Systematic Review

The quadriceps tendon autograft is an option for primary PCL reconstruction: a systematic review

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ABSTRACT

Importance: The posterior cruciate ligament (PCL) is involved in almost one-third of all knee injuries. Surgical management of PCL injuries is currently controversial, and no single graft material is determined as superior in primary PCL reconstruction. A growing body of literature has demonstrated the safety and versatility of the quadriceps tendon (QT) autograft in arthroscopic knee ligament reconstruction.

Objective: The objective of the study was to assess the QT autograft for use in primary PCL reconstruction with a focus on complication rates, revision rates, and functional outcomes.

Evidence review: The online databases Medline, Embase, Web of Science, and CENTRAL were searched on April 30, 2020. Retrieved records were screened by two independent reviewers. Eligible studies assessed the QT autograft in skeletally mature participants undergoing primary PCL reconstruction. Studies of multiligamentous repairs and revisions were excluded. A narrative summary of results from individual studies is presented.

Findings: Six articles met inclusion criteria with $n = 119$ participants (21% female) and a follow-up range from 12 months to 84 months. Complication rates ranged from 13% to 65% and included moderate ($n = 4$) and mild ($n = 4$) knee pain, reflex sympathetic dystrophy ($n = 3$), joint space narrowing ($n = 3$), superficial wound infections ($n = 2$), complex regional pain syndrome ($n = 2$), and flexion deficiency ($n = 2$). Revision rates ranged from 0% to 15% and included hardware removal ($n = 4$), manipulation under anaesthesia ($n = 2$), arthroscopic arthrolysis ($n = 2$), and arthroscopic refixation ($n = 2$). Subjective International Knee Documentation Committee scores increased from a preoperative range of 37.7 ± 21.4 to 39.5 ± 21 to a postoperative range of 74.5 ± 17.7 to 84.7 . Lysholm scores, Tegner activity scores, and posterior tibial laxity also demonstrated improvements postoperatively. No statistically significant differences were reported in the study that compared the QT autograft with the hamstring tendon autograft.

Conclusions and relevance: This systematic review reported functional outcomes and complication rates of a small QT autograft sample that were comparable with other graft materials used in PCL reconstruction. Heterogeneity of the included studies and reported outcomes precluded meta-analysis. Future studies of better methodological quality and larger sample sizes need to be conducted before the QT autograft may be concluded as safe and effective in primary PCL reconstruction.

Level of evidence: IV.

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What is already known?

- The quadriceps tendon (QT) has several qualities that make it an ideal candidate for recreation of the native posterior cruciate ligament (PCL).
- Presently, no systematic reviews have assessed the outcomes and complication profiles associated with the use of the QT autograft in primary PCL reconstruction surgery.

What are the new findings?

- Revision rates among included studies ranged from 0% to 15%, with hardware removal due to irritation accounting for most cases (44%) and none of the cases being due to graft failure (0%).
- The QT autograft demonstrated an improvement in International Knee Documentation Committee, Tegner activity, Lysholm, and posterior drawer test scores in the postoperative period across all included studies.
- Postoperatively, 74% (n = 61/82) of participants rated their activity level as “strenuous” or “moderate” after receiving autogenous QT for their PCL reconstruction.
- The complication rate was 23.5% (n = 28/119), which is comparable with other grafts’ (hamstrings and Achilles tendons) complication rates reported in the literature.
- This systematic literature review found evidence that the QT autograft had comparable outcomes with other graft options in primary PCL reconstruction and highlights a need for future studies.

Introduction

Posterior cruciate ligament (PCL) injuries occur in an estimated 3% to 37% of all knee injuries [1,2]. Common mechanisms of injury include noncontact hyperextension of the knee with a plantarflexed foot or the application of a posterior force to the tibia in a flexed knee during motor vehicle collisions (a “dashboard injury”) [1]. The variability in reported prevalence of PCL injuries likely represents their underdiagnosis secondary to mild presentations or co-occurrence in trauma settings [2,3]. Missed injuries and delayed treatment can be detrimental to the joint and debilitating to the patient [4–8].

