UCSF Benioff Children's Hospitals
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SPORTS MEDICINE CENTER
FOR YOUNG ATHLETES

Pediatric ACL Injuries: What's New?

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I have no conflicts of interest to disclose

UCSF Benioff Children's Hospitals Oakland | San Francisco

Introduction

". . .pediatric ligaments are stronger than bone."

- Leuder, R. Are children just little adults? 2003

". . .expected injury will take place at the tibial spine or physis."

- Salter, RB. Textbook of disorders and injuries of the musculoskeletal system. 1970

". . .because the growth plate is the weak link in the knee, traumatic complete midsubstance tears of the ACL are extremely rare."

- Rang, M. Children's fractures. 1974

Introduction

- ACL injuries and subsequent reconstruction are rapidly increasing in young athletes
- Due to sport specialization and intensive training as well as increased injury recognition
- A wide range of surgical techniques exist and have been reported on the literature

We are emphasizing skill development rather than fitness

Youth soccer injuries have skyrocketed

By Nadia Kounang, CNN
Updated 10:15 AM ET, Mon September 12, 2016

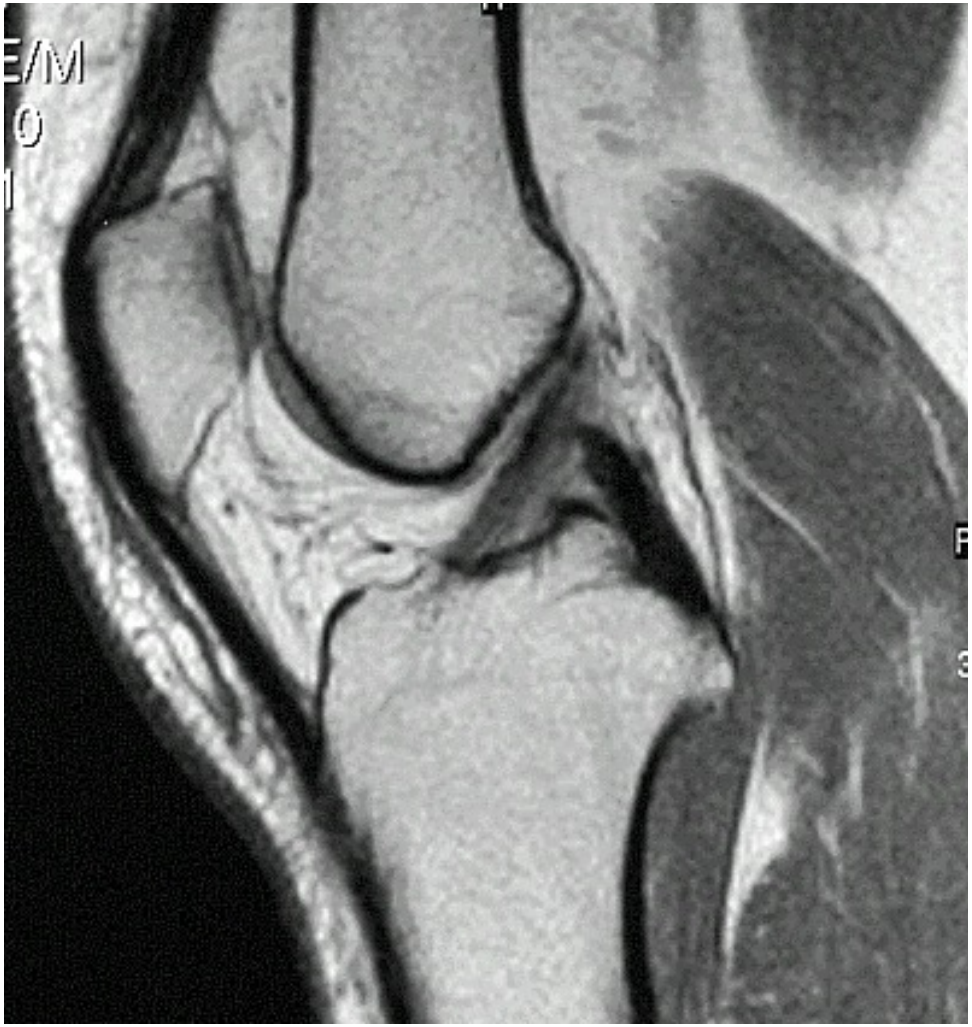
The JOURNAL of PEDIATRICS

111% increase in youth soccer injuries over last 14 years

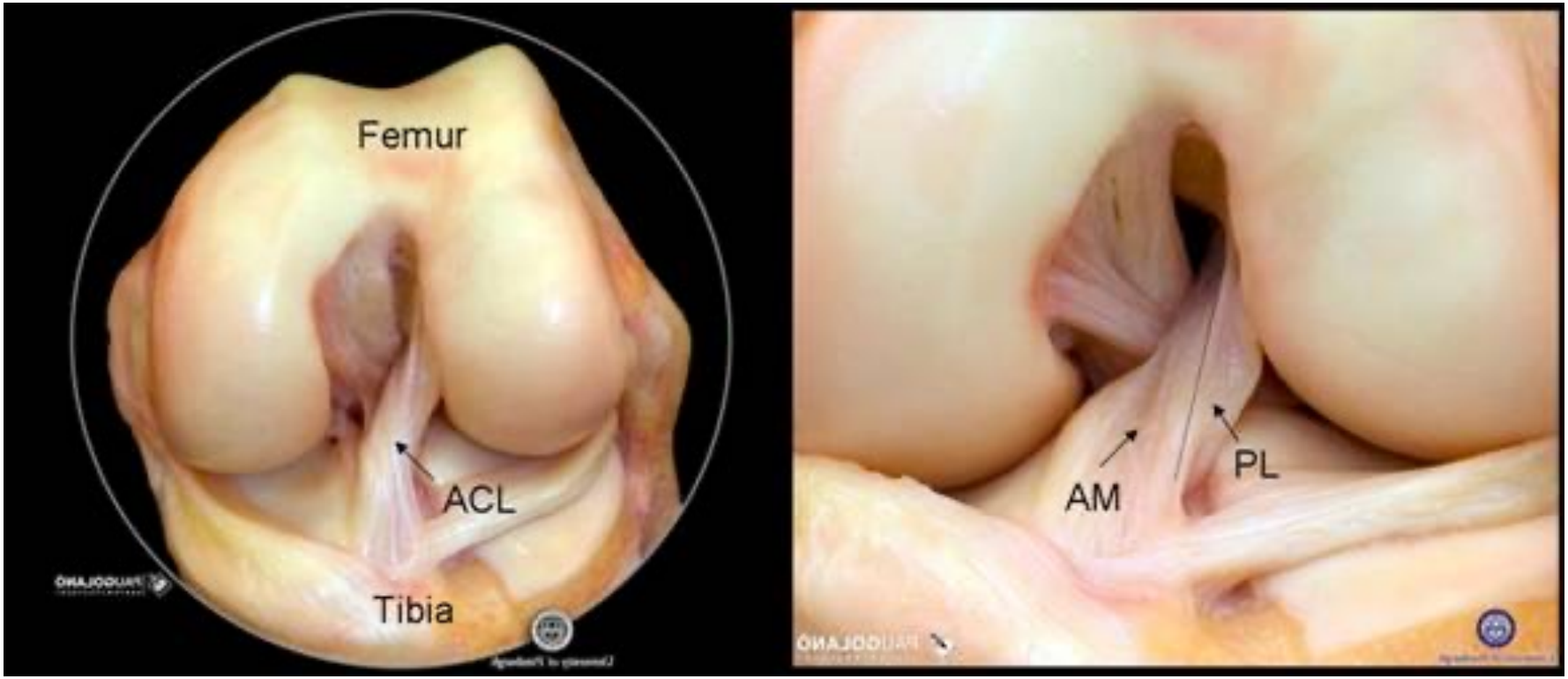
400 percent increase in youth ACL tears over the past decade!!!

