

# Current Concepts in the Operative Treatment of ACL Injuries

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## Disclosures

- I have nothing to disclose relevant to this presentation

## Outline

- Introduction
- Associated Injuries
  - Meniscus
- Graft Choices
  - Allograft
  - Quadriceps tendon
- Orthobiologics and ACL
- Return to Play Criteria

## Introduction

- Approximately 200,000/year
- Risk factors:
  - Cutting sports
  - Downhill skiing
  - Females: 2-4 x increased risk
  - Familial predisposition
  - ? (hormones, laxity, neuromuscular, tibial slope, notch width, limb alignment)

## Rule of 70

- 70% ACL tears *non-contact*
- 70% ACL tears *sports related*
- 70% *acute hemarthroses* are ACL tears
- 70% ACL tears feel *"pop"*

## Mechanisms of Injury

- Non-contact (majority)
  - Quad contraction with decreased relative hamstring strength
  - Knee valgus with internal tibial rotation
- Contact (25%)
  - Direct blow to knee or leg
  - Concurrent injuries frequent

### Associated Injuries

- Meniscus\*
  - 40% ACL injuries
  - Acute: Lateral > Medial
  - Chronic: Medial > Lateral
- Ligament tears
  - MCL
  - Posterolateral corner
- Articular cartilage

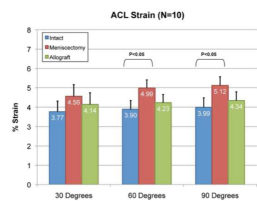
### Medial Meniscus

- Less mobility than lateral meniscus
- PHMM = most important secondary restraint to anterior tibial translation
  - Forces in the medial meniscus are doubled in the ACL deficient knee ACL graft force increases 33-50% with meniscectomy of the posterior horn
- Meniscal Root Avulsion
  - Loss of hoop stresses
  - Meniscal extrusion
  - Increased peak contact pressure
  - Decreased contact area
- Posteromedial meniscocapsular junction separation ("Ramp lesions")
  - Often overlooked
  - Results in increased ACL strain
- Meniscal Healing
  - 90% (62-96%) in conjunction with ACL reconstruction
  - 70% (50-75%) if isolated repair
  - 40% (17-62%) in setting of ACL deficiency

Arthroscopy, 2010 Feb;26(2):192-201. doi: 10.1016/j.arthro.2009.11.008.  
**The effect of medial meniscectomy and meniscal allograft transplantation on knee and anterior cruciate ligament biomechanics.**

Spaang JT<sup>1</sup>, Daria AB, Mazzocca A, Rincon L, Obopilwe E, Beynon B, Arclero RA.

- Cadaveric study
- Significantly increased tibial displacement after medial meniscectomy
- ACL strain significantly increased after meniscectomy at 60 degrees and 90 degrees of flexion
- Meniscal allograft transplant returned ACL strain values to near normal



Am J Sports Med. 2016 Feb;44(2):357-362. doi: 10.1177/0363546515737054. Epub 2017 Oct 24.  
**Medial Meniscus Resection Increases and Medial Meniscus Repair Preserves Anterior Knee Laxity: A Cohort Study of 4497 Patients With Primary Anterior Cruciate Ligament Reconstruction.**

Cristiani B<sup>1,2</sup>, Rönnblad E<sup>1,3</sup>, Engström B<sup>1,3</sup>, Forsblad M<sup>3</sup>, Ståhlman A<sup>1,3</sup>.

