Application of an Amniotic Membrane Graft at the Quadriceps Tendon Harvest Site after ACL Reconstruction Using Quadriceps Tendon Autograft: 2025 LOA Grant Update

Prospective, blinded randomized controlled trial evaluating whether amnion improves quadriceps recovery after anterior cruciate ligament reconstruction utilizing quadriceps tendon autograft.

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The Quadriceps Tendon as an ACL Graft Source

Understanding the harvest site and why recovery matters

Why Quad Tendon?

- Robust, multi-layer graft with high tensile strength
- Increased collagen density
- No patella tendon morbidity or hamstring harvest weakness
- Growing evidence base for equivalent ACL outcomes compared to BTB

The Harvest Site Problem

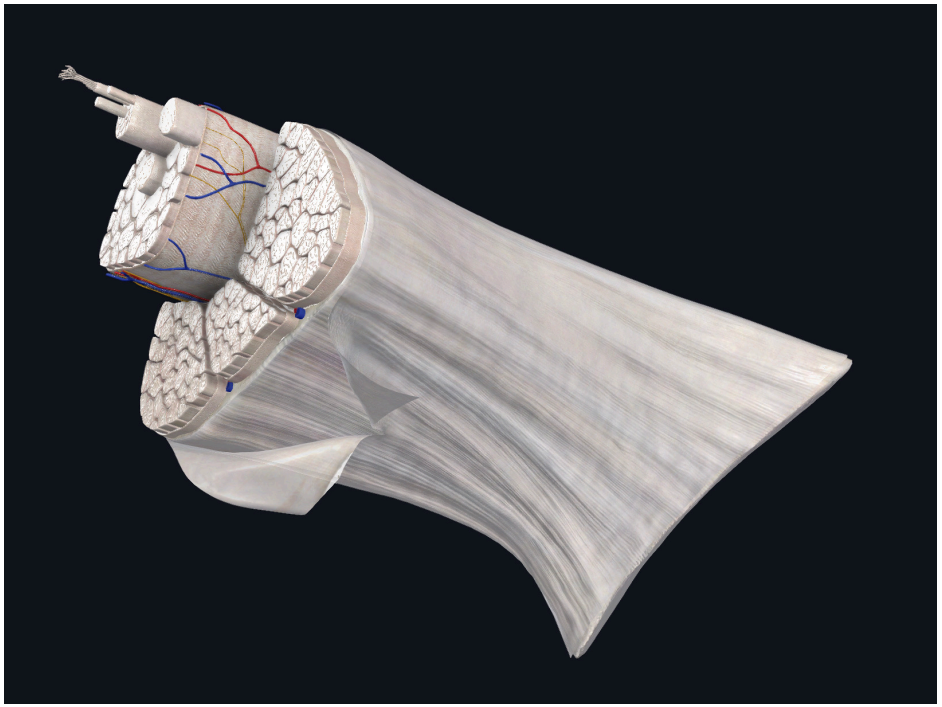
- Paratenon disruption impairs vascularity & innervation
- Proprioceptive loss from mechanoreceptor injury
- Proximal quad weakness may persist months post-harvest
- Early pain limits rehab participation (the recovery gap)

Our Intervention

- Amniotic membrane graft placed at the harvest site
- 3×8 cm graft over the paratenon
- Vicryl suture fixation through standard small incision
- Biologically active scaffold to accelerate healing