ACL Function

- Resists anterior translation of the tibia at 30º of flexion
- Prevents hyperextension
- 2º restraint to IR of tibia
- Resists AD/AB at full ext



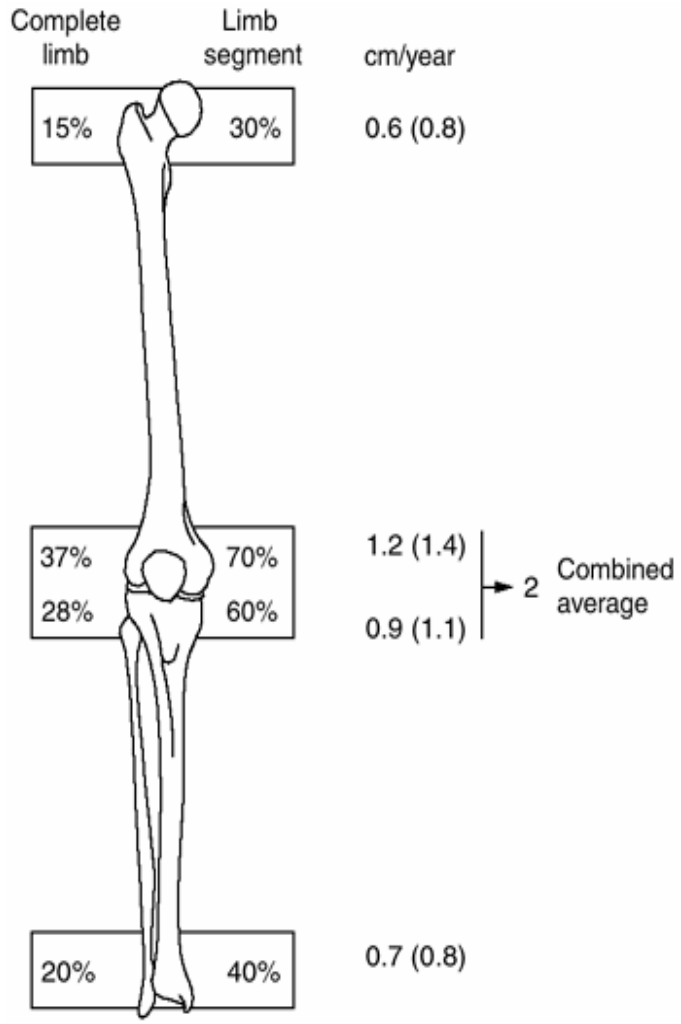
Anatomy



Anatomy - Physis

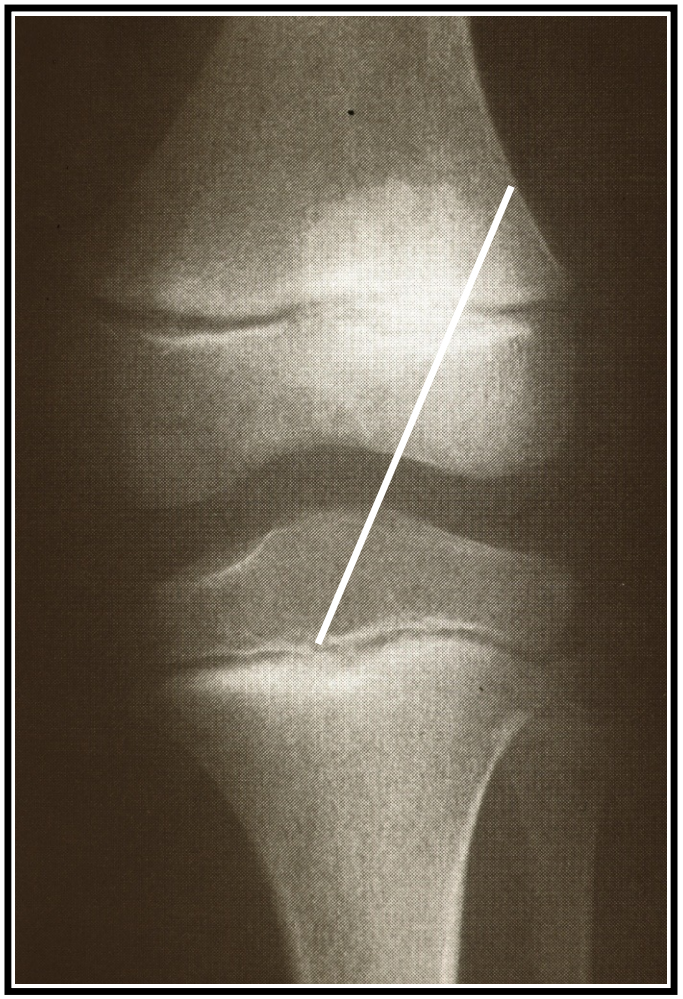
- Distal Femur & Proximal Tibia
- Greatest growth

- From birth to maturity, the knee grows about 42.5 cm in boys and 38.7 cm in girls



Diméglio, A. Lovell & Winter's 6 ed. ch2 p58-59

Anatomy

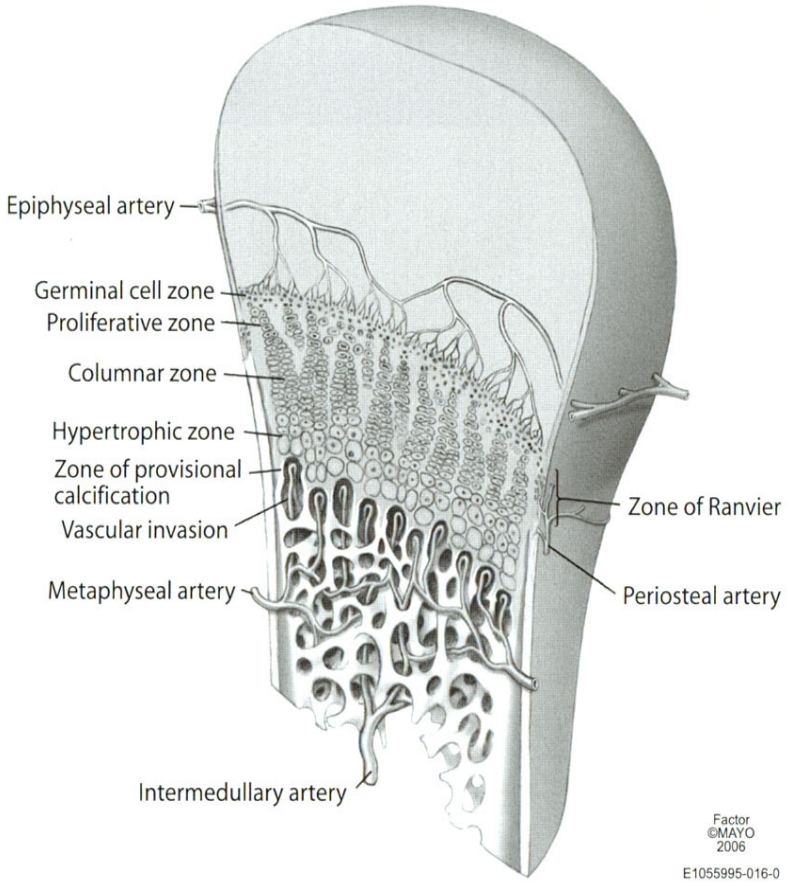


Violation of Physis = leg length discrepancy, angular deformity, recurvatum

Why are ACL tears in children different?

Some studies state a re-tear rate of at least 25% in patients under 14!!!

Why are ACL tears in children different?



vs.

Natural History: Non-Op

Am J Sports Med. 1994 Jul-Aug;22(4):478-84.

Patellar tendon graft reconstruction for midsubstance anterior cruciate ligament rupture in junior high school athletes. An algorithm for management.

McCarroll JR, Shelbourne KD, Porter DA, Rettig AC, Murray S.

Department of Research and Education, Methodist Sports Medicine Center, Indianapolis, Indiana 46202.

Arthroscopy: The Journal of Arthroscopic & Related Surgery
Volume 5, Issue 3, September 1989, Pages 197-200

doi:10.1016/0749-8063(89)90171-0 | How to Cite or Link Using DOI
Permissions & Reprints

Anterior cruciate ligament injury in children and adolescents

Kevin R. Angel , David J. Hall

Department of Orthopaedic Surgery, Adelaide Children's Hospital, North Adelaide, South Australia, Australia.

Arthroscopy. 1992;8(2):229-33.

Anterior cruciate ligament tears in skeletally immature patients: meniscal pathology at presentation and after attempted conservative treatment.

Graf BK, Lange RH, Fujisaki CK, Landry GL, Saluja RK.

Division of Orthopedic Surgery, University of Wisconsin Hospital and Clinics, Madison 53792.

Instability, Swelling, Pain, & Meniscal Injury

Natural History: Non-Op

Conservatively Treated Tears of the Anterior Cruciate Ligament

LONG-TERM RESULTS*

BY PEKKA KANNUS, M.D.†, AND MARKKU JÄRVINEN, M.D.‡, TAMPERE, FINLAND

From the University Central Hospital of Tampere, Tampere

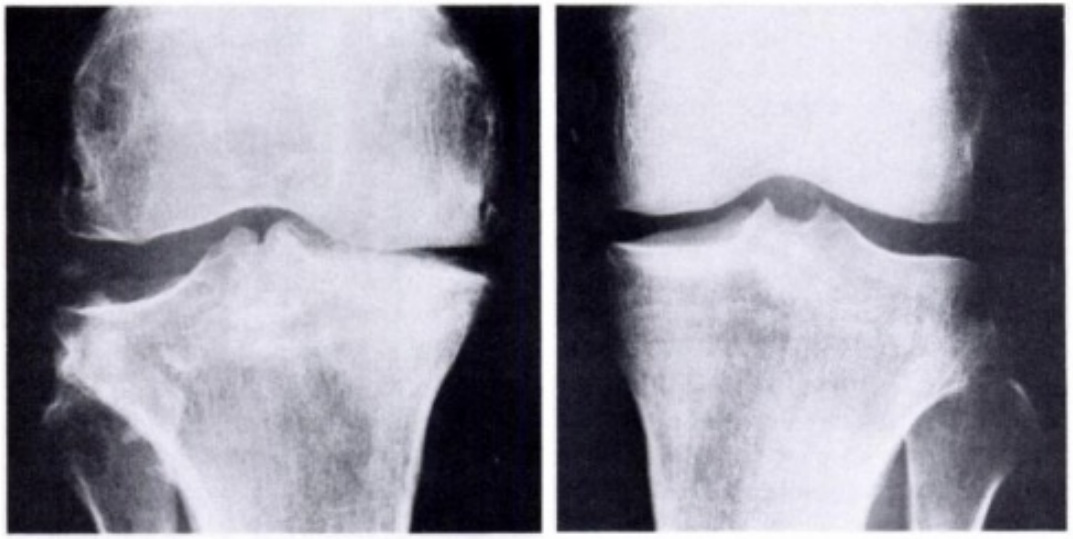


FIG. 1-A FIG. 1-B

Early Arthritis

What Is The Failure Rate?