Treatment of PCL injuries is controversial and lacks consensus [3,9,10]. The factors influencing this clinical conundrum include variability in PCL injury severity, concurrent injuries, patient factors, and the surgeon's preferences [1]. High-grade PCL tears and multiligamentous knee injuries are associated with instability and early osteoarthritis and warrant surgical intervention [7,8,11,12]. Reconstruction of the PCL may be indicated in unstable isolated grade II or III tears, in multiligamentous knee injuries, in coexisting tibial or femoral avulsion fractures, or in patients with persistent knee pain [2]. The primary goals of PCL reconstruction are to restore native knee anatomy, attain desired ligamentous laxity, and resolve symptoms [2,3]. Currently, results of PCL reconstruction remain highly variable, and no single graft material has produced consistently superior outcomes in the literature [3,12,13].

The ideal graft would have similar structural properties and dimensions to the native PCL, pass easily, provide secure fixation, incorporate quickly, and minimise harvest site morbidity [9,10]. The quadriceps tendon (QT) autograft has seen a resurgence in primary ACL reconstruction, medial patellofemoral ligament reconstruction, and revision knee ligament reconstruction because modern harvesting techniques provide robust soft tissue and a reduced risk of donor site morbidity [14–16]. The QT autograft is a strong candidate in PCL reconstruction because of its size, strength, and decreased morbidity of the harvest donor site when compared with the patellar tendon [3,16]. It also naturally divides into two limbs to mimic the anterolateral and posteromedial bundles of the native PCL for double-bundle reconstruction techniques [11,14]. Potential disadvantages of the QT autograft in PCL reconstruction include an increased risk of patellar fracture and anterior knee pain [11,14].

To date, the authors are not aware of any systematic reviews that have assessed the performance of the QT autograft in primary PCL reconstruction in the Cochrane Central Register of Controlled Trials (CENTRAL), Open Science Framework, or the International Prospective Register of Systematic Reviews. The purpose of this systematic literature review was to assess the QT autograft for use in primary PCL reconstruction with a focus on complication profiles and functional outcomes. Our hypothesis was that the QT autograft would be safe and have clinically comparable revision rates and functional outcomes compared with alternate grafts.

Methods

A protocol that specified the research question, study eligibility, and methodology was created *a priori* and agreed on by all authors. This

systematic review was performed and reported as per the Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines [17].

Search strategy

Independent search strategies were created with assistance from a health-sciences librarian. The following online databases were searched on April 30, 2020: OVID Medline Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE® Daily and Ovid MEDLINE® 1946 to present, Embase 1974 to present, Web of Science Core Collection 1976 to present, and the Cochrane Central Register of Controlled Trials (CENTRAL). Boolean operators were used to combine the following terms: “{(posterior cruciate ligament reconstruction) OR [(posterior cruciate ligament) AND (reconstruction)]} AND (quadriceps tendon)”. Figure 1 lists a complete search strategy. Included studies also had their references checked for potentially eligible records.

Study eligibility

Any study design that evaluated the QT autograft in primary reconstruction of the PCL in skeletally mature participants was eligible. Non-controlled studies and case series were included given the paucity of research into this topic and with the expectation that only a qualitative summary of results would be synthesised. Studies had to be peer-reviewed and published in English. Records were excluded if they were multiligamentous repairs, revision surgeries, studies of allograft tissue, studies of animals or cadavers, poster presentations, or abstracts without peer review.

Study screening

Two independent reviewers performed a blinded review of retrieved records in the online software program Rayyan QCRI (2010, Qatar Computing Research Institute, Doha, Qatar). A title-and-abstract screen was completed first; discrepancies at this stage were automatically included for full-text review. Discrepancies during the full-text review were resolved by consensus with a senior author. Inter-reviewer agreement during both the title-and-abstract and full-text reviews was measured using Cohen's kappa (k) coefficient [18]. Values of 0.81 to 0.99 are considered to be “almost perfect” agreement, 0.61 to 0.80 to be “substantial” agreement, 0.41 to 0.60 to be “moderate” agreement, 0.21 to 0.40 to be “fair” agreement, and 0.20 or less to be “slight” agreement [18].

