New ACL “Kid” on the Block

Quadriceps Tendon Autograft

Dr. Eric Samuelson

July 28th, 2023

Ortho Nebraska

Disclosures

- Conetic/RSW/Arthrex - cadaver lab and education
- Smith and Nephew - travel, cadaver lab, and education

Learning Objectives

- Describe the advantages and disadvantages of quadriceps tendon autograft versus other ACL graft sources.

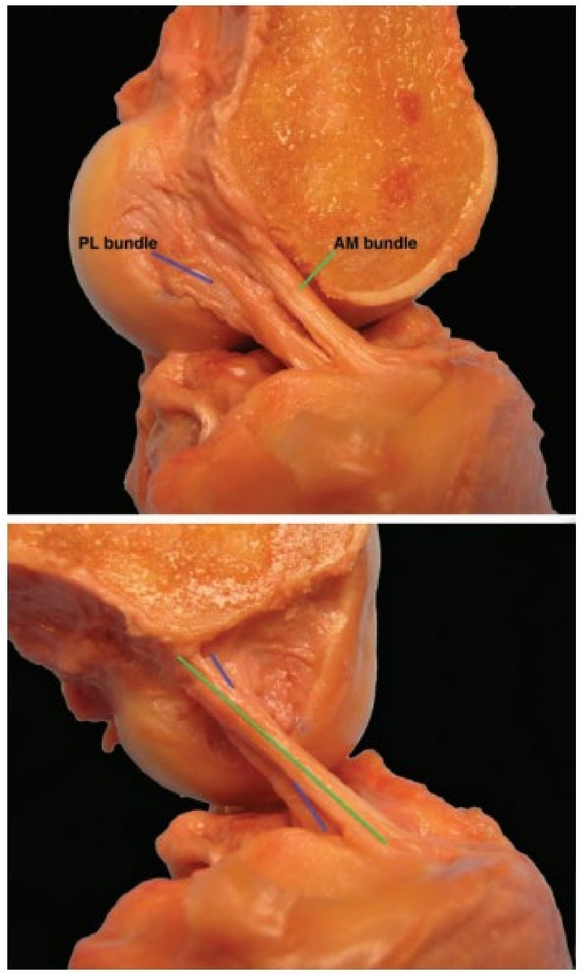
- Describe the current indications for use of quadriceps tendon autograft in ACL reconstruction.

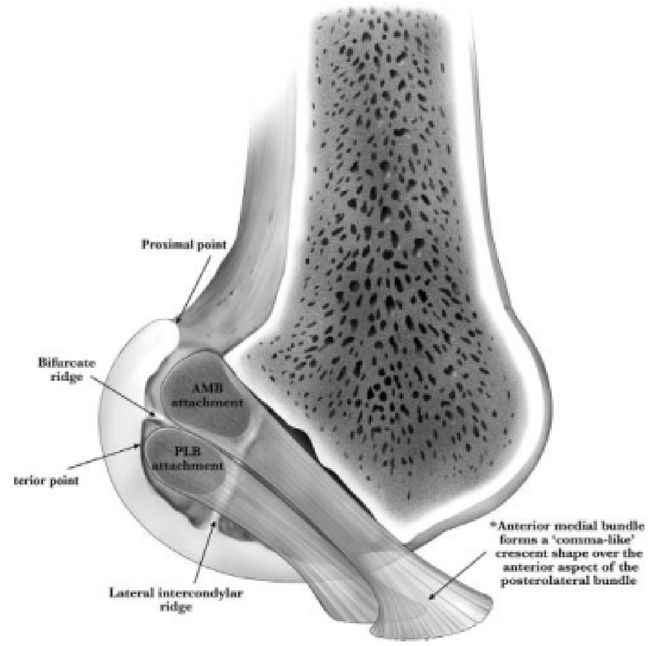
Outline

- Where did we start?
  - ACL reconstruction - Patellar Tendon versus Hamstring Tendon
- What did we see along the way?
  - Hamstring grafts - are they as good as we think?
  - Lateral extra-articular tenodesis
- Is there another way?
  - Quadriceps tendon autograft

ACL Anatomy and Biomechanics

- Anterior Cruciate Ligament
  - 2 bundles
    - Anteromedial
    - Posterolateral
  - Function
    - Prevents anterior translation (AM)
    - Rotational stability (PL)

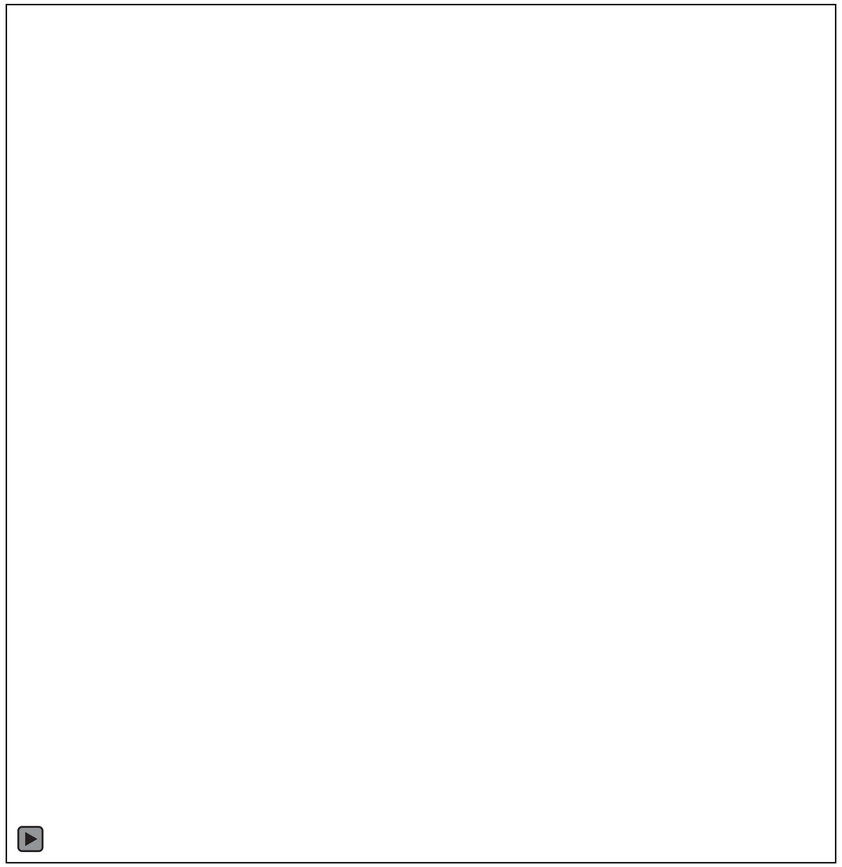




Ortho Nebraska

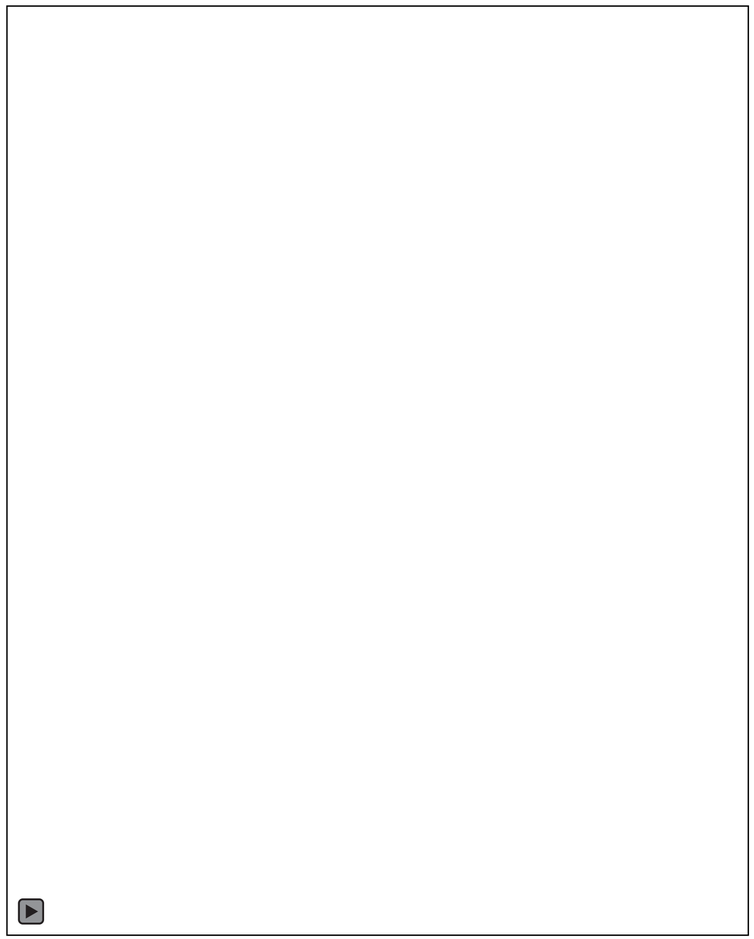
ACL Anatomy and Biomechanics

- Anterior translation
  - Lachman's Test
  - Anterior Drawer



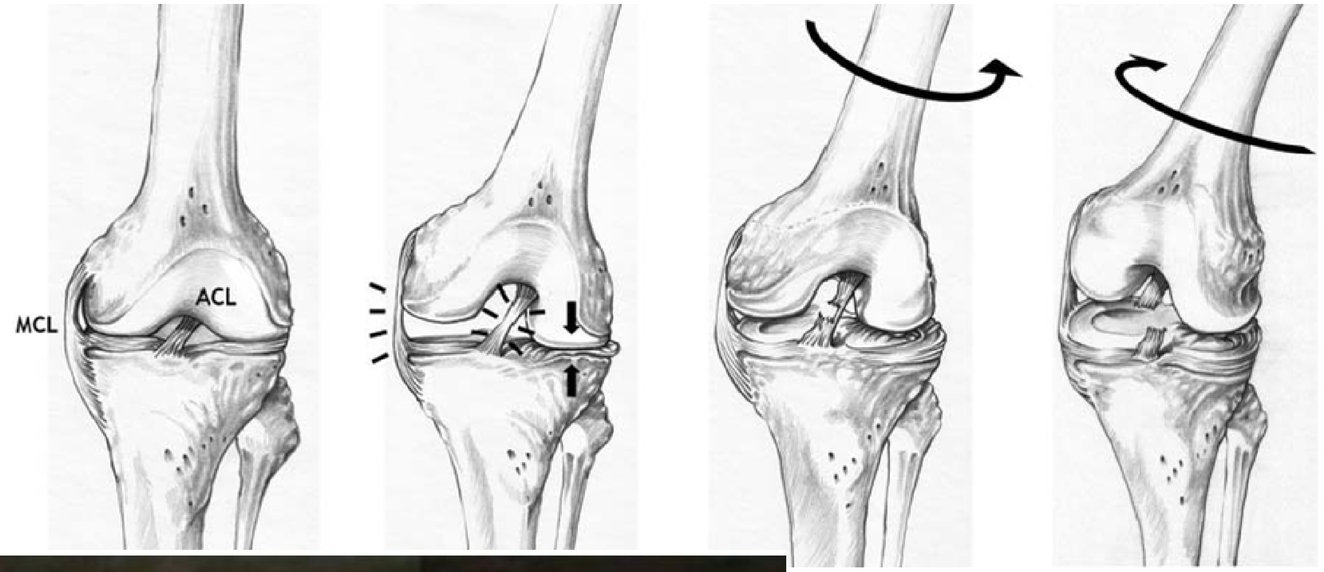
ACL Anatomy and Biomechanics

- Rotational Stability
  - Pivot Shift



ACL Tear

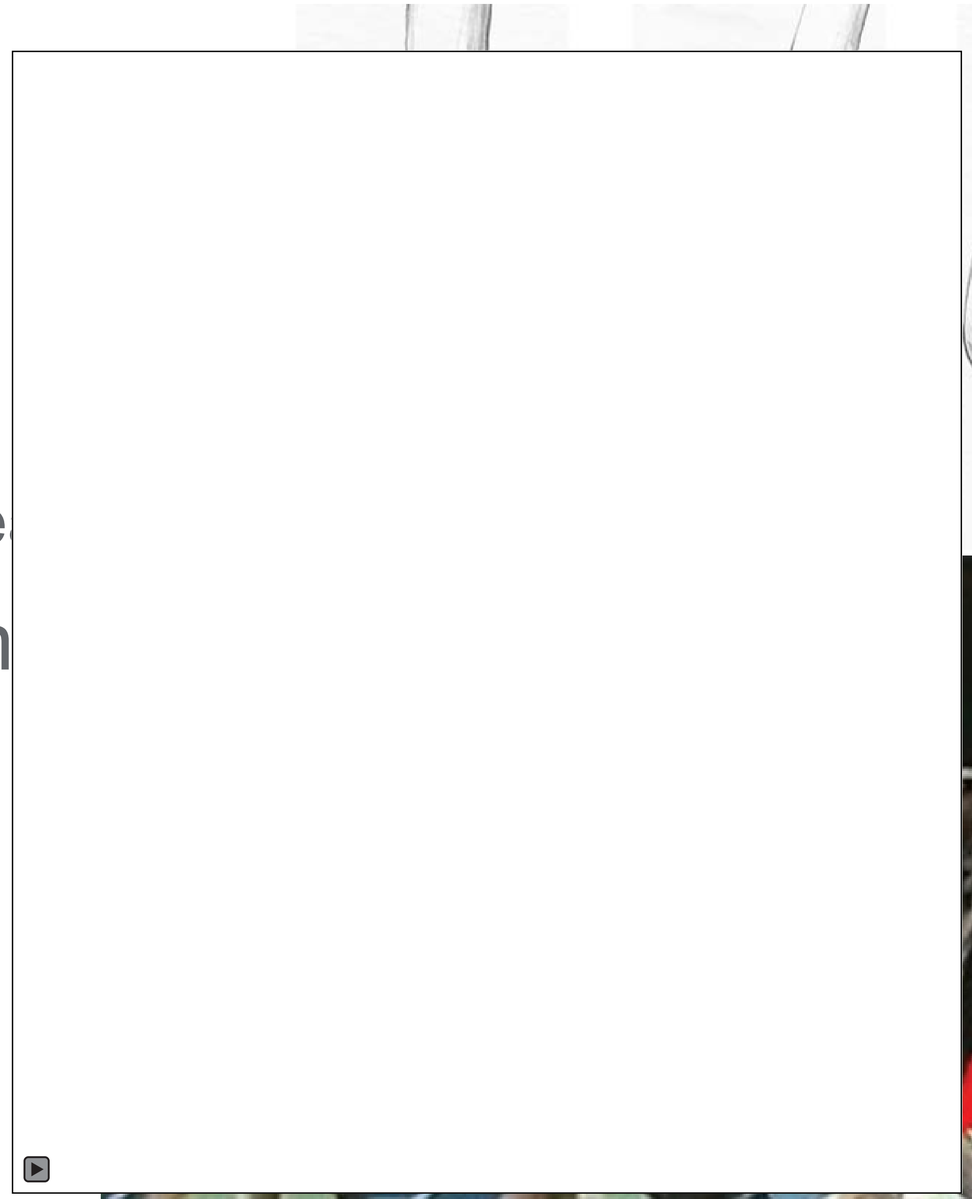
- Incidence
  - ~400,000 ACL reconstructions/year
- Injury mechanism
  - Contact
  - Noncontact

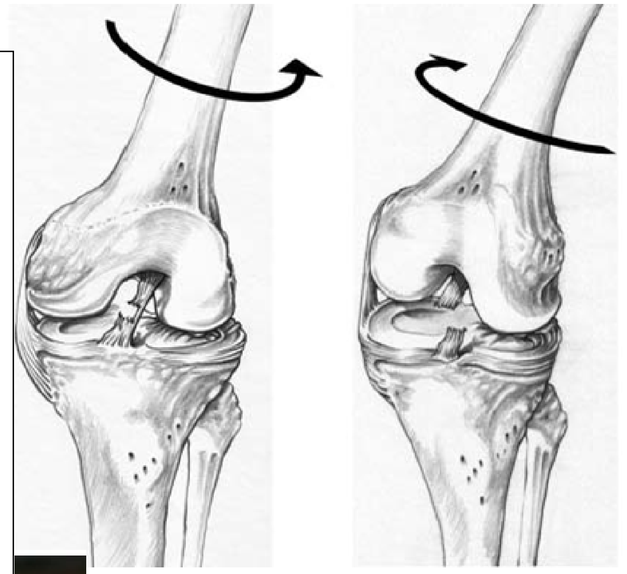


Ortho Nebraska

ACL Tear

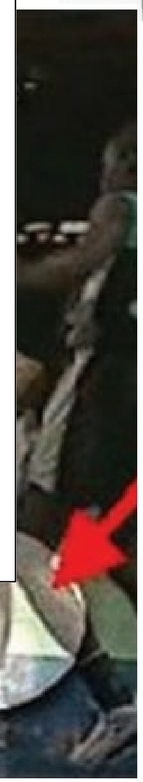
- Incidence
  - ~400,000 ACL reconstructions/ye
- Injury mechanism
  - Contact
  - Noncontact





