

The Continuum of Rotatory Knee Instability Associated with ACL Injury

Wake Forest Sports Medicine Lecture

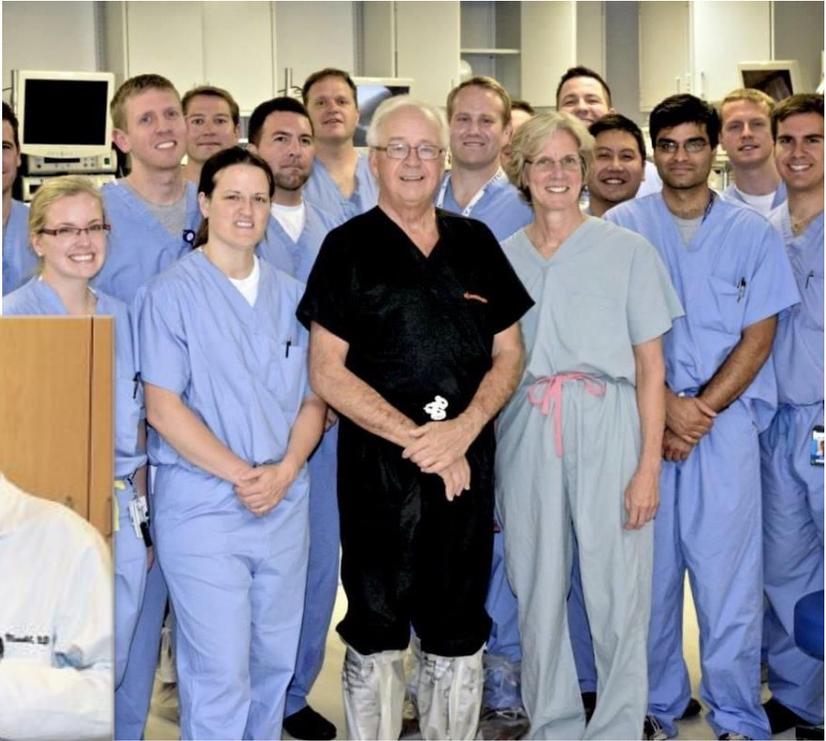
August 21, 2025

Jeremy M. Burnham, MD

Regional Section Head of Orthopedic Surgery & Sports Medicine
Medical Director of Therapy & Wellness



On The Shoulders of Giants



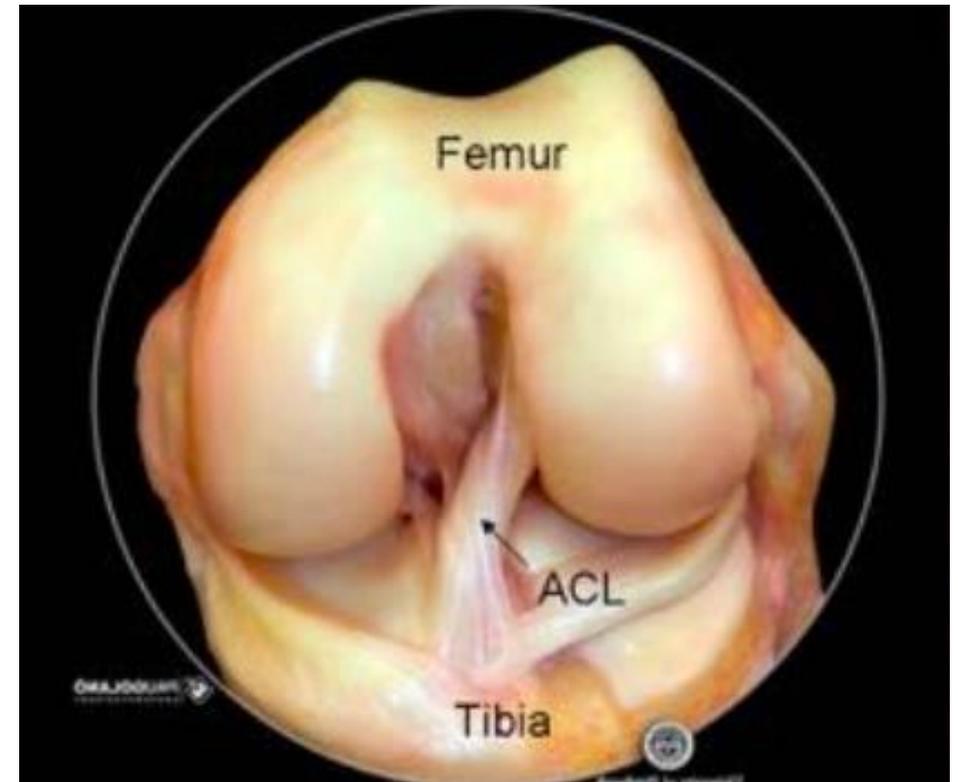
On The Shoulders of Giants



Anterolateral Rotatory Instability

Rotatory Knee Instability Defined

- Rotatory knee instability is an **abnormal, complex three-dimensional motion** that can involve pathology of the anteromedial, anterolateral, posteromedial, and posterolateral ligaments, bony alignment, and menisci.
- To understand the abnormal joint kinematics in rotatory knee instability, **the anatomical structures and their role in maintaining rotational stability, the importance of concomitant pathologies**, as well as the different components of the knee rotation motion must be understood.



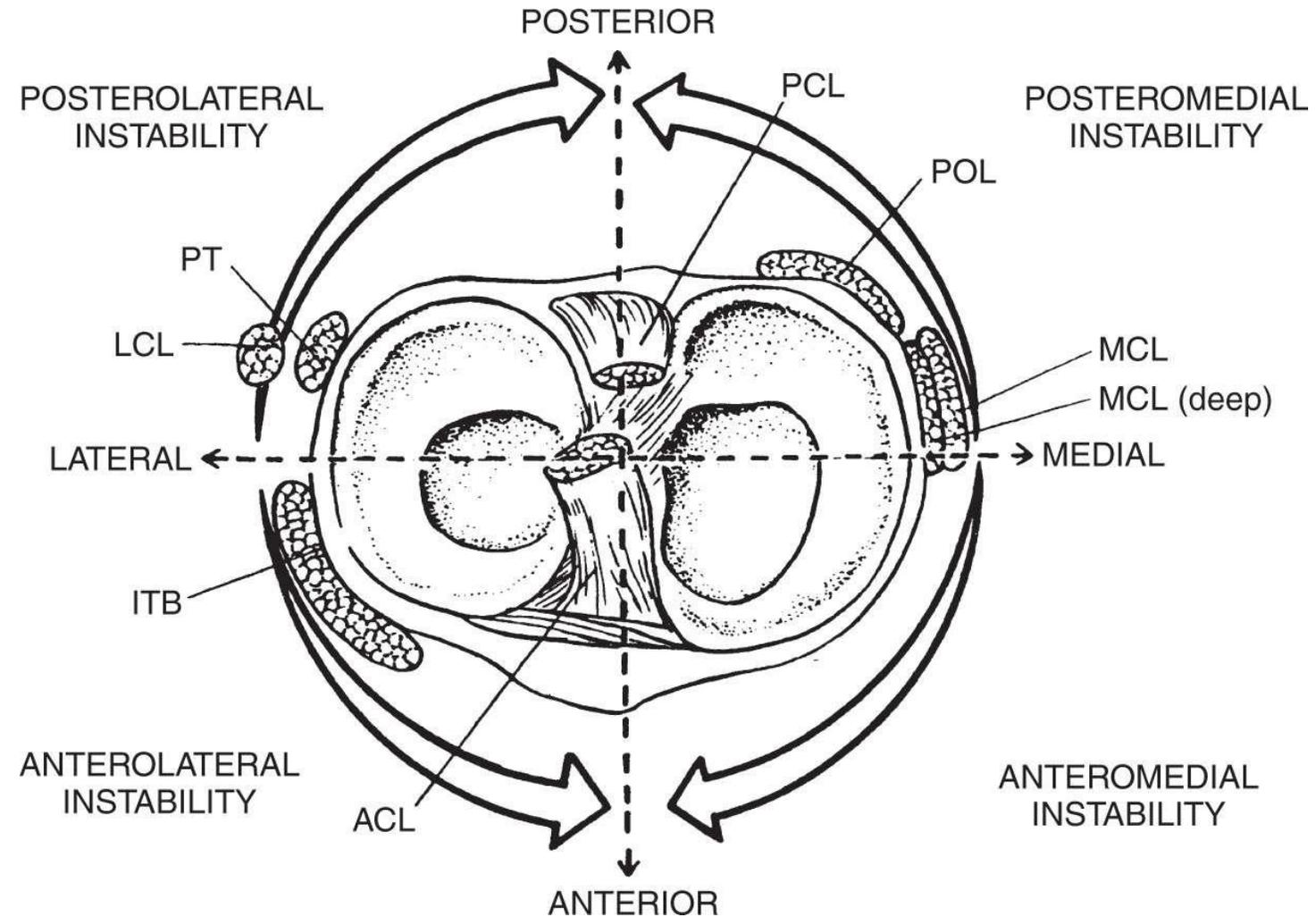
Diagnosis and treatment of rotatory knee instability

Jonathan D. Hughes¹, Thomas Rauer², Christopher M. Gibbs¹ and Volker Musahl^{1*}

Types of Rotatory Knee Instability

• Anterolateral

- Complex mechanisms but often is combined slight flexion, dynamic valgus, and femoral internal rotation and adduction
- Anterior subluxation of LTP relative to LFC
- ACL, Anterolateral complex, lateral meniscus posterior root, IT band, posterior condylar offset, posterior tibial slope



Hughes, Mushal et al JEO 2019

Introduction to Concept of Critical Factors



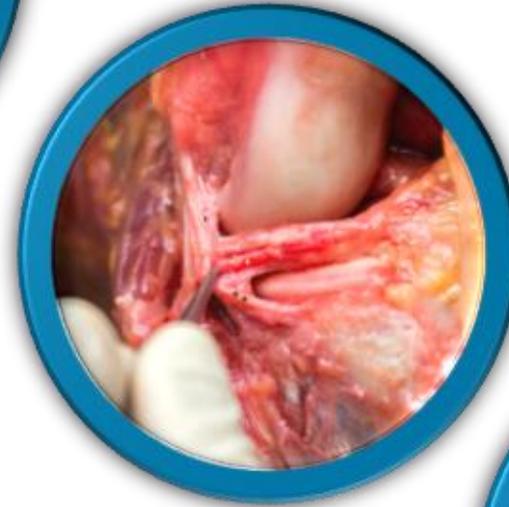
3 Critical Factors for Addressing Rotatory Instability

- Meniscus Status

- Medial Ramp Lesions
- Lateral Posterior Root



- Anterolateral Complex



- Posterior Tibial Slope (PTS)



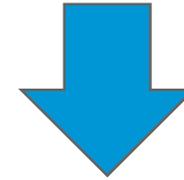
Dean, Larson, Waterman (2021)
Arthroscopy



ACL is the primary stabilizer



Continuous set of
fibers working
synergistically

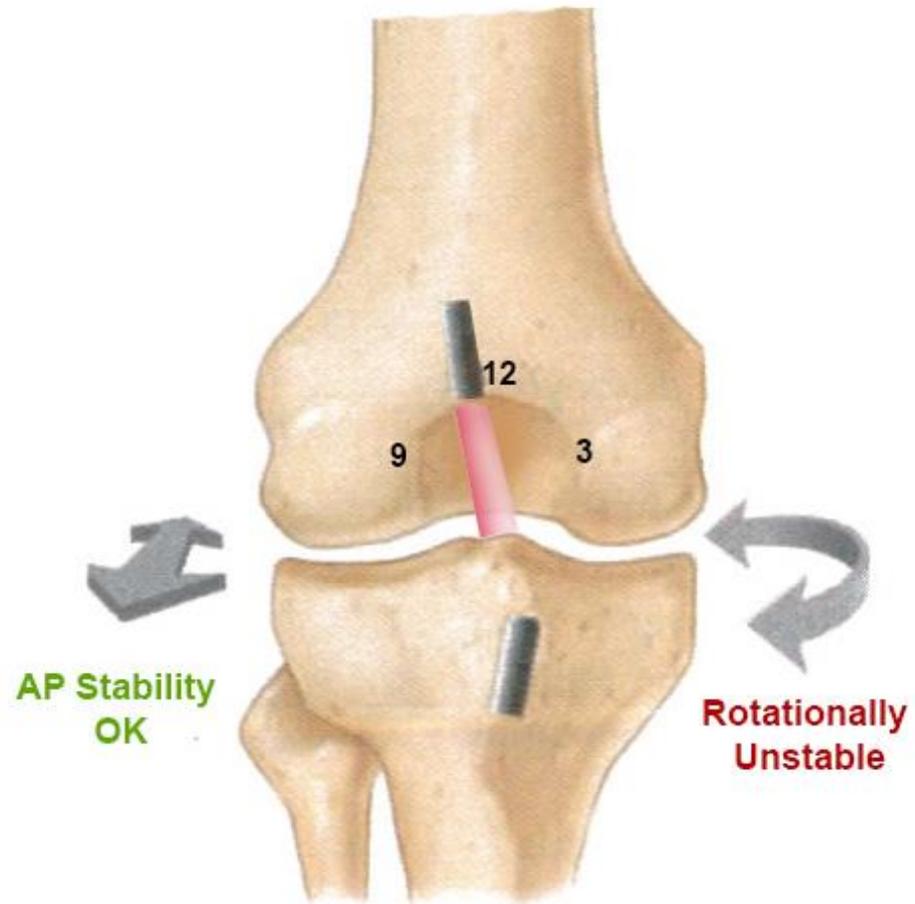


Anteroposterior
and rotational
stability of the knee

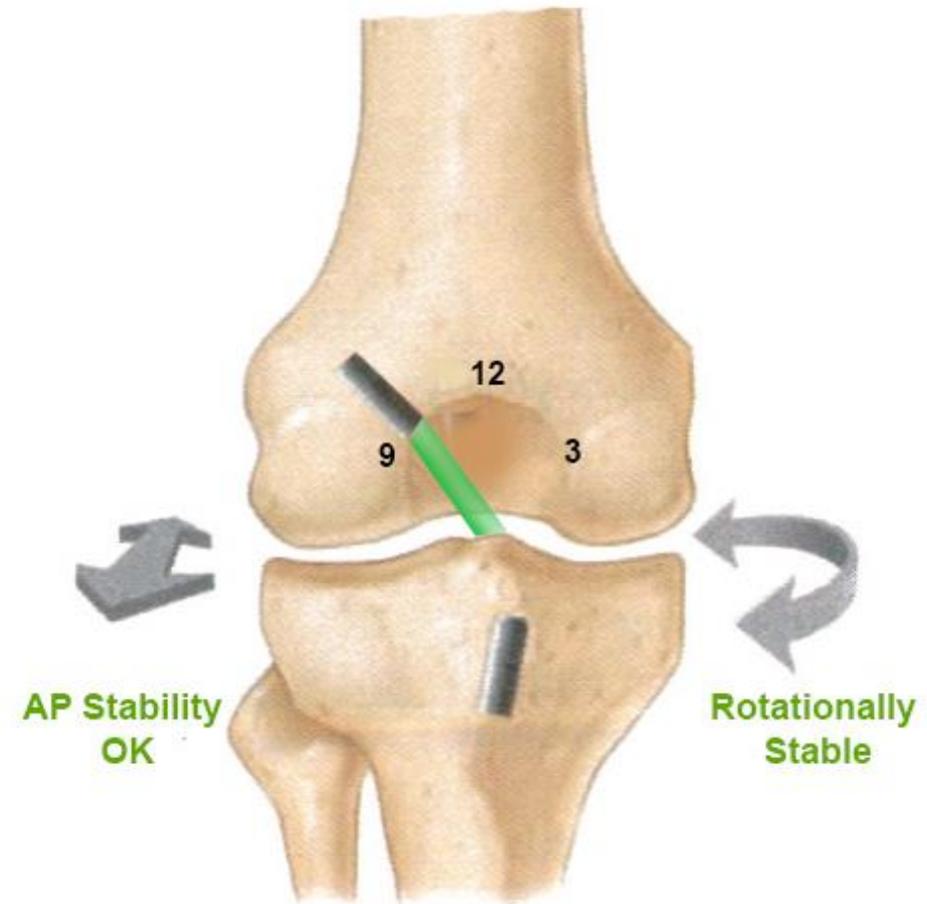


Importance of Anatomic ACL

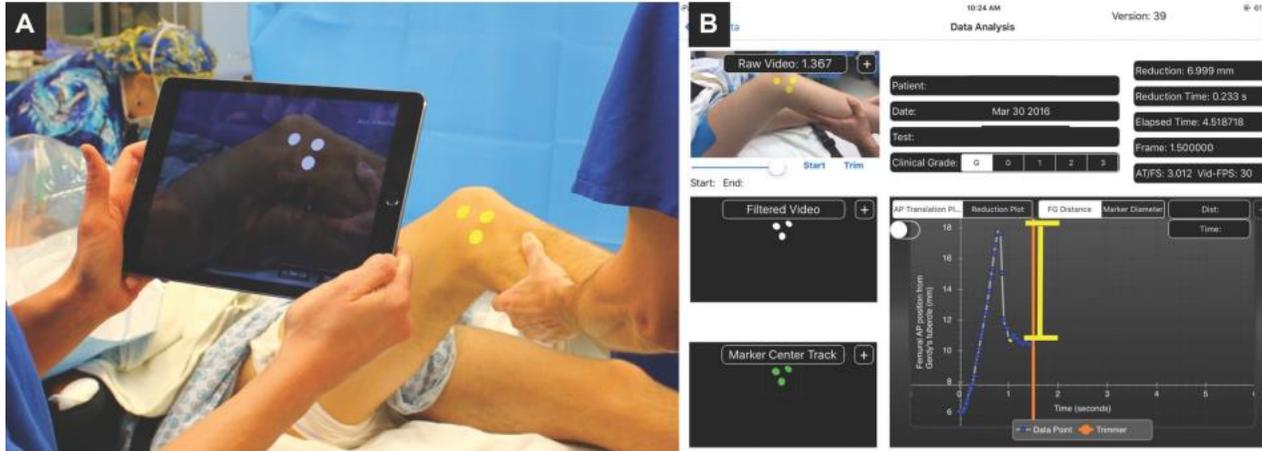
Vertical Graft



More-Horizontal Graft



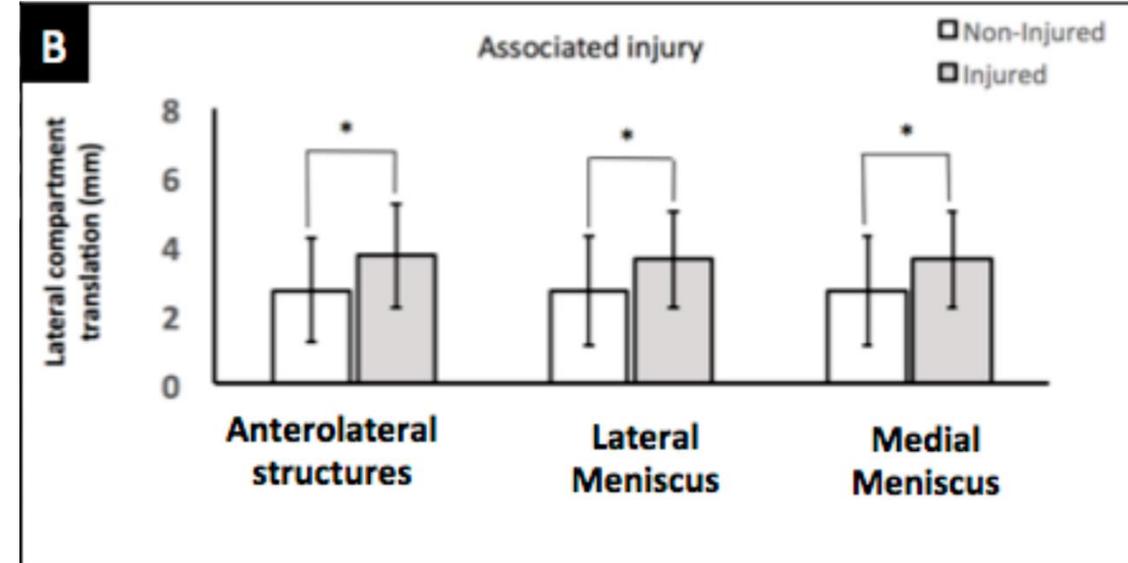
Rotatory Knee Instability is Multifactorial



Quantitative Pivot-Shift Test Results in ACL-Injured Knees Measured by the Image Analysis Technique^a

