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Received: 9 March 2026 | Accepted: 22 June 2026

DOI: 10.1002/ksa.70526

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Knee Surgery, Sports Traumatology, Arthroscopy WILEY

The rectus femoris tendon autograft in knee ligament reconstruction: Anatomy, biomechanics, clinical applications and results—A narrative review

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Abstract

The quadriceps tendon has gained significant momentum as a graft source for knee ligament reconstruction, with the isolated harvest of its superficial layer—the rectus femoris tendon—rapidly emerging as a popular technical refinement. This shift has been driven largely by practical considerations: the cost and limited availability of proprietary instrumentation promoted for partial quadriceps tendon harvesting, combined with the appeal of a familiar, hamstring-like workflow using standard tendon strippers. As a result, numerous surgical technique descriptions have appeared in recent years. However, the enthusiasm surrounding this graft has outpaced the evidence supporting it. This narrative review critically appraises the current state of knowledge regarding the rectus femoris tendon autograft by evaluating its anatomical basis, biomechanical properties and the first available clinical outcomes. Anatomical studies confirm the rectus femoris tendon as a consistent superficial layer separated from the deep vastus intermedius by a distinct cleavage plane, facilitating reproducible harvest. Biomechanically, the isolated graft demonstrates ultimate stress comparable to the patellar tendon, yet exhibits significantly higher elasticity, raising unresolved questions about long-term graft creep and laxity. Early clinical comparative studies report functional outcomes equivalent to hamstring tendon autografts in primary anterior cruciate ligament reconstruction, and folded soft-tissue quadriceps grafts show promising re-rupture rates in the revision setting. Despite these encouraging findings, the existing literature is predominantly Level III and IV evidence with short-term follow-up, and the heterogeneous definitions of 'quadriceps tendon graft' across studies preclude any formal meta-analysis of this specific graft entity. While the rectus femoris tendon autograft holds considerable potential as a versatile option for primary, revision and complex multi-ligament reconstruction, high-powered randomized controlled trials with long-term follow-up are needed

Abbreviations: ACL, anterior cruciate ligament; ALL, anterolateral ligament; AMOL, anteromedial oblique ligament; BPTB, bone–patellar tendon–bone; EMD, electromechanical delay; FQT, full-thickness quadriceps tendon; HT, hamstring tendon; IKDC, International Knee Documentation Committee; IPBSN, infrapatellar branch of saphenous nerve; LET, lateral extra-articular tenodesis; MPFL, medial patellofemoral ligament; MQTFL, medial quadriceps tendon femoral ligament; PCL, posterior cruciate ligament; PQT, partial-thickness quadriceps tendon; PT, patellar tendon; QT, quadriceps tendon; RF, rectus femoris; RFT, rectus femoris tendon; RTD, rate of torque development; VI, vastus intermedius.

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to determine whether it truly represents a paradigm shift or merely a technical variation.

Level of Evidence: Level V, narrative review.

KEYWORDS
ACL reconstruction, autograft, narrative review, quadriceps tendon, rectus femoris tendon

INTRODUCTION

The selection of the optimal autograft remains one of the most critical determinants of success in anterior cruciate ligament (ACL) reconstruction. Over the last decade, the orthopaedic community has witnessed a discernible paradigm shift away from the exclusive dominance of bone–patellar tendon–bone (BPTB) and hamstring tendon (HT) autografts toward the quadriceps tendon (QT) [47, 53]. This transition is driven by robust evidence regarding donor-site morbidity and graft failure rates. Large-scale comparative studies and meta-analyses have demonstrated that QT autografts result in significantly less anterior knee pain and superior kneeling tolerance compared to BPTB grafts. Furthermore, regarding graft survival, recent large cohort studies indicate that QT autografts exhibit significantly lower re-rupture rates compared to HT autografts, particularly in high-risk, active populations [4, 21, 47], while maintaining comparable functional outcomes [7, 27].

Despite these clear biological and clinical advantages, the widespread adoption of the QT has been historically hindered by practical, technical and economic barriers. Traditional harvesting techniques, such as those initially described by Blauth or Stäubli, required open incisions or the harvesting of a bone block, which reintroduced risks of patellar fracture and cosmetic dissatisfaction [3, 38, 50]. Subsequent refinements, most notably the minimally invasive technique standardized by Fink et al., successfully reduced soft-tissue trauma but introduced a new logistical hurdle: the reliance on specialized instrumentation (e.g., double-blade knives, tendon separators) [9, 43]. For the high-volume surgeon accustomed to the efficiency and workflow of hamstring harvesting, the transition to these QT techniques entailed a steep learning curve regarding graft sizing, complex suturing of the thick tendinous block and management of the tendon defect [38, 43].

To address these limitations, surgical techniques have rapidly evolved in recent years, shifting focus from 'block harvesting' to 'anatomical layering'. Recent morphological studies describing the 'multiceps femoris' concept have confirmed that the superficial layer—the rectus femoris tendon (RFT)—often exists as an anatomically distinct lamina, separated from the deep vastus intermedius (VI) by a consistent cleavage plane [17, 23, 37]. This anatomical insight has spurred the development of novel harvesting techniques that utilize standard tendon strippers to isolate the RFT, mimicking the familiar workflow of hamstring harvesting [34, 40, 43]

As these 'soft-tissue stripping' techniques for the RFT gain popularity—driven by their reproducibility and lack of need for special instrumentation—new questions regarding their biomechanical equivalence and clinical safety arise. The current literature is heterogeneous, often pooling results from full-thickness, partial-thickness and isolated RFT grafts, which complicates the interpretation of outcomes [6, 38]. While early clinical reports on isolated RFT grafts are promising [7, 16, 44], a consolidated evaluation of this specific graft entity is lacking.

This narrative review aims to critically synthesize the current state of knowledge regarding the isolated RFT autograft. We evaluate the anatomical rationale for layer-specific harvesting, analyse the emerging biomechanical data concerning graft elasticity and strength and assess the first available clinical outcomes to determine if this technique represents a viable new standard for knee ligament reconstruction.

LITERATURE SEARCH AND STRATEGY

PubMed/MEDLINE and Google Scholar were searched from inception through February 2026 using combinations of 'rectus femoris', 'superficial quadriceps' and 'knee ligament reconstruction'. The primary Boolean queries were ('rectus femoris tendon') AND ('knee ligament reconstruction' OR 'ACL reconstruction') and ('superficial quadriceps tendon') AND ('knee ligament reconstruction' OR 'ACL reconstruction'). The dual terminology reflects a geographic divergence in the literature: 'rectus femoris tendon' is predominantly used in European, North and South American publications, whereas 'superficial quadriceps tendon' is the term favoured in several Asian surgical series describing the same anatomical entity. The stand-alone term 'rectus femoris tendon' returned 89 records and 'superficial quadriceps tendon' returned 9 records; when combined with 'ligament reconstruction', the yield was 20 and 9

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records, respectively. ResearchGate was additionally searched for full-text availability. No language restrictions were applied. Reference lists were hand-searched, and targeted searches were conducted for landmark studies on QT anatomy, biomechanics and viscoelastic properties whose findings are transferable to the isolated rectus femoris (RF) layer. Title, abstract and full-text screening were performed independently by two authors (R. G. and C. P. H.), with disagreements resolved by discussion. Only studies for which the complete full text could be obtained were retained, with one pre-specified exception (see Exclusion criteria below). After deduplication, hand-searching of cross-references, and eligibility assessment, 25 studies formed the evidentiary basis of this narrative synthesis. A simplified selection flow diagram is provided in Figure 1. Studies reporting on the isolated RF tendon or superficial QT layer as an autograft for knee ligament reconstruction were included, encompassing technical, cadaveric, biomechanical and clinical investigations. Given the narrative nature of this review, no formal risk-of-bias assessment was performed; however, a qualitative appraisal of individual study limitations is provided in Table 1, and methodological caveats are addressed in the Limitations section.

Data synthesis, definitions and eligibility criteria

The initial screening identified a substantial body of literature regarding the QT; however, critical analysis revealed significant heterogeneity in graft definitions, with historic meta-analyses [27] frequently pooling full-thickness grafts (with or without bone blocks) and partial-thickness grafts under the single entity of 'QT'. To address this, we applied the following operational definition: the isolated RFT autograft is a soft-tissue graft obtained exclusively from Layer 1 of the proximal extensor mechanism, harvested via a tendon-stripping technique that preserves the deep quadriceps layers. Grafts were classified as RFT only when the original publication explicitly described isolation along the interlaminar cleavage plane and a partial-thickness, stripped (non-block) harvest. Inclusion criteria were: clinical, biomechanical, cadaveric or anatomical studies addressing the isolated RFT; technical notes describing stripped harvest techniques; and comparative studies using the RFT against other autografts. The diQuad technique [8] was included as a pre-specified conceptual exception: although technically a partial-thickness quadriceps graft which is harveted extending over the patella, its folded soft-tissue construct with suspensory fixation served as a direct precursor to the stripped RFT workflow. Full-thickness QT grafts with or without bone block, grafts of unspecified layering and publications without available full text were excluded. One further exception was the conference abstract by Rêgo et al. [44] reporting 80 consecutive RFT patients—retained as the largest available clinical cohort and explicitly identified as abstract-only in the text and in Table 1. Where data from full-thickness QT studies are cited to contextualize biomechanical or clinical claims, this extrapolation is flagged in the text and in Tables 2 and 3.

