

### Current Concepts of ACL Reconstruction



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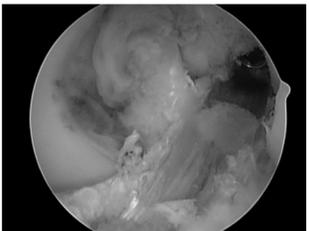
### Disclosure

- Member of Medical Board of Trustees and Consultant to MTF
- Royalties:
  - Zimmer Biomet
  - Elsevier

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### Demographics

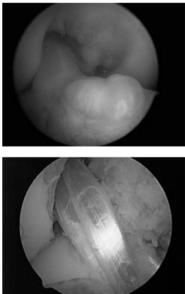
- 250,000 ACL reconstructions per year performed in United States
- Annual incidence of ACL tears in the US is 1 in 3000 Americans
- Average age: 26
- 70% occur from sports participation
- 70% are non-contact, 30% occur as result of direct contact
- Annual Cost is > 2 Billion dollars



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### Goals of ACL Reconstruction

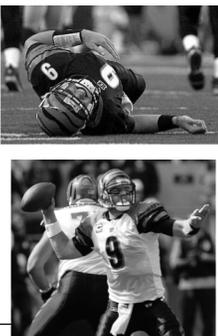
- Provide stable joint
- Avoid meniscal injury
- Return to full ROM
- Return to sport, work, daily activities
- Prevent osteoarthritis???



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### Success

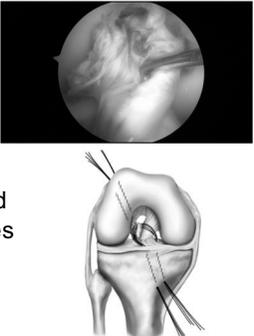
- Functional stability
- Relief of symptoms
- Return to pre-injury level of activity
- Objective outcomes:
  - Lachman, anterior drawer, pivot shift tests, KT 1000
  - Kocher et al. AJSM 2004
    - Pivot shift is the only test shown to correlate with subjective satisfaction



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### History

- ACL injury not well understood until 1970s
- Athletic injury with acute pain and swelling
- Eventually patients would complain: "My knee gives out"
- Repair failed



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### History

- ACL reconstruction not widely understood/embraced until 1980s
- Many failures and complications:
  - Synthetic/bovine grafts
  - Tunnels in wrong place
  - Extra-articular procedures
  - Inappropriate rehabilitation
    - Cast for 6 weeks post-op

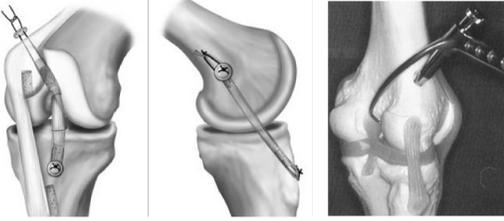


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### History

- Operation becomes anatomic in early 1990s with 2 incision technique for ACL reconstruction:

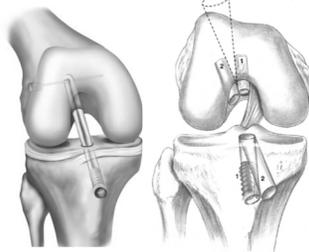


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### History

- Operation becomes less anatomic with advent of 1 incision endoscopic technique for femoral drilling in mid 1990s
- This results in grafts which are non-anatomic (too vertical) which results in PCL impingement, graft stretch-out and higher failure rates

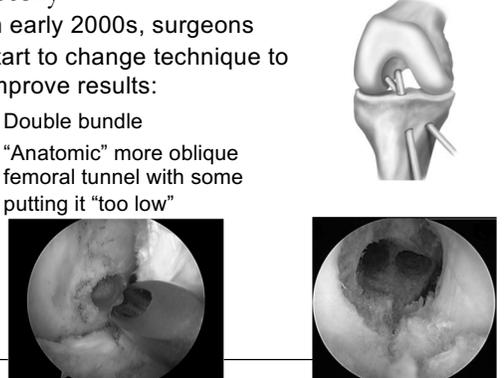


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### History

- In early 2000s, surgeons start to change technique to improve results:
  - Double bundle
  - "Anatomic" more oblique femoral tunnel with some putting it "too low"

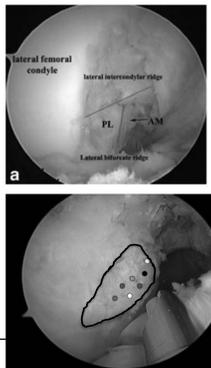


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### Life is full of Compromises...

