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Systematic Review

Critical evaluation of the parameters used in randomized controlled trials of quadriceps tendon, bone-patellar tendon-bone, and hamstring tendon for anterior cruciate ligament reconstruction: a systematic review

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ABSTRACT

Anterior cruciate ligament (ACL) reconstruction using autologous quadriceps tendon (QT), bone-patellar tendón-bone (BPTB), and hamstring tendon (HT) grafts has been extensively investigated in randomized controlled trials (RCTs). However, few systematic reviews have analyzed how functional and stability outcomes are measured or the methodological consistency of the evaluation tools employed. Objectives were to systematically review RCTs comparing QT, BPTB, and HT grafts for ACL reconstruction, emphasizing the assessment methods, parameters used, and methodological limitations. Eleven RCTs were included. Functional scales (IKDC, Lysholm, Tegner, KOOS), stability tests (Lachman, pivot-shift, KT-1000), pain and strength measurements, and follow-up duration were analyzed. Methodological consistency, completeness of outcome reporting, and comparability between studies were also assessed. Eleven RCTs comprising 692 patients were analyzed. Comparable clinical efficacy was observed among QT, BPTB, and HT grafts regarding joint stability and function. Nevertheless, significant heterogeneity existed in evaluation tools. Objective assessments such as quadriceps strength, KT-1000 anterior translation, and MRI follow-up were inconsistently reported. Most studies relied primarily on patient-reported outcome measures (PROMs) such as Tegner, Lysholm, and IKDC, without standardized timing or threshold values, limiting interstudy comparability. This review highlights substantial methodological variability in how clinical and functional outcomes are evaluated after ACL reconstruction. Beyond clinical equivalence among grafts, there is a pressing need to establish standardized, objective, and comprehensive assessment protocols to enhance the quality, reproducibility, and clinical relevance of future comparative trials.

Keywords: Anterior cruciate ligament reconstruction, Bone-patellar tendon-bone graft, Quadriceps autograft, Clinical outcomes, Knee function

INTRODUCTION

Anterior cruciate ligament (ACL) reconstruction is one of the most commonly performed procedures in orthopedic surgery, with more than 200,000 operations annually in the United States alone and an increasing incidence in young and high-performance athletes.[1] The choice of graft is a determining factor for functional outcomes, joint stability, and patient satisfaction. Traditionally, bone-patellar tendón-bone (BPTB) and hamstring tendon (HT) autografts have been the most widely used; however, in the last decade, there has been renewed interest in quadriceps tendon (QT) grafts as a safe and effective alternative.[2] QT autografts are known to be effective for ACL reconstruction and show functional results similar to BPTB grafts in randomized controlled trials (RCTs), with a lower incidence of complications.[3] In addition, it is associated with less anterior knee pain and a lower incidence of skin sensitivity alterations than BPTB grafts.[4] These properties have made it an increasingly popular graft, especially in physically active patients or in revision surgeries.[5] Early comparative studies demonstrated similar clinical results between QT and traditional grafts, finding equivalent results in Lysholm, Tegner, and IKDC-S scores.[5,6]

Recent systematic reviews reinforce these findings. Some of these conclude that QT grafting produces functional results comparable to BPTB and HT, with less anterior pain and lower donor site morbidity.[7] Meta-analyses focusing exclusively on randomized trials report similar rates of re-rupture, stability, and return to sport between QT and HT, with QT having an advantage in donor site tolerance.[8,9] Other reviews on the subject evaluate the prevalence of donor site morbidity and complications, finding no difference between graft types and recommending that their selection can be individualized.[10] Some other reviews compare scores on patient-validated scales (IKDC, Lysholm, Tegner) through meta-analysis, concluding that all three remain viable options for ACLR.[11] Make direct comparisons between QT vs. BPTB and HT, finding functional equivalence, less anterior pain, and slightly superior subjective results with QT on quality of life scales.[12] Furthermore, in more recent analyses, one study analyzes the methodological fragility of RCTs.[13]

Even with this evidence, the literature shows marked heterogeneity in the parameters used to evaluate results. There are wide variations in subjective measurement instruments (IKDC, Lysholm, KOOS, Tegner), objective methods (KT-1000, Lachman, pivot-shift), and strength assessment using cybex dynamometry or functional tests (single-leg hop, leg hop test, limb symmetry index).[4,14-17] For example, early reviews in 2015 point to a lack of uniformity in the evaluation criteria and follow-up times of studies on TQ.[18] On the other hand, some comparative studies between TKA and TKR show that although the functional results are equivalent, the methods of assessing laxity and anterior pain vary significantly between trials, and some others highlight the need to standardize outcome scales to more accurately define the clinical superiority of one graft over another.[19,20] Heterogeneous methodological structures were also observed in systematic reviews, which indicate that conclusions about efficacy depend largely on the type of functional parameter used and the follow-up time.[21.,22]

The growing adoption of QT in clinical practice worldwide, coupled with the diversity of methodologies used to measure outcomes, raises the need for a critical evaluation of the parameters used in RCTs. This analysis will identify which instruments are most reproducible, sensitive, and clinically relevant for assessing graft function, as well as propose standardized criteria to facilitate comparison between studies and the design of future high-quality research. In a context where the goal is not only to restore mechanical stability but also to optimize function and safe return to sport, standardization of the parameters evaluated is essential for evidence-based medicine applied to ACL surgery. Unlike previous reviews, which focus on synthesizing clinical results, the objective of this systematic review is to critically analyze the evaluation criteria used in RCTs to compare different types of grafts. We argue that the lack of a standardized evaluation protocol hinders direct comparison between studies and limits the validity of overall conclusions. Therefore, this work not only seeks to summarize what is already known, but also to highlight the need to establish comprehensive and consistent evaluation guidelines.