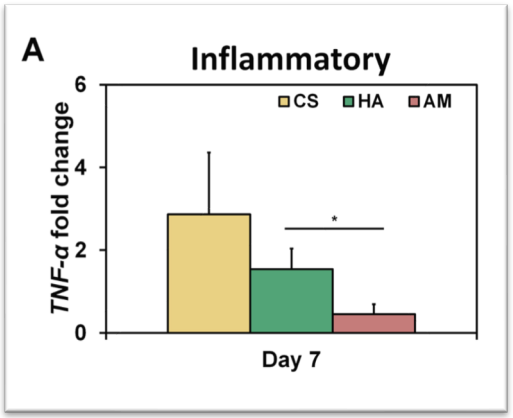
The Paratenon Plays an Important Role

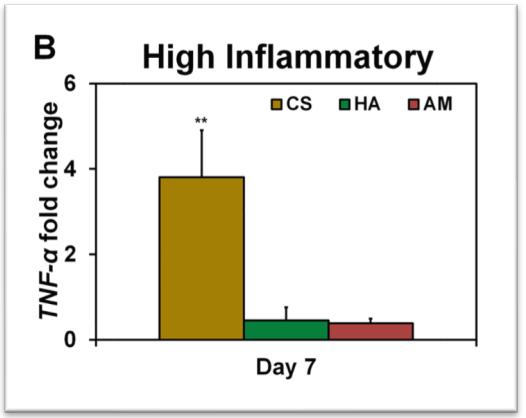
- Provides **vascularity** and **innervation**
  - **Watershed zone** of tendons supplied only by extrinsic/paratenon supply
- From the MTJ, **nerve fibers** enter the endotenon and paratenon, and then innervate epitenon & surface of tendon
  - Mechanoreceptors/Golgi organ
    - Pressure & Tension
    - Proprioception

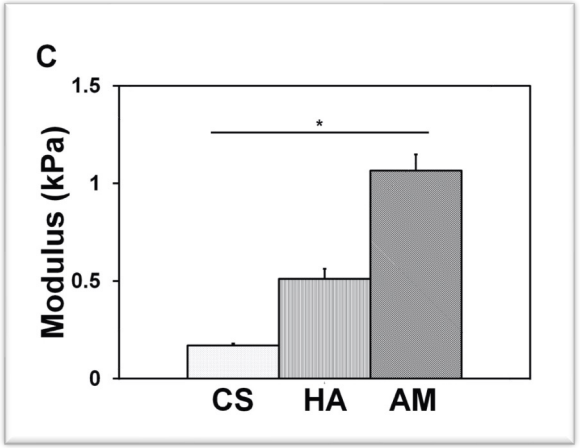


Amniotic Matrix Improves Collagen Healing

- Tendon repair normally occurs through disorganized collagen formation & inflammation
  - Poor mechanical properties
  - Scarring and adhesion
- Collagen scaffolds containing AM
  - Lower inflammatory markers
  - Higher metabolic activity of tenocytes
  - Better tensile properties







Immunomodulatory effects of amniotic membrane matrix incorporated into collagen scaffolds

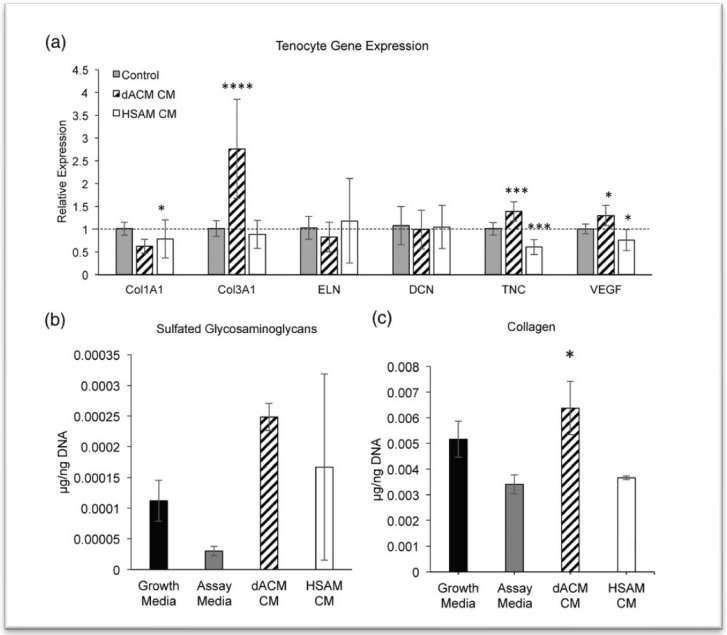
Rebecca A. Hortensius[1], **Jill H. Ebens**[2], and **Brendan A. C. Harley**[2,3]