Evaluated Structures for Concomitant Injuries	Quantitative Pivot Shift, mm		
	Intact	Injured	<i>P</i> Value
ALC	2.7 ± 1.5	3.6 ± 1.5	.04 ^b
Lateral meniscus	2.7 ± 1.3	3.7 ± 1.7	.03 ^b
Medial meniscus	2.7 ± 1.6	3.7 ± 1.4	.03 ^b

- Mean QPS in patients with isolated ACL was 2.26 ± 1.1 mm



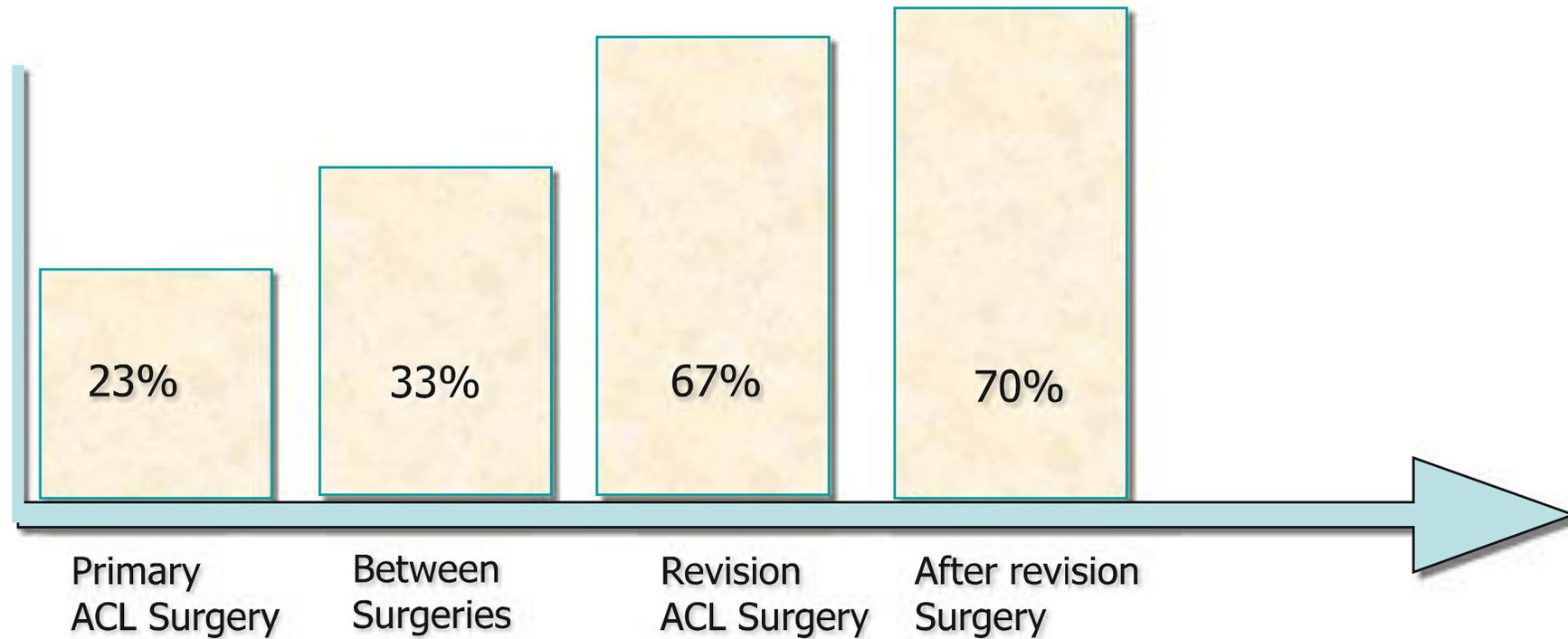
- Injury to ALC, lateral or medial meniscus was associated with increased amount of lateral compartment translation

1. Meniscus Status

Critical Factors to Address Rotatory Instability Associated with ACL Injury

The Meniscus is An Important Secondary Stabilizer

Cumulative Incidence of Meniscectomies



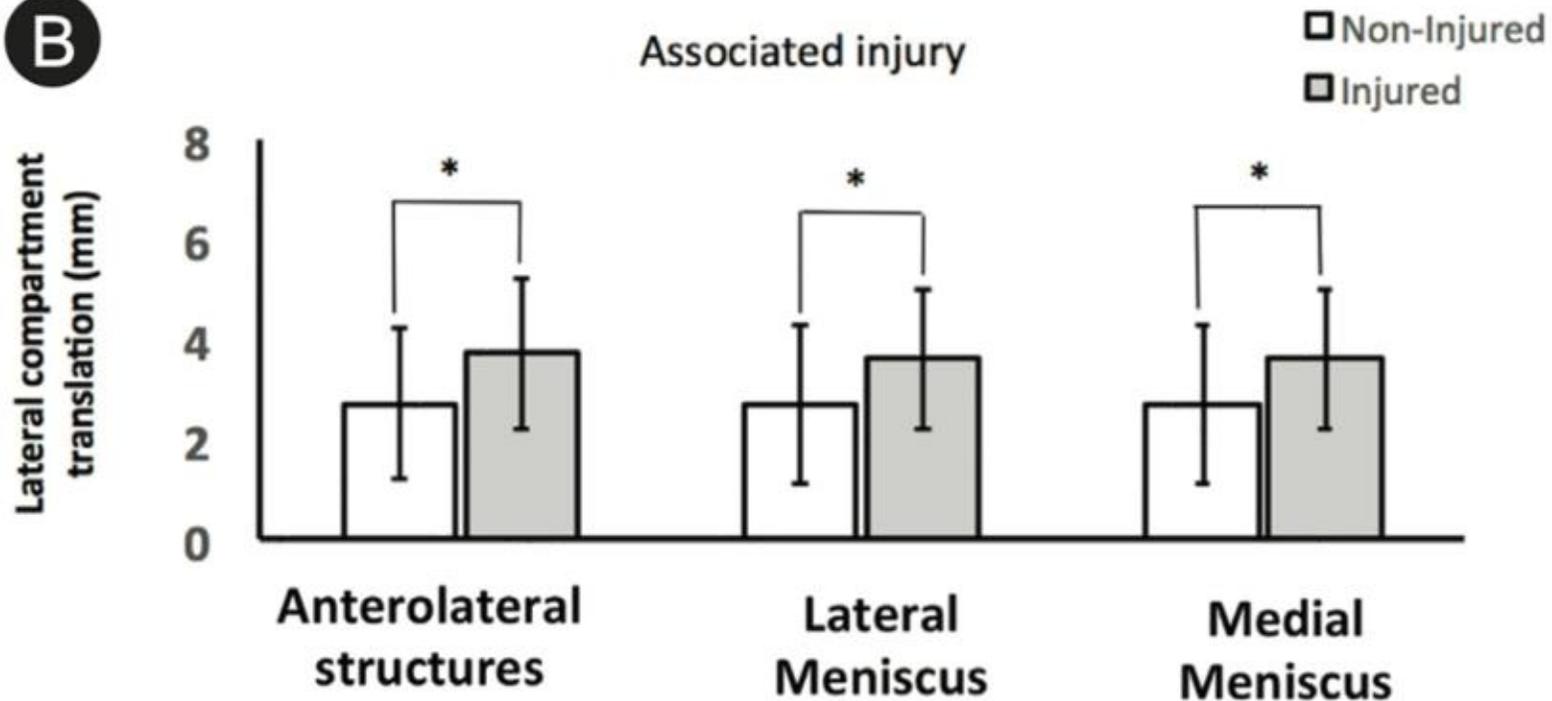
Trojani, KSSTA, 2011



Secondary Stabilizers of the Anterior Cruciate Ligament—Deficient Knee

Ata A. Rahnama-Azar, MD,^{*,†} Jason Zlotnicki, MD,^{*,†} Jeremy M. Burnham, MD,[†] Daniel Guenther, MD,^{*,†} Ashish Soni, MD,^{*,†} Richard E. Debski, PHD,^{*,†,‡} and Volker Musahl, MD^{*,†,‡}

B



A



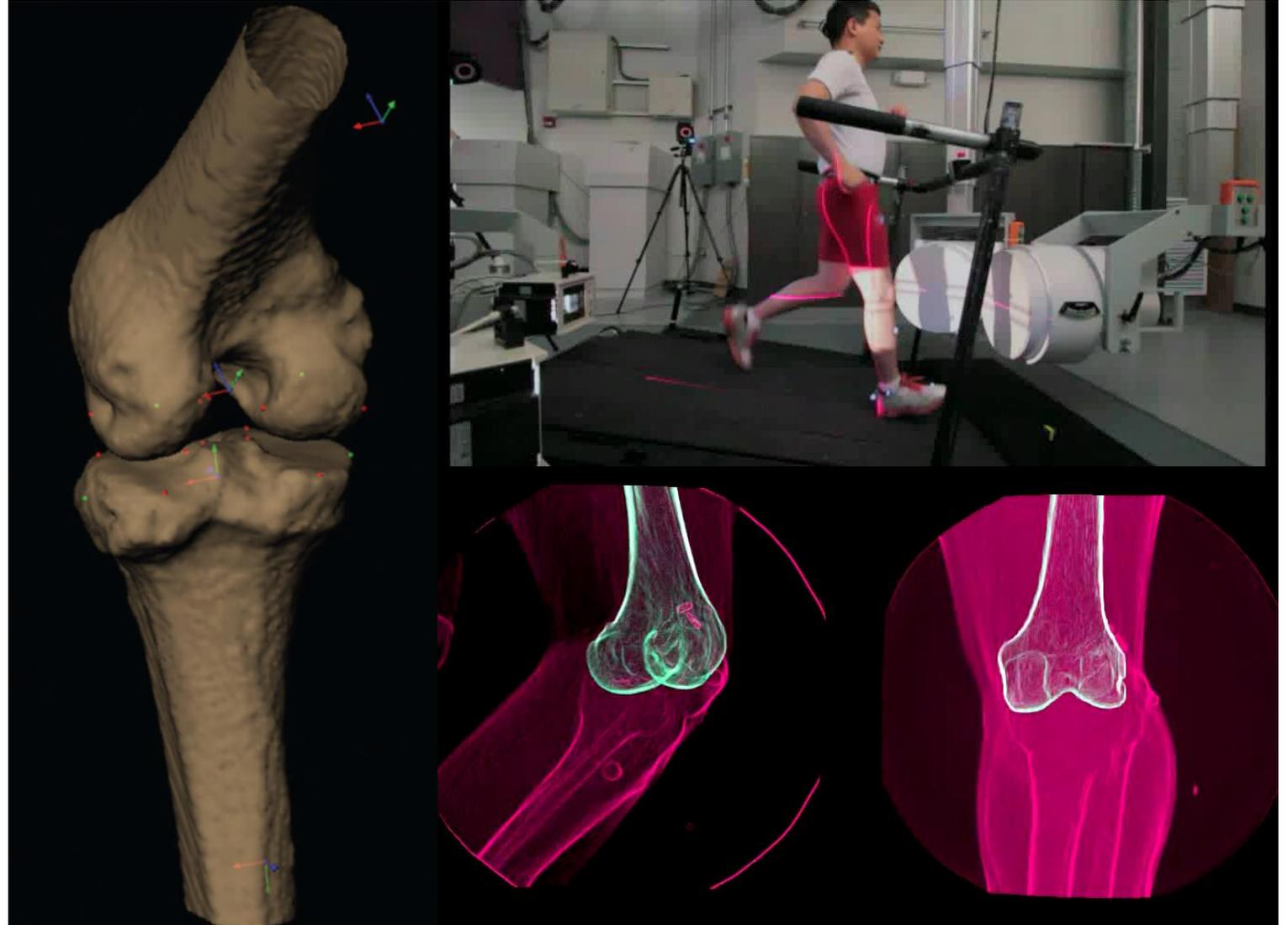
Start: End:

Start Trim

Measuring Functional Tibial Translation

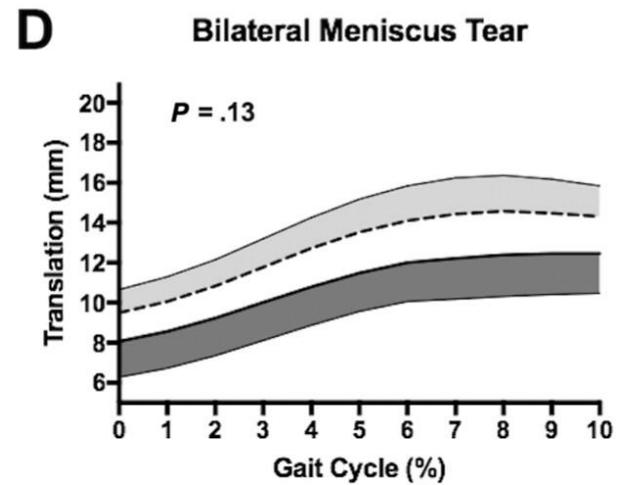
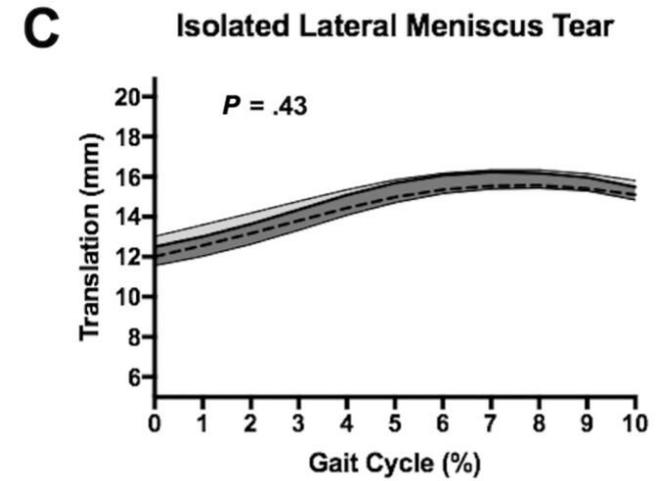
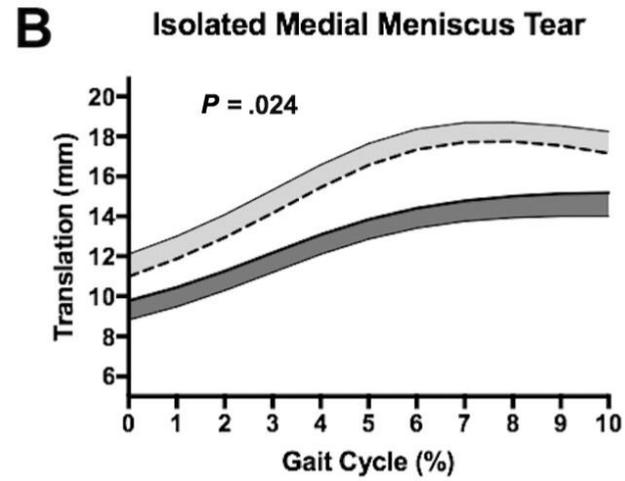
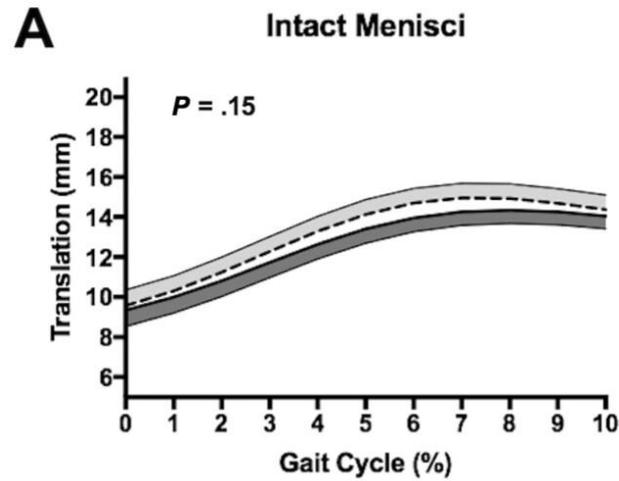
Akpinar, Irrgang, Fu, Anderst
AJSM 2018

- Downhill running
- 0.6mm CT slices
- Dynamic stereo radiographic analyses
 - 150 frames per second
 - 1-ms pulse to eliminate motion blur

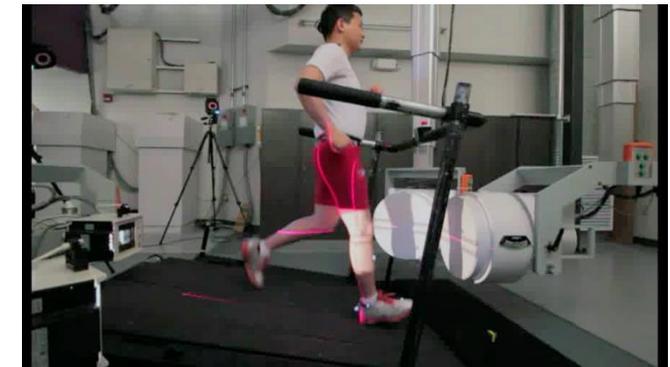


Measuring Functional Tibial Translation

Akpinar, Irrgang, Fu, Anderst
AJSM 2018



--- ACLR Knee
— Contralateral Knee



Medial & Lateral Menisci

- Secondary stabilizers to rotational and AP stability
- Experience more stress with a deficient ACL
- Lateral: Results in increased lateral compartment acceleration and translation
- Medial: Results in increased anterior translation

Musahl, Burnham et al KSSTA 2018

Hughes, Mushal et al JEO 2019



Sanders et al RSNA

Medial Meniscus Ramp Lesion

Taneja, Miranda, Rosenberg, Santos
Insights Imaging 2021

- Peripheral injuries affecting the posterior horn of the medial meniscus
- Can result in meniscocapsular or meniscotibial disruption
- Significant biomechanical implications but severely underdiagnosed

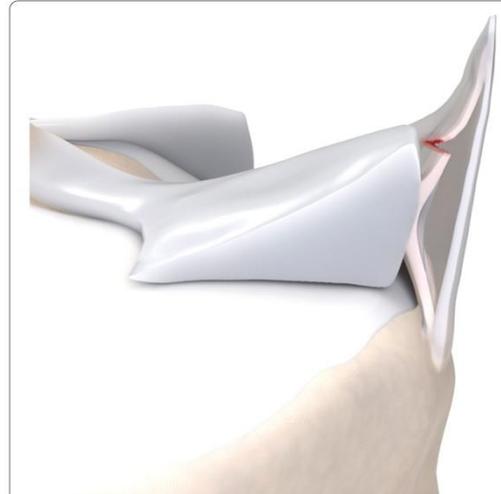


Fig. 2 Type 1 ramp lesion illustration, defined as meniscocapsular ligament tear

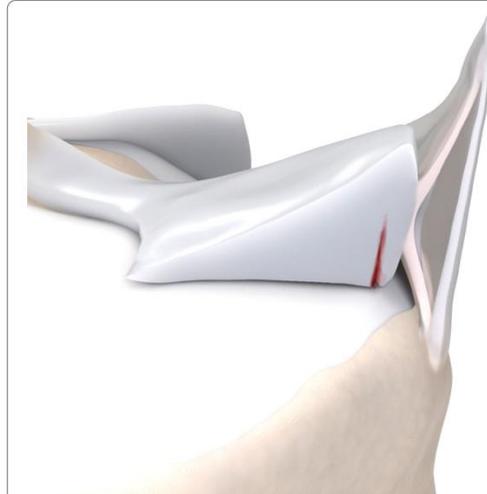


Fig. 6 Type 3A meniscal ramp lesion illustration, defined as partial inferior peripheral posterior horn meniscal tear

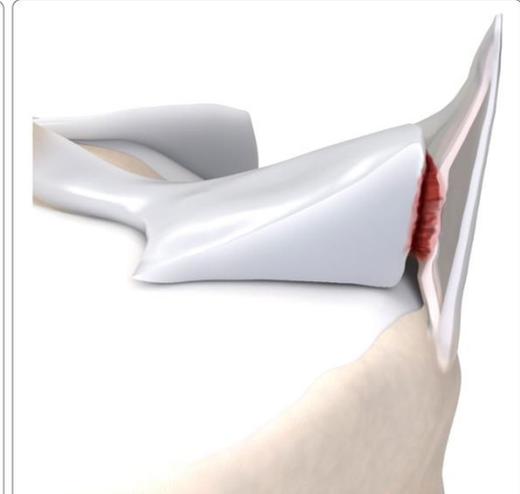


Fig. 12 Type 4B meniscal ramp lesion illustration, defined as complete meniscocapsular junction tear