METHODS

A systematic review was conducted in the PubMed, Cochrane Library, Scopus, and Web of Science databases, searching for eligible studies from January 1, 2000, to May 31, 2025, using MESH terms. All searches and article selections were performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria.[23-25] To guide the search, the question was formulated using the PICO acronym: P: Adult patients (over 18 years of age) undergoing ACL reconstruction. I: ACL reconstruction using an autologous quadriceps graft (quadriceps autograft). C: ACL reconstruction using autologous patellar tendon-bone graft (patellar tendon-bone graft) or hamstring autograft. O: Joint stability, muscle strength, pain, and functional recovery assessed in RCTs.

In adult patients undergoing ACL reconstruction, which graft is best for ACL reconstruction using autologous quadriceps graft versus autologous bone-tendon-bone graft or hamstring graft, comparing outcomes in terms of joint stability, muscle strength, pain, and functional recovery, according to evidence from RCTs?

Based on this question, a search strategy was developed using MESH terms. Example search strategy: "ACL reconstruction" and "quadriceps autograft" or "patellar tendon-bone graft" or "hamstring graft" and "randomized controlled trial."

Search criteria

Selection criteria

RCTs comparing the QT graft with bone-tendon graft or hamstring graft for ACL reconstruction will be included. Articles in any language were included, provided that an English translation is available at the time of the search.

Exclusion criteria

Reviews, non-randomized cohort or case-control studies, demographic studies, anatomical studies in cadavers or animals, case reports, expert opinions, unpublished studies, and studies investigating the results of reconstruction with other ligaments not including QT will be excluded from the analysis.

Type of intervention

Studies included

Adult patients over 18 years of age with primary ACL injury; primary ACL reconstruction with QT autograft; Studies comparing the results of QT autograft versus bone-tendon-bone or hamstring autograft.

Studies excluded

Patients with ACL repair; ACL reconstruction with any allograft; ACL reconstruction with another type of autograft; ACL repair or secondary ACL reconstruction.

Type of results

Patients undergoing primary ACL reconstruction.

Sources of information

Using Mesh terms and limiting the search to the period 2000-2025, 151 articles were found in PubMed, 71 in Cochrane, 271 in Scopus, and 64 in Web of Science, for a total of 557 articles. All records obtained were imported into the Zotero bibliographic manager and 240 duplicates were removed, leaving a total of 317 articles.

Study selection

Two authors evaluated the studies for selection, without blinding. After reading the title, 12 articles were selected, from which the full text was obtained.

One of them was removed because it was not an RCT, leaving a total of 11 articles selected for this review (Figure 1).

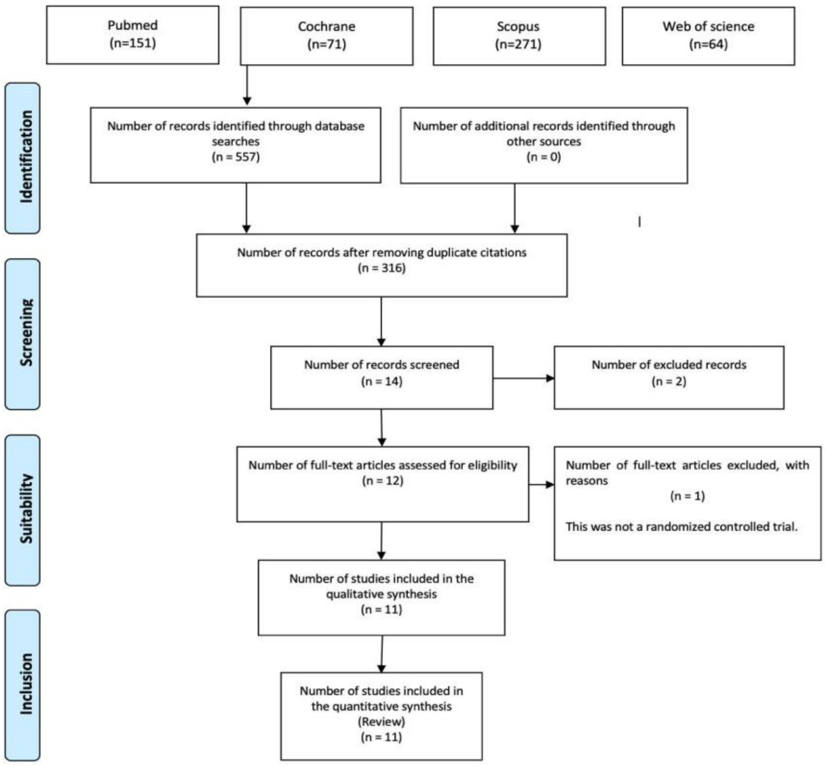

Figure 1: PRISMA flow diagram representing the RCT search work to evaluate the parameters used in QT, BTPB, and HT grafts in ACL reconstruction.