Amniotic Matrix Encourages Tenocyte Proliferation & Collagen Formation

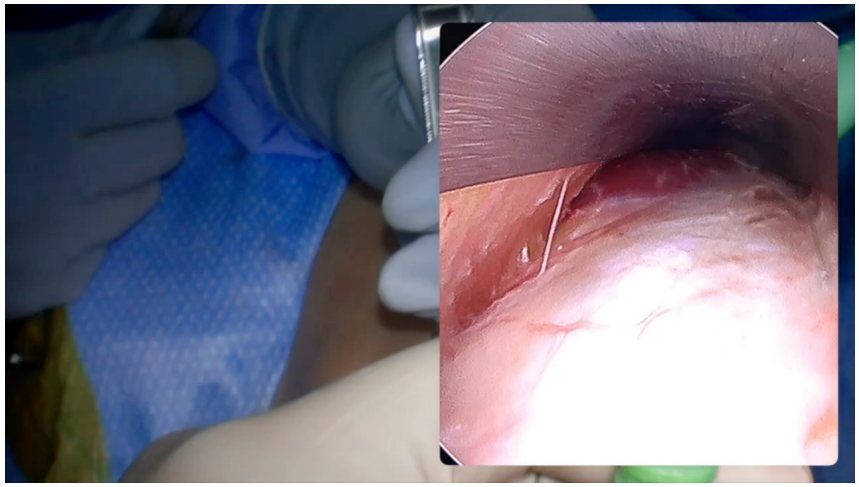
- Dehydrated amniotic matrix
  - Physiologically relevant growth factors necessary for tendon healing
  - **3.5x increased tenocyte proliferation**
  - **2.27x increased tenocyte migration**
  - Increased collagen gene expression and actual collagen proliferation

Evaluation of two distinct placental-derived membranes and their effect on tenocyte responses in vitro

John P. McQuilling[1] | Kelly A. Kimmerling[1] | Miranda C. Staples[2] | Katie C. Mowry[1]



Application of Amniotic Matrix at the Harvest Site



Surgical Technique

1 Harvest Site

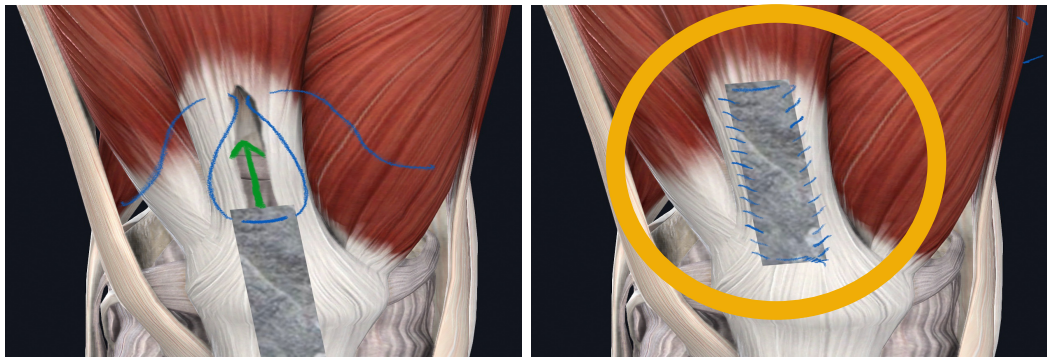
3×8 cm defect after QT harvest; paratenon exposed

2 Proximal Slide

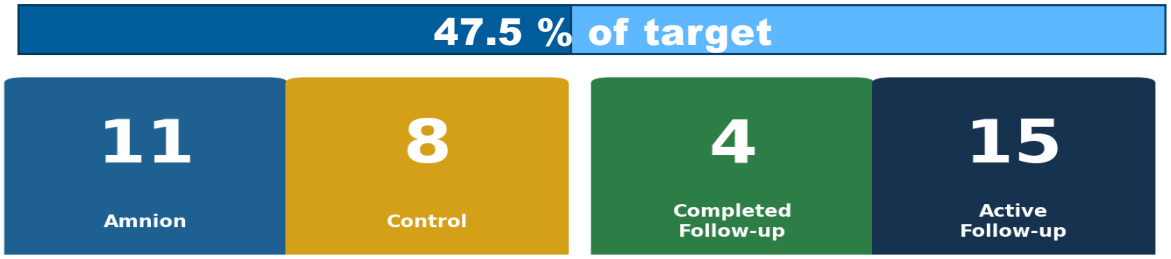
Amnion membrane positioned to cover the repaired tendon defect

