

The Knee

EID 424
Bioengineering Applications in Sports Medicine
Prof. Kremenec
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Outline

- + Anatomy
 - + Bony
 - + Ligamentous
 - + Soft tissue
 - + Musculature
 - + Constraints to abnormal motion
- + Common pathologies

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The Knee, Defined

- + Junction of femur and tibia
 - + Thigh and leg



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Bony Anatomy

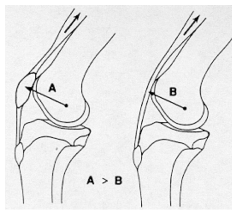
- + Femur
 - + Proximal
 - + Landmarks
 - + Greater trochanter (proximal end)
 - + Medial, lateral condyles (distal end)
- + Tibia
 - + Distal
- + Femoral condyles sit atop tibial plateau



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Bony Anatomy: Patella

- + Patella
 - + Kneecap
 - + Largest sesamoid bone
 - + Increase moment arm for quadriceps
- + Connections
 - + Patellar tendon (distal)
 - + Connects to tibial tuberosity
 - + Quadriceps tendon (proximal)
 - + Connects to quadriceps muscle
 - + Provides fulcrum for quadriceps
 - + Patellofemoral, patellotibial ligaments
- + Sits in femoral trochlea (groove)



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Bony Anatomy: Patella

- + Posterior surface of patella covered in articular cartilage
 - + Irritation to this surface called *chondromalacia patella*
 - + Softening
 - + Eventual tearing and damage
 - + Painful
 - + Common with runners

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Ligamentous Anatomy

- + Medial collateral ligament
 - + MCL
- + Lateral collateral ligament
 - + LCL
- + Restraints to varus-valgus rotation of knee
 - + Frontal plane rotation



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Ligamentous Anatomy

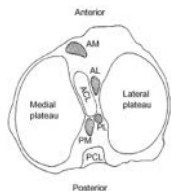
- + Anterior cruciate ligament
 - + ACL
 - + Originates from lateral femoral condyle
 - + Inserts on tibial plateau medial to anterior horn of lateral meniscus
 - + 31-38 mm long, 11mm wide
 - + Posterolateral bundle
 - + Tight in extension
 - + Anteromedial bundle
 - + Tight in flexion
 - + Prevents anterior translation of tibia relative to femur
 - + Prevents abnormal rotation of tibia relative to femur



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Ligamentous Anatomy

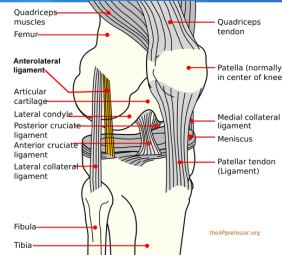
- + Posterior cruciate ligament
 - + PCL
 - + Prevents posterior translation of tibia relative to femur
 - + Assists in restraining rotation of tibia



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The New Ligament!

- + Anterolateral ligament
- + First proposed by Segond (1879)
- + Confirmed by Claes and Bellemans (2013)
- + Seems to have role in rotatory stability
- + Needs to be addressed in conjunction with ACL?



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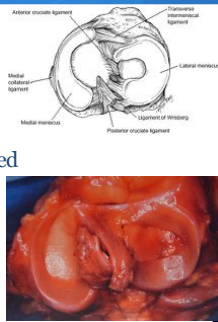
Soft Tissue

- + Joint capsule
 - + Membrane surrounding joint
 - + Holds in synovial fluid
 - + Clear, sticky fluid
 - + Lubrication for joint
 - + Nutrition for articular cartilage, menisci

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Menisci

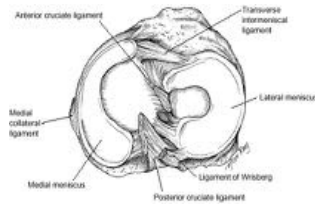
- + Medial/lateral meniscus
- + Sits atop tibial plateau
 - + Outside surface attaches to joint capsule
- + Help distribute load, contact pressure
 - + No menisci --> all pressure exerted by femoral condyles on tibial plateau
- + Knee stability
- + Proprioception
- + Position sense



