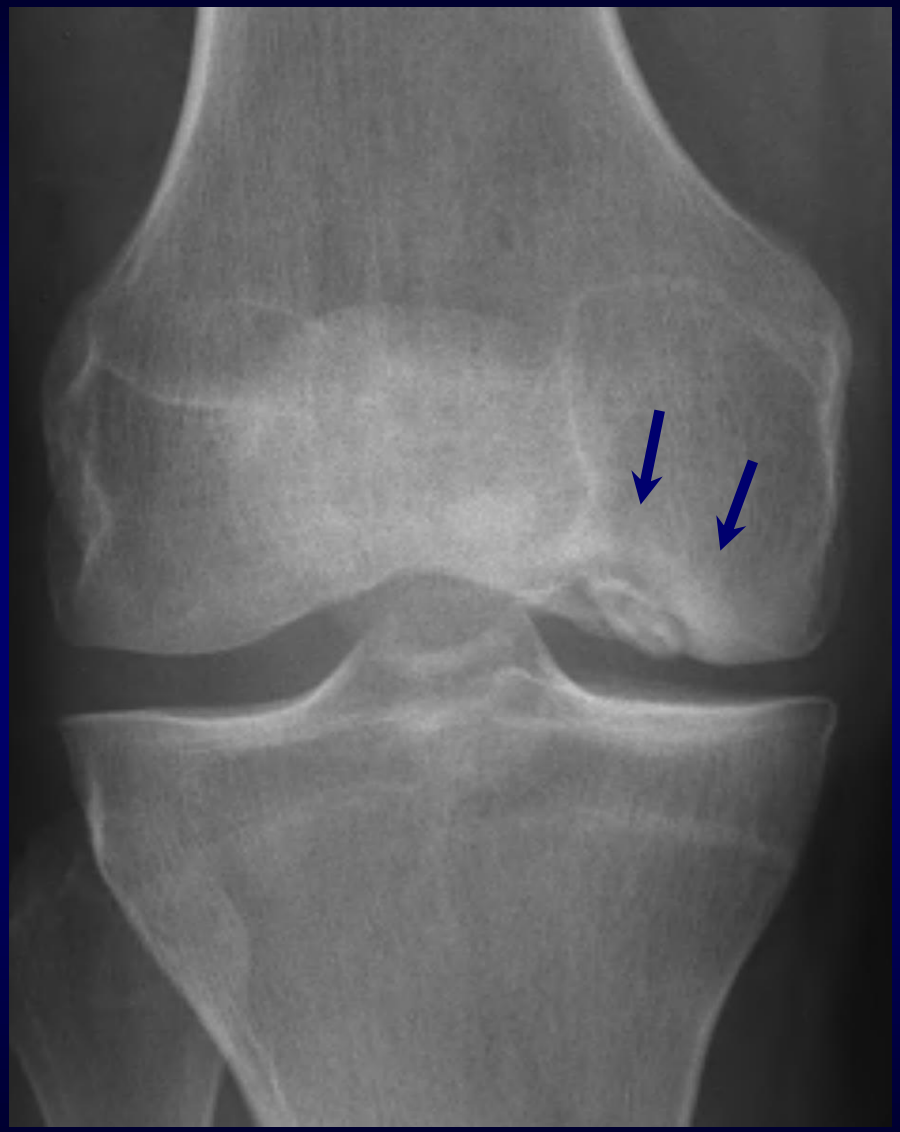
Transplantation fresh allograft

Treatment - large defects

> $3cm^2$, > 1cm depth



- Open surgical procedure
- Treatment/Transplantation
  - – Focal defects
  - – Entire articular surface



