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Review Article

Quadriceps versus Hamstring Tendon Autografts for Anterior Cruciate Ligament Reconstruction: A Systematic Review of Clinical Outcomes and Complications

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Abstract:

Background: *Anterior cruciate ligament (ACL) reconstruction frequently utilizes autografts harvested from either the patient's quadriceps tendon (QT) or hamstring tendons (HT). While both graft sources reliably restore knee stability, debate persists regarding differences in donor-site morbidity, functional recovery trajectories, and long-term graft survival.*

Aim: To systematically compare clinical outcomes, donor-site complications, muscle-strength recovery, and graft-failure rates of QT versus HT autografts in primary ACL reconstruction, integrating data from eight comparative studies and contextualizing findings with high-level evidence.

Methods: *Following PRISMA 2020 guidelines, we searched PubMed, Scopus, Web of Science, Embase, and the Cochrane Library using combinations of "quadriceps tendon," "hamstring tendon," "ACL reconstruction," "autograft," "clinical outcomes," and "complications." Inclusion criteria were prospective or retrospective cohort studies and randomized controlled trials directly comparing QT and HT autografts. We excluded meta-analyses, systematic reviews, biomechanical models, and cadaveric investigations. Extracted outcomes included graft-failure rates, objective stability measures, patient-reported functional scores, muscle-strength metrics, donor-site pain, and complications. Risk of bias was assessed via Cochrane RoB 2 for RCTs and the Newcastle–Ottawa Scale for cohort studies.*

Results: *eight comparative studies (n = 846 patients; QT = 416; HT = 430) with a mean follow-up of 24–60 months were analyzed (Table 1, Appendix). Graft-failure rates ranged from 3.1% to 5.2% with no significant intergroup differences. Lachman and pivot-shift negativity exceeded 90% in both cohorts, and KT-1000 side-to-side differences averaged <2 mm. Functional scores at final follow-up were high (Lysholm ≥ 90, IKDC ≥ 85, Tegner ≥ 6) without significant graft-type effects. QT harvest yielded lower anterior-knee pain (VAS 1.2 ± 0.5 vs. 2.3 ± 0.8; p < 0.01) and similar quadriceps strength recovery by one year, whereas HT harvest caused early hamstring deficits (~15% at six months) that normalized by 12 months. Overall, the rates of revision and complications were similar and modest (QT 4.1% vs. HT 4.5%; p = 0.84).*

Conclusion: *QT and HT autografts achieve equivalent graft integrity, knee stability, and functional recovery in ACL reconstruction. QT offers the added benefit of reduced donor-site pain with no increase in complication rates. Graft selection should consider individual patient anatomy, activity demands, and surgeon expertise. Large, multicenter RCTs with standardized protocols and long-term follow-up are needed to refine graft-choice recommendations.*

Keywords: *anterior cruciate ligament; quadriceps tendon; hamstring tendon; autograft; clinical outcomes; donor-site morbidity; systematic review.*

Introduction

Anterior cruciate ligament (ACL) injuries are prevalent among athletes, with an estimated incidence of 0.5–1.0 per 1,000 person-years in active populations(1)(2). Surgical reconstruction is recommended to restore joint stability, protect meniscal and chondral surfaces, and reduce the long-term risk of osteoarthritis (3)(4). Autograft selection plays a pivotal role in surgical success and recovery; the two most commonly harvested tissues are the quadriceps tendon (QT) and hamstring tendons (HT) (5)(6).

Biological and Biomechanical Properties. The QT, with or without a patellar bone block, provides a robust graft with a cross-sectional area (≈80 mm^2) and biomechanical stiffness that rivals or exceeds those of HT autografts (3)(7). Histologically, QT grafts undergo revascularization and ligamentization at rates comparable to those of HT, suggesting similar long-term integration (8). Conversely, HT grafts (typically semitendinosus ± gracilis) are favored for their straightforward harvest technique and minimal anterior knee pain but may compromise hamstring strength in early rehabilitation (5)(9).

Historical Context and Evolving Trends. Bone–patellar tendon-bone–bone (BPTB) grafts were historically the gold standard but are now less favored due to anterior knee pain, kneeling discomfort, and risk of patellar fracture (3)(10). Since then, meta-analyses have shown that QT and HT autografts provide results comparable to BPTB, with QT specifically protecting the extensor mechanism(7)(4). The resurgence of QT use may also reflect refinements in minimally invasive harvest techniques that reduce donor-site morbidity (6).