- Femoral footprint area ranges 85-200 mm<sup>2</sup>
  - Kopf KSSTA 2009
  - 10mm tunnel - area 79 mm<sup>2</sup>
- Can't fill the footprint – Must be strategic and select the most important region



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### Every Decade We Change Our Minds

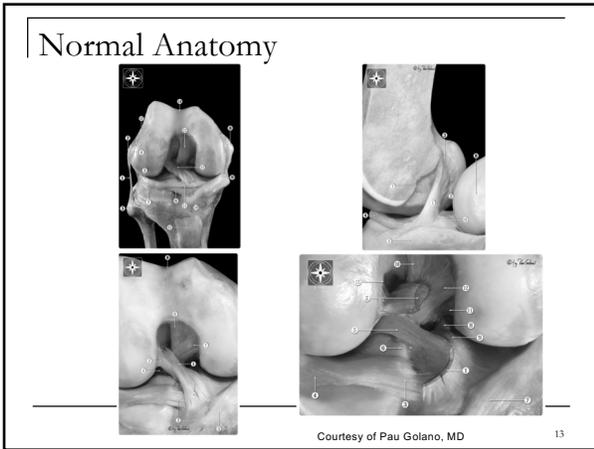
#### The Journey Around the Notch...

- 1980s
  - Isometric
- 1990s
  - 2 incision
  - Transtibial
- 2000s
  - Anatomic
- 2015 and beyond
  - IDEAL??

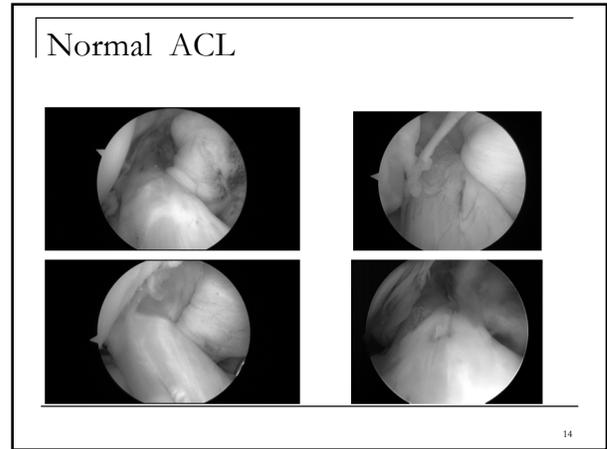


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### ACL Reconstruction Facts

- Tunnel position is important
- Fixation is important
- Rehabilitation following surgery is important
- Little difference between graft types (i.e. B-PT-B vs. Hamstring autograft)

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### Recent Trends in ACL Reconstruction: “Anatomic” ACL Reconstruction

- Lower femoral tunnel position
- Transtibial vs. AM portal creation of femoral tunnel
- Fill the footprint
- Extra-articular augmentation?
- ALL reconstruction
  - Why?
  - Where/How?
  - Who?
  - When?

**Goal: to restore laxity to normal**

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### Is Lower Femoral Tunnel Position Better?

- A number of surgeons have recently advocated a lower femoral tunnel position as more “anatomic”
- However, is lower necessarily more “anatomic”?

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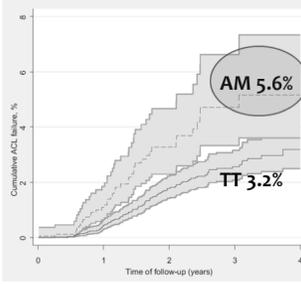
### Is Lower Femoral Tunnel Position Better?