MR Imaging - Assessment

Position graft

Congruence
- cartilage
- subchondral bone

Complications
- Collapse
- Fragmentation
- Displacement

Autologous Chondrocyte Transplantation

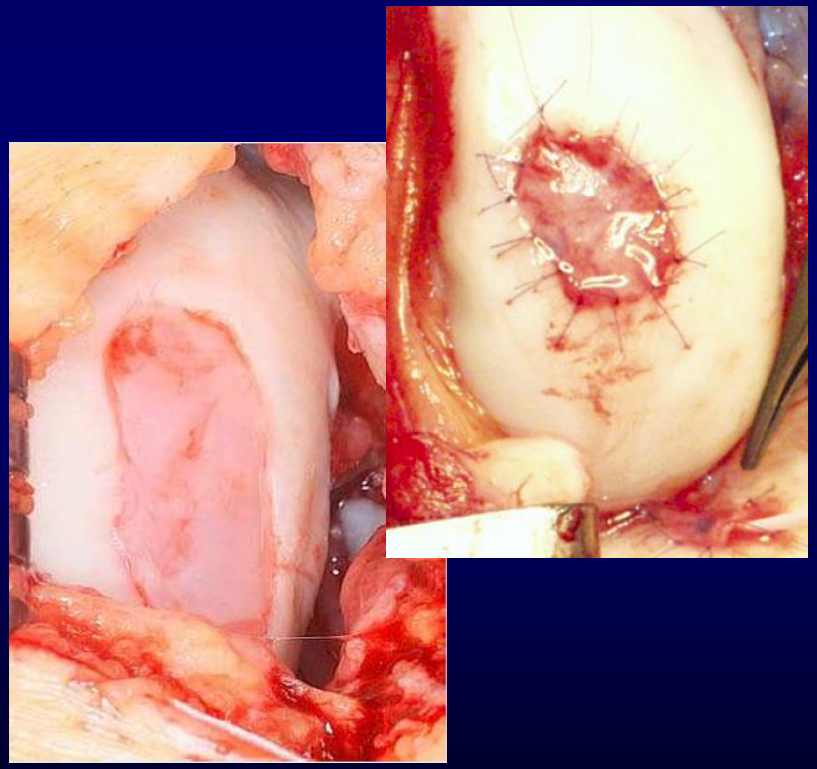
ACI – Autologous chondrocyte implantion

MACT – Matrix assisted chondrocyte Transplantation