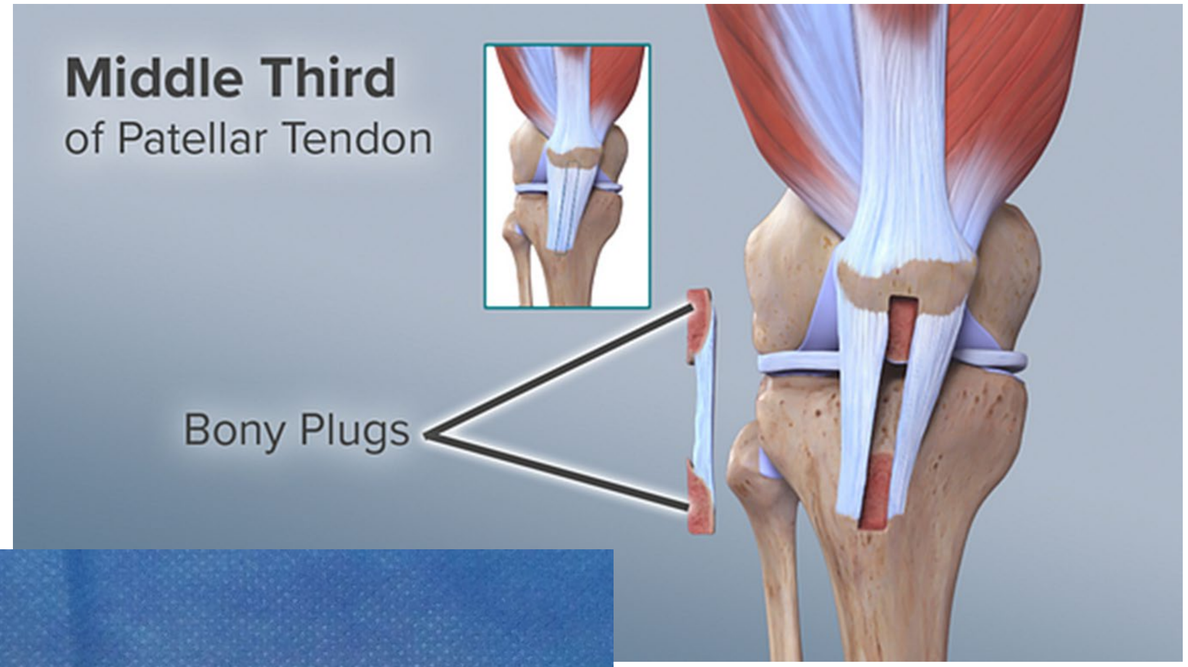
ACL Tear

- Incidence
  - ~400,000 ACL reconstructions/ye
- Injury mechanism
  - Contact
  - Noncontact



ACL Reconstruction - Autografts

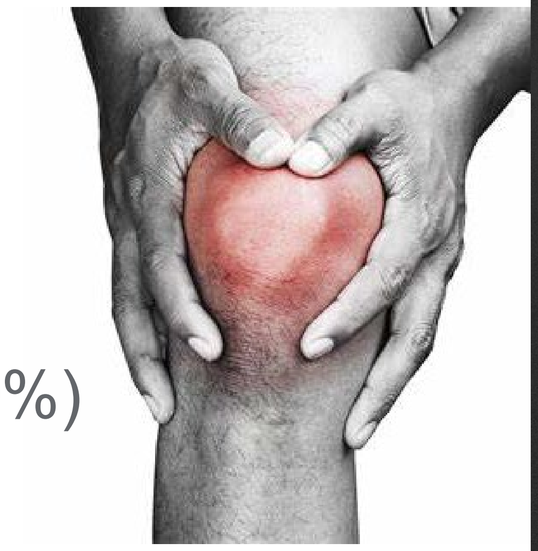
- Patellar Tendon (BTB)
  - "Old school gold standard"
- Advantages
  - Bone to bone healing
  - Good track record
  - More rigid fixation
  - Predictably to obtain appropriate graft diameter



Ortho Nebraska

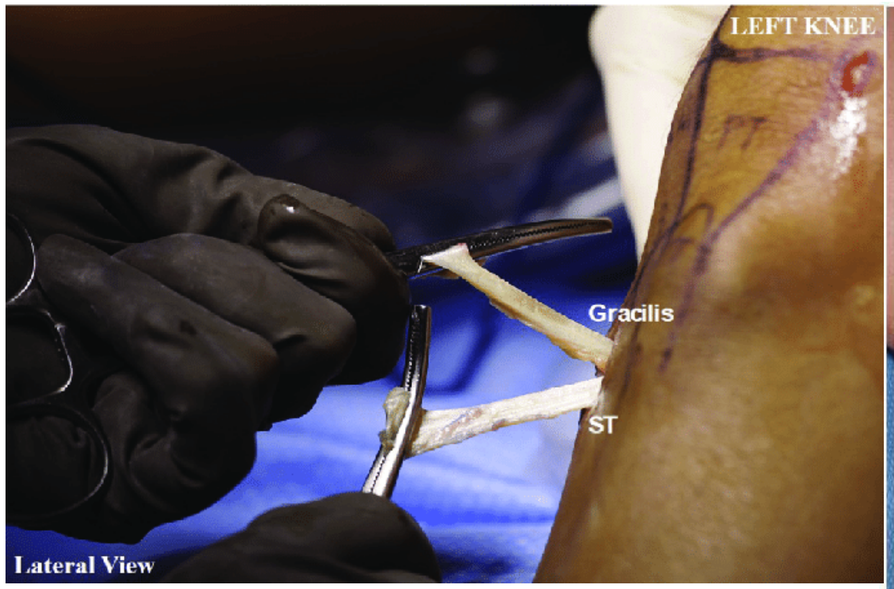
ACL Reconstruction - Autografts

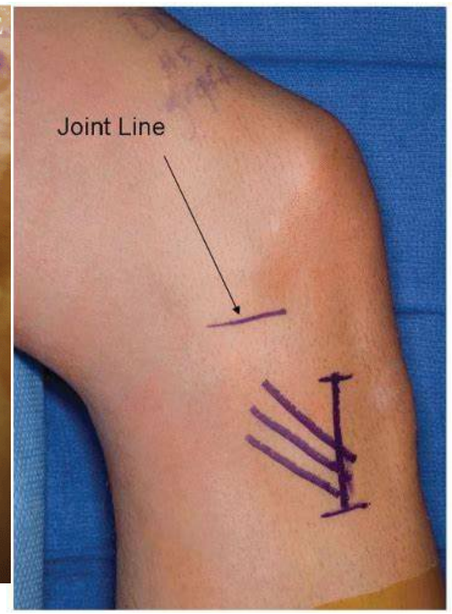
- Patellar Tendon (BTB)
  - “Old school gold standard”
- Disadvantages
  - Chronic anterior knee pain (~25-30%)
  - Patellofemoral DJD
  - Length-tunnel mismatch
  - Patella fracture
  - Growth plate injury in adolescents
  - Patellar tendon rupture

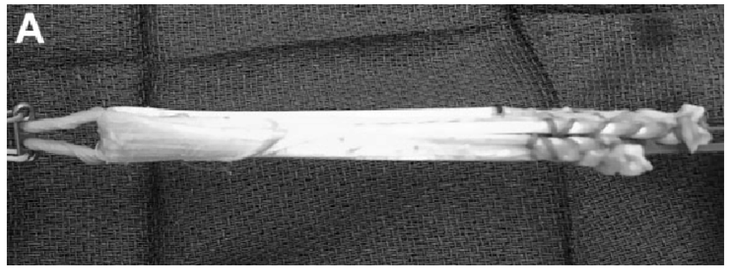


ACL Reconstruction - Autografts

- Hamstring Tendon
- Advantages
  - Smaller incision
  - Good track record
  - Avoid anterior knee pain
  - Less risk patellofemoral DJD
  - Minimal risk of patella fracture
  - Predictable graft length
  - Less risk of premature growth plate closure



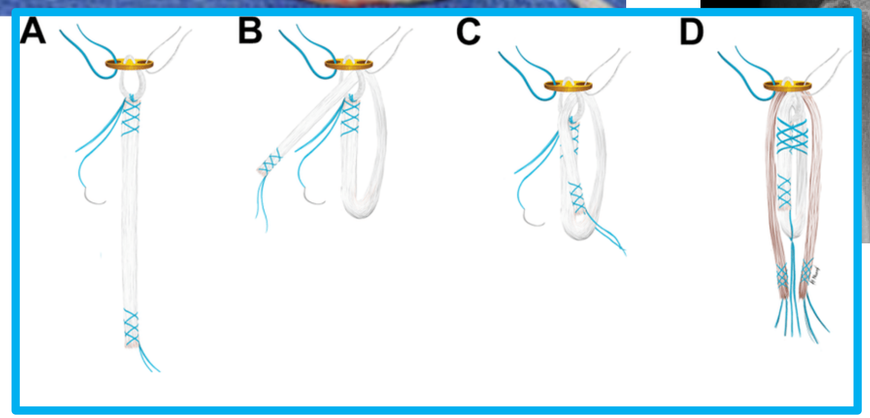


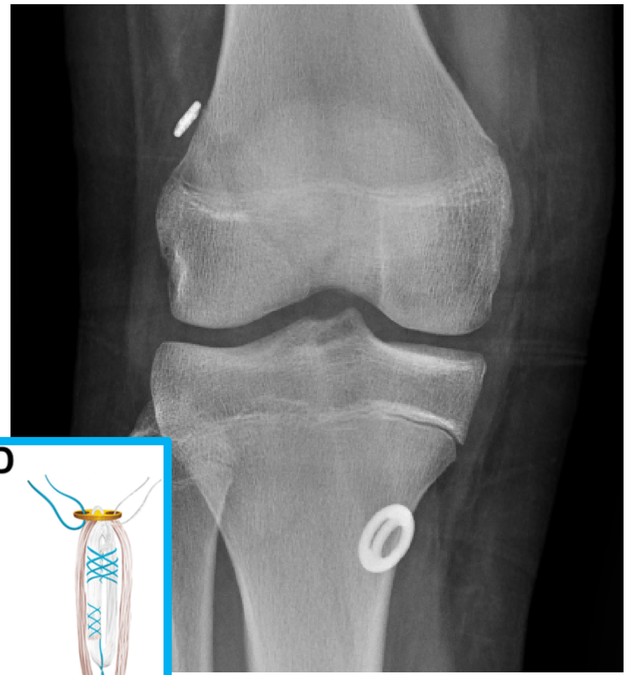


Ortho Nebraska

ACL Reconstruction - Autografts

- Hamstring Tendon
- Disadvantages
  - Unpredictable graft diameter
  - Less rigid fixation
  - Slower healing
  - “Wind shield wiper” effect





Ortho Nebraska

ACL Reconstruction - BTB vs Hamstrings

- AJSM 2003
  - Randomized controlled trial
  - 99 patients
    - 43 patellar tendon
    - 46 hamstring tendon
  - Minimum 21 month F/U
  - No statistically sig difference
    - Clinic or instrumented laxity
    - IKDC scores
    - Lysholm scores
    - Tegner scores

A Prospective Randomized Study of Patellar versus Hamstring Tendon Autografts for Anterior Cruciate Ligament Reconstruction

Kim A. Jansson, MD, Eric Linko, MD, Jerker Sandelin, MD, PhD, and Arsi Harilainen,* MD, PhD

ACL Reconstruction - BTB vs Hamstrings

- AJSM 2006
  - Randomized controlled trial
  - 64 patients
    - 32 patellar tendon
    - 32 hamstring tendon
  - Minimum 5 year F/U
  - No statistically sig difference
    - Clinic or instrumented laxity
    - Anterior knee pain
    - IKDC and Lysholm scores
    - Retear rates (8% vs 7%)
  - Statistically sig difference
    - XR DJD BTB - 50% vs Ham - 17%

A Prospective, Randomized Comparison of Semitendinosus and Gracilis Tendon Versus Patellar Tendon Autografts for Anterior Cruciate Ligament Reconstruction

Five-Year Follow-Up

TABLE 2
Lysholm Knee Scores 5 Years Postoperatively[a]

	Hamstring Tendon Group (n = 28)		Patellar Tendon Group (n = 26)	
Lysholm Score	n	%	n	%
Excellent (95-100)	16	58	11	43
Good (84-94)	9	32	13	50
Fair (65-83)	3	10	2	7
Poor (<65)	0	0	0	0

[a] $P = .888$.

ACL Reconstruction - BTB vs Hamstrings

- AJSM 2007
  - Cohort study (level II)
  - 180 patients
    - 90 patellar tendon
    - 90 hamstring tendon
  - Minimum 10 year F/U
  - No statistically sig difference
    - Clinic or instrumented laxity
    - IKDC and Lysholm scores
    - Retear rates (7.8% vs 13.3%)
  - Statistically sig difference
    - Radiographic DJD (BTB > hamstrings)
    - Harvest site symptoms

A 10-Year Comparison of Anterior Cruciate Ligament Reconstructions with Hamstring Tendon and Patellar Tendon Autograft: A Controlled, Prospective Trial

Leo A. Pinczewski, FRACS, Jeffrey Lyman, MD, Lucy J. Salmon, PhD, Vivianne J. Russell, BSc, Justin Roe, FRACS, and James Linklater, FRANZCR

Figure 6. Percentage of patients from hamstring tendon (HT) and patellar tendon (PT) groups with kneeling pain at each review.

Ortho Nebraska

ACL Reconstruction - BTB vs Hamstrings

- AJSM 2007
  - Cohort study (level II)
  - 180 patients
    - 90 patellar tendon
    - 90 hamstring tendon
  - M
  - N
    - Clinic & instrumented laxity
    - IKDC and Lysholm scores
    - Retear rates (7.8% vs 13.3%)
- Statistically sig difference
  - Radiographic DJD (BTB > hamstrings)
  - Harvest site symptoms

A 10-Year Comparison of Anterior Cruciate Ligament Reconstructions with Hamstring Tendon and Patellar Tendon Autograft: A Controlled, Prospective Trial

Leo A. Pinczewski, FRACS, Jeffrey Lyman, MD, Lucy J. Salmon, PhD, Vivianne J. Russell, BSc, Justin Roe, FRACS, and James Linklater, FRANZCR

Conclusions It is possible to obtain excellent results with both HT and PT autografts. We recommend HT reconstructions to our patients because of decreased harvest-site symptoms and radiographic osteoarthritis.

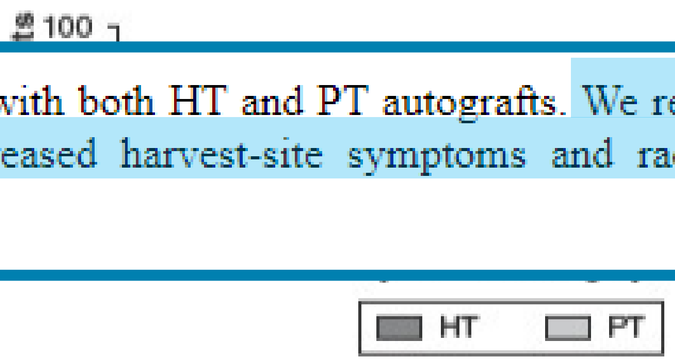


Figure 6. Percentage of patients from hamstring tendon (HT) and patellar tendon (PT) groups with kneeling pain at each review.

