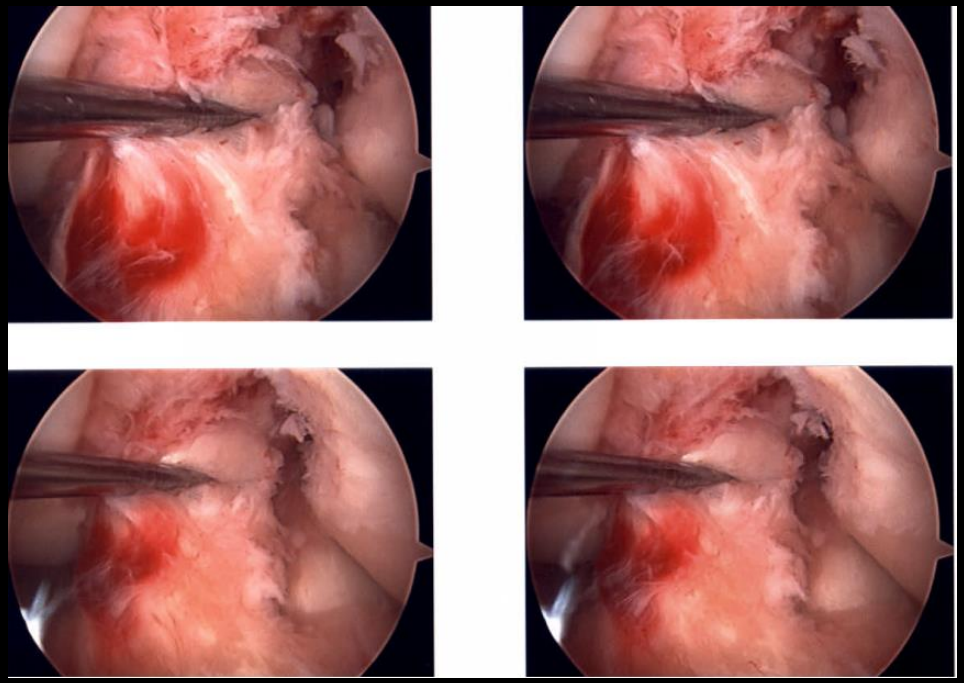
ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION AND ASSOCIATED POST SURGICAL COMPLICATIONS

Thao Wagner MD
Musculoskeletal Fellowship 2013-2014

ACL RUPTURE

Stump
entrapment



MECHANISM OF ANTERIOR CRUCIATE LIGAMENT INJURY: NONCONTACT INJURIES AND CONTACT INJURIES

Left Fig. 4 The classic football clip causes the "Terrible Triad of O Donaghue". A torn MCL, ACL & a torn medial meniscus

Right Fig. 5 A posteriorly directed force to the front of the tibia from a tackle or a car bumper will cause a PCL tear.

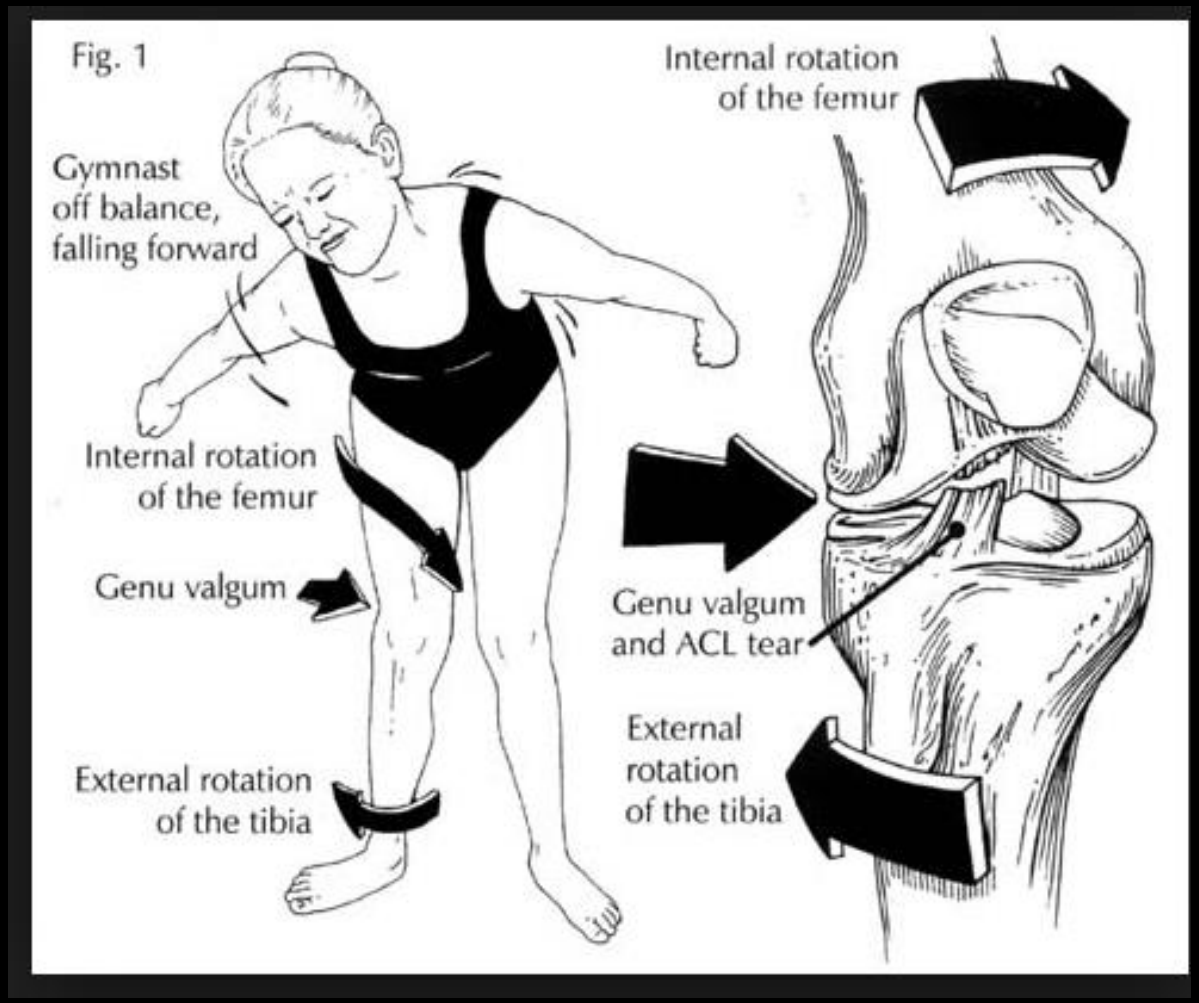
Fig. 6 A twisting and hyperextension injury commonly causes an ACL +/- PCL tear.

Fig. 7 A hyperextension injury in a nonweight bearing leg can cause an ACL or PCL tear.

Fig. 8 A hyperflexion injury such as a fall in skiing causes an ACL tear.

Non-contact Mechanism of Injury

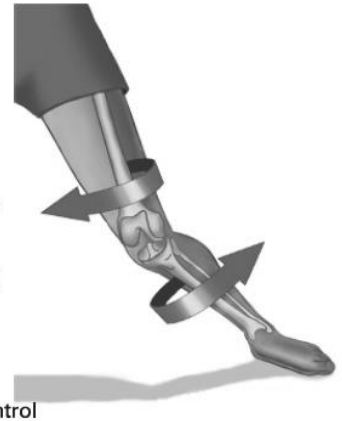
- Most common
- Occurring more in female athletes than male athletes
- Sudden deceleration, landing and pivoting maneuvers
- Lower leg forced forward in relation to the upper leg with a hyperextended knee (knee straightened more than 10 degrees beyond its normal maximal position)
- Slips and falls in people older than 40 years old from wear and tear



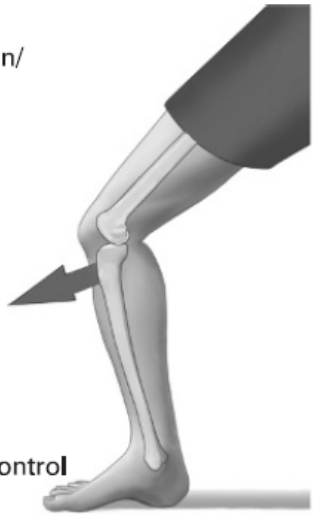
Shannon Miller

Female athlete: Valgus collapse

Multi-planar loading in women	
Body position	
Back	Forward flexed, rotated opposite side
Hips	Adduction internal rotation
Knee	Less flexed, valgus
Tibial rotation	Internal or external
Landing pattern	One foot out of control unbalanced



Sagittal plane loading in men	
Body position	
Back	Upright not rotated
Hips	Neutral little adduction/ rotation
Knee	More flexed less valgus
Tibial rotation	Minimal
Landing pattern	Both feet in control balanced



Contact Mechanism of Tear

Direct contact to the knee

Classic football clip

Hyperextension of the knee

Statistics

- High school football players and female soccer players most likely to present with ACL injuries.
- 617 ACL injuries occurred during the 5-year study period, translating to an estimated 216,000 injuries in those sports across the United States during that time.
  - 11 ACL injuries for every 100,000 times a single football player participated in a game or practice
  - 12 ACL injuries for every 100,000 exposures for girls' soccer
  - 10 per 100,000 for girls' basketball
  - Rates of ACL injury were below 5 injuries per 100,000 for the other sports
- Approximately three quarters of the injuries required surgery

Why Surgical Reconstruction?

- Prevent joint instability, which may further damage articular cartilage and menisci.
- Despite surgical intervention, symptomatic osteoarthritis after ACL reconstruction remains high (13.6%–21.5%)

FEMORAL TUNNEL

(Isometry of graft)