Repair "Large defects" 2-12 cm^2

2 stage procedures

- Biopsy/culture - cartilage
- Implantation



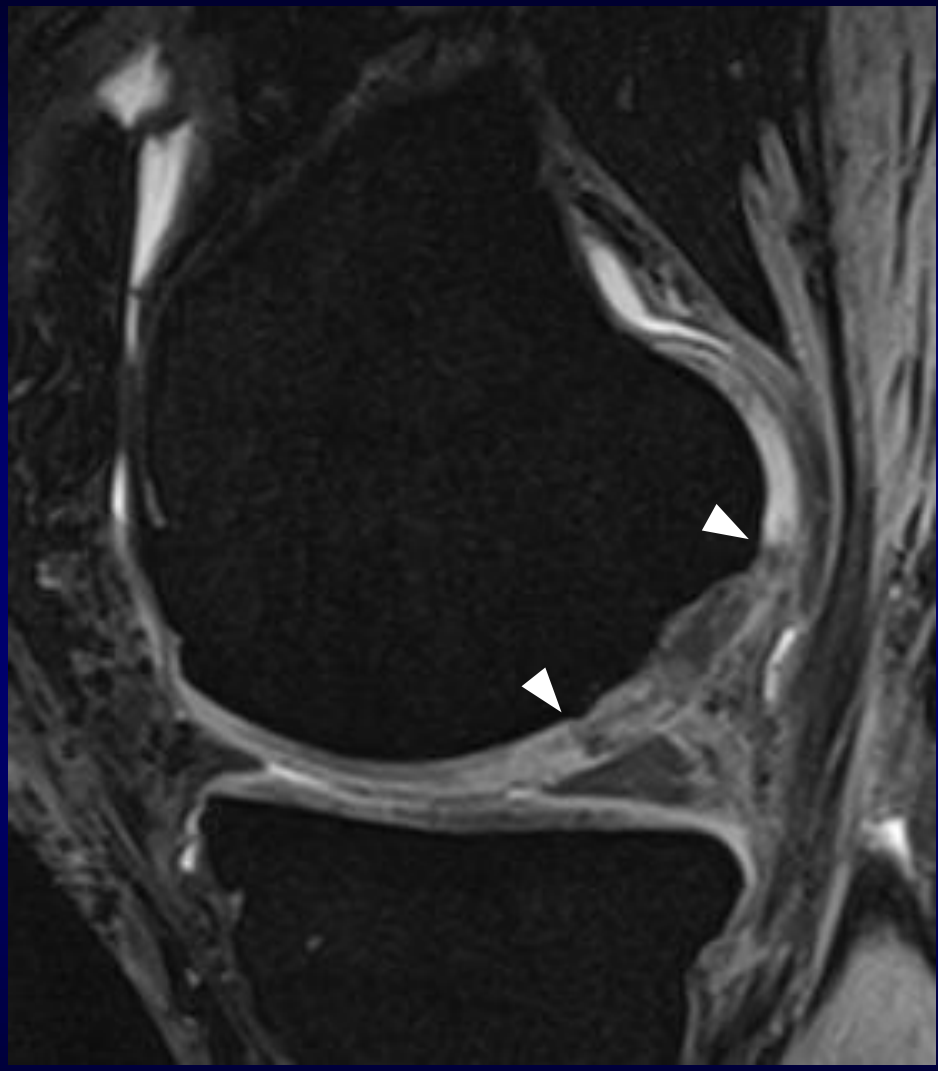
MR Imaging - Assessment

ACI, MACI

Defect fill

Integration
- cartilage
- subchondral bone

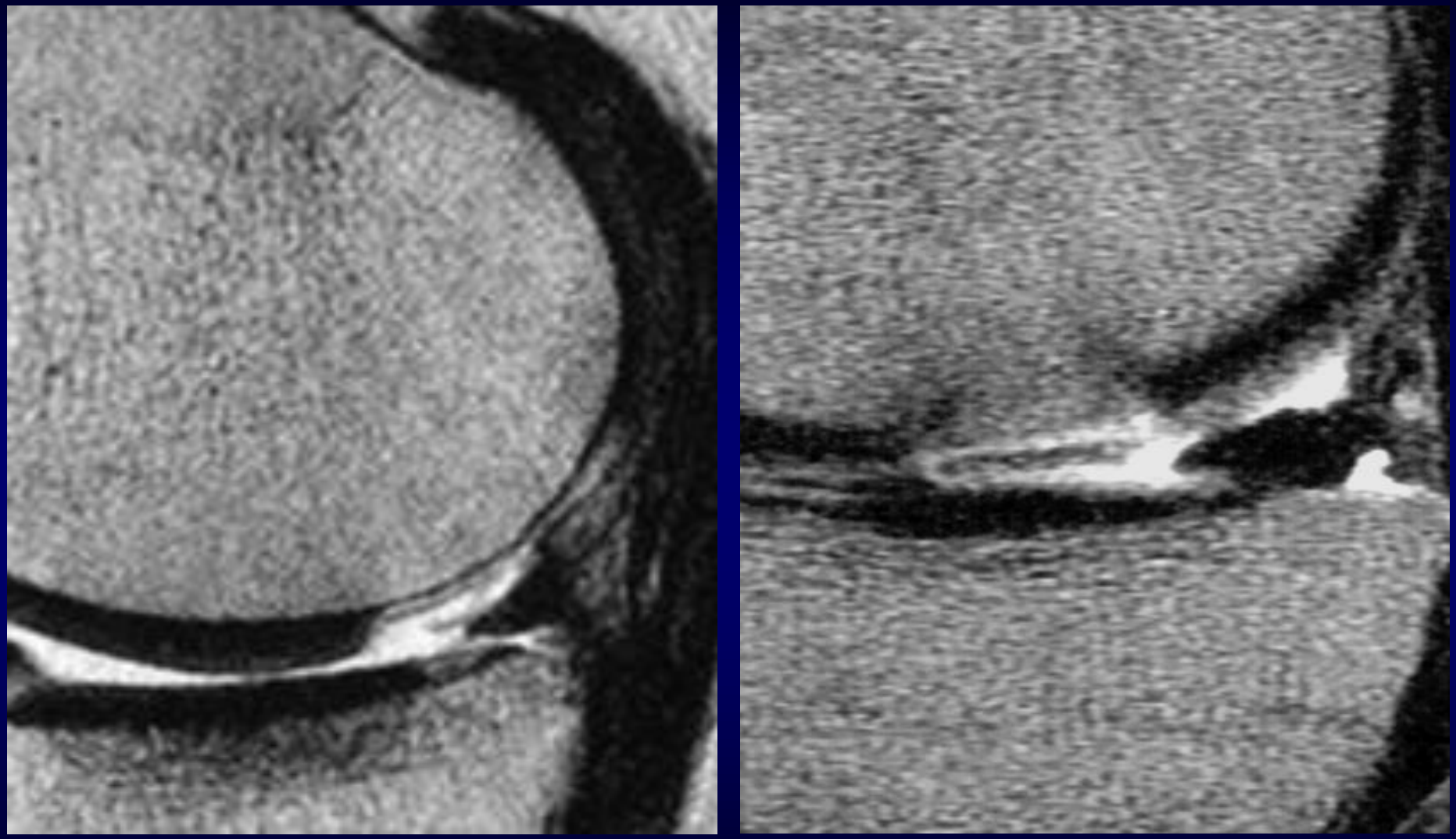
Complications
- Delamination
- Degeneration