Search #	Keyword	Results
1	Posterior Cruciate Ligament Reconstruction/	86
2	Posterior cruciate ligament* reconstruct*.mp.	525
3	PCL reconstruct*.mp.	532
4	1 or 2 or 3	784
5	Posterior Cruciate Ligament/	2298
6	Posterior cruciate.mp.	3951
7	PCL.mp.	11810
8	5 or 6 or 7	14129
9	reconstruct*.mp.	310783
10	Orthop?edic surg*.mp.	25099
11	Exp Orthopedic Procedures/	303087
12	9 or 10 or 11	594884
13	8 and 12	3033
14	4 or 13	3033
15	Quadriceps Muscle/	5078
16	quadricep*.mp.	17725
17	Tendons/	25979
18	tendon.mp.	64383
19	or/15-18	87479
20	14 and 19	750

Fig. 1. MEDLINE search strategy. Search results are for the database OVID Medline Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) 1946 to Present. The search was conducted on 30/04/20. A similar search strategy was repeated in Embase, Web of Science, and CENTRAL, with keywords adjusted.

Quality assessment of included studies

Quality assessment of included articles was completed in duplicate using the methodological index for non-randomised studies (MINORS) [19]. The MINORS is a validated instrument that assesses the methodological quality of non-randomised comparative or non-comparative surgical studies. There are eight scored items for non-comparative studies and twelve scored items for comparative studies [19]. Higher scores represent a lower risk of bias [19]. The maximum scores for non-comparative and comparative studies are 16 and 24, respectively [19].

Data abstraction

Two independent reviewers abstracted data into an online collaborative Google Excel Sheet (Google, California, USA) designed before the abstraction process. Features of study design, participant inclusion and exclusion criteria, participant demographics, surgical techniques and methodologies, and all reported outcomes were recorded. The primary outcomes were the frequencies of revision surgery and complications. Revision surgery was defined as a return to the operating room for any reason related to previous PCL reconstruction. Complications were defined as major adverse events if they were persistent and required surgical intervention or minor adverse events if they were transient and did not require intervention. Secondary outcomes were functional and included the Lysholm knee score, the Tegner activity scale, the International Knee Documentation Committee (IKDC) Questionnaire, activity levels, and posterior tibial laxity. Posterior tibial laxity was measured in included studies with a stress radiograph (taken while a Telos® arm

applied a consistent posterior-directed force to the anterior aspect of the tibia) [20,21].

Statistical analysis

The results of this systematic literature review were synthesised qualitatively. Measures of treatment effect from individual studies were reported as they were in the literature using mean and standard deviation. Descriptive summary estimates of included studies were reported as an overall range. Heterogeneity between studies' methodologies and reported outcomes precluded meta-analysis.

Results

Study selection

Six articles qualified for inclusion of 1579 non-duplicate records retrieved [20–25]. Figure 2 details the results of the study selection process and exclusions. Agreement during the title-and-abstract review was near-perfect ($k = 0.95$). Agreement during the full-text review was substantial ($k = 0.75$). A review of the references of included articles found no additional studies eligible for inclusion.

Study quality

The included articles consisted of one prospective cohort study (level III evidence) [23] and five case series (level IV evidence) [20–22,24,25]. The cohort study compared the QT autograft with a quadruple hamstring

Fig. 2. PRISMA flow diagram.

Table 1
Descriptive characteristics of included studies.

Study (year)	Study design	Level of evidence	MINORS total (points)	Graft(s) utilised	Sample size (n)	Lost to F/U	Final F/U (n)	M:F	Mean age (± SD)	Age range (years)	Mean F/U (range) (months)	Mean injury-Sx interval (months)
Chen et al. (1999)	Case series	IV	7/16	Quadriceps tendon autograft	12	0	12	9:3	29 (NR)	19-48	15.6 (12-18)	NR
Chen et al. (2002)	Prospective cohort study	III	16/24	Quadriceps tendon autograft	24	2	22	14:8	29 (NR)	19-54	30 (24-36)	12 acute, 10 chronic
				Hamstrings tendon autograft	30	3	27	18:9	27 (NR)	20-52	26 (24-30)	16 acute, 11 chronic
Noyes et al. (2005)	Case series	IV	12/16	Quadriceps tendon autograft	20	1	19	15:4	30 (NR)	17-43	35 (24-84)	43
Quelard et al. (2010)	Case series	IV	10/16	Quadriceps tendon autograft	17	0	17	15:2	29.3 (NR)	18-46	30 (12-60)	2 acute, 15 chronic
Wu et al. (2007)	Case series	IV	12/16	Quadriceps tendon autograft	22	0	22	17:5	27 (NR)	18-49	66 (60-76)	5
Zayni et al. (2011)	Case series	IV	11/16	Quadriceps tendon autograft	24	3	21	18:3	29 (NR)	18-46	28.9 (12-48)	28

Abbreviations: F/U: follow-up; M:F: males to females; MINORS: methodological index for non-randomised studies; NR: not reported; SD: standard deviation; Sx: surgery. NOTE: Acute mean injury-surgery interval is defined as surgery occurring in <12 weeks after the initial injury, and chronic mean injury-surgery interval is defined as surgery occurring >12 weeks after the initial injury.