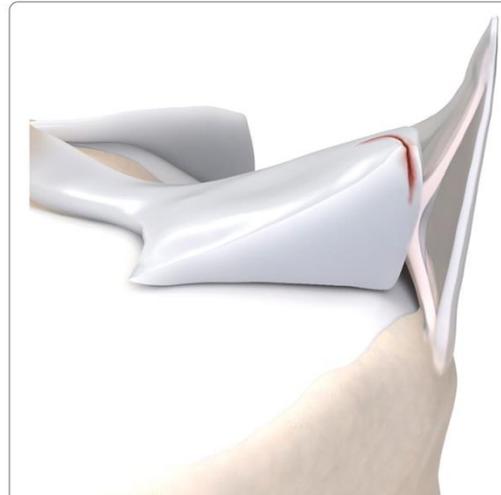


Fig. 4 Type 2 meniscal ramp lesion illustration, defined as partial superior peripheral posterior meniscal horn tear

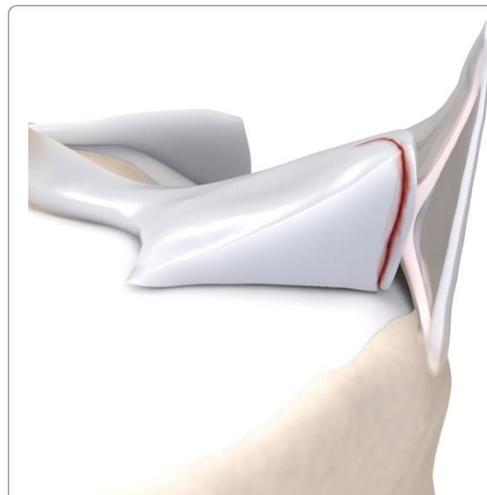


Fig. 10 Type 4A meniscal ramp lesion illustration, defined as complete peripheral posterior horn meniscal tear

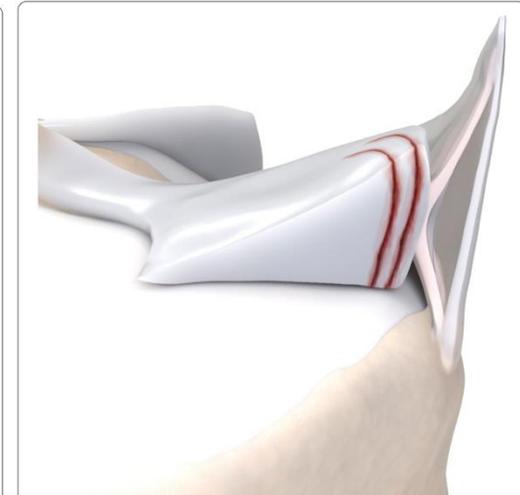


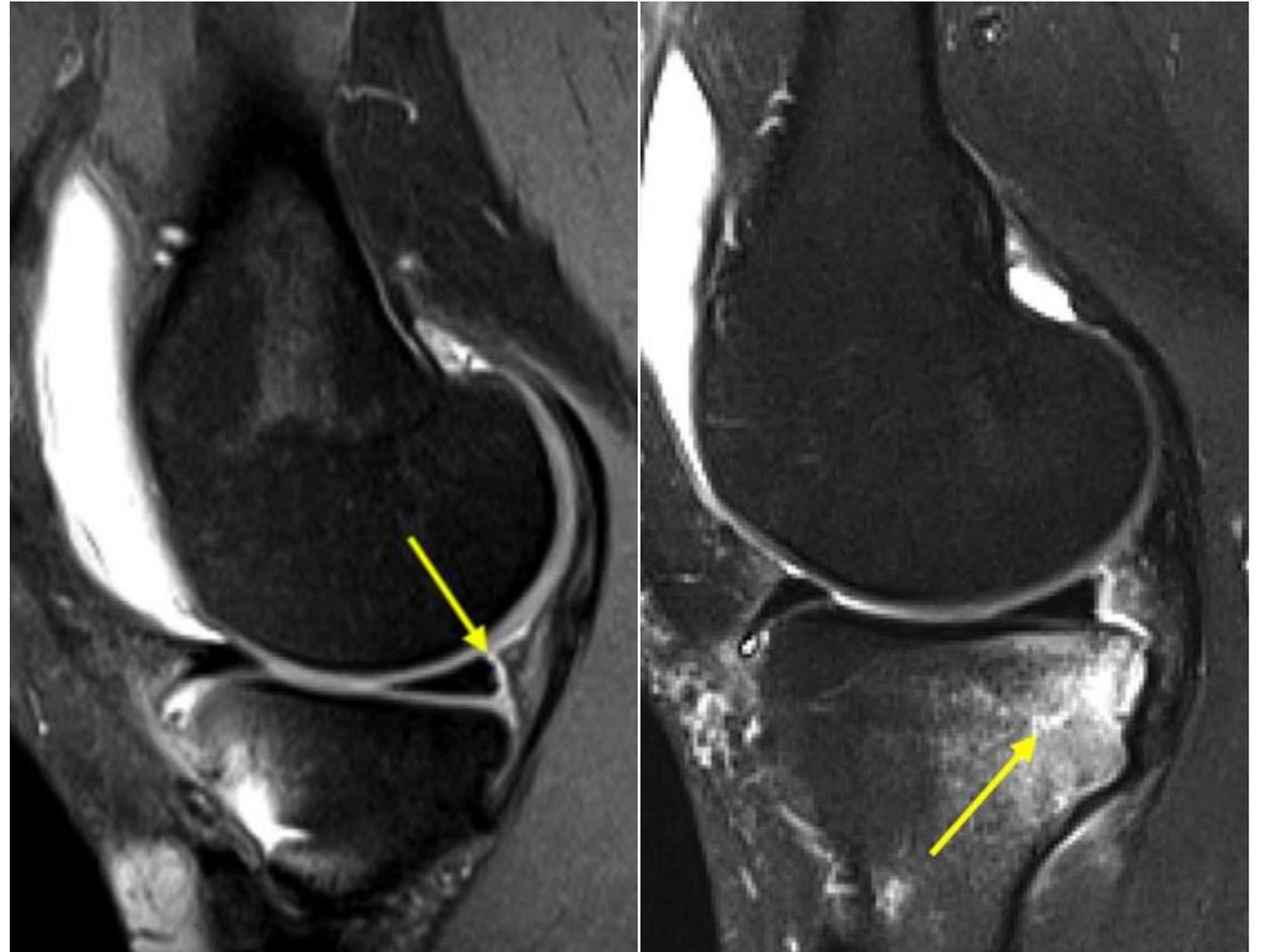
Fig. 14 Type 5 meniscal ramp lesion illustration, defined as peripheral posterior horn meniscal double tear



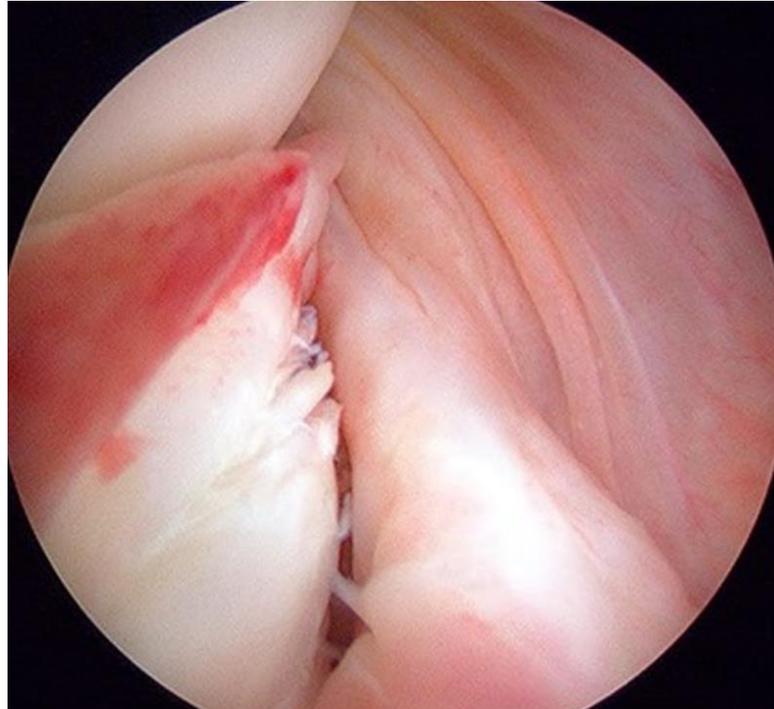
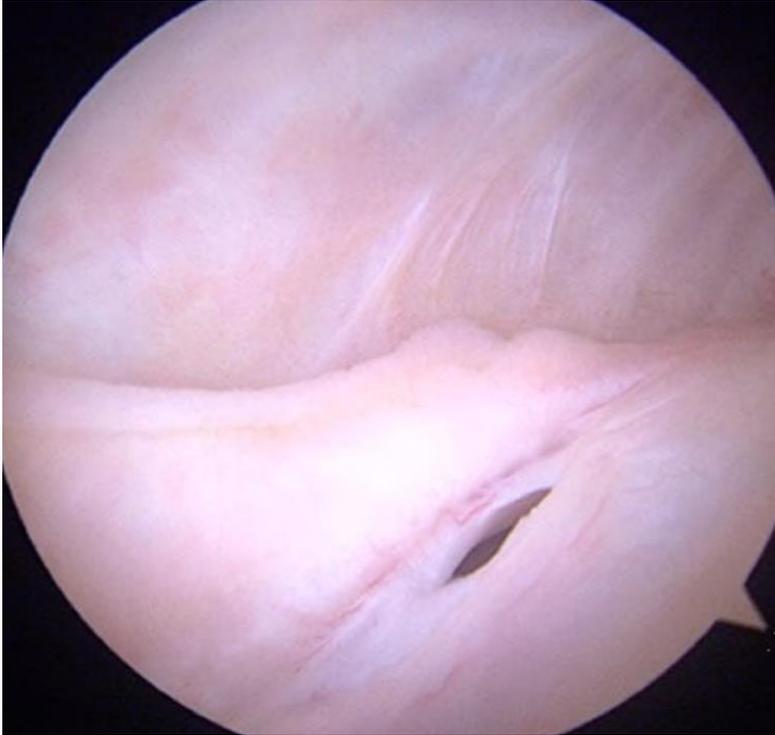
Medial Meniscus Ramp Lesion

Arner, Burnham, Fu, Musahl
KSSTA 2018

- MRI can accurately detect ramp lesions, but you must have a high degree of **suspicion**
- **Sensitivity** ranged from 53.9 - 84.6%
- **Specificity** range from 92.3 - 98.7%
- Intra-rater **reliability** 0.75 to 0.81

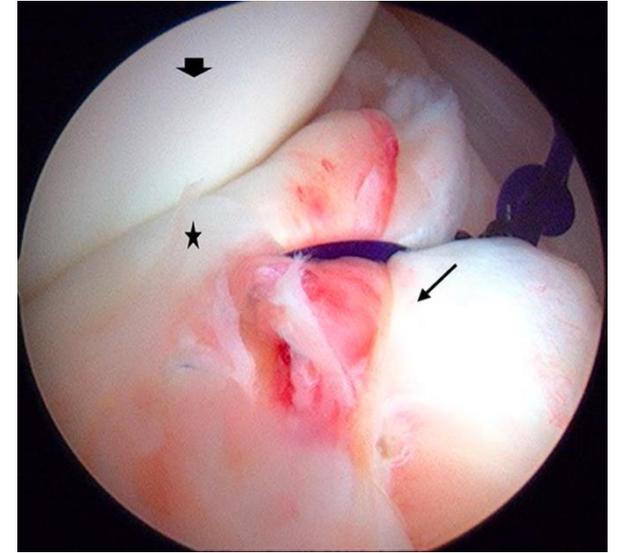
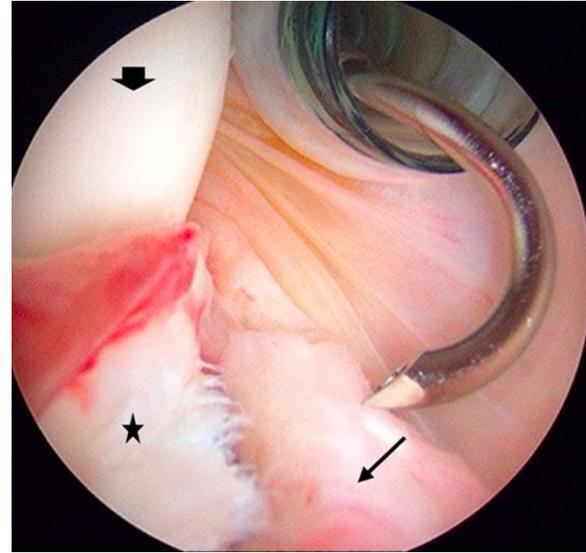
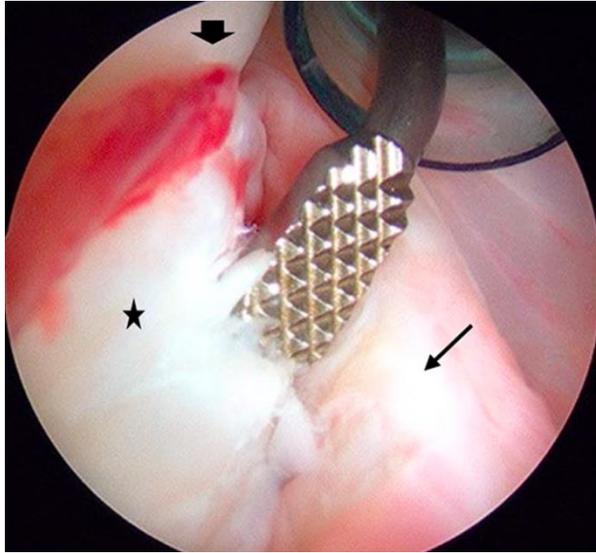


Medial Meniscus RAMP Lesion

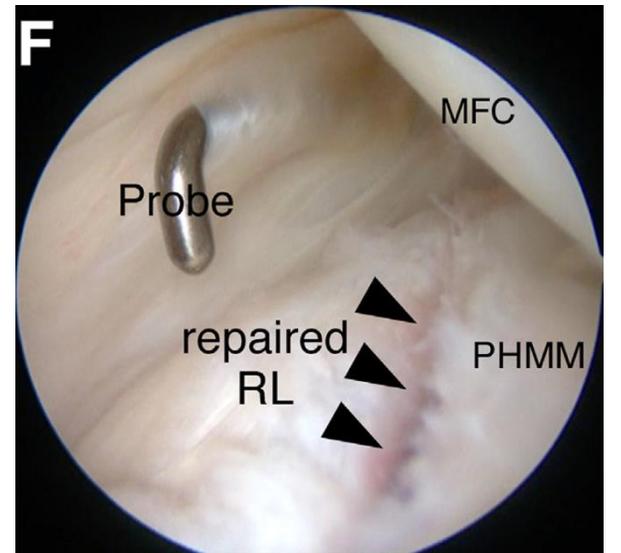
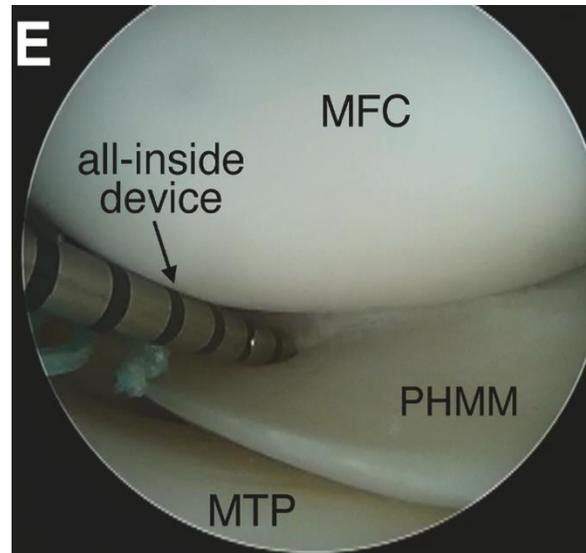
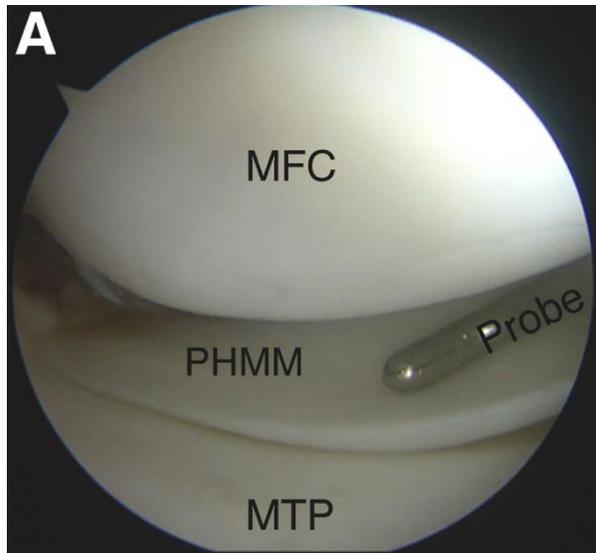


RAMP Lesion Repair Methods

Arner, Burnham, Musahl
KSSTA 2018
Posteromedial Portal



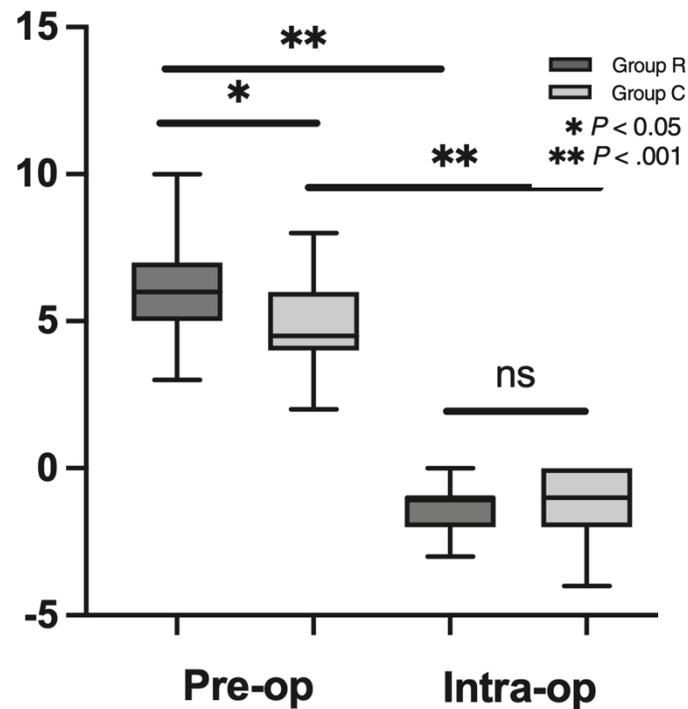
Fukushima, Nozaki
Arthroscopy 2025
All Inside



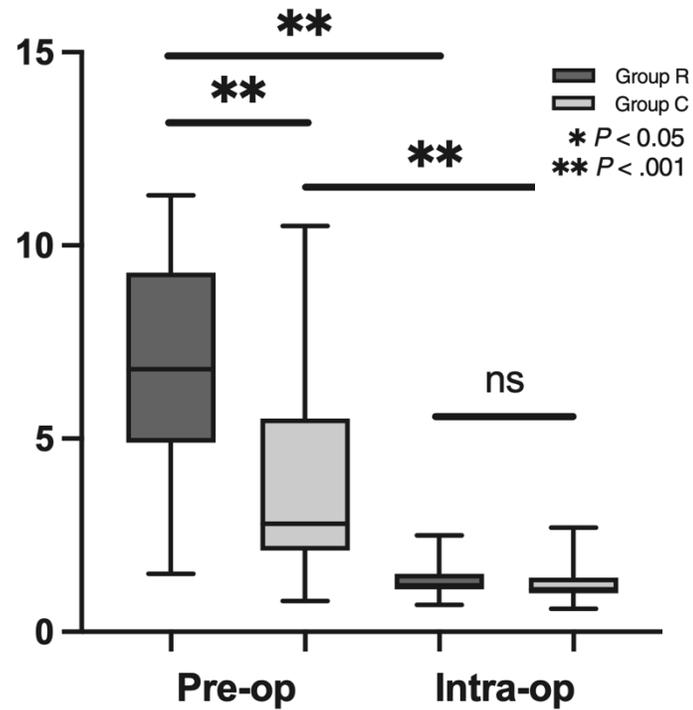
Medial Meniscus Ramp Lesion

Fukushima, Nozaki et al
Arthroscopy 2025

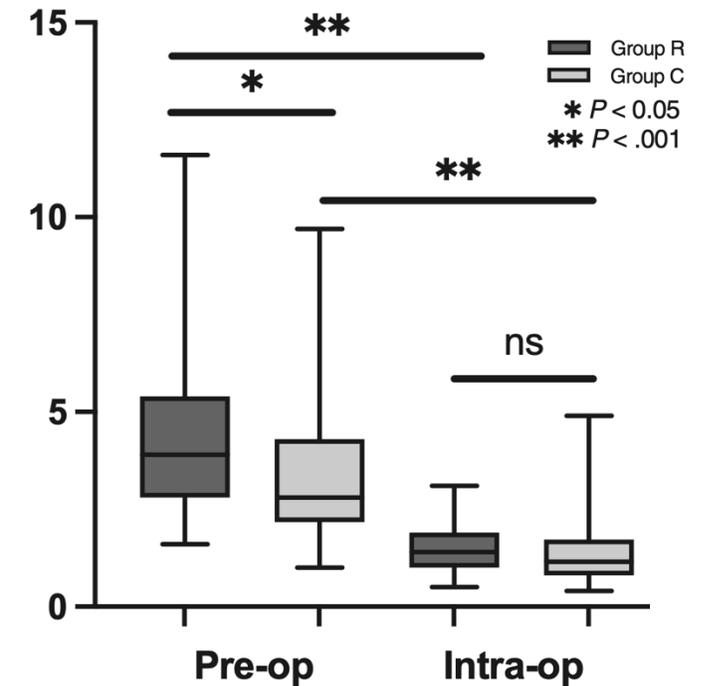
Anterior Tibial Translation



Tibial Acceleration (Pivot Shift)