MACI 24M - Courtesy S. Trattnig

MACI 6M - Courtesy S. Trattnig

ACI 12M - Courtesy C. Winalski



MACI 6M - Courtesy S. Trattnig

Osseous Injuries – General Principles

Impaction/Contusion fractures

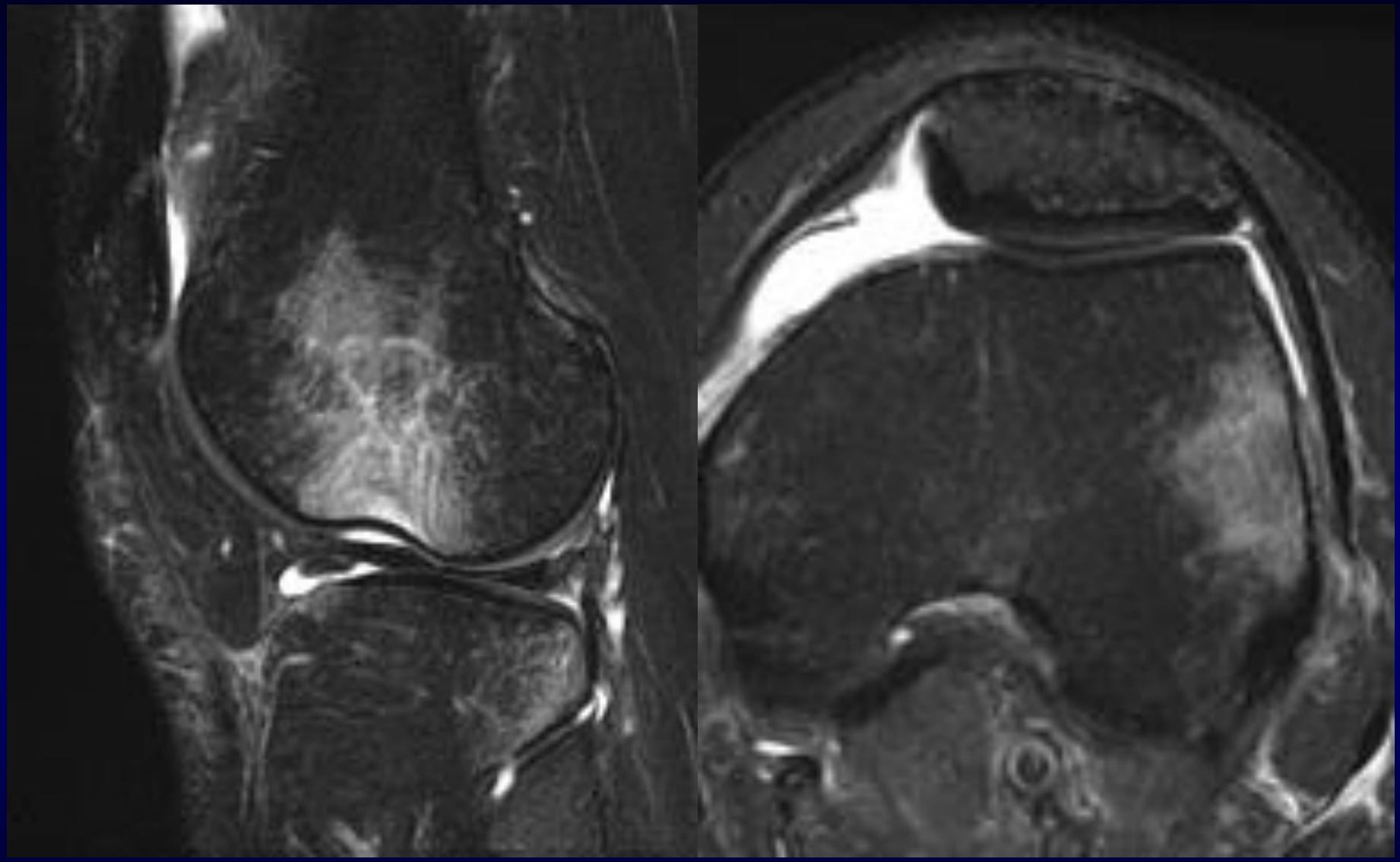
Pivot shift – ACL (lat fem condyle, lat tib plateau)