RESULTS

Eleven randomized clinical trials were identified that compared QT grafting with BPTB or HT for ACL reconstruction. Overall, the studies reported equivalent results in joint stability and clinical function between QT and the various comparative grafts (hamstring, bone-tendon-bone, and their technical variants). Likewise, the results on functional scales (IKDC, Lysholm, KOOS, Tegner, among others) showed significant postoperative improvements in all groups, with no clinically relevant differences.

However, some studies highlighted differences in specific aspects: greater donor morbidity and anterior pain with BPTB, differential muscle deficits between QT and HT, and slightly more favorable early functional recovery in HT. In the long term, studies with prolonged follow-up demonstrated equivalence in re-rupture rates, return to sports, and satisfaction, with the possible advantage of lower donor morbidity for quadriceps grafts.

Table 1: Summary of randomized clinical trials comparing quadriceps, hamstring, and bone-tendon-bone grafts in ACL reconstruction (2014-2025).

Authors	Country	Comparison	Design/ N°	Follow-up	Mean age (in years)	Stability	Function/ PROMs	Strength	Pain/donor-site morbidity	Return to sport	Complications	Authors' conclusions	Limitations
Horstmann et al	Germany	QT vs HT	RCT, 51 completed	24 momths	29	Improvement in both; no differences	IKDC, Lysholm: no differences	Isokinetic strength: no differences	-	Return to pre-injury level: 82±45.6 d (QT) vs 95.2±45.5 d (HT)	-	Clinical equivalence between QT and HT at 2 years	Small sample; 2-year follow-up
Lind et al	Denmark	QT vs HT (STG)	RCT, 99 (50/49)	24 momths	28	KT-1000, pivot-shift: no differences	IKDC, KOOS: no differences	Jump symmetry: 91% (QT) vs 97% (HT)	Lower donor-site morbidity in QT (27% vs 50%)	-	-	QT not inferior to HT; less donor-site morbidity with QT	2-year follow-up; single-center
Barié et al	Germany	QTB vs BPTB (press-fit)	RCT, 60 (43/17)	10 years	Athletes	KT-1000 <3 mn in 91%; equivalent	Lysholm, IKDC: equivalent	-	More anterior knee pain in BPTB (1 and 10 yrs)	RTS Tegner leve 6 at 10 yrs	1 rerupture at 10 yrs	QTB and BPTB equivalent; lower morbidity with QTB	Press-fit technique; athletic cohort only
Ebert et al	Australia	QT vs HT	RCT, 112 (55/57)	24 momths	28-29	>90% <3 mm KT-1000; no differences	Similar PROMs; ACL-RSI higher in HT at 3-12 mo	HT>QT in quadriceps; QT>HT in hamstrings	-	HT 76% vs QT 70% (ns)	1 rerupture (QT), 2 contralateral	Comparable stability and function; muscle deficits depend on graft	Unblinded; non-standardized rehab
Vilchez-Cavazos et al	Mexico	QT vs HT	RCT, 28 (14/14)	12 momths	23	—	Lysholm, IKDC, Tegner, SF-12 improved; no differences	-	2 cases of anterior knee pain in QT	-	-	Equivalent outcomes in pain and function at 1 year	Small sample; 1-year follow-up
Martín-Alguacil et al	Spain	QT vs HT (soccer players)	Secondary analysis of RCT, 51 (25/26)	12 momths	18-19	—	PPT and tendon thickness: no differences	-	-	-	-	QT and HT equivalent in sensitivity and tissue architecture	Secondary analysis; limited power
Şahin et al	Denmark	QT vs HT	RCT, 100 (50/50)	12 momths	28	—	IKDC improved in both groups	Extension deficit in QT; flexion deficit in HT	-	-	-	Similar functional recovery; graft-specific strength deficits	Short follow-up; 1 year
García-Linage et al	Mexico	QT vs HT	RCT, 26 (13/13)	12 momths (360 days)	27	Negative pivot and Lachman in all	Lysholm, modified CKRS: no differences	—	Higher VAS pain in QT at 30-180 d; no differences at 360 d	RTS: 239 d (QT) vs 266 d (HT) (ns)	-	Similar stability and function; greater early pain ir QT	Small sample; 1-year follow-up
Lund et al	Denmark	QTB vs BPTB	RCT, 51 (25/26)	24 momths	27	KT-1000: no differences	IKDC, KOOS: no differences	—	Less pain and numbness in QTB	-	-	QTB is a viable alternative to BPTE with lower donor morbidity	Level II; small sample
Buescu et al	Romania	FQT vs HT	RCT, 48 (24/24)	Immediat e postop	25	—	—	—	Less rescue analgesia in QT (50% none vs 13% HT)	-	-	QT associated with less acute postop pain	Immediate FU only; no functional or stability data
Martín-Alguacil et al	Spain	QT vs HT (soccer players)	RCT, 56	12-24 momths	19	—	Similar function at 24 mo	H/Q ratio better in QT at 12 mo	-	-	-	QT comparable to HT; H/Q advantage in QT	Specific cohort; soccer players only

*RCT: randomized clinical trial; QT: quadriceps tendon; QTB: quadriceps tendon with bone graft; FQT: free quadriceps tendon; HT: hamstrings; STG: semitendinosus-gracilis; BPTB: patellar bone-tendon-bone; PROMs: patient-reported outcome measures; H/Q: hamstring/quadriceps ratio; IKDC: International knee documentation committee; KOOS: Knee osteoarthritis outcome score; RTS: return to sport.