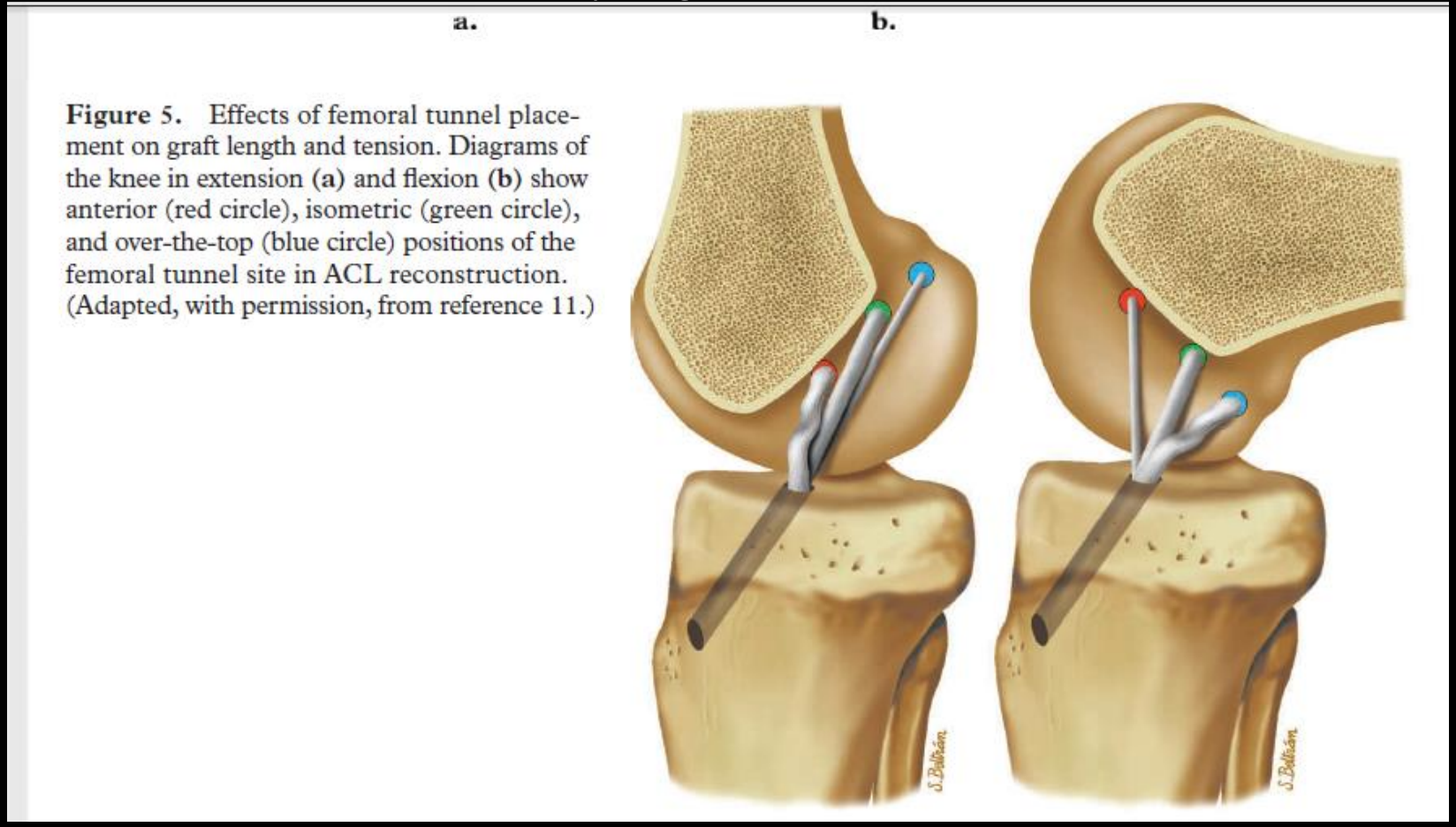
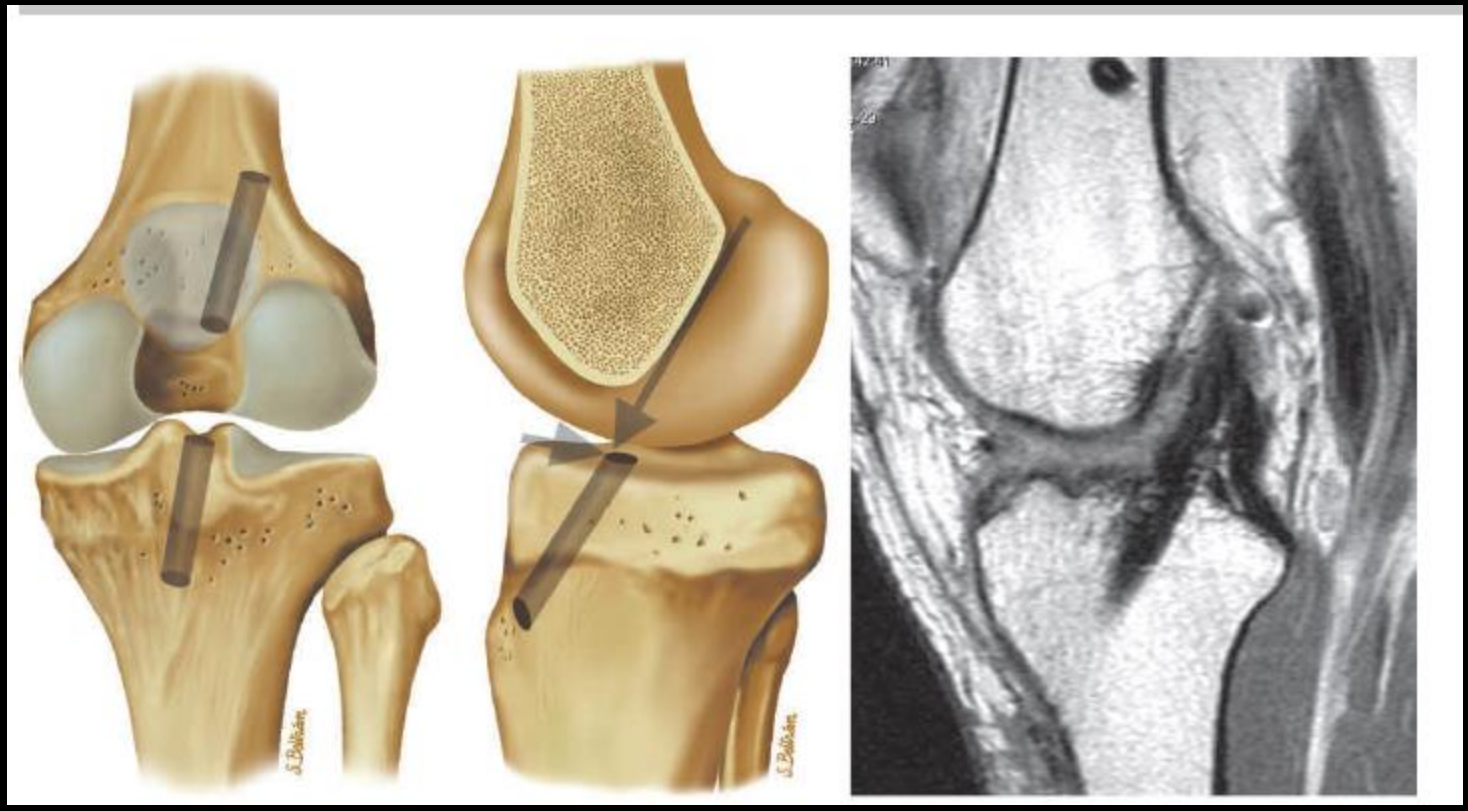


Figure 5. Effects of femoral tunnel placement on graft length and tension. Diagrams of the knee in extension (**a**) and flexion (**b**) show anterior (red circle), isometric (green circle), and over-the-top (blue circle) positions of the femoral tunnel site in ACL reconstruction. (Adapted, with permission, from reference 11.)

Green shows the accurate location of the femoral tunnel, which is essential to achieve isometry of the ACL graft. Isometry refers to adequate constancy in length and tension of the graft during the complete range of knee motion (from flexion to extension).

FEMORAL AND TIBIAL TUNNELS



Femoral tunnel: On a coronal plane, the femoral tunnel should open superiorly at the 1–2-o'clock position on the left knee and 10-11 o'clock on the right knee.
Tibial tunnel: On a sagittal plane, the tibial tunnel should open posterior to the intersection of the Blumensaat line and the tibia (arrows). Ex: **Sagittal proton-density–weighted MR image showing correct** orientation and positioning of the tibial tunnel.

Choices of ACL grafts

- Biological grafts
  - Autografts
    - Patellar tendon: commonly known as bone-patellar tendon-bone (BPTB)
    - Hamstring tendons
    - Quadriceps tendon
    - Iliotibial tract
  - Allografts
- Synthetic grafts (1980s-1990s)
  - Primary reconstruction graft
  - Used after failing biological grafts
  - Augmentation for a biological ACL graft

Choices of ACL grafts

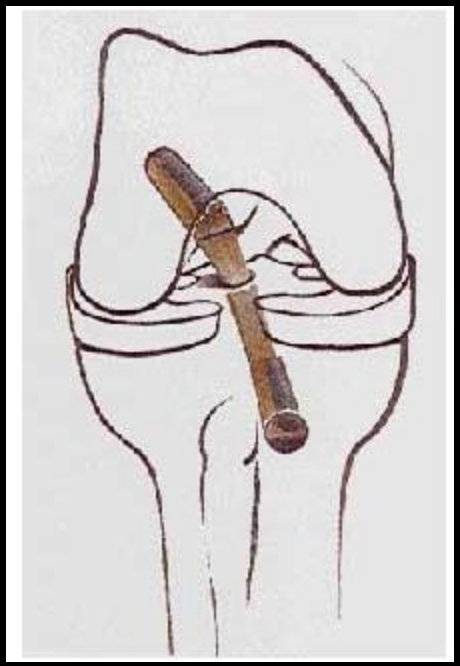
- Biological grafts
  - Autografts
    - Patellar tendon: commonly known as bone-patellar tendon-bone (BPTB)
    - Hamstring tendons
    - Quadriceps tendon
    - Iliotibial tract
  - Allografts

- Synthetic grafts (1980-1990)
  - Primary reconstruction graft
  - Used after failing biological grafts
  - Augmentation for a biological ACL graft

Bone-Patellar Tendon-Bone

- In 1969 Kurt Franke pioneered the use of free BPTB grafts consisting one third of patellar tendon and attached patellar and tibial bone block .
- “Gold standard” of all the other grafts.
- Advantages of BPTB
  - high strength and stiffness
  - consistency of the size of the graft
  - ease in harvesting
  - early graft incorporation
- Solid fixation using interference screw make it the commonest autograft to be used.

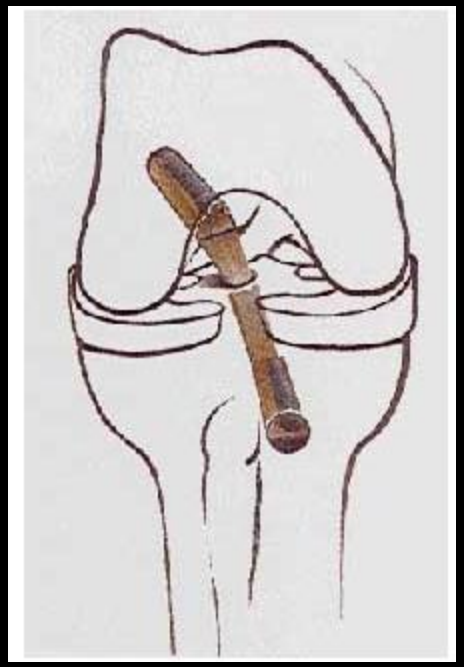
Bone-Patellar Tendon-Bone Graft



BPTB graft is harvested through a 3-4″ long vertical incision medial to the tendon. Few surgeons harvest it using two shorter horizontal incisions centered over each end of the tendon.

Middle third of the tendon 10-11mm wide is removed longitudinally along with 2-2.5 cm long bone blocks in continuity at each end of the graft from the tibial tubercle and the outer surface of the patella.

Bone-Patellar Tendon-Bone Graft



Right knee: femoral tunnel exiting at 10-11'oclock

One of the advantages of this construct is that because the bone-tendon interface is quite strong, the surgeon only has to fix the block of bone in the bone tunnel rather than trying to fix the soft tissue itself. A headless screw is simply inserted next to the bone plug (think of it as a square peg in a round hole) to interference fit and lock the bone in place. The patellar tendon fibers are thereby immediately secured and are stable enough to begin motion and weight bearing when tolerated. The ends of the graft heal bone-to-bone in around 6-8 weeks, which appears to be quicker than the healing process for soft tissue-to-bone. Interference screws are now available in a bioresorbable material that actually dissolves within the bone over 2 to 3 years.

Bone plugs from the bone patellar tendon bone graft are incorporated into the femoral and tibial tunnels.

Disadvantages of BPTB graft

- Anterior knee pain (17.4%) compared to hamstring graft (11.5%), especially with kneeling on donor incision site.
- Patellofemoral pain/patellar tendonitis with stairs, jumping, skiing or other such activities 6-12 months out from surgery
- Incision (scar) is bigger
- Almost all patients end up with a permanent loss of sensation 2-3" in size just lateral to the incision (numbness due to injury to the infra-patellar branch of the saphenous nerve).
- Risk of patellar tendon ruptures, as well as fracturing the patella both intraoperatively as well as postoperatively, although bone grafting the defect in the patella at the time of surgery has reduced the incidence of the latter.
- Loss of quadriceps function.

Not candidate for BPTB graft

- Patients who kneel a lot for a living or religious reasons (Muslims) are often unhappy with the patellar tenderness and sensitivity that can occur at the incision site and should probably consider an alternative graft choice.
- Petite individuals with narrow patellar tendons.
- Patients who have a history of patellar tendonitis, chronic patellofemoral pain or arthritis of the patellofemoral joint.

Choices of ACL grafts

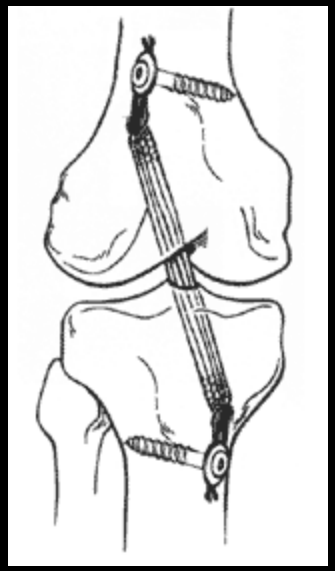
- Biological grafts
  - Autografts
    - Patellar tendon: commonly known as bone-patellar tendon-bone (BPTB)
    - Hamstring tendons
    - Quadriceps tendon
    - Iliotibial tract
  - Allografts
- Synthetic grafts (1980-1990)
  - Primary reconstruction graft
  - Used after failing biological grafts
  - Augmentation for a biological ACL graft

Hamstring tendon graft

- Four-strand hamstring graft often is made of segments from the semitendinosus tendon, the gracilis tendon, or both.
  - Tendon segments are folded and braided together to form a quadruple thickness strand.
- Low morbidity related to the graft harvesting site.
- Smaller incision and are usually less painful to harvest.
- No violation of the patellar tendon, so fewer problems with knee pain Hamstring incision is away from the patella so patients are usually comfortable kneeling after their reconstruction.
- Quadriceps extensor mechanism isn't violated with a hamstring harvest, so less initial quadriceps atrophy.
- Fully recovered patients returning to sports a month or two earlier than they might for a patellar tendon BTB graft. Patients returning to sports 3-4 months. (Patellar tendon tensile strength in rhesus monkeys suggested that the graft was actually weakest at 3 months out before maturing at 6 months post surgery)

HAMSTRING TENDON GRAFT

Doubled (i.e. folded over) combined semitendinosus tendon and gracilis tendon graft (DSTG) because this provides the strongest tensile strength for a hamstring construct.