- Bone bruising, trabecular impaction, +/- Fx line

Avulsive fractures

Segond, ACL footplate fracture

- Fracture line (T1, T2), relatively less “bone bruising”



Unique Osseous Injuries: Knee

Fatigue fracture

- summation of microfractures caused by repeated trauma (frequently seen in athletes)
- *normal bone abnormal load*

Insufficiency fracture

- osteoporotic / osteomalacic bone fractured by normal stress
- *abnormal bone normal load*

SONK – Spontaneous Osteonecrosis Knee

Bilateral knee pain, recent running

Fatigue fractures proximal tibiae

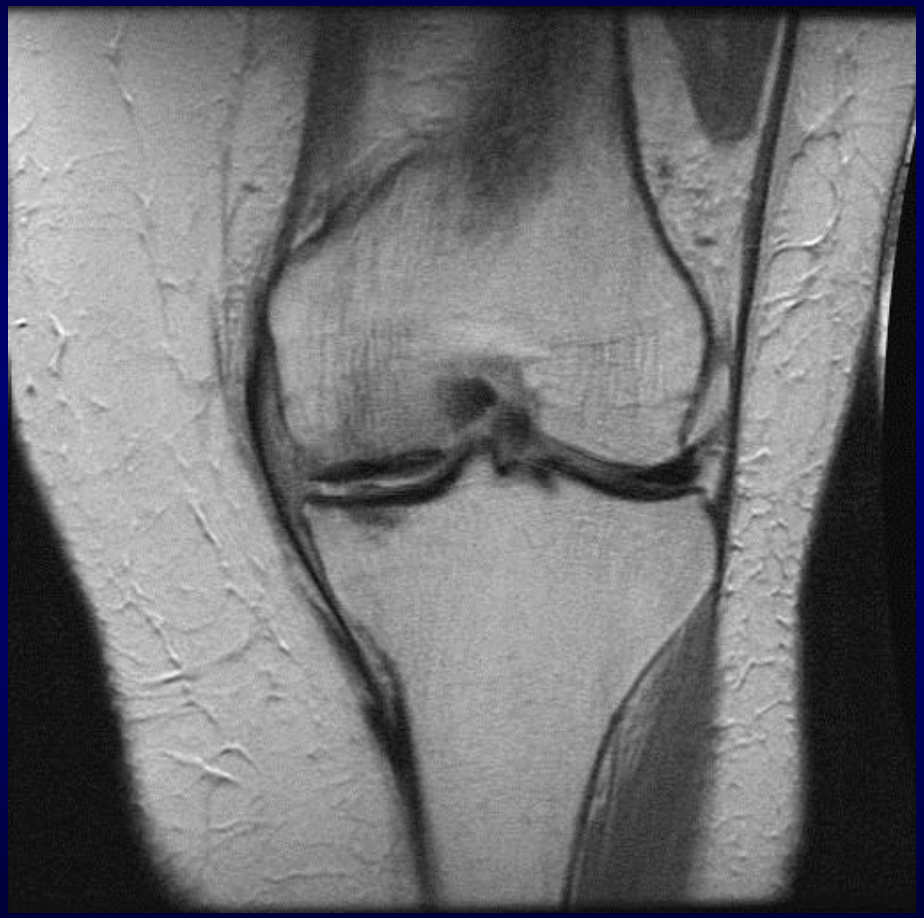
Fatigue fractures proximal tibiae

Spontaneous osteonecrosis of the knee (SONK)

- Female
- >55
- Acute onset severe pain
- Usually without a history of trauma
- Aetiology debated

Subchondral Insufficiency Fracture of the Knee

Subchondral Insufficiency Fracture of the Knee



Acute fracture occurs as a result of stress or minor trauma to a weakened subchondral bone plate

Avascular areas in biopsy specimens appear to be a secondary phenomenon and not the primary cause

Subchondral Insufficiency Fracture of the Knee

Acute fracture occurs as a result of stress or minor trauma to a weakened subchondral bone plate

Avascular areas in biopsy specimens appear to be a secondary phenomenon and not the primary cause

MRI knee: Cartilage and Bone

Cartilage

- Imaging
- Lesions

Osteochondral lesions

Cartilage “repair”

Bone

- Contusions, Avulsions
- Stress/Insufficiency fractures