- Cohort study, 4497 patients

Isolated ACLR (n = 2837)  
 ACLR + MM resection (n = 559)  
 ACLR + LM resection (n = 593)  
 ACLR + MM + LM resection (n = 148)  
 ACLR + MM suture (n = 207)  
 ACLR + LM suture (n = 153)

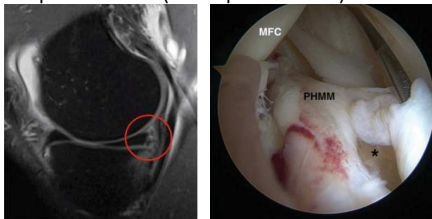
- Significantly increased post-op knee laxity in ACLR + MM resection or MM + LM resection groups
- Isolated ACLR had similar laxity to ACLR + MM repair group
- Significantly more surgical failures in ACLR + MM resection & ACLR + MM + LM resection groups

Knee Surg Relat Res. 2017 Mar 1;29(1):39-44. doi: 10.5792/korr.16.072.  
**Outcome of ACL Reconstruction for Chronic ACL Injury in Knees without the Posterior Horn of the Medial Meniscus: Comparison with ACL Reconstructed Knees with An Intact Medial Meniscus.**

Syam K<sup>1</sup>, Chouhan DK<sup>1</sup>, Dillon MS<sup>1</sup>.

- 77 ACLR patients
- 41 patients with intact menisci
- 36 patients with partial posterior horn medial meniscectomy
- Meniscectomy
  - Higher objective instability
  - Increased incidence of osteoarthritis

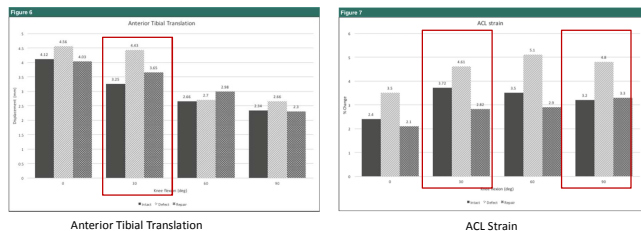
### Posteromedial Meniscocapsular Junction Separations (Ramp Lesions)



- 15.4-16.8 % may be missed
- 13.1% incidence in association with ACL tear

Journal of AAOS  
 Edgar, Cory, Kumar, Neil, Ware, James K.; More  
 JAAOS - Journal of the American Academy of Orthopaedic Surgeons. 27(4):e184-e192, February 15, 2019.

## Posteromedial Meniscocapsular Junction Separations (Ramp lesions)



## Meniscal Root Tears

- Avulsion injury of the meniscus attachment or a radial tear within 1cm of the insertion
- Disruption of meniscal circumferential fibers
- Loss of hoop stress generation
- Biomechanical effects approaching total meniscectomy

Orthop J Sports Med. 2017 Jun 15;56(6):2325967117695756. doi: 10.1177/2325967117695756. eCollection 2017 Jun.

### Lateral Meniscus Posterior Root and Menisocofemoral Ligaments as Stabilizing Structures in the ACL-Deficient Knee: A Biomechanical Study.

Frank JM<sup>1,2</sup>, Moatshe G<sup>1,2,4</sup>, Brady AW<sup>1</sup>, Doman GJ<sup>1</sup>, Coggins A<sup>1</sup>, Muckenhim KJ<sup>1</sup>, Slette EL<sup>1</sup>, Mikula JD<sup>1</sup>, LaPrade RC<sup>1,2</sup>.

- Cadaveric study
- Lateral meniscus posterior root = significant stabilizer of knee for anterior tibial translation during a simulated pivot-shift test at lower flexion angles and internal rotation at higher flexion angles
- Failure to address LM root tears at time of ACLR potentially increases load on graft and may increase failure



## Take Home Point

- Biomechanical and clinical studies support preservation of the medial and lateral meniscus
  - Arthritis
  - ACL strain
  - Laxity
- Increased awareness of ramp lesions and meniscal root lesions important to optimize ACL healing environment
- SAVE the Meniscus!