Hamstring grafts traditionally have been subject to slippage. Fixation of the hamstring tendons was performed by placing large sutures in the ends of the graft and tying these around a screw post outside of the bone tunnels.

This method of fixation required immobilization and a slower initial rehabilitation to prevent stressing the sutures while the tendons healed to the bone tunnels. The sutures at each end of the graft added to the length and elasticity of the whole unit thereby creating a "bungee cord" effect with a loss of graft stiffness; subsequently, this interferes with the ultimate healing of the graft soft tissue to its surrounding bone tunnel and may could result in a graft that was too loose due to its "give".

HAMSTRING TENDON GRAFT

Doubled (i.e. folded over) combined semitendinosus tendon and gracilis tendon graft (DSTG) because this provides the strongest tensile strength for a hamstring construct.

Interference screws with special blunt threads designed not to cut the hamstring tendons are now able to fix the tendon within the bone tunnel similar to the patellar tendon bone fixation.

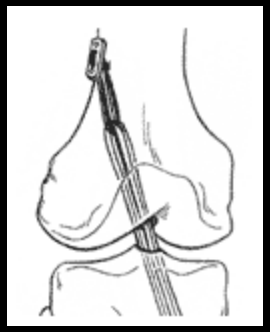
These interference screws are available in bioresorbable forms. One of the screw types even comes impregnated with hydroxyapetite (HA), a bone growth stimulant, to encourage both resorption of the screw as well as stimulate bone growth into the graft. Fixation of the graft within the bone tunnel itself effectively shortens the functional length of the soft tissue graft, thereby reducing the "bungee effect".

Bioresorbable hydroxyapetite-impregnated screw

HAMSTRING TENDON GRAFT

Doubled (i.e. folded over) combined semitendinosus tendon and gracilis tendon graft (DSTG) because this provides the strongest tensile strength for a hamstring construct.

Closed Loop Endobutton: This device acts similar to a wall anchor in that it is pushed through a small hole in the bone and then deploys as a "T" to lock and prevent the graft from pulling out. No longer using this fixation technique routinely, the endobutton is sometimes used for some situations, particularly in some revision (re-tear) operations.



Knotless "rope" loop that the hamstring tendons are passed through and which provides an extremely stiff and strong fixation.

Disadvantages of Hamstring Tendon Graft

- Ultimately relies on soft tissue-to-bone healing, which occurs at a slower rate than bone-to-bone healing.
- Higher incidence of tibial/femoral tunnel widening (seen as early as 3 months post-op)-compromising soft-tissue-to bone healing.
- Harvesting of hamstring tendons -technically demanding procedure requiring considerable surgical experience.
  Pitfalls such as transecting (cutting in half) a tendon or injuring nerves or ligaments in the area of dissection during the stripping process.
- Different technique for tensioning the hamstring tendon in the knee once the femoral end has been secured. The graft needs to be pre-tensioned and it's important that each of the four graft ends be individually tensioned during the tibial fixation for best results.
- Loss of hamstring strength-about 10% loss on the average after recovery.
- Should not use in candidates with history of recurrent hamstring tendon tears.

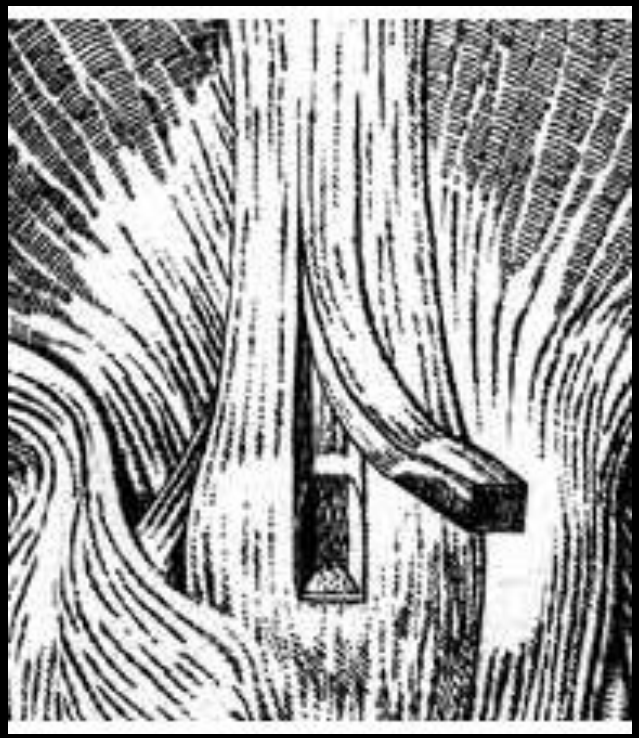
Choices of ACL grafts

- Biological grafts
  - Autografts
    - Patellar tendon: commonly known as bone-patellar tendon-bone (BPTB)
    - Hamstring tendons
    - Quadriceps tendon
    - Iliotibial tract
  - Allografts
- Synthetic grafts (1980-1990)
  - Primary reconstruction graft
  - Used after failing biological grafts
  - Augmentation for a biological ACL graft

Quadriceps Tendon Graft

- Primary ACL reconstruction or alternative choice for revision ACL surgeries.
- Tendon graft with bone on one end (similar to a patellar tendon graft) and soft tissue on the other.
- Bone block comes from the upper pole of the patella, so it is possible to obtain a graft even if there has been prior removal of a patellar tendon bone-tendon-bone graft.
- Quad tendon grafts have a thicker cross sectional area than a corresponding patellar tendon graft with about the same tensile strength.
- Harvesting a quad tendon graft is made just above the kneecap with a small transverse incision.

QUADRICEPS TENDON GRAFT



Popularized by Dr. John Fulkerson in recent years and consisted of harvesting a strip of the end of the quadriceps tendon along with a block of bone off the top surface of the patella. Quadriceps tendon graft fixation in the bone tunnels utilizes the techniques employed for both patellar tendons and hamstrings. Typically the bone end of the quad tendon is fixed in the femur with an interference screw. Any of the variety of methods used for hamstring graft fixation can then be used to secure the tibial end of the quadriceps tendon graft.

Advantage of Quadriceps Tendon Graft

- Alternative choice for revision ACL surgeries- i.e prior bone-patellar tendon-bone graft.
- Rare to get patellar tendonitis symptoms upon returning to sports.
- Able to kneel without too much discomfort.
- Rare to have numbness at the quad tendon incision.

Disadvantage of Quadriceps Tendon Graft

- Potential complications of the patellar and hamstring tendon grafts apply.

Drawback of Autografts

- Donor site morbidity
- Longer recovery time
- Local tenderness
- Pain-i.e. knee with kneeling
- Weakness of the extensor mechanism or hamstrings
- Dependent of skills of surgeons harvesting the grafts
- Longer surgical time

Allografts (Cadaveric donors)

- Patellar tendon
- Hamstring tendon
- Ankle tendons (due to availability issues)
  - Achilles tendon
  - Anterior tibialis tendon
  - Posterior tibialis tendon

Advantages of Allografts

- Completely eliminate disadvantages associated with donor site morbidity-no risks, pain, or scars from the donor site.
- Shorter surgical time.
- Less discomfort postoperatively.
- Reduced incidence of joint stiffness and atrophy of the quadriceps muscle.
- Good choice when there are limitations in a patient's own tissue availability.
- Used with complicated multiple ligament reconstructions needing several grafts (ACL and PCL)
- Revision of ACL after patient failed primary ACL autografts.

Disadvantages of Allografts

- Risk of contracting a serious infection from the cadaveric tissue
  - HIV and/or hepatitis
  - Bacterial infection: not fatal but compromises the graft and can lead to arthritis (septic)

- Grafts can't be 100% sterilized without altering or even destroying the tensile strength of the graft tissue
  - Heating: To adequately kill viruses-must autoclave the tissue (equivalent to pressure cooking a piece of meat at 270 degrees F for 10 minutes)
  - Radiating: over 2.5 Mrads is required to neutralize HIV leads to altering the collagen tissue and reducing the graft's tensile strength.

High failure rate of sterilized and irradiated allografts

- Allografts sterilized with osmotic treatment, oxidation, acetone solvent drying, and gamma irradiation had a 45%-95% rupture rate at 6 years' follow-up.
- Failure rate of the ACL reconstruction with irradiated allograft (34.4%) was higher than that with autograft (6.1%) and non-irradiated allograft (8.8%) in a 31 month follow-up after reconstruction

Current practices in allograft treatments

- Tissue is harvested, cleaned (proprietary cleaning techniques), and stored in liquid nitrogen.
- If possible, donating cadaver is screened for HIV and hepatitis-either via blood testing or tissue sampling.
- Lifestyle analysis for high risk behaviors of donating cadavers if possible
- Published rate of contracting HIV from these tissue allografts is between 1 in 1.2 to 2 million.

Immunologic response to allografts?

- Very low risk (unlike organ transplants)
- Grafts are washed and the bone ends are completely cleansed of any marrow elements.
- Majority of the grafts are primarily made up of collagen, which has very low antigenicity.
- Hypothetically, a family member can donate a tendon graft to another (i.e. parent to a child) but a fresh, non-prepared, un-cleaned graft would have to be tissue-typed (just as blood donations are) to be sure that the tissue match would be compatible. Most facilities are not set up for proper graft preparation. Also, an older donor's graft tissues may not be strong enough to handle the loads and demands of the child's activities especially if he/she is a competitive 21-year-old athlete.

  IDENTICAL TWINS WOULD WORK

Disadvantages of Allografts

- Healing and incorporation of allografts take longer than autografts but allograft patients' recovery time is quicker (3-4 months)—so the patients return to their activities sooner and do not allow adequate time for the allograft to heal and incorporate –risking graft stretching and rupturing. Studies have not supported this concern but a concern that allograft patients should be aware of. Can take up to 3 years to incorporate per some studies.

- Very expensive-- from $2000 to $10,000-- depending on the tissue type and geographic location. Increasing demand combined with a low supply of suitably qualified cadavers (there just aren't a lot of young, healthy cadaver donors with low-risk life styles).

Drawback of Biological Grafts

- Autografts
  - Donor site morbidity
  - Longer recovery time
  - Local tenderness
  - Pain-i.e. knee with kneeling
  - Weakness of the extensor mechanism or hamstrings
  - Dependent of skills of surgeons harvesting the grafts
  - Longer surgical time
- Allografts
  - Infections/Disease transmission
  - Sterilization/Cleaning/Storage of the graft weakens the tissue
  - Expensive

Popularity of the Synthetic Grafts (1980s-1990s)

- Lack of donor morbidity
- Immediate loading
- Reduced postoperative rehabilitation
- Abundant supply
- Significant strength
- No transmission of disease seen from allografts

Types of Synthetic Grafts

- Carbon
- Polytetrafluorethylene (PTFE): Gore-Tex
- Polyester: Dacron

Carbon Grafts

- Carbon
  - Proplast ligaments (Vitex-Inc, Houston, TX, USA) made of Teflon and carbon and
  - Polyflex (Richard, Memphis, TN, USA) made of polypropylene.
  - Intergraft, OsteonicsBiomaterials, Livermore, CA, USA).
  - These carbon grafts had high rupture rates, inflammatory reaction to surrounding tissues, synovitis of the knee, and carbon deposits within liver.

Polytetrafluorethylene Grafts

- Polytetrafluorethylene (PTFE): Gore-Tex
  - Failures were related to mechanical fatigue due to the lack of tissue ingrowth
  - Presence of wear debris
  - Synovitis
  - Tunnel osteolysis with progressive tunnel enlargement leading to late failure
  - Inguinal lympadenopathy with PTFE particles within these lymph nodes
  - Withdrew from the market in 1993

Polyester Grafts

- Polyester: Dacron
  - High rate of rupture
  - Synovitis
  - Osteoarthrosis of knee (>50% narrowing of knee joint) in 40% of studied patients over a 9 year period.
  - Withdrew from market in 1994.

