

ACL Injuries: Treatment Options and Outcomes in a Case Management Framework

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Objectives

- 1. Identify graft options for anterior cruciate ligament (ACL) reconstruction and their indications based on patient-specific factors.**
- 2. Describe the benefits and limitations of each graft type and their impact on recovery, rehabilitation, and functional outcomes.**
- 3. Explain the risk of re-rupture associated with different graft choices and how this influences care planning and return-to-activity decisions.**



Everyone knows...

- ACL tears are a devastating injury for young athletes and laborers (really anyone)
- ACL reconstruction remains standard of care for active patients to stabilize the knee, protect the meniscus and cartilage, and to return to an active lifestyle
- For reconstruction we need a graft from somewhere



Does everyone need ACL Reconstruction?



NO!



“ACL Copers”

- Older
- Minimal laxity on exam
- Low demand
 - No cutting/pivoting activities
- Negative prognostic indicators:
 - Meniscal tears
 - High frequency of buckling
 - Heavy manual labor
- Treatment Approach
 - ACL deficiency bracing
 - Physical Therapy – 3 months min.
 - Lifestyle modifications
- If attempt this and fail can still proceed to reconstruction



ACL Reconstruction

- Create a new ACL which requires a tissue graft from somewhere
 - Debride residual ACL stump
 - Address concomitant pathology
 - Drill femoral and tibial bone tunnels
 - Pass the graft and secure it
- Standard of operative care



ACL Graft Options

Allograft

- Donated tissue

Autograft

- From the patient during ACL surgery



ACL Autografts

Quad-Patella Bone (Autograft)



Patellar Tendon (Autograft)



Hamstring Tendons (Autograft)



But...which graft is best???

Quadriceps Tendon (QT)



Bone Patellar Tendon Bone (BTB)



Hamstring Tendon (HT)



Allograft



It Depends on Patient Characteristics



Allograft

- Pros
 - No harvest site morbidity
 - Shorter surgical time
- Ideal Patient:
 - > 30 – 40 yo
 - Lower/moderate demand
 - Accepts risks of disease transmission
- Cons
 - Longer incorporation time
 - Increased cost
 - Risk of disease transmission
 - HIV < 1:1.6 million
 - 4.3 x higher risk of rupture in young athletes



Historically

- BTB
 - The Gold Standard
 - Higher morbidity harvest
- Hamstring
 - Soft tissue alternative
 - Open growth plates
 - Ease of use, less technically challenging
 - Lower donor site morbidity
- Quadriceps was used typically only in revision settings
 - Lack of reliable, commercially available fixation
 - Use started increasing significantly in 2010s
 - Corresponds with commercially available fixation devices



BTB Autograft Pros

- Longest history of use → Gold Standard
- Bone to bone healing leads to faster incorporation times
- Multiple fixation options
 - Can rigidly fixate the graft with screws
 - Can use suspensory fixation on femur



BTB Autograft Cons

- Painful, high morbidity harvest
- Larger scar
- Risk of patella fracture (intraop and during rehab)
- Risk of patellar tendon rupture
- Highest incidence of anterior knee pain and kneeling pain – need to consider in kneeling laborers i.e. electrician, plumber, welding, etc
- Cannot cross open growth plates with bone



