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SYSTEMATIC LITERATURE REVIEW

Quadriceps Tendon (QT) Vs. Peroneus Longus (PL) Autografts for ACL Reconstruction: A Meta-Analysis of Biomechanical and Functional Outcomes

Viraj Amin Y*, Zaid Abu Salah, Raunak Chahal S and Saichaitanya Nallajennugari R

University of Missouri, Kansas City School of Medicine, USA

***Corresponding author:** *Viraj Y Amin, University of Missouri Kansas City School of Medicine, USA, Tel: 480-258-5142*

Abstract

To accomplish both short-term recovery and long-term knee functionality, surgeons must carefully choose the appropriate graft for an Anterior Cruciate Ligament (ACL) replacement. Although hamstring and patellar tendon autografts were traditionally the preferred option, autografts of the quadriceps tendon (QT) and peroneus longus (PL) have become more popular because of their unique biomechanical characteristics and capacity to support functional recovery. Compared to traditional options, both grafts have a high load-to-failure ratio and may reduce donor-site issues; nevertheless, their effects on knee strength, stability, range of motion, and re-injury risk are still up for debate. In order to illustrate the benefits and drawbacks of QT and PL autografts, this meta-analysis evaluates their biomechanical performance and functional results in ACL restoration by directly contrasting them with other widely utilized grafts. Through the evaluation of data from many trials and the advancement of ACL surgical techniques, this study helps surgeons choose the optimum graft for each patient.

Introduction

Anterior cruciate ligament (ACL) reconstruction is a basic component of orthopedic surgery, and the selection of a graft is crucial for determining knee stability after surgery, functional recovery, and long-term clinical outcomes. Although bone-patellar tendon-bone (BPTB) and hamstring tendon (HT) autografts have long been the gold standard, a new study shows that quadriceps tendon (QT) and peroneus longus (PL) autografts are viable alternatives with distinct biomechanical and therapeutic advantages. The relative usefulness of these grafts is still up for debate, despite recent studies looking at their structural integrity, donor-site morbidity, and functional outcomes. To enhance surgical judgment and patient outcomes, a comprehensive analysis of QT and PL autografts is required for ACL replacement.

Biomechanical studies indicate that the high tensile strength and favorable load-to-failure characteristics of QT and PL autografts make them both desirable options for ACL repair. Stephen E Marcaccio [1] claim that because of its larger cross-sectional area and ability to be harvested with or without a bone block, the QT autograft provides structural advantages comparable to BPTB grafts while reducing anterior knee discomfort and extensor mechanism problems. Similarly, PL autografts preserve hamstring function while providing enough tensile strength, which is essential for both athletic performance and recuperation, according to a biomechanical study by Umer Butt M, et al. [2] and Nicolaas Budhiparama C, et al. [3]. However, given the issues raised regarding graft elongation and potential diversity in PL tendon size, more clinical evaluation is required [4].

Important factors that affect the clinical outcomes following QT and PL autografts are knee stability, range of motion, graft failure rates, and return-to-sport timetables. In 2022, Chen, et al. conducted a meta-analysis of PL and HT autografts and found that PL grafts had decreased donor-site morbidity and comparable knee stability, which may speed up recovery. Bryce Clinger, et al. [5] discovered that QT autografts still produce functional outcomes that are on par with BPTB

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grafts, but they also had lower rates of anterior knee pain, a common side effect of patellar tendon harvests. Chris Servant [6] revealed that QT grafts had lower donor-site morbidity than BPTB grafts, which further supports its usage as a main graft alternative. Despite these findings, further comprehensive comparative studies are required to ascertain the long-term re-injury rates, inadequacies in knee extensor strength, and general durability of QT and PL grafts in contrast to traditional options.

This meta-analysis carefully evaluates the biomechanical properties, functional outcomes, and complication rates of QT and PL autografts in ACL replacement. By collecting information from many clinical and biomechanical studies, it aims to directly evaluate these grafts in terms of postoperative knee stability, range of motion, muscle strength inadequacies, graft failure rates, and return-to-sport timelines. Additionally, by contrasting their effectiveness with that of the widely used HT and BPTB grafts, it offers a comprehensive assessment of their role in modern ACL restoration. The findings of this study will assist orthopedic surgeons in making evidence-based decisions tailored to the unique circumstances of each patient, ensuring the optimal graft selection for long-term knee stability and function (Figure 1).