3 Secure Graft & Cover with Paratenon

Vicryl suture fixation through standard incision



Study Design, Enrollment & Current Status



Study Design

- **Prospective, double-blinded randomized controlled trial**
- **Target enrollment**: 40 patients (20 per arm)
- **Follow-up**: 2 wk, 6 wk, 3, 6, 9, 12, 24 months
- **Primary**: Isokinetic quad LSI @ 3, 6, 9, 12, 24 mo
- **Secondary**: Thigh circumference, harvest-site pain (NPS), serial PROs, biomechanical LSI (motion capture kinematics)

Trial Timeline

Surgery
Enrollment ongoing since 2023

Motion Capture Integration
July 2025; after workflow & IRB setup

Current
Mar 2026 — n=19

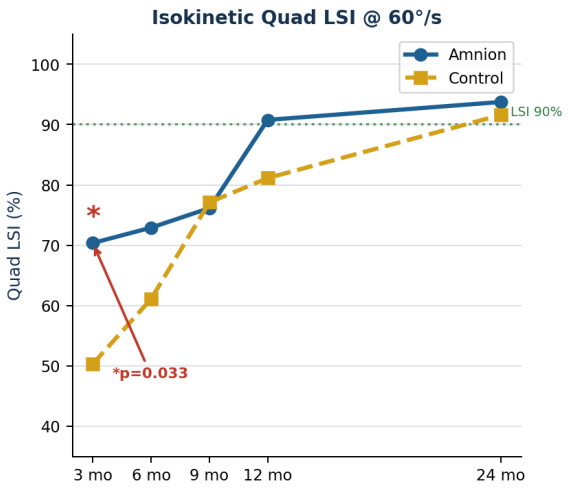
Target
n=40, 24-month follow-up complete

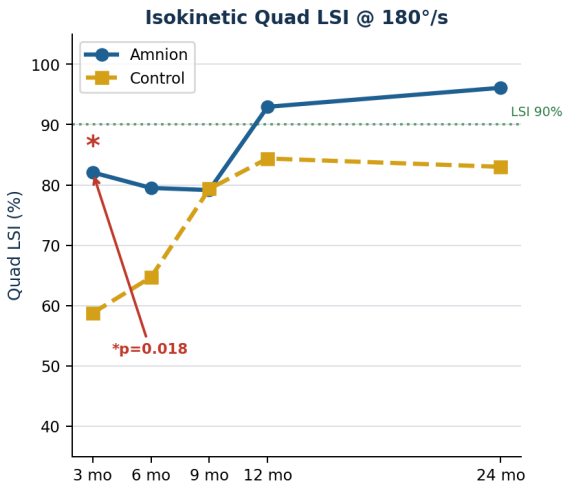
Exclusions (n=3)

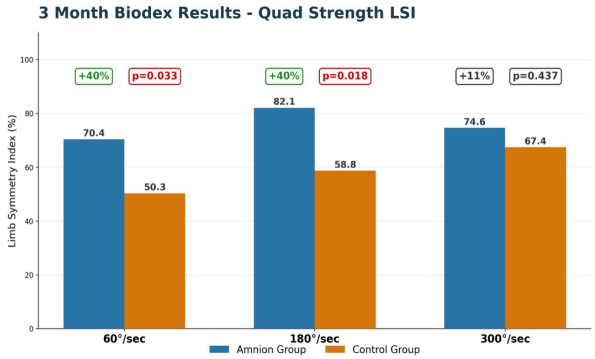
Inability to adhere to postoperative rehabilitation protocols