ORIGINAL ARTICLE

Risk Factors for Early ACL Reconstruction Failure in Pediatric and Adolescent Patients: A Review of 561 Cases

Brian Ho, BA, Eric W. Edmonds, MD,*† Henry G. Chambers, MD,*† Tracey P. Bastrom, MA,† and Andrew T. Pennock, MD*†*

- 561 ACL Reconstructions
- Failure rate 9.6%
- Soft tissue grafts were twice as likely to fail compared with patellar tendon grafts (13% vs. 6%; P<0.001)

What Is The Failure Rate?

eC **A commentary by Charles L. Cox, MD, MPH,** is linked to the online version of this article at jbjs.org.

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

Travis J. Dekker, MD, Jonathan A. Godin, MD, MBA, Kevin M. Dale, MD, William E. Garrett, MD, PhD, Dean C. Taylor, MD, and Jonathan C. Riboh, MD

Investigation performed at the Department of Orthopaedic Surgery, Duke University Medical Center, Durham, North Carolina

- 112 ACL Reconstructions
- Failure rate 19%
- Contralateral tear 13%

What Is The Failure Rate?

ORIGINAL ARTICLE

Pediatric ACL Reconstruction and Return to the Operating Room: Revision is Less Than Half of the Story

Christopher J. DeFrancesco, BS,† Eileen P. Storey, BA,* John M. Flynn, MD,* and Theodore J. Ganley, MD**

- 419 ACL Reconstructions
- Failure rate 10.3%
- Half of re-tears occurred before clearance to return to full activities

What Is The Failure Rate?

Seventeen-Year Follow-up After Meniscal Repair With Concomitant Anterior Cruciate Ligament Reconstruction in a Pediatric and Adolescent Population

Adam J. Tagliero,* MD, Vishal S. Desai,* BS, Nicholas I. Kennedy,* MD, Christopher L. Camp,* MD, Michael J. Stuart,* MD, Bruce A. Levy,* MD, Diane L. Dahm,* MD, and Aaron J. Krych,*† MD
Investigation performed at Department of Orthopedic Surgery, Mayo Clinic, Rochester, Minnesota, USA

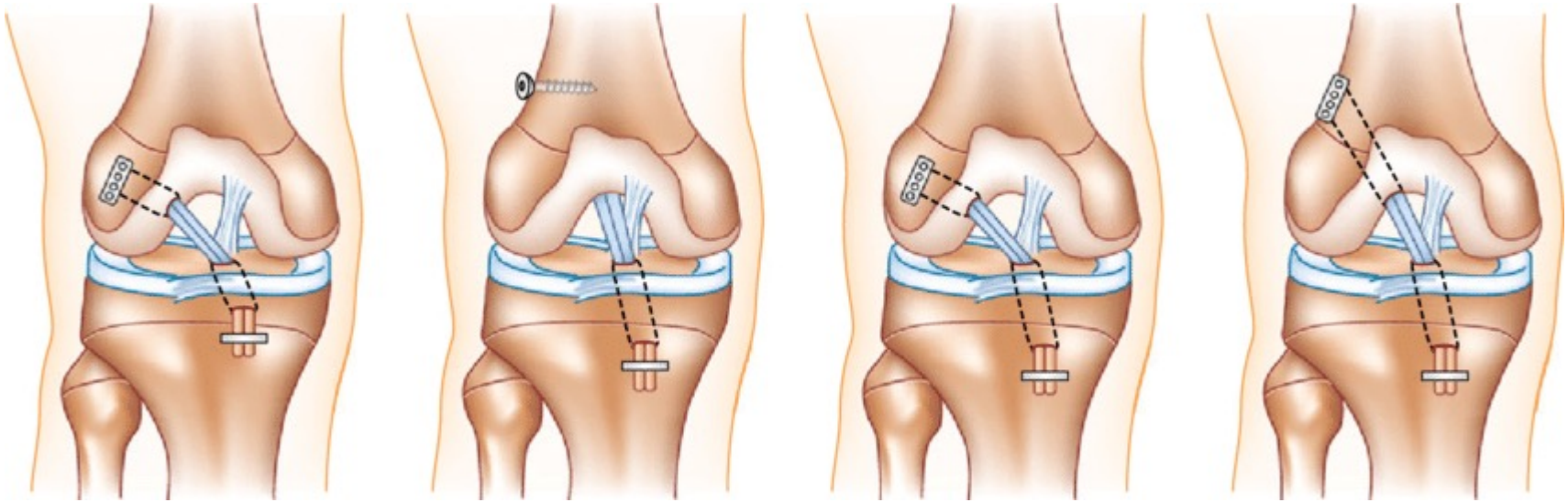
- 47 ACL Reconstructions
- 17 year follow-up
- Repeat surgery in 28%

What Group Is Most Susceptible?

Return to Sport and Reoperation Rates in Patients Under the Age of 20 After Primary Anterior Cruciate Ligament Reconstruction

Risk Profile Comparing 3 Patient Groups Predicated Upon Skeletal Age

Frank A. Cordasco,*† MD, MS, Sheena R. Black,‡ MD, Meghan Price,§ BS, Colleen Wixted,§ BS, Michael Heller,† ATC, PES, BES, Lori Ann Asaro,† PA-C, MS, Joseph Nguyen,‖ MPH, and Daniel W. Green,¶ MD, MS
Investigation performed at Hospital for Special Surgery, New York, New York, USA



What Group Is Most Susceptible?

Return to Sport and Reoperation Rates in Pati ents Under the Age of 20 After Primar ament Recon

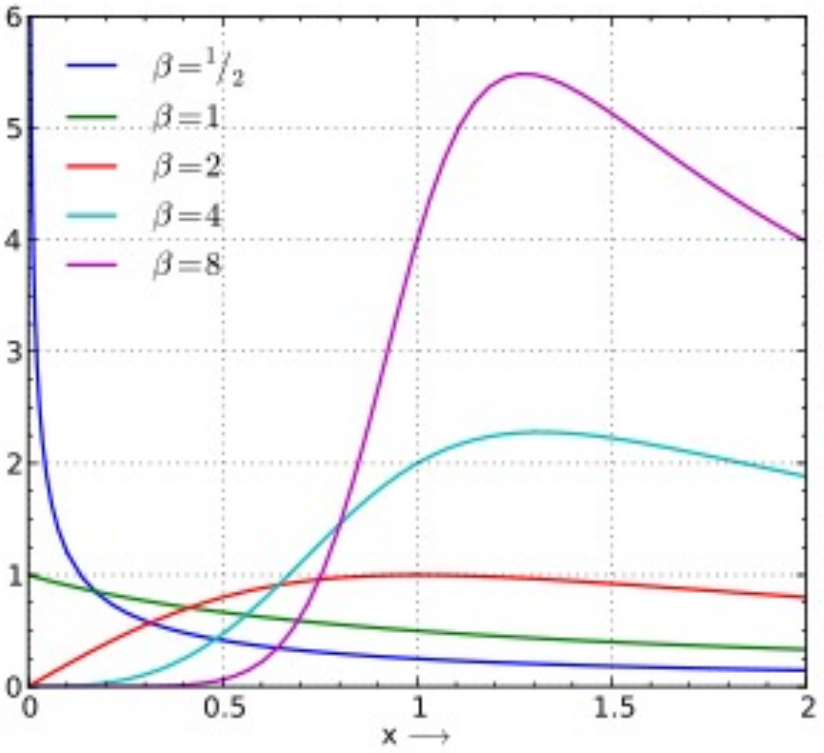
Risk Pro os Predicat

Frank A. Cor n Price,[§] BS,
Colleen Wixte n Asaro,[†] PA-C, MS,
Joseph Nguy
Investigation *ork, New York, USA*

Group 2 athletes (mean age 14) had a significantly higher revision ACLR rate (20%) compared with group 1 (6%; P = 0.039, mean age 12) and group 3 (6%; P = 0.001, mean age 16).