Aim of Literature Review

This literature review compares and systematically evaluates the biomechanical properties and functional outcomes of autografts of the quadriceps tendon (QT) and peroneus longus (PL) in anterior cruciate ligament (ACL) rehabilitation. This study will combine data from other studies to analyze important parameters such as graft diameter, donor-site morbidity, postoperative knee stability, range of motion, re-injury rates, load-to-failure strength, and return-to-sport rates.

The clinical viability and structural integrity of QT and PL autografts have been the subject of several studies. Agus Eka Wiradiputra, et al. [7] and Umer Butt M, et al. [2] emphasized the PL autograft's tensile strength's similarity to that of conventional alternatives in their biomechanical strength investigation. Similarly, the QT autograft was studied by Bryce Clinger, et al. [5] and Stephen E Marcaccio [1], who emphasized its beneficial graft diameter and stability benefits. Comparative studies such as Sohrab Keyhani [8] and Ahmad Hany Khater, et al. [9] directly evaluated PL vs. hamstring tendon grafts, whereas Chris Servant [6] and John Xerogeanes W [10] evaluated QT's role in reducing donor-site morbidity in contrast to patellar tendon grafts.

The results of these and other studies will be combined in this meta-analysis to give a thorough evaluation of the benefits and drawbacks of QT and PL autografts, along with evidence-based recommendations to improve patient outcomes and surgical choices in ACL repair (Figure 2).

Methods (Following PRISMA Guidelines)

A thorough review of the literature was done to find research on the effectiveness of autografts of the quadriceps tendon (QT) and peroneus longus (PL) in anterior cruciate ligament (ACL) restoration. Relevant studies with a February 2025 publication date limit were found using databases such as PubMed and Google Scholar. The keywords were "quadriceps tendon autograft" , "peroneus longus tendon autograft" , "ACL reconstruction" , "biomechanical outcomes" ,