Severe osteoarthrosis (Grade V) in a patient 18 years after the synthetic ACL graft reconstruction.

Animal studies showing synthetic grafts inducing osteoarthrosis

The effect of wear debris has been studied using animal models at Pittsburg University. Olson et al. reported the in vivo and in vitro behaviour of seven artificial ligaments on synovial cells; the foreign-body reaction induced by the synthetic particles led to giant cell aggregation and synovial hypertrophy close to the wear debris [51]. All grafts were associated with increased expression of cytokines such as interleukin-1 (IL-1) and various metalloproteinases (MMPs), including gelatinases and collagenases. These MMPs are involved in the unbalanced matrix degradation process that initiates cartilage degeneration in osteoarthritis [52]. Studies demonstrate that the inflammatory reaction caused by wear particles of a foreign body leads to peculiar modification in the composition of the synovial fluid: the protein concentration within the synovial fluid increases in response to synovitis signalling reactions [53]. The depletion of cartilage matrix that follows is responsible for the development of osteoarthritis.

Why Synthetic Grafts Grew Out of Favors

- Structural failures
  - high rupture rate has been related to the loss of strength due to foreign-body reaction with increased permeability of the ligament to synovial liquid
  - loss of wear particles leading to inflammatory reaction that inhibits the ligamentization process
  - incapacity to reproduce an implant mimicking the correct anatomy of the natural ACL
- Immunological response against the artificial ACL
- Tunnel osteolysis
- Femoral and tibial fractures near the tunnels
- Cross-infections
- Foreign-body synovitis
- ?Induces/Expedites osteoarthrosis of knee
  - rate of osteoarthritis observed in the long-term follow-up was higher than the one previously described after primary repair, with most patients having grade III.
  - Wear particle debris
  - Chronic synovitis/inflammatory response

Augmented Synthetic Grafts

- Kennedy Ligament Augmentation Device (LAD)—no longer used
- Leeds - Keio (LK) Ligament
- Ligament Advanced Reinforcement System (LARS). These ligaments are made of polyethylene terephtalate (PET) and their structure allows tissue ingrowth in the intra-articular part.
- Artelon

Kennedy Ligament Augmentation Device (LAD)

Objective: To make tissue graft more durable.
Mechanism: 8-mm diameter ribbon of polypropylene was inserted and fixed on top of the ACL tissue graft to augment and protect the reconstruction while gradually transferring the stress load to the tissue graft.
Unintended outcome: The device only shielded the graft from normal stress loads that were needed to help the graft heal and mature correctly. LAD would fail because it had different stretch characteristics than the autograft, and the underlying tissue graft was then abruptly exposed to high tensile stresses to which it hadn't yet adapted. The result then was often stretching or failure of the biologic graft itself.

Leeds-Keio Ligament

- Developed in 1982 from collaboration between University of Leeds, UK and University of Keio, Japan.
- Made by woven polyester fibers constituting a tubular bundle measuring 10 mm in diameter.
- “Scaffold” type of prosthesis, inducing tissue in growth; porous coating allows the induction of biological tissue and promotes the formation of a neo-ligament on the intra-articular portion.
- 152 patients followed for more than four years: 90.1% had a negative Lachman test and 82.2% a negative anterior drawer sign; no major complications.
- Second-look arthroscopies performed three and six months after surgery reported a good coverage of the implanted ligament; ruptures occurred only in 3.3% of cases.
- 10-16 years follow-up studies concluded: all postoperative knees had increased degenerative changes compared with their opposite joint and that LK ligaments do not give satisfactory guarantees in ACL reconstruction.

Ligament Advanced Reinforcement System (LARS)

- Made of polyethylene terephtalate (PET) and the ligament structure allows tissue ingrowth in the intra-articular part.
- Follow-up studies: LARS ligament gave better subjective and objective outcomes during the initial years, while no difference with the autologous procedure could be found 24 months after surgery.
- In a retrospective study, Liu et al. compared LARS artificial ligaments to four-strand hamstring tendon autografts four years after implantation. They observed excellent functional outcomes, with a higher knee stability in the LARS group.
- More research still pending.

Artelon

- Series of woven polymer fibers with similar mechanical properties to ligaments (being studied in Europe)
- Biocompatible
- Serves as a scaffold to allow native tissue to gradually grow in over 3-4 years. It slowly weakens over time which gives the new biologic tissue a progressive load stimulus that allows it to adapt and strengthen to its ultimate maturity.

Possible graft options

- Xenografts (nonhuman animal tissues)
  - Kangaroo-initially studied in 1929
  - Pig grafts-still being considered

Complications of ACL reconstruction

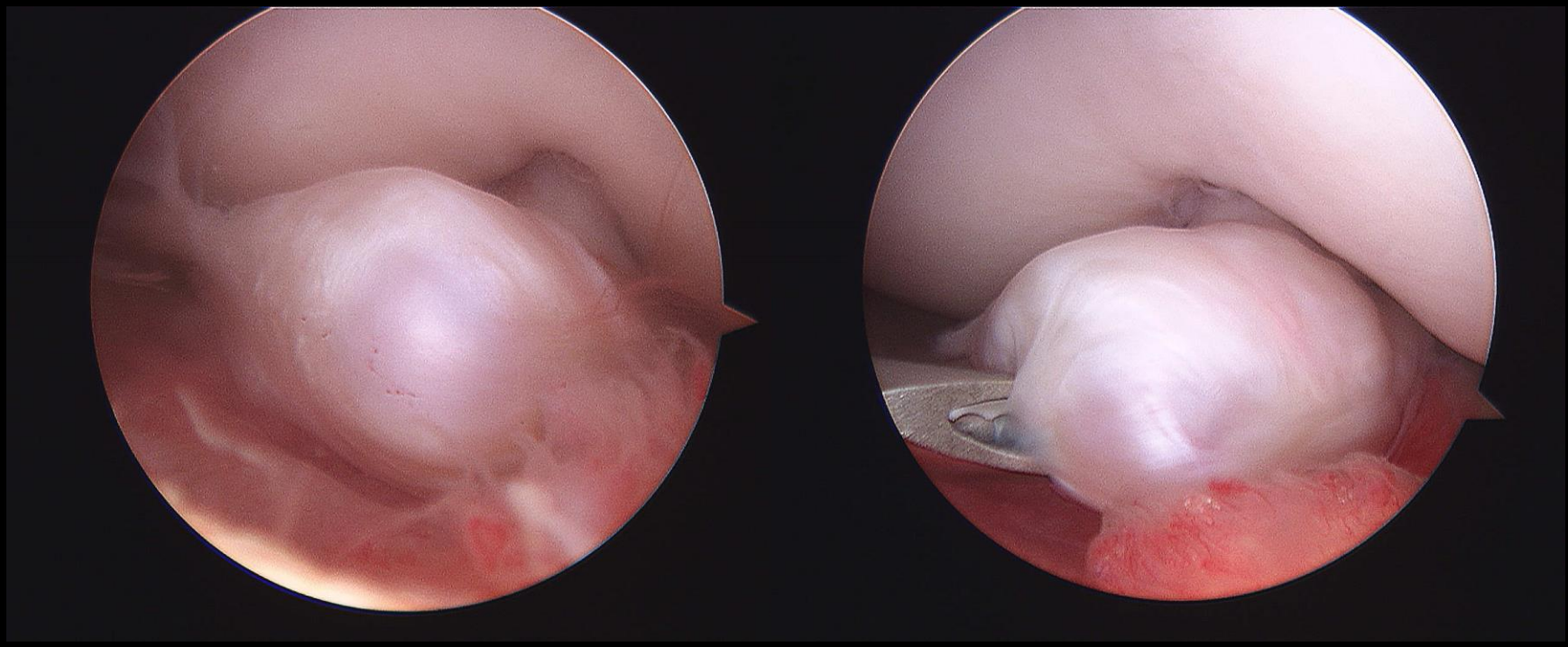
- Arthrofibrosis
- Tunnel Cysts
- Roof Impingement
- Iliotibial Band Friction Syndrome
- Hardware-related Complications
- Infection
- Partial graft tearing
- Complete graft tear

Arthrofibrosis

- Defined as the presence of scar tissue in at least one compartment of the knee joint, leading to a decreased range of motion.
- Localized anterior arthrofibrosis, or “cyclops” lesion, has been reported in 1%–10% of patients with ACL reconstruction.
- True cyclops nodules contain osseous or cartilaginous tissue and are more prone to entrapment (cyclops syndrome).
- Cyclopoid scars contain only fibroproliferative tissue and are easily compressed by adjacent bones without limiting knee extension.
- MR imaging findings of a cyclops lesion include an anterior intercondylar nodule with mixed intermediate signal intensity on T1-weighted, T2-weighted, and proton-density–weighted fast spin-echo images. The lesion extends in a linear fashion along the intercondylar roof.