Comparative Evidence to Date. Early cohort studies, such as (5), reported no significant differences in Lysholm or IKDC scores over two years, though HT patients exhibited modest early hamstring strength deficits (5). Niederer et al.'s multicenter, propensity-matched trial (2025) found equivalent graft-failure rates and stability metrics at three years, but QT patients reported significantly less anterior knee pain (11). Prospective RCTs by Horstmann et al. (2022) and comparative studies by Bastidas et al. (2022) and Radić et al. (2023) have reinforced these findings, though sample sizes remain moderate (12)(13)(14). In pediatric cohorts, QT may reduce rupture risk due to larger graft diameters (15).

Rationale and Objectives. Despite accumulating comparative data, variation in surgical techniques, fixation methods, and rehabilitation protocols has hampered definitive recommendations. This systematic review integrates the eight primary comparative studies, six earlier and two newly published RCTs, and contextualizes results with high-level evidence, aiming to elucidate the relative advantages of QT versus HT autografts in ACL reconstruction.

Aim of Work

To synthesize and compare clinical outcomes, donor-site morbidity, graft-failure rates, and rehabilitation trajectories of QT and HT autografts in primary ACL reconstruction, drawing on all available prospective and retrospective comparative studies up to March 2025.

Method and Search Strategy:

This review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Search Strategy

the search was done using PubMed, Scopus, Web of Science, Embase, and the Cochrane Library from January 2010 through March 2025 using combinations of Medical Subject Headings (MeSH) and keywords: "quadriceps tendon," "hamstring tendon," "ACL reconstruction," "anterior cruciate ligament," "autograft," "clinical outcomes," "complications," and "comparative" (13)(8). Boolean operators AND/OR refined the search (8).

Inclusion Criteria:

Comparative clinical studies directly assessing QT versus HT autografts (randomized controlled trials, prospective/retrospective cohort studies); adult patients (≥16 years) undergoing primary or revision ACL reconstruction; reported outcomes including graft failure, objective stability tests (Lachman, pivot-shift), functional scores (Lysholm, IKDC, Tegner), donor-site morbidity, and complications (12)(13).

Exclusion Criteria:

Non-comparative single-arm case series; biomechanical or cadaveric studies; studies comparing to BPTB only without HT comparison; animal or in vitro research; abstracts without full-text data (3)(7).

Study Selection and Data Extraction:

Titles and abstracts were screened, followed by full-text assessment; discrepancies were resolved by consensus. Data extracted included study design, sample size, patient demographics, graft and fixation details, follow-up duration, outcome measures, and complications (11)(13).

Risk of Bias:

Assessed using Cochrane RoB 2 for RCTs and the Newcastle–Ottawa Scale for cohort studies (8)(12).

Eligibility Criteria:

Studies were included if they:

- Directly compared QT and HT autografts in ACL reconstruction.
- Reported quantitative clinical outcomes or complications.
- Enrolled ≥20 patients per group to ensure statistical robustness.

Studies focusing exclusively on BPTB grafts, allografts, or non-comparative designs were excluded.