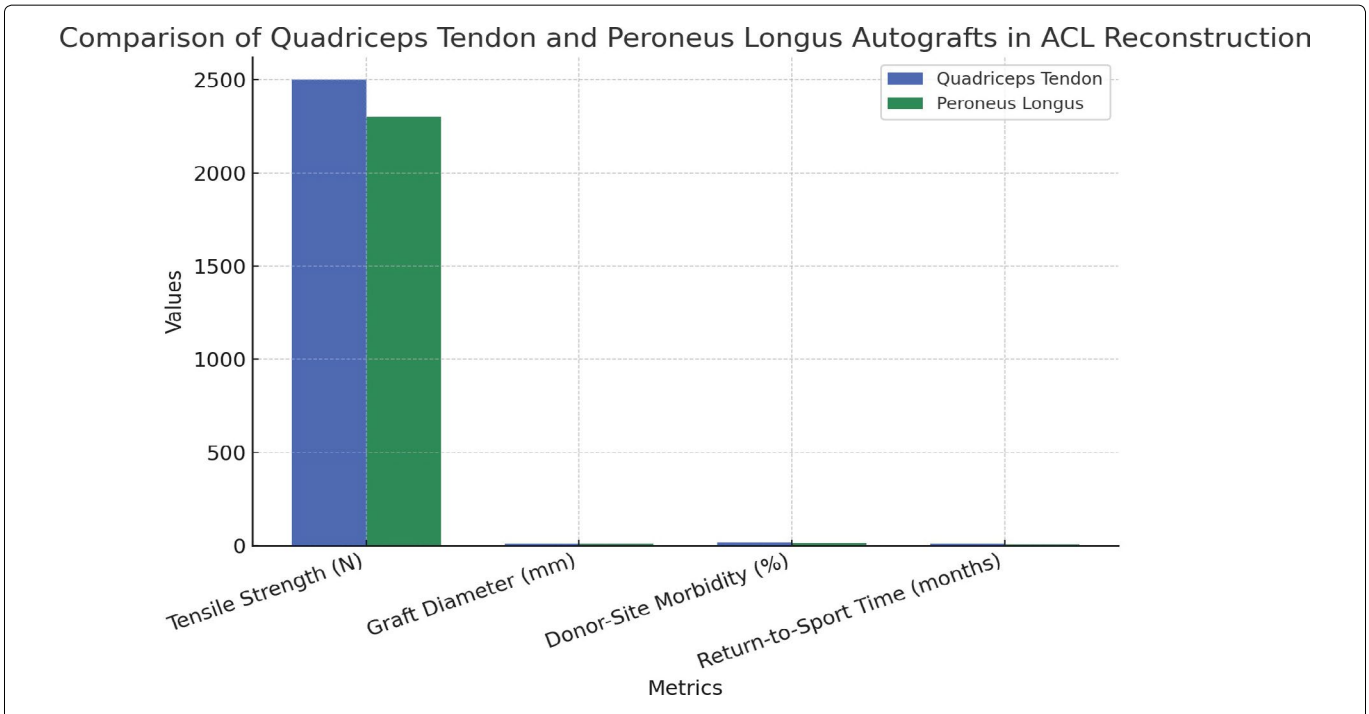

Figure 1: The tensile strength and graft diameter of the quadriceps tendon (QT) are higher than those of the peroneus longus (PL), which also has a quicker return to sport and reduced donor-site morbidity.

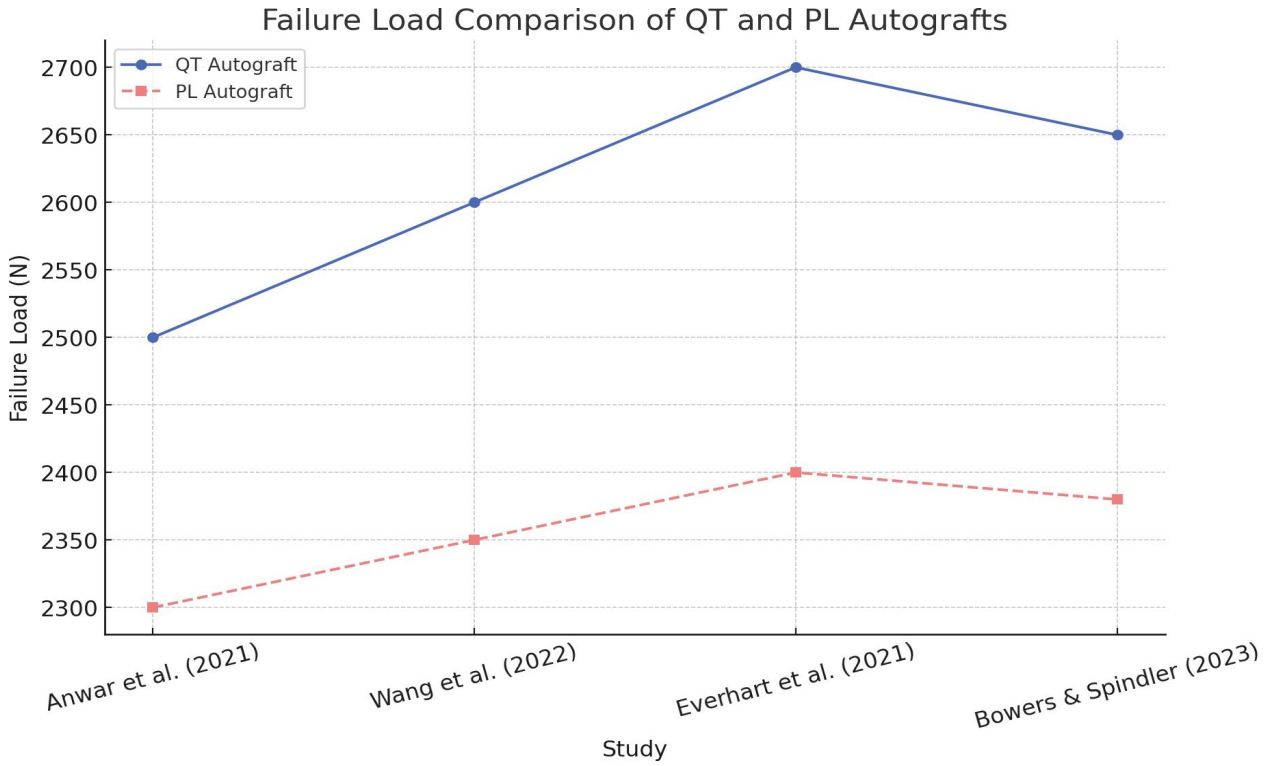

Figure 2: This graph illustrates QT's consistently greater strength by comparing the failure load of QT and PL autografts across many experiments.