Angular Velocity (Pivot Shift)



Lateral Meniscus Posterior Root

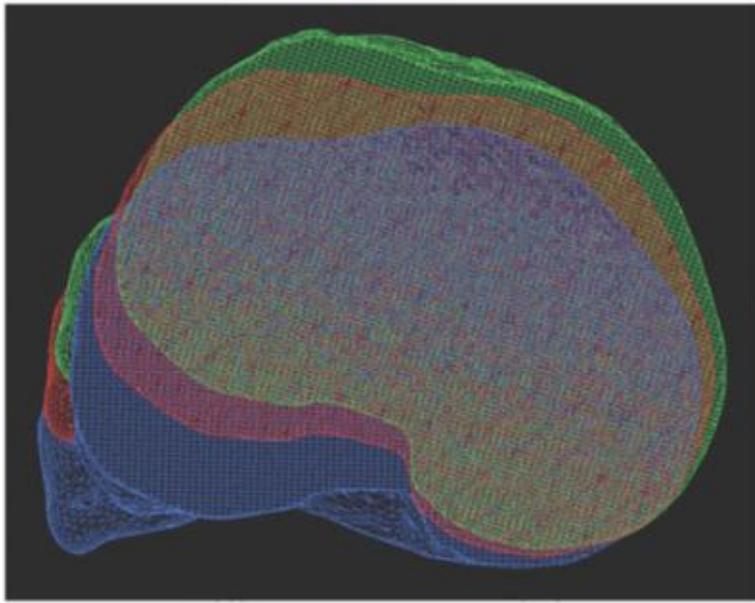


Figure 2. A 3-dimensional computerized motion analysis system is used to determine kinematic measurements of specimens undergoing testing. This specimen illustrates the increased pivot shift seen in the anterior cruciate ligament-deficient/lateral meniscal posterior root avulsion state (ACL-D/LMR-A) (green). Blue = ACL-intact; red = ACL-deficient.

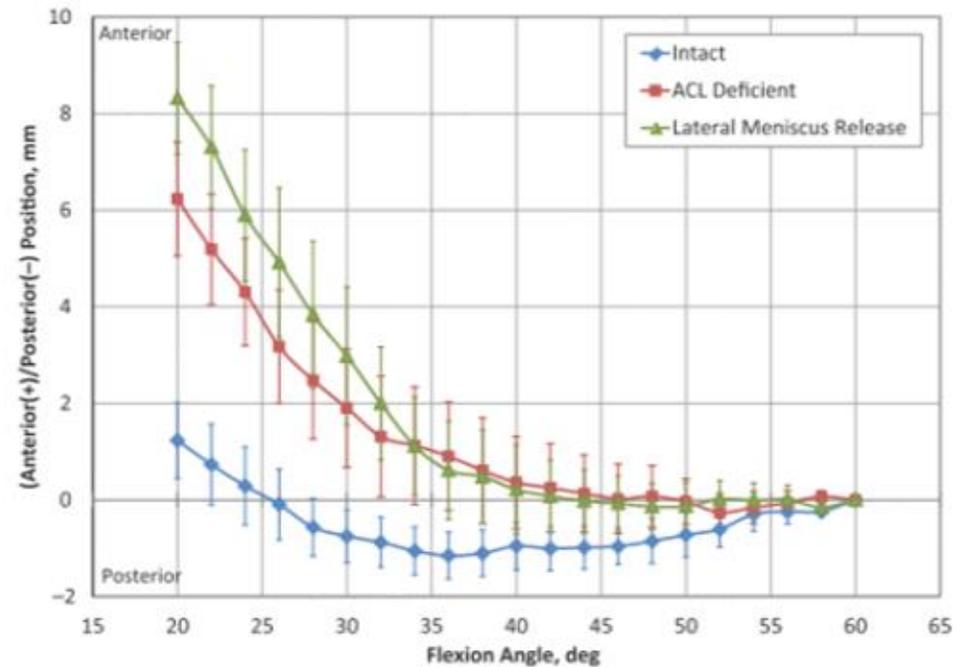
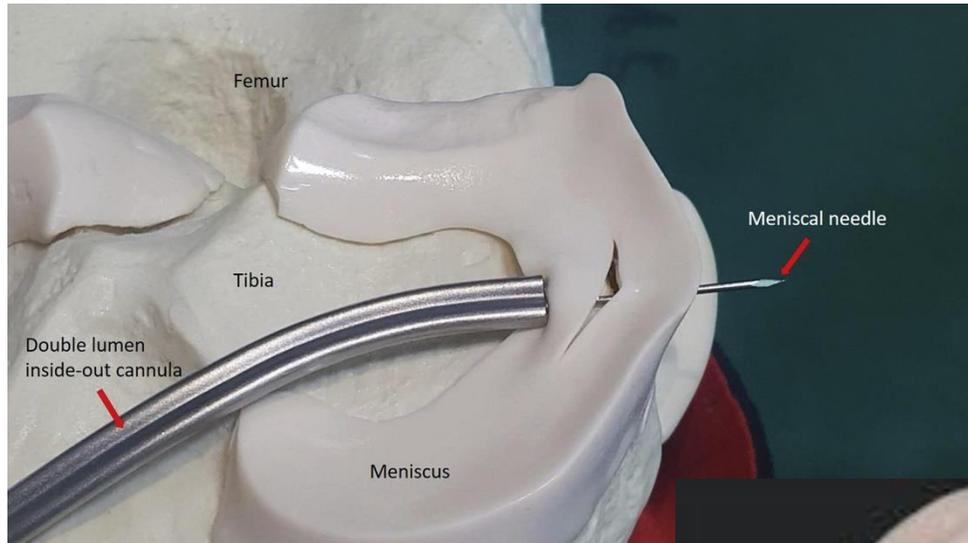


Figure 3. Average tibia versus femur anterior-posterior motion during the pivot shift relative to 60° of knee flexion. ACL, anterior cruciate ligament.

Lateral meniscus posterior root tears exacerbate rotatory instability in an ACL deficient knee.

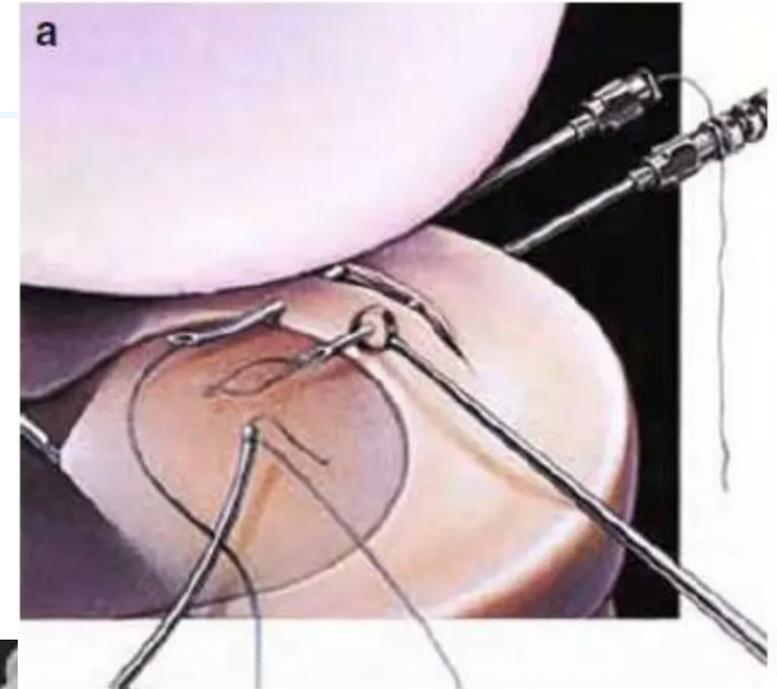


Repair Techniques



Inside-Out
Gold Standard

All-Inside



Outside-In

Repair vs. Meniscectomy

The cost-effectiveness of meniscal repair versus partial meniscectomy: A model-based projection for the United States

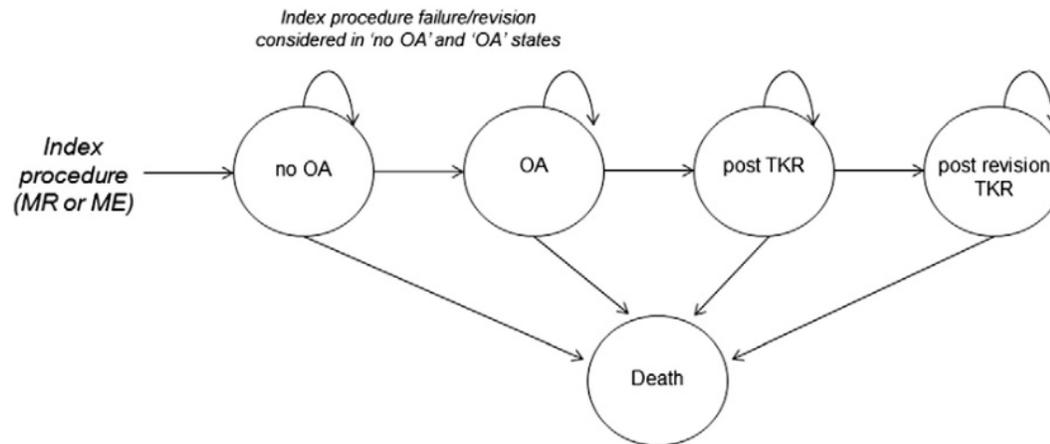
Brian T. Feeley^{a,*}, Shan Liu^{b,c}, Abigail M. Garner^b, Alan L. Zhang^a, Jan B. Pietzsch^{b,d}

^a University of California, San Francisco, San Francisco, CA, USA

^b Wing Tech Inc., Menlo Park, CA, USA

^c University of Washington, Seattle, WA, USA

^d Stanford University, Stanford, CA, USA



If 10% of meniscectomies changed to repairs, would save \$43 million

- Repairs **may fail more, but still more cost effective**
- Improves Outcomes
- Decreases overall costs of treatment



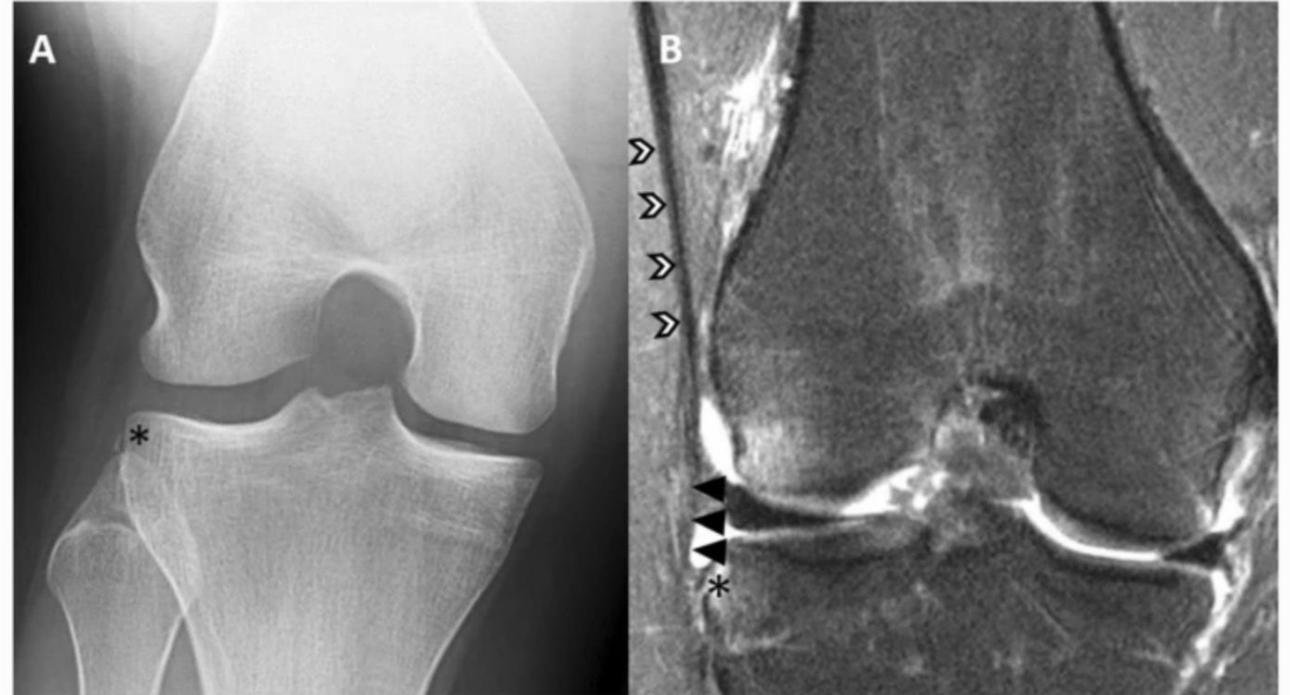
2. Anterolateral Complex

Critical Factors to Address Rotatory Instability Associated with ACL Injury

Anterolateral Rotatory Knee Instability

- First described by Segond in 1870
 - **Segond fracture**
- Exists in conjunction with ACL injury or ACL dysfunction
- **Subluxation of LFC posterior to LTP**
- Secondary stabilizers
 - Meniscus
 - **Anterolateral capsule**
 - ITB
- **Bony anatomy**
 - Posterior tibial slope
 - Posterior condylar offset

Fig. 1

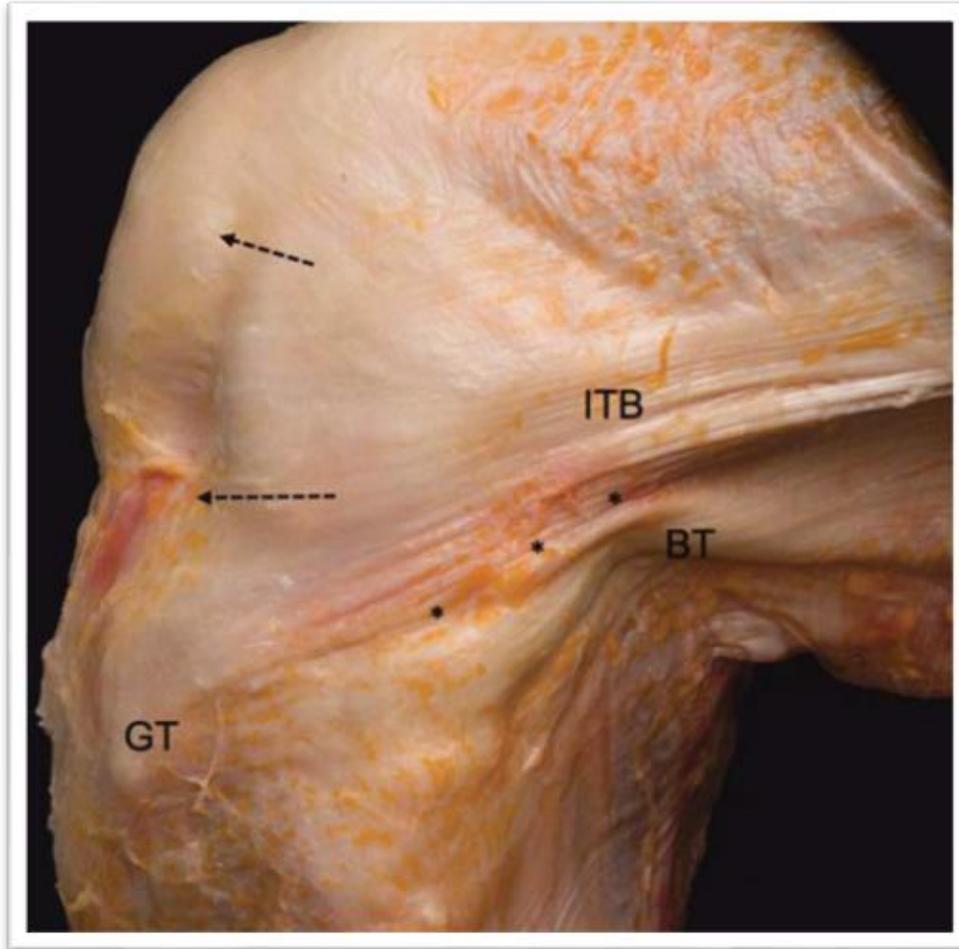


Radiograph (a) and magnetic resonance imaging exam (b) of a Segond fracture with injury to the anterolateral capsule. The black star denotes the Segond fracture, or an avulsion fracture off the lateral tibial plateau. The black and white errors denote the iliotibial band, while the black arrows demonstrate the anterolateral capsule