Table 2

Revision rates and complication of included studies.

Study (year)	Graft(s) utilised	Sample size	Revision rate (%)	Complication rate (%)	Total #	Major	Minor	Description of reasons for revisions and complication(s)
Chen et al. (1999)	Quadriceps tendon autograft	12	NR	NR	NR	NR	NR	NR
Chen et al. (2002)	Quadriceps tendon autograft	24	2/24 (8%)	4/24 (17%)	4	2	2	2 superficial wound infections, 2 hardware removals
Noyes et al. (2005)	Hamstrings tendon autograft	30	6/30 (20%)	6/30 (20%)	6	6	0	6 hardware removals
	Quadriceps tendon autograft	20	3/20 (15%)	3/20 (15%)	3	3	0	2 patients with MUA, 1 patient with new onset instability leading to arthroscopic refixation
Quelard et al. (2010)	Quadriceps tendon autograft	17	0/17 (0%)	11/17 (65%)	11	2	9	4 patients with moderate residual pain, 3 patients with moderate radiological narrowing of medial joint space, 2 patients with complex regional pain syndrome, 2 patients with flexion deficiency
Wu et al. (2007)	Quadriceps tendon autograft	22	3/22 (14%)	3/22 (14%)	3	3	0	2 hardware removals, 1 arthroscopic arthrolysis for ROM restriction
Zayni et al. (2011)	Quadriceps tendon autograft	24	1/24 (4%)	7/24 (29%)	7	3	4	4 patients with transitory mild knee pain, 3 patients with reflex sympathetic dystrophy syndromes, 1 patient with new onset instability leading to arthroscopic refixation

Abbreviations: MUA: manipulation under anaesthesia; NR: not reported; n: sample size; ROM: range of motion.

tendon autograft and had a MINORS score of 16/24 [23]. MINORS scores for the non-comparative studies ranged from seven to 12 of a possible 16 points (Table 1) [20–22,24,25]. These scores reflect a fair level of evidence among included studies.

Study characteristics

Individual study characteristics are presented in Table 1. Publication dates ranged from 1999 to 2011. There were initially n = 119 participants, but six (attrition rate 5%) were lost to follow-up, resulting in a final sample size of n = 113. There were n = 88 men (74%) and n = 25 women (21%). Ages ranged from 17 to 54 years. Follow-up ranged from 12 to 84 months (1 to 7 years). The overall interval from injury to surgery ranged from 0.69 to 216 months (0.06 to 18 years). Of the studies that reported the mechanism of injury (n = 4/6), there were n = 38 road accidents, n = 36 sport-related injuries, three falls, and two work-related injuries [20,21,23,25]. Overall, n = 113 QT autografts and n = 27 quadruple hamstring tendon autografts were analysed at the final follow-up. All QT grafts included a proximal patellar bone plug.

Revision rates

Revision rates were reported in n = 5 of 6 included studies and ranged from 0% to 15% [20,22–25]. Table 2 details revision rates and complications from individual studies. No cases of revision were due to QT

autograft failure in the form of a new tear or requiring re-implantation of new graft material. Hardware removal due to irritation accounted for the majority (44%) of revisions. Other reasons for revision included manipulation under anaesthesia (n = 2), arthroscopic arthrolysis (n = 2), and arthroscopic refixation (n = 2).

Complications

Five studies reported complications [20,21,23–25]. Fifteen minor and 13 major adverse events were reported among the quadriceps cohort with a total complication rate of 23.5% (n = 28/119). Complications included moderate (n = 4) and mild (n = 4) knee pain, reflex sympathetic dystrophy (n = 3), joint space narrowing (n = 3), superficial wound infections (n = 2), complex regional pain syndrome (n = 2), and flexion deficiency (n = 2). Individual study complication rates ranged from 14% (n = 3/22) to 65% (n = 11/17) [20,25].