Rationale for narrative review

While high-quality meta-analyses exist for the general use of the QT [27, 47], a formal quantitative meta-analysis specifically for the isolated, stripped RFT autograft is currently not feasible for several reasons:

1. Technique novelty: The specific technique of harvesting the RFT using a tendon stripper (mimicking hamstring harvest) has only recently been standardized [40, 43], resulting in a limited number of long-term follow-up studies.
2. Data scarcity: While early comparative studies [7, 44] and retrospective cohorts [8, 15] are available, there is currently an insufficient volume of randomized controlled trials (RCTs) with identical methodologies to generate statistically powered forest plots for this specific subgroup.
3. Heterogeneity of comparators: Existing studies vary in their control groups (vs. hamstrings, vs. BPTB) and graft preparation (double-layered vs. four-fold), precluding a unified statistical synthesis.

Therefore, this article is structured as a Current Concepts Narrative Review. It aims to qualitatively synthesize the biological rationale, technical feasibility and early clinical evidence to provide a comprehensive 'surgeon-to-surgeon' update on this evolving graft option.

Anatomy of the proximal extensor mechanism

The concept of layering was established by Stäubli et al. [50] in their seminal 1996 study. Using cryosections and magnetic resonance arthrography, they were among the first to detail the 'trilaminar' nature of the QT tendon and the presence of fat pads. While Stäubli emphasized the suprapatellar fat pad (deep to Layer 3) as a landmark to avoid joint penetration during full-thickness harvest, he also described the connective tissue planes between the superficial layers.

Recent anatomical work by Olewnik et al. redefined the muscle as a 'multiceps femoris'. Crucially for the surgeon, they identified significant variability in how and where these layers fuse. They described five distinct morphological types based on the number of

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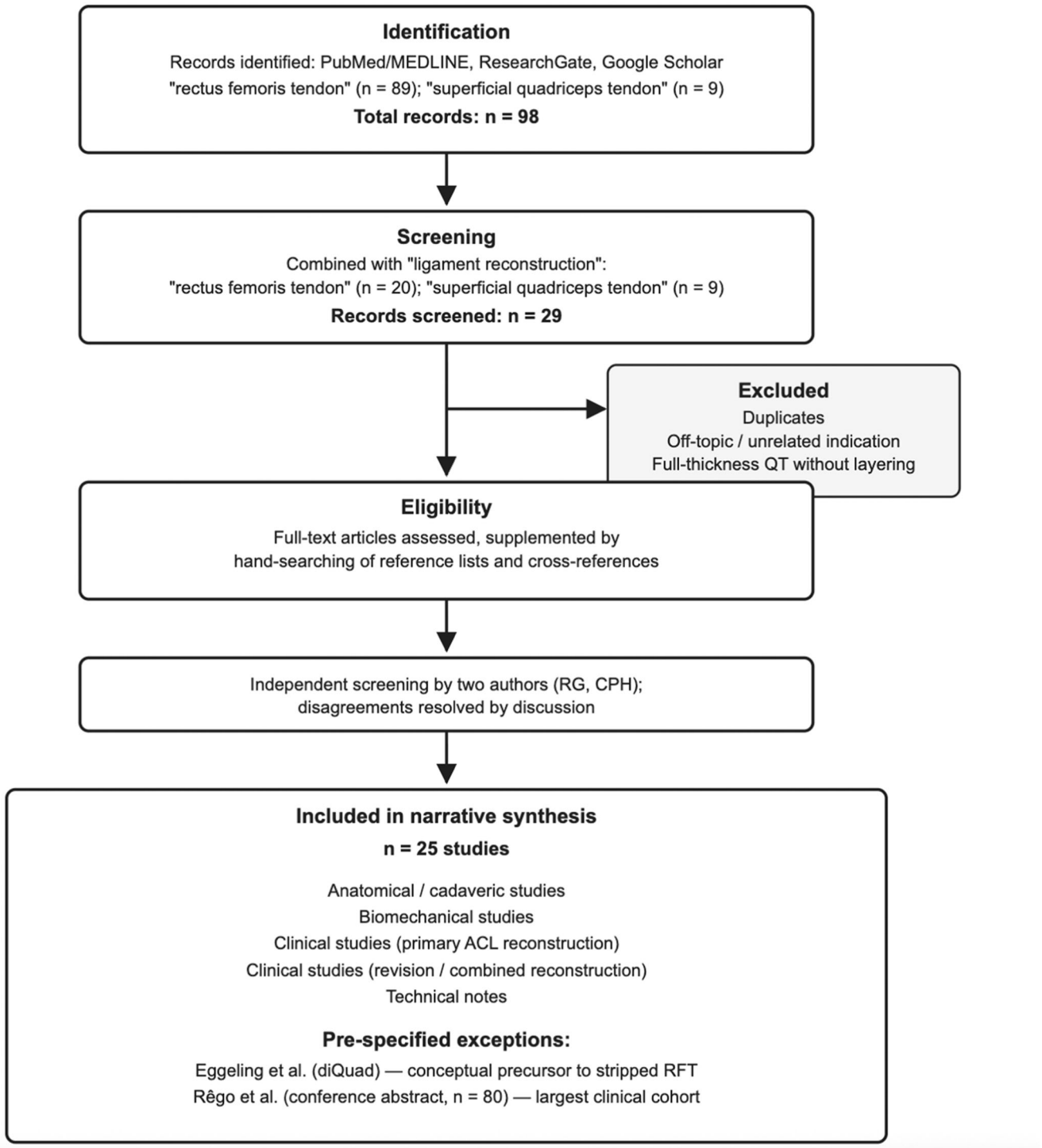


FIGURE 1 Literature selection flow diagram. Dual search terminology reflects geographic divergence ('rectus femoris tendon' vs. 'superficial quadriceps tendon'). Screening was performed independently by two authors (R. G. and C. P. H.). Two pre-specified exceptions were retained: Eggeling et al. [8] (conceptual precursor-harvesting quadriceps long enough to fold it) and Rêgo et al. [44] (largest clinical cohort, conference abstract). Total included: 25 studies. ACL, anterior cruciate ligament; RFT, rectus femoris tendon; QT, quadriceps tendon.

heads and tendon layering. Of clinical relevance is the Type V configuration (found in ~2.4% of specimens but conceptually relevant for outliers). In this variant, the muscle consists of up to eight heads, and crucially, the resulting common QT is extremely short, measuring only 27.9 mm on average [30, 31, 37]. Olewnik et al. explicitly warn that this configuration is 'the least suitable morphology for [traditional] autograft use' because the layers do not fuse sufficiently to form a cohesive block proximal to this short zone.

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TABLE 1 Summary of key studies on the isolated RFT autograft in knee ligament reconstruction.

Study	Year	Design/LOE	*n*	Key finding	FU	Study limitations
Biomechanical						
Pineda et al.	2025	Paired cadaveric	14	Ultimate stress RFT 46.4 versus PT 52.9 MPa (n.s.); elongation RFT 1.23% versus PT 0.26% ($p < 0.001$)	—	Paired cadaveric ($n = 10$ pairs); time-zero testing; no cyclic loading protocol
Dansby et al.	2025	Cadaveric biomech.	16	PQT load to failure 1881 N versus PT 1723 N (n.s.); mechanically sufficient	—	Time-zero cadaveric; no in vivo remodelling data; mixed partial-thickness definition
Adams et al.	2006	Cadaveric biomech.	14	Residual QT 2430 N after harvest (−34%); remaining QT > intact PT (1920 N)	—	Full-thickness QT data extrapolated to RFT; no layered harvest tested
Clinical—Primary ACL						
Dhariwal et al.	2024	Retro. comp./III	40	Equivalent Lysholm, IKDC, Tegner; 0% graft failure (40 RFT vs. 40 HT)	24 months	Non-randomized; single centre; short FU; no blinded assessment
Rêgo et al.[a]	2024	Cross-sect./III	80	Lysholm 97.1; PASS 100%; 0% graft failure; 3.6% harvest transection (learning curve); 5% haematoma; 1.25% infection	18 months	Conference abstract only; peer-reviewed publication pending; no detailed complication analysis
Clinical—Revision ACL						
Panisset[b]	2004	Case series/IV	40	Laxity 12.2 → 2.6 mm (Telos); 2 patellar fractures (bone block); 50% RTS	24 months	Unpublished congress report; bone-block technique (not stripped RFT); no validated PROMs
Eggeling et al.	2021	Retro. comp./III	43	Re-rupture dlQUAD 2.3% versus HAT ($n = 46$) 17.4% ($p = 0.031$); SSD 1.3 versus 1.8 mm	27 months	Non-randomized; mixed partial-thickness QT definition; short FU; single centre
Huber et al.	2024/25	Retro. comp./III	28	Four-fold RFT Ø 9.0 mm; comparable PROMs versus HT ($n = 27$); 50% fewer two-stage procedures; 7.1% cyclops re-op	42 months	Single-surgeon series; no blinded outcome assessment; small sample size

Abbreviations: ACL, anterior cruciate ligament; comp., comparative; dlQUAD, double-layered quadriceps; FQT, full-thickness quadriceps tendon; FU, follow-up; HAT, hamstring autograft; HT, hamstring tendon; IKDC, International Knee Documentation Committee; LOE, level of evidence; MPa, megapascal; *n*, number of patients; n.s., not significant; PASS, Patient Acceptable Symptom State; PQT, partial-thickness quadriceps tendon; PROMs, patient-reported outcome measures; PT, patellar tendon; QT, quadriceps tendon; Retro., retrospective; RFT, rectus femoris tendon; RTS, return to sport; SSD, side-to-side difference; Ø, mean diameter.