## Graft Choice

- **Ideal Graft Choice**
  - Structural properties similar to native ACL
  - Minimal donor site morbidity
  - Low cost
  - Enables stable initial fixation
  - Permit rapid biologic incorporation
- **Common Graft Choices**
  - Hamstring
  - Bone patellar tendon
  - Quadriceps
  - Allograft

## Autograft Choices

- **Patellar tendon**
  - Pros: Ease of harvest, rigid fixation, bone-to-bone healing, favorable clinical outcomes
  - Cons: Donor site morbidity (kneeling pain, anterior knee pain), patella fracture
- **Hamstring tendons**
  - Pros: excellent stiffness & tensile load properties, reduced harvest morbidity,
  - Cons: higher degree of reported laxity and lower return to preinjury activity levels, terminal hamstring weakness
- **Quadriceps tendon**
  - Pros: Less donor site morbidity, favorable clinical outcomes
  - Cons: Least studied

## Allografts

- Advantages
  - No harvest morbidity
  - Shorter OR time
  - Faster early recovery
  - Repeat availability
- Disadvantages:
  - Risk of disease transmission (HIV/Hepatitis – 1/1.6 million)
  - 3 mrad needed to kill HIV, but weakens graft
  - Higher re-tear rate in young active patients
  - Longer time to bio-incorporate
  - More expensive
  - Low grade immune response

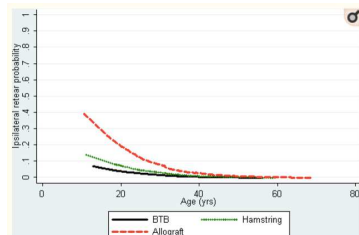
## Single vs. Double Bundle

- Basic science studies:
  - Increased rotational control
  - More closely replicates normal knee kinetics
- Clinical studies
  - *May* have better pivot shift results
  - *No difference* in patient reported outcomes

## Allograft vs. Autograft

- MOON Cohort
- Allograft ACLR
  - 6.9% retear rate
  - 5.2x greater odds of graft retear vs. autograft
  - Most clinically relevant in younger, active patients
  - No clinically significant difference by the mid-30's

Am J Sports Med. 2015 Jul;43(7):1583-90. doi: 10.1177/0363546515579836. Epub 2015 Apr 21.  
**Risk Factors and Predictors of Subsequent ACL Injury in Either Knee After ACL Reconstruction: Prospective Analysis of 2488 Primary ACL Reconstructions From the MOON Cohort.**  
 Kaeding CC<sup>1</sup>, Pedrosa AD<sup>2</sup>, Reinke EK<sup>3</sup>, Huston LJ<sup>3</sup>, MOON Consortium, Spindler KP<sup>4</sup>.



## Quadriceps Tendon

- Gaining popularity
- Least studied, least used autograft –
- 1% orthopaedic surgeons
- Pros:
  - Predictable graft size
  - Less donor-site morbidity than BTB autograft
  - Biomechanics: superior to BTB autograft in terms of load to failure, strain at failure, and Young's modulus of elasticity
  - Greater cross sectional area
  - Mean percentage volume of residual QT greater than after patellar tendon graft harvest
  - Versatility in skeletally immature



Arthroscopy. 2015 Mar;31(3):541-54. doi: 10.1016/j.arthro.2014.11.010. Epub 2014 Dec 25.

**Quadriceps tendon autograft for anterior cruciate ligament reconstruction: a comprehensive review of current literature and systematic review of clinical results.**

Slone HS<sup>1</sup>, Romine SE<sup>2</sup>, Premkumar A<sup>2</sup>, Xerogeanes JV<sup>3</sup>.

- Systematic literature review
- Less donor site morbidity vs. BTB autograft
- Similar outcomes to BTB autograft:
  - Stability (Lachman, pivot shift, instrumented laxity testing)
  - Functional outcomes (IKDC, Lysholm scores)
  - Overall patient satisfaction
  - ROM
  - Complications

## Take Home Point

- ❖ Autograft superior to Allograft in young, active patient population
- ❖ Bone patellar tendon bone autograft still considered the gold standard by most surgeons for young athletes
- ❖ Single bundle favored over double bundle ACLR
- ❖ Quadriceps tendon grafts are gaining popularity and have shown favorable clinical results