Functional outcomes

The IKDC score was the most frequently reported functional outcome. All six studies reported at least one of its subcategories from the preoperative and postoperative periods. Overall IKDC ratings from the preoperative period were reported by n = 3 of 6 studies (n = 60) and found 100% of participants were in the “abnormal” or “severely abnormal” categories [20,21,25]. Overall IKDC ratings from the postoperative

Table 3

IKDC individual study outcomes.

Study (year)	Graft(s) utilised	IKDC subjective mean (points)		IKDC overall rating							
		Preop	Postop	Normal		Nearly normal		Abnormal		Severely abnormal	
				Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop
Chen et al. (1999)	Quadriceps tendon autograft	NR	84.7 ± NR	NR	1	NR	7	NR	4	NR	0
Chen et al. (2002)	Quadriceps tendon autograft	NR	NR	NR	5	NR	13	NR	3	NR	1
	Hamstrings tendon autograft	NR	NR	NR	7	NR	15	NR	4	NR	1
Noyes et al. (2005)	Quadriceps tendon autograft	NR	NR	NR	0	NR	7	NR	3	NR	1
Quelard et al. (2010)	Quadriceps tendon autograft	37.7 ± 21.4	74.5 ± 17.8	0	5	0	10	10	2	7	0
Wu et al. (2007)	Quadriceps tendon autograft	NR	NR	0	18 ^a	0	N/A	22 ^b	4 ^b	N/A	N/A
Zayni et al. (2011)	Quadriceps tendon autograft	39.5 ± 21	74.5 ± 17.7	0	8	0	9	10	4	11	0

Abbreviations: N/A: not applicable; NR: not reported; Postop: postoperative; Preop: preoperative.

NOTE: N/A is designated for categories that were reported as a combined total across two separate categories with individual data not reported (see the information in the following for further clarification).

^a The value is listed in the normal category but reported as a total distributed across the normal and nearly normal categories.^b The value is listed in the abnormal category but is reported as a total distributed across the abnormal and severely abnormal categories.

Table 4
Functional outcomes reported by included studies.

Study (year)	Graft(s) utilised	Posterior drawer test (mm)		Lysholm score (points)		Tegner activity score (points)		Thigh girth difference (mm)		Extensor strength ratio (mm)		Flexor strength ratio (mm)		KT-2000 arthrometer side-to-side (mm)	
		Preop	Postop	Preop	Postop	Pre-injury	Preop	Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop
Chen et al. (1999)	Quadriceps tendon autograft	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Chen et al. (2002)	Quadriceps tendon autograft	NR	NR	90.6 ± 7.7	NR	NR	NR	NR	8.6 ± 4.6	NR	87.6 ± 5.9	NR	89.1 ± 7.3	NR	NR
	Hamstring tendon autograft	NR	NR	91.4 ± 6.2	NR	NR	NR	NR	9.1 ± 5.7	NR	88.2 ± 6.8	NR	86.7 ± 8.0	NR	NR
Noyes et al. (2005)	Quadriceps tendon autograft	11.6 ± 2.9	5.1 ± 2.5	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	10.8 ± 3.0	2.0 ± 2.2
Quelard et al. (2010)	Quadriceps tendon autograft	11.9 ± 4.4	3.8 ± 2.3	40.5 ± 18.9	82.3 ± 10.9	NR	3 ± 2.1	NR	7 ± 1.8	NR	NR	NR	NR	NR	NR
Wu et al. (2007)	Quadriceps tendon autograft	11 ± 3.6	3.5 ± 2.7	67 ± 9	89 ± 10	7.2 ± 1.4	3 ± 1.7	16.7 ± 7.44	6.0 ± 2.6	75.4 ± 10.3	91.3 ± 9.5	79.6 ± 9.3	93.5 ± 8.4	NR	NR
Zayni et al. (2011)	Quadriceps tendon autograft	11.9 ± 3.3	3.6 ± 2.2	41.5 ± 18	81.7 ± 10	7.8 ± 1.7	2.8 ± 2.2	NR	6.7 ± 2	NR	NR	NR	NR	NR	NR

Abbreviations: mm: millimetres; NR: not reported; Postop: postoperative; Preop: preoperative.

period were reported by all studies ($n = 105$); 79% of participants ($n = 83/105$) met criteria for the “normal” or “nearly normal” categories, whereas 21% ($n = 22/105$) remained in the “abnormal” or “severely abnormal” categories. Subjective IKDC measures were reported by three studies [20–22]. The preoperative range (mean and standard deviation) 37.7 ± 21.4 to 39.5 ± 21 increased to 74.5 ± 17.7 to 84.7 postoperatively [20–22].