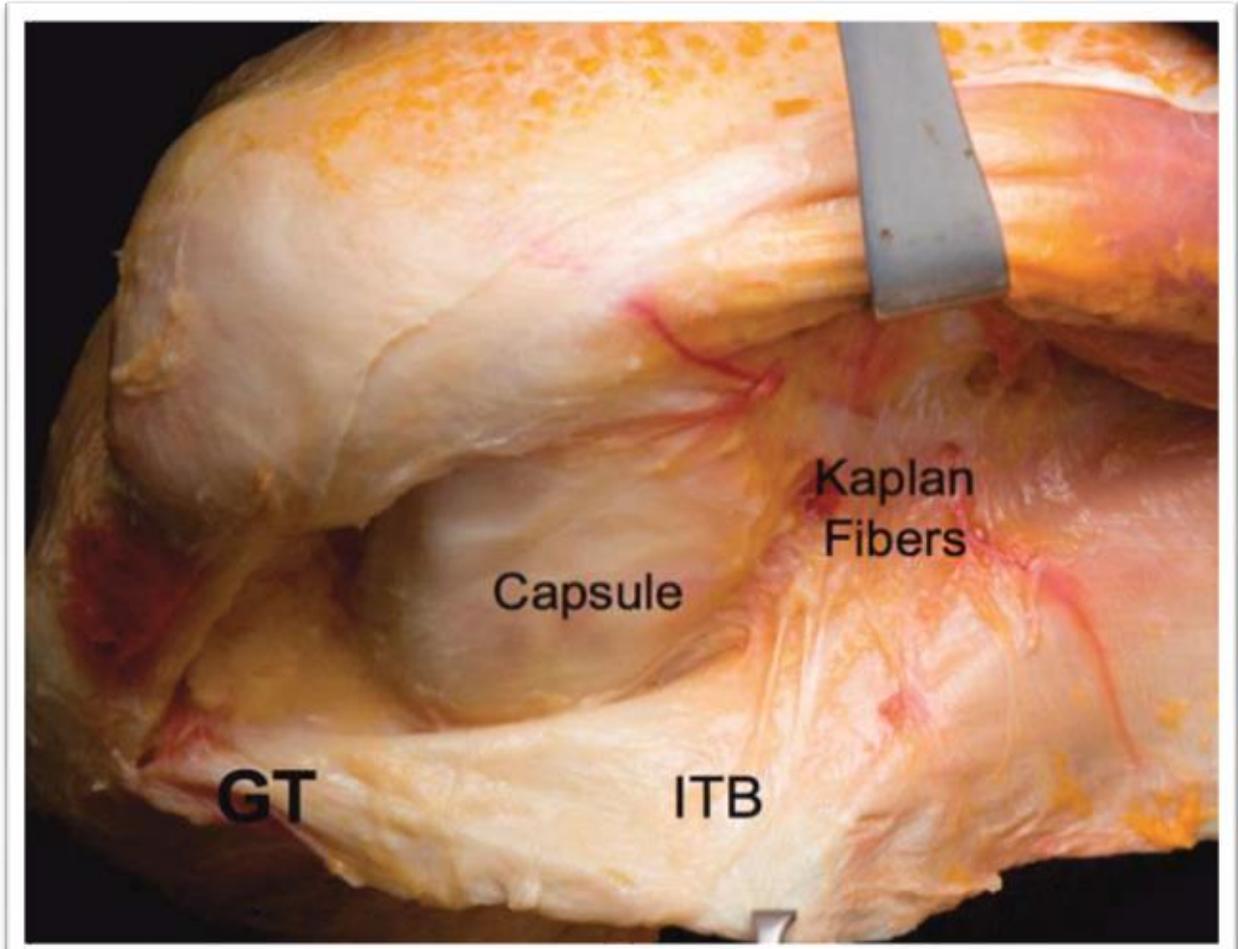
Herbst, Burnham, Musahl OJSM 2017

Hughes, Musahl et al JEO 2019

Anterolateral Complex - Superficial Layer



Herbst, Burnham, Musahl KSSTA 2017



Herbst, Burnham, Musahl OJSM 2017

Anterolateral Knee Complex

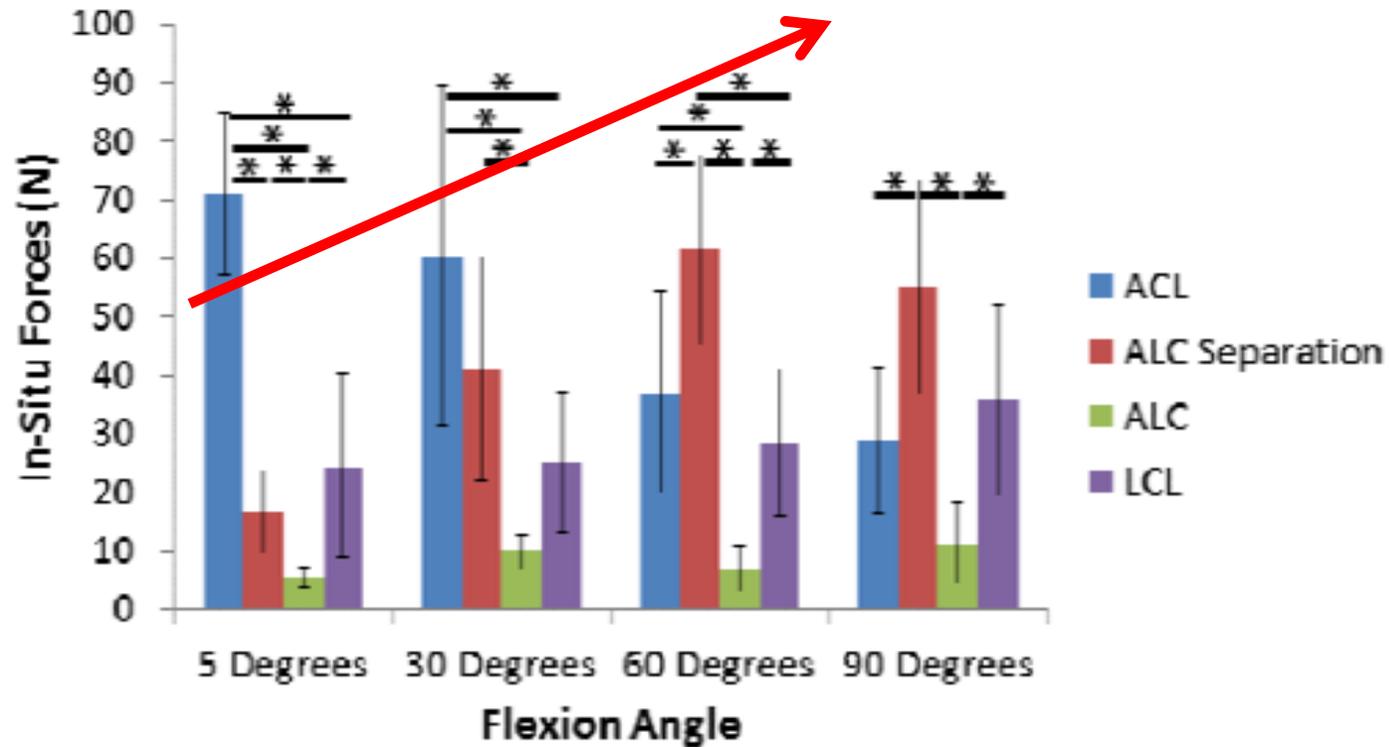
- sITB inserts on wide area of proximal tibia
 - Gerdy's and anterolateral and lateral tibia
- KF connect sITB to distal femoral metaphysis/condyle
- ALC contains superficial & deep layers, merge anteriorly
- Capsulo-osseous Layer (*)
 - Continuous with lateral gastroc fascia
 - Merges with ITB
 - Inserts between fibular head and GT

Herbst, Burnham, Musahl
KSSTA & OJSM 2017



Anterolateral Capsule/Complex (ALC)

Bell et al
ORS Paper No. 126



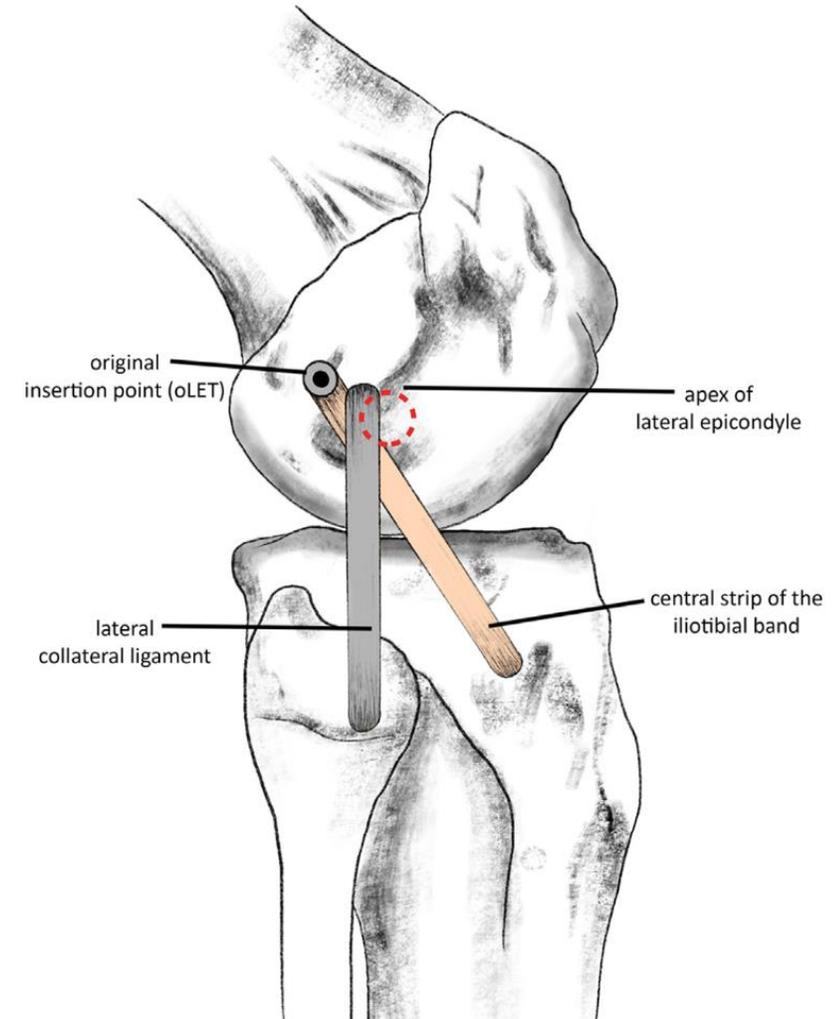
- ALC becomes increasingly important stabilizer of tibial internal rotation with progressive knee flexion



Preferred LET Technique – Modified Lemaire

Sigloch, Coppola, Mayr
Arthroscopy 2025

- Central strip of Iliotibial Band (ITB)
- 1 cm in width, leaving posterior cuff for repair
- 8-10 cm in length
- Leave attached at Gerdy's
- Pass deep to the LCL
- Fix at the femur posterior and proximal to the Lateral Epicondyle (LE)

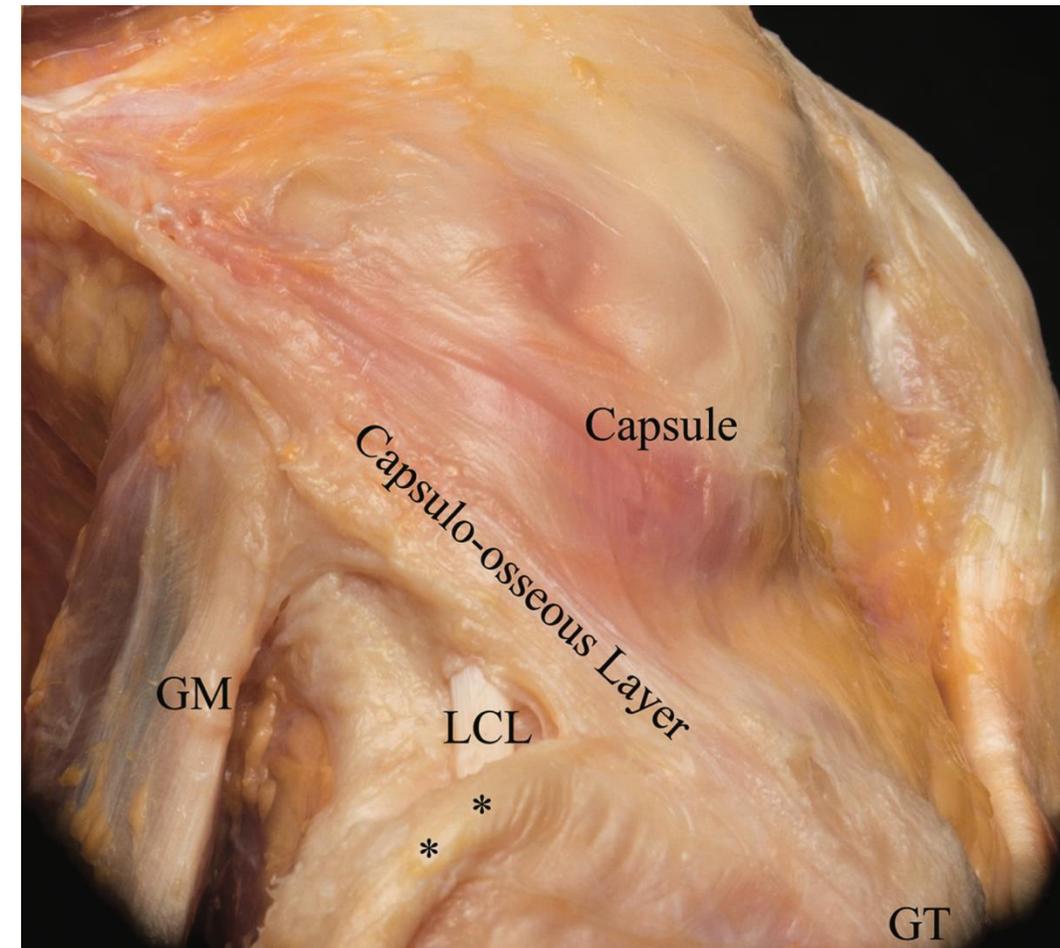
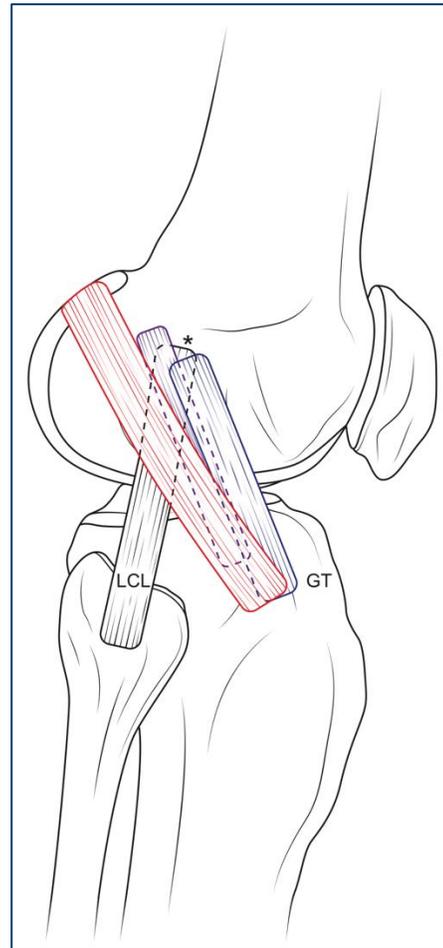


Femoral Fixation Point Controversy

Anterolateral Knee Complex

Musahl, Herbst, Burnham, Fu
JAAOS 2018

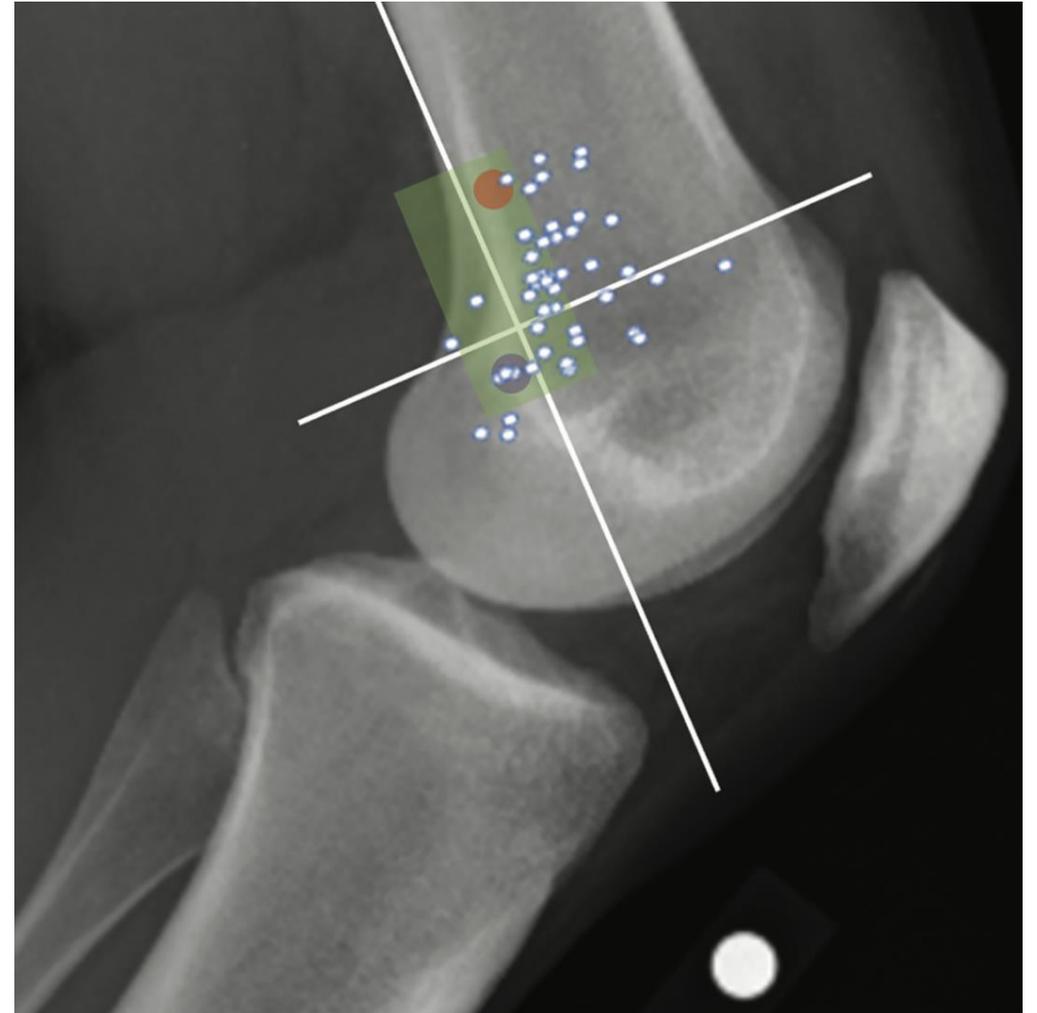
- Considerable overlap between anterolateral knee structures
- Mid-third capsular ligament (blue), capsulo-osseous layer (red), & the anterolateral ligament (purple)
 - Span from the proximal tibia to the distal femur
 - Cross the LCL



LET Femoral Fixation Site

Kanakamedala Ajay, Godin J, Vidal A
AJSM 2024

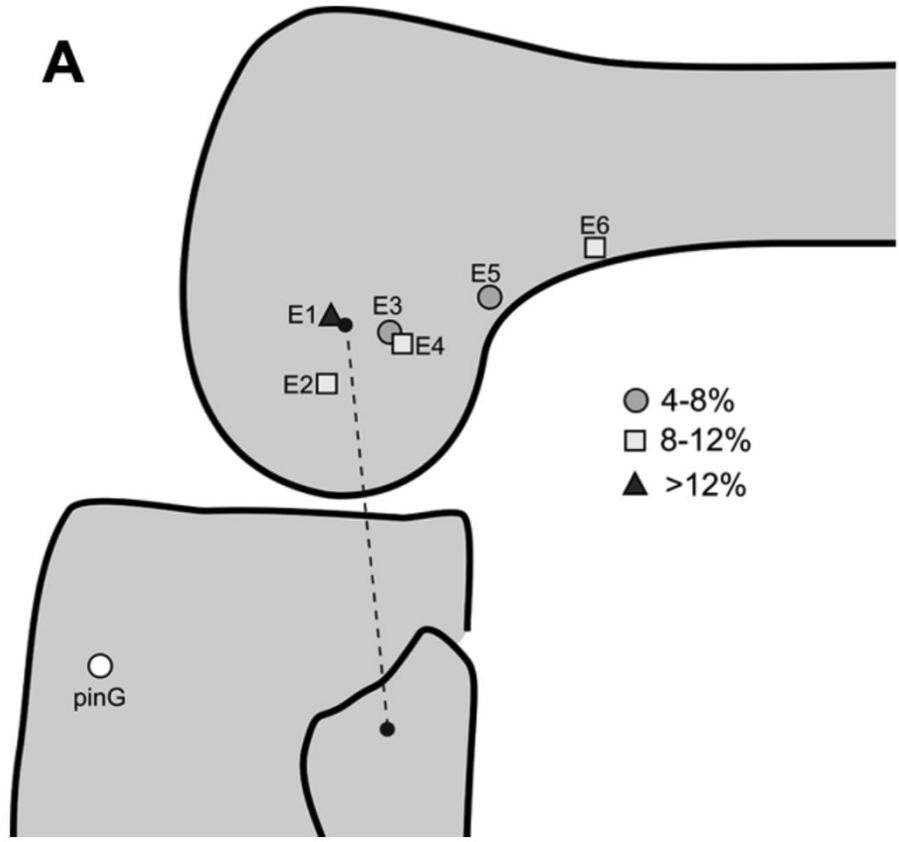
- Level 4 Cross-sectional study (47 cases)
- Large variation in the location of LET fixation points
- Nearly half were outside of the predefined isometric zone
- Variability likely stems from the lack of a specific anatomic structure reconstructed by the LET