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Medial Meniscus

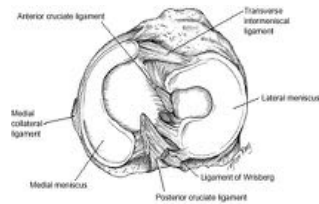
- + Semicircular
- + Wider posterior than anterior
- + ≈ 3.5 cm long



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Lateral Meniscus

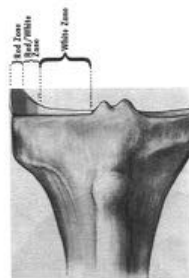
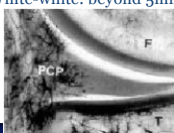
- + Circular shape
- + Uniform width



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Meniscal Anatomy

- + Only outer third has blood supply
- + Needed for nutrition, healing
 - + Inner two-thirds derives nutrition from diffusion of synovial fluid
- + Three zones (Arnoczky, Warren)
 - + Red-red: 3mm of periphery
 - + Red-white: 3-5 mm
 - + White-white: beyond 5mm



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Anterior Thigh Musculature

- + Quadriceps muscles
 - + Vastus lateralis
 - + Vastus medialis
 - + Rectus femoris
 - + Vastus intermedius
- + Extend the knee
 - + RF also hip flexor (*two-joint muscle*)

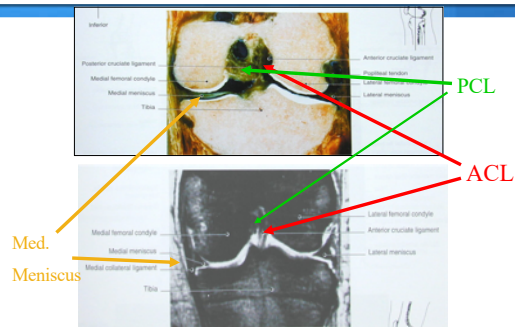
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Posterior Thigh Musculature

- + Hamstrings
 - + Semimembranosus
 - + Semitendinosus
 - + Biceps femoris
- + Knee flexors
 - + Also extend hip

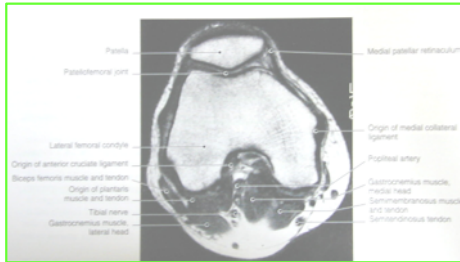
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Coronal Plane Knee MRI



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Transverse Plane Knee MRI

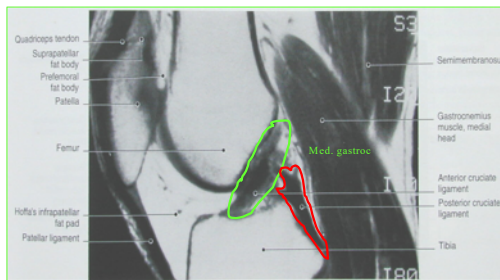


Lateral

Medial

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Sagittal Plane Knee MRI



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Common Pathologies

- + Ligament tears
 - + ACL
 - + PCL
 - + MCL/LCL
- + Meniscal tears
- + Patellofemoral pain
- + Knee dislocation

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ACL Tears

- + Very popular injury
- + Most often (70%) non-contact injury
 - + Rotation of tibia with foot planted
 - + Sudden deceleration with direction change
 - + Landing from jump
- + Contact injury often in auto accident
- + Painful
- + "Heard a pop"
- + Swelling
- + +/- instability



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ACL Tears

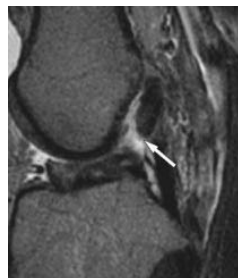
- + MRI T1 images
 - + Good for anatomy



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ACL Tears

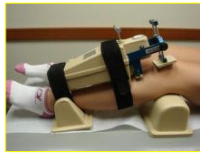
- + MRI T2 image
 - + Good for pathology
 - + Fluid shows up very bright