## Orthobiologics and ACL Surgery

- Potential benefits:
  - Enhancement of graft incorporation & strength, gene activation, trophic induction, and microenvironment facilitation and signaling with cells or bioactive factors to optimize, delay, or prevent premature progression of osteoarthritis
  - Potential positive growth factors: TGF-B1, FGF-2, Insulinlike GF, epidermal GF, PDGF, VEGF
    - Positive effects on cell proliferation, cell migration, angiogenesis, and extracellular matrix in vivo and in vitro models
  - Fibroblast = primary cell in the ACL
    - Receptors for PDGF, TGF-B, FGF
- Products
  - Platelet-rich plasma
  - Stem Cells
  - Bone marrow aspirate concentrate (BMAC)
  - Hyaluronic acid

## Orthobiologics

- Platelet-rich plasma (PRP)
- Hyaluronic acid
- Bone marrow aspirate concentrate (BMAC)
- Stem Cells

### Partial anterior cruciate ligament tears treated with intraligamentary plasma rich in growth factors

*World J Orthop* 2014 July 18; 5(3): 373-378

Roberto Seijas, Oscar Ares, Xavier Cuscó, Pedro Álvarez, Gilbert Steinbacher, Ramón Cugat

- 19 professional soccer players with partial ACL tears
- PDGF injected into remaining intact bundle
- 18/19 able to return to prior level of play at mean 16.2 weeks
- 81.75% (16/19) returned to pre-injury level of sport activity
- KT-1000 values normalized in all cases

### Comparison of Magnetic Resonance Imaging Findings in Anterior Cruciate Ligament Grafts With and Without Autologous Platelet-Derived Growth Factors

Fernando Radice, M.D., Roberto Yáñez, M.D., Vicente Gutiérrez, M.D., Julio Rosales, M.D., Miguel Pinedo, M.D., and Sebastián Coda, M.D.

*Arthroscopy: The Journal of Arthroscopic and Related Surgery*, Vol 26, No 1 (January), 2010: pp 50-57

- Case-control study
- 50 ACL reconstructions
- Platelet-rich plasma gel vs. no gel
- MRI 3-9 months (Group A) 3-12 months (Group B)
- Graft homogeneity time 177 days (A) vs 369 days (B)
- PRPG group needed only 48% of the time group B required to achieve the same MRI image

### The effect of platelet-derived growth factors on knee stability after anterior cruciate ligament reconstruction: a prospective randomized clinical study\*

Matjaž Vogrin<sup>1,2</sup>, Mitja Rupreht<sup>1</sup>, Anton Crnjac<sup>1,3</sup>, Dejan Dinevski<sup>1</sup>, Zmago Krajnc<sup>1</sup>, Gregor Rečnik<sup>1</sup>

*Wien Klin Wochenschr* (2010) 122 (Suppl 2): 91-96

- Platelet-leukocyte gel
- RCT Hamstring autograft ACL
  - 25 with platelet-leukocyte gel
  - 25 without gel
- KT-2000: Gel group better AP knee stability at 6 months post-op

### Has Platelet-Rich Plasma Any Role in Anterior Cruciate Ligament Allograft Healing?

Juan Ramón Valentí Nin, M.D., Ph.D., Gonzalo Mora Gasque, M.D., Ph.D., Andrés Valentí Azcárate, M.D., Jesús Dámaso Aquerreta Beola, M.D., Ph.D., and Milagros Hernandez Gonzalez, M.D., Ph.D.

*Arthroscopy: The Journal of Arthroscopic and Related Surgery*, Vol 25, No 11 (November), 2009: pp 1206-1213

- Level 1, RCT
- 100 ACLR with BTB allograft
- Platelet-enriched gel (50), no gel (50)
- Results:
  - Inflammatory markers – no difference
  - MRI appearance – no difference
  - Clinical scores (VAS, IKDC, KT-100) – no difference

### Biological Augmentation of ACL Refixation in Partial Lesions in a Group of Athletes: Results at the 5-Year Follow-up

Alberto Gobbi, MD, Georgios Karnatzikos, MD, Sukesh R. Sankineani, MD, and Massimo Petreca, MD  
*Techniques in Orthopaedics* • Volume 28, Number 2, 2013

- 50 athletes with partial ACL tears treated with primary repair + bone marrow stimulation + PRP gel
- 5-year follow-up
- 78% returned to pre-injury sports activities
- Significant decrease in the side-to-side difference in anterior translation, post-op Tegner score, SANE scores
- 4 retears, 1 residual laxity
- Survival rate 90% at 5-year follow-up

### Ligamentization of Tendon Grafts Treated With an Endogenous Preparation Rich in Growth Factors: Gross Morphology and Histology

Mikel Sánchez, M.D., Eduardo Anitua, M.D., Juan Azofra, M.D., Roberto Prado, Ph.D., Francisco Muruzabal, Ph.D., and Isabel Andia, Ph.D.