What Causes The Higher Failure Rate??

- Graft Choice?
- Sport After ACL Reconstruction?
- PT Compliance?
- Surgical Technique?
- Skeletal Development?



What Causes The Higher Failure Rate??

ORIGINAL ARTICLE

Complications After Pediatric ACL Reconstruction: A Meta-Analysis

Stephanie E. Wong, MD, Brian T. Feeley, MD, and Nirav K. Pandya, MD

Results: In total, 45 studies were included with 1321 patients and 1392 knees. The average age was 13.0 years, 67% were male, and mean follow-up was 49.6 months. There were 115 (8.7%) reruptures in the initial 160 studies reviewed. In total, 94.6% of patients with rerupture required revision ACL surgery. There were 58 total growth disturbances (16 required corrective surgery, or 27.6%). Eighteen knees (3.7%) developed angular deformity, most commonly valgus. There were 37 patients (7.5%) had at least a 1 cm limb-length discrepancy. A total of 23 studies reported International Knee Documentation Committee scores (range, 81 to 100, 88% grade A or B). In total, 20 studies reported excellent Lysholm scores with mean scores of 94.6.

Conclusions: Growth disturbance can occur with any of the reconstruction techniques. Proper surgical technique is likely more important than the specific reconstruction technique utilized. Patients with rerupture require surgery at much higher rates than those with growth disturbance. Although much attention has been focused on growth disturbance, we suggest that equal attention be given to the prevention of rerupture in this age group.

- 1392 ACL reconstructions
- 8.7% re-tear rate of which 94.6 % needed revision
- 4.1% growth disturbance rate of which 27.6 % needed correction
- Preventing re-tear is important!
  - Best treatment is to not re-tear!

Growth Disturbance Review

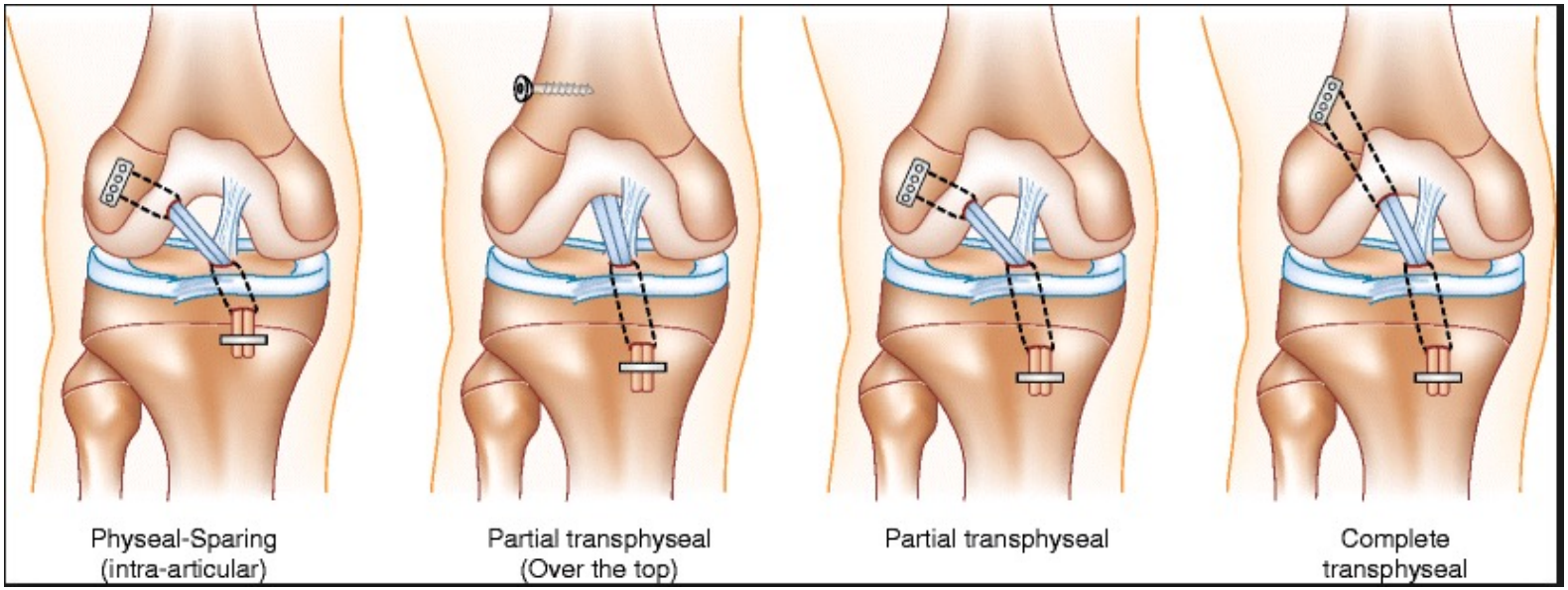
Author	Year	Growth Disturbance	Re-rupture
Higuchi et al.	2009	MRI narrowing in 8, frank closure in 2	0
Chotel et al.	2010	One with LLD 1.5cm, one with valgus deformity and 1cm LLD	0
Liddle et al.	2008	One with valgus deformity	1
McIntosh et al.	2006	One with LLD of 1.5cm	2
Koman et al.	1999	One with valgus deformity	0
Andrews et al.	1994	Two patients > 10 mm LLD	1
Lipscomb et al.	1986	One LLD 1.3cm, one LLD 2cm	2
Lemaitre et al.	2014	Two with valgus deformity	0
Kohl et al.	2014	One with valgus deformity	0
Kumar et al.	2013	One with valgus deformity	1
Lawrence et al.	2011	One with valgus deformity after revision ACL	1
Robert et al.	2010	One with valgus deformity	0
Zimmerman et al.	2015	One with LLD of 2.8cm	0
Rozbruch et al.	2013	One with varus, recurvatum, and LLD of 4.5 cm	0
Henry, et al.	2009	One with valgus deformity	0
Mauch et al.	2011	One with valgus-flexion deformity	0
Nathan et al.	2013	One with LLD of 2.7cm	0
Shifflett et al.	2016	Two with recurvatum, two with valgus deformity	0

Table 1. Individual Studies

- More likely to have valgus than LLD
- LLD is more likely overgrowth
- Recurvatum with tibial tubercle violation
- Patients with 2-4 years of growth remaining more likely to have disturbance than > 4 years
  - Physis 'older'
  - Less chance to correct

Surgical Dilemma

Balance the Risk of Growth Disturbance Versus Anatomic Reconstruction




Pediatric anterior cruciate ligament reconstruction

History

- Contact
- Non-contact
- Deceleration
- Internal rotation
- Hyper-extension
- Heard a "pop"
- Acute painful swollen knee

Acute Hemarthrosis

- Preadolescents (7-12)
  - ACL injuries 47%
  - Meniscal tears 47%
  - Osteochondral fractures 13%
- Adolescents (13-18)
  - ACL injuries 65%
  - Meniscal tears 45%
  - Osteochondral fractures 5%

Physical Exam Accuracy

- Using arthroscopy and MRI as reference standard:

- (+) Pivot shift test is best for ruling in an ACL rupture
  - *specificity 0.97-0.99*
- (-) Lachman test is best for ruling out an ACL rupture
  - *sensitivity 0.63-0.93*
- Anterior drawer was inconclusive for drawing strong conclusions