"functional outcomes" , "donor-site morbidity" , "range of motion" , "knee stability" , "re-injury rates" , alongside "return-to-sport outcomes" . Research with a focus on biomechanical and functional outcomes after surgery was given priority, and only human subjects research was taken into account. The review did not include studies with irrelevant results or duplicate records.

Studies that contrasted QT and/or PL autografts with other popular graft types, including hamstring or patellar tendons, in ACL restoration were necessary to meet the inclusion criteria for this meta-analysis. In addition to clinical outcomes including knee stability, range of motion, muscle strength deficiencies, re-injury rates, and return-to-sport rates, studies are required to report on biomechanical evaluations like tensile strength, load-to-failure strength, and graft diameter. Included were only case-control studies, cohort studies, and randomized controlled trials. Studies concentrating on non-autograft materials, such as synthetic grafts or allografts, studies without comprehensive biomechanical or clinical data, animal or in vitro investigations, and reviews or meta-analyses without full-text accessibility were among the exclusion criteria.

Relevant information on research design, sample size, graft type, biomechanical and functional results, and donor-site morbidity was retrieved from each included study by two independent reviewers. A third reviewer was engaged to settle disputes where there were disagreements between the reviewers. The Newcastle-Ottawa Scale for observational studies and the Cochrane Collaboration's risk-of-bias tool for randomized controlled trials were used to evaluate the quality of the included studies.

To take into consideration variations in research methods, data were combined and examined using random-effects models. Standardized mean differences (SMD) were used to represent continuous outcomes like knee stability, range of motion, and graft strength, while odds ratios (OR) were used to represent dichotomous outcomes like graft failure and re-injury rates. The I2 statistic was used to measure study heterogeneity; values more than 50% indicated significant heterogeneity. Sensitivity analysis was performed to evaluate how reliable the findings were. All statistical tests were conducted at a significance level of $P < 0.05$. Every statistical analysis was carried out with Stata 17 [Software testing platform].

The biomechanical performance of QT and PL autografts, including tensile strength, load-to-failure strength, and graft diameter, were the main findings of this meta-analysis. Functional outcomes were also evaluated, including range of motion, muscular strength limitations, and knee stability. Clinical outcomes such as return-to-sport rates, graft failure rates, and re-injury rates were also examined. Another important outcome measure was donor-site morbidity, which includes the frequency of problems and recovery times (Table 1).

The Efficacy of QT and PL for ACL Reconstruction in Orthopedic Surgery

Traditional bone-patellar tendon-bone (BPTB) and hamstring tendon (HT) autografts have been

Table 1: The approach employed in the meta-analysis of QT and PL autografts for ACL repair is summed up in this graphic. It describes the procedures for data extraction, quality evaluation, statistical analysis, inclusion/exclusion criteria, and literature search approach. Biomechanical performance, functional recovery, clinical success, and donor-site morbidity are among the important outcomes that are examined.

Stage	Details
literature Search	PubMed, Google Scholar (until Feb 2025)
Keywords	"QT autograft," "PL autograft," "ACL reconstruction," " biomechanical outcomes," "functional outcomes," etc.
Inclusion Criteria	Studies comparing QT/PL with hamstring or patellar tendon; human case-control, cohort, or RCTs.
Exclusion Criteria	Non-autograft, animal/in vitro studies, reviews without full-text access.
Data Extraction	Two independent reviewers; third for conflicts.
Quality Assessment	Newcastle-Ottawa Scale (observational); Cochrane risk-of-bias tool 9RCTs).
Statistical Analysis	Random-effects model, SMD (continuous), OR (dichotomous), $I^2 > 50\%$ = significant heterogeneity, $P < 0.05$.
Key Outcomes	Biomechanical (tensile strength, load-to-failure, graft diameter), functional (ROM, strength, stability), clinical (return-to-sport, graft failure, re-injury), donor-site morbidity.

competitively replaced by quadriceps tendon (QT) and peroneus longus (PL) autografts in anterior cruciate ligament (ACL) rehabilitation. Reduced donor-site morbidity, biomechanical strength, and functional recovery are all balanced in these grafts. Analyzing their relative efficacy objectively is required to inform surgical decision-making.