[a]Conference abstract.

[b]Unpublished congress report.

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Clinical implication for RFT

This limitation of the common tendon paradoxically supports the rationale for the isolated RFT harvest. Even in these complex variants where deep fusion is minimal, the superficial rectus femoris remains a distinct, continuous anatomical entity running over the deep layers. By abandoning the attempt to harvest a 'fused block' and instead selectively stripping the superficial layer, the surgeon respects this anatomical separation rather than fighting against it.

Defining the surgical plane

The 'Fat Pad' below the RFT as the key landmark to safe execution of the RFT harvest relies on the correct identification of the interval between Layer 1 (rectus femoris) and Layer 2 (VI/lateralis/medialis). In the literature, this interval is variously described, but represents a single functional entity:

The Interlaminar Cleavage Zone: This zone describes the potential space where the tendon layers can slide against each other. Marot et al. defined this quantitatively as a 'free zone' extending from the *distal fusion point* (approximately 22 mm proximal to the patella) to the *proximal fusion point* (approximately 58 mm proximal to the patella) [23].

The 'Fat Pad': This is the visual marker of the cleavage zone. Huber et al. and Pires et al. emphasize that a distinct 'fatty layer' or 'thin layer of fat' separates the rectus femoris from the VI tendon [15, 40]. This may help to identify the correct plane for stripping.

As noted by Iriuchishima et al. and Marot et al. [17, 23], the RFT becomes firmly fused to the underlying VI in this zone. However, functionally, the superficial RFT fibres extend beyond this fusion, running continuously over the anterior patella without a distinct bony insertion [51], permitting prepatellar stripping (Figure 2) if additional graft length is required [8, 13].

Modern techniques have essentially shifted the surgical focus from the deep fat pad (to protect the joint) to the superficial/interlaminar fat pad (to isolate the RFT), utilizing Stäubli's architectural map for a new purpose [13, 50].

Evolution of surgical techniques

The surgical utilization of the extensor mechanism evolved from open, full-thickness harvesting to minimally invasive, layer-specific soft-tissue stripping. Marshall et al. [24] first described a central quadriceps strip in continuity with the prepatellar retinaculum, requiring extensive open arthrotomy. Blauth [3] then harvested a 15 cm graft from the middle third of the quadriceps, crucially recognizing the layering by taking one strip from the rectus tendon and one from the vastus lateralis/intermedius—establishing the rectus femoris as a distinct graft source. Stäubli et al. subsequently propagated the full-thickness QT graft with patellar bone block as the reference standard, providing anatomical safety rules for avoiding the suprapatellar pouch but firmly advocating bone-block fixation [50]. Concerns regarding patellar fractures and anterior knee pain drove the shift to soft tissue: Fulkerson [11] proposed the 'Central Quadriceps Free Tendon' graft,

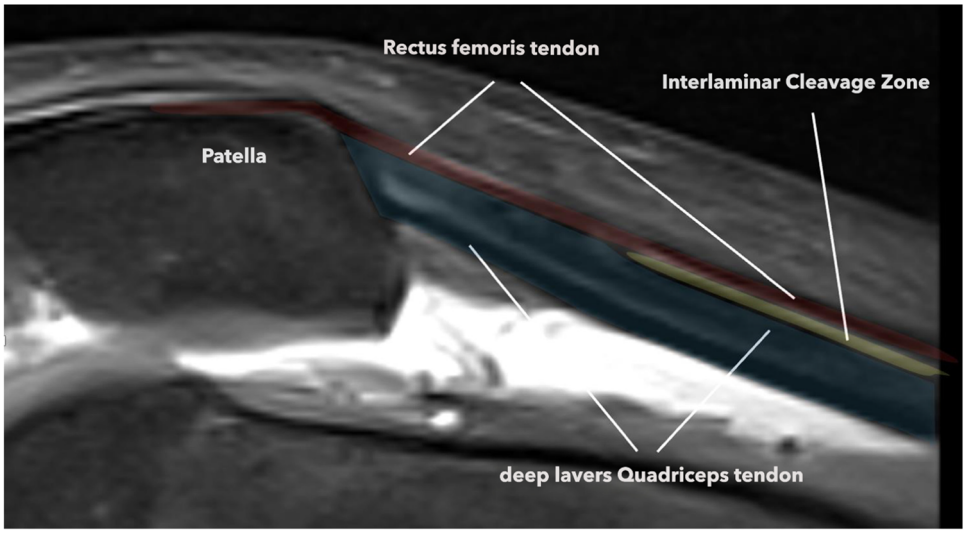


FIGURE 2 Sagittal T2-weighted MRI of the suprapatellar knee. The rectus femoris tendon (red) is separated from the deep quadriceps tendon layers (blue) by the interlaminar cleavage zone (yellow), which represents the fatty interface serving as the surgical landmark for layer-specific harvesting. Note the progressive narrowing of the cleavage zone distally toward the patellar insertion, where accurate plane identification becomes critical. MRI, magnetic resonance imaging.

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demonstrating that a purely soft-tissue graft could provide 50% more collagen than a BPTB graft of similar width, though the technique still required deep dissection. Fink et al. [9] then revolutionized reproducibility with a standardized minimally invasive partial-thickness harvest using specialized instrumentation (double-blade knife and tendon separator), establishing the modern reference standard but introducing a dependency on specific—and often costly—devices.

The modern era: Layer-specific 'stripping'

Recent innovations have focused on cost-reduction, anatomical precision and 'hamstring-like' handling.

The concept of using the RFT for revision ACL reconstruction originated with Philippe Chambat (Lyon, France) in the late 1990s. Panisset of his group reported satisfactory results in 40 patients at the SOFCOT Annual Congress in 2003 [33], but the technique was never formally published in the indexed literature.

Driven by the need for a cost-effective solution in a resource-limited setting, Raman in 2022 described identifying the 'fatty cleavage plane' between the rectus femoris and VI tendon to strip the superficial layer safely without special knives [43]. They have demonstrated in their video technique that a 30 cm long superficial graft can be harvested. Even if required, the width of the graft can also be increased. Such a large soft tissue graft can be used for any ligament reconstruction in a multiligament injury scenario, as well as for revision scenarios (Figure 3).

Pires et al. refined the minimally invasive soft-tissue harvest, emphasizing the release of the tendon 2–3 cm proximal to the patella before introducing the stripper to avoid the distal 'fusion zone' [40].

Panas et al. introduced 'Proximal-to-Distal' stripping—starting the harvest 8 cm proximally (in the 'free zone'), clearly defining the RFT and avoiding the complex distal fusion and reducing the risk of arthrotomy for monobloc quadriceps [32]. Lee et al. harvested bidirectionally, starting with proximal stripping—open stripper then distal closed, allowing the surgeon to harvest the whole rectus tendon without distal preparation [20, 32] but with a special single-use device. Bidirectional stripping was described for posterior hamstring harvest by Kodkani et al. [19] and Franz and Ulbrich [10] in 2004. This principle is directly applicable to the RFT and is the technique currently practiced by the authors [18]. Regardless of the harvesting sequence, the critical determinant of graft quality remains consistent identification of the correct dissection plane proximal to the distal confluence of the quadriceps layers. Inaccurate plane selection increases the risk of premature graft transection or insufficient graft dimensions [15, 42]. Adequate graft dimensions have been shown in a cadaveric study by Thamrongskulsiri [55].

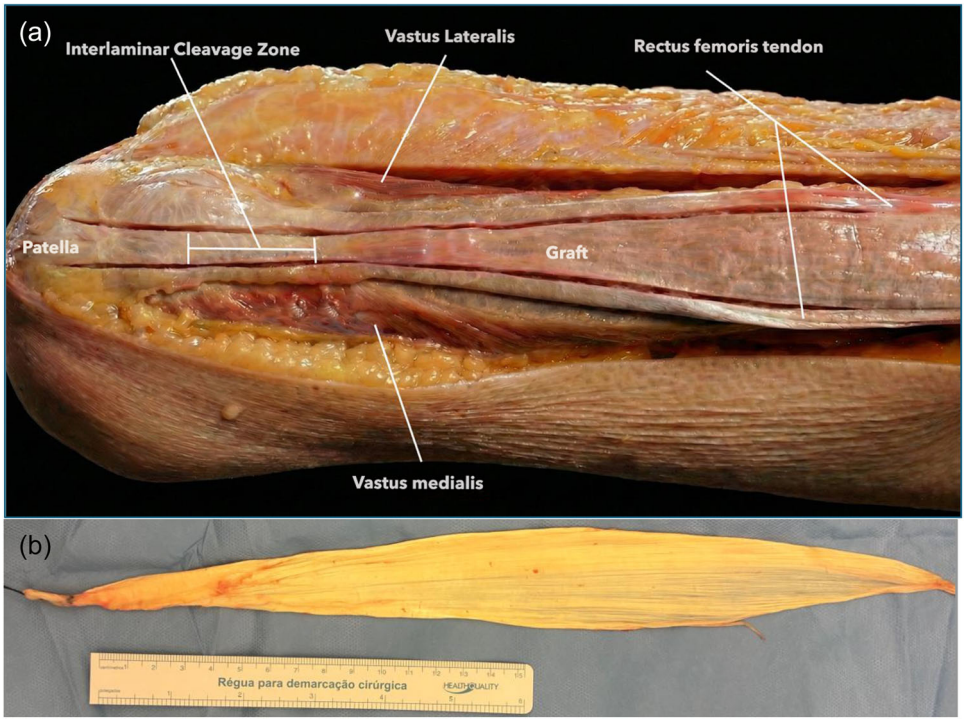


FIGURE 3 (a) Right knee, anterior view. Rectus femoris muscle belly removed. Rectus femoris tendon with the typical graft portion. The graft can be dissected distally beyond the superior pole of the patella (AI anatomical specimen visualization—OperativeInk—inspired by Marot [23]). (b) actual intraoperative graft. AI, artificial intelligence.