Ortho Nebraska

ACL Reconstruction - BTB vs Hamstrings

- AJSM 2013
  - Cohort study (level II)
  - Registry - 12,643 pts
    - 3,428 patellar tendon
    - 9,215 hamstring tendon
  - Mean 4 year F/U
  - Overall revision rate - 4.2%
  - Statistically sig difference
    - Retear rates

	PT	Hamstring
Overall	2.1%	5.1%

5-in-5

Increased Risk of Revision With Hamstring Tendon Grafts Compared With Patellar Tendon Grafts After Anterior Cruciate Ligament Reconstruction

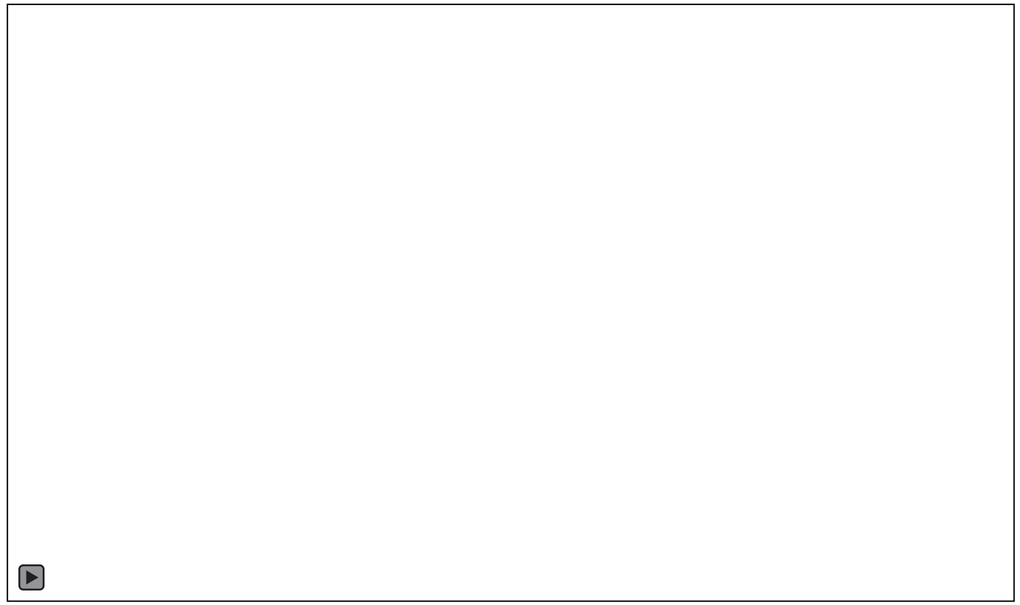
A Study of 12,643 Patients From the Norwegian Cruciate Ligament Registry, 2004-2012

Andreas Persson,*† MD, Knut Fjeldsgaard,† MD, Jan-Erik Gjertsen,† MD, PhD, Asle B. Kjellsen,† MD, Lars Engebretsen,‡§ MD, PhD, Randi M. Hole,† MD, and Jonas M. Fevang,† MD, PhD
Investigation performed at the Department of Orthopaedic Surgery, Haukeland University Hospital, Bergen, Norway

Ortho Nebraska

ACL Reconstruction - My Training 2013-2014

- Summary of my knowledge
- Hamstring Tendon
  - Adolescents with open growth plates
  - Non-contact athletes
  - “Older” patients (>25 yo, not participating in contact sports)
  - Those needing/wanting to avoid anterior knee pain
- Patellar Tendon
  - Competitive and/or contact athletes at or near skeletal maturity
  - Prefer lower risk of graft rupture vs anterior knee pain



ACL Reconstruction - BTB vs Hamstrings

- AJSM 2013
  - Cohort study (level II)
  - Registry - 12,643 pts
    - 3,428 patellar tendon
    - 9,215 hamstring tendon
  - Mean 4 year F/U
  - Overall revision rate - 4.2%
  - Statistically sig difference
    - Retear rates

Increased Risk of Revision With Hamstring Tendon Grafts Compared With Patellar Tendon Grafts After Anterior Cruciate Ligament Reconstruction

A Study of 12,643 Patients From the Norwegian Cruciate Ligament Registry, 2004-2012

Andreas Persson,*† MD, Knut Fjeldsgaard,† MD, Jan-Erik Gjertsen,† MD, PhD, Asle B. Kjellsen,† MD, Lars Engebretsen,‡§ MD, PhD, Randi M. Hole,† MD, and Jonas M. Fevang,† MD, PhD
Investigation performed at the Department of Orthopaedic Surgery, Haukeland University Hospital, Bergen, Norway

	PT	Hamstring
Overall	2.1%	5.1%
Youngest group (15-19 yo)	3.5%	9.5%

ACL Reconstruction - BTB vs Hamstrings

- AJSM 2017
  - Cohort study (level III)
  - 139 patients
    - 60 patellar tendon
    - 79 hamstring tendon
  - Median 6 year F/U
  - Mean age - 16.9 yo

AOSSM 2017 Annual Meeting

Increased Risk of Graft Failure after ACL Reconstruction in Young Female Athletes with Hamstring Grafts

Mark V. Paterno, PhD, PT[1], Staci Thomas, MS[2], Timothy E. Hewett, PhD, FACSM[3], Robert A. Magnussen, MD[4], Laura Schmitt, PhD, PT[5]

[1]Sports Medicine Biodynamics Ctr, Cincinnati, OH, USA, [2]Cincinnati Children's Hospital, Milford, OH, USA, [3]Mayo Clinic, Rochester, MN, USA, [4]The Ohio State Univ. Sports Medicine Ctr., Columbus, OH, USA, [5]The Ohio State University, Columbus, OH, USA

Table 1: Distribution of 2nd ACL Injury after ACLR and Return to Sport (RTS)

All Subjects (n=139)			
	HS (n=79)	BTB (n=60)	p-value
Ipsilateral (RTS+1 year)	11 (13.9%)	1 (1.7%)	0.013
Ipsilateral (Overall)	14 (17.7%)	2 (3.4%)	0.014
Contralateral (RTS+1 year)	2 (2.2%)	9 (15.0%)	0.010
Contralateral (Overall)	6 (7.6%)	12 (20.0%)	0.031

ACL Reconstruction - BTB vs Hamstrings

- AJSM 2017
  - Cohort study (level III)
  - 139 patients
    - 60 patellar tendon
    - 79 hamstring tendon
  - Median 6 year F/U
  - Mean age - 16.9 yo

AOSSM 2017 Annual Meeting

Increased Risk of Graft Failure after ACL Reconstruction in Young Female Athletes with Hamstring Grafts

Mark V. Paterno, PhD, PT[1], Staci Thomas, MS[2], Timothy E. Hewett, PhD, FACSM[3], Robert A. Magnussen, MD[4], Laura Schmitt, PhD, PT[5]

[1]Sports Medicine Biodynamics Ctr, Cincinnati, OH, USA, [2]Cincinnati Children's Hospital, Milford, OH, USA, [3]Mayo Clinic, Rochester, MN, USA, [4]The Ohio State Univ. Sports Medicine Ctr., Columbus, OH, USA, [5]The Ohio State University, Columbus, OH, USA

~5-6x risk

Table 1: Distribution of 2nd ACL Injury after ACLR and Return

All Subjects (n=139)			
	HS (n=79)	BTB (n=60)	p-value
Ipsilateral (RTS+1 year)	11 (13.9%)	1 (1.7%)	0.013
Ipsilateral (Overall)	14 (17.7%)	2 (3.4%)	0.014
Contralateral (RTS+1 year)	2 (2.2%)	9 (15.0%)	0.010
Contralateral (Overall)	6 (7.6%)	12 (20.0%)	0.031

Ortho Nebraska

ACL Reconstruction - BTB vs Hamstrings

- AJSM 2019
  - Cohort study (level III)
  - 256 female patients
    - 175 patellar tendon
    - 81 hamstring tendon
  - Minimum 2 year F/U

Anterior Cruciate Ligament Reconstruction in Young Female Athletes

Patellar Versus Hamstring Tendon Autografts

Hytham S. Salem,* MD, Vahe Varzhapetyan,* MD, Nimit Patel,* MD,
Christopher C. Dodson,* MD, Fotios P. Tjoumakaris,* MD, and Kevin B. Freedman,*† MD
Investigation performed at Rothman Institute, Philadelphia, Pennsylvania, USA

TABLE 2
Reinjuries[a]

	BTB (n = 175)	HS (n = 81)	*P* Value
Graft rupture	12 (6.9)	11 (13.6)	.09
Femoral tunnel drilling technique			.75
Anteromedial	7 of 112 (6.25)	10 of 70 (14.29)	
Transtibial	5 of 63 (7.94)	1 of 11 (9.09)	
Contralateral ACL rupture	13 (7.4)	5 (6.2)	.72
Meniscal tear	2 (1.1)	3 (3.7)	.17
Collateral ligament injury	2 (1.1)	1 (1.2)	.95

ACL Reconstruction - BTB vs Hamstrings

- AJSM 2019
  - Cohort study (level III)
  - 256 female patients
    - 175 patellar tendon
    - 81 hamstring tendon
  - Minimum 2 year F/U

Anterior Cruciate Ligament Reconstruction in Young Female Athletes

Patellar Versus Hamstring Tendon Autografts

Hytham S. Salem,* MD, Vahe Varzhapetyan,* MD, Nimit Patel,* MD,
Christopher C. Dodson,* MD, Fotios P. Tjoumakaris,* MD, and Kevin B. Freedman,*† MD
Investigation performed at Rothman Institute, Philadelphia, Pennsylvania, USA

TABLE 3
Reinjuries by Age Group[a]

Age: Injury	BTB	HS	*P* Value
15-20 y	140	63	
Graft rupture	9 (6.4)	11 (17.5)	**.02**
Contralateral ACL rupture	12 (8.6)	5 (7.9)	.89
21-25 y	35	18	
Graft rupture	3 (8.6)	0	.21
Contralateral ACL rupture	1 (2.9)	0	.47

ACL Reconstruction - BTB vs Hamstrings

- AJSM 2019
  - Cohort study (level III)
  - 256 female patients
    - 175 patellar tendon
    - 81 hamstring tendon
  - Minimum 2 year F/U

Anterior Cruciate Ligament Reconstruction in Young Female Athletes

Patellar Vers s Ham ng Tendon Autografts

Hytha m MD, Nimit Patel,* MD,
Christop makaris,* MD, and Kevin B. Freedman,*† MD
lia, Pennsylvania, USA

~3x risk

TABLE 3
Reinjuries by Age Group[a]

Age: Injury	BTB	HS	*P* Value
15-20 y	140	63	
Graft rupture	9 (6.4)	11 (17.5)	**.02**
Contralateral ACL rupture	12 (8.6)	5 (7.9)	.89
21-25 y	35	18	
Graft rupture	3 (8.6)	0	.21
Contralateral ACL rupture	1 (2.9)	0	.47

Vol. 48 No. 2 February 2020

The American Journal of Sports Medicine

Medical Publishing Group
American Orthopaedic Society for Sports Medicine®

AJSM Table of Contents

Articles

Ortho Nebraska

ACL Reconstruction - MOON Group

- AJSM 2020
  - Cohort study (level II)
  - 839 patients
    - 492 patellar tendon
    - 278 hamstring tendon
- Minimum 6 year F/U
- Predictors of re-rupture
  - Young age
  - High-grade preop knee laxity
  - Use of hamstring autograft

Anterior Cruciate Ligament Reconstruction in High School and College-Aged Athletes: Does Autograft Choice Influence Anterior Cruciate Ligament Revision Rates?

	Ipsilateral Knee	
	OR (95% CI)	*P* Value
Age, y	0.84 (0.74-0.96)	**.009**
High-grade knee laxity		
No		
Yes	2.35 (1.40-3.93)	**.001**
Autograft type		
BTB		
Hamstring	2.12 (1.27-3.54)	**.004**

ACL Reconstruction - MOON Group

- AJSM 2020
  - Cohort study (level II)
  - 839 patients
    - 492 patellar t
    - 278
  - Minimum
  - Predictor
    - Young age
    - High-grade preop
    - Use of hamstring autograf

With hamstring autograft:
2.1 increased odds of re-rupture

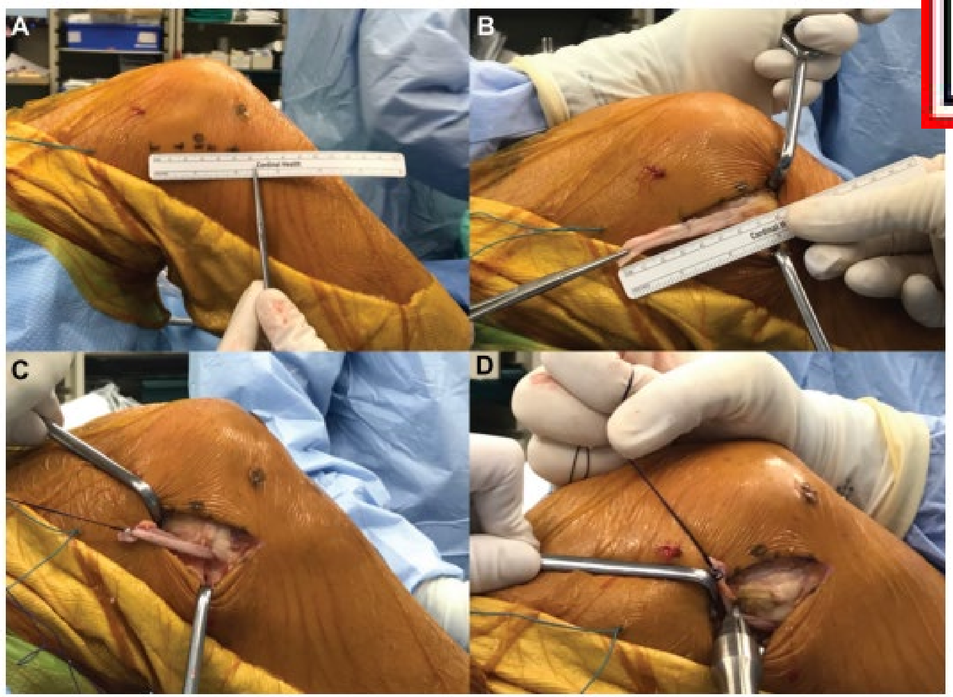
Anterior Cruciate Ligament Reconstruction in High School and College-Aged Athletes: Does Autograft Choice Influence Anterior Cruciate Ligament Revision Rates?

	Ipsilateral Knee	
	OR (95% CI)	*P* Value
	(0.74-0.96)	.009
	2.35 (1.40-3.93)	.001
	2.12 (1.27-3.54)	.004

Ortho Nebraska

ACL Reconstruction - Stability Trial

- Lateral Extra-articular Tenodesis (LET)
  - Lateral incision
  - Take a central slip of the iliotibial band
  - Tunnel this portion of the IT band deep to the femoral attachment of the lateral collateral ligament
  - Fixation near/at origin of the anterolateral ligament (ALL)



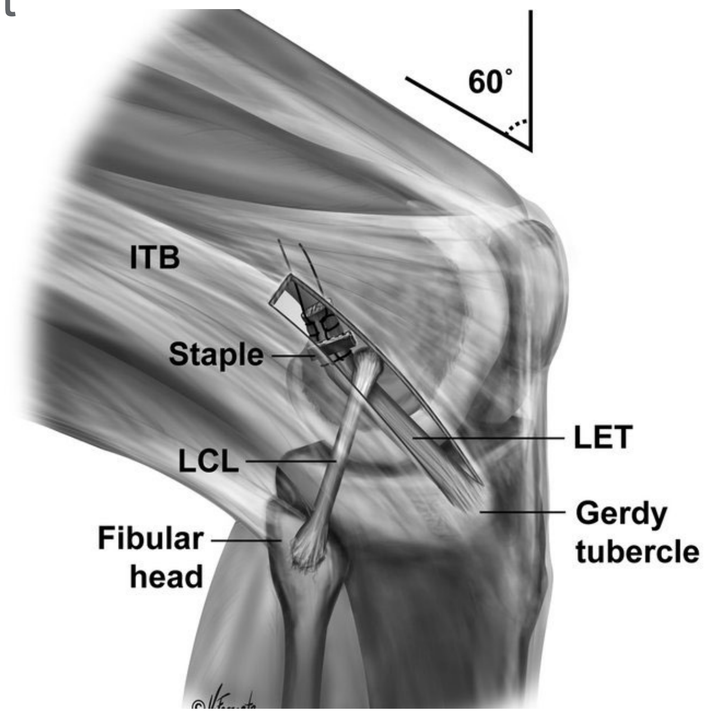
Ortho Nebraska

ACL Reconstruction - Stability Trial

- AJSM 2020
  - Randomized controlled trial
  - High-risk for retear (2 of 3 factors)
    - Grade ≥ 2 pivot shift
    - Desire to return to high-risk sport
    - Generalized ligament laxity
- 618 patients (<25 yo)
  - 298 ACLR-hamstrings
  - 291 ACLR-hamstrings with LET
- Minimum 2 year F/U

Lateral Extra-articular Tenodesis Reduces Failure of Hamstring Tendon Autograft Anterior Cruciate Ligament Reconstruction

2-Year Outcomes From the STABILITY Study Randomized Clinical Trial



ACL Reconstruction - Stability Trial

- AJSM 2020
  - Randomized controlled trial
  - High-risk for retear (2 of 3 factors)
  - Statistically sig difference
    - Retear rates (11% vs 4%)

Lateral Extra-articular Tenodesis Reduces Failure of Hamstring Tendon Autograft Anterior Cruciate Ligament Reconstruction

2-Year Outcomes From the STABILITY Study Randomized Clinical Trial

B

Study or Subgroup	ACLR + LET Events	Total	ACLR alone Events	Total	Weight	Risk Ratio M-H, Fixed, 95% CI
14 to 19 yo	10	171	28	187	81.2%	0.39 [0.20, 0.78]
20 to 25 yo	1	120	6	112	18.8%	0.16 [0.02, 1.27]
Total (95% CI)		**291**		**299**	**100.0%**	**0.35 [0.18, 0.67]**
Total events	11		34			

Heterogeneity: $Chi^2 = 0.67$, $df = 1$ ($P = 0.41$); $I^2 = 0\%$

Test for overall effect: $Z = 3.19$ ($P = 0.001$)

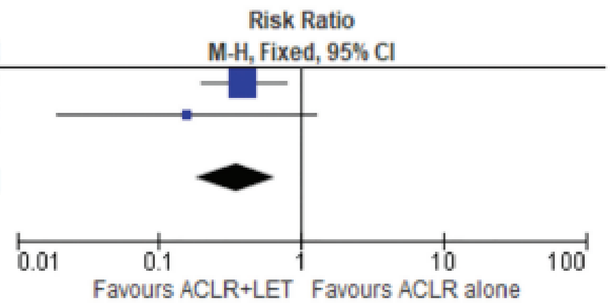


Figure 4. Forest plots showing (A) clinical failure by age 14-19 years and 20-25 years and (B) graft failure by age 14-19 years and 20-25 years. ACLR, anterior cruciate ligament reconstruction; LET, lateral extra-articular tenodesis; M-H, Mantel-Haenszel.