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ACL Tears

- + Lachman test
 - + Most sensitive exam
 - + Graded in comparison to uninjured side
 - + Feel for amount of translation as well as a **firm end point**
 - + Grade 1 : 1-5 mm
 - + Grade 2 : 6-10 mm
 - + Grade 3 : >10mm
- + Instrumented version
 - + KT-1000
 - + Does not assess rotational component



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ACL Tears

- + Commonly seen in:
 - + Football
 - + Basketball
 - + Volleyball
 - + Skiing
 - + Soccer



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ACL Tears



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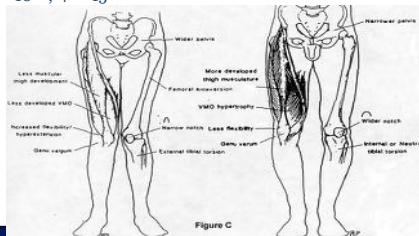
ACL Tears: Male vs Female

- + Women at greater risk than men
 - + Given similar levels of physical activity
 - + 6x greater, NCAA soccer, (Lindenfield, 1993)
 - + 8x greater, NCAA basketball (Malone, 1993)
 - + 4x greater, NCAA overall (Arendt, 1995)
- + Possible mechanisms:
 - + Training
 - + Less involvement in sports from early age
 - + Anatomical
 - + General ligamentous laxity
 - + ACL size
 - + Lower extremity alignment (Q angle, etc)
 - + Estrogen

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ACL Tears: Male vs Female

- + Q angle
 - + ASIS [anterior superior iliac spine], center of patella, tibial tubercle
 - + $\sigma = 10^\circ$, $\varphi = 15^\circ$



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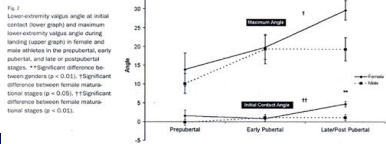
ACL Tears: Male vs Female

- + Increasing body of work indicates this may be a training issue
 - + See work of Tim Hewett
 - + "Boys land like a hinge on stiff springs...girls land like a ball and socket on loose springs."
 - + Jumping and landing training programs for ACL injury prevention

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ACL Tears: Male vs Female

- + Females display decreased neuromuscular control during landing following maturation [Hewett, JBJS 2004]
- + Similar to males prior to puberty
- + Effectiveness of continuous landing/balance training from early age?
- + No gender disparity in dancers



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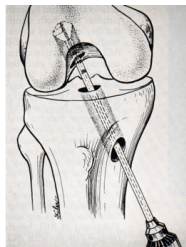
Conservative Treatment of ACL Tears

- + Some patients do well with ACL tears
 - + "Copers" [Snyder-Mackler, various papers]
 - + Increased hamstring co-contraction to stabilize knee
 - + "Rule of thirds" [Noyes]
 - + 1/3 need surgery, 1/3 do fine, 1/3 do fine with lowered activity
- + Otherwise, surgery
 - + Reconstruction, not repair!
 - + Repair: repair (i.e., suture together) existing damaged tissue
 - + Reconstruction: replace damaged structure with similar tissue/device

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ACL Reconstruction

- + Recreate ACL with tissue graft
- + Performed arthroscopically
 - + Small incisions
 - + Holes
 - + Insert instruments, camera through holes
 - + Much faster healing than traditional open procedures



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ACL Reconstruction: Allograft

- + Tissue from donor subject (i.e., cadaver)
- + No issues with donor site (weakness, pain, etc)
- + Faster surgical time
- + Allows multiple ligament reconstruction
- + Disease transmission?
- + Longer healing time
- + Immune system response to foreign tissue

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ACL Reconstruction: Allograft

- + Commonly-used grafts:
 - + Patellar tendon
 - + Achilles tendon
- + Used most often for:
 - + Multiple ligament reconstructions
 - + Revision of failed reconstruction
 - + Patients who are not high-performance athletes