Lysholm knee scores were reported by four studies and increased from a preoperative range of 40.5 ± 18.9 to 67 ± 9 to a postoperative range of 81.7 ± 10 to 90.63 ± 7.74 [20,21,23,25]. Tegner activity scores were reported by three studies and demonstrated a similar improvement from the preoperative range of 2.8 ± 2.2 to 3.0 ± 2.1 to a postoperative range of 6.0 ± 2.6 to 7 ± 1.8 [20,21,25]. Postoperative Tegner activity scores did not meet pre-injury scores (range: 7.2 ± 1.4 to 7.8 ± 1.7) and revealed an incomplete return to baseline function. Posterior tibial laxity was reported by four studies [20,21,24,25]. Preoperatively, posterior tibial laxity ranged from $11 \text{ mm} \pm 3.6 \text{ mm}$ to $11.9 \text{ mm} \pm 4.4 \text{ mm}$ and improved to a range of $3.5 \text{ mm} \pm 2.7 \text{ mm}$ to $5.1 \text{ mm} \pm 2.5 \text{ mm}$ postoperatively [20,21,24,25].

Activity levels in the pre-injury, preoperative, and postoperative periods were reported by four studies. One study did not stratify the isolated PCL cohort from the multiligamentous cohort, and the data were not included in these summary estimates [24]. Almost all (94%, $n = 77/82$) participants reported they were involved in “strenuous” ($n = 44$) or “moderate activity” ($n = 33$) before their PCL injuries. After injury and preoperatively, 73% ($n = 60/82$) of participants had their activity levels decline to “light” or “sedentary”, and only 27% ($n = 22/82$) of participants maintained “strenuous” or “moderate activity”. Postoperatively, 74% ($n = 61/82$) of participants rated their activity as “strenuous” or “moderate”. Tables 3 and 4 list individual studies’ results and other functional outcomes of thigh girth difference, extensor strength ratios, flexor strength ratios, and KT 2000 arthrometer side-to-side differences.

Comparative study

One study compared a QT autograft cohort with a hamstring tendon cohort in primary PCL reconstruction [23]. Higher complication and revision rates were reported in the hamstring tendon cohort (Table 2) [23]. No statistically significant differences were reported for any functional outcome measures (Tables 3 and 4) [23].

Discussion

This systematic literature review summarised and assessed the literature on the use of the QT autograft in primary isolated PCL reconstruction. Six studies were eligible for inclusion, and one study compared the QT autograft with the hamstring tendon. This small, heterogeneous sample of QT autografts demonstrated revision rates and postoperative functional outcomes that were comparable with other graft materials in the literature [26–30]. There were no reported cases of graft tear, rupture, postoperative patellar instability, or failure requiring implant of new graft material. However, follow-up was as little as 12 months. The included studies had a fair level of evidence, and a meta-analysis was not performed, so these results should be interpreted with caution until better quality investigations are complete.

Isolated PCL injuries are less frequently diagnosed relative to other ligamentous knee pathologies and have traditionally been treated non-operatively which challenges the investigation of the ideal graft material for primary reconstruction [6,31–33]. A previous systematic review found no significant differences in clinical outcomes except for anteroposterior knee laxity between autogenous and allogeneous tissue in PCL reconstruction [34]. Another review of all available grafts for PCL reconstruction concluded there were no statistically significant differences in outcome measures or complication rates [35]. Currently, the Achilles tendon allograft and hamstring tendon autograft are most

commonly used for PCL reconstruction and have demonstrated good long-term results in the literature [27,36–39]. Between 78% and 99% of participants who received allogeneous Achilles tendon reported “normal” or “near normal” IKDC scores, whereas 85% to 100% of participants who received autogenous hamstring tendon for PCL reconstruction reported “normal” or “near normal” IKDC scores [26–30]. The QT autograft was performed similarly in this systematic literature review.