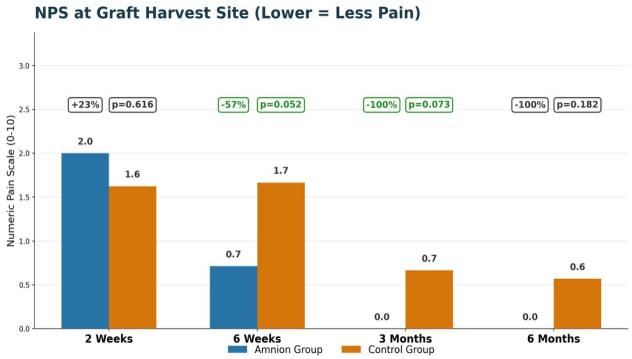
Interim Clinical Findings: 3-Month Signal Favors Amnion

Isokinetic strength, thigh circumference, and harvest-site pain — all point to accelerated early recovery









Quad LSI @ 60°/s

Amnion 70.4% vs Control 50.3% at 3 months — p = 0.033 ✓

Quad LSI @ 180°/s

Amnion 82.1% vs Control 58.8% at 3 months — p = 0.018 ✓

Total Work Symmetry

@ 180°/s: 81.7% vs 59.2% at 3 months — p = 0.043 ✓

Key Takeaway

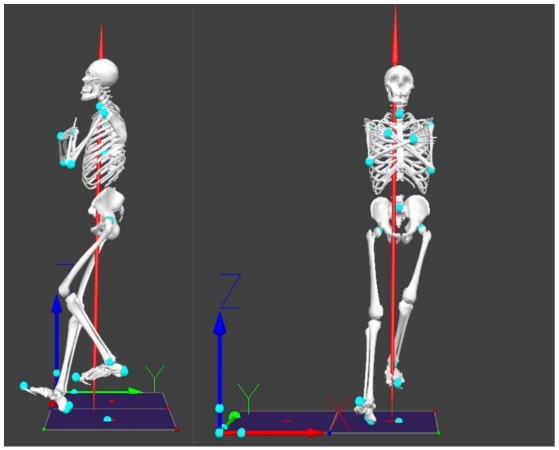
Amnion appears to accelerate early quad recovery; not create a different late endpoint.

Thigh circumference: +7.0–7.7% vs −2.3% at 12 & 18 cm above patella (p<0.02).

Groups converge by 9 months as controls catch up; the early window matters most.

LOA-Funded Innovation: Markerless Motion Capture Platform

Theia3D markerless system + force plates; measuring HOW patients move



What LOA Funding Enabled

✓ Theia markerless capture system; no reflective markers needed
✓ Embedded force plates for bilateral/unilateral GRF measurement
✓ Bilateral and unilateral squat protocols at rehab timepoints
✓ IRB amendment + workflow development (Started July 2025)

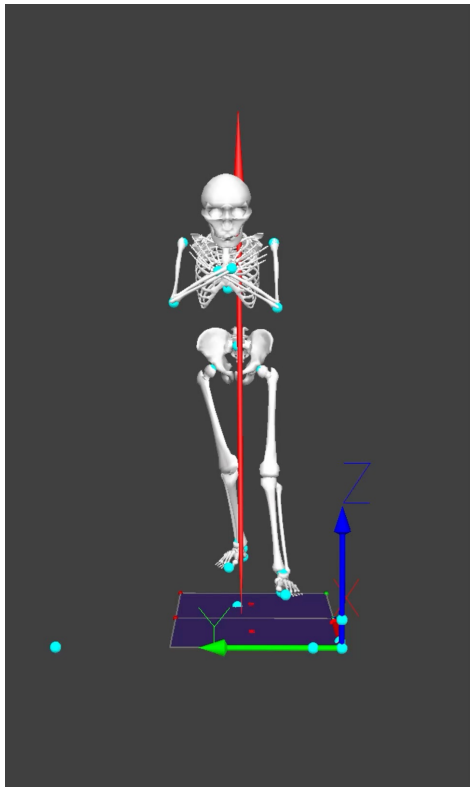
Metrics Captured

• Peak Knee Flexion Angle (bilateral & unilateral)
• Peak Knee Extensor Moment (Nm/kg)
• Limb Symmetry Index (LSI) for both metrics
• Bilateral squat & single-leg squat tasks
• Coefficient of variation per trial
• Force plate GRF symmetry