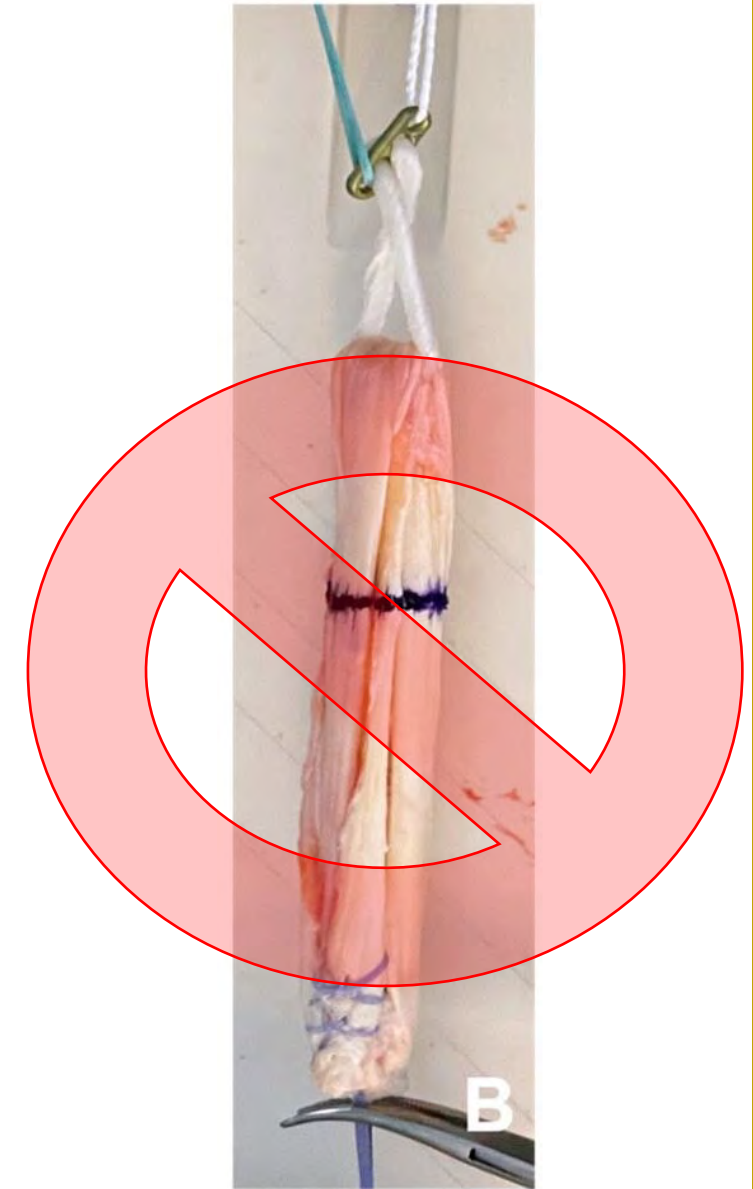
Hamstring Autograft Pros

- Less painful harvest
- Smaller incision
- Less anterior knee pain
- Can cross open growth plates



Hamstring Autograft Cons

- Highest risk of rerupture
 - Reduced stability / Increased graft laxity
- Risk of graft truncation during harvest
- Variable and unknown size & length
- Concern of hamstring weakness leading to re-rupture
- “Windshield wiper” effect at bone graft interface
 - Increased with mismatch in graft and tunnel size
- Tunnel widening
- Weakness in hip extension and knee flexion
- Higher infection rate



Quadriceps Autograft Pros

- Small incision in area you don't kneel on (2-3 cm longitudinal vs 2 cm transverse)
- Harvest with or without bone block
- Composed of several layers which add to it's favorable properties (BTB & HT are all parallel fibers)
- Cross-sectional area 2x > BTB
 - Reduces windshield wiper effect
 - Decreases inflow of synovial fluid into tunnel (implicated in tunnel widening)
- Can use suspensory fixation on both sides (ensure a taught graft)
- Can cross open growth plates
- Similar patient reported and functional outcomes as BTB
- Can use a bone block or not



Quadriceps Autograft Cons

- “Windshield wiper” effect with suspensory fixation
- Must ensure closure of any rents made in the joint capsule during harvest to reduce fluid extravasation
- Biomechanics of bone tendon interface less reliable than inferior pole with BTB
- Doesn't have the time longevity of research that BTB does



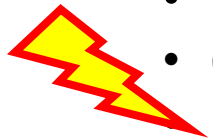
Biomechanics of the Quadriceps Graft

- Vs. BTB, the QT:
 - Contains 20% more collagen
 - Higher fibril-interstitial ratio
 - Higher fibroblast density
- More favorable soft tissue tensile properties
 - Higher load to failure
 - Higher strain at failure
 - Higher Young's modulus of elasticity
- QT-bone complex & PT-bone complexes have similar tensile properties