ACL Reconstruction - Stability Trial

- AJSM 2020
  - Randomized controlled trial
  - High-risk for retear (2 of 3 factors)
  - Statistically sig difference
    - Retear rates (11% vs 4%)
    - Better IKDC and KOOS scores in ACLR alone group at 3 and 6 months
    - Painful hardware in ACLR + LET group
    - ACLR + LET had more pain at 3 months post-op
    - Increase in time to RTS in ALCR+LET

Lateral Extra-articular Tenodesis Reduces Failure of Hamstring Tendon Autograft Anterior Cruciate Ligament Reconstruction

TABLE 3
LET-Related Adverse Events[a]

Complication/Adverse Event	Frequency, n (%)
Intraoperative	
LET graft difficulties at surgery	6 (2)
Damage to FCL attachment (repaired)	1 (<1)
Postoperative	
Hematoma over LET site	3 (<1)
ITB snapping	2 (<1)
LET hardware removal	10 (3)
Overconstrained lateral compartment	1 (<1)

[a]FCL, fibular collateral ligament; ITB, iliotibial band; LET, lateral extra-articular tenodesis.

ACL Reconstruction - Stability Trial

- AJSM 2020
  - Randomized controlled trial
  - High-risk
  - Statistica
    - Retear ra
    - Better IK
      ACLR al
    - Painful h
    - ACLR +
      months p
    - Increase

Lateral Extra-articular Tenodesis Reduces Failure of Hamstring Tendon Autograft Anterior Cruciate Ligament Reconstruction

Hamstring ACL reconstruction
+
Lateral Extra-articular Tenodesis
in these high-risk patients

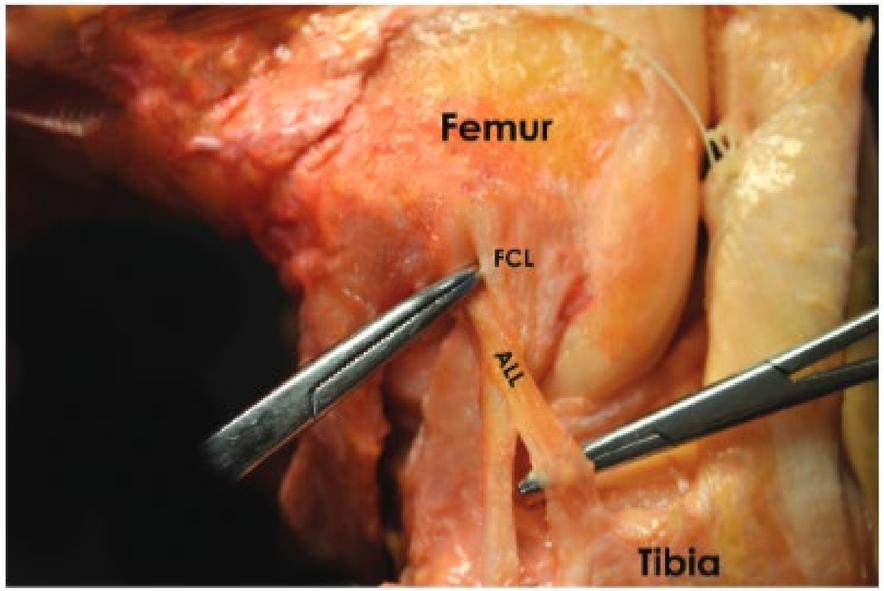
ts[a]

Frequency, n (%)
6 (2)
1 (<1)
3 (<1)
2 (<1)
10 (3)
1 (<1)

ial band; LET, lat-

Lateral Extra-articular Tenodesis Concerns

- Overconstraint?



Winner of the 2016 Excellence In Research Award

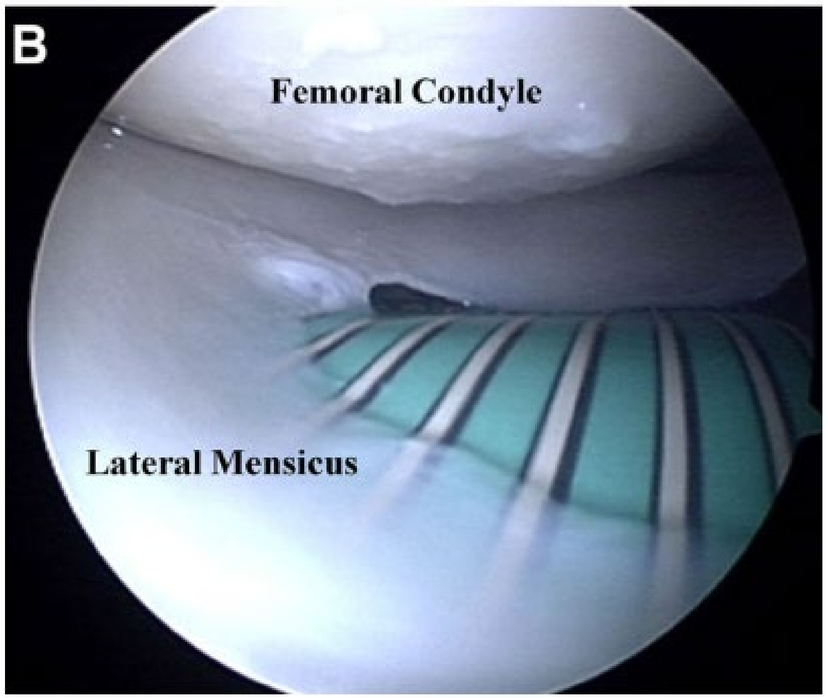
Anatomic Anterolateral Ligament Reconstruction of the Knee Leads to Overconstraint at Any Fixation Angle

Jason M. Schon,* BS, Gilbert Moatshe,*†‡ MD, Alex W. Brady,* MSc, Raphael Serra Cruz,*§ MD, Jorge Chahla,* MD, Grant J. Dornan,* MSc, Travis Lee Turnbull,* PhD, Lars Engebretsen,†‖ MD, PhD, and Robert F. LaPrade,*¶# MD, PhD
Investigation performed at the Department of Biomedical Engineering of the Steadman Philippon Research Institute, Vail, Colorado, USA

Ortho Nebraska

Lateral Extra-articular Tenodesis Concerns

- Overconstraint?



Lateral Compartment Contact Pressures Do Not Increase After Lateral Extra-articular Tenodesis and Subsequent Subtotal Meniscectomy

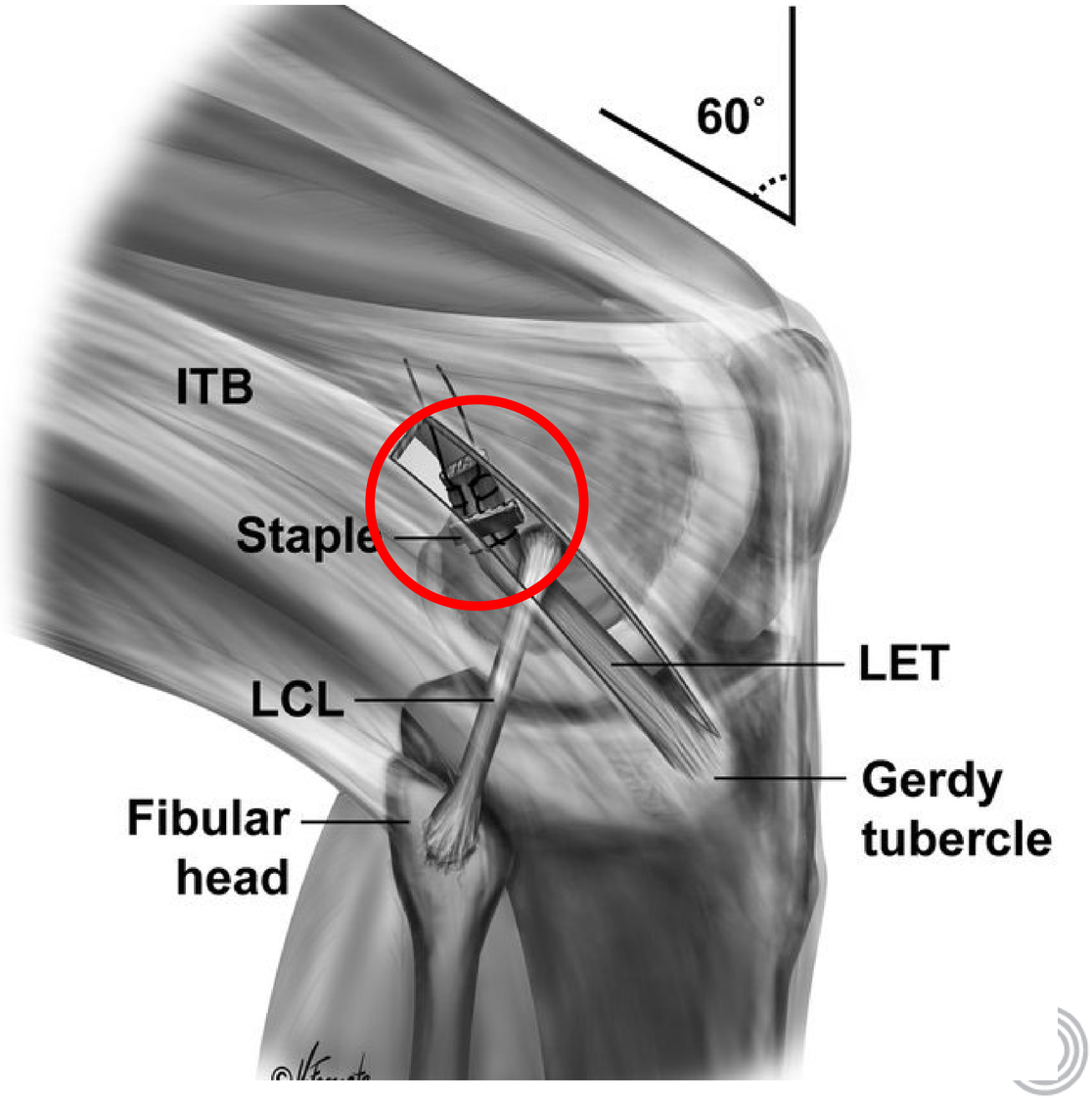
Tomoyuki Shimakawa,* MD, Timothy A. Burkhart,†‡ PhD, Cynthia E. Dunning,‡ PhD, PEng, Ryan M. Degen,* MD, and Alan M. Getgood,*§ MPhil, MD, FRCS(Tr&Orth)

Investigation performed at Western University, London, Ontario, Canada

Ortho Nebraska

Lateral Extra-articular Tenodesis Concerns

- Overconstraint?
- Hardware complications

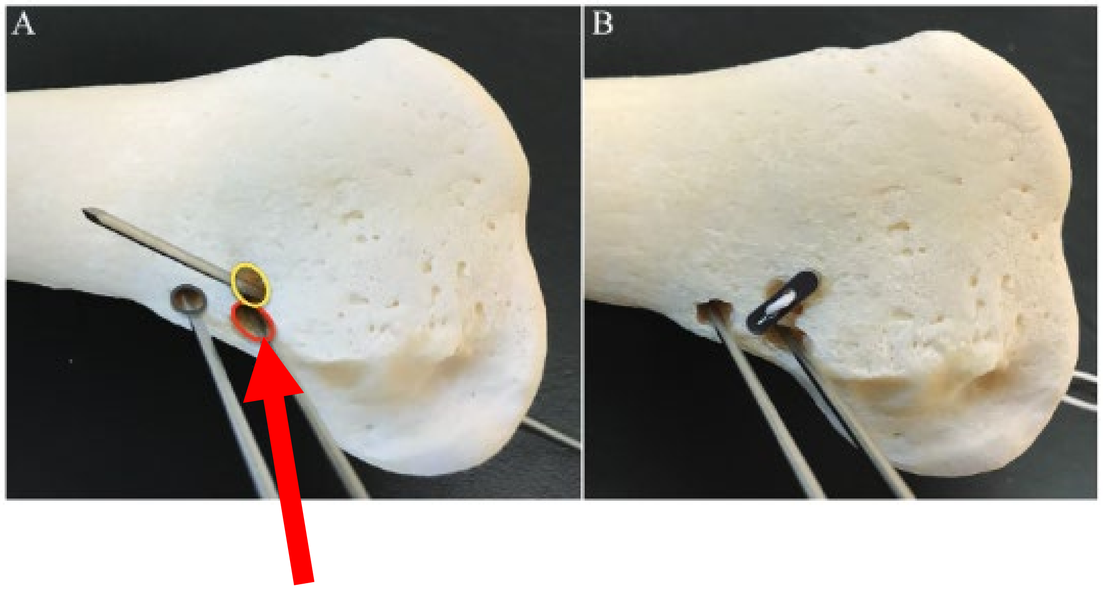


Lateral Extra-articular Tenodesis Concerns

- Overconstraint?
- Hardware complications
- Cost $$$$

Lateral Extra-articular Tenodesis Concerns

- Overconstraint?
- Hardware complications
- Cost $$$$
- Tunnel Convergence



High Risk of Tunnel Convergence in Combined Anterior Cruciate Ligament Reconstruction and Lateral Extra-articular Tenodesis

Vera Jaecker,* MD, Philip Ibe,† MD, Christoph H. Endler,‡ MD, Thomas R. Pfeiffer,* MD, Mirco Herbort,§ MD, and Sven Shafizadeh,‖¶ MD
Investigation performed at the Department of Orthopaedic Surgery and Sports Traumatology, Witten/Herdecke University, Sana Medical Centre Cologne, Köln, Germany

Ortho Nebraska

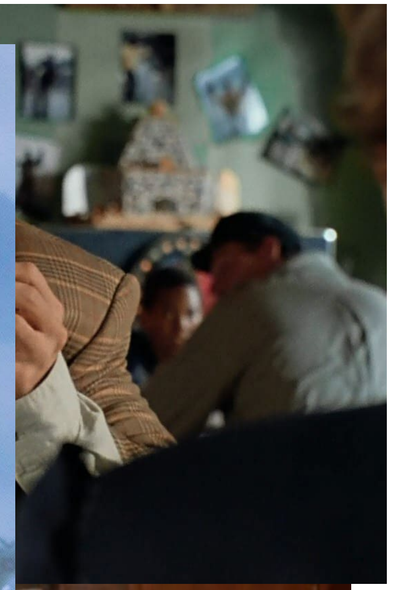
Choices . . .