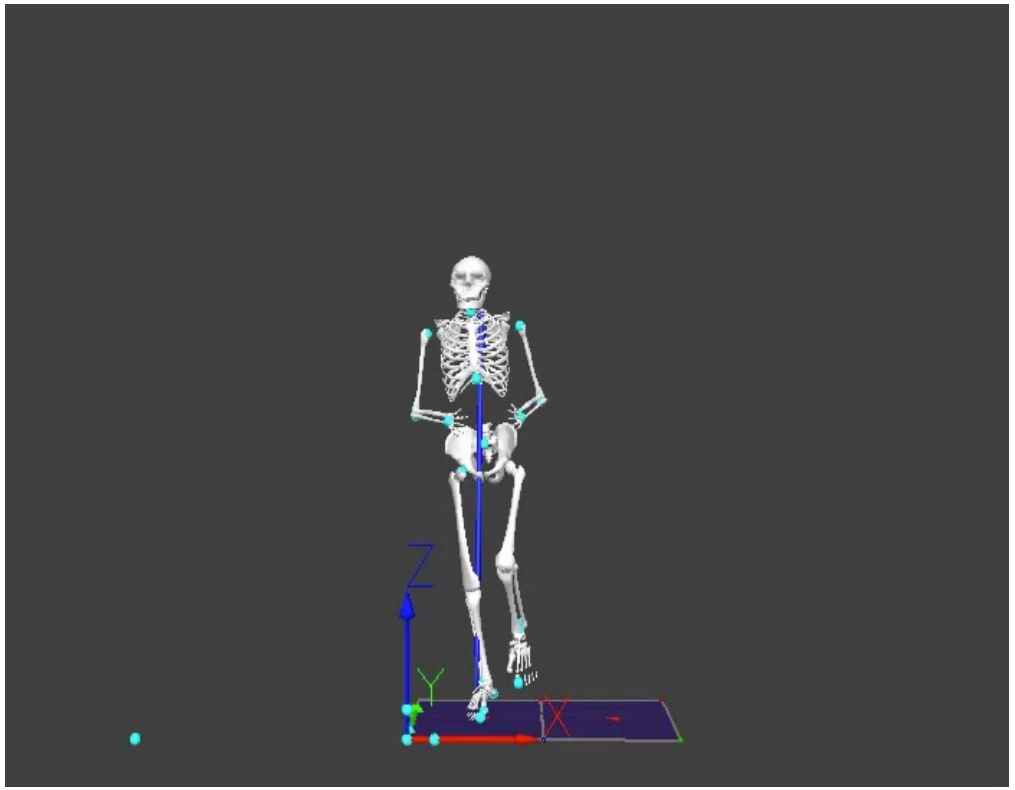
Why This Matters

- Quad inhibition after QT harvest can appear as protective unloading BEFORE it shows on routine exam.
- Moment asymmetry detects patients who look 'strong enough' on isolated testing but still avoid loading.
- This grant transformed the project from a conventional outcomes study into a translational rehab platform.
- "Not just WHETHER patients recover; but HOW they move while recovering."