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Revision ACL and complex instabilities

The diQuad technique describes a partial-thickness graft that is harvested from proximal over the patella to create a longer soft-tissue construct, which is then folded and compatible with suspensory buttons, showing superior results to hamstrings in revisions [8].

Huber et al. validated the isolated RFT for revision surgery. Using an open stripper, the authors demonstrated that the large volume of the four-fold RFT (mean Ø 9.0 mm) allows for single-stage revisions even in cases with tunnel widening, reducing the need for bone grafting [15, 16].

Combined reconstructions—The 'one-graft' solution

The exceptional length of the stripped RFT (30–35 cm) has enabled complex combined reconstructions with a single graft harvest (Figure 4, Table 2 graft retention).

Several authors have described techniques where the long RFT is used to reconstruct the ACL and then passed deep to the iliotibial band to reconstruct the anterolateral ligament (ALL), eliminating the need for separate hamstring harvesting [2, 28, 49]. Pettinari et al. demonstrated the use of the RFT for combined revision ACL and lateral extra-articular tenodesis (LET), confirming the graft's versatility [36]. Morin et al. introduced a hybrid technique harvesting the rectus femoris with a patellar bone block. Designed for combined ACL and ALL reconstructions, this approach leverages the bone plug for robust femoral fixation while utilizing the long soft-tissue tail for lateral tenodesis [26]. A practical advantage of these continuous-graft techniques is the avoidance of femoral tunnel convergence. When ACL and ALL are reconstructed with separate grafts and independent femoral tunnels, convergence rates of up to 67% have been reported [29]. The use of a single RFT graft through one shared femoral tunnel eliminates this risk entirely while preserving lateral femoral bone stock.

One group used the RFT for combined ACL and anteromedial oblique ligament (AMOL) reconstruction to address anteromedial rotatory instability, again sparing the hamstrings [46] (Figure 5).

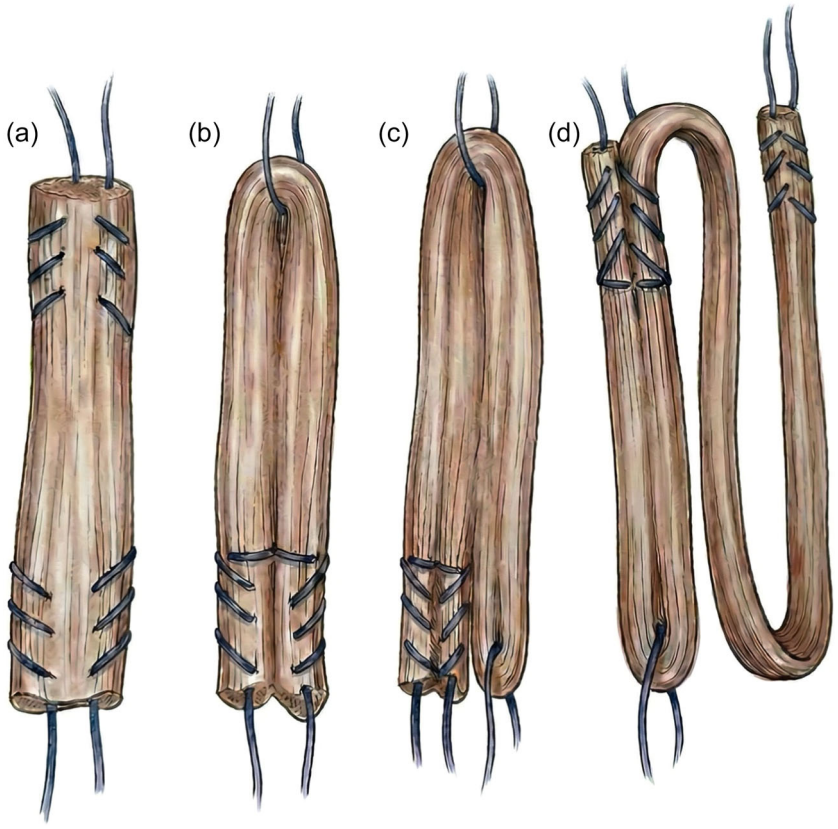


FIGURE 4 Graft configurations after preparation. (a) Monoblock soft-tissue quadriceps tendon graft. (b) Double-layered partial-thickness quadriceps tendon graft (dlQUAD). (c) Isolated rectus femoris tendon (RFT) graft, folded into a four-strand construct for standard ACL reconstruction. (d) Isolated RFT graft in asymmetric combined reconstruction configuration: doubled portion (~7 cm) for intra-articular ACL reconstruction, single-strand tail (~16 cm) for extra-articular procedures. ACL, anterior cruciate ligament.

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TABLE 2 Published combined reconstruction techniques utilizing the RFT as a single graft source.

Combination	Authors	Indication	Graft routing
ACL + lateral extra-articular procedure (LEAP)	Sonnery-Cottet/Di Muro/Barroso/ Pettinari	Anterolateral rotatory instability	ACL intra-articular; ALL or tail passed deep to ITB for reconstruction, Sonnery-Cottet double bundle ALL
ACL + ALL (Hybrid)	Morin et al.	Anterolateral rotatory instability	RFT with patellar bone plug; press-fit femoral fixation; soft-tissue tail for lateral ALL tenodesis
ACL + AMOL	Rêgo et al.	Anteromedial rotatory instability	ACL intra-articular; tail routed medially for AMOL reconstruction
PCL double-bundle	Martins et al.	Posterior instability	RFT in Y-shape configuration; base at tibial tunnel, splits into anterolateral and posteromedial femoral bundles (Ø 10–12 mm base)
MPFL + MQTFL	Shekar et al.	Patellofemoral instability	RFT as anatomical ribbon from medial femoral epicondyle to medial patella border; no patellar bone tunnels required

Note: The exceptional length of the stripped RFT enables combined reconstructions from a single harvest that would otherwise require separate graft sources or allografts.

Abbreviations: ACL, anterior cruciate ligament; AL, anterolateral bundle; ALL, anterolateral ligament; AMOL, anteromedial oblique ligament; ITB, iliotibial band; LEAP, lateral extra-articular procedure; MPFL, medial patellofemoral ligament; MQTFL, medial quadriceps tendon femoral ligament; PCL, posterior cruciate ligament; PM, posteromedial bundle; RFT, rectus femoris tendon; Ø, diameter.

Non-ACL applications

Posterior cruciate ligament (PCL)

Anatomical double-bundle PCL reconstruction typically requires a significant amount of tissue. Martins et al. described a technique using the RFT graft in a Y-shape. This creates two femoral bundles (anterolateral and posteromedial) from a single autograft, providing a cost-effective, biological solution with sufficient diameter (10–12 mm base) to restore posterior stability [25]. De Paula published a technique using combined superficial quadriceps and semitendinosus autografts for double bundle PCL reconstructions [35].

Medial patellofemoral complex (MPFC)

Shekar et al. utilized RFT to perform a combined reconstruction of the medial patellofemoral ligament (MPFL) and the medial quadriceps tendon femoral ligament (MQTFL) [48].

Instruments

Authors consistently emphasize the need for a long, rigid tendon stripper—either open or closed—such as those routinely used for hamstring harvest [40, 43]. Pires et al. [40] note that considerable force is sometimes required to advance the stripper against the resistance of the interconnections, necessitating a sturdy instrument to maintain the correct trajectory. The aperture of a closed stripper must accommodate the broad, flat anatomy of the RFT; most techniques recommend 8–9 mm [15, 43]. Smaller apertures (e.g., 7 mm) have been used in anatomical studies [52] but risk truncating graft edges or premature transection; if only a small stripper is available, a narrower distal dissection strip is recommended, accepting a potentially smaller final graft diameter.

Common principles

Despite variations in indication, the modern RFT technique converges on three principles distinguishing it from other QT harvests:

Instrumental simplicity—standard reusable tendon strippers replace specialized single-use devices.

Anatomical preservation—strict adherence to the interlaminar cleavage plane harvests only the superficial rectus femoris layer, leaving the deep extensor mechanism and substantial parts of the rectus femoris tendon intact.