- If I continue to use hamstring autograft:
  - Need to perform LET in high risk patients to reduce retear rates
  - Yet still significant concerns about LET
- If I begin to use more BTB:
  - Risk of anterior knee pain and early DJD
  - Injury to growth plates in young adolescents

Reconstruction in High-Risk Patients

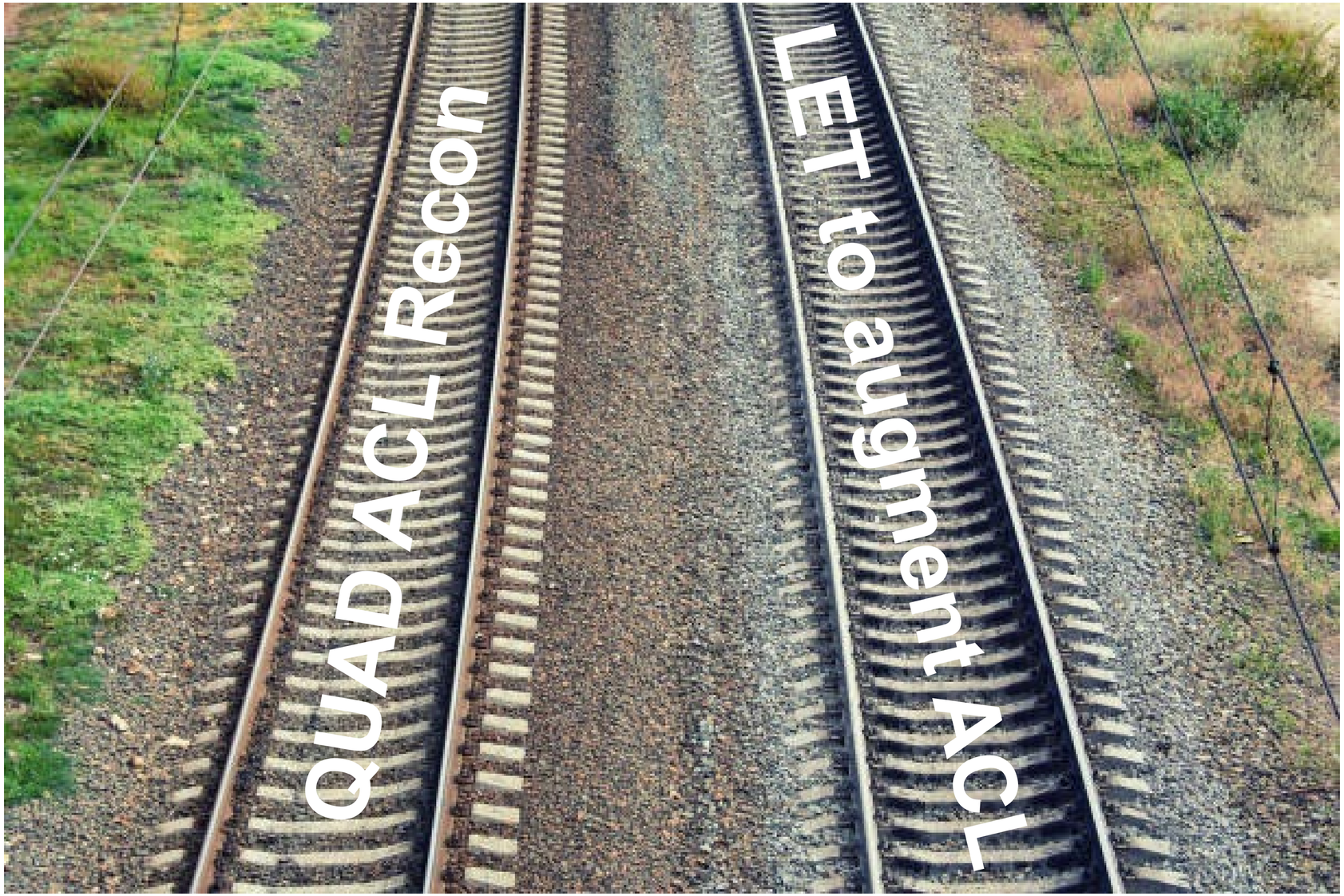
Choices

- If I continue to u
  hamstring autog
  - Need to perform L
    risk patients to red
    rates
  - Yet still significant
    about LET
- If I begin to use
  - Risk of anterior kn
    early DJD
  - Injury to growth pla
    adolescents



Ortho Nebraska

Parallel Tracks



Ortho Nebraska

Quadriceps Tendon Autograft

- Originally described by Marshall et al CORR 1979

The Anterior Cruciate Ligament:
A Technique of Repair and Reconstruction

JOHN L. MARSHALL, D.V.M., M.D., F.A.C.S.,* RUSSELL F. WARREN, M.D., F.A.C.S.,**
THOMAS L. WICKIEWICZ, M.D.,† AND BRUCE REIDER, M.D.‡

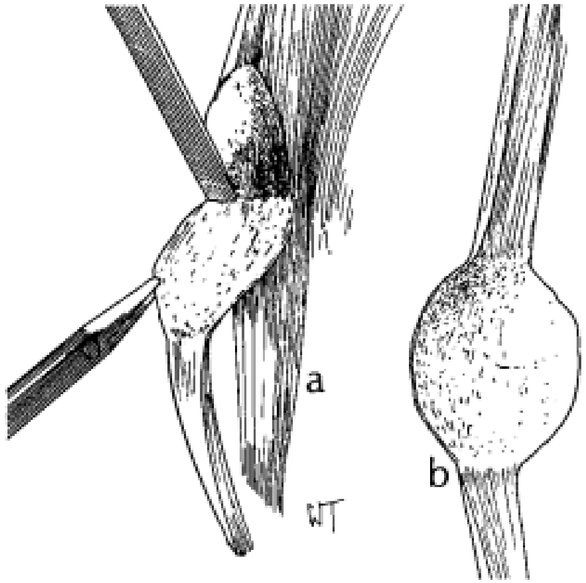
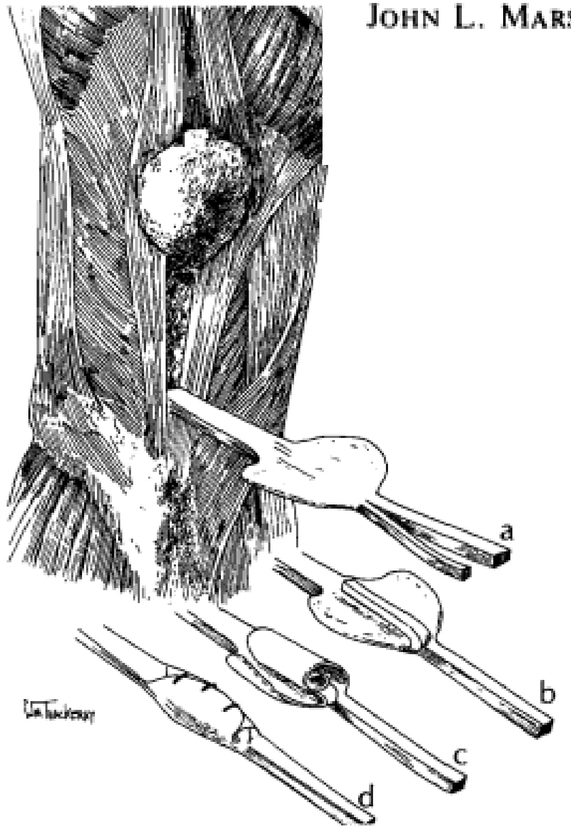
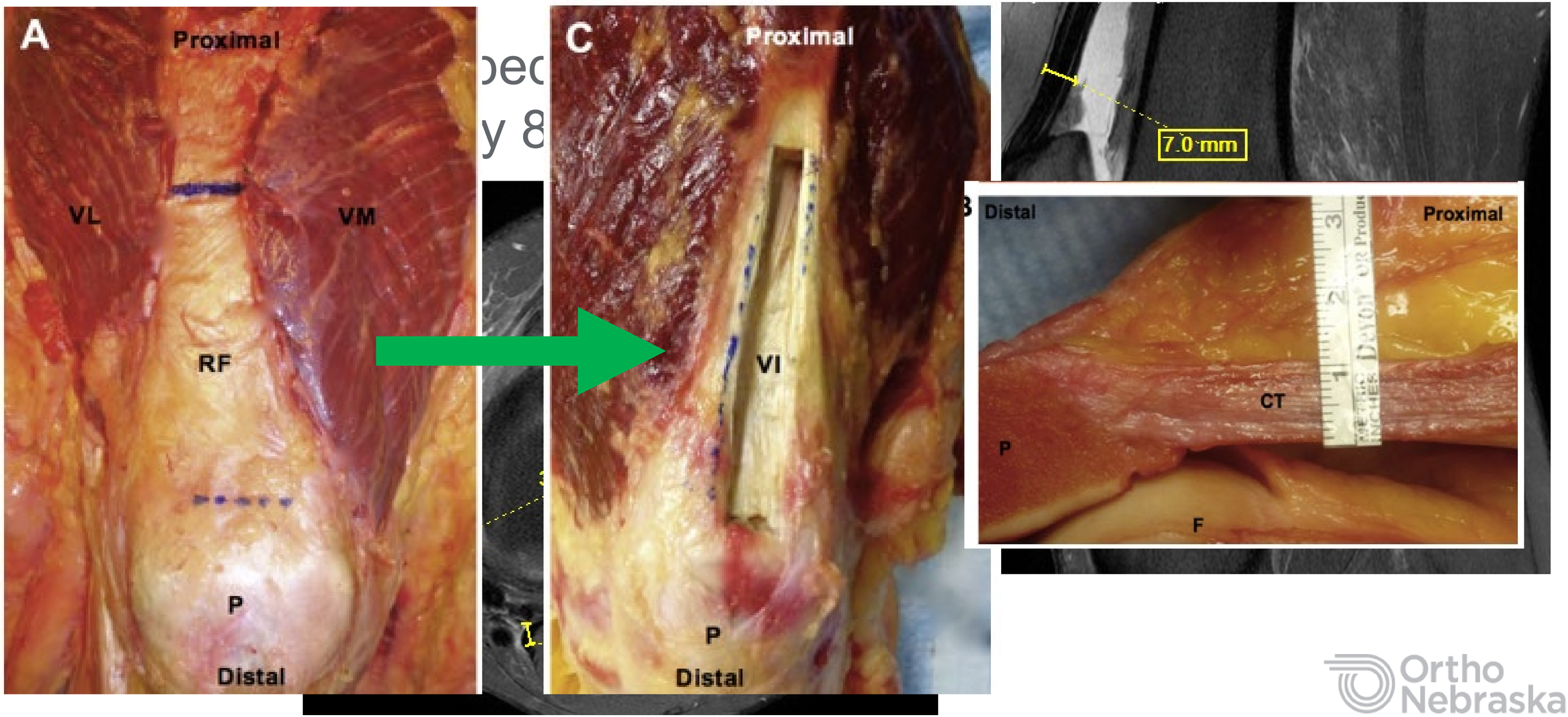


FIG. 6. The graft is harvested from the entire patellar surface. The prepatellar portion of the graft is the part that will be intraarticular in location at the completion of the repair.



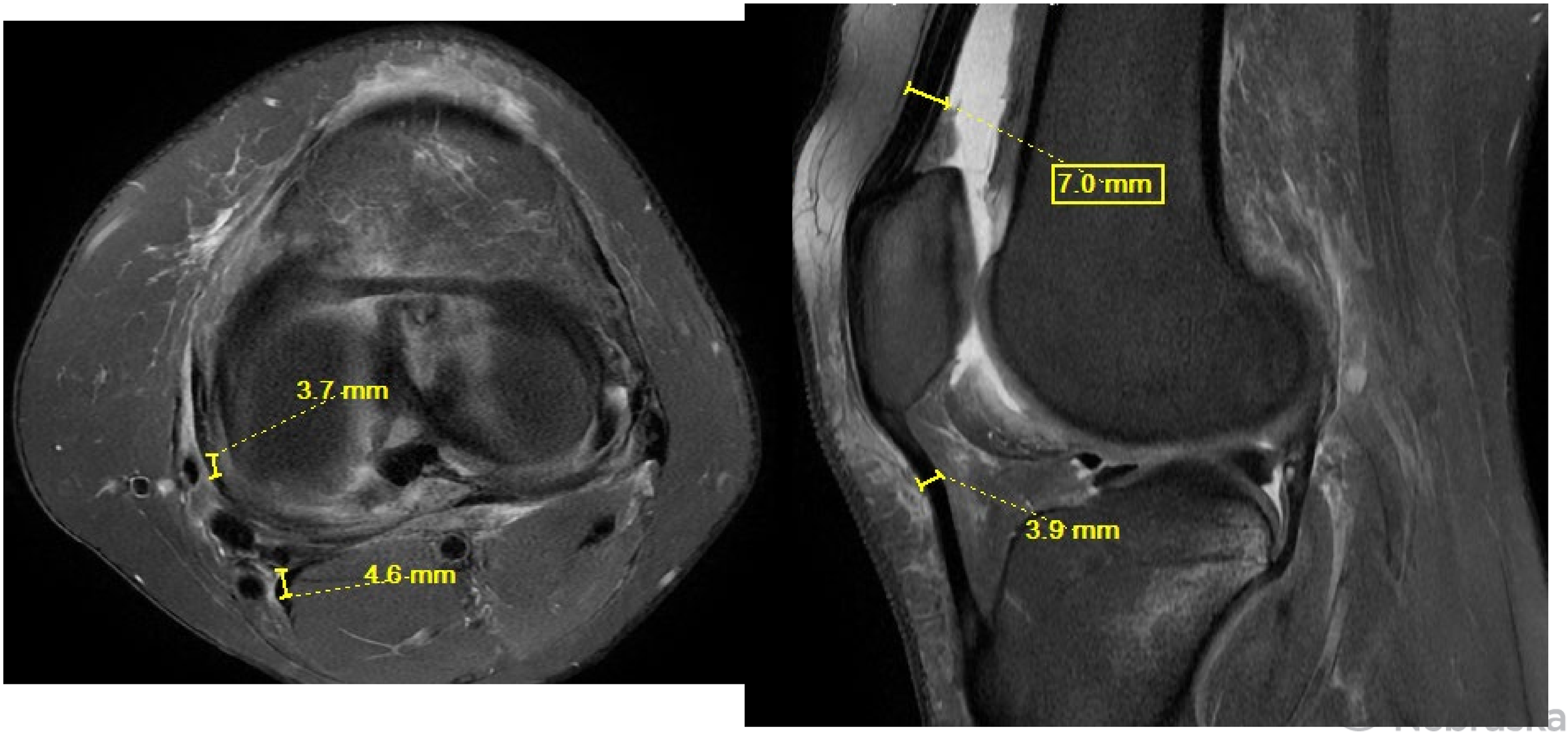
Ortho Nebraska

Quadriceps Tendon Autograft



Ortho Nebraska

Quadriceps Tendon Autograft



Quadriceps Tendon Autograft

- Biomechanical data

Contemporary Graft Options in Anterior Cruciate Ligament Reconstruction

Nima Mehran, MD, MS,* Jack G. Skendzel, MD,† Bryson P. Lesniak, MD,† and Asheesh Bedi, MD†,‡

Table 1 Common ACL Grafts, Including Data from West and Harner[4]

Tissue	Ultimate Tensile Load (N)	Stiffness (N/mm)	Cross-Sectional Area (mm²)
Intact ACL	2160	242	44
Bone-patellar-tendon bone (10 mm)	2977	620	35
Quadrupled hamstring	4090	776	53
Quadriceps tendon (10 mm)	2352	463	62