*Arthroscopy: The Journal of Arthroscopic and Related Surgery*, Vol 26, No 4 (April), 2010; pp 470-480

- Level III, Case-control study
- 37 patients s/p either conventional (n=15) or PRGF ACLR with hamstring autograft
- Second-look arthroscopy
  - Arthroscopic appearance of graft: PRGF (57.1% excellent) vs . Conventional (33.3% excellent)
  - Newly formed connective tissue envelope around graft 77.3% vs 40% controls

### Orthobiologics & ACL Surgery

- Currently, the literature is inconsistent in providing definite conclusions on outcomes and usage of biologics for the treatment of musculoskeletal injuries; but laboratory, animal, and some clinical studies have provided promising results for the future direction of ortho- pedic treatment protocols and rehabilitation.

### ACL Repair

### Return to Play After ACLR

- Not as high as previous thought
- Risk of re-injury
  - Ipsilateral ACL graft
  - Contralateral ACL
  - Other knee structures
    - Meniscus
    - Knee
- Young patients at highest risk

*Br J Sports Med*. 2011 Jun;45(7):596-606. doi: 10.1136/bjsm.2010.076364. Epub 2011 Mar 11.

### Return to sport following anterior cruciate ligament reconstruction surgery: a systematic review and meta-analysis of the state of play.

Ardern CL<sup>1</sup>, Webster KE, Taylor NF, Feller JA.

- 48 studies, 5770 patients
- Results:
  - ~ 90% normal or nearly normal knee function (laxity, strength)
  - 85% normal or nearly normal IKDC
  - BUT ....
  - Only 63% returned to preinjury level of participation
  - Only 44% returned to competitive sport at final follow-up

Am J Sports Med. 2016 Jul;44(7):1861-76. doi: 10.1177/0363546515621554. Epub 2016 Jan 15.

### Risk of Secondary Injury in Younger Athletes After Anterior Cruciate Ligament Reconstruction: A Systematic Review and Meta-analysis.

Wiggins AJ<sup>1</sup>, Grandhi RK<sup>2</sup>, Schneider DK<sup>3</sup>, Stanfield D<sup>4</sup>, Webster KE<sup>5</sup>, Myer GD<sup>6</sup>.

- Total second ACL reinjury rate = 15%
- Ipsilateral reinjury rate = 7%
- Contralateral injury rate = 8%
- Secondary ACL injury rate (ipsilateral + contralateral)
  - < 25 y/o = 21%
  - Athletes who return to a sport = 20%
  - <25 y/o + return to a sport = 23%

### Return To Play

- Criteria for return to play after ACL reconstruction
  - NO CONSENSUS!
- 2017 Herodocus Society Meeting (~ 100 team physicians > 10 years experience)
  - ~ 50% - 5-6 months
  - Rest – 6-12 months (with 1/3 > 9 months)
- Literature – all over the place

Orthopedics. 2014 Feb;37(2):e103-8. doi: 10.3928/01477447-20140124-10.

### Return to sport after ACL reconstruction.

Harris JD, Abrams GD, Bach BR, Williams D, Heidloff D, Bush-Joseph CA, Verma NN, Forsythe B, Cole BJ.