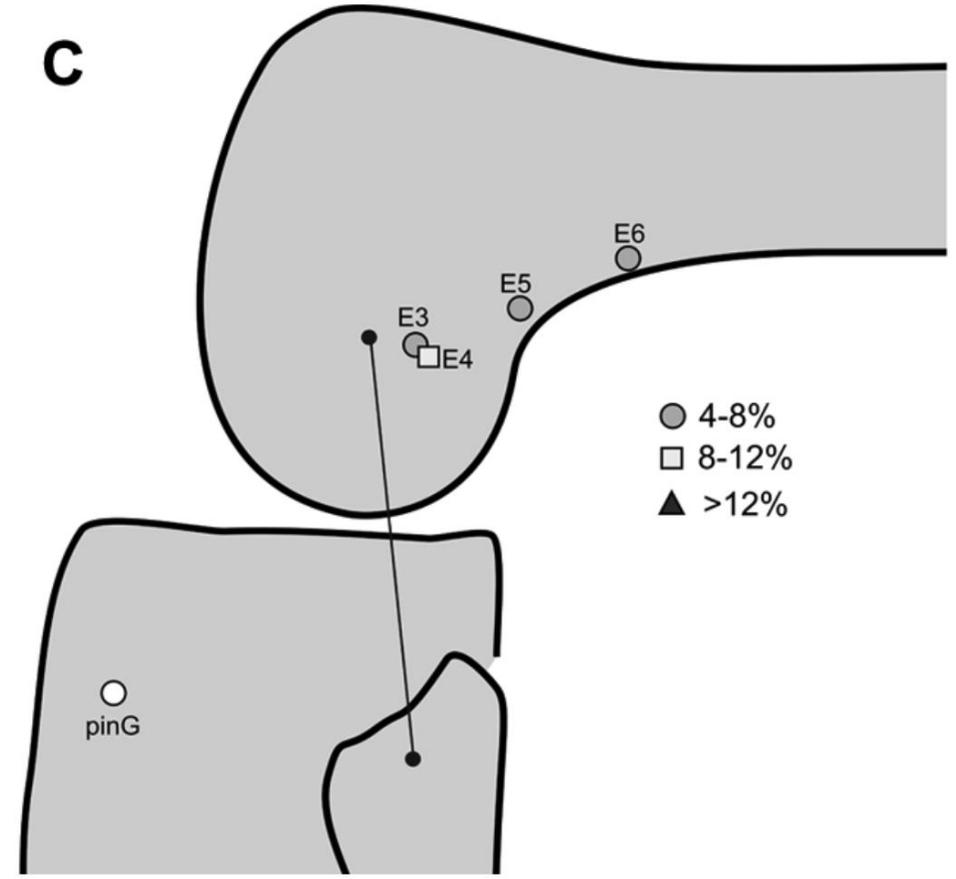
LET Femoral Fixation Site

Kittl, Williams A, Amis A
AJSM 2014

Superficial to LCL



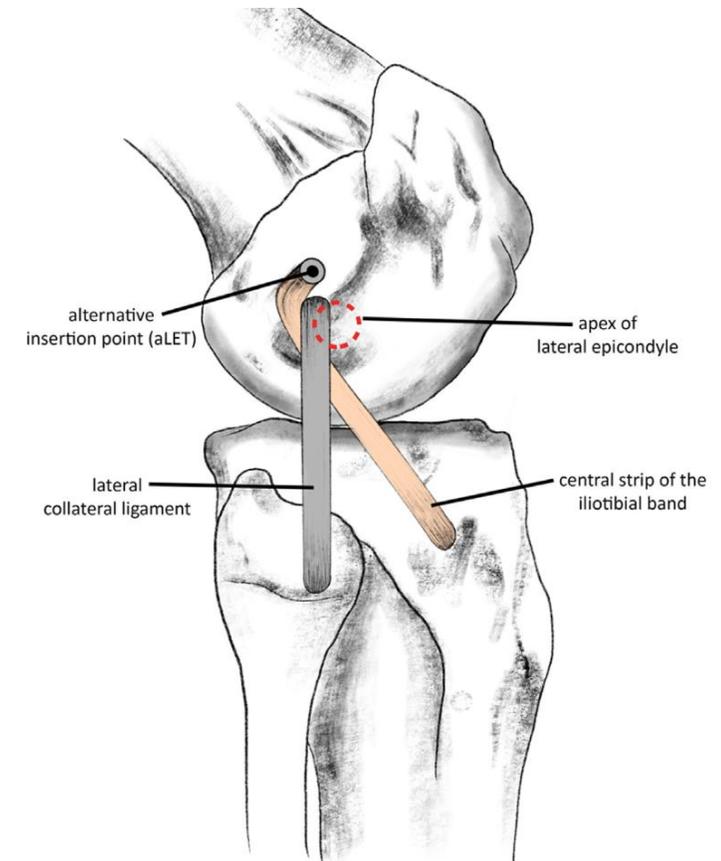
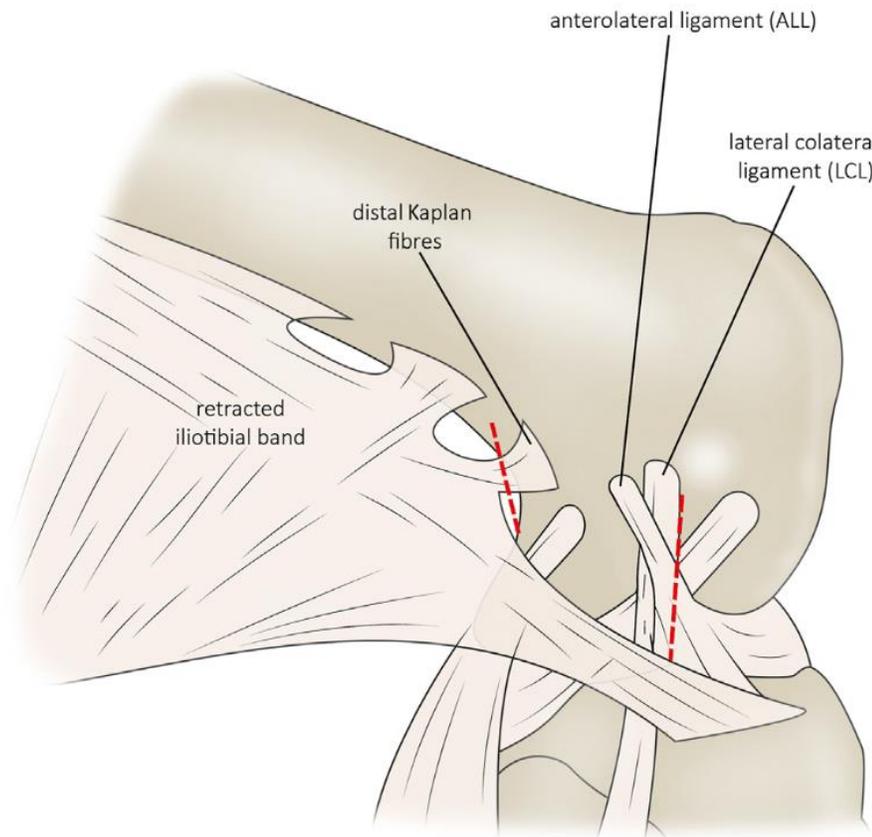
Deep to LCL



Femoral Fixation – Modified Lemaire

Sigloch, Coppola, Hoermann, Alt, Mayr
Arthroscopy 2025

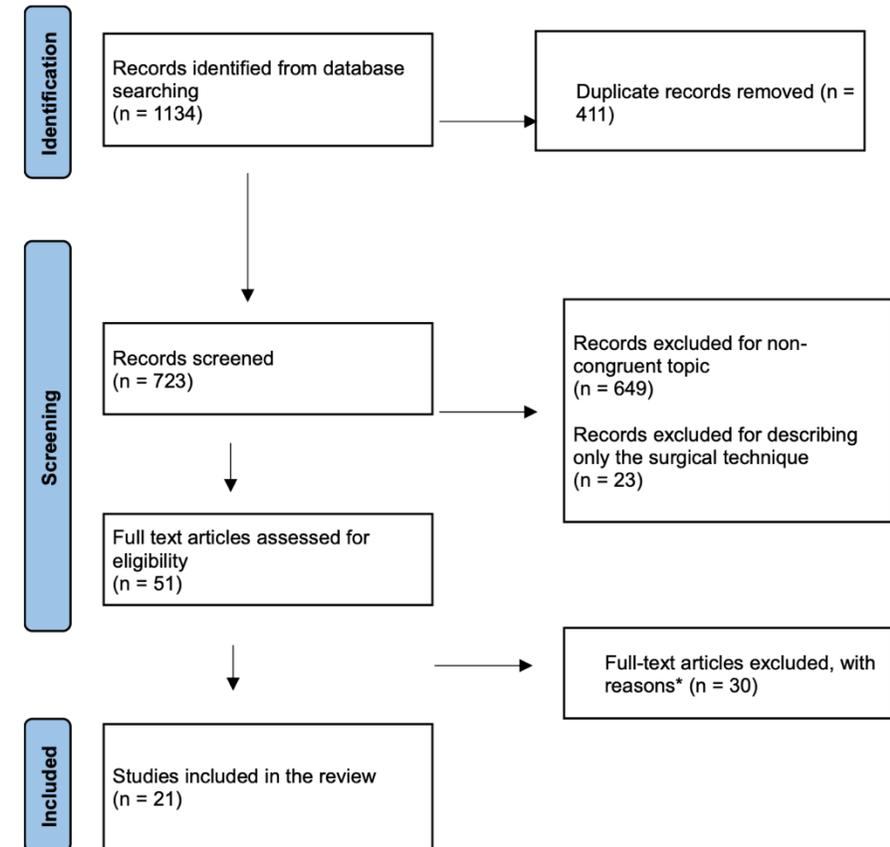
An anterior fixation point may decrease over-constraint if passed deep to the LCL.



LET Fixation Knee Flexion Angle

Compagnoni, Klasan, Menetrey
JEO 2025

- Systematic Review of 21 studies
- Significant variability in the literature, from full extension to 90 degrees of flexion
 - All with good clinical results
- Trend toward fixation at 30 degrees
 - Represents good balance between stability and mobility
- Further studies needed



ACL + LET Outcomes



• STABILITY 1

- Multicenter RCT (**Hamstring** +/- LET); 618 high risk patients
- Re-tear rates
 - Hamstring auto: 11%
 - Hamstring + LET: 4%

• STABILITY 2

- Multicenter RCT (BTB/**Quad** +/- LET)
- Enrolled 1,242 patients (ends May 2025)

2024 FREDDIE FU PANTHER SPORTS MEDICINE SYMPOSIUM

Original Research

When is anterolateral complex augmentation indicated? Perspectives from the 2024 Freddie Fu Panther Sports Medicine Symposium

• PANTHER GROUP

- LET should be considered in revision cases or cases of increased anterolateral instability
- Level V Evidence



ACL + LET Outcomes

Adding a Lateral Extra-articular Tenodesis Is Cost-Effective in Primary Anterior Cruciate Ligament Reconstruction: A Markov Analysis

- Meta-analysis of 1072 patients
- Graft failure 5.1% for ACLR+LET compared to 11.2% for ACLR alone
- Over 5 years, total cost:
 - ACLR: \$68,605
 - ACLR + LET: \$56,217

Varady, Oeding, Inclan, Ranawat, Strickland, Pearle, Rodeo S, Williams R
Arthroscopy 2025

The Effect of Lateral Extra-articular Tenodesis on Anterior Cruciate Ligament Graft Forces and Knee Stability Compared With Slope Reduction Osteotomy in the Setting of Increased Posterior Tibial Slope

- Controlled laboratory study
- 8 Fresh frozen cadavers
- Increasing PTS increased graft forces
- LET reduced graft loads by 22.1% at 10 degrees and 36.6% at 20 degrees
- 10-degree SRO demonstrated 2.6% reduction at 10 degrees and 23.9% at 20 degrees

Lemme, Badida, Molino, Quinn, Hague, Fleming, Owens B
AJSM 2025



History of Present Injury (HPI)

- 42-year-old



Case Study: LET Case

Surgical Technique Video – Loop & Tack LET

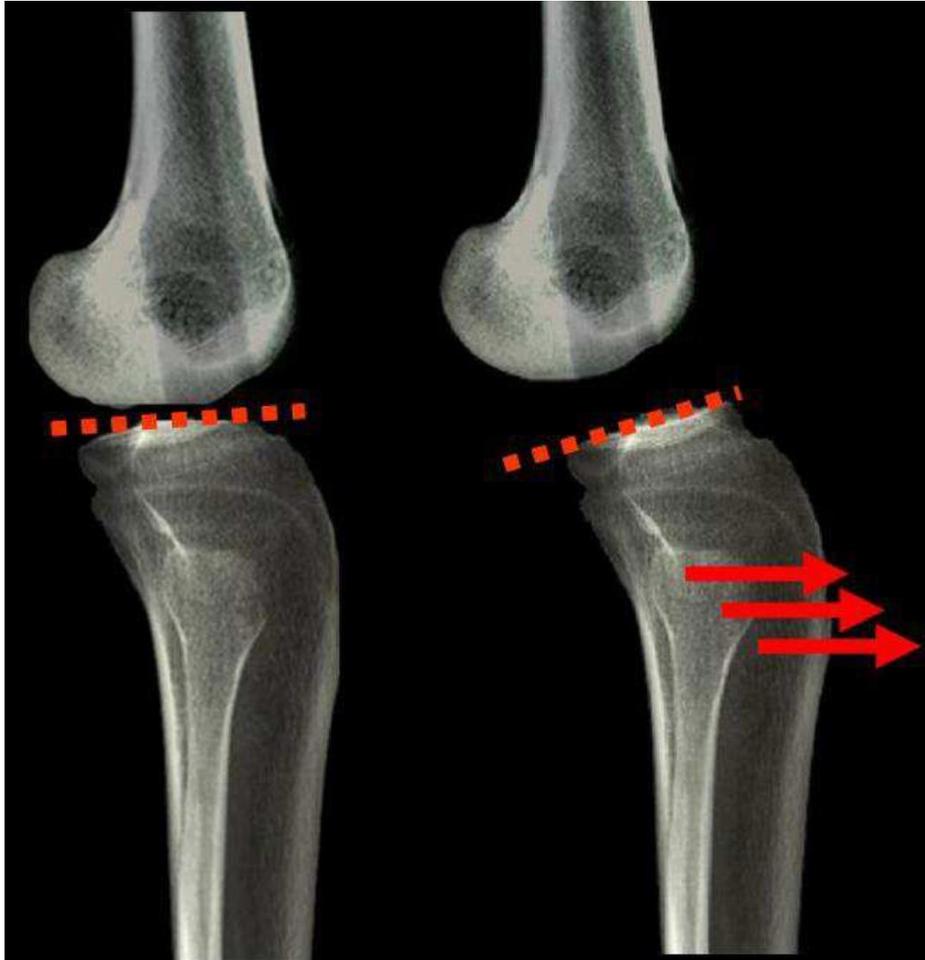


3. Posterior Tibial Slope

Critical Factors to Address Rotatory Instability Associated with ACL Injury

Increased Tibial Slope (Lateral)

Bisicchia et al

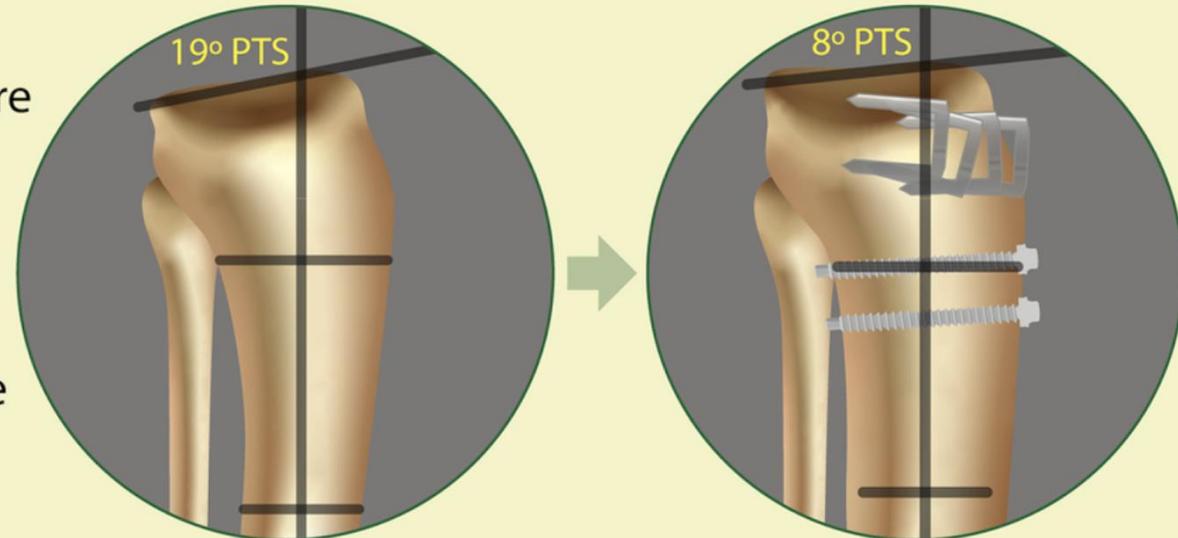


Burnham, Fu et al AOJ



ACL RECONSTRUCTION (ACLR) CONSIDERATIONS

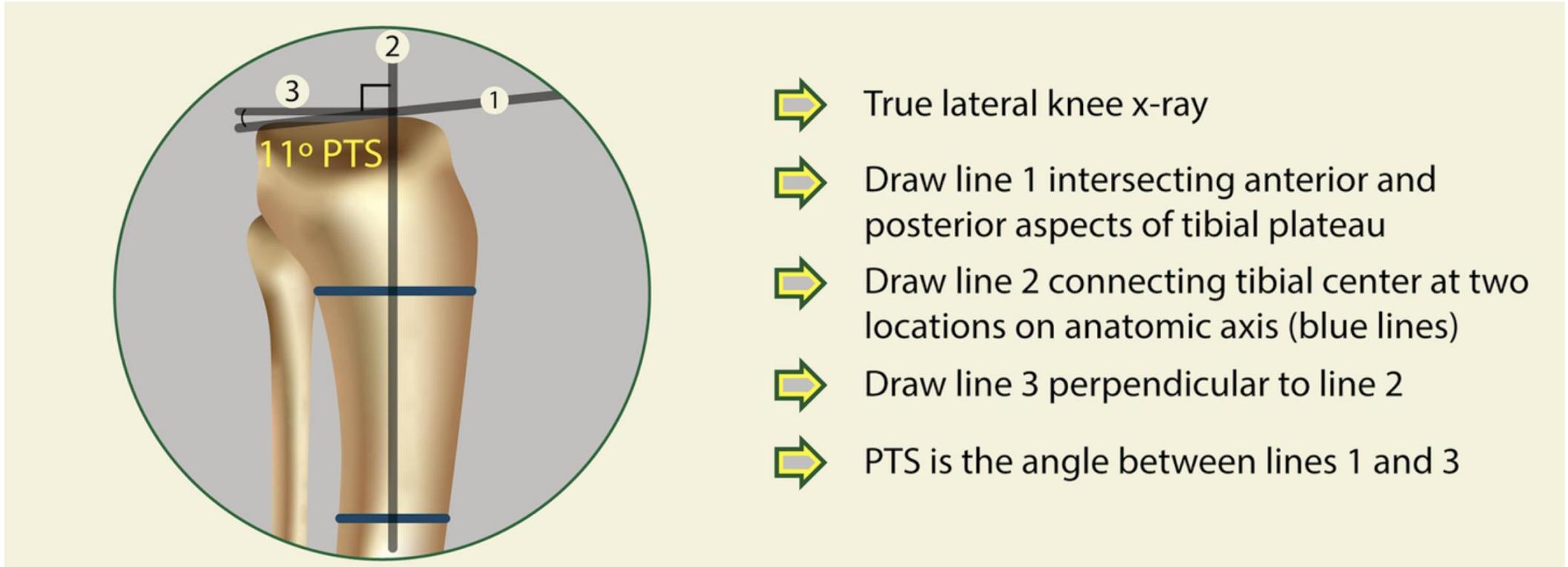
- ✔ Increased PTS is associated with increased risk of ACLR graft failure
- ✔ For primary ACLR, consider lateral extra-articular augmentation if $PTS > 12^\circ$
- ✔ Consider anterior closing wedge osteotomy for revision ACLR if $PTS > 12^\circ$