DISCUSSION

The reconstruction of the ACL using QT autografts has become established in recent years as a valid alternative to HT and BPTB grafts.

A synthesis of eleven randomized clinical trials confirms that the clinical results and joint stability achieved with QT are equivalent to those obtained with traditional grafts, with more notable differences in aspects related to muscle strength, donor site morbidity, and early postoperative pain.[26-36]

In terms of stability, multiple studies agree that there are no significant differences between QT and HT or BPTB. Studies by Horstmann, Lind, Ebert, García-Linage, Lund, and Barié report equivalent results in both KT-1000 instrumented tests and clinical maneuvers such as pivot shift or anterior drawer, with more than 90% of patients maintaining a translation <3 mm even in prolonged follow-ups of up to 10 years.[26-29.33.34] These findings confirm that QT offers biomechanical restoration of joint stability comparable to that of conventional grafts.

Functional outcomes measured using validated questionnaires (IKDC, KOOS, Lysholm, Tegner, SF-12) improved significantly in all groups studied, with no relevant differences between grafts. None of the trials found functional inferiority of QT compared to BPTB or HT, and Barié even reports equivalence at 10 years in athletic patients.[28] It should be noted that Ebert and his group of collaborators observed that the ACL-RSI score was higher in patients with HT during the first 12 months, suggesting a better self-perception of safety to resume sports activity in the early stages, although this difference disappeared in the second year.[29]

Muscle strength is the area where clear differential patterns are observed. Studies by Sahin and Ebert document specific deficits depending on the donor site: deficit in knee extension after TQ use and deficit in flexion after HT.[29,32] Lind corroborates these findings by reporting lower symmetry in functional jump tests in the TQ group at one year, although the differences were slight.[27] Martin-Alguacil and his group of researchers, working with soccer players, describe a better H/Q ratio with QT at 12 months, which could have a protective effect against re-ruptures in pivot sports.[36] These findings reinforce the need for individualized rehabilitation protocols depending on the type of graft used.

In terms of pain and morbidity at the donor site, the data consistently favor QT over BPTB and, in some respects, also over HT. Lind reports lower donor site morbidity with QT (27% vs. 50% in HT), while Barié and Lund show more pain when kneeling and greater residual sensitivity in patients with BPTB, confirming an advantage of QT over patellar grafting.[27,28,28] With regard to early postoperative pain, the findings are heterogeneous: Buescu et al. report lower analgesic consumption and less need for rescue medication in patients with TQ, while García-Linage et al report higher VAS values in TQ at 30 and 180 days, a difference that disappeared after one year.[33,35] This indicates that early pain may depend both on the graft and on contextual factors such as surgical technique and analgesic management.

The return to sporting activity showed comparable times between grafts. Horstmann and his group of researchers report a return to the previous level in 82 days for QT and 95 days for HT, with no significant differences.[26] García-Linage concludes that the times to return to competitive sports activity were similar between both groups (239 days for QT vs. 266 days for HT).[33] No study showed differences in the rates of return to sports activity, suggesting that the type of graft is not a determining factor in this outcome.

Complications and re-ruptures were rare in all studies. Ebert reports one ipsilateral rerupture in the QT interval and two contralateral reruptures in a 24-month follow-up, while Barié and his research group document minimal failures in both groups after 10 years of follow-up.[28,29] These data confirm the safety of both grafts in terms of recurrences and reoperations.

Beyond clinical outcomes, it is important to analyze the comprehensiveness and methodological consistency of the included trials. Although all reported functional outcomes and stability, there is heterogeneity in the parameters, scales, and methods used. Some studies prioritized instrumented tests (KT-1000, pivot shift), while others focused their analyses on PROMs (IKDC, KOOS, Lysholm, SF-12).[26-31,33,34] In the case of pain, the methods varied between the visual analog scale (VAS), analgesic rescue, and sensitivity tests, making direct comparison difficult.[32-34]

Furthermore, few studies incorporated objective and consistent measurements of isokinetic strength, despite the fact that this aspect represents a key difference between grafts.[27,29,32,36]

These methodological discrepancies highlight the need to standardize results in RCTs on ACL reconstruction, defining a basic set of common parameters that include objective stability, patient-reported function, isokinetic strength, and return to sports competition. Similarly, follow-up periods in most trials were short (≤24 months), limiting the assessment of re-ruptures, joint degeneration, or sustained sports outcomes.[26,27,29-32,35,36]

Based on these findings, we propose that future clinical studies use a standardized protocol that includes at least seven fundamental domains: minimum follow-up, functionality, stability, strength, donor site morbidity, return to sport, and imaging studies. Each of these aspects represents an essential component for obtaining a comprehensive and reproducible assessment of postoperative outcomes.