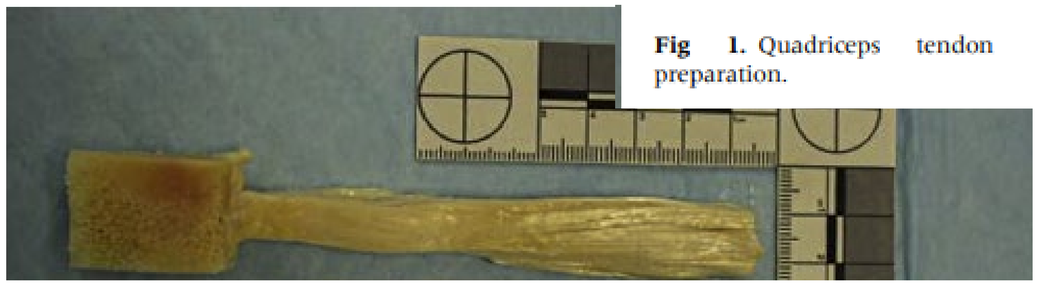
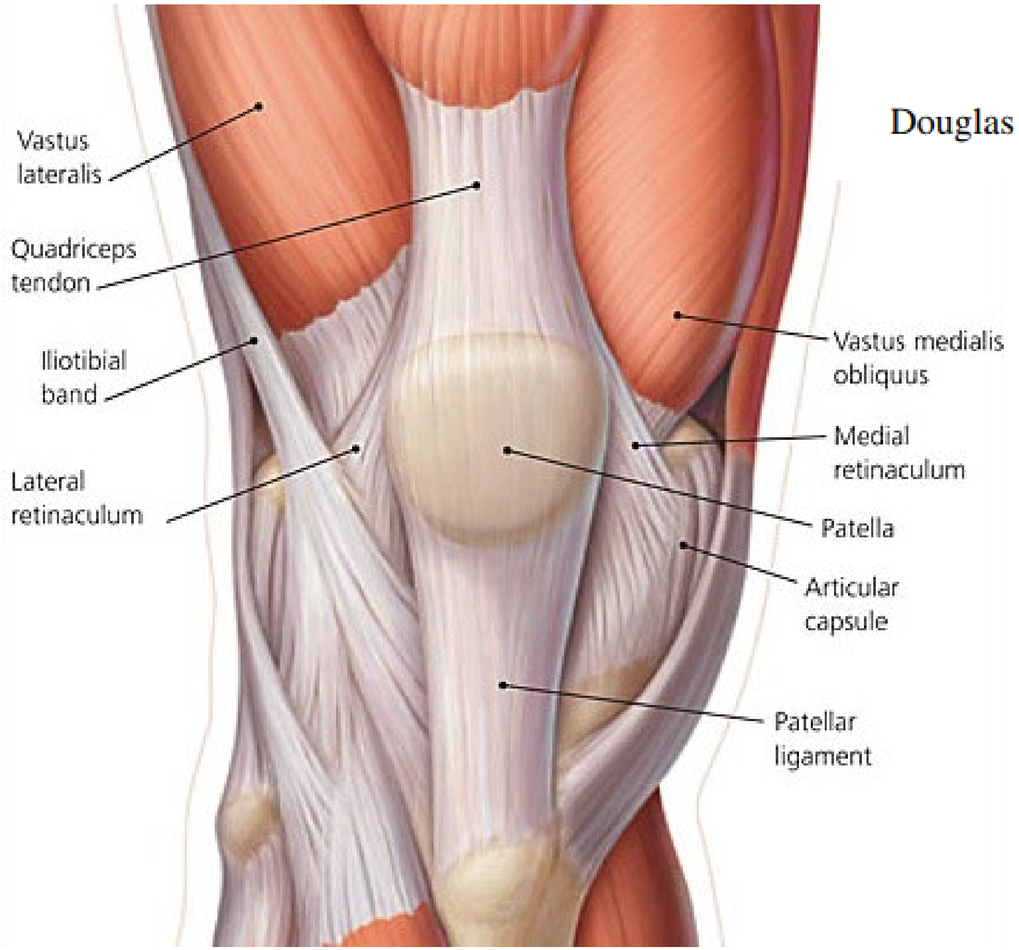


Fig 1. Quadriceps tendon preparation.

Fig 2. Bone–patellar tendon–bone preparation.

Quadriceps Tendon Rupture???

- Arthroscopy 2006

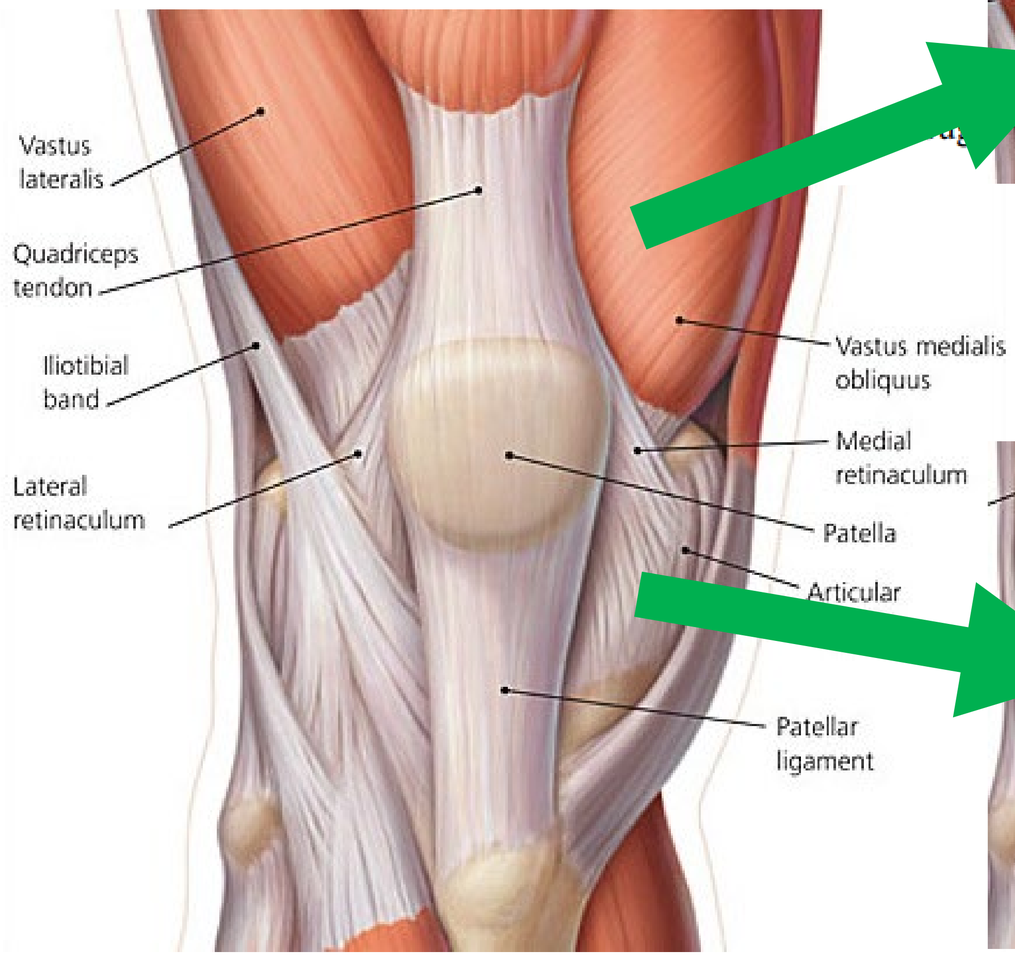


Residual Strength of the Quadriceps Versus Patellar Tendon After Harvesting a Central Free Tendon Graft

Douglas J. Adams, Ph.D., Augustus D. Mazzocca, M.D., and John P. Fulkerson, M.D.

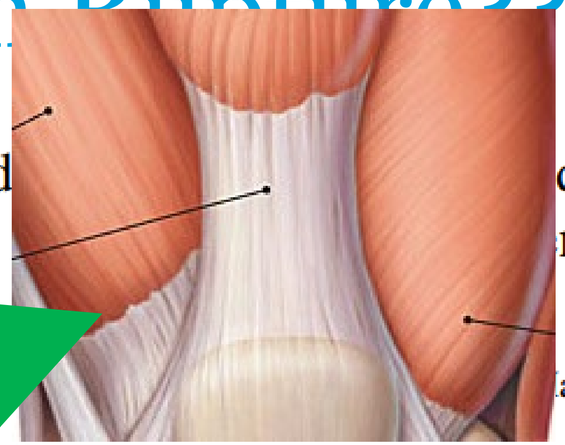
Quadriceps Tendon Rupture???

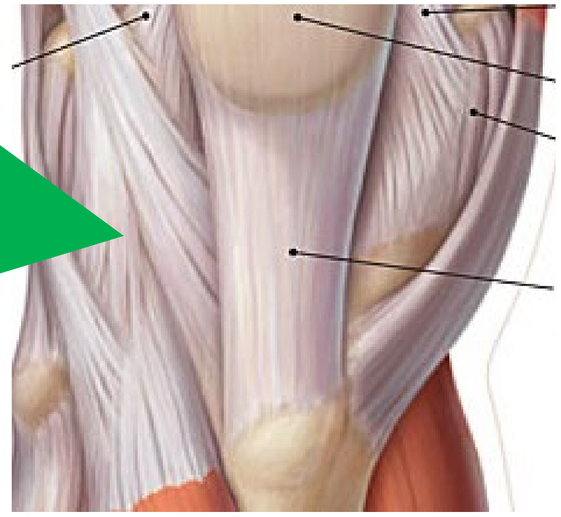
- Arthroscopy 2006



Resid driceps Versus Patellar Tendon
ntral Free Tendon Graft

azzocca, M.D., and John P. Fulkerson, M.D.

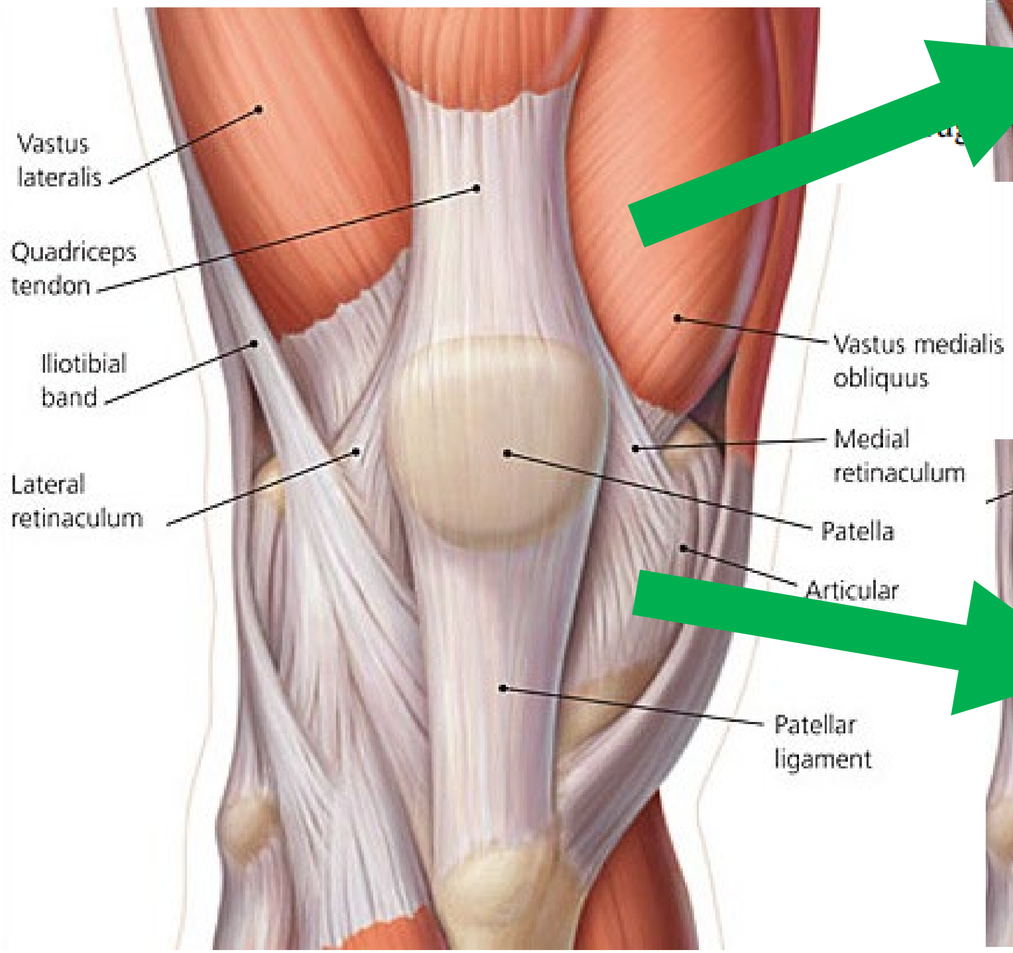


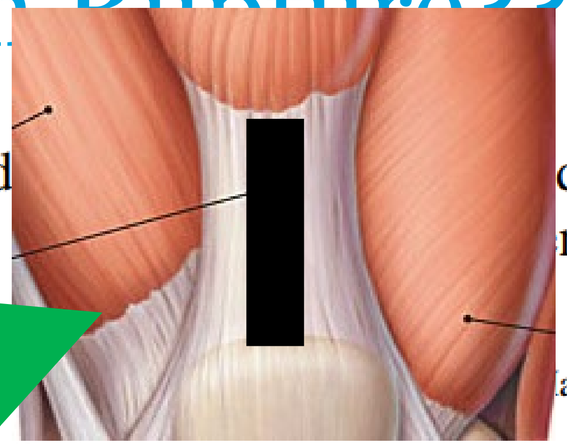


Ortho Nebraska

Quadriceps Tendon Rupture???

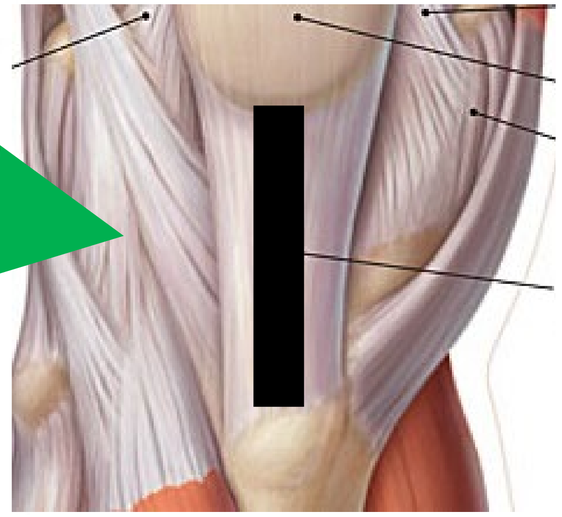
- Arthroscopy 2006





Resid driceps Versus Patellar Tendon
ntral Free Tendon Graft

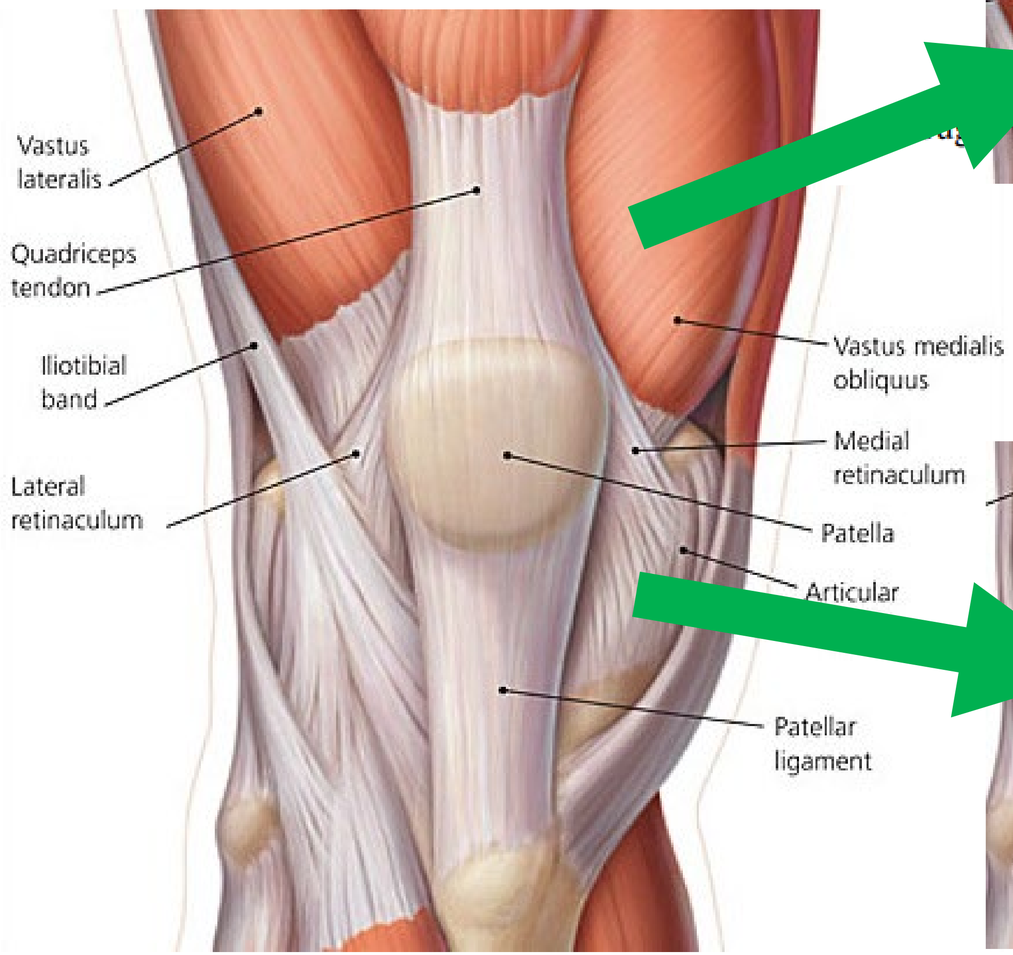
azzocca, M.D., and John P. Fulkerson, M.D.