Ostrowski JA: J Athl Train. 2006 Jan-Mar;41(1):120-1

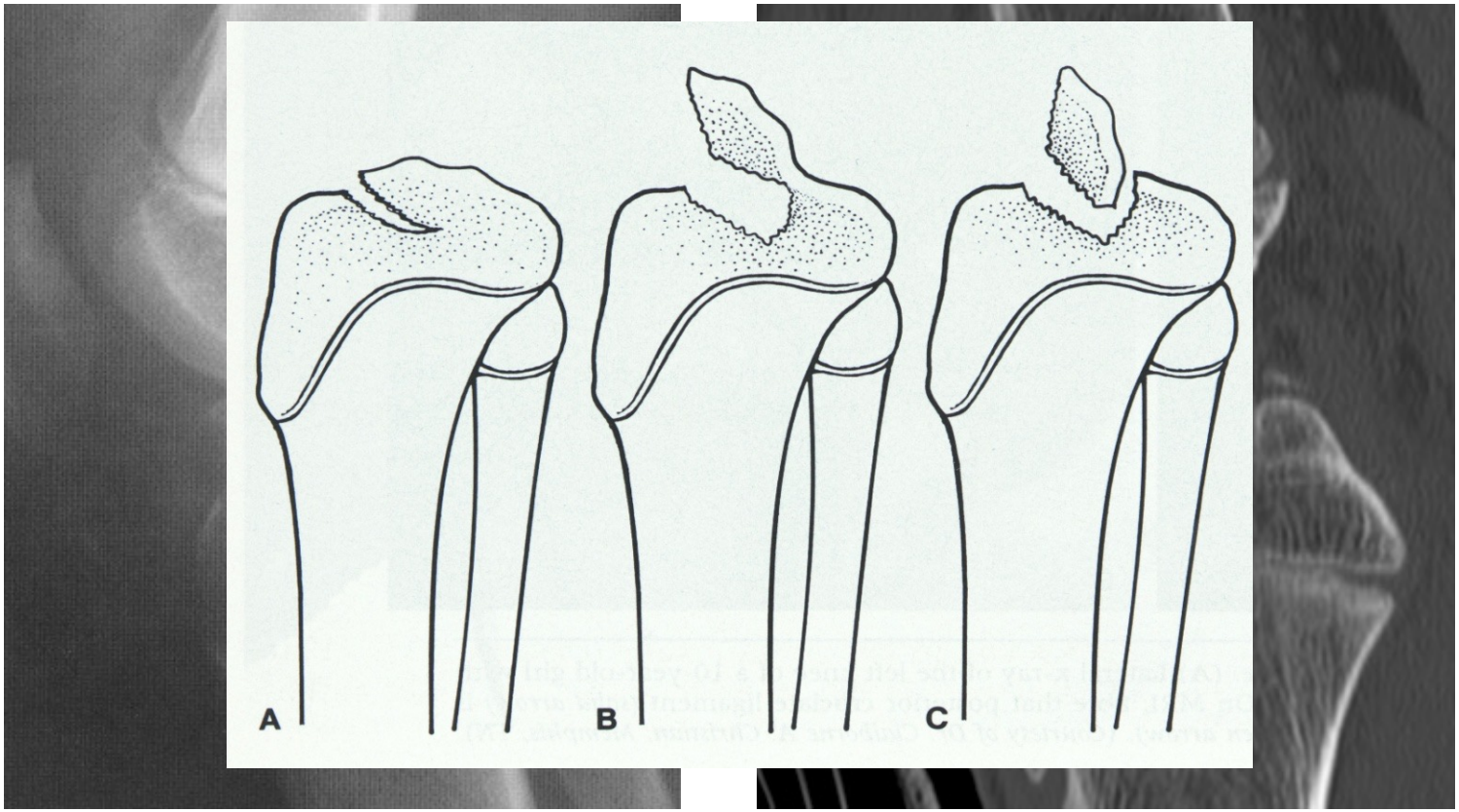
Assessment of Maturity

- Chronologic age >>> not reliable
- Physiologic age >>> look for markers of immaturity
- Physes - open
- Tanner Stages - 1 or 2
- Menarche - no
- Growth spurt - no
- Height patient - at least 10 cm less than parent
- Shoe size increase - no

Radiographic Evaluation

- Imaging:
  - X-ray (AP/Lat/Notch/Merchant)
    - r/o physeal fractures, epiphyseal injuries, tumors, tibial spine fx
  - MRI
    - Evaluates soft tissue injuries
    - Associated injuries
    - Meniscus!!!

Radiographic Evaluation



Tibial Spine Fracture

Radiographic Evaluation

Physeal Fracture

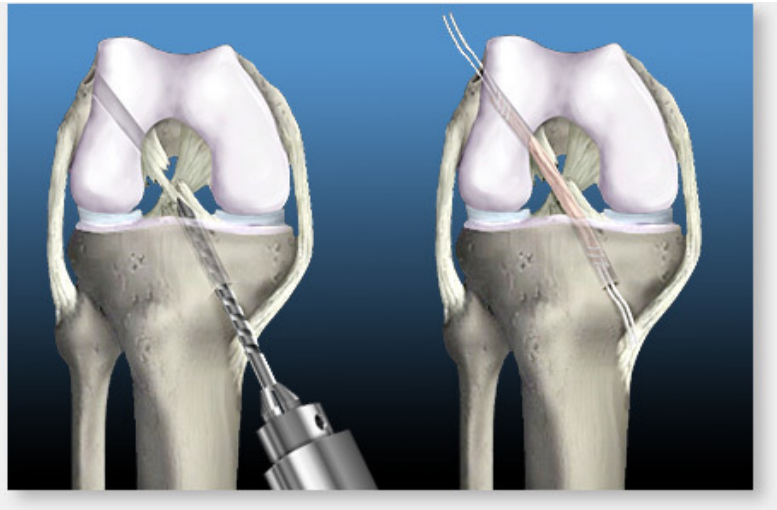
Assess Emotional Maturity

- Non-compliance with protocol
- Non-adherence to home exercises

Delay reconstruction until family or patient mature

Treatment Options for Intrasubstance ACL Injuries

- Extra-Articular reconstruction
- Physeal Sparing reconstruction
- Transphyseal reconstruction (partial vs complete)



Autograft vs. Allograft

[Orthopaedic Surgery]

Allograft Versus Autograft Anterior Cruciate Ligament Reconstruction: Predictors of Failure From a MOON Prospective Longitudinal Cohort

Christopher C. Kaeding, MD,*† Brian Aros, MD,‡ Angela Pedroza, MPH,† Eric Pifel, MD,§ Annunziato Amendola, MD,‖ Jack T. Andrish, MD,¶ Warren R. Dunn, MD, MPH,# Robert G. Marx, MD,** Eric C. McCarty, MD,†† Richard D. Parker, MD,¶ Rick W. Wright, MD,‡‡ and Kurt P. Spindler, MD#

Results: Patient age and ACL graft type were significant predictors of graft failure for all study surgeons. Patients in the age group of 10 to 19 years had the highest percentage of graft failures. The odds of graft rupture with an allograft reconstruction are 4 times higher than those of autograft reconstructions. For each 10-year decrease in age, the odds of graft rupture increase 2.3 times.

Graft Choice

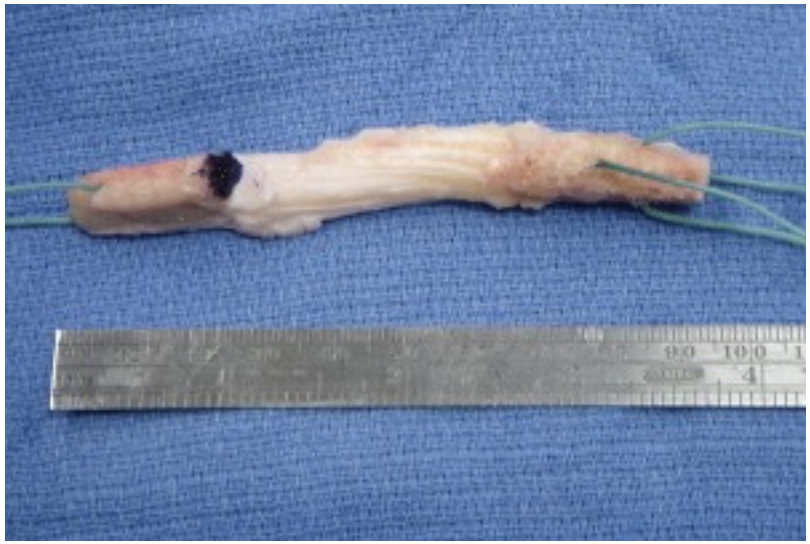
If skeletally immature:

- Hamstring
- Quad tendon

Graft Choice

If skeletally mature:

- Hamstring (contralateral)
- Quad tendon
- BTB

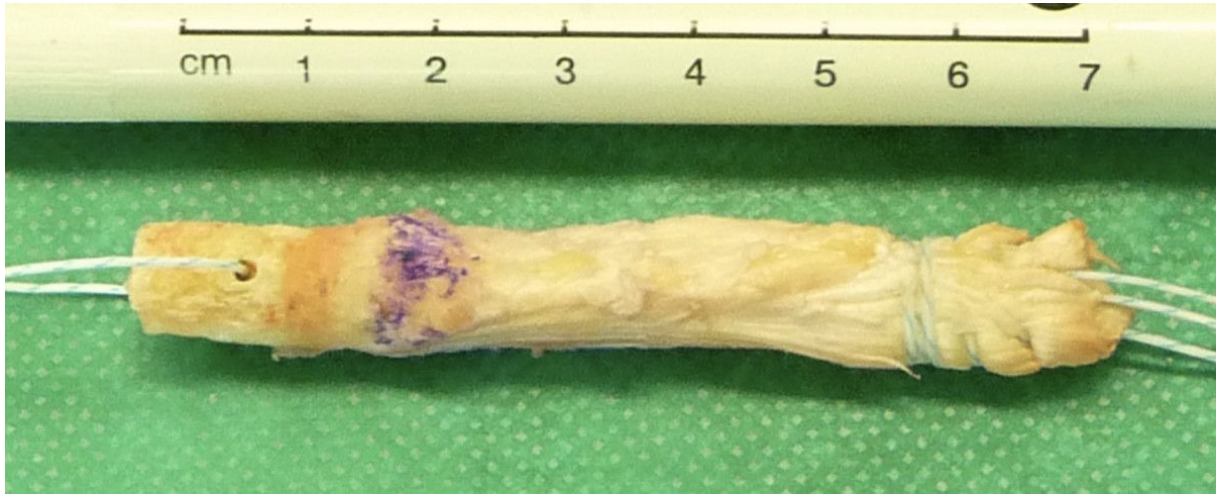


Graft Choice

Anterior Cruciate Ligament Reconstruction in Pediatric and Adolescent Patients Using Quadriceps Tendon Autograft