Firstly, the minimum follow-up period should be at least twenty four months, with intermediate evaluations at six and twelve months. The literature has shown that many relevant clinical outcomes, such as graft failure, persistent laxity, degenerative joint changes, and complete functional recovery, manifest late and cannot be adequately assessed in short follow-ups.[37,38]

Longitudinal studies comparing BPTB and HT grafts with follow-ups of more than ten years have shown that differences in stability and revision rates may emerge several years after surgery.[39]

With regard to functionality, the use of patient reported outcome measures (PROMs) should be considered indispensable. Scales such as Lysholm, Tegner, IKDC-S, and KOOS have proven to be valid, reliable, and sensitive tools for quantifying the patient's subjective perception of their function and quality of life after reconstruction.[40-42]

The standardization of these instruments allows for comparison between studies and the performance of homogeneous meta-analyses. In addition, the incorporation of scales such as the ACL-return to sport after injury scale (ACL-RSI) complements the functional assessment with a psychological approach that is crucial for returning to sports.[43]

Joint stability, meanwhile, must be assessed objectively using validated instruments such as the KT-1000 or KT-2000 arthrometer. These devices allow the anteroposterior translation of the tibia relative to the femur to be quantified by comparing the operated side with the contralateral side.[44] Their standardized use (same test load, position, and blind operator) ensures reproducibility and comparability between studies.[44,45]

The arthrometer remains the most accessible and widely accepted clinical standard for quantifying residual laxity.[46] The incorporation of this measurement is essential, given that objective stability does not always correlate directly with the patient's subjective perception.[46]

In terms of muscle strength, studies agree that residual deficiencies persist for months or years depending on the type of graft used. Isokinetic analysis, using computerized dynamometry, remains the gold standard method for objectively quantifying quadriceps and hamstring torque at different angular velocities.[47]

Patients with HT grafts often have persistent flexion deficits, while BPTB and QT grafts are associated with quadriceps extensor weakness.[48] At the same time, functional jump tests-single-leg hop test, triple hop, or crossover hop test-provide a dynamic assessment of performance and interlimb symmetry, correlating closely with athletic function.[49] The combination of isokinetic and functional tests provides a comprehensive view of both quantitative and functional muscle recovery.[48,49]

Donor site morbidity is an aspect that is often underestimated and poorly standardized. The type of graft determines specific local sequelae: BPTB grafting is associated with anterior knee pain, patellar tendinopathy, and discomfort when kneeling, while HT can cause residual weakness or hamstring contracture.[50,51] Meanwhile, QT grafts tend to cause less anterior pain, although they may produce residual tendon defects or temporary discomfort.[52]

Standardized assessment of morbidity should include visual analog scales (VAS) for pain, evaluation of local residual strength, sensitivity analysis, and imaging or ultrasound to characterize the integrity of the remaining tendon.[54] Return to sport is one of the most relevant outcomes from a functional and social point of view. It has been observed that the success of reconstruction depends not only on graft integrity, but also on psychological factors and functional performance.[55]

Therefore, the literature recommends using objective parameters such as the percentage of patients who return to the same competitive level, the time to return (in months), and combined functional criteria (e.g., jump symmetry ≥90%, isokinetic strength ≥90% compared to the contralateral limb, and absence of pain).[56] Scales such as the ACL-RSI and the Tegner Activity Scale allow the patient's perception to be integrated with their physical performance.[43]

Finally, imaging studies, particularly magnetic resonance imaging (MRI), should be part of the structural follow-up of the graft. This method allows for the evaluation of maturation (“ligamentization”), thickness, continuity, and signal of the graft, as well as alterations in the bone tunnels.[57]

MRI also makes it possible to analyze the morphology of the donor site and its healing process, providing objective information that complements clinical and functional evaluations.[55,56] In this way, imaging becomes a useful tool both for correlating functional findings with the biological integration of the graft and for detecting asymptomatic complications at an early stage.

Together, the systematic integration of these seven domains-minimum follow-up, functional PROMs, objective stability tests, strength quantification, donor site morbidity, return to sport, and MRI-will enable standardization of methodology in future comparative studies of ACL reconstruction grafts.

This standardization will not only promote the reproducibility and methodological quality of trials, but will also facilitate the performance of robust meta-analyses and the formulation of evidence-based guidelines to guide the selection of the ideal graft according to the patient's functional profile.

Table 2: Proposed parameters for the clinical evaluation of graft type in ACL reconstruction in RCTs.