- Does placing the femoral tunnel at 9:30 to 10 o'clock provide the graft with a better mechanical advantage?
- No change in pivot-shift, kinematics or AP laxity
- Graft forces increased!
- The rationale for placing the femoral tunnel at a more oblique position in the notch is questioned.
  - Markolf et. al. AJSM 2010
  - Markolf et. Al. JBJS-A 2009
  - Markolf et. al. JOR 2002

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### Is Lower Femoral Tunnel Position Better?

- Report of the Danish ACL registry (9,239 patients) that the revision rate for failed reconstruction for the anteromedial portal technique was 2X greater than that for the transtibial technique
  - Wagner et al, KSSTA 2012

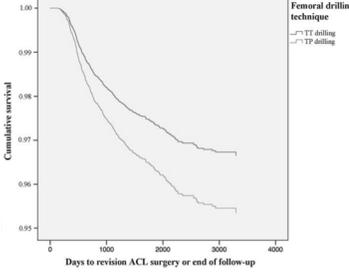


The graph shows cumulative ACL failure percentage on the y-axis (0 to 8) and time of follow-up in years on the x-axis (0 to 4). Two curves are shown: AM (Anteromedial) and TT (Transtibial). The AM curve is significantly higher than the TT curve. Callouts indicate AM failure at 5.6% and TT failure at 3.2%.

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### Is Lower Femoral Tunnel Position Better?

- Report of the Swedish ACL registry (17,682 patients) that the revision rate for failed reconstruction for the anteromedial portal technique was 1.4 X greater than that for the transtibial technique
  - Desai et al, KSSTA 2016

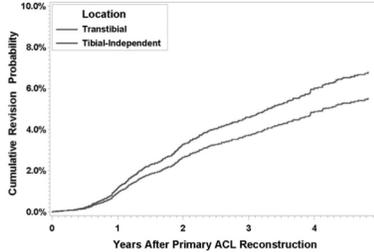


The graph shows cumulative survival on the y-axis (0.95 to 1.00) and days to revision ACL surgery or end of follow-up on the x-axis (0 to 4000). Two curves are shown: TT drilling (Transtibial) and TP drilling (Transtopliteal). The TP drilling curve is lower than the TT drilling curve, indicating a higher revision rate.

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### Is Lower Femoral Tunnel Position Better?

- Report of the Kaiser registry (19,059 patients) that the revision rate for failed reconstruction for the anteromedial portal technique was 1.28X greater than that for the transtibial technique and the risk was increased 1.41X in patients younger than 22 years of age
  - Tejwani et al, AJSM 2018



The graph shows cumulative revision probability on the y-axis (0.0% to 10.0%) and years after primary ACL reconstruction on the x-axis (0 to 5). Two curves are shown: Transtibial and Tibial-independent. The Tibial-independent curve is higher than the Transtibial curve.

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### Transtibial vs. Anteromedial Reaming of Femoral Tunnel

- There are multiple studies with conflicting results
- However, many of the studies favor anteromedial reaming
  - Bowers et al, Arthroscopy, 2011
  - Bedi et al, Arthroscopy, 2011
  - Gadikota, AJSM 2012



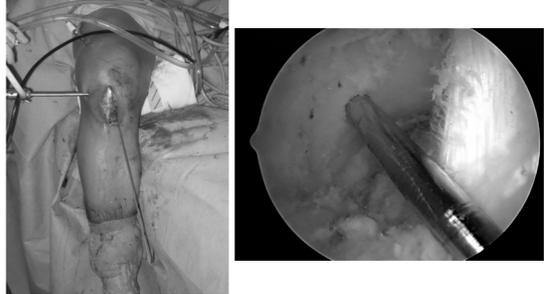
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### Transtibial vs. Anteromedial Reaming of Femoral Tunnel

- Tibial and femoral tunnels can be positioned in a highly anatomic manner using a transtibial technique but require careful choice of the tibial starting position.
- A transtibial single-bundle technique can accomplish a highly anatomic reconstruction
  - Piasecki et al, AJSM, 2011