- Meta-analysis of Level I/II studies
  - 24% studies failed to report when athletes were allowed RTP without restrictions
  - 90% studies failed to use *objective* criteria
  - 65% studies failed to use any criteria

### Traditional RTP Criteria

- Biomechanical
- Biological (healing)
- Functional (i.e. performance/neuromuscular)
- Other
  - Psychological (fear of re-injury)
  - Lifestyle (moving, school, work, etc)

### Biologic Healing of the ACL

- Graft in tunnels
  - BTB – 6 weeks
  - Hamstring – 6-12 weeks
  - Allografts – longer
- Ligamentization
  - Cellular necrosis
  - Repopulation
  - Maturation
- Most data on ACL biologic healing from animal models – may not be able to extrapolate to humans

### Return to play

- What does the evidence show?
  - Autografts heals better and faster than allograft
  - Healing times in humans definitely > 6 months (9-12 months preferred)
  - Younger athletes who RTP early to high risk sports – 25-35% higher rate of second ACL injury
- Need to develop improved, accurate, cost efficient ways to assess graft healing that will help clinician develop safe RTP timelines
  - PET scan
  - UTE MRI

## Traditional Return to Play Criteria

- Classic
  - Cybex testing
  - Hop testing
- Time
- “Clinical judgement”
- Formalized/comprehensive functional testing

## Time

- 6 months – most widely accepted
- But ..... Persistent Deficits
  - Impaired knee function & movement asymmetry persist at 12 & 24 months
  - Single limb balance deficits at one year
  - Hip ankle coordination deficits in reinjured athletes
  - Avg strength deficit 23% at 6 months, 14% at one year
  - Gait disturbance at 1 year

Kryitidis et al, *Br J Sports Med*, 2016, Aug;50(15):946-51.  
 Nawasreh et al, *AJSM*, 2017 Apr;45(5):1037-1048  
 Hatton et al, *Gait Posture*, 2017 Feb;52:22-25  
 Lepley et al, *J Orthop Sports Phys Ther*, 2015 Dec;45(12):1017-25 Lepley, Sports Health, 2015 May;7(3):231-8.  
 Hasegawa, *J Appl Biomech* 2015, Oct;31(5):330

Br J Sports Med. 2016 Jul;50(13):804-8. doi: 10.1136/bjsports-2016-096031. Epub 2016 May 9.

### Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study.

Grindem H<sup>1</sup>, Snyder-Mackler L<sup>2</sup>, Moksnes H<sup>3</sup>, Engebretsen L<sup>4</sup>, Risberg MA<sup>5</sup>.

- Reinjury rate significantly reduced by 51% for each month RTS delayed until 9 months post-op

J Bone Joint Surg Am. 2017 Jun 7;99(11):897-904. doi: 10.2106/JBJS.16.00758.

### Return to Sport After Pediatric Anterior Cruciate Ligament Reconstruction and Its Effect on Subsequent Anterior Cruciate Ligament Injury.

Dekker TJ<sup>1</sup>, Godin JA, Dale KM, Garrett WE, Taylor DC, Riboh JC.

- 32% reinjury rate (ipsilateral and contralateral)
- Each month delay return protective

## “Clinical Judgement”

Am J Sports Med. 2015 Jul;43(7):1648-56. doi: 10.1177/0363546515578249. Epub 2015 Apr 13.

### Functional Testing Differences in Anterior Cruciate Ligament Reconstruction Patients Released Versus Not Released to Return to Sport.

Mayer SW<sup>1</sup>, Queen RM<sup>2</sup>, Taylor D<sup>1</sup>, Moorman CT 3rd<sup>1</sup>, Toth AP<sup>1</sup>, Garrett WE Jr<sup>1</sup>, Butler RJ<sup>3</sup>.

- Insufficient
- Typical exam criteria insufficient to distinguish those with functional deficits

## Return to Play – Functional Criteria

- 2014 AAOS Guidelines
  - “Limited strength evidence does not support waiting a specific time from surgery/ injury, or achieving a specific functional goal prior to return to sports participation after ACL injury or reconstruction”
- Traditional Guidelines
  - Hamstring-to-quadriceps strength ratio of at least 85% baseline
  - 90% symmetry of uninvolved leg for time and distance for single-legged, crossover, and triple hops for distance and 6-m timed hop test