Versatile fixation—the long, pliable graft permits fixation with adjustable loop buttons as well as interference screws, aligning the workflow with familiar hamstring techniques.

Biomechanics

Material properties and structural competence

Recent 'time-zero' controlled laboratory studies have provided critical distinctions between the material quality of the rectus femoris tissue and the structural behaviour of the graft construct.

Ultimate stress. Pineda et al. conducted a paired cadaveric study comparing the isolated RFT against the

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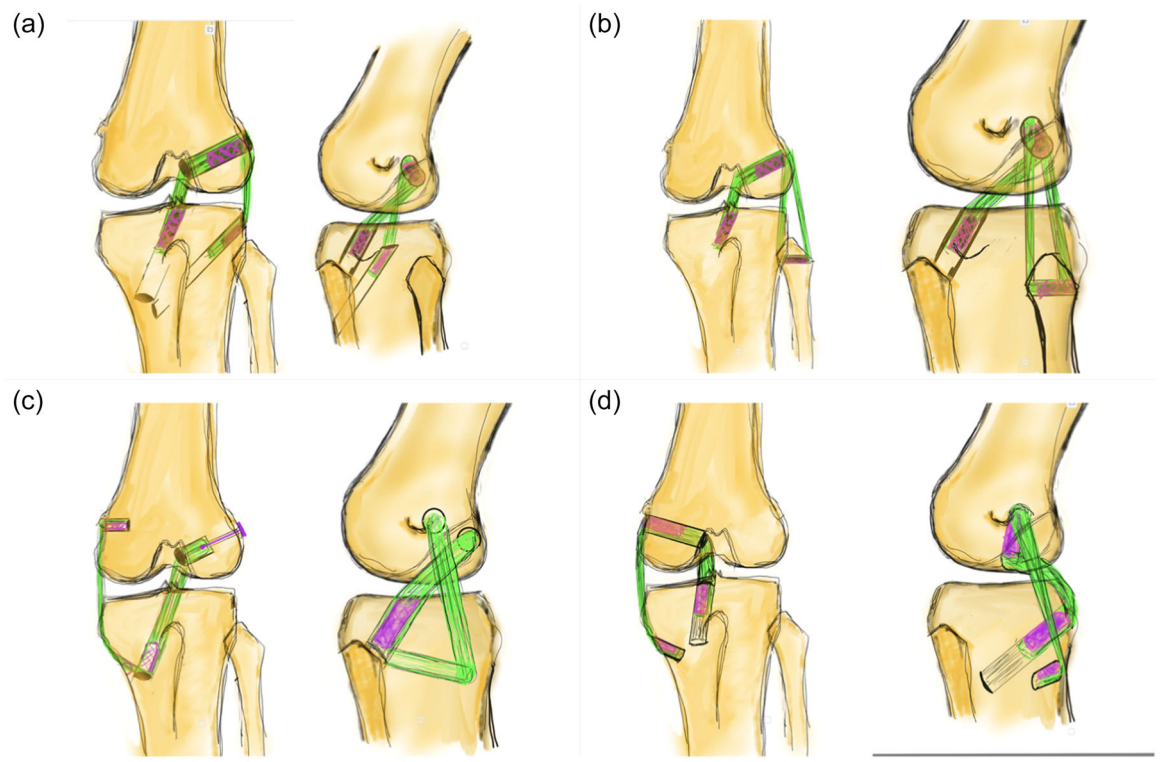


FIGURE 5 Combined knee ligament reconstruction configurations using a single rectus femoris tendon autograft. Anteroposterior (left) and lateral (right) views. Green = graft; pink/purple = fixation devices. (a) ACL + ALL reconstruction: The intra-articular portion reconstructs the ACL through an anatomical femoral tunnel. The free lateral end is redirected to reproduce the ALL, extending from the lateral femoral epicondyle to its tibial insertion between Gerdy's tubercle and the fibular head. (b) ACL + MCL reconstruction: Following intra-articular ACL reconstruction, the distal free end is redirected to reconstruct the superficial medial collateral ligament, extending from the medial femoral epicondyle to its tibial insertion approximately 6 cm distal to the joint line. (c) ACL + LCL reconstruction: The lateral free end of the graft is redirected to reconstruct the lateral collateral ligament, passing from the lateral femoral epicondyle to the proximal fibular insertion via a fibular tunnel. (d) PCL + MCL reconstruction: The graft reconstructs the PCL intra-articularly. The free medial end is redirected distally to reproduce the superficial MCL, enabling combined posterior and medial stabilization. The rectus femoris graft allows multiple redirection pathways to reconstruct cruciate and collateral ligaments simultaneously, minimizing the number of femoral tunnels and preserving bone stock while enabling multiplanar stabilization tailored to patient-specific ligament insufficiencies. ACL, anterior cruciate ligament; ALL, anterolateral ligament; LCL, lateral cruciate ligament; MCL, medial cruciate ligament; PCL, posterior cruciate ligament.

patellar tendon (PT). They demonstrated that the ultimate stress (load to failure per unit area) of the RFT is statistically comparable to that of the PT (46.4 ± 10.5 MPa vs. 52.9 ± 9.7 MPa; $p = 0.184$). This confirms that the RFT consists of high-quality collagenous tissue not inferior to the gold standard [39].

Elongation and elasticity. Pineda et al. [39] also identified a significantly higher elongation at failure for the RFT (1.23%) compared to the stiffer PT (0.26%; $p < 0.001$) in a double-stranded configuration. This inherent elasticity may indicate that while the tissue is strong, it is less stiff than a bone-tendon-bone construct.

The clinical implications of this higher elongation at failure—including optimal graft tensioning protocols, fixation strategy and rehabilitation progression—remain entirely undefined for the isolated RFT, and no study has yet compared the cyclic creep behaviour of RFT tissue against hamstring or PT grafts under identical viscoelastic loading conditions. The higher elasticity may hypothetically bring the viscoelastic behaviour of the RFT closer to that of the native ACL; however, this interpretation is derived from time-zero cadaveric testing, and no in vivo data currently support a clinical advantage. This observation should be regarded as hypothesis-generating and requires validation in prospective studies. As with any soft-tissue graft, systematic intraoperative pretensioning is advisable to reduce viscoelastic elongation prior to final fixation [22].

Partial-thickness versus full-thickness constructs

Mechanical properties

While full-thickness quadriceps tendon (FQT) grafts were significantly stronger and stiffer due to their massive cross-sectional area, the partial-thickness quadriceps tendon (PQT) grafts showed no significant

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difference in ultimate tensile strength or stiffness compared to soft-tissue PT grafts (load to failure: PQT 1881 N vs. PT 1723 N). This supports the premise that harvesting the superficial layer alone provides a mechanically sufficient graft for ACL reconstruction without the morbidity associated with full-thickness harvesting [6].

Donor site morbidity and residual strength

The biomechanical rationale for the isolated RFT technique is further supported by studies analysing the donor site.

Residual extensor strength

Adams et al. [1] demonstrated that harvesting a 10 mm wide partial-thickness central graft reduces the tensile strength of the QT by approximately 34% (from 3660 to 2430 N) (data derived from full-thickness QT; direct RFT-specific evidence is currently lacking). Crucially, the remaining QT (consisting of the VI and lateral/medial pillars) retains a failure load significantly higher than that of an intact PT (1920 N). This may provide a large safety margin for early rehabilitation [1].

Neuromuscular preservation

Parrino et al. highlighted the functional impact of harvest depth. They found that full-thickness harvesting resulted in a significantly slower rate of torque development (RTD) and longer electromechanical delay (EMD) in the vastus medialis compared to partial-thickness harvesting. By preserving the deep VI layer, the RFT technique appears to minimize disruption to the extensor mechanism's neuromuscular efficiency, potentially facilitating a faster return to explosive muscle function [34].

Patellofemoral pressure

Prentice et al. [41] reported that a QT autograft may be a risk factor for osteoarthritis development after ACL reconstruction (data derived from full-thickness QT; direct RFT-specific evidence is currently lacking). When harvesting the rectus femoris, closing the defect is not mandatory as in partial or especially FQT harvesting. While some authors advocate closure of the rectus femoris defect, others do not approximate the edges. The fact that closure is not required—and consequently does not increase tension—may minimize any potential increase in patellofemoral joint forces. However, this hypothesis requires further study.

Clinical outcomes

Primary ACL reconstruction

Functional equivalence and safety. The transition from traditional HT autografts to the isolated RFT is supported by recent Level III evidence demonstrating functional equivalence with potentially lower morbidity (Table 2).

Patient-reported outcomes. In a prospective comparative study, Dhariwal et al. [7] evaluated 80 patients allocated to either superficial RFT or HT autografts. While the authors described a randomized graft selection process, the study design was reported as a prospective cohort. At a 2-year follow-up, no statistically significant differences were observed in functional scores between the RFT and HT groups (Lysholm: 90.3 vs. 91.2; International Knee Documentation Committee: 86.6 vs. 87.4). Crucially, the authors noted zero graft ruptures in the RFT group, validating the graft's structural sufficiency even in a resource-limited setting.