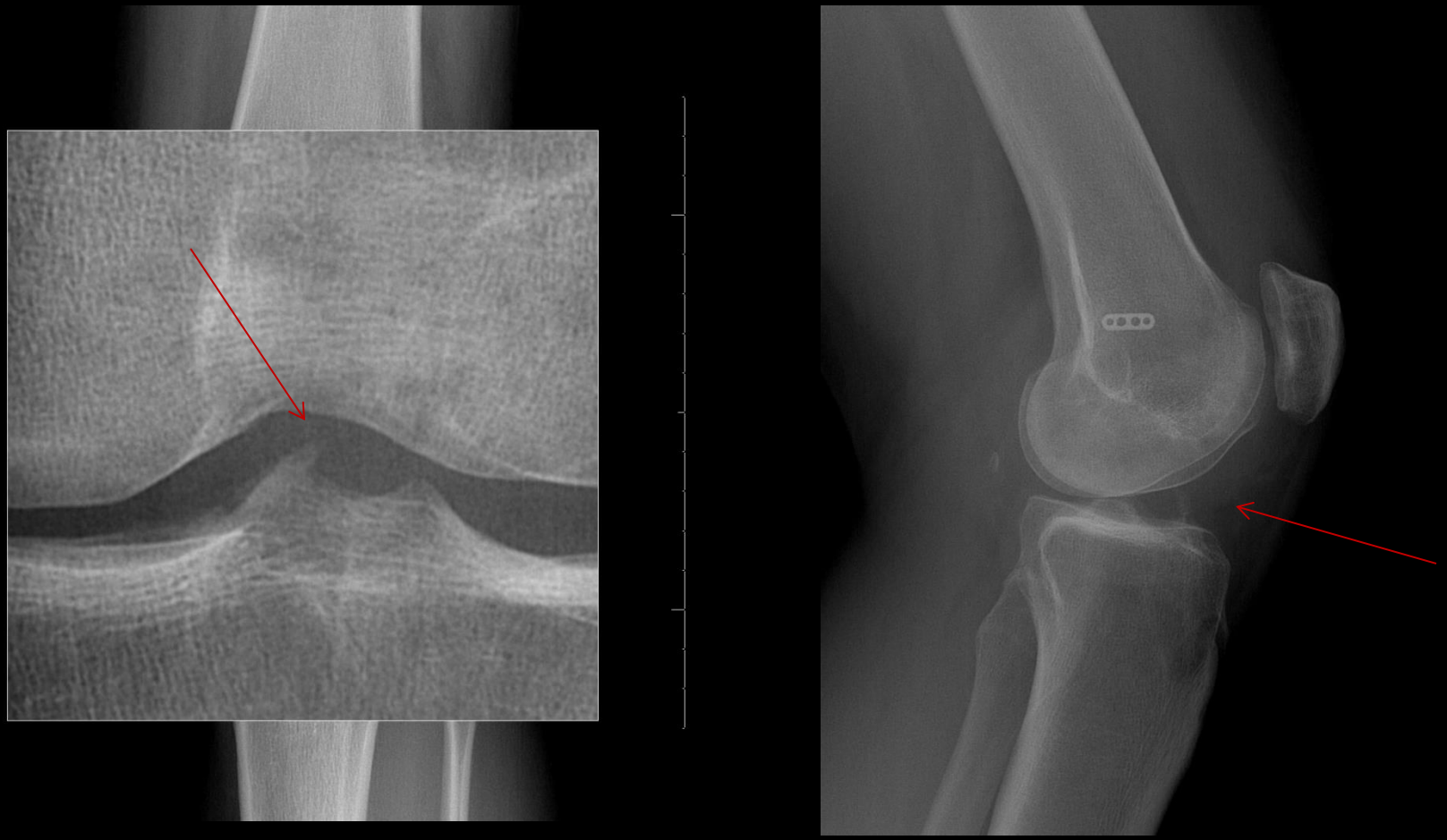
CYSTIC CYCLOPS

Cystic Cyclops

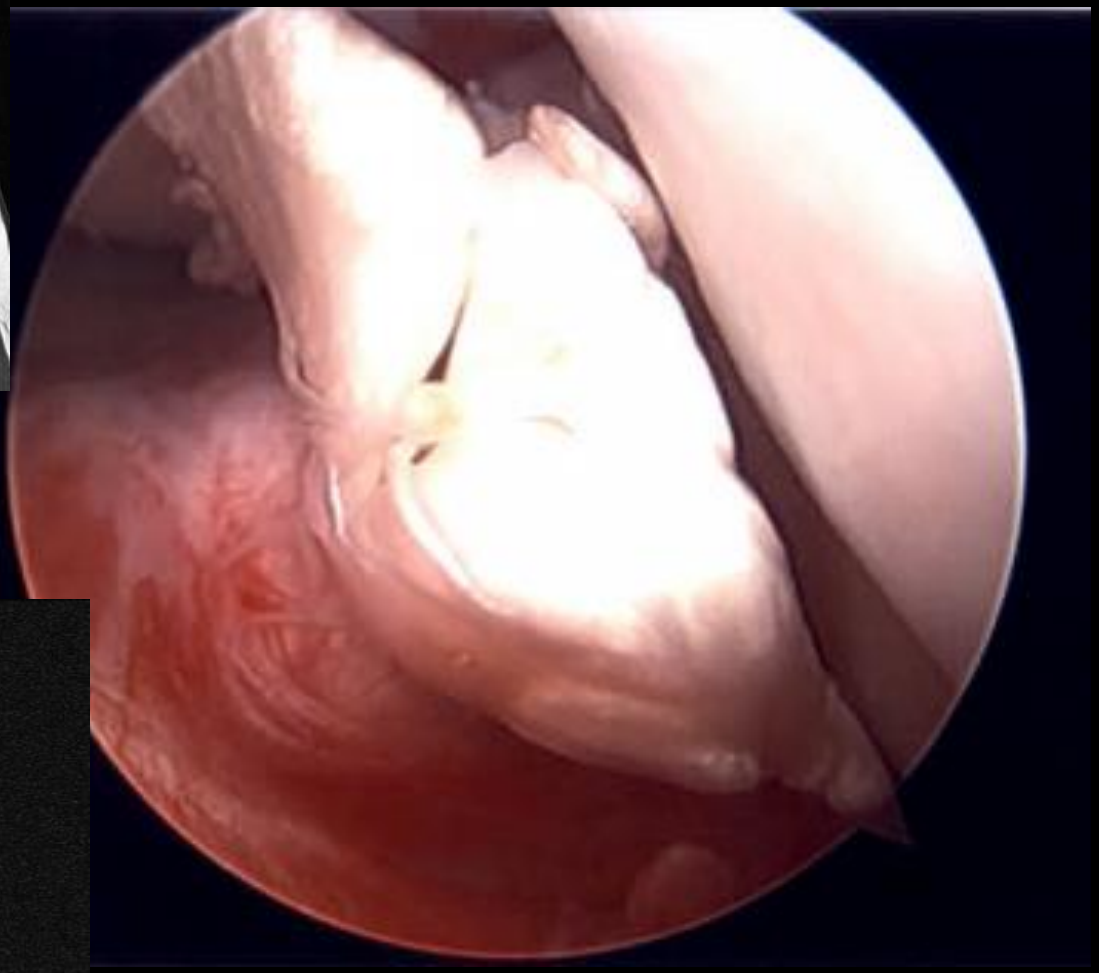


BONY CYCLOPS

5/29/13



Radiographs obtained due to continual hesitation with extension post ACL reconstruction, and chondroplasty, partial resection of medial and lateral menisci.



Tunnel Cysts/Tunnel Enlargement

- Small amounts of fluid may be seen within the tibial and femoral tunnels during the 1st year after ACL reconstruction-- reabsorbed within 18 months after surgery and does not necessarily lead to tunnel expansion, ganglion formation, or graft failure..
- Incomplete incorporation of allograft tissue within the bone tunnels and subsequent tissue necrosis may allow synovial fluid to be transmitted through the tibial tunnel to pretibial subcutaneous tissues.
- Bioabsorable interference screws, nonabsorbable suture fragments, and joint fluid leakage during failed ACL revision surgery also have been implicated in tunnel cyst formation.
- “Bungee-cord” or “windshield-wiper” tunnel widening may occur when intraosseous fixation is not performed.
- Extrusion of joint fluid into the tunnel may lead to formation of a ganglion.
- Rare to have femoral tunnel cysts, which are more likely associated with complete disruption of ACL graft.

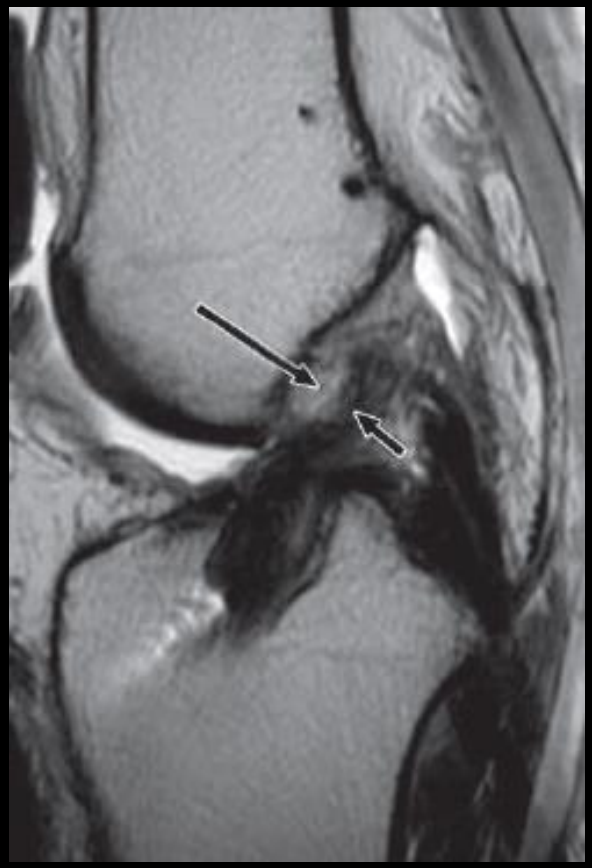
The cyst can get quite large and symptomatic.

Cystic enlargement of the tibial and femoral tunnel with complete failure of the ACL graft.

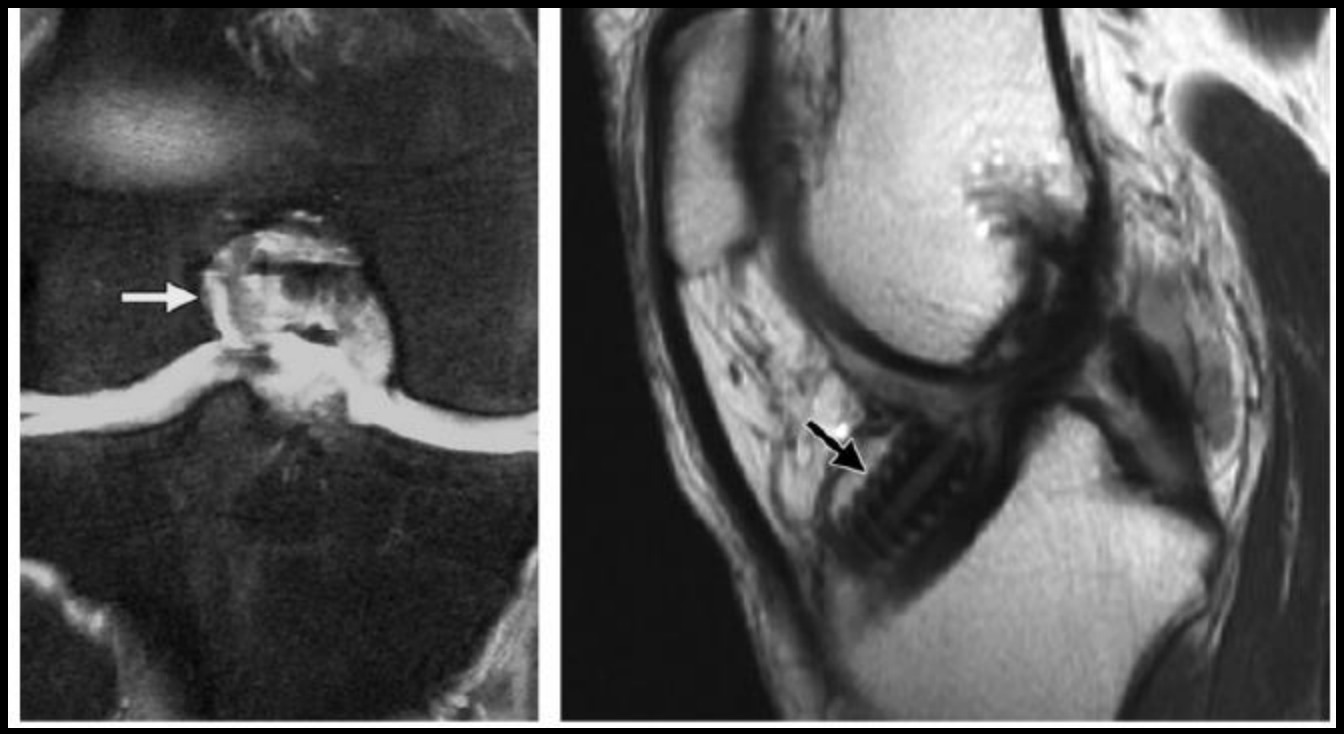
Roof Impingement

- Often secondary to an abnormal position of the tibial tunnel anterior to the intersection of the Blumensaat line and the tibia when the knee is fully extended.
- Determine whether anterior tibial translation is the cause of the abnormal position of the tibial tunnel.
- In some patients, tightening of the posterior capsular restraints after ACL disruption may lead to fixed anterior translation of the tibia over the femur.
- MR imaging: the impinged graft is in contact with the anteroinferior margin of the intercondylar roof and may appear posteriorly bowed.
- Signal intensity alteration selectively involves the anterior two-thirds of the graft.