Quadriceps vs. BTB Failure Rates

- Multiple studies have shown **no significant difference in graft failure rates**:
 - **Mourabes et al 2019 meta-analysis**: outcomes and survival rates of QT were similar to BTB
 - **Dai et al 2022 meta-analysis**: no significant difference in graft failure rates
 - Hurley et al **2022 meta analysis**: QT lower rerupture risk vs HT (2.5% vs 8.7%) & slightly better for residual pivot shift
 - Khalefa et al **2025 systematic review**: no significant difference in graft failure rates sQT vs BTB; graft failure rate 3%
 - Sharma et al **2026 systematic review** young female failure rates:
 - BTB 6.2%
 - QT 7.4%
 - HT 14.9%



2019 Systematic Review & Meta-analysis

- QT graft failure rate 2.1% (21 studies, 1,554 patients)
- No significant differences found in:
 - **Stability Outcomes** using:
 - KT arthrometer (4 studies)
 - Side to side diff > 3 mm (6 studies)
 - Lachman (4 studies)
 - Pivot shift (5 studies)
 - **Functional Outcome**
 - Lysholm (5 studies)
 - IKDC (4 studies)
 - **Graft rupture** (6 studies)
- Significant difference found in donor site pain in favor of QT (RR 0.25)
- QT had better functional scores (Lysholm) vs. HT



2022 Systematic Review and Meta-analysis

- 7 RCTs (388 patients)
- 17 Observational studies (19,196 patients)
- Study showed **no significant difference for BTB vs QT:**
 - Graft failure
 - IKDC
 - Side to side difference in stability
- And showed significant reduction in donor site morbidity
- Results were similar for QT with bone plug vs. all soft tissue

Quadriceps Tendon Autograft Versus Bone-Patellar Tendon-Bone and Hamstring Tendon Autografts for Anterior Cruciate Ligament Reconstruction

A Systematic Review and Meta-analysis

Wenli Dai,* MD, Xi Leng,[†] MD, Jian Wang,[‡] MD, Jin Cheng,* MD, Xiaoqing Hu,*[§] MD, and Yingfang Ao,*[§] MD, PhD

Investigation performed at Peking University Third Hospital, Beijing, China

The American Journal of Sports Medicine

2022;50(12):3425–3439

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US Cohort Risk of Revision & Reoperation QT vs. BTB vs. HT

**Risk of Revision and Reoperation
After Quadriceps Tendon Autograft
ACL Reconstruction Compared With
Patellar Tendon and Hamstring Autografts
in a US Cohort of 21,973 Patients**

Justin S. Yang,^{*,†} MD, Heather A. Prentice,[‡] PhD, Chelsea E. Reyes,[‡]
Christopher R. Lehman,[§] MD, and Gregory B. Maletis,^{||} MD
Investigation performed at Kaiser Permanente, San Diego, California, USA

The American Journal of Sports Medicine
2024;52(3):670–681
DOI: 10.1177/03635465231222267

- 21,973 ACLRs, 290 surgeons, 53 hospitals over 10 years
 - QT= 5% (1,103)
 - BTB = 43.3% (9,519)
 - HT = 51.7% (11,351)
- Found no difference in risk of revision or reoperation at 4 years f/u
 - QT 2.7% vs BTB 3.0%
 - QT 2.7% vs HT 4.5%
- Number needed to treat:
 - 573 QT vs BTB
 - 62 QT vs HT
 - 30 QT vs HT for patients <22 yo
 - 36 BTB vs HT for patients <22 yo
- **Found a 1.5x higher risk of revision of HT vs. BTB with up to 9 yrs f/u**



Residual Quadriceps Weakness?

- Han et al found quadriceps isokinetic strength at 1 year postop statistically similar QT vs. BTB
- Lee et al found no differences in isokinetic quadriceps testing at 1 year QT vs. HT
- BTB also violates the extensor mechanism



Currently

- Quadriceps autograft is surging in popularity
 - Reliable, commercially available fixation
 - Low donor site morbidity harvest
 - Continued solid research results
- Is this the “graft of the future”?



Pros

- Quadriceps
 - Favorable biomechanics
 - Large cross-sectional area
 - Ease of harvest
 - Predictability (can define length, width, thickness)
 - Less analgesic use
- BTB
 - Bone to bone healing
 - Breadth/longevity of data supporting outcomes
- Hamstring
 - ?????? Not allograft ??????