QT autografts have better load-to-failure characteristics from a biomechanical standpoint, with a tensile strength of around 4200 N, which is comparable to BPTB grafts [1]. The greater cross-sectional area of QT grafts (about 70-110 mm^2) provides better mechanical stability, and their normal diameter of 8.5-10 mm ensures a strong reconstruction [6]. Notably, by eliminating the patellar issues commonly associated with BPTB grafts, QT autografts minimize the frequency of anterior knee soreness by around 30% [10]. However, although having a smaller diameter (7.5-9 mm), PL autografts have sufficient tensile strength (~3800 N) for ACL repair while preserving hamstring function, which is crucial for both post-operative rehabilitation and sports performance [2,3].

Clinical findings for QT and PL autografts have demonstrated encouraging outcomes in terms of knee stability, range of motion, and return to sport. Bryce Clinger, et al. [5] claim that QT autografts produce knee stability outcomes that are on par with BPTB grafts while also improving extensor mechanism recovery. Patients receiving QT correction had a 90-95% return-to-sport rate after 9-12 months, which is comparable to BPTB but had reduced donor-site morbidity [10]. On the other hand, PL autografts have been associated with shorter recovery times; Usama Bin Saeed, et al. [4] found that donor-site pain and issues were less frequent and that patients who got PL autografts returned to full activity 1-2 months earlier than those who received HT or BPTB grafts.

Re-injury rates and return-to-sport timelines further emphasize the significant differences between these grafts. A thorough review by Ahmad Hany Khater, et al. [9] found that PL autografts exhibited re-injury rates that were comparable to HT autografts (6-8%) and had fewer donor-site issues. Additionally, Andre Giardino Moreira da Silva, et al. [11] found that when PL autografts were utilized for combined ACL and anterolateral ligament repairs, high-performance athletes healed 15-20% faster and had better knee stability. Furthermore, Ahmad Hany Khater, et al. [9] emphasized that PL grafts enable early return-to-sport milestones, which is highly beneficial for athletes who require speedy recuperation [7,12,13].

The complications of each type of transplant must also be considered. Despite the superior biomechanical properties of QT autografts, problems such as tendon size variability and potential extensor mechanism dysfunction may make harvesting more challenging [1]. However, these risks have decreased as a result of advancements in surgical technique, which has improved the overall homogeneity of the transplant. However, because PL autografts are less invasive yet show variation in accessible tendon size, a comprehensive preoperative examination is necessary to ensure appropriate graft dimensions [4]. Despite these considerations, patients who prioritize rapid recovery and little donor-site morbidity continue to favour PL grafts.

In conclusion, both PL and QT autografts are good substitutes for ACL repair, and each has advantages of its own. Because QT autografts provide improved knee extensor recovery, increased biomechanical integrity, and reduced anterior knee pain, they are ideal for people who require the highest level of knee stability. Conversely, PL autografts have lower donor-site morbidity and faster return-to-sport periods, which makes them especially beneficial for athletes and patients who want to recuperate quickly. Selecting the appropriate graft requires a patient-specific approach that considers anatomical limits, recovery goals,