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### Oblique Tibial Tunnel



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## My Conclusions

- ACL reconstruction with an oblique femoral tunnel is a successful operation
- More obliquity is not better and likely predisposes to graft failure
- Let's be careful about changing a "successful" operation
- Placing the graft anatomically is not new

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## Graft Selection: Auto vs. Allo

- Allograft
  - Advantages
    - Shorter operative time
    - Smaller incisions
    - Avoid donor site morbidity
    - No size limitation (for large tunnel diameters can use a large bone plug)
  - Disadvantages
    - May play role in failure
      - Higher Failure rate in MARS cohort (Wright et al AJSM, 2014)
    - Longer incorporation times
    - Immunologic reaction
    - Higher cost
    - Disease transmission
      - Radiation kills viruses but required dosage alters graft integrity

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## Use of Allograft in Young Athletes

- A prospective cohort study of cadets at the United States Military Academy was performed to assess performance of ACL reconstructions performed before entrance to service.
- A total of 120 cadets underwent 122 ACL reconstructions before matriculation and compose the prospective cohort.
  - 61 bone-patellar tendon-bone (BPTB)-11% failures
  - 45 hamstring-13% failures
  - 16 allograft-44% failures
- Palis et al, AJSM 2012

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## Use of Allograft in Young Athletes

- Those cadets with an allograft were 6.7 times more likely to experience a subsequent graft failure during the follow-up period when compared with the autograft group.
- In this young active cohort, individuals having undergone an allograft ACL reconstruction were significantly more likely to experience clinical failure requiring revision reconstruction compared with those who underwent autologous graft reconstruction.
  - Palis et al, AJSM 2012

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## Use of Allograft in Young Athletes

- Evaluated patients with allograft and autograft PTACL reconstruction.
- Patients undergoing BPTB autograft reconstruction reported significantly fewer problems on a visual analog scale and scored significantly higher on the postoperative Tegner activity scale than patients undergoing allograft reconstruction.
- The active allograft group was 2.6 to 4.2 times more likely to fail compared with low-activity allografts and low- and high-activity autografts.
- Concluded that fresh-frozen BPTB allografts should not be used in young patients who have a high Tegner activity score because of their higher risk of failure.
  - Barrett et al, Arthroscopy, 2010

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## Use of Allograft in Young Athletes

- Evaluated patients who had ACL reconstruction with allograft and autograft bone-patellar tendon-bone.
- Allograft (29.2%) resulted in significantly higher failure rates than bone-patellar tendon-bone grafts (11.8%) in the age group of patients 25 years and younger.
- These data suggest that autografts may be a better graft source for young, active individuals.
  - Barrett et al, AJSM 2011

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### Use of Allograft in Young Athletes

- Twenty-one patients with ACL graft failure were identified over a 2-year period. Forty-two age- and sex-matched controls were identified over the same period.
- Univariate logistic regression models showed an increased odds of ACL graft failure for those with high activity level compared with low activity level and for allografts compared with autografts .
- Higher activity level after reconstruction and allograft use for reconstruction are risk factors for ACL graft failure.
  - Borchers et al, AJSM 2009

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### Surgical Technique

- Most avoidable cause of graft failure
- Technical Errors:
  - Non-anatomic tunnel placement
  - Inadequate notchplasty
  - Inadequate graft fixation
  - Improper graft tensioning
  - Improper graft selection
  - Failure to address secondary stabilizers

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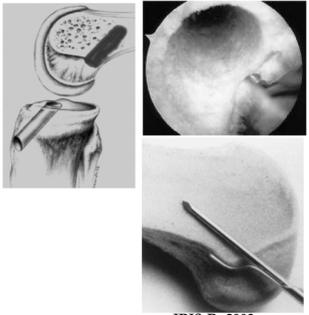
### Surgical Technique

- The most common cause of graft failure following ACL reconstruction is a combination of:
  - Re-injury
  - Loss of fixation
  - Tunnels place improperly
  - Graft fails to incorporate

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### Femoral Tunnel Placement