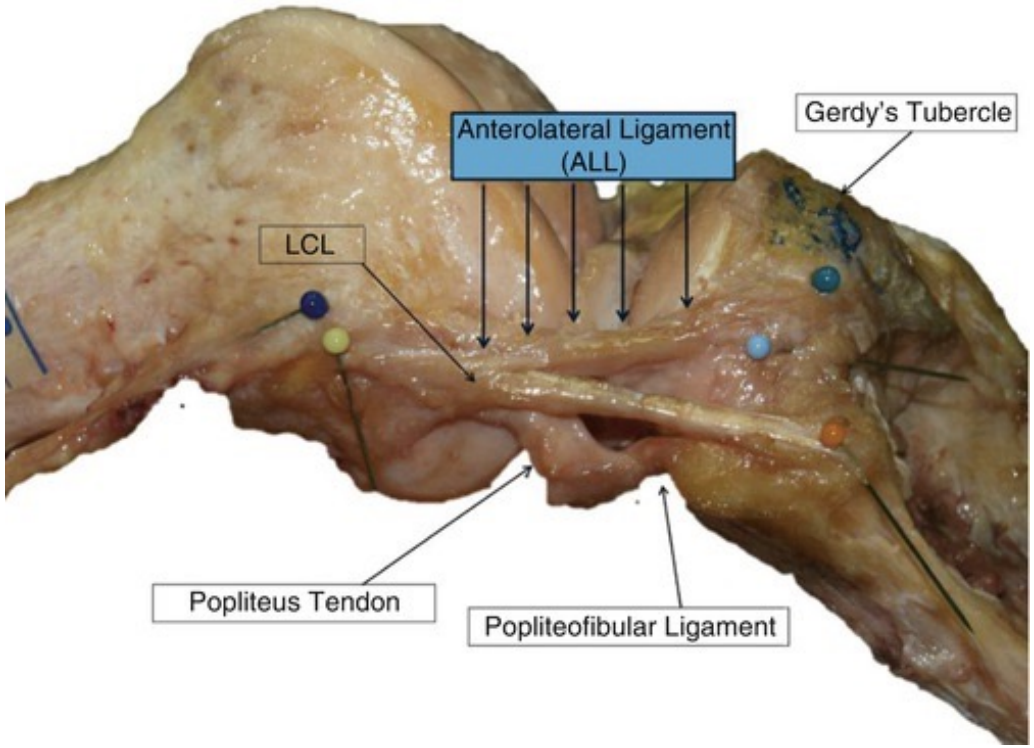
Albright, Jay MD; Lepon, Ariel Kiyomi BA; Mayer, Stephanie MD

Sports Medicine and Arthroscopy Review: December 2016 - Volume 24 - Issue 4 - p 159–169
doi: 10.1097/JSA.0000000000000128
Review Articles

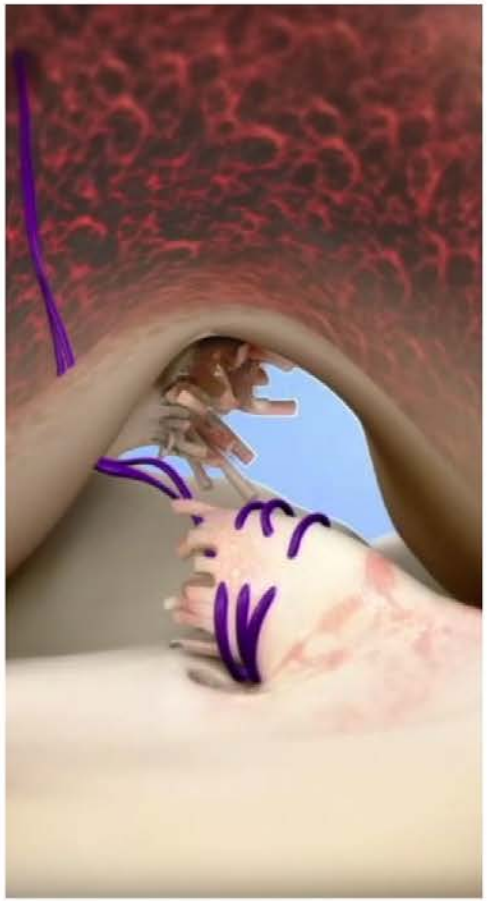


ALL / IT Band Tenodesis

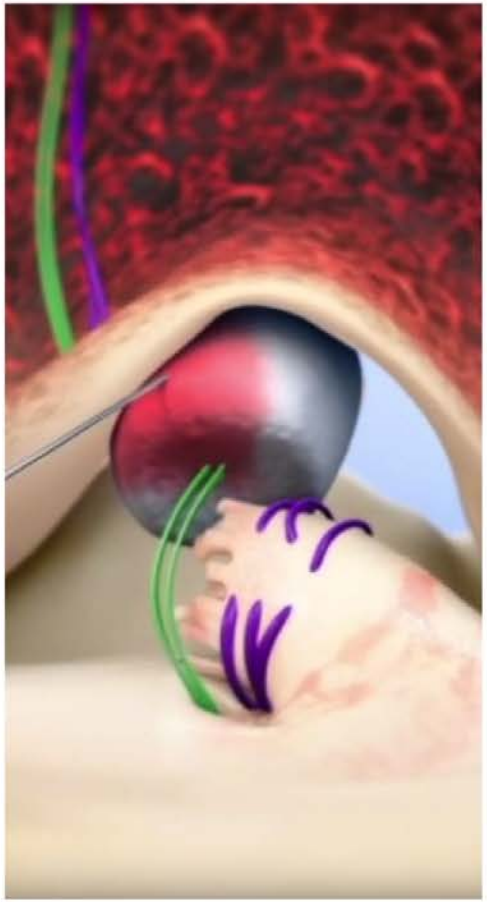
- If ligamentously lax, maybe at primary
  - Definitely with all revision cases



[redacted]