Rêgo et al. [44] reported results from the first 80 consecutive patients (53% male; mean age 29.0 years) treated with isolated RFT autografts at a mean follow-up of 18 months. Functional outcomes were excellent (mean Lysholm 97.1 ± 2.6; 100% PASS). Notably, graft transection during harvest occurred in 3.6% of cases (3/83), all within the first 10 procedures, reflecting a learning-curve effect. The overall complication rate was 6.25%, comprising donor-site haematoma (5%), one infection (1.25%) and no graft failures (0%).

Isokinetic performance. A primary concern regarding quadriceps harvesting is the potential for persistent extensor weakness. Rêgo et al. [45] addressed this in a cross-sectional study of 75 male patients at 6 months postoperatively. While the RFT group did show a deficit compared to the non-operated limb (Peak Torque: 173.0 vs. 242.4 Nm; $p < 0.001$), this deficit was not significantly different from that observed in the HT group (173.0 vs. 167.7 Nm; $p = 0.689$). This suggests that harvesting the superficial layer does not induce greater extensor inhibition than standard ACL rehabilitation itself, debunking the fear of excessive donor-site morbidity.

Failure rates. Eggeling et al. [8] provided critical proof-of-concept data for plied soft-tissue quadriceps grafts and suspensory fixation in a comparative revision cohort. The study revealed a significantly lower re-rupture rate for plied QT grafts (2.3%) compared to HT grafts (17.4%; $p = 0.031$). Furthermore, the postoperative side-to-side laxity was significantly lower in the QT group (1.3 vs. 1.8 mm; $p = 0.043$), establishing the plied soft-tissue quadriceps as a superior revision graft.

Huber et al. [16] demonstrated that the four-fold isolated RFT consistently yields a large diameter graft (mean Ø 9.0 mm). This robust volume allowed for single-stage revision surgery in 50% more cases compared to hamstrings in their series, as the graft could sufficiently fill enlarged tunnels without the need for prior bone grafting. Although the re-operation rate

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for non-graft related issues (e.g., cyclops syndrome, meniscal tears) was 25%, the graft retention rate was high (92.9%) at a mean follow-up of 40 months.

DISCUSSION

This review highlights a critical evolution in knee ligament surgery: the transition from the generic QT graft to the anatomically defined RFT autograft. The distinct advantage of the RFT technique lies in its precise anatomical targeting. By utilizing the cleavage plane identified by Marot, surgeons can harvest a long and high-volume graft while preserving the deep VI [23]. This creates a 'best of both worlds' scenario: the biological robustness of the extensor mechanism is accessed via a minimally invasive 'stripping' workflow familiar to any surgeon accustomed to hamstring handling [40, 43].

Rectus femoris versus hamstrings

The comparison between RFT and HT autografts extends beyond simple failure rates to the preservation of dynamic knee stability (Table 3).

While direct long-term comparative data for the stripped RFT is still maturing, the biological superiority of the extensor mechanism in high-demand patients is well-supported. Runer et al. showed that in highly active patients (Tegner > 6), the revision rate for QT grafts was less than half that of HT grafts (5.0% vs. 11.1%) (data derived from standard QT; direct RFT-specific evidence is currently lacking) [47]. The early RFT-specific cohorts by Rêgo et al. [44] and Dhariwal et al. [7] reinforce this, reporting 0% graft failure at short-term follow-up. This may suggest the RFT maintains the structural advantages of the traditional QT without the morbidity of full-thickness harvest. Beyond graft survival, the RFT carries strategic implications for dynamic knee stability. Vermorel et al. demonstrated that the medial hamstrings act as valgus stabilizers, contributing most significantly between 0° and 30° of flexion [54]. Gaugg et al. confirmed this clinically, showing significantly greater dynamic valgus during drop jump landings after semitendinosus harvest compared to QT harvest ($p = 0.027$) [12]. Although studied for full-thickness QT, these findings are transferable to the RFT as the extensor mechanism remains fully intact after superficial-layer harvesting. In patients with medial compartment pathology or valgus laxity, the RFT thus preserves ipsilateral hamstring function entirely.

Furthermore, Buescu et al. [4] showed in a Level I RCT that QT harvesting produced significantly less postoperative pain than hamstring harvesting, with 50% of QT patients requiring no rescue analgesia versus 13% in the HT group ($p = 0.002$) (data derived from full-thickness QT; direct RFT-specific evidence is currently lacking). Reduced donor-site pain may reasonably be expected with the even less invasive RFT technique. Additionally, the suprapatellar harvest site eliminates the risk of iatrogenic injury to the infrapatellar branch of the saphenous nerve, which occurs in up to 76% of patients after hamstring harvest but in only 17.8% after QT harvest—attributable entirely to the tibial tunnel incision [14].

A pervasive concern preventing the adoption of quadriceps grafts is the fear of persistent extensor weakness. The data from Rêgo et al. provide a crucial, realistic perspective. At 6 months, patients with RFT grafts indeed showed a significant strength deficit compared to their non-operated limb (~28%); however, this deficit was not statistically different from that observed in the HT group [45]. This indicates that the 'quadriceps avoidance' strategy often employed by surgeons using HT grafts does not necessarily result in superior early quadriceps recovery. Furthermore, the partial-thickness nature of the RFT harvest may offer a neurophysiological advantage. Parrino et al. found that preserving the deep tendon layers (as done in RFT harvest) results in significantly better EMD and rate of torque development compared to full-thickness harvesting [34]. Thus, while an extension deficit is a reality of early rehabilitation, the RFT technique appears to minimize the neuromuscular inhibition historically associated with 'block' quadriceps harvesting. But long-term data on RFT is missing.

Perhaps the strongest argument for the soft-tissue RFT comes from the revision setting, where it competes directly with other soft-tissue options. Eggeling et al. provided compelling evidence that soft-tissue quadriceps grafts are superior to hamstrings in revision ACLR, with a failure rate of just 2.3% versus 17.4% [8]. Crucially, this debunks the historical dogma that a bone block (BPTB) is required for revision stability. The soft-tissue RFT, folded to 9–10 mm diameter as described by Huber, provides sufficient collagenous density to achieve stability even in widened tunnels [16]. By eliminating the need for a bone block, the RFT avoids the risks of patellar fracture and anterior knee pain that often complicate BPTB revisions [5, 27] while offering a 'hamstring-like' flexibility for easy passage and fixation.

LIMITATIONS

A primary limitation of this review and the broader literature is the inconsistent nomenclature surrounding quadriceps grafts. Historic meta-analyses [27] and registry studies [47] frequently pool full-thickness and partial-thickness grafts under the generic umbrella of 'QT', making extraction of data

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TABLE 3 Rectus femoris/QT versus HT autograft—translational comparison.

Domain	RFT/Extensor mechanism	HTs	Source
Graft properties			
Material quality	Ultimate stress 46.4 MPa—comparable to PT	Lower material quality per unit area	Pineda 2025
Graft dimensions	28–35 cm; four-fold Ø 9.0–9.2 mm (consistent)	ST 24–28 cm; Ø 7.5–9.0 mm (variable)	Huber 2024; Marot 2025
Donor-site strength	Remaining QT 2430 N (66%); >intact PT	Regeneration 30%–80%; residual strength unreliable	Adams 2006[a]
Clinical outcomes			
Re-rupture (primary)	QT 5.0% in high-demand (Tegner > 6)	HT 11.1% (Tegner > 6)	Runer et al.[a]
Re-rupture (revision)	Soft-tissue folded QT 2.3%	HT 17.4% ($p = 0.031$)	Eggeling 2021
Extensor deficit (6 months)	~28% versus contralateral	Comparable deficit ($p = 0.689$)	Rêgo 2024
Functional trade-offs			
Neuromuscular	Partial-thickness preserves RTD + EMD	Full harvest eliminates dynamic flexors	Parrino 2023[a]
Dynamic valgus stability	No valgus increase; hamstrings fully preserved	Significantly greater valgus during drop jump ($p = 0.027$)	Gaugg 2025[a]; Vermorel 2023[a]
Postoperative pain	50% required no rescue analgesia (Level I RCT)	87% required rescue analgesia ($p = 0.002$)	Buescu 2017[a]
Sensory nerve injury	IPBSN lesion 17.8% (tibial incision only)	IPBSN lesion 76% ($p = 0.0002$)	Horteur 2020[a]
Practical advantages			
Instrumentation	Standard tendon stripper (=HT workflow)	Standard tendon stripper	Raman 2022
Combined reconstruction	ACL + ALL, ACL + AMOL, PCL from single graft	Requires separate graft or allograft	Sonnery-Cottet 2025; Rêgo 2024
Revision availability	Available after prior HT or BPTB harvest	Unavailable after prior ipsilateral harvest	Huber 2024

Note: Where data specific to the isolated stripped RFT is unavailable, evidence from partial-thickness or folded soft-tissue quadriceps constructs is cited.

Abbreviations: ACL, anterior cruciate ligament; ALL, anterolateral ligament; AMOL, anteromedial oblique ligament; BPTB, bone–patellar tendon–bone; EMD, electromechanical delay; HT, hamstring tendon; IPBSN, infrapatellar branch of the saphenous nerve; PCL, posterior cruciate ligament; PT, patellar tendon; QT, quadriceps tendon; RCT, randomized controlled trial; RFT, rectus femoris tendon; RTD, rate of torque development; ST, semitendinosus.