ROOF IMPINGEMENT



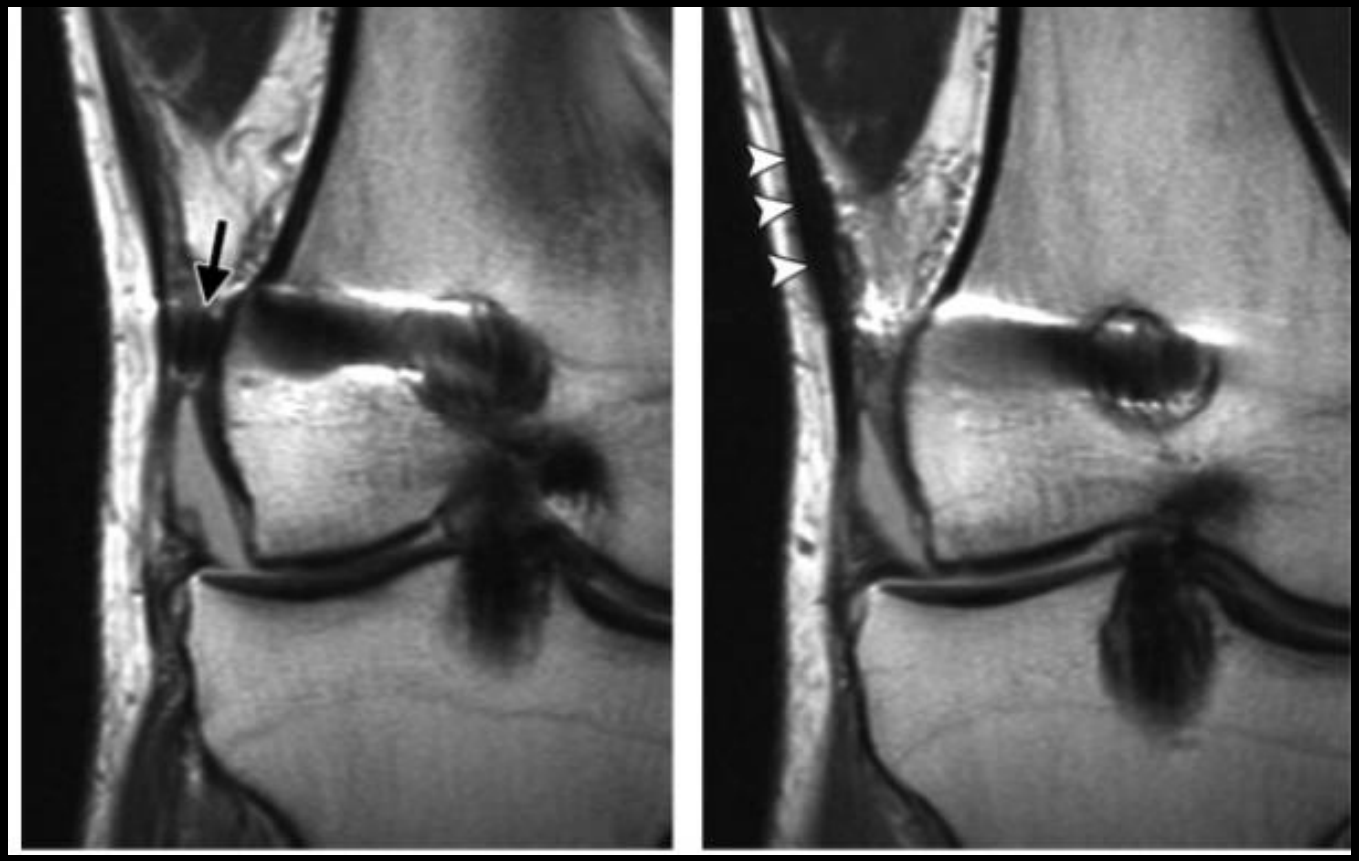
Sagittal proton-density–weighted MR image shows spurring (long arrow) of the anterior margin of the intercondylar roof and posterior bowing of the graft (short arrow). An area of increased, intermediate signal intensity is seen within the anterior two-thirds of the graft.



Notchplasty. Coronal T2-weighted fat-suppressed MR image shows a focal cortical defect in the anterior aspect of the medial wall of the lateral femoral condyle (arrow), a finding suggestive of notchplasty. **Tibial interference screw. Sagittal proton density–**weighted MR image shows an interference screw (arrow) within the tibial tunnel, anterior to the ACL graft. The screw was placed to correct roof impingement, which was discovered intraoperatively.

Iliotibial Band Friction Syndrome

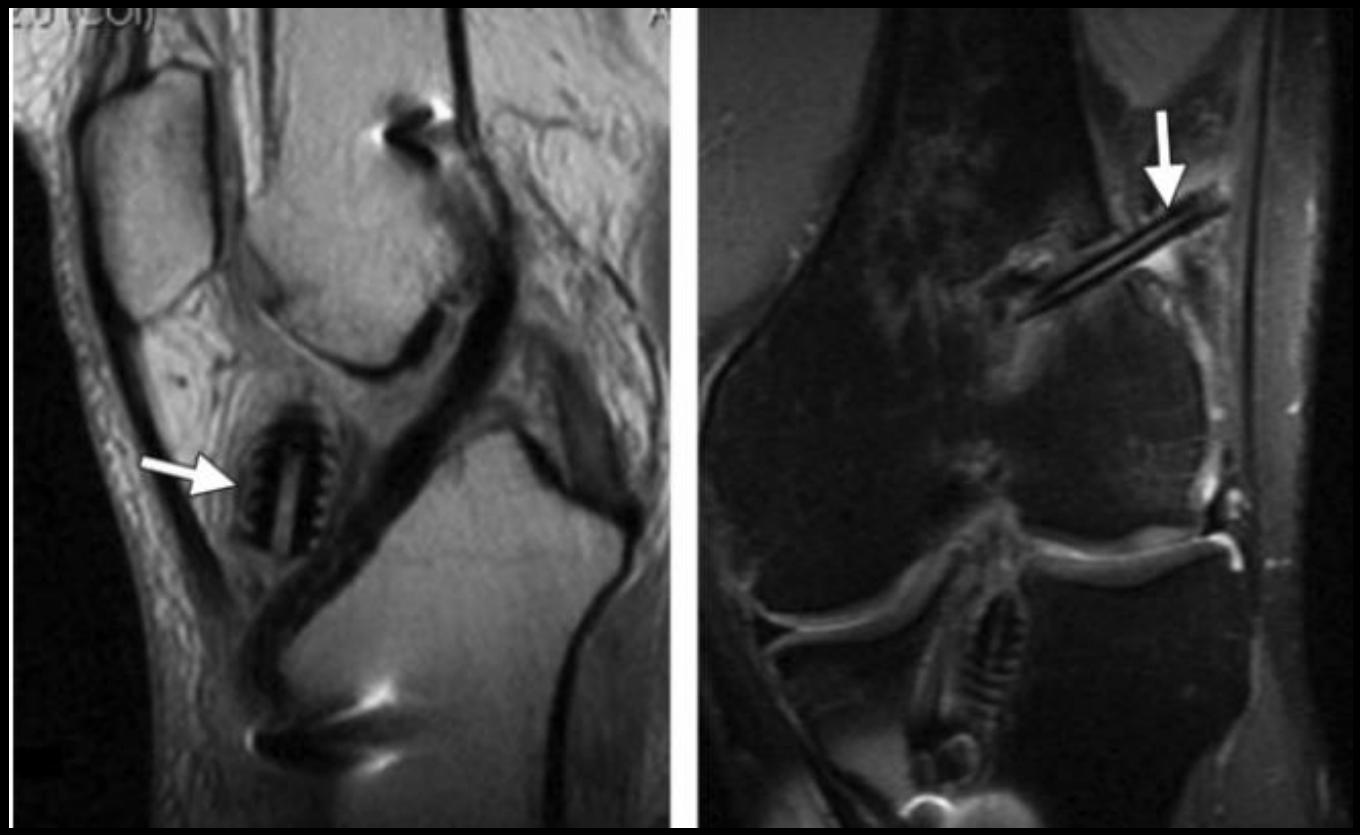
- Potential complication of ACL reconstruction with the use of a hamstring graft and bioabsorbable cross pins (transfix device).
- Partially dislodged or fragmented cross pins may contact the adjacent iliotibial band and cause frictional thickening or tearing.



Iliotibial band friction syndrome. Sequentially acquired coronal proton-density–weighted fast spin-echo MR images show focal fusiform thickening of the iliotibial tract (arrowheads in **b) due to friction** caused by contact with a femoral ACL fixation pin .

Hardware-related Complications

- Fixation devices that may loosen or become displaced include bioabsorbable interference screws, metallic setscrews, and pins.



Hardware failure. **(a) Sagittal proton-density–weighted fast** spin-echo MR image shows a loosened tibial interference screw (arrow). **(b) Coronal T2-weighted fast spin-echo MR image shows a loosened and** partially dislodged cross pin (arrow) used for femoral fixation in ACL graft reconstruction.

Infection

- Uncommon to have septic arthritis following ACL reconstruction--reported cumulative incidence of 0.1%–0.9%.
- Very difficult to correctly diagnose infection at an early stage because classic symptoms of infection are often absent: erythema, warmth, severe restricted motion, and severe pain.
- Possible signs: mild local pain and effusion associated with an increased C-reactive protein level and increased erythrocyte sedimentation rate that extended beyond the 1st postoperative week
- Use MR imaging to look for: synovitis, bone erosion, periarticular edema, marrow edema, sinus tracts, and soft-tissue abscesses

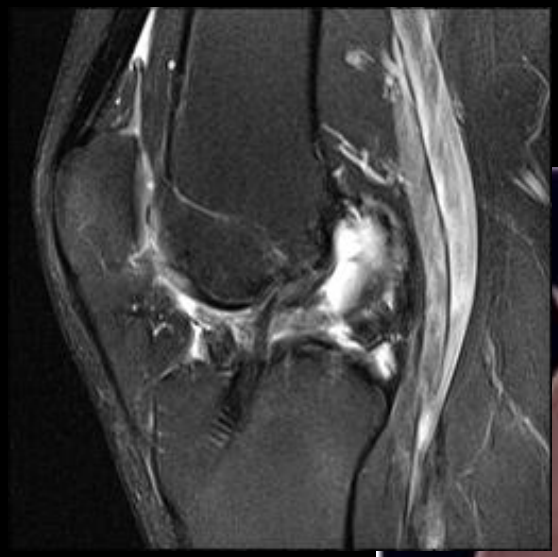
Infected infrapatellar bursitis. Sagittal T2-weighted fat-suppressed fast spin echo MR image shows a subcutaneous fluid collection overlying the opening of the anterior tibial tunnel. Reactive marrow edema is seen in the proximal tibia. No evidence of osteomyelitis was found at intraoperative biopsy.

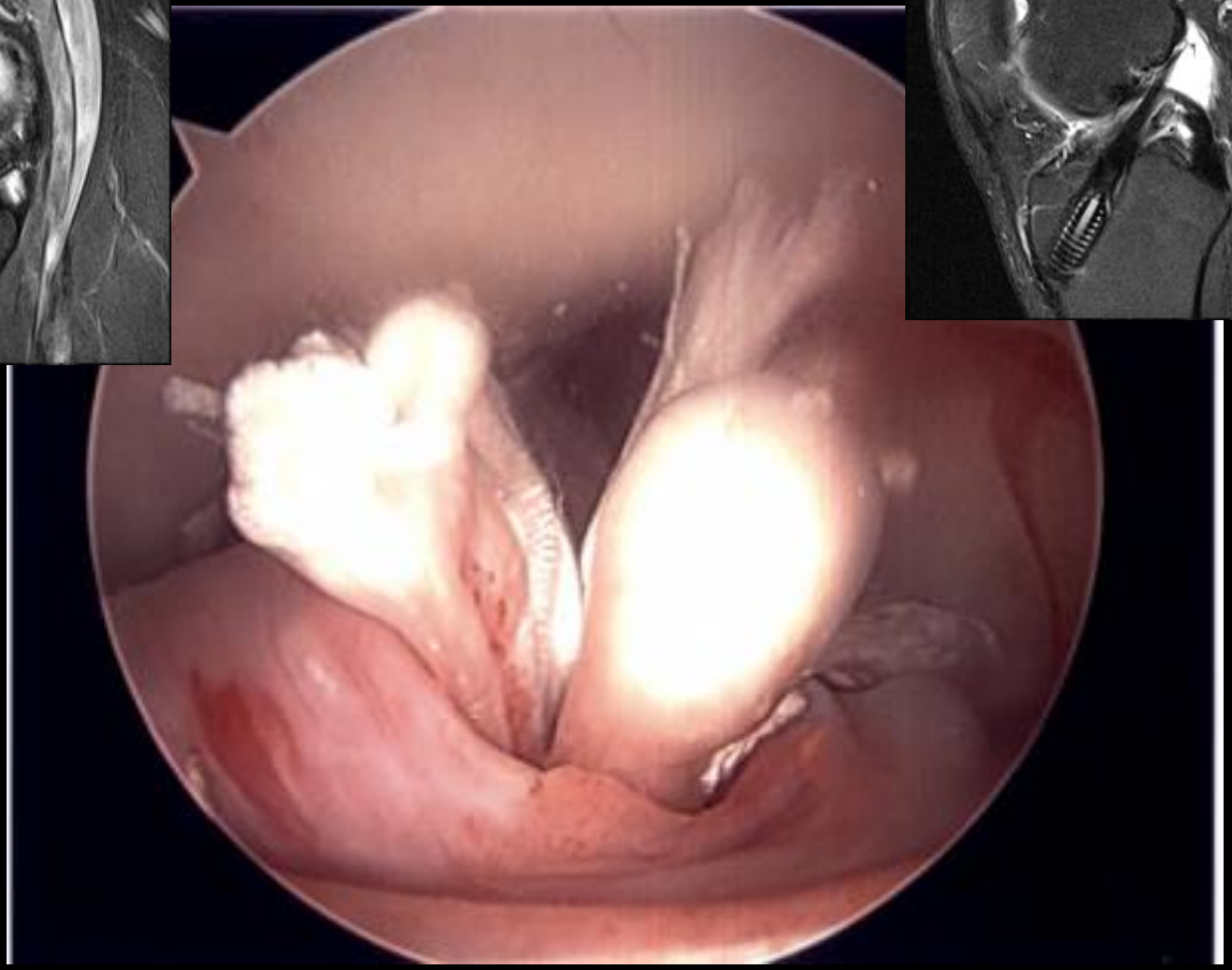
Graft failure (Partial-thickness or full-thickness tear)

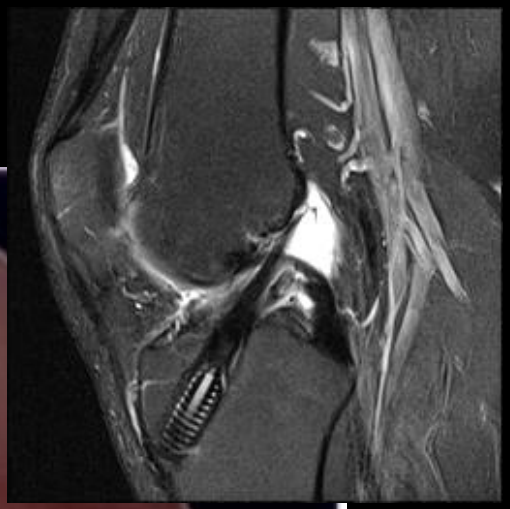
- Defined as pathologic laxity of the reconstructed ACL
- The prevalence of recurrent instability after primary ACL reconstruction ranges from 1% to 8%.
- Early failures, those that occur within the first 6 months, often are secondary to poor surgical technique, failure of graft incorporation, or errors in rehabilitation.
- Late failures, those that occur more than 1 year after surgery, likely are related to new trauma and graft tearing.