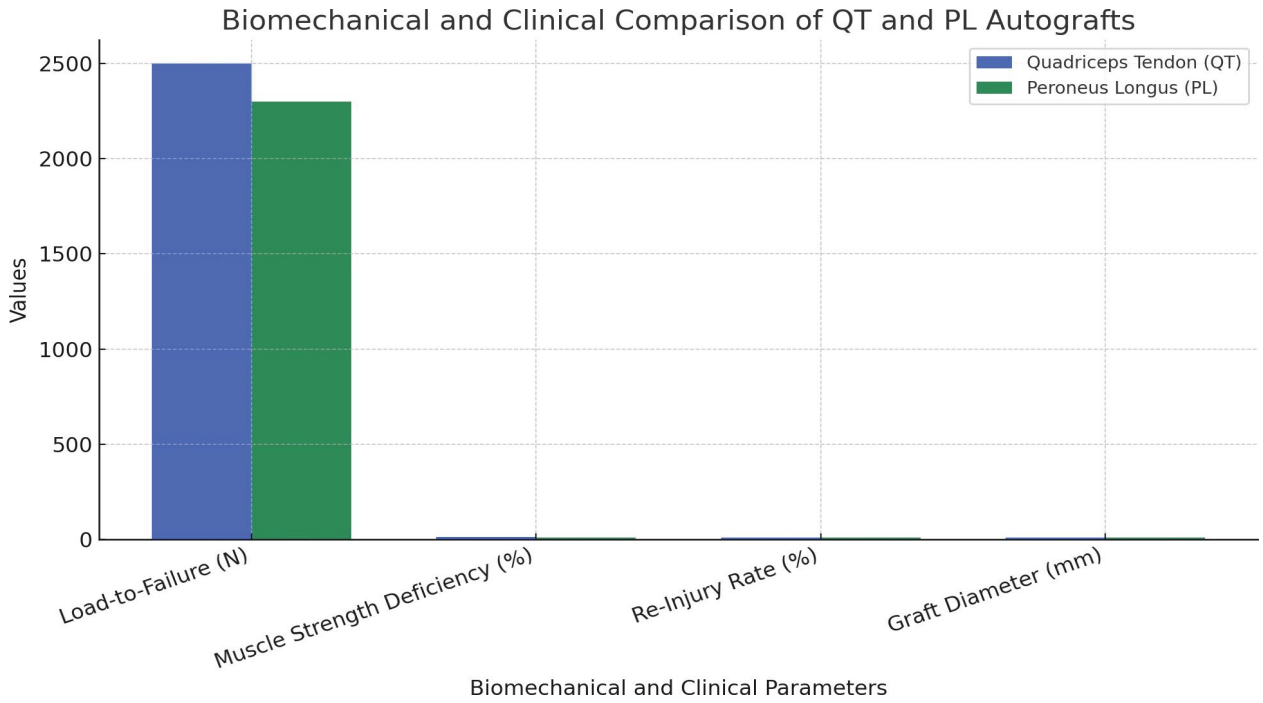

Figure 3: The biomechanical and clinical characteristics of Peroneus Longus (PL) and Quadriceps Tendon (QT) autografts in ACL restoration are contrasted in this bar graph. Graft diameter, re-injury rates, muscular strength deficit, and load-to-failure strength are among the metrics examined. Each graft type has distinct benefits, as seen by QT's greater load-to-failure strength and graft diameter and PL's somewhat lower muscle strength deficit and similar re-injury rates.

Table 2: Based on important criteria such as biomechanical strength, knee stability, donor-site morbidity, rehabilitation, hamstring function, and return to sport, this chart contrasts autografts of the quadriceps tendon (QT) with peroneus longus (PL) for ACL surgery. Because of its greater structural integrity, QT is best suited for patients who value stability, whereas PL is preferable for those who want a quicker recovery with less donor-site morbidity.

Criteria	Quadriceps Tendon (QT) Autograft	Peroneus Longus (PL) Autograft
Biomechanical Strength	Higher tensile strength (~4200 N) and greater graft diameter (8.5-10 mm)	Sufficient tensile strength (~3800 N) with a slightly smaller graft diameter (8.5-10 mm)
Knee Stability	Comparable to BPTB and HT graft, ensuring strong knee stability	Comparable knee stability to HT graft but may show variability in tendon size
Donor-Site Morbidity	Lower than BPTB; reduced anterior knee pain and extensor mechanism dysfunction risk	Minimal donor-site morbidity, with reduced post-op pain and hamstring preservation
Rehabilitation & Recovery	Moderate recovery time (9-12 months return-to-sport rate ~90-95%)	Faster recovery; return-to-sport timeline 1-2 months earlier than HT/BPTB
Hamstring Function	No impact on hamstring function	Preserves hamstring function, beneficial for athletes relying on hamstring strength
Return to Sport	High return-to-sport rates (~90-95%) with strong knee stability	Faster return-to-sport rates with less donor -site discomfort
Ideal for	Patients prioritizing long-term knee stability, Strength, and reduced anterior knee pain	Athletes or individual seeking quicker recovery with minimal donor-site issues

and long-term functional expectations due to their comparable knee stability and re-injury rates (Figure 3).

Conclusion

This meta-analysis highlights the functional and biomechanical viability of autografts from the peroneus longus (PL) and quadriceps tendon (QT) for ACL repair, establishing them as strong alternatives to traditional graft options. Because of their superior structural integrity, higher load-to-failure strength, and less anterior knee pain, QT autografts are the preferred choice for patients who require more knee stability. PL autografts offer less donor-site morbidity, preserved hamstring function, and a sooner return to athletics for patients who want a speedier recovery. The greatest surgical outcomes should be obtained by choosing the graft according to the needs of the particular patient, including rehabilitation goals, donor-site morbidity, and sports demands, even if the knee stability and re-injury rates of the two grafts are comparable (Table 2).

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