Cons

- Quadriceps
 - Possible increase in formation of cyclops lesions. (Sharma)
 - ? Residual decreased quadriceps strength
- BTB
 - Painful harvest
 - Risk of patella fracture, patellar tendon rupture
 - Anterior knee pain / difficulty kneeling
 - Graft tunnel mismatch
- Hamstring
 - Highest risk of rerupture
 - Reduced stability / Increased graft laxity
 - Risk of graft truncation during harvest
 - Variable size & length
 - Delayed graft incorporation
 - Weakness in hip extension and knee flexion
 - Higher infection rate



Limitations

- There is not enough data, especially long term data, on QT grafts
 - QT grafts started increasing in popularity in 2010s
 - Lower total volumes
 - Less long term follow-up
 - 6+ decades of research on BTB vs. 1-2 decades on QT



Summary



- A quadriceps tendon autograft demonstrates:
 - No differences in PROMs, knee stability, graft failure, revision rates
 - Less graft site morbidity vs. BTB
 - Better functional outcomes vs. HT
 - Lower rerupture rate vs. HT
- Early data shows that QT grafts are **equivalent in function** and may have some **benefit in graft harvest and pain**
- BTB and quad tendon are both acceptable autograft choices
 - **Occupational considerations with BTB and anterior knee pain**
- As volume and surgeon experience with QT increase I anticipate the additional data will only strengthen the case for QT



Currently....

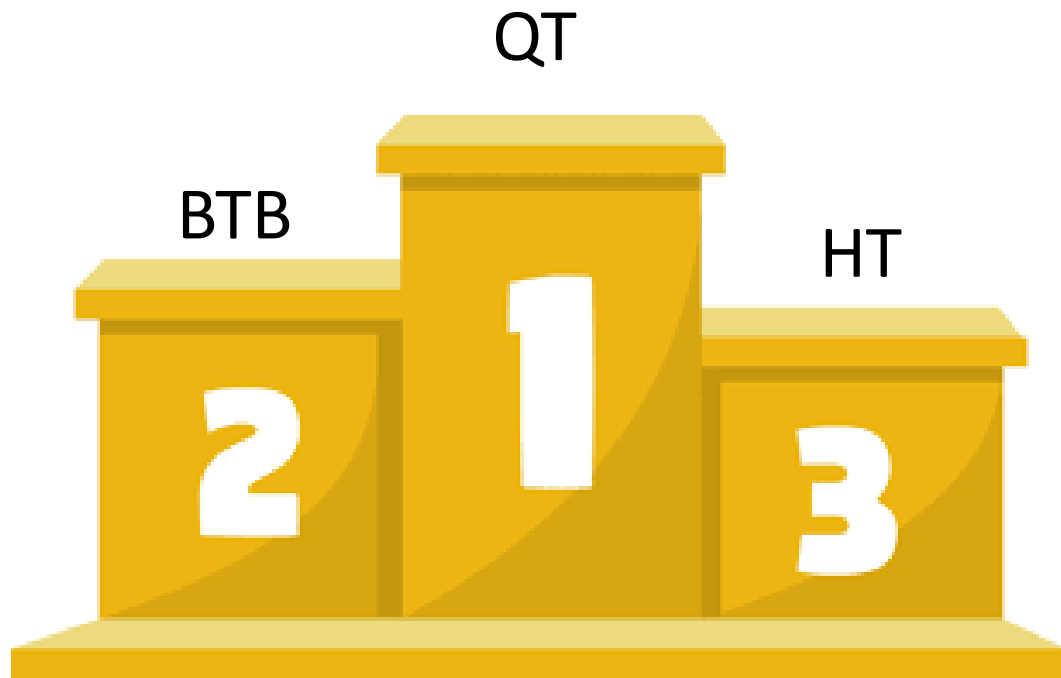
QT & BTB



HT



In the future....