[a]Data derived from full-thickness QT, extrapolated to RFT context.

specific to the isolated stripped RFT challenging. Despite our operational definition, several sections—particularly the discussion of patellofemoral biomechanics [41], postoperative pain [4] and registry outcomes [47]—necessarily rely on full-thickness QT data extrapolated to the RFT context; these instances are flagged in the text and in Table 3.

The evidence supporting the stripped RFT is predominantly Level III and IV (small retrospective cohorts and case series with inherent selection bias and non-randomized allocation) [7, 15]. Biomechanical data are limited to time-zero cadaveric testing without in vivo remodelling data [6, 39]. Prospective comparative data are emerging [7], but high-powered RCTs with long-term follow-up (>5 years) are absent. Whether the higher elongation at failure translates to clinical laxity over a decade remains a critical unanswered question. A qualitative appraisal of individual study limitations is provided in Table 1.

The clinical cohorts specific to the RFT technique are relatively small (e.g., Huber $n = 28$; Dhariwal $n = 40$ per group; Rego $n = 80$) [7, 16, 44]. These sample sizes, while sufficient for functional scoring, may be underpowered to detect rare complications or subtle differences in rupture rates compared to established hamstring grafts. Furthermore, selection bias is inherent in the retrospective studies reviewed, where graft choice may have been influenced by surgeon preference or specific patient anatomy.

As with any recently introduced technique, the available RFT literature is susceptible to publication bias favouring positive outcomes and a learning-curve

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effect, as current reports originate predominantly from experienced, high-volume centres.

CONCLUSION

The isolated RFT autograft represents a logical evolution in knee ligament reconstruction, successfully bridging the gap between the biological robustness of the extensor mechanism and the surgical versatility of soft-tissue grafts. Notably, this evolution has been driven significantly by pioneering work from Asia and South America, where surgeons established the clinical feasibility and versatility of this graft before its broader adoption. Current anatomical, biomechanical and early clinical evidence confirms that the RFT is a consistent, biomechanically sufficient and safe graft option, offering functional outcomes and donor-site morbidity comparable to HTs in primary cases while demonstrating superior graft survival in revision settings.

The conclusions of this review should be interpreted considering the predominantly Level III–IV evidence, short-term follow-up and the necessary extrapolations from FQT data outlined in the Limitations section.

As the technique moves toward standardization, the research focus must shift from feasibility to rigorous validation. The primary imperative for the next decade is the initiation of high-powered RCTs with long-term follow-up. Specifically, future RCTs should define standardized primary and secondary endpoints including graft re-rupture and re-operation rates, serial arthrometric laxity measurement, patient-reported outcome measures (PROMs), magnetic resonance imaging (MRI)-based graft remodelling assessment, validated return-to-sport criteria and isokinetic extensor and flexor recovery at defined time points. Direct comparative trials against both hamstring autografts and traditional monoblock quadriceps constructs, with a minimum follow-up of 2 years, are required to establish non-inferiority, graft laxity progression and survivorship of the RFT grafts.

By eliminating the necessity for specialized instrumentation, this graft effectively 'democratizes' the QT. It enables surgeons worldwide to access the advantages of the extensor mechanism using a familiar, less invasive workflow, positioning the RFT autograft as a versatile workhorse for both primary and revision knee ligament surgery with extended possibilities in multiligament reconstructions.

AUTHOR CONTRIBUTIONS

Richard Glaab conceived the study, performed the literature search and drafted the manuscript. Matthieu Ollivier contributed surgical illustrations and critically revised the manuscript. Wolf Petersen critically revised the manuscript and contributed to the discussion. Tomás Pineda contributed biomechanical analysis and critically revised the manuscript. VM contributed anatomical data and critically revised the manuscript. Nguyen Quang Ton Quyen, Abhijit Sen, Jia Ying Lee, Zi Yang Chia and Francesco Pettinari critically reviewed the manuscript and contributed technical expertise from their respective clinical experience. Camilo P. Helito supervised the project, contributed to study design and data analysis and critically revised the manuscript. All authors read and approved the final manuscript. In accordance with International Committee of Medical Journal Editors (ICMJE) and Wiley guidelines, AI-assisted tools (Claude, Anthropic; NotebookLM, Google; OperativeInk) were used to support literature organization, language editing and figure preparation. All scientific content, clinical interpretation and final editorial decisions were made exclusively by the authors.

ACKNOWLEDGEMENTS

AI-assisted tools (Claude, Anthropic; NotebookLM, Google; OperativeInk) were used to support literature organization, language editing and figure preparation. All scientific content, clinical interpretation and final editorial decisions were made exclusively by the authors. The authors have no funding to report.

FUNDING INFORMATION

The authors have no funding to report.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

No datasets were generated or analysed during the current study. All data discussed are available in the cited published literature.

ETHICS STATEMENT

The authors have nothing to report.

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REFERENCES

1. 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):76–9.
2. Barroso BG, Canuto SMdeG, Helito CP, Rêgo MCF, Martins FS, Rêgo MCF. Combined anterior cruciate ligament and anterolateral ligament reconstruction using the superficial layer quadriceps tendon graft: surgical technique description. Arthrosc Tech. 2024;13(10):103067.
3. Blauth W. [2-strip substitution-plasty of the anterior cruciate ligament with the quadriceps tendon]. Unfallheilkunde. 1984; 87(2):45–51.
4. Buescu C, Onutu A, Lucaciu D, Todor A. Pain level after ACL reconstruction: a comparative study between free quadriceps tendon and hamstring tendons autografts. Acta Orthop Traumatol Turc. 2017;51(2):100–3.