Partial-thickness Graft Tear

- Partial thickness graft tear: At T2-weighted MR imaging, focal areas of increased signal intensity covering a portion of the graft, with intact fibers still present.
- Differential diagnosis for partial graft tear includes the normal "ligamentization" phase that occurs in immature grafts and signal heterogeneity between the individual bundles in multistrand hamstring grafts.
- Ligamentization with small focal areas (<25% of the graft substance) of increased intermediate signal intensity within the graft can persist for as long as 4 years after ACL graft reconstruction.

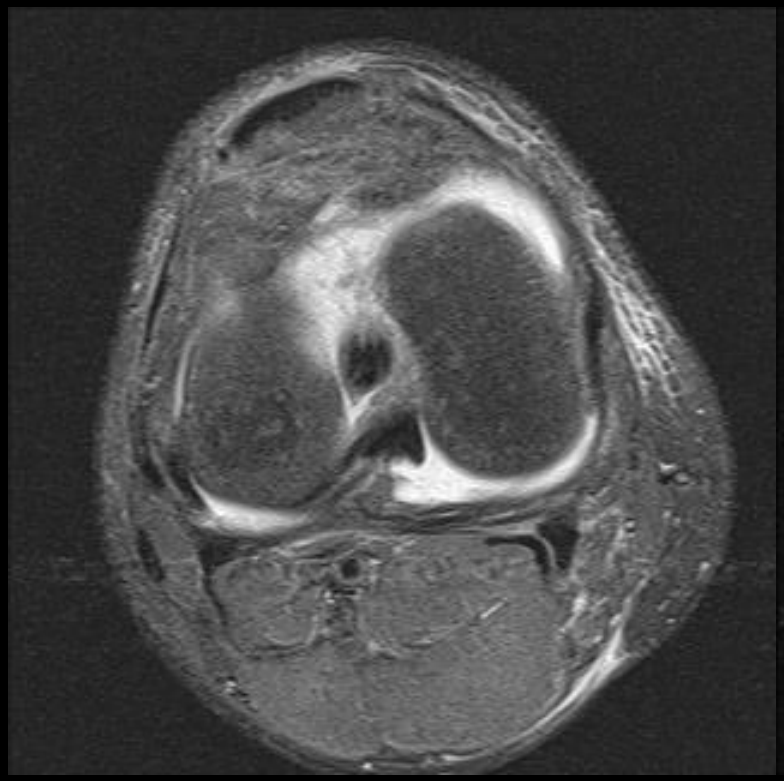




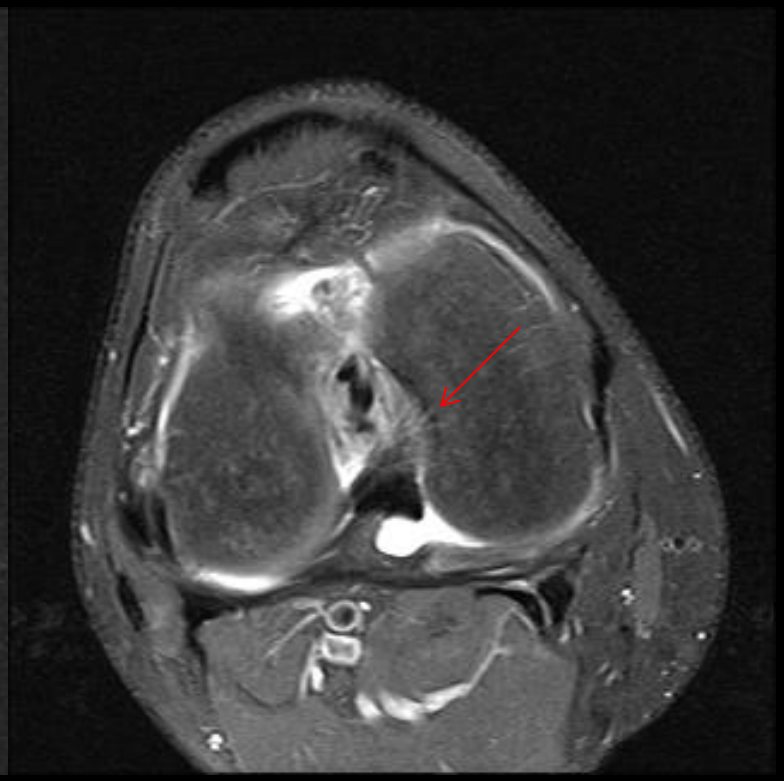


Partial thickness tearing of ACL graft and small cyclops

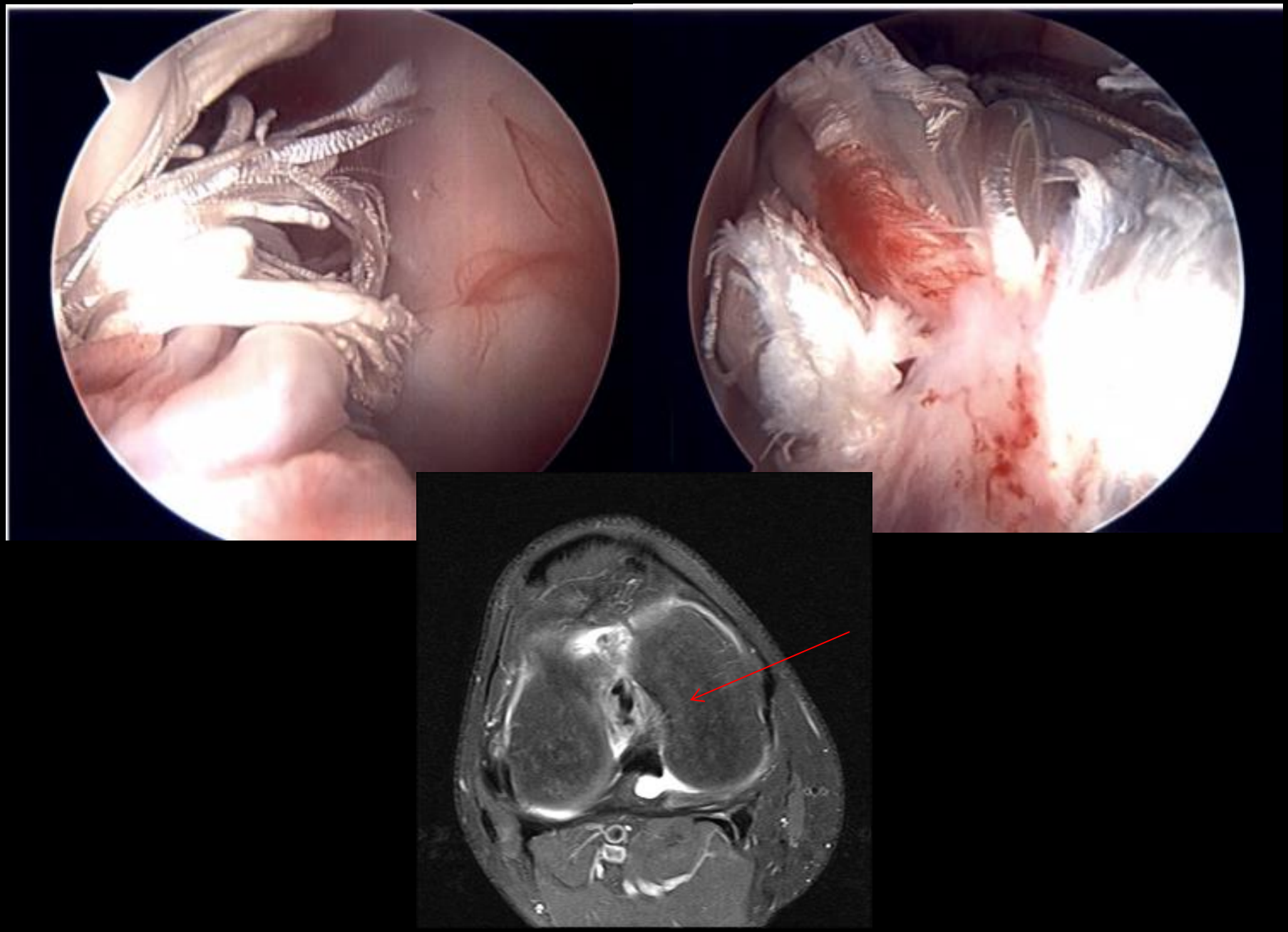
Partial-thickness tearing of hamstring tendon graft