Robert S. Dean, BS, Christopher M. Larson, MD, Brian R. Waterman, MD

<https://www.arthroscopyjournal.org/>

Posterior Tibial Slope



Robert S. Dean, BS, Christopher M. Larson, MD, Brian R. Waterman, MD

<https://www.arthroscopyjournal.org/>

Posterior Tibial Slope

Stone, Tollefson, Shoemaker, LaPrade
AOJ 2024



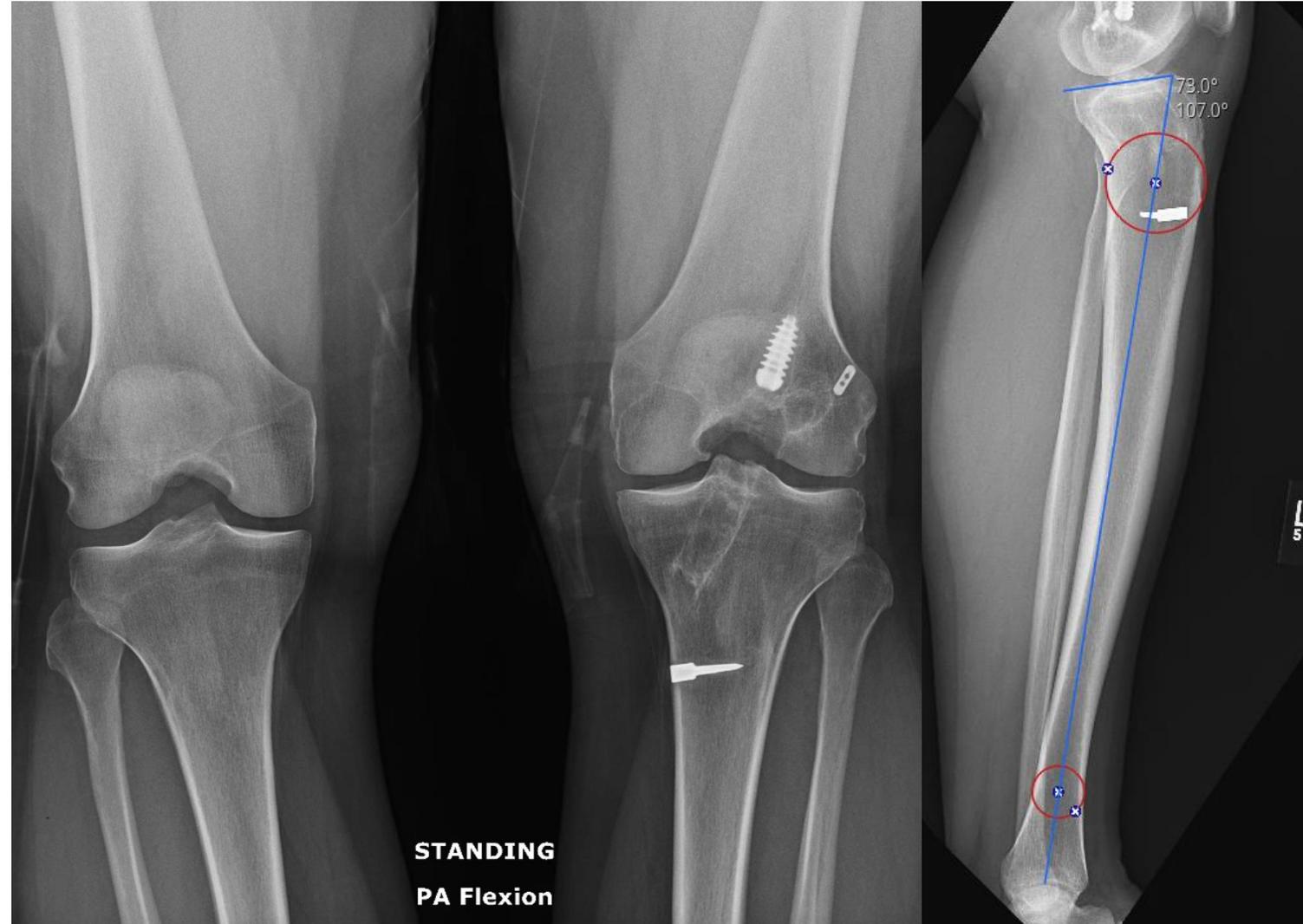
Mansour, Steward, Warth, Lowe
OJSM 2024

- PTS measurements obtained on FLL radiographs are not interchangeable with those obtained on SSK radiographs
- 2/3 of patients had over a 2-degree difference on PTS measurements between radiographs

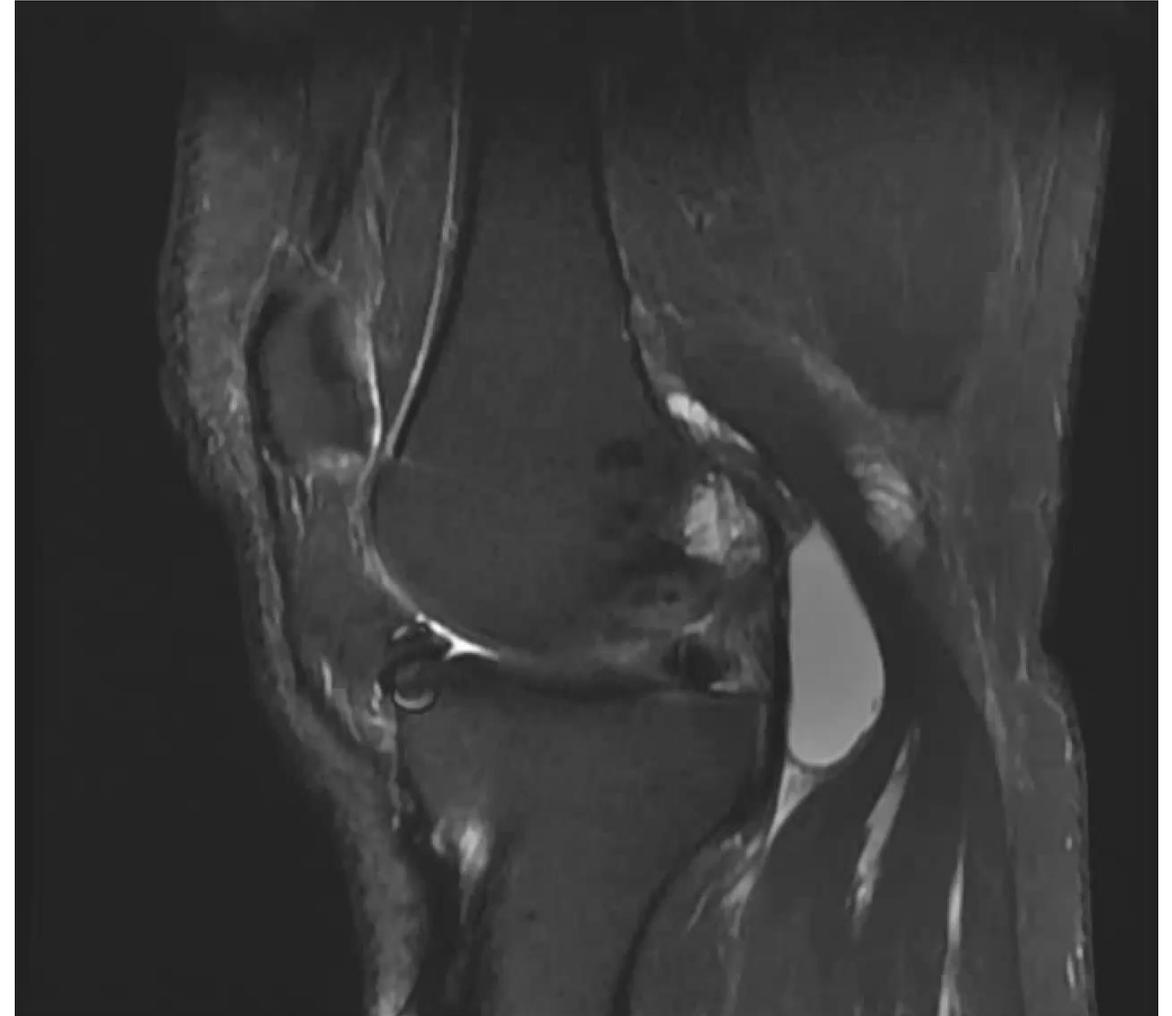
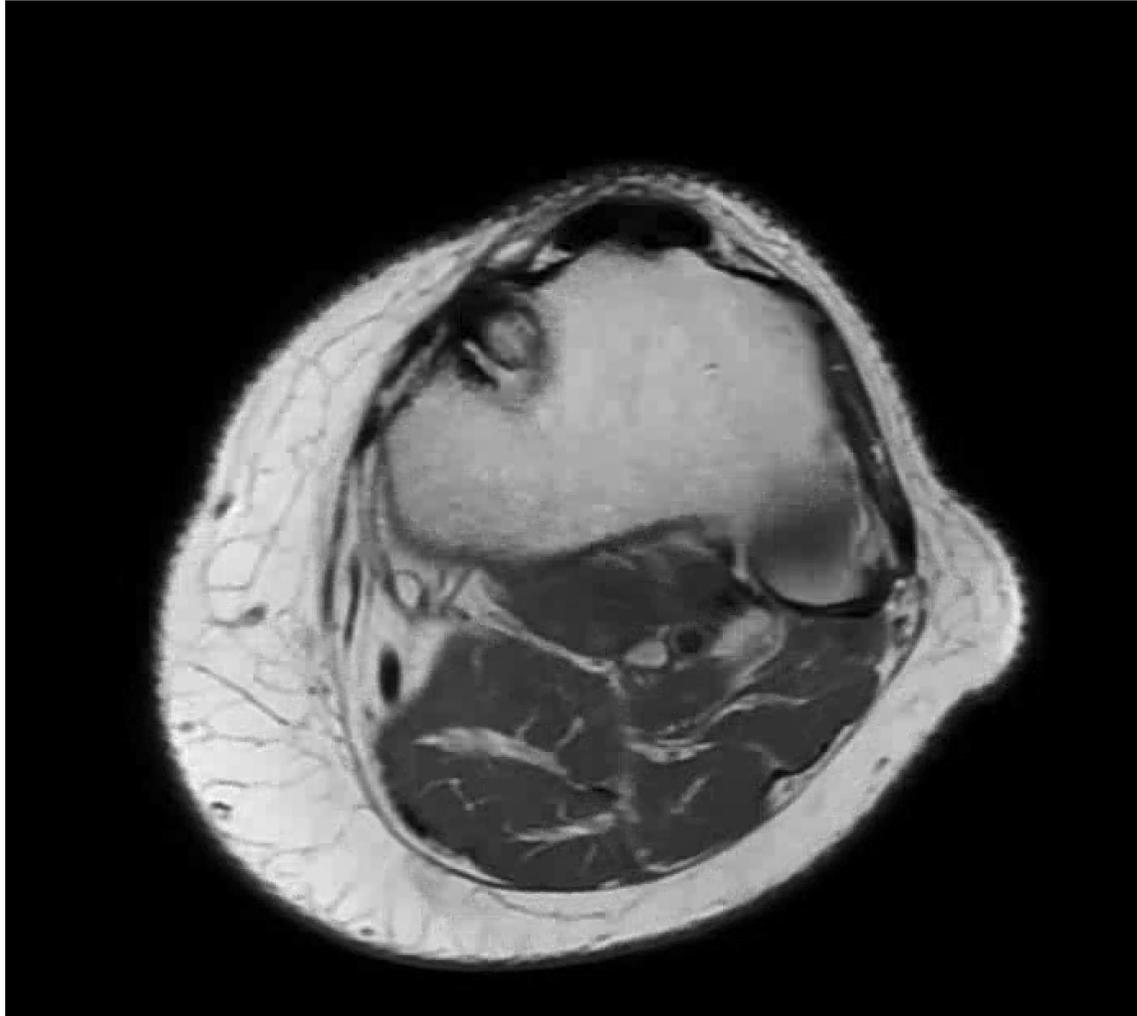


History of Present Injury (HPI)

- 42-year-old male plant supervisor
- Left knee pivot injury playing football on the beach one month prior
- Previous history of 2 prior ACL reconstructions
 - BTB autograft in 2000
 - Allograft & ?Meniscus Surgery in 2018
- Main complaints are left knee pain and instability

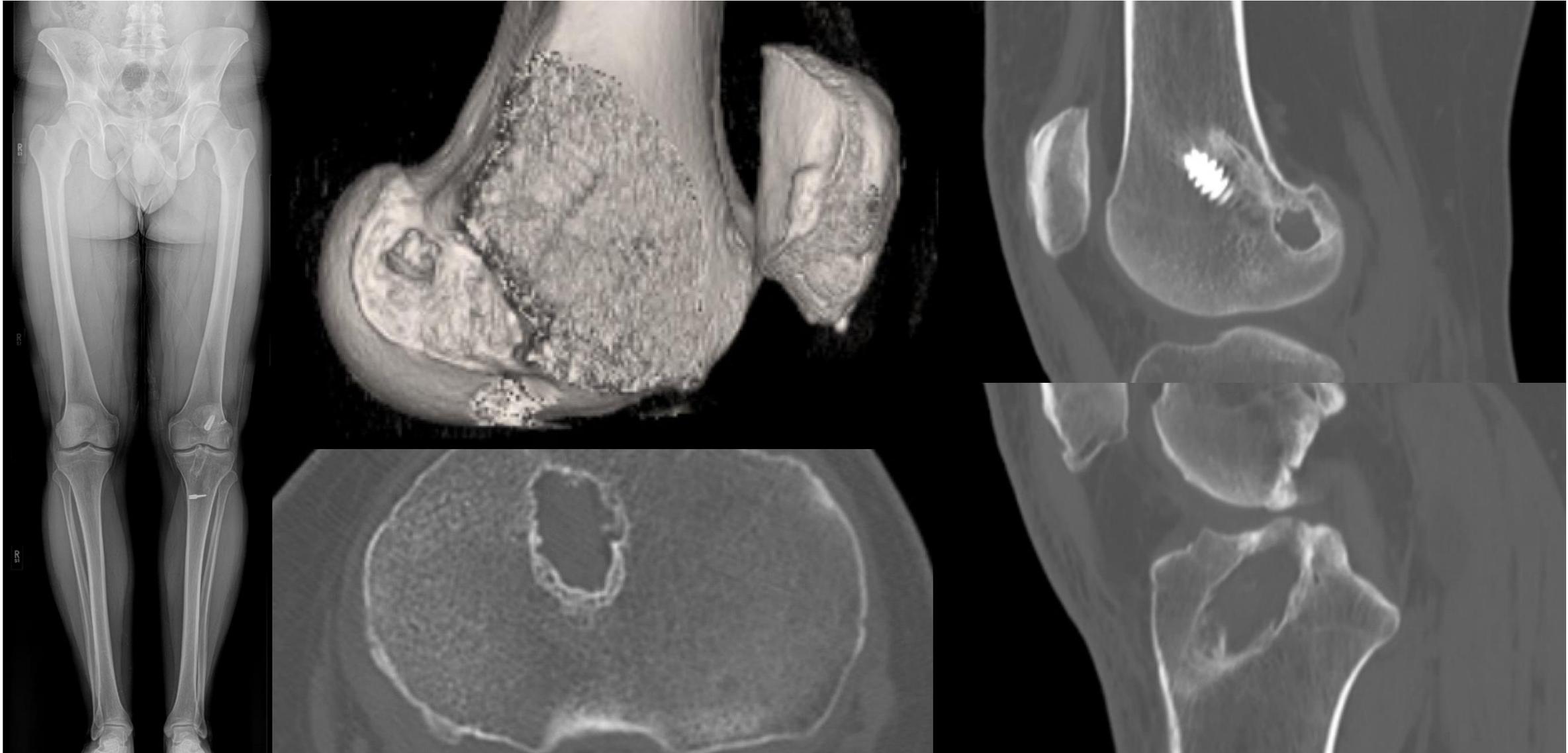


Initial Imaging



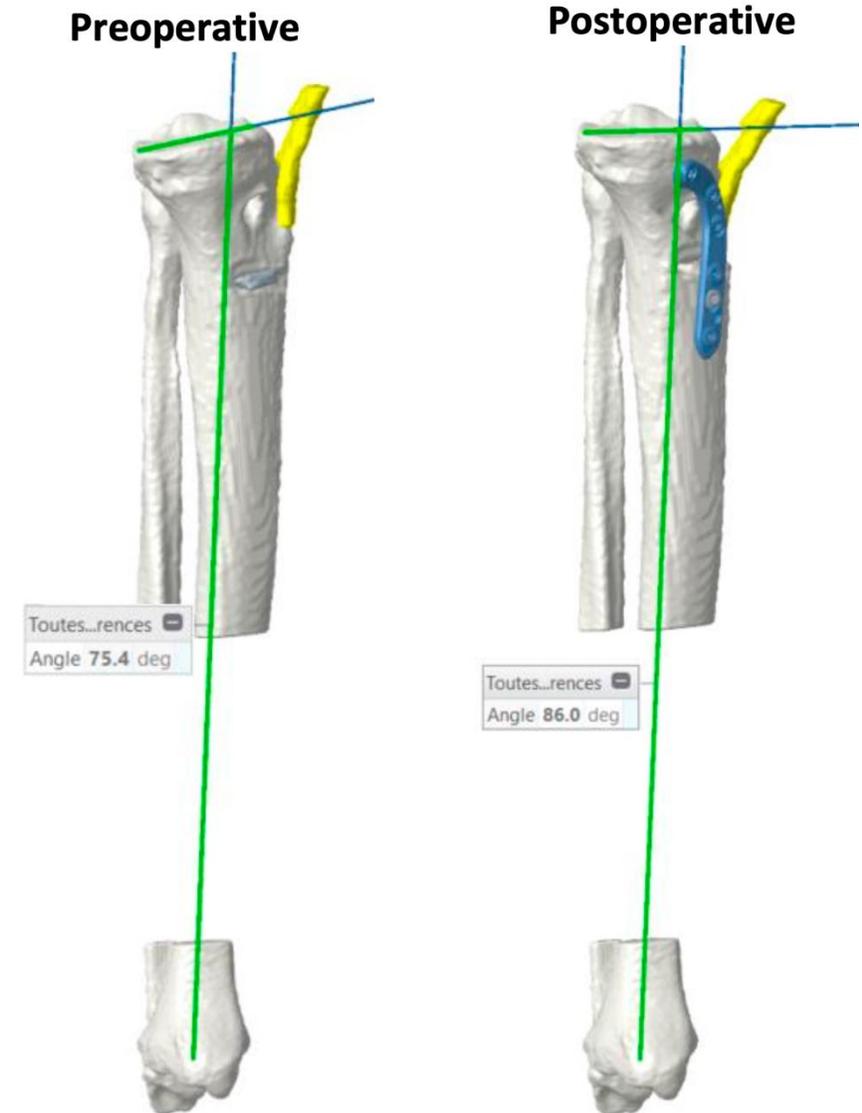
Case Study: Multiple ACL Revisions with Elevated PTS

Initial Imaging



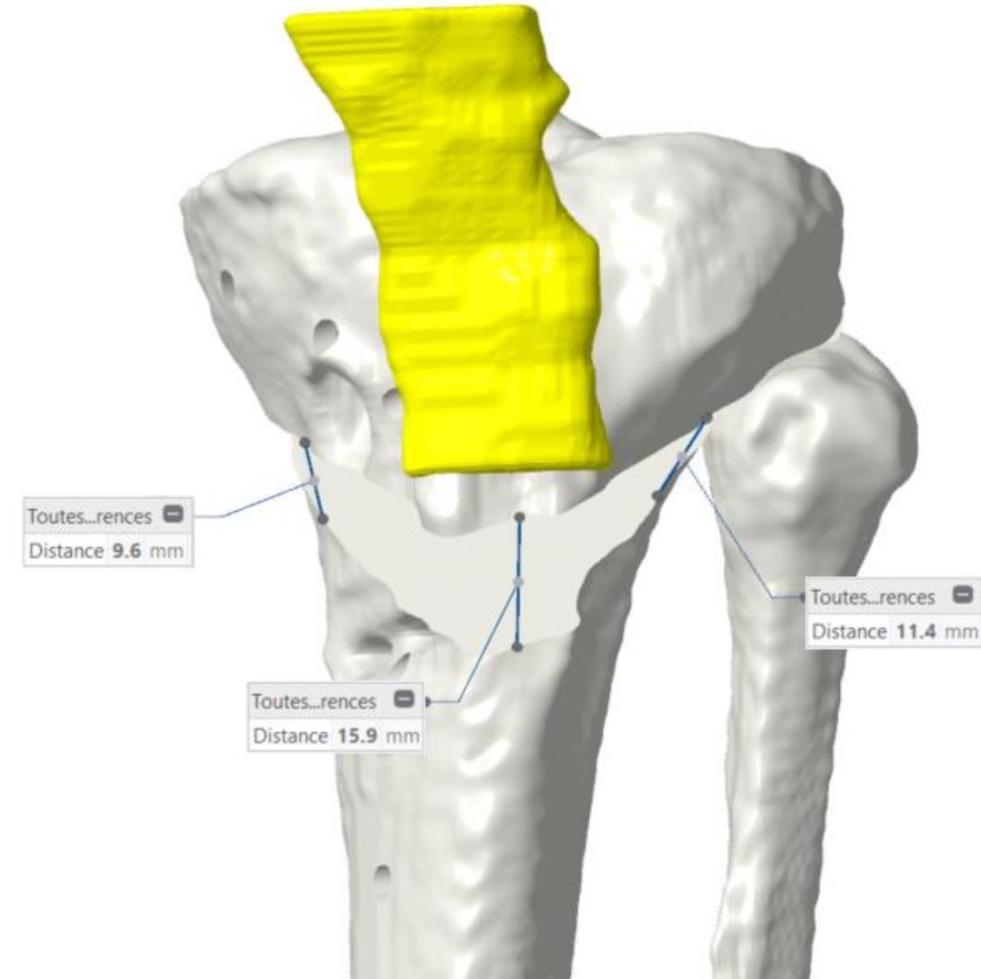
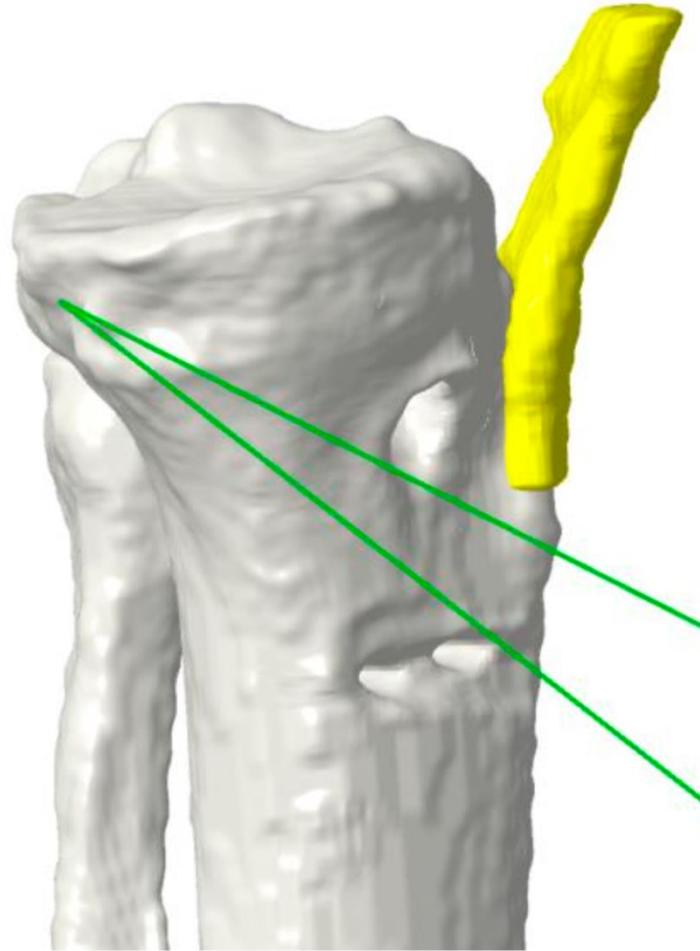
Surgical Planning