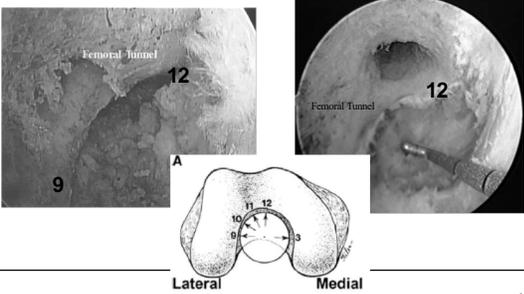
- As posterior in the notch as possible without violation of the posterior cortical wall
- 1-2 o'clock or 10-11 o'clock position
  - Tunnel that is too vertical results in PCL impingement
- Lower is not always better!



JBJS-Br 2003

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### Femoral Tunnel Placement



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### Femoral Tunnel Placement

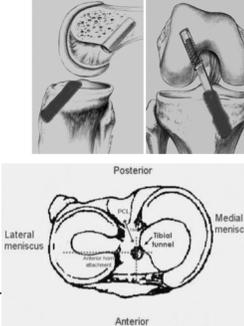
- Too Anterior
  - Most common error
  - Tight in flexion
  - Lax in extension
  - Loss of Flexion or stretch-out of graft



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### Tibial Tunnel Placement

- Adjacent to anterior horn of lateral meniscus
- Native ACL footprint
- In between the tibial spines



The diagrams illustrate the anatomical landmarks for tibial tunnel placement. The top row shows two views of a knee joint with a tunnel being drilled. The bottom diagram is a cross-section of the knee, labeling the Lateral meniscus, Medial meniscus, Anterior, Posterior, and Tibial tunnel. The tunnel is shown passing between the tibial spines.

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### Aberrent Tibial Tunnel Placement

- Too Anterior
  - Notch impingement
- Too Posterior
  - PCL impingement

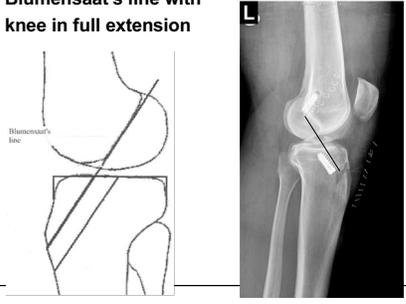


The X-ray shows a lateral view of a knee with a line indicating the position of a tibial tunnel. The tunnel is placed too anteriorly, which can lead to notch impingement, or too posteriorly, which can lead to PCL impingement.

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### Tibial Tunnel Placement

- Parallel and posterior to Blumensaat's line with knee in full extension

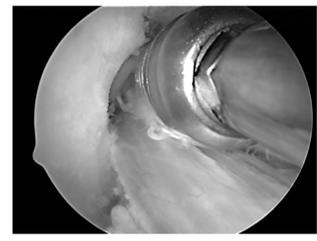


The diagram on the left shows a schematic of the knee joint with Blumensaat's line drawn. The X-ray on the right shows a lateral view of a knee with a line indicating the placement of a tibial tunnel, which is parallel and posterior to Blumensaat's line.

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### Graft Fixation

- Direct fixation:
  - interference screws, staples
- Indirect fixation:
  - endobutton, cross-pin
- Aperture fixation (Near):
  - interference screw, press fit fixation
- Suspensory fixation
  - Endobutton, screw post



The arthroscopic image shows a graft being fixed to the tibia. The fixation device is visible, and the surrounding joint structures are clearly visible.

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### Graft Fixation

- Tibial fixation is weak point
  - Less bone density
    - Dual Photon Absorptometry (DEXA) of the tibial metaphysis less bone density than femoral metaphysis.
  - Angle of force
    - Line of force on graft directly in line with tibial tunnel
    - Line of force on graft oblique to femoral tunnel during most weight bearing activities



The X-ray shows a lateral view of a knee with a graft fixation. A line is drawn through the graft, and an angle of 3.5 degrees is indicated between this line and the tibial tunnel.