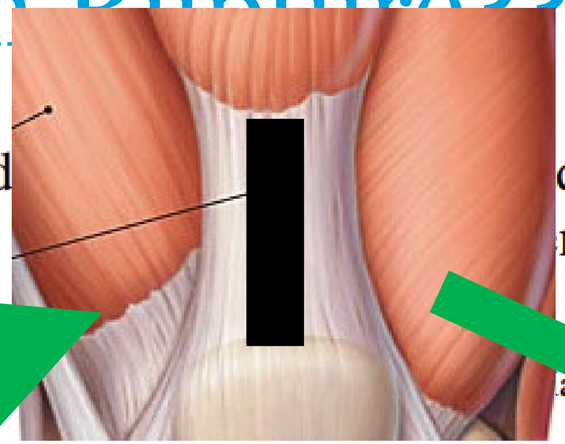


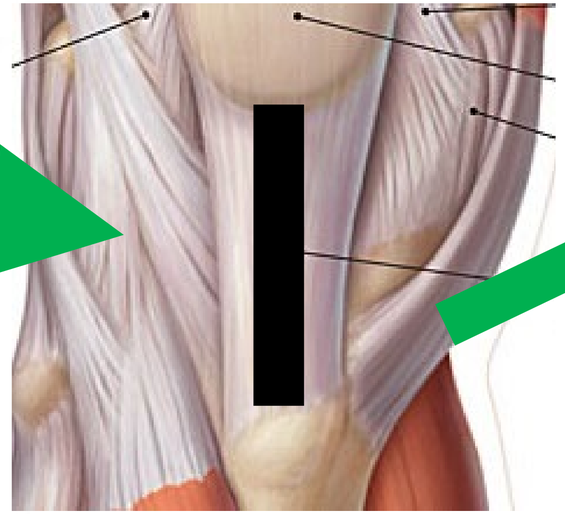
Ortho Nebraska

Quadriceps Tendon Rupture???

- Arthroscopy 2006







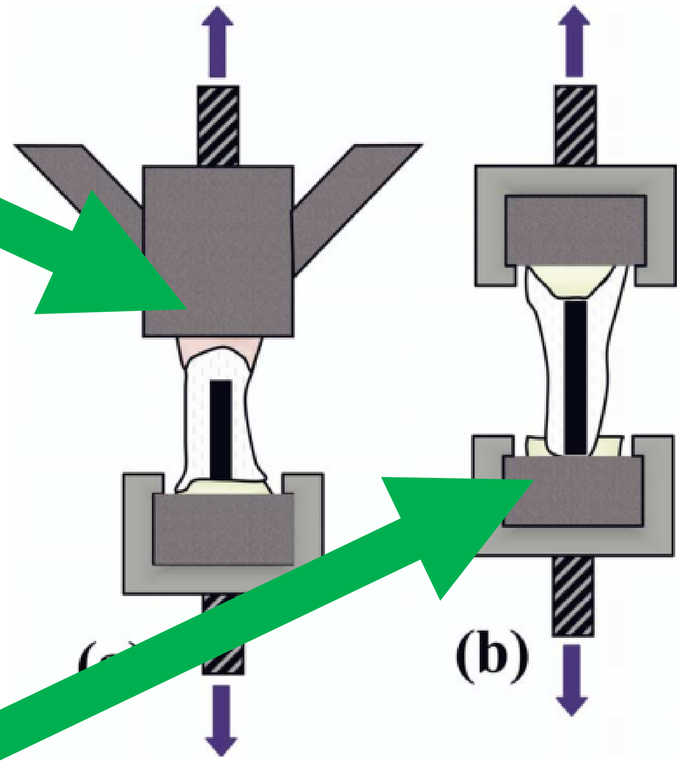


Figure 1. (A) Quadriceps tendon constructs were tested in tension to failure after potting the proximal patella bone block in PMMA and clamping the proximal soft tissue in a serpentine Cryoclamp. (B) Patellar tendon constructs were tested by potting the bone blocks of the distal patella and tibial tubercle in PMMA.

Quadriceps Tendon Rupture???

- Arthroscopy 2006

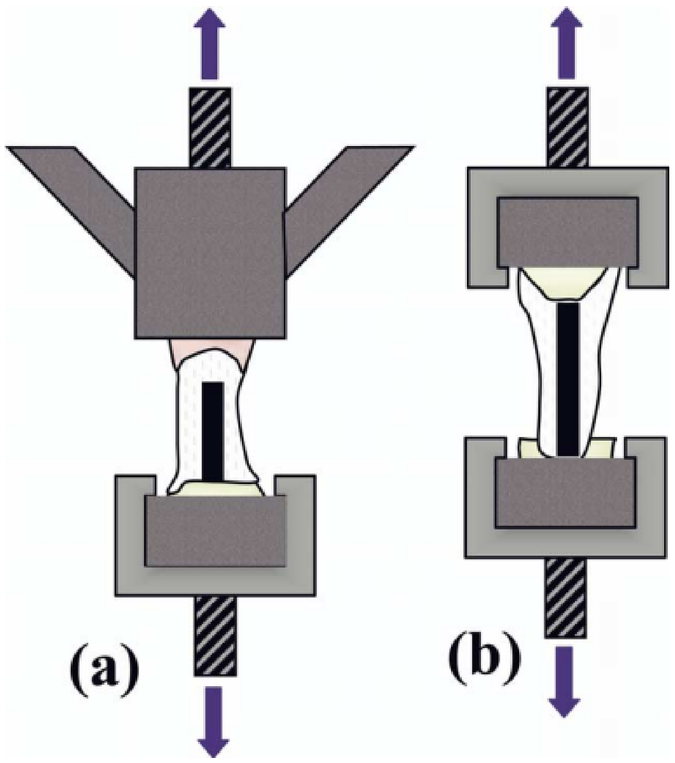
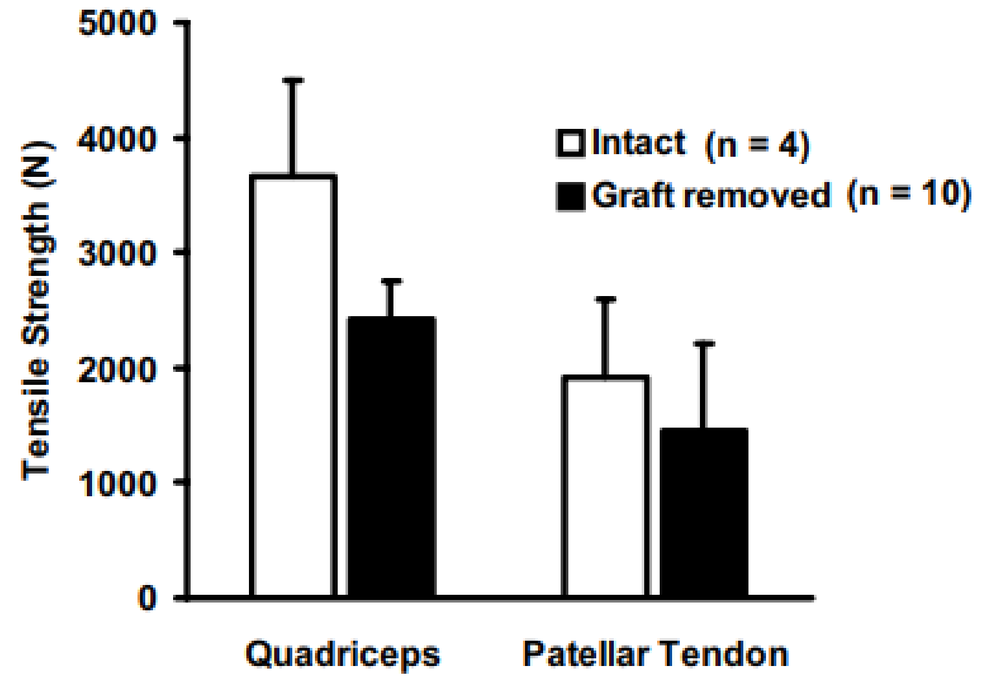


FIGURE 1. (A) Quadriceps tendon constructs were tested in tension to failure after potting the proximal patella bone block in PMMA and clamping the proximal soft tissue in a serpentine Cryoclamp. (B) Patellar tendon constructs were tested by potting the bone blocks of the distal patella and tibial tubercle in PMMA.

Residual Strength of the Quadriceps Versus Patellar Tendon After Harvesting a Central Free Tendon Graft

Douglas J. Adams, Ph.D., Augustus D. Mazzocca, M.D., and John P. Fulkerson, M.D.



ACL Reconstruction - Quad vs Patellar Tendon

- Arthroscopy 2014
  - Randomized (level II)
  - 51 patients
    - 25 - Patellar Tendon
    - 26 - Quad tendon
- Statistically sig diff
  - Positive pivot shift
  - Anterior kneeling pain
- No sig diff
  - IKDC scores
  - KT-1000 laxity

Is Quadriceps Tendon a Better Graft Choice Than Patellar Tendon? A Prospective Randomized Study

Bent Lund, M.D., Torsten Nielsen, B.A. Phys., Peter Faunø, M.D., Svend Erik Christiansen, M.D., and Martin Lind, M.D., Ph.D.

Table 2. Preoperative and 1- and 2-Year Subjective Outcome Parameters

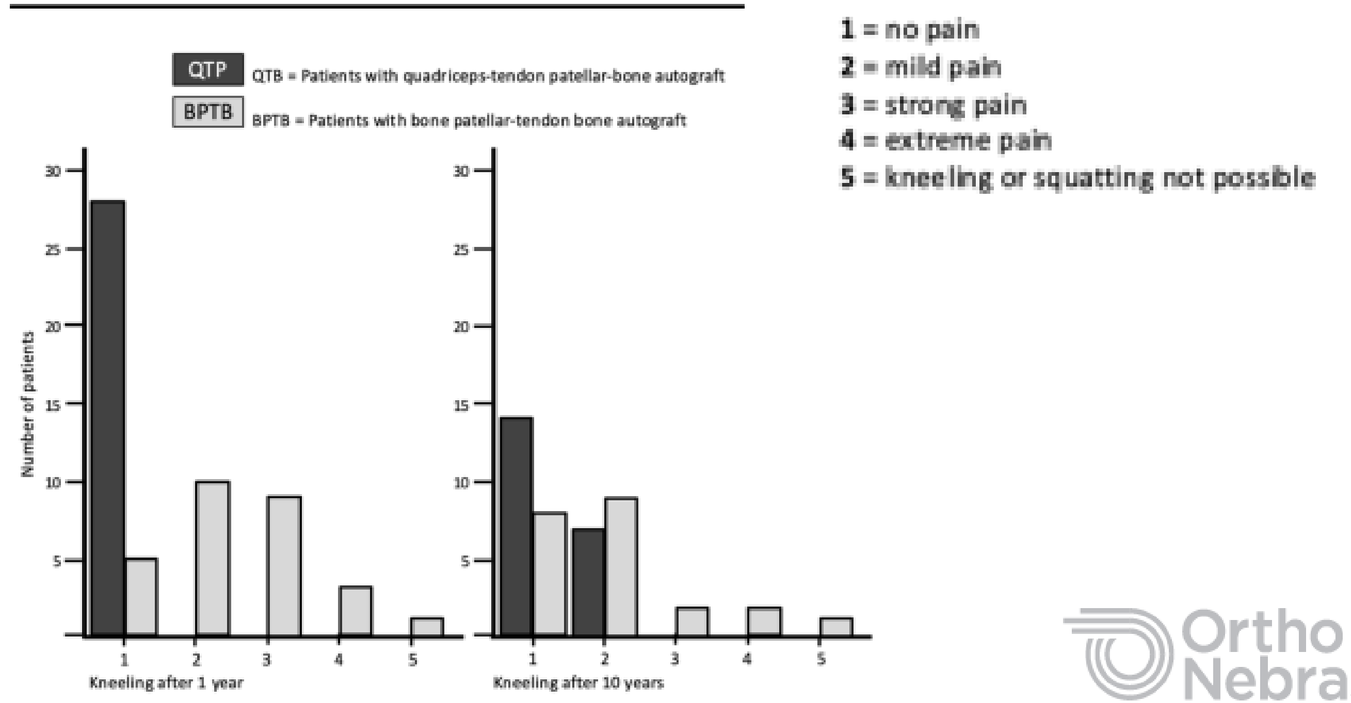
Variable	BPTB Preoperatively	QTB Preoperatively	BPTB 1 Year	QTB 1 Year	BPTB 2 Years	QTB 2 Years
KOOS subscores*						
Symptoms	73 ± 17	79 ± 12	76 ± 14	78 ± 15	82 ± 15	84 ± 13
Pain	71 ± 15	80 ± 13	82 ± 13†	80 ± 15	84 ± 14	90 ± 10†
Activity of daily living	79 ± 18	88 ± 12	87 ± 12†	88 ± 11	87 ± 13†	95 ± 6†
Sports/recreation	39 ± 20	56 ± 17	59 ± 17†	61 ± 25†	64 ± 23†	80 ± 19†
Quality of life	38 ± 13	46 ± 13	55 ± 15†	54 ± 17†	60 ± 21†	75 ± 18†
$KOOS_4$‡	55 ± 23	65 ± 20	69 ± 18†	68 ± 21‡	72 ± 21‡	82 ± 16‡
Subjective IKDC score	61 ± 17	68 ± 14	75 ± 13†	76 ± 16‡	70 ± 16†	84 ± 13†

ACL Reconstruction - Quad vs Patellar Tendon

- Archives of Ortho and Trauma Surg 2020
  - Randomized (level II)
  - 60 patients
    - 30 - Patellar Tendon
    - 30 - Quad tendon
- Statistically sig diff
  - Kneeling/squatting pain
- No sig diff
  - IKDC, Lysholm, Tegner scores
  - KT-1000 laxity

Quadriceps tendon vs. patellar tendon autograft for ACL reconstruction using a hardware-free press-fit fixation technique: comparable stability, function and return-to-sport level but less donor site morbidity in athletes after 10 years

Alexander Barié[1] · Thomas Sprinckstub[2] · Jürgen Huber[3] · Ayham Jaber[1]



Ortho Nebraska

ACL Reconstruction - Quad vs Hamstrings

- AJSM 2017
  - Cohort - level III
  - 86 patients
    - 41 - Hamstrings
    - 45 - Quad tendon
- Statistically sig diff some PROMs

Is Quadriceps Tendon Autograft a Better Choice Than Hamstring Autograft for Anterior Cruciate Ligament Reconstruction?

A Comparative Study With a Mean Follow-up of 3.6 Years

TABLE 2
Comparison of Postoperative Functional Scores[a]

	All (n = 83)	QT (n = 44)	HT (n = 39)	*P*
Lysholm	86.4 ± 6	89 ± 6.9	83.1 ± 5.3	**<.05**
KOOS				
Pain	89 ± 6.9	90 ± 6.8	86 ± 7.2	.23
Symptoms	85 ± 10.7	90 ± 11.2	81 ± 10.3	**.017**
ADL	93 ± 5.2	95 ± 5.3	90 ± 4.9	.08
Sport	73 ± 14	82 ± 11.3	67 ± 12.4	**.003**
QOL	79 ± 12.3	78 ± 14.7	79 ± 10.3	.22
Tegner				
Last follow-up	5.7 ± 1.5	5.9 ± 1.4	5.6 ± 2	.42
Difference in preoperative	1 ± 1.4	1 ± 1.05	1.2 ± 1.8	.24
IKDC subjective	83 ± 15	84 ± 13	80 ± 17	.20

ACL Reconstruction - Quad vs Hamstrings

- AJSM 2017
  - Cohort - level III
  - 86 patients
    - 41 - Hamstrings
    - 45 - Quad tendon
  - Statistically sig diff some PROMs
  - Statistically sig diff in stability
    - Lachman
    - Pivot shift
    - KT-1000

Is Quadriceps Tendon Autograft a Better Choice Than Hamstring Autograft for Anterior Cruciate Ligament Reconstruction?