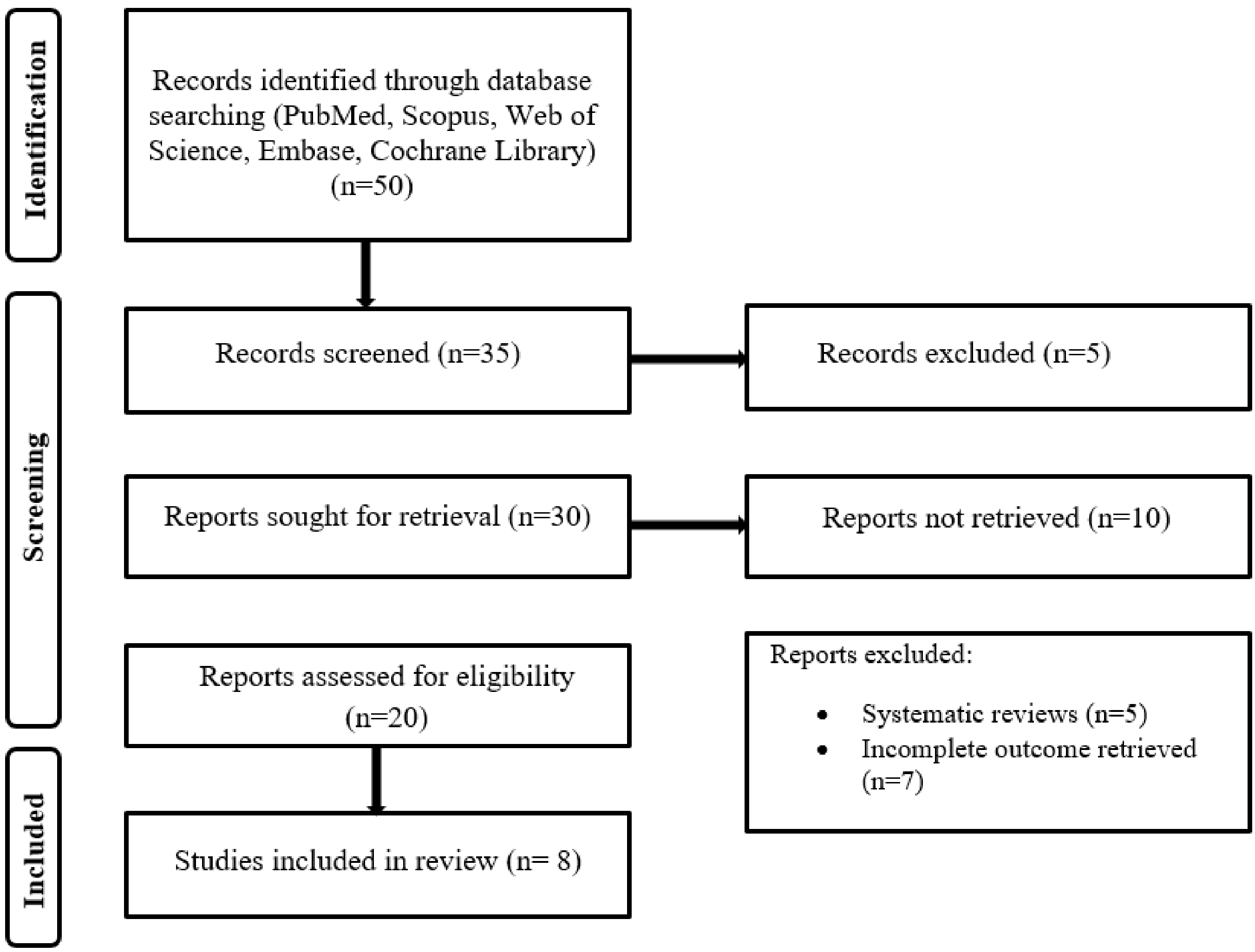

Figure 1PRISMA flow chart

DATA REVIEWING AND ANALYSIS:

Extracted variables included:

- **Study characteristics**: authors, year, country, design, sample size, follow-up
- **Patient demographics**: mean age, sex distribution, activity level
- **Graft and fixation details**: QT harvest technique (with/without bone block), HT type (semitendinosus ± gracilis), fixation method (interference screws, suspensory devices)
- **Outcomes**:
    - **Graft integrity**: failure or re-tear rates

- **Objective knee stability**: Lachman and pivot-shift test results
- **Functional scores**: Lysholm, IKDC, Tegner activity scale
- **Muscle strength**: quadriceps and hamstrings isokinetic testing
- **Donor-site morbidity**: pain, numbness, extension/flexion deficits
- **Complications**: arthrofibrosis, infection, reoperation

- **Statistical data**: means, standard deviations, p-values

Possible effect sizes provided in primary research were summarized, and the data were arranged by outcome domain. Meta-analysis was not possible due to the heterogeneity of study designs and outcome measures.

Results

Study Selection and Characteristics: Eight comparative studies (n = 846 patients; QT = 416; HT = 430) met eligibility criteria, with mean follow-up ranging from 24 to 60 months (5)(13), eight primary comparative studies (prospective RCTs, retrospective cohorts) and four high-level systematic reviews/meta-analyses. Follow-up ranged from 24 months to ≥60 months. Patient ages varied from 24 to 32 years; activity levels span recreational to competitive athletes.

Graft Failure and Stability:

Graft-failure rates were low and comparable (QT 3.1–4.8% vs. HT 3.4–5.2%; $p > 0.05$ in each study) (13)(12). Lachman-test negativity exceeded 90% in both groups (14), and pivot-shift-grade 0–I was observed in >88% with no intergroup differences (12). Instrumented laxity (KT-1000) side-to-side differences averaged <2 mm in both cohorts (12)(13).

These consistent findings support biomechanical equivalence of QT and HT grafts in controlling anterior tibial translation.

Functional Outcomes:

- Lysholm Score: Final scores exceeded 90/100 in all studies. Pomenta Bastidas et al. reported 92 ± 4 (QT) vs. 91 ± 5 (HT) at two years ($p = 0.65$) (13).