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ACL Reconstruction: Autograft

- + No risk of disease transmission
- + Low risk of large inflammatory response
- + Faster recovery
- + Donor site morbidity
- + Longer surgical time

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ACL Reconstruction: Autograft

- + Commonly-used grafts:
 - + Patellar tendon
 - + Hamstring tendon
- + East coast/West coast debate
 - + Orthopaedics just like 1990s hip-hop!
 - + Jury is out with regard to which is better

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ACL Reconstruction: Hamstring Tendon

- + 2-strand or 4-strand
- + Extremely strong
 - + Failure load 4108 N
- + Stiffness similar to ACL (4-strand), lower than ACL (2-strand)
- + Less knee pain?
- + Hamstring pain/weakness
 - + Hamstring helps stabilize knee
- + Fixation?

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ACL Reconstruction: Bone-Patellar Tendon-Bone

- + Central third of patellar tendon
 - + Chunk of bone at either end
 - + Patella
 - + Tibial tubercle
- + Failure load, stiffness similar to ACL
- + Excellent fixation
 - + Bone at either end
- + Faster healing
- + Knee pain
- + Patellar fracture?
 - + See Rice, Jerry
 - + Anecdotal: don't jump to conclusions

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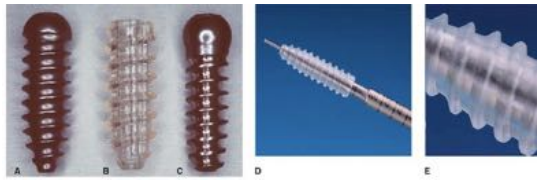
ACL Reconstruction: Synthetic

- + Use advanced, space-age material to replace ACL
- + **DOESN'T WORK**
 - + Immune/inflammatory response
 - + Debris
 - + Tend to be very weak reconstructions
 - + Fail over time
 - + Off the market
 - + ...But now we're working on it again

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ACL Reconstruction: Graft Fixation

- + Gold standard: interference screw



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ACL Reconstruction: Graft Fixation

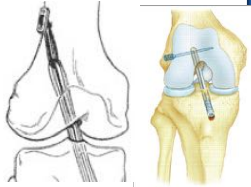


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ACL Reconstruction: Graft fixation

+ Other methods

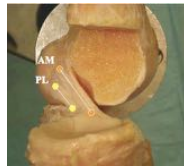
- + Endo-button
 - + Cortical fixation
 - + Far from joint
 - + Bungee Cord Effect
 - + Creep/laxity in line with linkage
- + Windshield Wiper Effect
 - + Shearing forces of graft in tunnel may cause tunnel expansion



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ACL Reconstruction: Single vs Double Bundle

- + Using double bundle will more accurately recreate biomechanics of original ligament
- + No benefit seen clinically [so far; short term follow up]
- + Longer, more complex surgery



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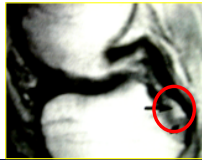
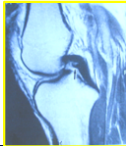
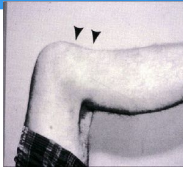
PCL Tears

- + Not nearly as common as ACL tears
 - + Often can function well without PCL
- + Traumatic
 - + In conjunction with other ligamentous injury (e.g., ACL)
- + Athletic
 - + Hyperflexion of knee

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PCL Tears

+ "Lag sign"



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MCL/LCL Tears

- + MCL more commonly injured
 - + Blow to outside of knee
- + Almost always treated conservatively
 - + Very large
 - + Heal well
 - + Therapy
 - + Bracing

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Meniscal Tears

- + More common in males than females
- + About one-third associated with ACL tears
 - + Acute ACL tear
 - + More lateral meniscal tears than medial
 - + Chronic ACL tear
 - + More medial meniscal tears than lateral
- + Often twisting injury