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### Tunnel Placement

- Anatomic /within footprint
- Use whatever technique is necessary to get the femoral tunnel in the correct location
  - Trans-tibial drilling
  - Anteromedial reaming
  - Flip cutter
  - Two incision technique



The X-ray shows a lateral view of a knee with a line indicating the placement of a femoral tunnel. The tunnel is shown passing through the femur.

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### Graft Fixation

- Secure graft fixation is critical
- May re-enforce primary fixation
  - Post and washer
  - Staple
  - Endobutton
  - Stacked interference screws



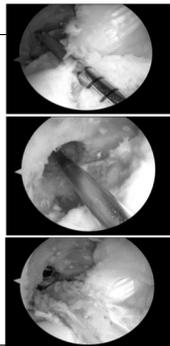
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### Femoral Tunnel Position

- Isometry
- Direct Fibers
- Eccentric/Equidistant
- Anatomic
- Low tension
  - Midway between PCL and LFC articular cartilage
  - 1 mm posterior wall

Pearle et al, AJO 2015

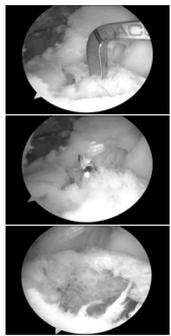


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### Tibial Tunnel Position

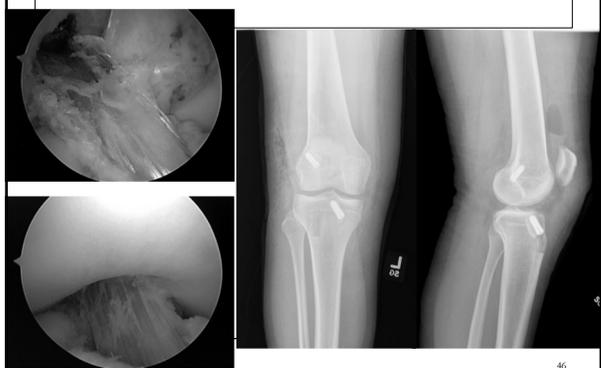
- Within native ACL tibial footprint
- Adjacent to anterior horn of lateral meniscus
- In between the tibial spines
- Avoid notch/roof impingement



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### Graft Position/No Impingement



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### Summary

- ACL reconstruction will continue to increase in frequency
- Single bundle reconstruction
- Place tunnels in proper position
- Use whatever technique best gets you to the femoral attachment of the ACL
- Tension and fix tibial side of graft at or near full extension
- Avoid allografts in young athletes

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Thank You

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### “Anatomic” Double Bundle ACL Reconstruction

1. Is DB more “anatomic” than SB ACL reconstruction?”
2. Is it all about maximizing the filling of the tibia and femoral footprints (attachments) to reproduce the anatomy?
3. Don’t forget about biomechanics!

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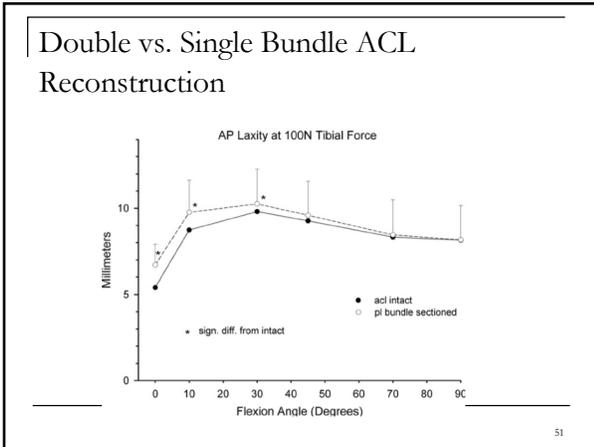
### Double vs. Single Bundle ACL Reconstruction

- What are the contributions of the Native PL bundle of the ACL?
  - Laxity
  - ACL Force
- Methods
  - 14 cadaver knees instrumented with load cell
  - AP laxity testing at 100 N of applied tibial force
  - Tested before and after cutting native PL bundle
    - Markolf et al, Arthroscopy 2008