3D Motion Capture & Force Plate Testing in Post-ACLR Follow-Up



Single Leg Step Down Test



Single Leg Hop Test

Motion Capture Results: LSI Trajectories vs Days Post-Surgery

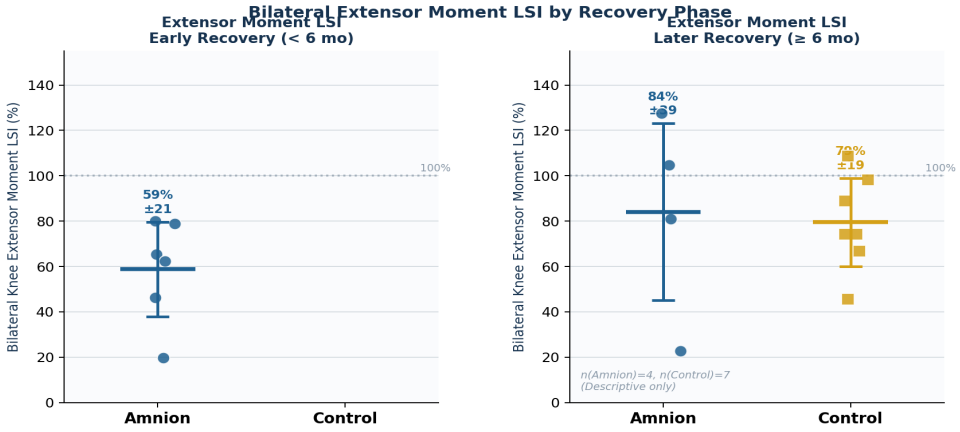
Individual observations: Descriptive analysis with trend lines

Legend

- **Amnion**
- **Control**
- **-- Lines connect repeated patients**

MoCap Readout: Clinical Interpretation of Early Data

Moment symmetry reveals the loading gap that strength testing misses



What the Plots Show

- Angle LSI often remains near symmetric
- Extensor moment LSI shows greater early asymmetry
- This suggests preserved motion with persistent protective unloading
- Descriptive only at current sample density

Why Descriptive Only?

- MoCap launched July 2025
- Irregular follow-up timing
- ≤2 captures per patient
- Study still enrolling.
- Plotting LSI vs days post-op preserves the information without over-claiming statistical inference.

What Matures This Dataset?

- Density at 3, 6, and 12-month timepoints
- Once ≥3 repeated measures per patient are available
- A linear mixed-effects model with random intercept per patient becomes appropriate.

LOA Grant's Role Here

- Without LOA funding, this dataset would not exist.
- Now operational capturing biomechanical recovery in real patients, creating a unique longitudinal platform no other ACL trial has built.

Interpretation, Limitations & 2026 Priorities

Honest assessment of where the data stand — and what comes next

What the Data Show	Current Limitations	2026 Priorities
○ At 3 months, amnion produces significantly higher quad strength LSI at 60°/s (p=.033) and 180°/s (p=.018) ○ Total work symmetry at 180°/s also significant at 3 months (p=.043) ○ Thigh circumference LSI improved more with amnion at 12 cm (p=.019) and 18 cm (p=.010) ○ Harvest-site pain trends lower with amnion at 6 weeks (p=.077, borderline) ○ Groups converge by 9 months; amnion accelerates early recovery, not a different late endpoint ○ MoCap demonstrates feasibility; captures loading asymmetry not visible on isolated testing	○ Enrollment still below target sample size (n=19 of 40); underpowered for secondary endpoints ○ Most clinical endpoints and nearly all MoCap observations are sparse at later timepoints ○ MoCap dataset not yet ready for formal longitudinal modeling ○ 3 patients excluded for inability to adhere to post-op protocols — no safety concerns or adverse events ○ Blinding preserved for all active patients, but small N limits definitive conclusions ○ 24-month data available for only n=3 — final endpoint incomplete	○ Complete enrollment to target n=40 while preserving blinding ○ Increase MoCap density at 3, 6, and 12-month windows ○ Revisit formal MoCap results once ≥3 repeated captures per patient available ○ Present integrated story at LOA, AOSSM, and other meetings ○ Initiate manuscript after enrollment completion with adequate 12-month follow-up ○ Final conclusions at 24-month primary endpoint

LOA funding has helped produce a functioning motion capture pipeline and a clinically relevant early recovery signal — the next gain is scale.

Thank You

Questions & Feedback Welcome

This update represents an actively maturing trial.
The LOA-funded biomechanics and motion capture platform has helped this project to gain meaningful clinical insight.

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