A Comparative Study With a Mean Follow-up of 3.6 Years

TABLE 4
Comparison of Postoperative Side-to-Side Differences in Stability[a]

	All	QT (n = 44)	HT (n = 39)	*P*
Mean, mm	2.01 ± 1.0	1.1 ± 0.9	3.1 ± 1.3	**.037**
No. of patients with > 3-mm difference	26	5	21	**<.05**

TABLE 3
Comparison of Postoperative Va
Related to Stability[a]

	All	QT (n = 44)	HT (n = 39)	*P*
Lachman				**<.005**
0	59 (71)	41 (93.1)	18 (46.2)	
1	21 (25.3)	4 (6.9)	17 (43.6)	
2	4 (4.7)	0	4 (10.2)	
Pivot shift				.052
0	66 (79.5)	41 (93.1)	25 (64.1)	
1	14 (16.8)	4 (6.9)	10 (25.6)	
2	4 (4.7)	0	4 (10.2)	

ACL Reconstruction - Quad vs Hamstrings

- AJSM 2020
  - Cohort - level III
  - 875 patients
    - 658 - Hamstrings
    - 217 - Quad tendon
- No sig difference in PROMs
- Risk factors for revision surgery
  - Age - 5.5x < 15 yo
  - Activity level - 3.64x
  - Graft type - 2.67x in hamstring grafts

Anterior Cruciate Ligament Reconstructions With Quadriceps Tendon Autograft Result in Lower Graft Rupture Rates but Similar Patient-Reported Outcomes as Compared With Hamstring Tendon Autograft

TABLE 5
Binary Logistic Regression for Revision Surgery[a]

Factor	Odds Ratio (95% CI)	*P* Value
Intercept	0.01 (0.00-0.03)	**<.001**
Age group, y (baseline >45)		
<15	5.54 (1.52-26.49)	**.015**
15-30	3.76 (1.24-16.31)	**.037**
31-45	1.24 (0.34-5.87)	.76
Physical activity level[b] (baseline: low)		
Medium	1.34 (0.44-5.86)	.64
High	3.64 (1.23-15.66)	**.04**
Graft type (baseline QT): HT	2.67 (1.37-5.75)	**.007**

ACL Reconstruction - Quad vs Hamstrings

- AJSM 2020
  - Cohort - level III
  - 875 patients
    - 658 - Hamstrings
    - 217 - Quad tendon
- No sig difference ir
- Risk factors for rev surgery
  - Age - 5.5x < 15 yo
  - Activity level - 3.64x
  - Graft type - 2.67x in hamstring grafts

Anterior Cruciate Ligament Reconstructions With Quadriceps Tendon Autograft Result in Lower Graft Rupture Rates but Similar Patient-Reported Outcomes as Compared With Hamstring Tendon Autograft

Retear Rate

4.9% hamstrings

vs

2.8% quad tendon

TABLE 5
Binary Logistic Regression for Revision Surgery[a]

	Odds Ratio (95% CI)	*P* Value
	0.01 (0.00-0.03)	**<.001**
	5.54 (1.52-26.49)	**.015**
	3.76 (1.24-16.31)	**.037**
	1.24 (0.34-5.87)	.76
	1.34 (0.44-5.86)	.64
	3.64 (1.23-15.66)	**.04**
	2.67 (1.37-5.75)	**.007**

Ortho Nebraska

ACL Reconstruction - Quad vs Ham. vs BTB

- AJSM 2019
  - Meta-analysis
  - 27 studies, 2,856 patients

Anterior Cruciate Ligament Reconstruction

A Systematic Review and Meta-analysis of Outcomes for Quadriceps Tendon Autograft Versus Bone–Patellar Tendon–Bone and Hamstring-Tendon Autografts

	BTB vs Quad	Hamstring vs Quad
Side to side diff	No diff	No diff
Side to side > 3 mm	No diff	No diff
Neg Lachman	No diff	No diff
Neg Pivot Shift	No diff	No diff
Lysholm Score	**No diff, but trend favor BTB**	**Sig diff, in favor of Quad**
IKDC A or B	No diff	No diff
Donor Site Pain	**Sig diff, in favor of Quad**	No diff
Graft Survival	No diff	No diff

Ortho Nebraska

ACL Reconstruction - Quad vs Ham. vs BTB

- AJSM 2019
  - Meta-analysis
  - 27 studies, 2,856 patients

Anterior Cruciate Ligament Reconstruction

A Systematic Review and Meta-analysis of Outcomes for Quadriceps Tendon Autograft Versus Bone–Patellar Tendon–Bone and Hamstring-Tendon Autografts

Conclusion: QT autograft had comparable clinical and functional outcomes and graft survival rate compared with BPTB and HT autografts. However, QT autograft showed significantly less harvest site pain compared with BPTB autograft and better functional outcome scores compared with HT autograft.

	BTB vs Quad	Hamstring vs Quad
Side-to-side < 3 mm	No diff	No diff
Neg Lachman	No diff	No diff
Neg Pivot Shift	No diff	No diff
Lysholm Score	**No diff, but trend favor BTB**	**Sig diff, in favor of Quad**
IKDC A or B	No diff	No diff
Donor Site Pain	**Sig diff, in favor of Quad**	No diff
Graft Survival	No diff	No diff

Ortho Nebraska

ACL Reconstruction - Quad vs Ham. vs BTB

- AJSM 2021
  - Meta-analysis
  - 24 studies, 19,584 patients

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

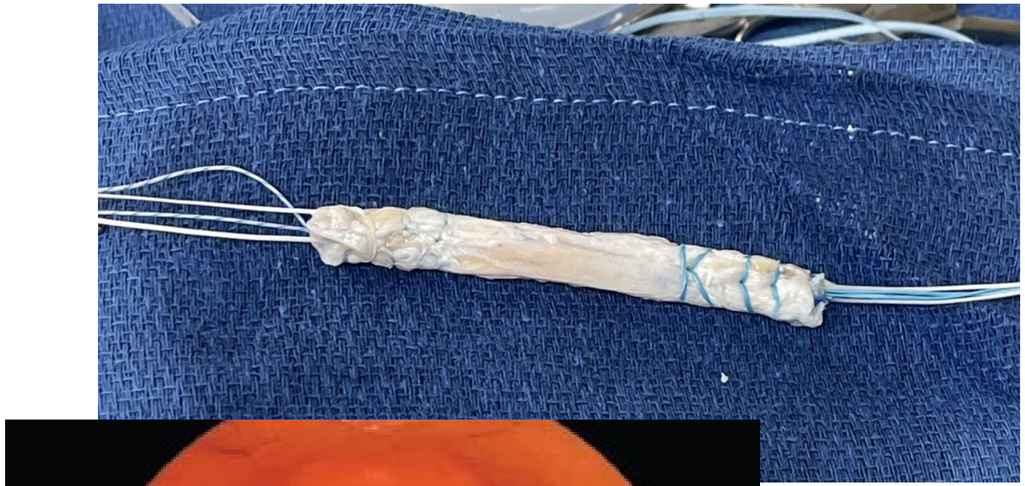
CME

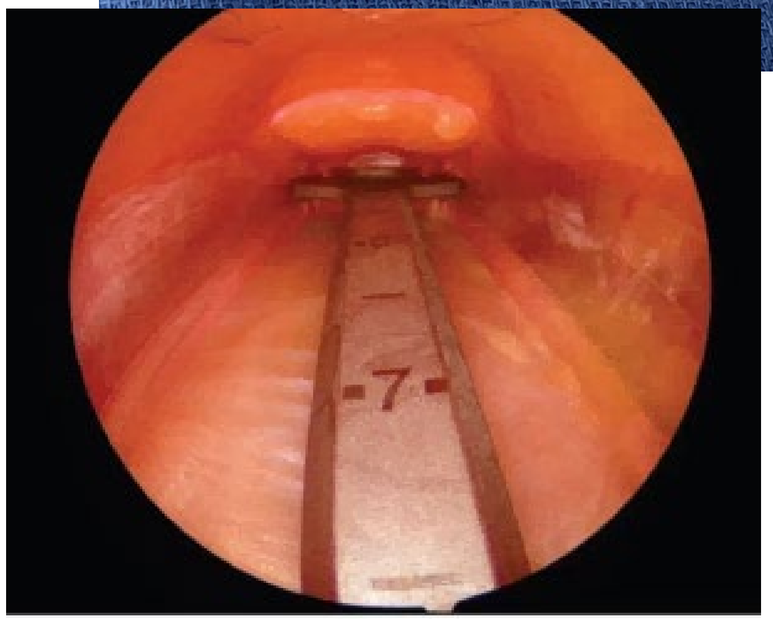
A Systematic Review and Meta-analysis

	BTB vs Quad	Hamstring vs Quad
Side to side diff	No diff	No diff
IKDC	No diff	No diff
Donor Site Pain	**Sig diff, in favor of Quad**	**Sig diff, in favor of Quad**
Graft Survival	No diff	No diff
Muscle Strength	**??? - 2 studies showed a diff, but one did not**	No diff

Quadriceps Tendon Autograft

- Advantages
  - Predictably to obtain appropriate graft diameter
  - Relatively small incision
  - Avoid anterior knee pain
  - Less risk patellofemoral DJD
  - Lower risk of patella fracture (if taken without bone block)
  - Less risk of premature growth plate closure
  - ?? Less morbidity than hamstring graft





Ortho Nebraska

Quadriceps Tendon Autograft

- Disadvantages
  - Increased risk of patella fracture (if taken with bone block)
  - Less rigid fixation than BTB, similar to hamstrings
  - Unpredictable graft length
  - Slower healing than BTB, similar to hamstrings
  - Quadriceps tendon rupture?

Summary

- Patellar tendon (BTB) grafts continue to withstand the test of time
- Isolated hamstring autograft ACL reconstruction in high-risk athletes may not be adequate
- Quadriceps tendon is reasonable alternative

Ortho Nebraska

References

- Adams DJ, Mazzocca AD, Fulkerson JP. Residual Strength of the Quadriceps Versus Patellar Tendon After Harvesting a Central Free Tendon Graft. Arthroscopy 2006;22(1):76-79.
- Barie A, Sprinckstub T, Huber J, et al. Quadriceps Tendon vs Patellar Tendon Autograft for ACL reconstruction Using a Hardware-free Press-fit Fixation Technique: Comparable Stability, Function, and Return-to-sport Level But Less Donor Site Morbidity in Athletes After 10 Years. Arch Orthop Trauma Surg. 2020;140(10):1465-1474.
- Cavaignac E, Coulin B, Tscholl P, et al. Is Quadriceps Tendon Autograft a Better Choice Than Hamstring Autograft for Anterior Cruciate Ligament Reconstruction. AJSM 2017;45(6):1326-1332.
- Dai W, Leng X, Wang J, et al. Quadriceps Tendon Autograft Versus Bone-Patellar Tendon-Bone and Hamstring Tendon Autografts for Anterior Cruciate Ligament Reconstruction. AJSM 2022;50(12):3425-3439.
- Freedman KB, D'Amato MJ, Nedeff DD, et al. Arthroscopic Anterior Cruciate Ligament Reconstruction: A Metaanalysis Comparing Patellar Tendon and Hamstring Tendon Autografts. AJSM 2003;31(1):2-11.
- Getgood AMJ, Bryant DM, Litchfield R, et al. Lateral Extra-articular Tenodesis Reduces Failure of Hamstring Tendon Autograft Anterior Cruciate Ligament Reconstruction. AJSM 2020;48(2):285-297.
- Jansson KA, Linko E, Sandelin J, Harilainen A. A Prospective Randomized Study of Patellar versus Hamstring Tendon Autografts for Anterior Cruciate Ligament Reconstruction. AJSM 2003;31(1):12-18.
- Jaecker V, Ibe P, Endler CH, et al. High Risk of Tunnel Convergence in Combined Anterior Cruciate Ligament Reconstruction and Latera Extra-articular Tenodesis. AJSM 2019;47(9):2110-2115.
- Kennedy JC, Stewart R, Walker DM. Anterolateral Rotatory Instability of the Knee Joint. JBJS 1978;60(8):1031-1039.
- Lund B, Nielsen T, Fauno P. Is Quadriceps Tendon a Better Graft Choice Than Patellar Tendon? A Prospective Randomized Study. Arthroscopy 2014;30(5):593-598.
- Marshall JL, Warren R, Wickiewicz TL, et al. The Anterior Cruciate Ligament: A Technique of Repair and Reconstruction. Clin Orthop Rel Research 1979;143:97-106.
- Mehran N, Skendzel JG, Lesniak BP, et al. Contemporary Graft Options in Anterior Cruciate Ligament Reconstruction. Operative Techniques in Sports Medicine 2013;21(1):10-18.
- Mouarbes D, Menetrey J, Marot V, et al. Anterior Cruciate Ligament Reconstruction - A Systematic Review and Meta-analysis of Outcomes for Quadriceps Tendon Autograft Versus Bone-Patellar Tendon-Bone and Hamstring-Tendon Autografts. AJSM 2019;47(14):3531-3540.

Ortho Nebraska

References

- MOON Knee Group. Anterior Cruciate Ligament Reconstruction in High School and College-Aged Athletes. AJSM 2020;48(2):298-309
- Persson A, Fjeldsgaard K, Gjertsen J, et al. Increased Risk of Revision With Hamstring Tendon Grafts Compared With Patellar Tendon Grafts After Anterior Cruciate Ligament Reconstruction. AJSM 2013;42(2):285-291.
- Pinczewski LA, Lyman J, Linklater J, et al. A 10-Year Comparison of Anterior Cruciate Ligament Reconstruction with Hamstring Tendon and Patellar Tendon Autograft: A Controlled, Prospective Trial. AJSM 2007;35(4):564-574.
- Runer A, Csapo R, Hepperger C, et al. Anterior Cruciate Ligament Reconstructions with Quadriceps Tendon Autograft Result in Lower Graft Rupture Rates but Similar Patient-Reported Outcomes as Compared with Hamstring Tendon Autograft. AJSM 2020;48(9):2195-2204.
- Sajovic M, Wengust V, Komadina R, et al. A Prospective, Randomized Comparison of Semitendinosus and Gracilis Tendon Versus Patellar Tendon Autografts for Anterior Cruciate Ligament Reconstruction. AJSM 2006;34(12):1933-1940.
- Salem SH, Varzhapetyan V, Patel N, et al. Anterior Cruciate Ligament Reconstruction in Young Female Athletes. AJSM 2019;47(9):2086-2092.
- Samuelson BT, Wester KE, Johnson NR, et al. Hamstring Autograft versus Patellar Tendon Autograft for ACL Reconstruction: Is There a Difference in Graft Failure Rate? A Meta-analysis of 47,613 Patients. Clin Orthop Relat Res 2017(475):2459-2468.
- Schmucker M, Haraszuk, Holmich P, et al. Graft Failure, Revision ACLR, and Reoperation Rates After ACLR with Quadriceps Tendon Versus Hamstring Tendon Autografts. AJSM 2021;49(8):2136-2143.
- Schon JM, Moatshe G, Brady AW, et al. Anatomic Anterolateral Ligament Reconstruction of the Knee Leads to Overconstraint at Any Fixation Angle. AJSM 2016;44(10):2546-2556.
- Schuette HB, Kraeutler MJ, Houck DA, et al. Bone-Patellar Tendon-Bone Versus Hamstring Tendon Autografts for Primary Anterior Cruciate Ligament Reconstruction: A Systematic Review of Overlapping Meta-analyses. OJSM 2017;5(11):1-9.
- Shani RH, Umpierez E, Nasert M. Biomechanical Comparison of Quadriceps and Patellar Tendon Grafts in Anterior Cruciate Ligament Reconstruction. Artthroscopy 2016;32(1):71-75.
- Shimakawa T, Burkhart TA, Dunning CE. Et al. Lateral Compartment Contact Pressures Do Not Increase After Lateral Extra-articular Tenodesis and Subsequent Subtotal Meniscectomy. OJSM 2019;7(6):1-8.
- Slone HS, Romine SE, Premkumar A, et al. Quadriceps Tendon Autograft for Anterior Cruciate Ligament Reconstruction: A Comprehensive Review of Current Literature and Systematic Review of Clinical Results. Arthroscopy 2015;31(3):541-554.

Ortho Nebraska