- Posterior tibial slope measurements
 - 17 degrees on full length radiograph
 - 15 degrees on CT
- Tibial bone tunnel
 - 16mm and 17mm diameters measurements on sagittal and axial slices
- Surgical Plan
 - 2-Stage procedure
 - Bone grafting, HW removal, slope osteotomy
 - Revision ACL with quad tendon & LET

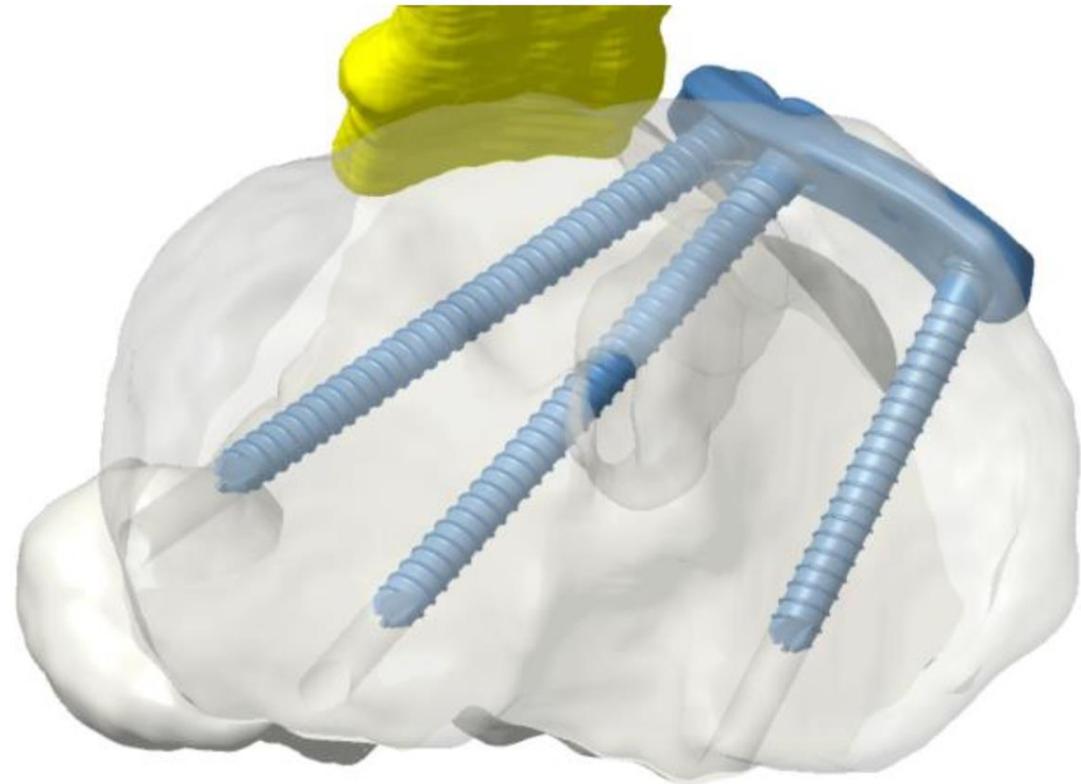
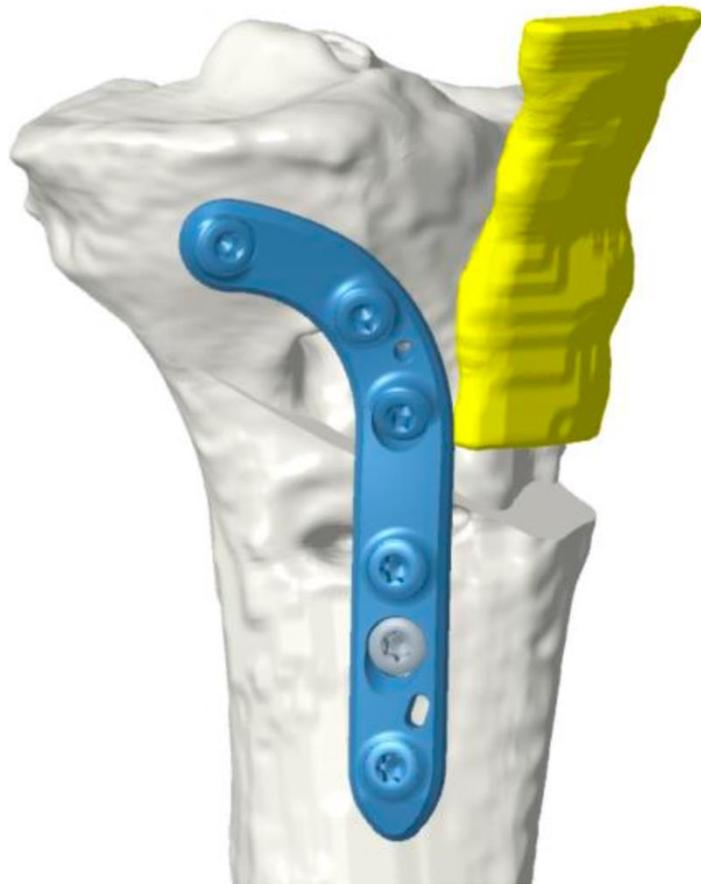


Surgical Planning

- Planned for an infratubercle approach
- 16mm bone wedge planned for removal
- Anteromedial locking plate that would allow room for ACL tibial tunnel if needed

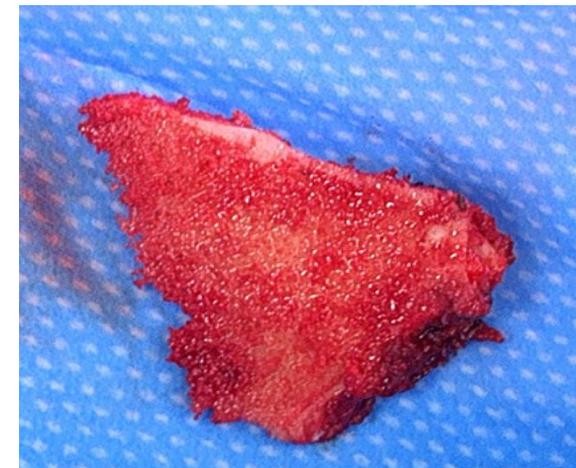
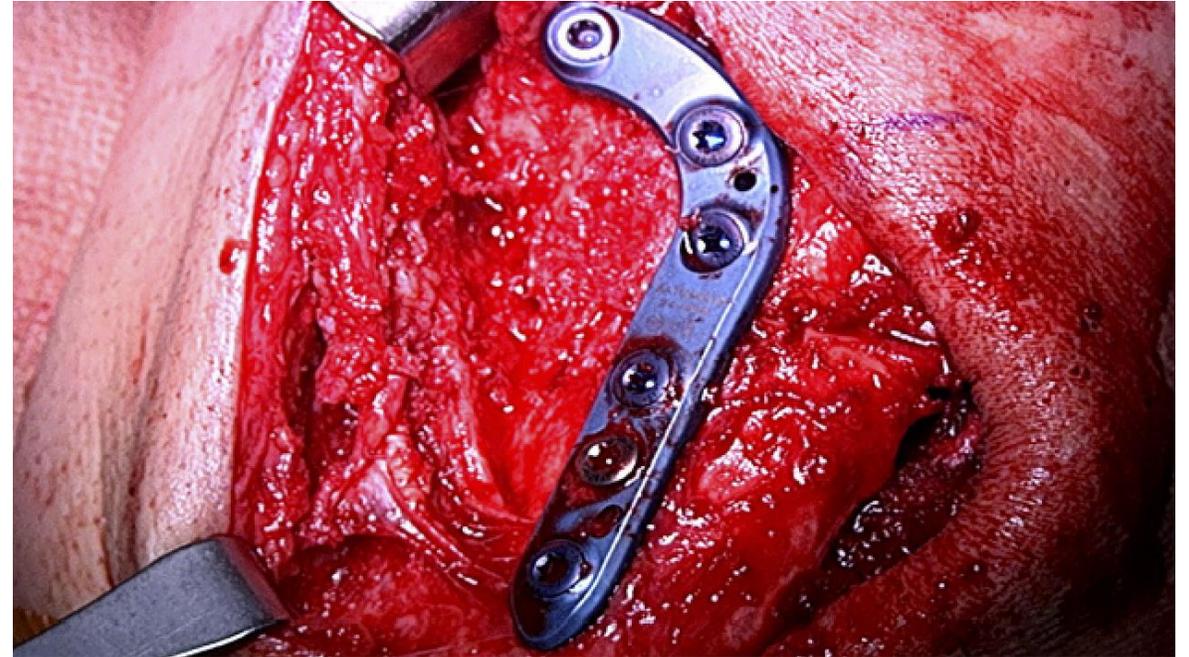
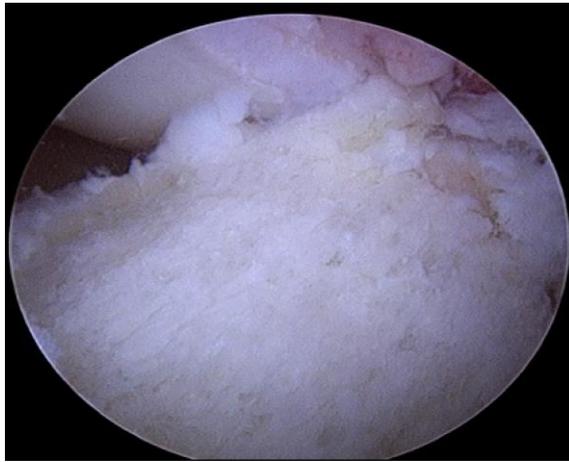


Surgical Planning



Case Study: Multiple ACL Revisions with Elevated PTS

Intraoperative Pictures (Stage 1)



Postoperative Results (Stage 1)

- Posterior Tibial Slope
 - Preop: 17 degrees
 - Postop: 4 degrees



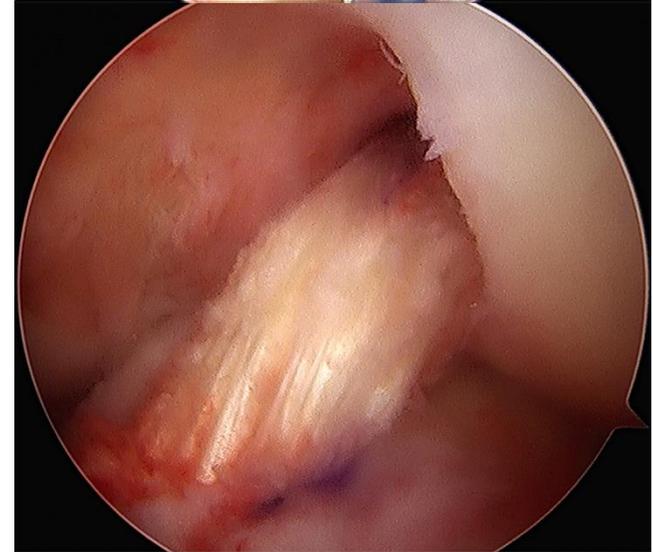
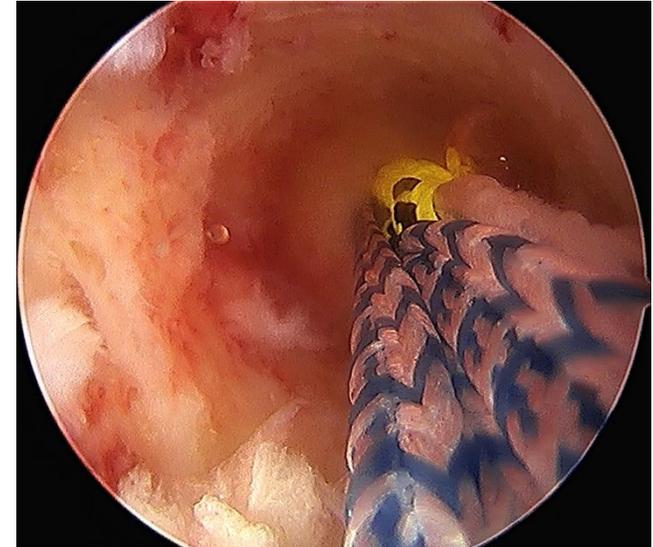
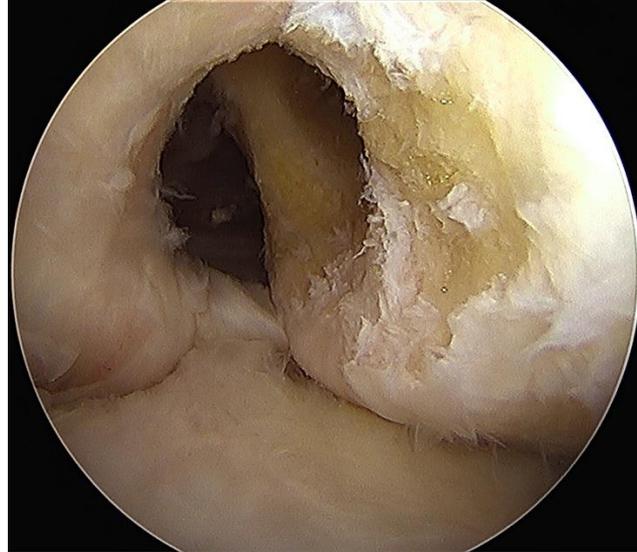
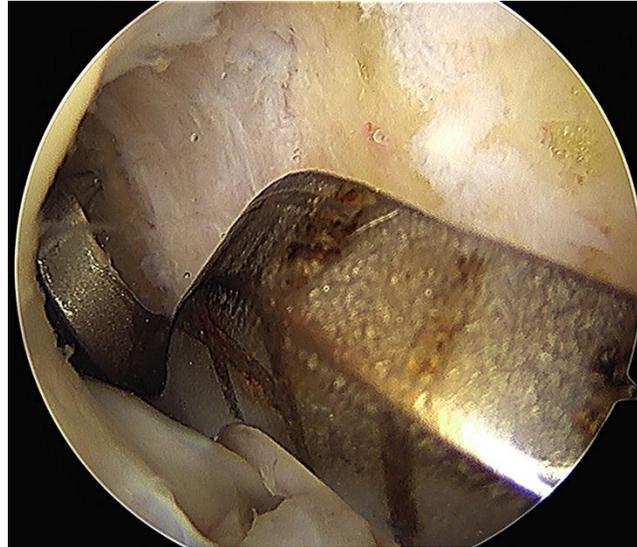
4 months s/p Stage 1

- Instability symptoms have improved
- Main complaint is tenderness directly over the plate
- CT scan and radiographs demonstrated healed osteotomy and tunnels
- Planned for Stage 2 revision with HWR, Quad ACL, and LET



Case Study: Multiple ACL Revisions with Elevated PTS

Intraoperative Pictures (Stage 2 – 8 months s/p Stage 1)



Intraoperative Pictures (Stage 2)



Multiple ACL Revisions with Elevated PTS

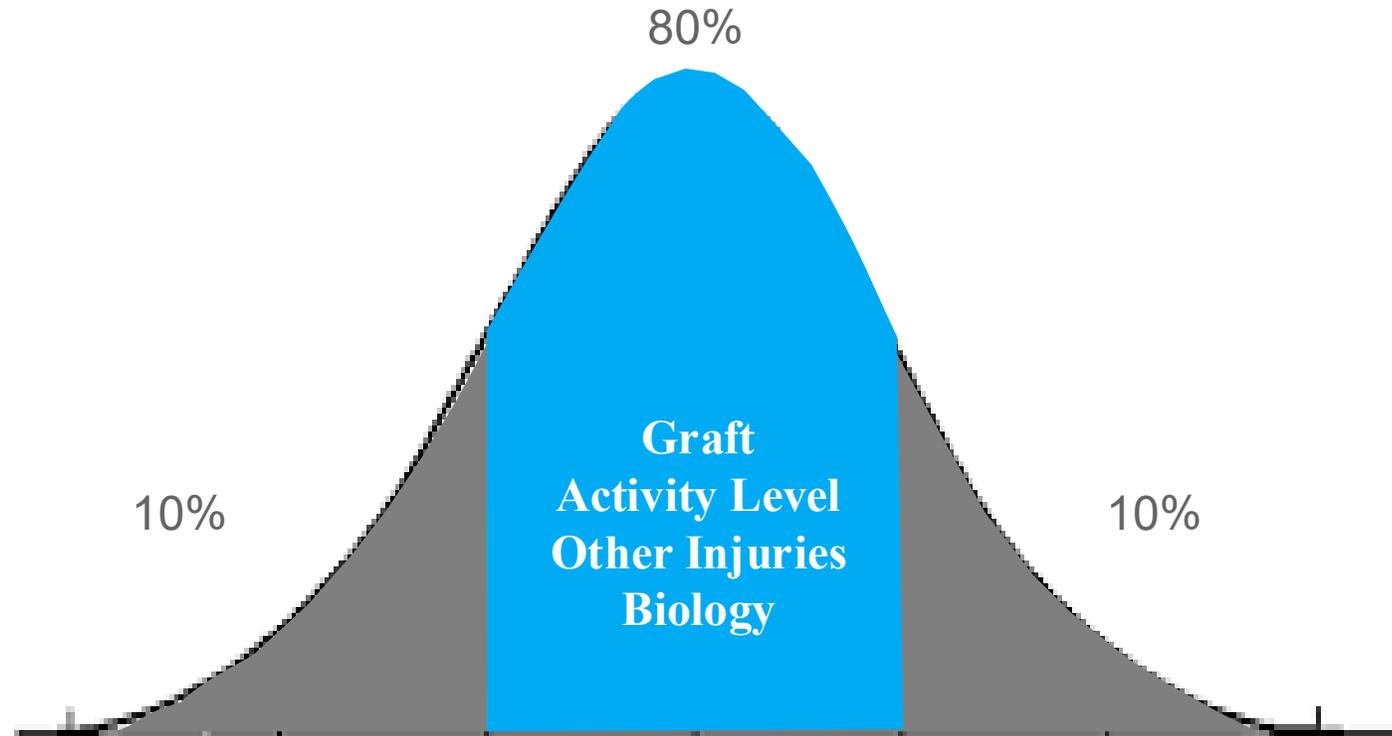
- Outcome



Summary

Continuum of Rotatory Instability Associated with ACL Injury

Individualized, Anatomic Treatment Plan



Treat 100% of Patients!



Professor Freddie H. Fu: admit that you make mistakes—learning never stops!

- *“There is no one-size-fits-all approach.”*
- *“Relentlessly conduct research, keep learning and making progress.”*
- *“That’s a problem if you think you know everything. Learning never stops. Learning is forever.”*



Dr. Freddie Fu (1950-2021)

Thank You



Thank You