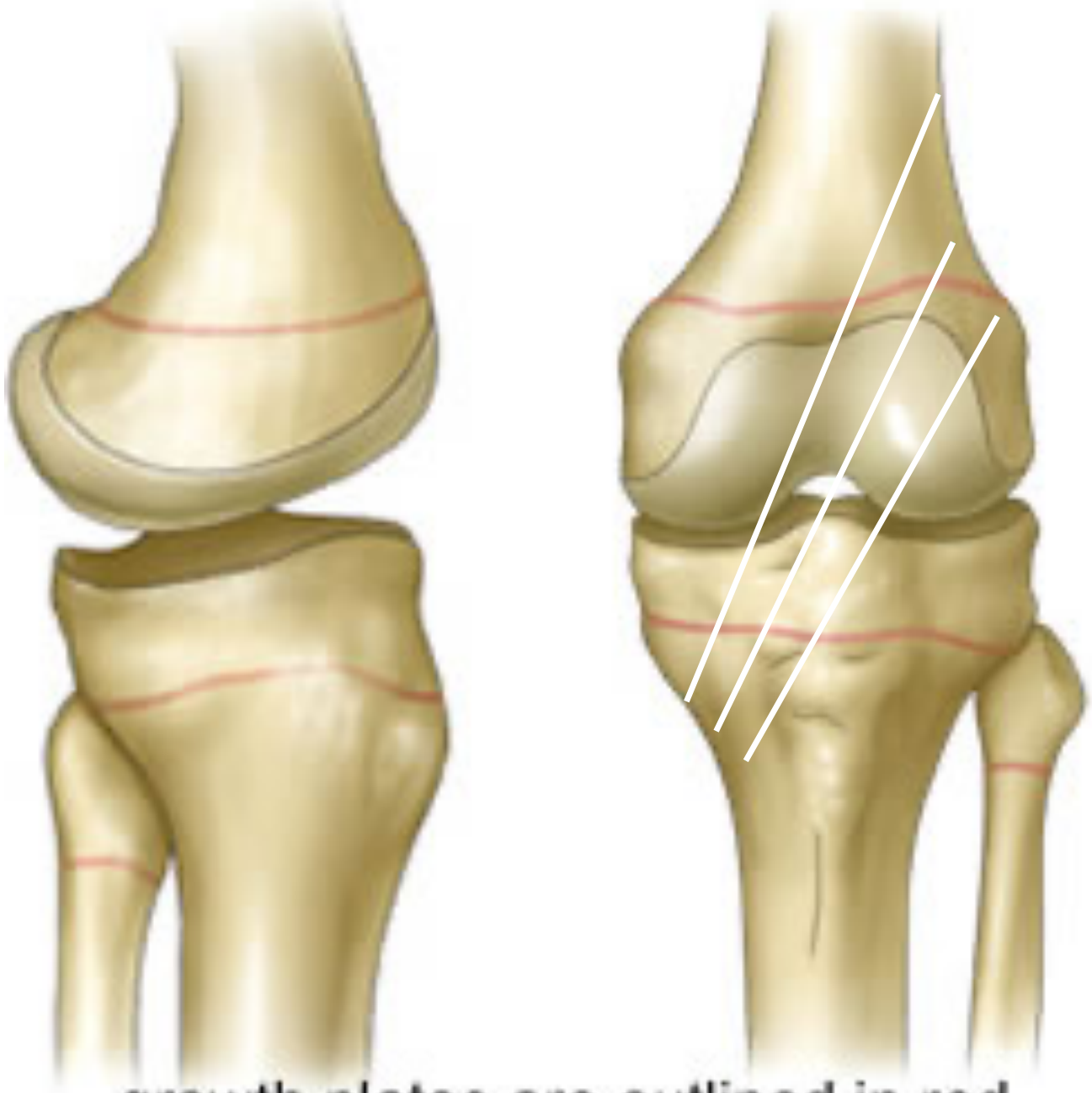
Torn ACL



Surgeon adds patient's own blood to [redacted] Implant

Surgeon inserts [redacted] Implant between torn ends of ACL

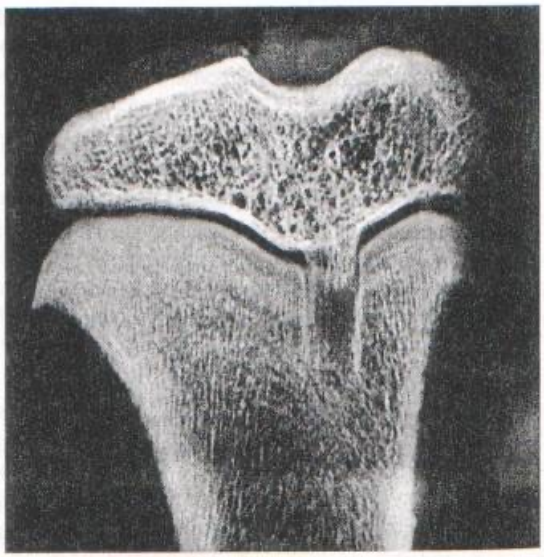
As ACL heals, [redacted] Implant is absorbed by the body, usually within eight weeks



growth plates are outlined in red

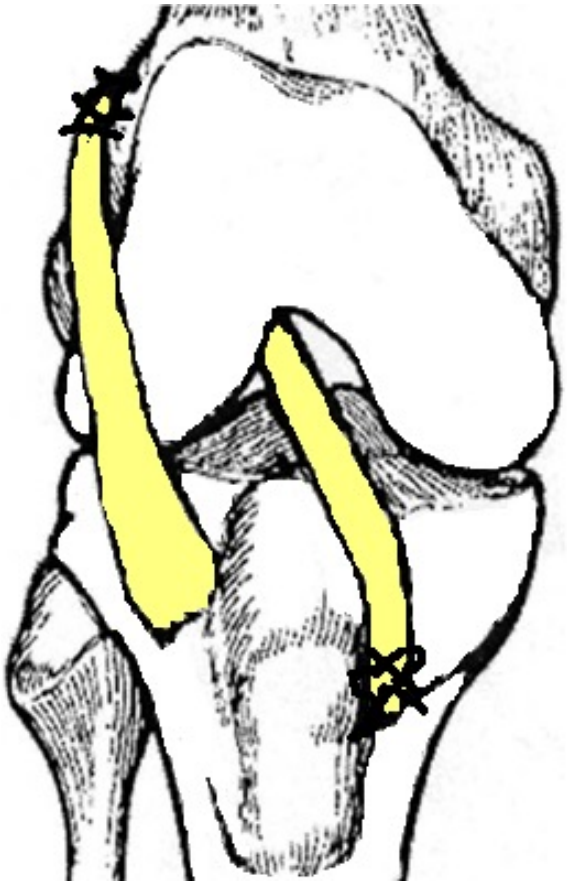
Avoiding Physeal Damage

- Drill < 7 % of the physis
- Soft tissue across physis
- Medial, distal, and vertical drill holes



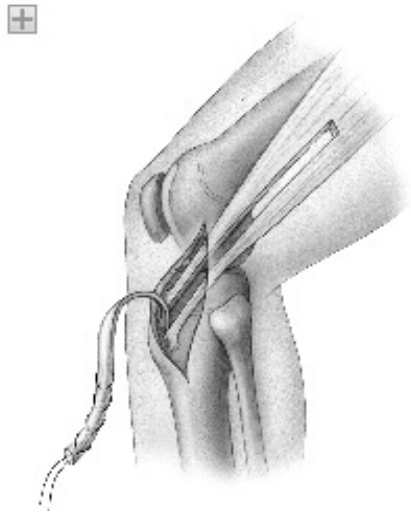
Physeal Sparing: Combined Intra- and Extra-Articular Reconstruction

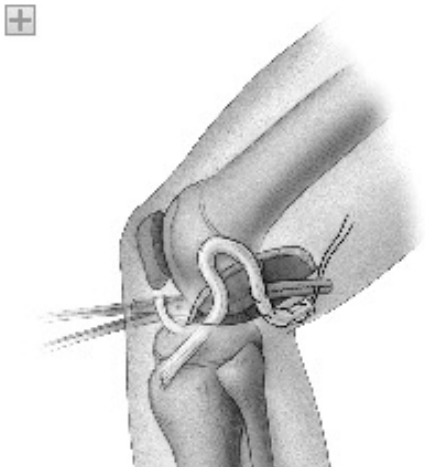
- ITB Autograft: Over-the-top femur, over-the-front tibia under inter-meniscal ligament

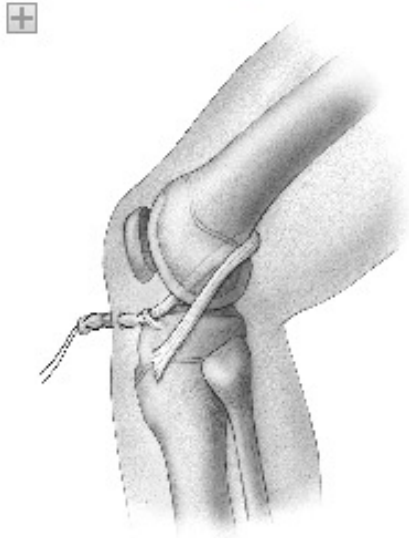


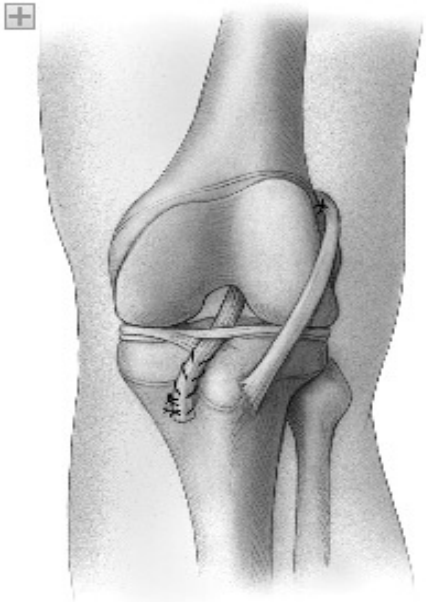
Kocher MS et al. J Bone Joint Surg Am. 2005;87:2371-2379