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5. Calvert ND, Ebert JR, Radic R. Kneeling tolerance when using quadriceps tendon autograft for anterior cruciate ligament reconstruction is superior to hamstring tendon autograft. Knee Surg Sports Traumatol Arthrosc. 2025;33(7):2390–6.
6. Dansby J, Tibone J, Huang DT, Nakla A, Batten C, Metzger MF. Biomechanical comparison of full-thickness versus partial-thickness quadriceps tendon grafts for ACL reconstruction. Orthop J Sports Med. 2025;13(6).
7. Dhariwal VH, Rajamanickam P, Kannaiyan M, Iyyappan A. Comparative functional outcome study of superficial quadriceps tendon versus hamstring tendon autograft in arthroscopic anterior cruciate ligament reconstruction. J Arthrosc Surg Sports Med. 2025;7:51.
8. Eggeling L, Breer S, Drenck TC, Frosch K-H, Akoto R. Double-layered quadriceps tendon autografts provide lower failure rates and improved clinical results compared with hamstring tendon grafts in revision ACL reconstruction. Orthop J Sports Med. 2021;9(12).
9. Fink C, Herbort M, Abermann E, Hoser C. Minimally invasive harvest of a quadriceps tendon graft with or without a bone block. Arthrosc Tech. 2014;3(4):e509–13.
10. Franz W, Ulbrich J. Eine neue Technik zur Entnahme der Semitendinosussehne für den Kreuzbandersatz. Arthroskopie. 2004;17:104–7.
11. Fulkerson JP, Langeland R. An alternative cruciate reconstruction graft: the central quadriceps tendon. Arthroscopy. 1995;11(2):252–4.
12. Gaugg F, Bierke S, Hees T, Siemßen K, Wolfarth B, Petersen W. Dynamic valgus after ACL reconstruction: quadriceps- vs. semitendinosus tendon grafts. Arch Orthop Trauma Surg. 2025; 145(1):377.
13. Grob K, Manestar M, Filgueira L, Ackland T, Gilbey H, Kuster MS. New insight in the architecture of the quadriceps tendon. J Exp Orthop. 2016;3(1):32.
14. Horteur C, Cavalié G, Gaulin B, Cohen Bacry M, Morin V, Cavaignac E, et al. Saphenous nerve injury after anterior cruciate ligament reconstruction: reduced numbness area after ligamentoplasty using quadriceps tendon compared with hamstring tendon. Knee. 2020;27(4):1151–7.
15. Huber T, Frühwirth M, Hartenbach F, Franzmair S, Ullmann D, Rath B. A novel surgical technique for revision anterior cruciate ligament reconstruction using an isolated rectus femoris tendon autograft. Arch Orthop Trauma Surg. 2024;144(6): 2723–30.
16. Huber T, Frühwirth M, Hartenbach F, Franzmair S, Ullmann D, Trieb K, et al. Revision anterior cruciate ligament reconstruction using rectus femoris or hamstring tendon shows comparable patient-reported outcome measurements at short-term follow-up: a retrospective cohort study. J Clin Med. 2025;14(10):3512.
17. Iriuchishima T, Shirakura K, Yorifuji H, Fu FH. Anatomical evaluation of the rectus femoris tendon and its related structures. Arch Orthop Trauma Surg. 2012;132(11):1665–8.
18. Karaqi A, Braken P, Nelson J, Petersen W, Canuto S, Glaab R. Harvesting the tendon of the rectus femoris muscle as a graft for reconstructive ligament surgery on the knee joint. Oper Orthop Traumatol. 2026;epub ahead of print.
19. Kodkani PS, Govekar DP, Patankar HS. A new technique of graft harvest for anterior cruciate ligament reconstruction with quadruple semitendinosus tendon autograft. Arthroscopy. 2004; 20(8):e101–4.
20. Lee JY, Soong JW, Huang D, Chang P, Cong T, Ollivier M, et al. Bidirectional tendon strip: a rectus femoris graft harvesting technique for anterior cruciate ligament reconstruction. Arthrosc Tech. 2025;14(12):103916.
21. Liukkonen RJ, Ponkilainen VT, Reito A. Revision rates after primary ACL reconstruction performed between 1969 and 2018: a systematic review and metaregression analysis. Orthop J Sports Med. 2022;10(8).
22. Lockwood WC, Marchetti DC, Dahl KD, Mikula JD, Williams BT, Kheir MM, et al. High-load preconditioning of human soft tissue hamstring grafts: an in vitro biomechanical analysis. Knee Surg Sports Traumatol Arthrosc. 2017;25(1):138–43.
23. Marot V, Carrozzo A, Chahla J, Martinel V, Sonnery-Cottet V, Limam K, et al. Rectus femoris tendon morphometry and practical landmarks for harvesting: a cadaveric study. Knee Surg Sports Traumatol Arthrosc. 2025; Epub ahead of print.
24. Marshall JL, Warren RF, Wickiewicz TL, Reider B. The anterior cruciate ligament: a technique of repair and reconstruction. Clin Orthop Relat Res. 1979;97(143):106.
25. Martins FS, Cardoso Filho AT, Canuto SM, de G, Helito CP, Barroso BG, et al. Double-bundle posterior cruciate ligament reconstruction using the rectus femoris graft-superficial layer of the quadriceps: surgical technique. Arthrosc Tech. 2025; 14(11):103866.
26. Morin V, Veyrat G, Pennec E, Gaulin B, Girard P, Ollivier M, et al. Continuous bone–quadriceps tendon–rectus femoris autograft for revision anterior cruciate ligament and anterolateral ligament reconstructions. Arthrosc Tech. 2025; 14(12):103985.
27. 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.
28. Di Muro A, Pettinari F, Macchiarella E, Taha ZA, Azzola F, Civinini R, et al. Combined anterior cruciate ligament and anterolateral ligament reconstruction using rectus femoris tendon autograft. Arthrosc Tech. 2025;14(11):103845.
29. Noailles T, Toanen C, Geffroy L, Lopes R, Hardy A. Anterior cruciate ligament and anterolateral ligament reconstruction with pedicular hamstrings tendon graft, single-strand gracilis for all and single blind femoral tunnel. Arthrosc Tech. 2023;12: e1145–54.
30. Olewnik Ł, Landfald IC, Ruzik K, Cavalcante JC, Piagkou M, Triantafyllou G, et al. Beyond four heads: should the quadriceps femoris be reclassified as multiceps muscle? Ann Anat. 2026; 263:152737.
31. Olewnik Ł, Zielinska N, Aragones P, Ruzik K, Paulsen F, Borowski A, et al. The accessory heads of the quadriceps femoris muscle may affect the layering of the quadriceps tendon and potential graft harvest lengths. Knee Surg Sports Traumatol Arthrosc. 2023;31(12):5755–64.
32. Panas K, Salomon K, Shen V, Munassi S, Remaley DT. Minimally invasive anterior cruciate ligament with quadriceps tendon graft: a proximal-to-distal harvest technique. Arthrosc Tech. 2022;11(11):e2067–72.
33. Panisset JC. Rectus femoris tendon graft for repeated anteior cruciate ligament tears: a consecutive series of 40 patients. Orthop Proc. 2004;86–B(SUPP_I):46.
34. Parrino RL, Adams W, Letter MI, Ripic Z, Baraga MG, Kaplan LD, et al. Impact of quadriceps tendon graft thickness on electromechanical delay and neuromuscular performance after ACL reconstruction. Orthop J Sports Med. 2023;11(10).
35. de Paula L. Cury R, Correa VNM, Rahal RR, Netto AdosS, de Oliveira VM, Mestriner MB. Double-bundle posterior cruciate ligament reconstruction using superficial quadriceps and semitendinosus tendon autografts. Arthrosc Tech. 2025; 14(6):103460.
36. Pettinari F, Di Muro A, Macchiarella E, Taha ZA, Civinini R, Matassi F. Combined revision of anterior cruciate ligament and lateral extra-articular procedure using rectus femoris autologous graft. Arthrosc Tech. 2025;14(11):103783.
37. Piagkou M, Triantafyllou G, Georgiev GP, Tsakotos G, Olewnik Ł, Landfald IC, et al. Systematic review and prevalence meta-analysis of quadriceps femoris morphology: significance

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of the quadriceps tendon in anterior cruciate ligament reconstruction. J Funct Morphol Kinesiol. 2025;10(3):250.
38. Pineda T, Cavaignac E, Neri T, Canuto S, Helito C, Ollivier M. Rectus femoris tendon: an emerging option in ACL reconstruction. Knee Surg Sports Traumatol Arthrosc. 2025;3(4):1927–9.
39. Pineda T, Sewpaul Y, Morin V, Jacquet C, Horteur C, Ollivier M. The rectus femoris tendon demonstrates comparable ultimate stress to the patellar tendon: a paired biomechanical study. Knee Surg Sports Traumatol Arthrosc. 2025;Online ahead of print.
40. Pires D, Monteiro L, Rego MCF, de Souza GLPC, de Paula RE, Pádua VBC, et al. Harvesting the quadriceps tendon with a minimally invasive approach. Video Journal of Sports Medicine. 2023;3(6).
41. Prentice HA, Chan PH, Paxton EW, Felson DT, Funahashi TT, Maletis GB. Patient and operative risk factors for osteoarthritis after primary anterior cruciate ligament reconstruction: a cohort study of 41,976 patients. Am J Sports Med. 2024;52(10): 2482–92.
42. Quyen NQT, Hieu DM, Hieu VT, Vinh PD, Hung TNK, Nam Anh TH. Technique for harvest of superficial quadriceps tendon autograft. Arthrosc Tech. 2024;13(4):102920.
43. Raman R, Mishra BN, Sen A. A minimally invasive and simple technique of superficial quadriceps tendon graft harvesting. Arthrosc Tech. 2022;11(12):e2347–55.
44. Rego M, Mameri E, Barroso B, Helito C, Franciozi C. Anterior cruciate ligament reconstruction with the rectus femoris autograft—results from the first 80 patients. Orthop J Sports Med. 2024;12(11_suppl4).
45. Rêgo MCF, de Barros ACM, Brasileiro JS, Rêgo MCF, Helito CP, et al. Comparable isokinetic quadriceps performance six months after ACL reconstruction with rectus femoris versus hamstring tendon autografts. J Exp Orthop. 2025;12(4):e70601.
46. Rêgo MCF, Barroso BG, Helito CP, Rêgo MCF, Marinho de Gusmão Canuto S, de Oliveira DE, et al. Combined anterior cruciate ligament and anteromedial oblique ligament reconstruction using the rectus femoris tendon: description of surgical technique. Arthrosc Tech. 2025;14(2):103224.
47. Runer A, Csapo R, Hepperger C, Herbort M, Hoser C, Fink C. 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: a comparison of 875 patients. Am J Sports Med. 2020;48(9):2195–204.
48. Shekhar A, Tapasvi S, Helito C. Medial patellofemoral complex reconstruction using the rectus femoris tendon. Arthrosc Tech. 2025;14(12):103971.
49. Sonnery-Cottet V, Alayane A, Mouarbes D, Pailhe R, Cavaignac E. The quad 2.0 technique: a single rectus femoris tendon autograft solution for combined anterior cruciate ligament and double-bundle anterolateral ligament reconstruction. Arthrosc Tech. 2025;14(8):103669.
50. Stäubli H-U, Schatzmann L, Brunner P, Rincón L, Nolte L-P. Quadriceps tendon and patellar ligament: cryosectional anatomy and structural properties in young adults. Knee Surg Sports Traumatol Arthrosc. 1996;4(2):100–10.
51. Strauss M, Kennedy ML, Brady A, Moatshe G, Chahla J, LaPrade RF, et al. Qualitative and quantitative anatomy of the human quadriceps tendon in young cadaveric specimens. Orthop J Sports Med. 2021;9(9).
52. Thamrongskulsiri N, Khwanjaipanich V, Limskul D, Tanpowpong T, Kuptniratsaikul S, Itthipanichpong T. Superficial band of the quadriceps tendon harvested with a minimally invasive technique provides adequate graft dimensions: a cadaveric study. SICOT J. 2025;11:37.
53. Tuca M, Valderrama I, Eriksson K, Tapasvi S. Current trends in anterior cruciate ligament surgery. A worldwide benchmark study. J ISAKOS. 2023;8(1):2–10.
54. Vermorel PH, Testa R, Klasan A, Putnis SE, Philippot R, Sonnery-Cottet B, et al. Contribution of the medial hamstrings to valgus stability of the knee. Orthop J Sports Med. 2023;11(10).
55. Yau W. Relationship between body dimensions and the diameter of a 4-strand ACLR graft. J Exp Orthop. 2025;12(3):e70329

How to cite this article: Glaab R, Ollivier M, Petersen W, Pineda T, Marot V, Quyen NQT, et al. The rectus femoris tendon autograft in knee ligament reconstruction: anatomy, biomechanics, clinical applications and results—a narrative review. Knee Surg Sports Traumatol Arthrosc. 2026;1–16. https://doi.org/10.1002/ksa.70526

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