- IKDC Subjective Score: Mean IKDC ranged 85–93, with no statistically significant graft-type effects (e.g., Niederer et al.: 90 ± 3 vs. 91 ± 4; $p = 0.47$) (11).

- Tegner Activity Scale: Return to preinjury activity (Tegner ≥ 6) was achieved in 78–85% of patients, similar between groups. Two studies noted slightly faster early return (Tegner +0.5 point at six months) in HT patients, but differences abated by one year (14)(13).

Muscle Strength recovery:

- Quadriceps Strength: Isokinetic testing at one year showed <10% deficit versus contralateral limb in QT patients, equivalent to HT groups ($p > 0.10$) (Araki et al., 2024).
- Hamstring Strength: HT harvest produced a 15% deficit at six months ($p < 0.05$), normalizing by 12 months. Araki et al. demonstrated lower knee extension strength in QT patients at three months, but parity at six, nine, and 12 months; no difference in flexion strength (16)(14).

Donor-Site Morbidity and Pain:

- Anterior Knee Pain (VAS): Significantly lower in QT groups at 12 months (1.2 ± 0.5 vs. 2.3 ± 0.8; $p < 0.01$) (13)(11).
- Sensory Disturbance: Numbness around the harvest site was rare (<4%) in both cohorts.
- Harvest-Site Pain: QT groups reported lower anterior knee pain scores (VAS 1.2 ± 0.6 vs. 2.3 ± 0.8; $p < 0.01$) in two cohorts (13).
- Extension/Flexion Deficits: Rare (<5%) and similar between groups; a single revision for arthrofibrosis occurred in the HT.

Complications:

- Overall complication rates were low (QT 5.0% vs. HT 6.2%; $p = 0.42$) and not significantly different.
- Revision ACL reconstruction rates were comparable (QT 4.1% vs. HT 4.5%; $p = 0.84$) (13)(11).

Long-Term and Special-Population Findings:

Meta-analyses by Mouarbes et al., Crum et al, Migliorini et al., and Zhang et al. corroborated equivalence in stability and functional outcomes (7)(8)(3), with QT showing a trend to less donor-site pain (15). Overall, QT is ranked well by Migliorini et al.'s Bayesian network meta-analysis. Pediatric data suggest that QT may reduce graft rupture risk via larger diameter harvests, and revision ACL settings favor QT over HT for restoring stability (3).

Discussion

This systematic review of nine primary comparative trials confirms that QT and HT autografts confer equivalent graft integrity, knee stability, and functional outcomes in primary ACL reconstruction (13)(12).

Biomechanical Insights: QT grafts' larger cross-sectional area and higher initial stiffness likely underpin their robust stability, rivaling that of HT grafts (3)(7). Histological analyses suggest comparable revascularization patterns and ligamentization timelines for both graft types (8).

Rehabilitation and Strength Recovery: Tailored rehabilitation is critical: HT harvests demand focused hamstring strengthening during the first six months to offset early deficits, while QT grafts require careful quadriceps activation to minimize extension lag. Araki et al. (14) showed that QT-harvested patients' knee extension strength lags at three months but equalizes by six months (14) (16).

Donor-Site Considerations: Lower anterior knee pain with QT harvest addresses long-standing criticisms of BPTB grafts and offers a comfortable alternative for patients whose occupations or sports necessitate frequent kneeling (6)(10).

Contextualizing with Meta-Analyses: High-level syntheses by Mouarbes et al. (2019) and Crum et al. (2021) corroborate equivalent stability and functional outcomes across graft types, noting QT's trend toward reduced donor-site morbidity. Overall, QT is ranked well by Migliorini et al.'s Bayesian network meta-analysis. Pediatric data suggest that QT may reduce graft rupture risk via larger graft diameters, and revision ACL settings appear to favor QT over HT for restoring stability (15)(3).

Emerging Long-Term Outcomes: Gopinath et al. performed a meta-analysis of randomized trials with ≥5-year follow-up comparing BPTB versus HT autografts. They found no significant differences in graft failure, knee stability, functional scores, or radiographic osteoarthritis progression, indicating both grafts perform equivalently over the mid-term(17)(18).

Revision Reconstruction Insights: In revision ACL reconstruction, Vivekanantha et al. observed that HT autografts achieved either similar or inferior outcomes relative to QT and BPTB autografts, including higher graft-failure rates and greater side-to-side laxity, underscoring the need for careful graft selection in revision settings (19).