Physeal Sparing: Combined Intra-and Extra-Articular Reconstruction



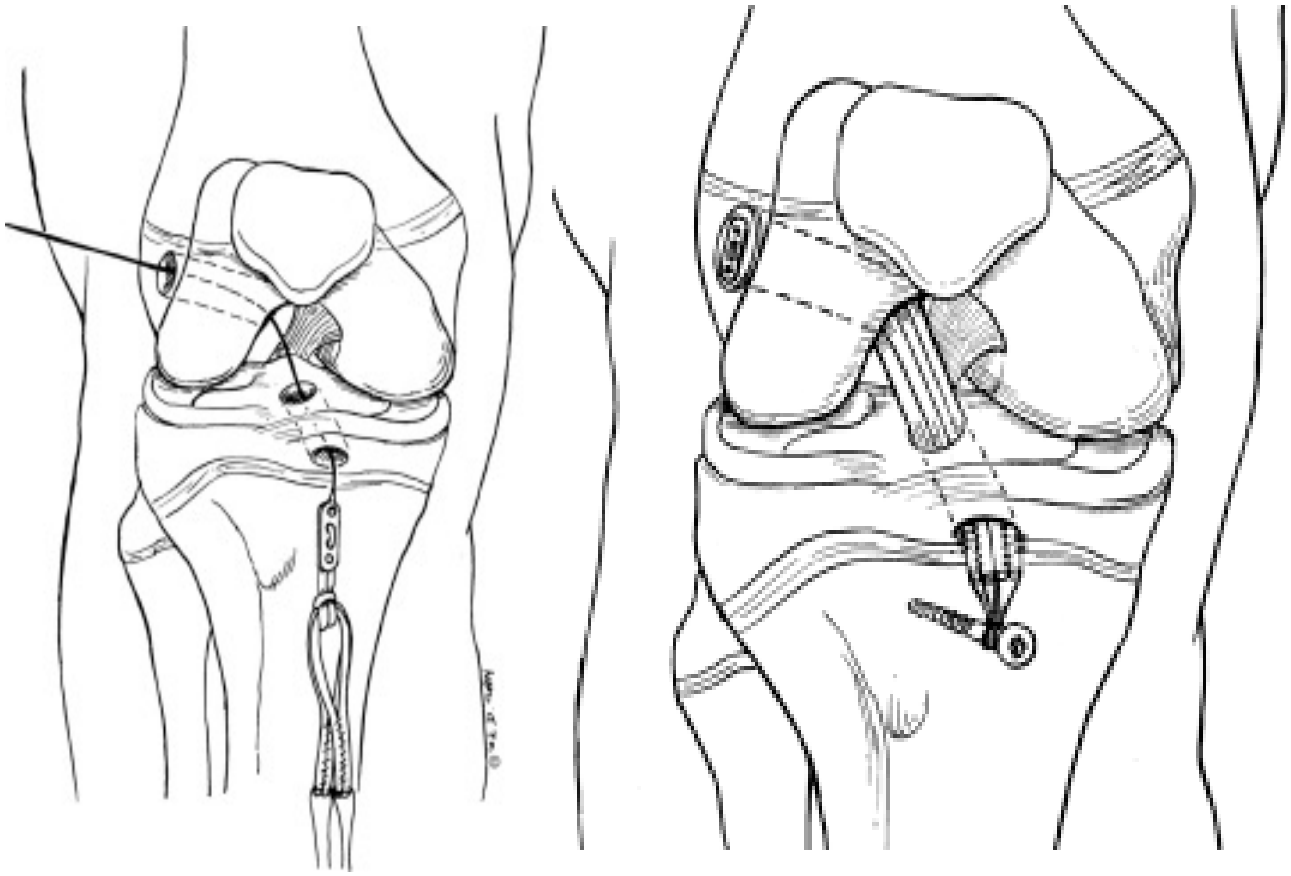






Physeal Sparing: Intra-Epiphyseal Reconstruction

- Flouroscopic guided
- Drill holes in epiphysis
- Soft tissue graft



Anderson AF et al. J Bone Joint Surg Am. 2003

Partial Transphyseal Anterior Cruciate Ligament Reconstruction: Clinical, Functional, and Radiographic Outcomes

Caitlin C. Chambers, MD*, Emily J. Monroe, MD, Christina R. Allen, MD, more... Show all authors

First Published April 17, 2019 | Research Article | Find in PubMed | Check for updates
https://doi.org/10.1177/0363546519836423

Article information

Altmetric 2

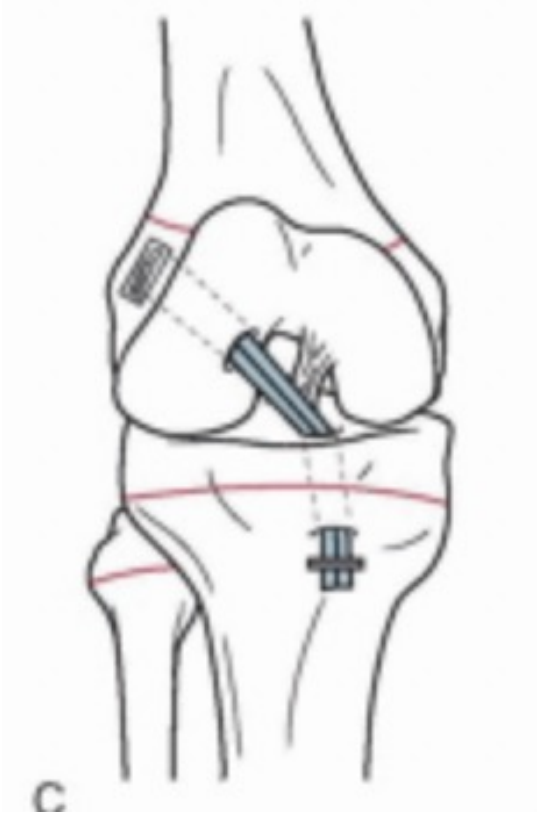
Abstract

Background:

With a steadily increasing rate of anterior cruciate ligament (ACL) injury and reconstruction in the pediatric population, disagreement remains regarding the optimal reconstruction technique for patients with ACL injury and ≥2 years of growth remaining.

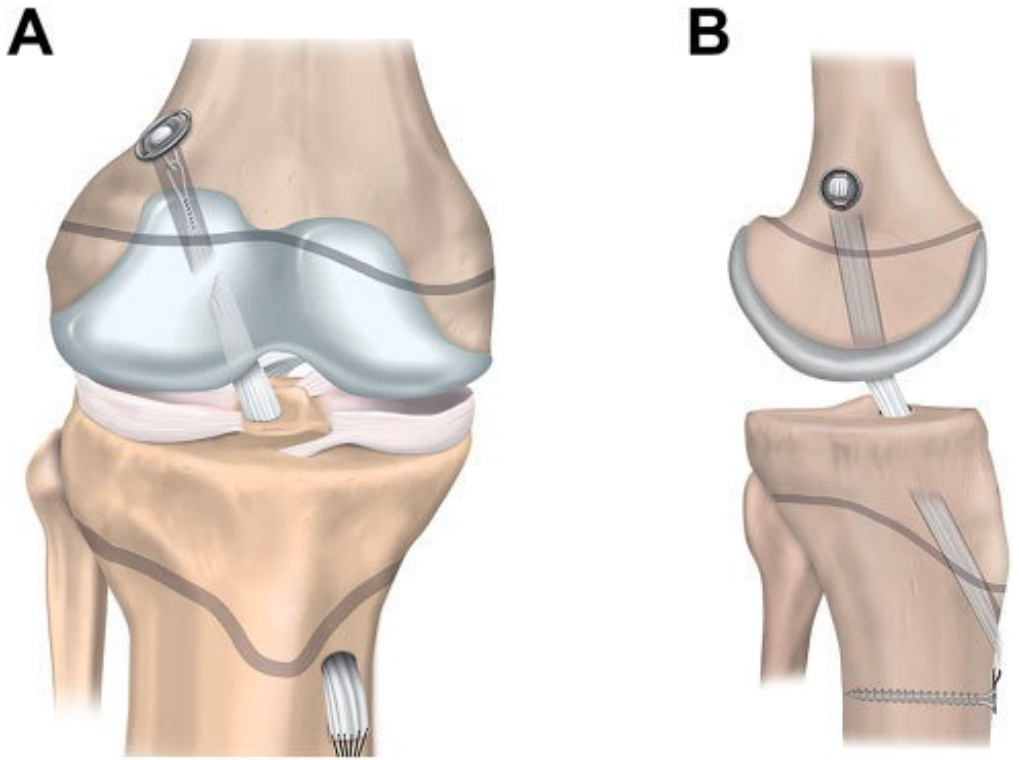
Purpose:

This study aims to quantify the incidence of linear and angular growth disturbance of adolescents undergoing partial transphyseal ACL reconstruction (ACLR) while assessing graft failure rates, reoperation rates, and functional outcomes in the population.



Transphyseal Reconstruction

- Adult-type reconstruction
- Improved isometry and stability
- Smaller tunnels
- Soft tissue grafts
- Metaphyseal fixation
- Risks physeal damage



ACL Reconstruction in Children: the Algorithm

- Prepubescent Children (substantial growth remaining)
  - Physeal-sparing combined intra-articular and extra-articular reconstruction
  - Intra-epiphyseal reconstruction
  - Partial transphyseal
- Pubescent Adolescents (variable amount of growth)
  - Transphyseal with metaphyseal fixation and soft tissue grafts
- Older Adolescents (nearing skeletal maturity)
  - Transphyseal ACL reconstruction, similar to adult reconstruction using autograft or allograft

Summary

1. ACL Injuries are Increasing
2. Youth Sports Are a Risk Factor
3. Balance Growth Disturbance vs. Arthritis
4. Balance Growth Disturbance vs. Failure Rate
5. Non-Op Treatment = Arthritis
6. Higher Failure Rate Than Adult Population
7. Assess for Family / Patient Emotional Maturity
8. Various Ways to Assess Skeletal Maturity
9. Look Out For Tibial Spine Fractures
10. Have A Consistent Age Based Treatment Algorithm
11. Treat Modifiable Risk Factors

Thank You