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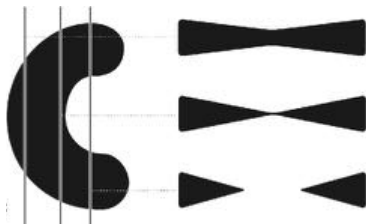
Meniscal Tears

- + Able to ambulate after injury
- + Insidious onset of swelling/stiffness
 - + Recurrent
- + Eventually leads to painful clicking, popping, locking

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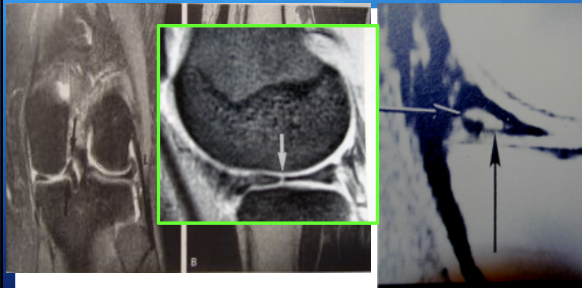
Meniscus on MRI

- + "Bow-tie sign" is good



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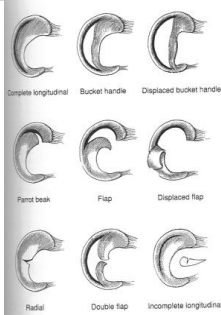
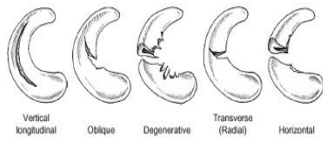
Meniscal Tear MRI



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Classification of Meniscal Tears

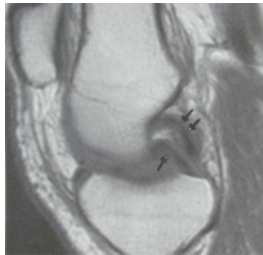
- + Based on orientation and appearance of tears
- + Can be full or partial thickness



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Bucket Handle Tear

- + "Double-PCL" sign



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Treatment of Meniscal Tears

- + Save the meniscus
- + Good candidates for repair:
 - + Young, athletic patients
 - + Concomitant ACL reconstruction
- + Consider:
 - + Size/age/location of tear
 - + Ligamentous stability of knee
 - + Motivation/compliance of patient
- + Best chance for repair:
 - + Smaller acute (< 8 wks), vertical longitudinal tear in vascular zone in stable knee

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Nonoperative Treatment of Meniscal Tears

- + Small tear
 - + < 1 cm
- + Stable (i.e., not mobile tear)
 - + < 3 mm displacement
- + Partial thickness tear
- + Degenerative tear

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Indications for Meniscal Repair

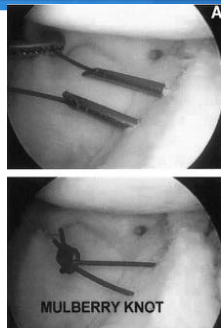
- + Vertical longitudinal tears
- + Vascular zone
 - + Peripheral 3 mm
- + < 4 cm long

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Meniscal Repair

- + Arthroscopic
- + Several techniques
 - + Inside-out
 - + Outside-in
 - + All-inside
- + Be careful!
 - + Lots of structures (nerves, etc) in there!



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Meniscal Repair

- + Sutures vs devices (arrows, etc)
- + Enhanced healing techniques
 - + Trephination
 - + Make holes to promote bleeding



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Meniscectomy

- + Removal of meniscus
- + Total
 - + Historic
- + Partial
 - + Remove only part that is troublesome
- + Keep as much as possible!

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Indications for Meniscectomy

- + Can't be repaired
- + Symptomatic, abnormally mobile meniscal tissue not amenable to repair
- + Isolated degenerative or complex tears
- + Flap and radial tears more than 5mm in length

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Meniscectomy

- + Remove abnormally mobile fragments
- + Meniscal rim contour should be gradual
- + Preserve meniscocapsular attachment
- + Maintain conservative resection
- + Use probe frequently
 - + Dig into tissue
 - + Ensure good tissue

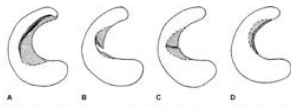


Figure 3 Principles of partial meniscectomy (shaded areas) for different types of meniscal tears. Retaining the meniscal rim with a vertical longitudinal tear (A), an oblique tear (B), a transverse radial tear (C), and a horizontal tear (D). (Adapted with permission from Newman 87, Daniels 82, Turker 81. Principles and decision making in meniscal surgery. Arthroscopy 1992;9:33-51.)