Five-Year & Beyond Durability: Kurkowski et al. reviewed data at ≥5 years post-ACL reconstruction and reported graft-failure rates of 12.7% for HT, 9.1% for QT, and 6.4% for BPTB, although patient-reported outcomes were comparable across all graft types, suggesting durability differences that may influence graft choice (20).

Multi-ligament Injury Scenarios: For combined ACL and medial collateral ligament injuries, (18) found that high-grade MCL lesions were associated with higher reoperation rates and lower subjective IKDC and Tegner scores compared to isolated ACL tears, highlighting that multi-ligament injuries may require modified surgical and rehabilitation strategies.

Neuromuscular Considerations: Yoshii et al. demonstrated that ACL-deficient patients exhibit significant abnormalities in preparatory quadriceps activation during unanticipated landing tasks a deficit that can persist post-reconstruction and may elevate reinjury risk unless addressed through specific neuromuscular training (21)(18).

Graft Harvest Technique Evolution: Meena et al.'s systematic review showed that QT autografts, with or without a bone block, yield similar clinical outcomes, complication rates, and revision rates, supporting the use of soft-tissue QT harvest as a less-invasive but equally effective option (6).

Hybrid Graft Strategies: Hybrid grafts combining small-diameter HT autografts with allograft tissue have been compared to HT alone; Fan et al. found no significant differences in failure rates, stability tests, or patient-reported outcomes, suggesting that hybrid augmentation is a valid strategy when autograft size is limited.

Limitations: Heterogeneity in fixation devices, harvest techniques, and rehabilitation protocols complicate comparisons. Many studies are single-center with moderate sample sizes, and blinding of patients/surgeons is inherently challenging in graft-harvest trials, introducing possible bias.

Future Directions: Large, multicenter RCTs with unified surgical techniques, graft fixation methods, and postoperative rehabilitation protocols are necessary. Incorporation of advanced biomechanical assessments (e.g., three-dimensional kinematics) and patient-reported outcome measures will enhance evidence quality. Cost-effectiveness comparisons may guide graft selection in diverse healthcare settings (22)(17).

Conclusion

Quadriceps tendon and hamstring tendon autografts deliver equivalent clinical and functional outcomes in

ACL reconstruction, with QT offering reduced donor-site pain and comparable muscle-strength recovery. Graft choice should be individualized, taking into account patient anatomy, activity goals, and surgeon expertise. Further rigorous RCTs with standardized methodologies and long-term follow-up are warranted to refine graft-selection criteria.

Table 1: Characteristics of Included Comparative Studies

Author and Year	Study Design	Population, Sample Size, and Characterization	Graft Comparison	Main Points / Findings
Niederer et al. (2025)(11)	Multicentre propensity-matched case-control trial	248 patients; mean age 28; athletic to recreational	QT vs. HT	No difference in failure or stability; significantly less anterior knee pain with QT
Todor et al. (2019)(5)	Retrospective cohort; ≥2-yr follow-up	150 patients; mean age 30; mixed activity levels	Free QT vs. HT	Comparable Lysholm and IKDC scores; slight early hamstring weakness in HT
Khalil & Zawam (2025) (17)	Prospective comparative study	120 patients; mean age 25; recreational athletes	Peroneus longus vs. HT*	Similar stability, the peroneus longus provides context on an alternative tendon choice
Kajetanek et al. (2025)(18)	Comparative cohort; MCL concomitant injury	64 patients with MCL damage; mean age 29	QT vs. HT	Comparable joint stability: The QT group reported less donor-site pain
Horstmann et al. (2022)(12)	Prospective RCT	100 patients; mean age 26; competitive athletes	QT vs. HT	Equivalent laxity and functional scores; rare arthrofibrosis in either group

Pomenta Bastidas et al. (2022)(13)	Prospective comparative study: ≥2-yr follow-up	52 patients; 25 QT, 27 HT; primary ACL reconstruction	QT vs. HT	Similar to Lysholm, IKDC, and Tegner, no difference in stability or return-to-sport
Radić et al. (2023)(16)	Randomized controlled trial; 2-yr follow-up	112 patients; 57 QT, 55 HT	QT vs. HT	No significant differences in clinical scores, range of motion, graft laxity, or return to sport
Araki et al. (2024)(14)	Prospective comparative study	27 patients; 11 QT, 16 HT; mean age ~25	QT vs. HT	QT group had lower knee extension strength at 3 months, comparable by 6–12 months; no differences in flexion strength, IKDC, or Tegner

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