Parameters	Description
Minimum follow-up	24 months
Age range (in years)	>18 and <60
Stability assessment	Instrumented laxity testing using KT-1000/2000 arthrometer at 6, 12, 18, and 24 months. Clinical stability tests including anterior drawer, Lachman, and pivot-shift tests at 6, 12, 18, and 24 months.
Functional assessment/PROMs	Patient-reported outcome measures (Tegner, Lysholm, KOOS, and IKDC-S) recorded at 6, 12, 18, and 24 months.
Muscle strength	Isokinetic dynamometry at 12 and 24 months. Single-leg hop or leg hop test performed for functional strength symmetry.
Pain/donor-site morbidity	Evaluation using the VAS and cutaneous sensitivity testing at serial follow-ups.
Return to sport	Mean time to return to sport (RTS) recorded and compared between groups. ACL-return to sport after injury (ACL-RSI) scale applied for psychological readiness.
Imaging studies	MRI performed at 24 months to assess graft integrity and tunnel status.

*RCT: randomized clinical trial. ACL: anterior cruciate ligament.

CONCLUSION

Evidence from eleven randomized clinical trials shows that the QT offers comparable results in terms of stability and function compared to hamstring and bone-tendon-bone grafts in ACL reconstruction, although it presents a transient extensor deficit and heterogeneous results in terms of early postoperative pain.

Interpretation is limited by small sample sizes, heterogeneous assessment methods, and short follow-up periods. More standardized randomized clinical trials that meet standard parameters defined by the literature are needed to more accurately define the role of the QT as the graft of choice in young patients and athletes.

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REFERENCES

1. Sanders TL, Maradit Kremers H, Bryan AJ, Larson DR, Dahm DL, Levy BA, et al. Incidence of Anterior Cruciate Ligament Tears and Reconstruction: A 21-Year Population-Based Study. Am J Sports Med. 2016;44(6):1502-7.
2. Slone HS, Romine SE, Premkumar A, Xerogeanes JW. Quadriceps tendon autograft for anterior cruciate ligament reconstruction: a comprehensive review of current literature and systematic review of clinical results. Arthroscopy. 2015;31(3):541-54.
3. Cavaignac E, Coulin B, Tscholl P, Nik Mohd Fatmy N, Duthon V, Menetrey J. 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. Am J Sports Med. 2017;45(6):1326-32.
4. Mouarbes D, Menetrey J, Marot V, Courtot L, Berard E, Cavaignac E. 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. Am J Sports Med. 2019;47(14):3531-40.
5. Runer A, D'Ambrosi R, Armin R, Akshya R, Manish A, Elisabeth A, et al. Quadriceps tendon autograft for primary ACL reconstruction-clinical and functional results. Knee Surg Sports Traumatol Arthrosc. 2023;31(6):3181-91.
6. Meena A, et al. Both Hamstring and Quadriceps Tendon Autografts Offer Comparable Outcomes. Knee Surg Sports Traumatol Arthrosc. 2024;32(4):171220.
7. Dai W, Xi L, Jian W, Jin C, Xiaoqing H, Yingfang A. Quadriceps Tendon Autograft Versus BPTB and HT Autografts: Meta-analysis. Am J Sports Med. 2022;50(12):3425-39.
8. Tan TK, Arjun GS, Jay RE, Ross R. Quadriceps vs Hamstring Autografts for ACL Reconstruction: Systematic Review and Meta-analysis. Am J Sports Med. 2022;50(14):3974-86.
9. Raj S, Ali R, Henry KCS, Chetan K, Imran A, Andrew M, et al. Quadriceps vs Hamstring Tendon Graft for Primary ACL Reconstruction: Systematic Review and Meta-analysis. Knee. 2024;49:226-40.
10. Kunze KN, Moran J, Polce EM, Pareek A, Strickland SM, Williams RJ 3rd. Lower donor site morbidity with hamstring and quadriceps tendon autograft compared with patellar tendon autograft after anterior cruciate ligament reconstruction: a systematic review and network meta-analysis of randomized controlled trials. Knee Surg Sports Traumatol Arthrosc. 2023;31(8):3339-52.
11. White T, Castro M, Antonio L, Hing W, Tudor F, Sattler L. Quadriceps, hamstring and patella tendon autografts for primary anterior cruciate ligament reconstruction demonstrate similar clinical outcomes, including graft failure, joint laxity and complications: A systematic review with meta-analysis of