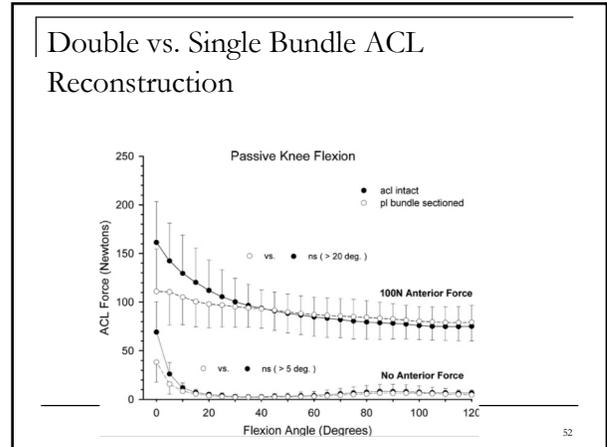
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### Double vs. Single Bundle ACL Reconstruction

- Small increases (about 1mm) in AP laxity after cutting of the PL bundle at 0° and 10°
- Consistent with decreases in resultant force of the ACL from anterior tibial loading after the PL bundle has been cut
- Suggests that the PL bundle plays a somewhat minor role in providing AP stability

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### Double vs. Single Bundle ACL Reconstruction

- What are the abilities of single-bundle and anatomic double-bundle reconstructions to restore?
  - Laxity
  - Kinematics
  - Graft Force
    - Markolf, et al, JBJS-A, 2009

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### Double vs. Single Bundle ACL Reconstruction

- **Methods**
  - 14 cadaver knees instrumented with load cell
  - Native ACL force and tibial rotations
  - AM and PL reconstruction
  - Single (AM only tensioned) vs. Double (AM/PL tensioned)
  - 4 different tensioning protocols for DB

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### Double vs. Single Bundle ACL Reconstruction

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### Double vs. Single Bundle ACL Reconstruction

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### Double vs. Single Bundle ACL Reconstruction

- **Conclusions**
  - The single-bundle reconstruction produced graft forces, knee laxities, and rotations that were closest to normal.
  - Adding a posterolateral graft to an anteromedial graft tended to reduce laxities and tibial rotations, but with markedly higher forces in the posterolateral graft near 0 that occasionally caused it to fail.

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### Anatomic ACLR Double or Single Bundle?

#### EBM: Clinical Outcomes

- Yasuda et al., Arthroscopy 2006: Level II
- Aglietti et al., CORR 2007: Level II
- Kurosaka, CORR 2007: Level II
- Muneta, Arthroscopy 2007: Level I

**No difference in subjective results**

**DB has better objective results (about 1mm)**

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### Comparison of Rotatory Stability after ACL Reconstruction between Single and Double Bundle Techniques

- Level 3, cohort
- 23 patients SB; 25 DB
- Less AP laxity in DB (about 1 mm)
- No difference in pivot grades
- No difference in subjective outcome scores

Izawa, et al, AJSM 2011

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Outcome of Arthroscopic Single and Double Bundle reconstruction of the ACL: A Preliminary 2-year Prospective Study

- Level 2, prospective
- 50 patients SB; 63 DB
- No difference in AP laxity
- No difference in pivot grades
- No difference in subjective outcome scores

Park, et al, Arthroscopy 2010

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**Outcome of Single-Bundle Versus Double-Bundle Reconstruction of the Anterior Cruciate Ligament**

**A Meta-Analysis**

- Meta-analysis
- First: Level 1 (4 RCTs)
- Second: Level 1, 2, 3 (5 additional)
- No difference between DB and SB ACLR
  - KT 1000 though .52 mm closer to nl in DB
  - Pivot Shift

Lubowitz, et al.: AJSM 36 (7) 2008

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Clinical Failure of PL Bundle

- 3% in Kondo et al, Arthroscopy, 2007
- 7% Asagumo et al, Arthroscopy, 2007
- 11% Otsubo et al, KSSTA, 2007

This means that some of these patients are left with a single bundle (usually 2-ply) hamstring reconstruction

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Is this Better?

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