MRI 12/21/12

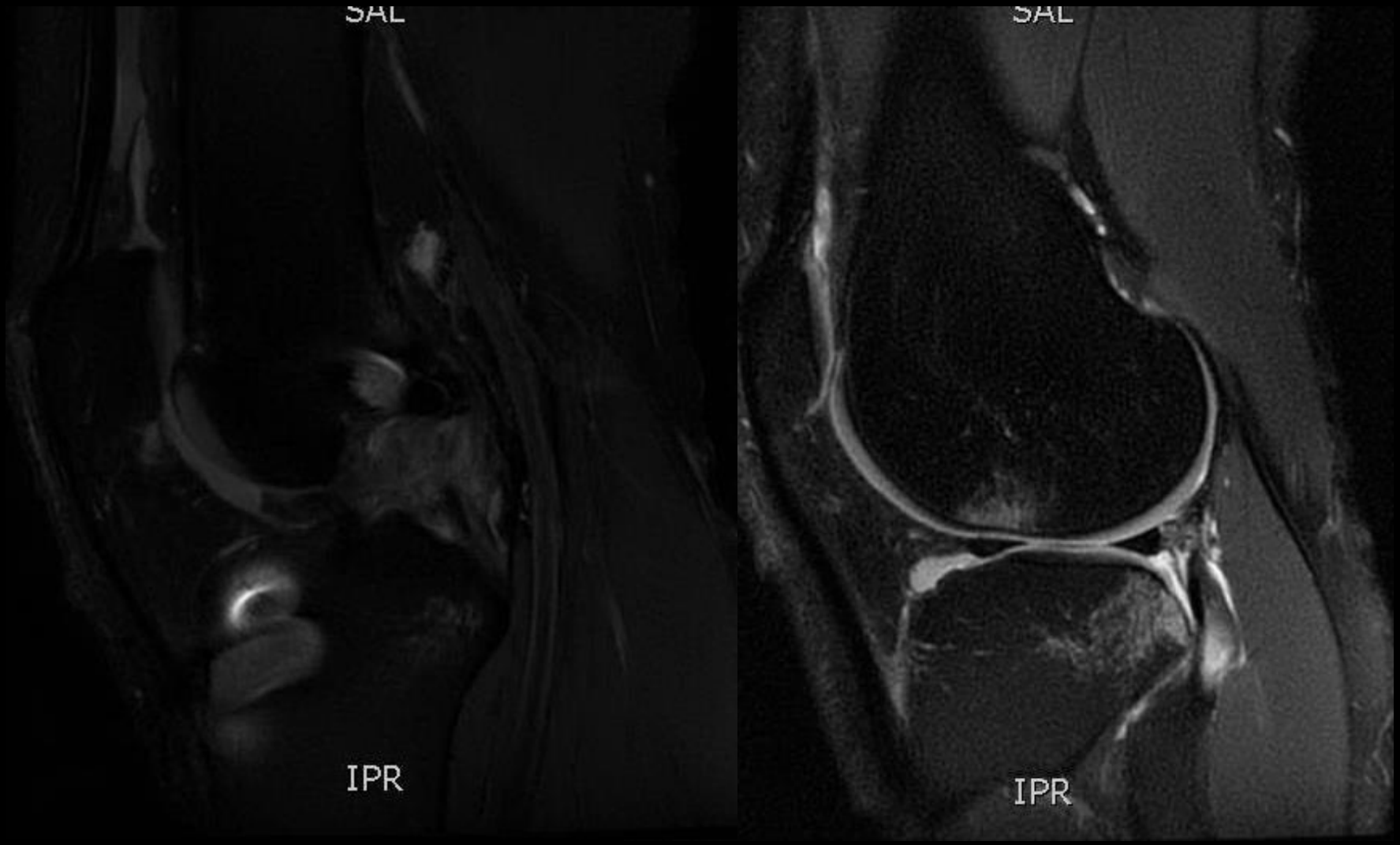


MRI 7/29/13-can see torn fibers



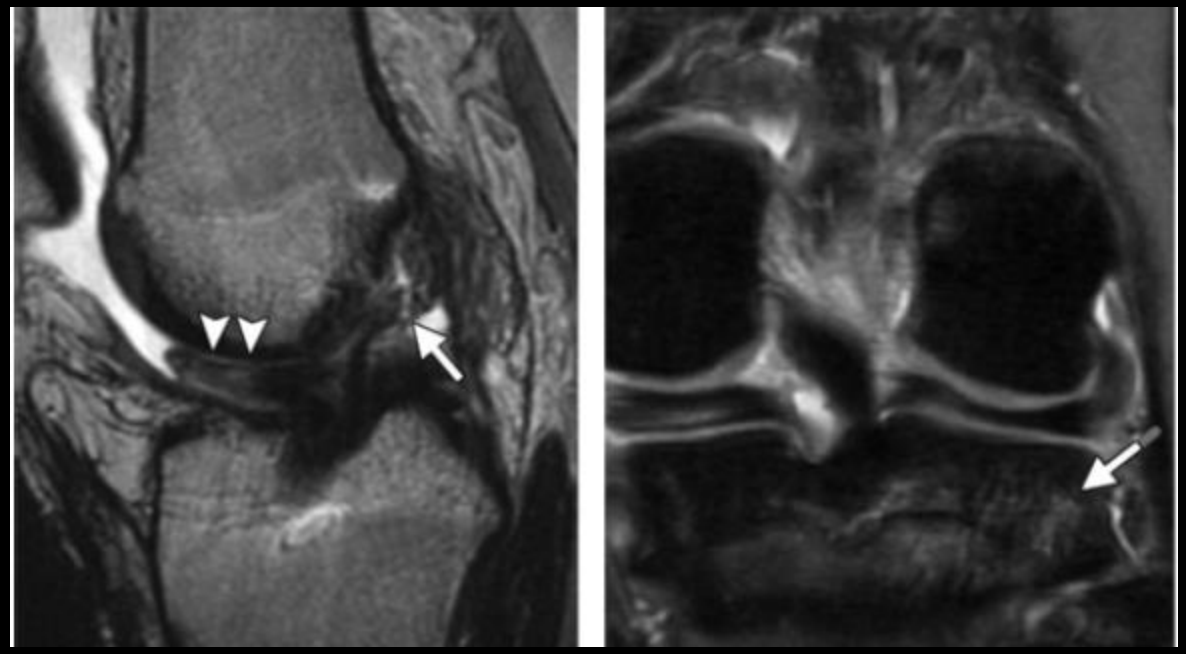
Full-thickness Graft Tear

- Often the result of acute trauma.
- Possibly nonisotropic positioning of the graft tunnel resulting in abnormal stress to the graft during normal range of motion.
- T2-weighted MR imaging findings of acute complete graft disruption include an absence of intact graft fibers and a fluid-filled defect.
- Presence of a large effusion and pivot-shift bone bruises in the lateral compartment are highly specific and have great positive predictive value for the identification of complete graft tear.
- MR imaging signs of complete ACL disruption include a horizontal graft orientation or laxity and resorption of graft fibers.



Full thickness tearing of ACL graft from acute trauma (football injury) with anteriorly displaced torn fibers and lateral bone contusion.

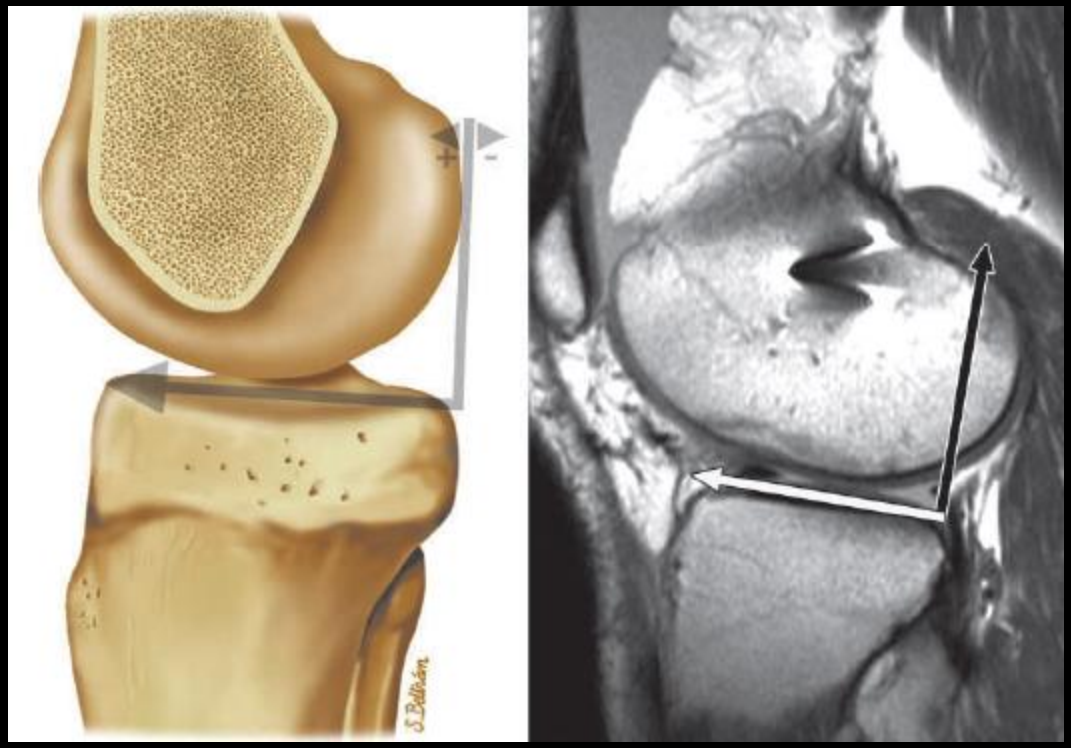
Complete Graft Tear



Sagittal T2-weighted fast spinecho MR image shows a fluid-filled graft defect (arrow) and anterior flip of the torn fibers (arrowheads), findings indicative of an acute complete graft tear.

Coronal T2-weighted fat-suppressed fast spin-echo MR image (obtained in the same patient as **a) shows a** contusion of the tibial bone marrow (arrow), a finding indicative of recurrent trauma.

Complete Graft Tear



Anterior tibial translation:**(a) Diagram shows normal alignment of the tibia (arrows),** with respect to the femur, in the sagittal plane.

Sagittal proton-density–weighted MR image shows an abnormal anterior position of the tibia (arrows) caused by fixed anterior translation of the tibia over the femur.

CONCLUSION

- ACL injury and ACL reinjury becoming common occurences.
- Increasing number of surgical interventions.
- Continual search for the perfect graft, striving to improve surgical techniques, and optimizing rehabilitation without compromising the graft (especially perioperative period).
- Increasing usage of imaging to evaluate the initial injury, status of ACL graft after surgery, and complications associated with the ACL reconstruction.

Research Project?

- Current ACL graft comparison/integrity and rate of failure studies are based on history and physical examination. Does imaging have a role in these annual routine follow-ups?

- Can imaging be used to tell when a patient can start rehab and how intense that rehab should be?

REFERENCES

Jenny T. Bencardino, MD • Javier Beltran, MD • Marina I. Feldman, MD, MBA • Donald J. Rose, MD. MR Imaging of Complications of Anterior Cruciate Ligament Graft Reconstruction. *Radiographics*. November 2009 Volume 29, Issue 7

Claudio Legnani & Alberto Ventura & Clara Terzaghi & Enrico Borgo &Walter Albisetti. *Anterior cruciate ligament reconstruction with synthetic grafts. A review of literature.* International Orthopaedics (SICOT) (2010) 34:465–471 DOI 10.1007/s00264-010-0963-2

Matthew J. Kraeutler, BS*,†, Jonathan T. Bravman, MD† and Eric C. McCarty, MD **Bone–Patellar Tendon–Bone Autograft Versus Allograft in Outcomes of Anterior Cruciate Ligament Reconstruction A Meta-analysis of 5182 Patients.** *Am J Sports Med April 12, 2013 0363546513484127.*

Medscape. Anterior Cruciate Ligament Injury. Matthew Gammons, MD; Chief Editor: Sherwin SW Ho, MD

David J Biau , Caroline Tournoux, Sandrine Katsahian, Peter J Schranz, Rémy S Nizard. **Bone-patellar tendon-bone autografts versus hamstring autografts for reconstruction of anterior cruciate ligament: meta-analysis.** *BMJ 2006;332:995*

ACL Graft Choices. www.orthoassociates. com

Sujay K. Dheerendra*,1, Wasim S. Khan2, Rohit Singhal3, Deepak G. Shivarathre4, Ravi Pydisetty5 and David Johnstone. **Anterior Cruciate Ligament Graft Choices: A Review of Current Concepts.** ***The Open Orthopaedics Journal, 2012, 6, (Suppl 2: M4) 281-286***

Graft selection for anterior cruciate ligament reconstruction: a level I systematic review comparing failure rates and functional outcomes. Reinhardt KR, Hetsroni I, Marx RG. Orthop Clin North Am. 2010 Apr;41(2):249-62. doi: 10.1016/j.ocl.2009.12.009. Review. PMID: 20399364

C E Quatman and T E Hewett. **The anterior cruciate ligament injury controversy: is "valgus collapse" a sex-specific mechanism?** *Br J Sports Med 2009 43: 328-335 originally published online April 15, 2009*

Bing Yu, William E Garrett. Mechanisms of non-contact ACL injuries. Br J Sports Med 2007;41(Suppl I):i47–i51. doi: 10.1136/bjsm.2007.037192

Ryan T. Li, BSE*,†, Stephan Lorenz, MD*, Yan Xu, MD*, Christopher D. Harner, MD*, Freddie H. Fu, MD, DSc* and James J. Irrgang, PT, PhD, ATC, FAPTA. **Predictors of Radiographic Knee Osteoarthritis After Anterior Cruciate Ligament Reconstruction.** *Am J Sports Med December 2011 vol. 39 no. 12 2595-2603 .*

Eun-Kyoo Song, MD*, Jong-Keun Seon, MD*,†, Ji-Hyeon Yim, MD*, Seong-Hwan Woo, MD*, Hyoung-Yeon Seo, MD* and Keun-Bae Lee, MD*. **Progression of Osteoarthritis After Double- and Single-Bundle Anterior Cruciate Ligament Reconstruction.** *Am J Sports Med October 2013 vol. 41 no. 10 2340-2346 .*

Alec A. Macaulay, Dean C. Perfetti and William N. Levine. **Anterior Cruciate Ligament Graft Choices.***Sports Health: A Multidisciplinary Approach 2012 4: 63 originally published online 1 June 2011*

Zhong-tang Liu, Xian-long Zhang, Yao Jiang, Bing-Fang Zeng . **Four-strand hamstring tendon autograft versus LARS artificial ligament for anterior cruciate ligament reconstruction.** International Orthopaedics .January 2010, Volume 34, Issue 1, pp 45-49

THANK YOU