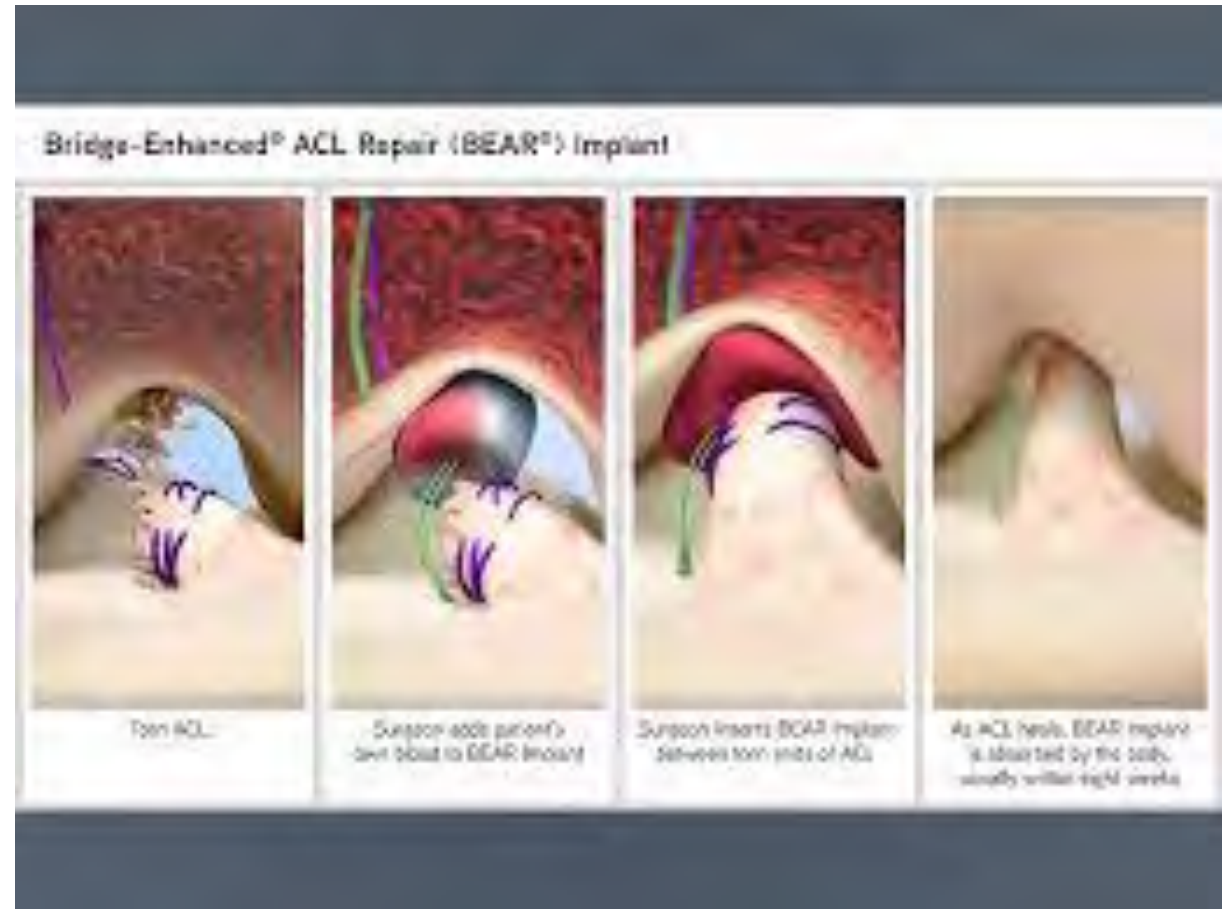


ACL Repair

- Historically a high failure rate
- Was largely abandoned as reconstruction is so reliable
- Becoming a viable option again for the right patient with the progression of technology and the BEAR implant
 - Pediatric population
 - Femoral or tibial sided avulsions
 - Partial thickness repairs



BEAR Implant



- Hydrophilic, bovine-derived extracellular matrix and collagen
- Coated in autologous whole blood



BEAR Implant

- Preserves knee anatomy and landmarks
- No grafts or donor tissue required
- Works by creating a protective environment for the ACL to heal
 - Shields from the harsh synovial fluid
 - Supports cell migration and proliferation
- Resorbed by 8 weeks and replaced by native tissue that continues to mature
- Clinically proven and validated with Level 1 Clinical Evidence



BEAR Implant

- Return to sport around 9 months
- 2025 first 100 cases post-commercialization: 0% retear at 1 year, 2.1% retear final followup
- 2026 meta-analysis showed comparable IKDC scores at 12 and 24 months



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Thank you!

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