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Rehab Following Meniscal Repair/Meniscectomy

- + Controversial
 - + Competing views
- + Much longer following repair
 - + Typically, knee braced in extension for several weeks following repair
 - + Meniscectomy back to activity in that time frame

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Patellofemoral Pain

- + Anterior knee pain
 - + Chondromalacia, etc
 - + "My knee hurts"
 - + Can be very difficult
 - + Almost always worse on stairs
 - + Good way to elicit pain, esp going down
- + Often attributed to incorrect tracking of patella
 - + Q angle

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Patellofemoral Pain

- + One school of thought:
 - + Abnormal tracking of patella results from inequality between pull of vastus lateralis, vastus medialis
 - + Generally VM weaker
 - + Strengthen quadriceps muscles
 - + How to train selectively the VM and not other quad muscles?

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Knee Dislocation

- + EMERGENCY!!!!
 - + Lots of structures in there to get disrupted
 - + Don't want people to lose their legs



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Treatment of Articular Cartilage Defects

- + Debridement
 - + Clean up defect
 - + Cut out loose body, "bad tissue"
 - + "Crabmeat"
 - + Leaves a hole
 - + OK if small, but will likely progress

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Treatment of Articular Cartilage Defects

- + Microfracture
 - + Clean out, down to underlying bone
 - + Jab an awl (sharp hunk of metal) into bone in multiple locations
 - + Blood and bone marrow (has some stem cells)
 - + Bleeding necessary for body's "healing response"
 - + Stem cells from marrow will help build new cartilage to fill defect
 - + Usually fibrocartilage, not hyaline cartilage

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Microfracture Surgery Case Study

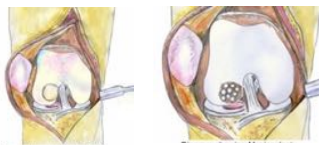
- + Kenny Philips
 - + Safety, NY Giants
 - + Patellofemoral arthritis
 - + Surgery 2009
 - + Starter 2010, 2011, best seasons of career
 - + Non-contact knee injury 2012
 - + Signed with Eagles after season
 - + Released by Eagles 2013
- + Many other pro athletes
 - + Esp. basketball
- + No good way to regrow cartilage



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Treatment of Articular Cartilage Defects

- + OATS
 - + Osteochondral autograft transfer surgery
 - + Take plug of cartilage (with underlying bone) from non-weightbearing surface to fill defect
 - + If defect very large, use multiple pieces
 - + Mosaicplasty



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Treatment of Articular Cartilage Defects

- + OATS issues
 - + Careful sizing
 - + Insertion of plug
 - + Must be flush
 - + Hammering will damage tissue
 - + Contour of plug must match contour of defect
 - + Creation of new defect?

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Treatment of Articular Cartilage Defects

- + Autologous chondrocyte implantation (ACI)
 - + Two surgeries
 - + No. 1:
 - + Take sample of healthy cartilage from non-weightbearing area
 - + Ship off to lab
 - + Pixie dust sprinkled, sample grown from small number of chondrocytes to enough to fill defect
 - + 4-6 weeks

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Treatment of Articular Cartilage Defects

- + ACI
 - + No. 2:
 - + Clean out defect
 - + Inject cells
 - + Cover with flap (periosteum)
 - + Watch new cartilage grow!

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Platelet-Rich Plasma [PRP]

- + Platelets are full of healing factors
 - + Concentrate them
- + Draw blood from patient
- + Centrifuge
 - + Remove now-concentrated platelets
- + Inject into injured area
- + Being used for all kinds of things
 - + Too early to tell
 - + Seems to help with a lot of tendonitis

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