Use of the QT autograft in ACL and PCL reconstruction has garnered recent interest because of improved harvesting techniques and a growing body of clinical evidence that suggests equivalent or superior outcomes compared with other graft options [14,40]. Direct comparator studies showed no significant differences in functional outcomes between the hamstring tendon autograft or Achilles tendon allograft and the QT (autograft or allograft) for PCL reconstruction [23,41]. The QT autograft had a lower revision rate (8.3%) than the hamstring tendon autograft (20.0%) [23]. Autogenous QT has the advantages of being self-available, of superior size and strength compared with other graft materials, of providing a one-sided bone plug, and of having a simple harvesting technique to surgeons already experienced with patellar tendon harvest [42]. Included studies elected to use the QT autograft for PCL reconstruction because of its superior length and cross-sectional area, ability to provide a two-stranded graft, and superior biomechanical properties compared with the bone-patellar tendon [23,24]. Still, surgeon preference and graft availability remain two of the main influencing factors in PCL graft selection [25].

Surgical techniques used by the studies summarised in this systematic literature review included the tibial inlay and transtibial approaches [21, 24]. The QT provided adequate length to accommodate both techniques. Five included studies used a single-bundle QT reconstruction, and one used a double-bundle reconstruction [24]. The data were insufficient to investigate the effects of different techniques and different graft preparations. Future comparisons of double- and single-bundle reconstructions using the QT will be important. Although a double-bundle anatomical reconstruction seems preferred from a biomechanical principle, single-bundle reconstruction provided similar outcomes in function, ligament laxity, and radiographic changes in previous studies and may be less technically challenging [43,44]. The preferred surgical technique for donor graft harvest, preferred placement of femoral tunnel(s) and tibial fixation, and the preferred number of graft bundles remain to be determined in using the QT autograft for PCL reconstruction. Future comparative studies with larger sample sizes, blinded assessment of outcomes, standardised reporting of preoperative and postoperative measures, and longer follow-up will advance this body of literature. Finally, future studies should seek to identify which patient populations would most benefit from the QT autograft for PCL reconstruction.

Eight participants in this review demonstrated transitory mild knee pain consistent with postoperative patellofemoral pain or tendinitis. It has been proposed that preoperative evaluation includes an assessment of adequate patellar depth before harvesting the QT graft to reduce the risk of patella-related complications [45]. Previous literature has suggested the bone block be harvested from the medial side of the patella and not exceed 30% of its depth to avoid risk of patellar fracture [45].

This systematic review is the first to evaluate the surgical outcomes, complications, and revision rates of using the QT autograft in primary isolated PCL reconstruction. The overall attrition rate was 5% ($n = 6/119$). We excluded studies with multiligamentous repairs which allowed for a closer approximation of the true effect of the QT on functional outcomes, complications, and revision rates. The QT autograft has demonstrated itself to be versatile and safe in ACL reconstruction; it should be one of the options in the complex knee surgeon's armamentarium [14,46]. The results of this systematic literature review provide further evidence on the safety and utility of the QT autograft in isolated PCL reconstruction. Further investigation of its use in PCL reconstruction may facilitate its widespread adoption into clinical practice.

Limitations

This review is limited by the quantity and quality of evidence it summarised. Only six articles with $n = 119$ participants met inclusion criteria, limiting statistical power and external validity. The narrow amount of published literature on isolated PCL injuries may be attributed to lower incidence rates and the propensity to treat their often-benign course nonoperatively [6]. All included studies were given a “fair” level of evidence. Outcomes were inconsistently reported, and study designs varied which ultimately precluded meta-analysis. We excluded articles that were not peer-reviewed or published, and this may make the body of literature summarised here prone to publication bias. There were no objective measures of graft-donor site morbidity, which precluded the interpretation of the safety of harvesting the QT. However, prior studies of the QT autograft in ACL reconstruction have observed complication rates similar to other grafts in the literature, and modern minimally invasive techniques have mitigated the likelihood of harvest site morbidity [14,46]. These results may translate to the QT autograft for PCL reconstruction as well, but nonetheless need to be investigated further. The minimum follow-up of 12 months and maximum of seven years may influence modest revision rates reported by included studies. Longer and more robust follow-up may reveal more complications and clinical failures outside of those considered for the QT in primary PCL reconstruction. No return to sport data was reported among the reviewed articles, further limiting interpretation of the results.

Conclusion

This systematic literature review summarised and assessed the literature on the use of the QT autograft in isolated PCL reconstruction. The QT autograft had revision rates and postoperative functional outcomes that were comparable with other graft materials in the literature, but prospective studies with better methodologies are needed before a conclusion on its safety and effectiveness in primary PCL reconstruction can be made with confidence.

Declaration of competing interest

No conflict of interest.

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