randomised controlled trials. Knee Surg Sports Traumatol Arthrosc. 2025;NA.
12. Zhang XF, Pan L, Jun-Wu H, Yao-HH. Efficacy and safety of quadriceps tendon autograft vs BPTB and HT autografts: Systematic review and meta-analysis. J Orthopaed Traumatol. 2024;25:65.
13. Dworsky-Fried J, Bernardini L, Vivekanantha P, Gyemi L, Meena A, Tapasvi S, et al. How statistically fragile are randomized controlled trials comparing quadriceps tendon autografts with hamstring or bone-patellar tendon-bone autografts in anterior cruciate ligament reconstruction? Knee Surg Sports Traumatol Arthrosc. 2025;33(8):2729-44.
14. Al-Gburi M, Kristiansen JB, Christensen KB, Krogsgaard MR. Functional performance tests, clinical measurements, and patient-reported outcome measures do not correlate as outcomes 1 year after anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc. 2023;31(12):5905-12.
15. Abrams GD, Harris JD, Gupta AK, McCormick FM, Bush-Joseph CA, Verma NN, et al. Functional performance testing after anterior cruciate ligament reconstruction: a systematic review. Orthop J Sports Med. 2014;2(1):2325967113518305.
16. Beere M, Ebert JR, Joss B, Ackland T. Isometric dynamometry, dependent on knee angle, is a suitable alternative to isokinetic dynamometry when evaluating quadriceps strength symmetry in patients following anterior cruciate ligament reconstruction. Knee. 2022;34:124-33.
17. Dutaillis B, Collings T, Bellinger P, Timmins RG, Williams MD, Bourne MN. Time course changes in lower extremity strength, vertical jump metrics, and their relationship to patient informed outcomes after anterior cruciate ligament reconstruction. Sports Knee Surgery Traumatol Arthrosc. 2025;33(7):2684-99.
18. Slone HS, Spencer ER, Ajay P, John WX. Quadriceps tendon autograft for ACL reconstruction: A comprehensive review. Arthroscopy. 2015;31(3):541-54.
19. Ajrawat P, Dwyer T, Whelan D, Theodoropoulos J, Murnaghan L, Bhargava M, et al. Comparison of Quadriceps Tendon Autograft With Bone-Patellar Tendon-Bone Autograft and Hamstring Tendon Autograft for Primary Anterior Cruciate Ligament Reconstruction: A Systematic Review and Quantitative Synthesis. Clin J Sport Med. 2021;31(4):392-9.
20. Herman ZJ. Outcomes of BPTB and QT Autografts for ACL Reconstruction. Orthop J Sports Med. 2024;12(4):2325967124123456.
21. Ashy C, Evan B, Joshua H, Emily B, Rachel B, William MP, et al. Quadriceps Tendon Autograft Has Similar Clinical Outcomes to HT and BPTB Autografts. Knee Surg Sports Traumatol Arthrosc. 2023;31(7):2891-02.
22. Cordasco FA, Sofia HP, Tyler JU, Danielle EC, Nicolas PL, Alexandra HA, et al. Quadriceps Tendon ACL Reconstruction in Skeletally Immature Patients: 3-Year Outcomes. Am J Sports Med. 2024;52(9):2230-6.
23. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. Declaración PRISMA 2020: una guía actualizada para la presentación de informes de revisiones sistemáticas. PLoS Med. 2021;18:e1003583.
24. Liberati A, Altman DG, Tetzlaff J, Cynthia M, Peter CG, John PAI, et al. The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions: Explanation and Elaboration. Ann Int Med. 2009;151(4):W-65-94.
25. Page MJ, Moher D, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. BMJ. 2021;372:160.
26. Horstmann H, Maximilian P, Uwe T, Gernot F, Christian K, Michael J, et al. Quadriceps and hamstring tendon autografts in ACL reconstruction yield comparably good results in a prospective, randomized, controlled clinical trial. Arch Orthop Trauma Surg. 2022;142(2):281-9.
27. Lind M, Torsten GN, Ole GS, Bjarne MK, Peter F. Quadriceps tendon grafts do not cause worse outcomes compared to hamstring grafts: a 2-year randomized controlled trial. Brit J Sports Med. 2020;54(3):183-7.
28. Barié A, Thomas S, Jürgen H, Ayham J. Quadriceps tendon autograft vs. Patellar tendon with pressure fixation: 10-year results in athletes. Arch Orthoped Trauma Surg. 2020;140(10):1465-74.
29. Ebert JR, Nicholas DC, Ross R. A Prospective Randomized Controlled Trial Investigating Quadriceps Versus Hamstring Tendon Autograft in Anterior Cruciate Ligament Reconstruction. Am J Sports Med. 2024;52(3):660-9.
30. Vilchez-Cavazos F, Dávila-Martínez A, de la Garza-Castro S, Simental-Mendía M, Garay-Mendoza D, Tamez-Mata Y, et al. Anterior cruciate ligament injuries treated with quadriceps tendon autograft versus hamstring autograft: A randomized controlled trial. Cirugía y Cirujanos. 2020;88(1):76-81.
31. Martin-Alguacil JL, Arroyo-Morales M, Martin-Gómez JL, Lozano-Lozano M, Galiano-Castillo N, Cantarero-Villanueva I, et al. Comparison of knee ultrasound and pressure pain threshold after anterior cruciate ligament (ACL) reconstruction with quadriceps tendon versus hamstring tendon autografts in soccer players. Acta Orthopaed Traumatol Turcica. 2019;53(4):260-5.
32. Şahin K, Torsten GN, Lars GH, Martin L, Ulrik D. Effects of autograft types on muscle strength and functional capacity in anterior cruciate ligament (ACL) reconstruction: a randomized controlled trial. Sports Med. 2020;50(7):1393-403.
33. García-Linage R, Lassard-Rosenthal J, Noval-García R, Muñiz-Madrazo A, Fraind-Maya G, Palmero-Picazo J, et al. Injerto autólogo de isquiotibiales

versus cuádriceps en la plastía de ligamento cruzado anterior. Estudio comparativo con enfoque al Return-To-Sport. Acta Ortopédica Mex. 2025;39(1):19-26.
34. Lund B, Nielsen T, Fauno P, Christiansen SE, Lind M. Is the quadriceps tendon a better graft option than the patellar tendon? A prospective randomized study. Arthroscopy. 2014;30(5):593-8.
35. Buescu CT, Adela HO, Dan OL, Adrian T. Pain level after anterior cruciate ligament (ACL) reconstruction: comparative study between free quadriceps tendon and hamstring tendon autografts. Acta Orthop Traumatol Turcica. 2017;51(2):100-3.
36. Martin-Alguacil JL, Manuel AM, Jose LMG, Isidro MMC, Juan FAG, Francisco ER, et al. Strength recovery after anterior cruciate ligament reconstruction with quadriceps tendon versus hamstring tendon autografts in soccer players: A randomized controlled trial. Knee. 2018;25(4):704-14.
37. Gifstad T, Anita S, Torbjørn S, Gisle U, Torbjørn G, Jon OD. Long-term follow-up after ACL reconstruction using patellar tendon or hamstring autograft. Am J Sports Med. 2014;42(2):230-8.
38. Wiggins AJ, Ravi KG, Daniel KS, Denver S, Kate EW, Gregory DM, et al. Risk of secondary injury in younger athletes after ACL reconstruction. Am J Sports Med. 2016;44(7):1861-76.
39. Mohtadi NG, Denise SC. A randomized clinical trial comparing patellar tendon, hamstring tendon, and quadriceps tendon autografts. Am J Sports Med. 2019;47(13):3227-37.
40. Irrgang JJ, Anderson AF, Boland AL, Harner CD, Kurosaka M, Neyret P, et al. Development and validation of the IKDC Subjective Knee Form. Am J Sports Med. 2001;29(5):600-13.
41. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. KOOS development and validation for ACL injury. J Orthop Sports Phys Ther. 1998;28(2):88-96.
42. Lysholm J, Gillquist J. Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. Am J Sports Med. 1982;10(3):150-4.
43. Webster KE, Feller JA. Development and validation of the ACL-RSI scale. Am J Sports Med. 2018;46(3):743-9.
44. Daniel DM, Stone ML, Sachs R, Malcom L. Measurement of knee laxity using the KT-1000 arthrometer. Am J Sports Med. 1985;13(6):401-7.
45. Isberg J, Eva F, Sveinbjörn B, Bengt IE, Johan K, Jon K. KT-1000 versus radiostereometric analysis. Am J Sports Med. 2006;34(9):1404-11.
46. Daniel DM, Stone ML, Sachs R, Malcom L. Instrumented measurement of anterior knee laxity in patients with acute anterior cruciate ligament disruption. Am J Sports Med. 1985;13(6):401-7.
47. Fischer F, Fink C, Herbst E, Hoser C, Hepperger C, Blank C, et al. Higher hamstring-to-quadriceps isokinetic strength ratio during the first post-operative months in patients with quadriceps tendon compared to hamstring tendon graft following ACL reconstruction. Knee Surg Sports Traumatol Arthrosc. 2018;26(2):418-25.
48. Gustavsson A, Neeter C, Thomeé P, Silbernagel KG, Augustsson J, Thomeé R, et al. A test battery for evaluating hop performance in patients with an ACL injury and patients who have undergone ACL reconstruction. Knee Surg Sports Traumatol Arthrosc. 2006;14(8):778-88.
49. Hardy A, Casabianca L, Andrieu K, Baverel L, Noailles T, Junior French Arthroscopy Society. Complications following harvesting of patellar tendon or hamstring tendon grafts for anterior cruciate ligament reconstruction: Systematic review of literature. Orthop Traumatol Surg Res. 2017;103(8S):S245-8.
50. Ahldén M, Samuelsson K, Sernert N, Magnus F, Jón K, Jüri K. The Swedish National Anterior Cruciate Ligament Register: a report on baseline variables and outcomes of surgery for almost 18,000 patients. Am J Sports Med. 2012;40(10):2230-5.
51. Grindem H, Snyder-Mackler L, Moksnes H, Lars E, May AR. Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Norway cohort study. Br J Sports Med. 2016;50(13):804-8.
52. Noyes FR, Barber SD, Mangine RE. Abnormal lower limb symmetry determined by functional hop tests after anterior cruciate ligament rupture. Am J Sports Med. 1991;19(5):513-8.
53. Barber-Westin SD, Noyes FR. Factors used to determine return to unrestricted sports activities after anterior cruciate ligament reconstruction. Arthroscopy. 2011;27(12):1697-705.
54. Webster KE, Feller JA, Lambros C. Development and preliminary validation of a scale to measure the psychological impact of returning to sport after anterior cruciate ligament reconstruction surgery. Am J Sports Med. 2008;9(1):9-15.
55. van der List JP, DiFelice GS. The Role of MRI in the Evaluation of the ACL Reconstructed Knee. J Knee Surg. 2017.
56. Claes S, Verdonk P, Forsyth R. The "ligamentization" of anterior cruciate ligament grafts. Am J Sports Med. 2011;39:2476-83.
57. Potter HG, Jain SK, Ma Y, Black BR, Fung S, Lyman S. Cartilage injury after acute, isolated anterior cruciate ligament tear: immediate and longitudinal effect with clinical/MRI follow-up. Am J Sports Med. 2012;40(2):276-85.

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