Systematic Review

Both Quadriceps and Bone–Patellar Tendon–Bone Autografts Improve Postoperative Stability and Functional Outcomes After Anterior Cruciate Ligament Reconstruction: A Systematic Review

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Purpose: To compare postoperative knee stability, functional outcomes, and complications after anterior cruciate ligament (ACL) reconstruction using bone–patellar tendon–bone (BPTB) versus quadriceps tendon autograft. **Methods:** In accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines, the PubMed, Embase, and Cochrane Library databases were searched for studies published in 2002 or later. Studies were included if they met the following criteria: randomized controlled trials that included patients who underwent ACL reconstruction with BPTB or quadriceps tendon autograft including all soft tissue and bone–quadriceps tendon and in which measures of postoperative stability and functional outcomes were reported. Studies that were not written in English and those that analyzed animals or cadavers, were not randomized controlled trials, or used other grafts (e.g., hamstring) were excluded. **Results:** The initial search identified 348 studies, 6 of which were included in this systematic review. Two of the six studies found no significant difference in performance outcomes or complications between quadriceps and BPTB autografts. One study found that patients receiving quadriceps autograft self-reported improved knee functional status compared with those receiving BPTB autograft. Another study found that quadriceps autograft resulted in a significantly reduced Quadriceps Index postoperatively compared with BPTB autograft (69.5 vs 82.8, $P = .01$) but found no difference in postoperative quadriceps strength. An additional study found that the outcomes of quadriceps tendon and BPTB autografts were equivalent per the International Knee Documentation Committee scale, but anterior knee pain was less severe in patients with quadriceps tendon autograft. Furthermore, one study revealed the overall International Knee Documentation Committee score was reported as normal significantly more often in patients who underwent ACL reconstruction with BPTB autograft (85% vs 50%, $P < .001$) and that donor-site morbidity was greater in patients with quadriceps autograft. No significant difference was found in complications requiring reoperation across studies. **Conclusions:** Patients undergoing ACL reconstruction with either BPTB or quadriceps tendon autograft reported improved postoperative knee stability and functional outcomes. There is no significant difference in complications between quadriceps autograft use and BPTB autograft use. **Level of Evidence:** Level III, systematic review of Level III retrospective studies.

Injuries to the anterior cruciate ligament (ACL) are debilitating, and ACL reconstruction aims to improve knee stability and restore athletic performance.[1,2] The most commonly used autografts are hamstring tendon, bone–patellar tendon–bone (BPTB), and quadriceps tendon (QT) autografts.[3,4] Whereas hamstring and BPTB are the traditional autografts used for ACL reconstruction, the QT autograft has received attention in recent years owing to its clinical stability and comparable harvesting risk profile to other types of

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autograft.[5-8] BPTB autograft has stiffness, load, and density qualities that make it a suitable substitute for the native ACL[2]; however, there are several common complications that can occur after ACL reconstruction using BPTB autograft, including patellar fracture, patellar tendon rupture, kneeling pain, numbness over the anterior aspect of the knee, and knee flexion contracture.[5,6] Overall, BPTB patients have favorable outcomes after ACL reconstruction, and previous studies have shown that patients undergoing ACL reconstruction with BPTB autograft are often able to return to strenuous sports with improved knee stability and function compared with their preoperative states.[1]

In addition to BPTB autograft, QT autograft is a good option for ACL reconstruction and can be harvested with a bone plug from the proximal aspect of the patella or solely as a soft-tissue graft.[7] Postoperatively, patients with quadriceps autograft tend to have high knee stability and functional scores, as well as a low rerupture rate.[5,6,8] Numerous studies have shown excellent patient outcomes based on the Lysholm, International Knee Documentation Committee (IKDC), and Tegner scales. Some common complications that may occur after ACL reconstruction using QT autograft include rectus femoris muscle injury, patellar fracture, and tendinopathy.[9] In general, however, QT autograft produces favorable outcomes in patients undergoing ACL reconstruction with relatively minimal morbidity and good to excellent outcomes at 2 years postoperatively.[5] Good postoperative outcomes and high levels of patient satisfaction have been observed after ACL reconstruction with both QT and BPTB autografts. We performed this study to specifically compare patient-reported outcomes (PROs) in studies that directly evaluated these outcomes across the 2 graft choices.

This study aimed to compare postoperative knee stability, functional outcomes, and complications after ACL reconstruction using BPTB versus QT autograft. We hypothesized that both graft types would produce similar functional outcomes with similarly low complication rates when used for ACL reconstruction.

Methods

Literature Search Methodology

A comprehensive search of the PubMed, Embase, and Cochrane Library databases was performed in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines.[10] Studies were included if they met the following criteria: they included male and female patients of any age group who underwent ACL reconstruction with either BPTB or QT autograft including all soft tissue and bone–quadriceps tendon (B-QT), they were randomized controlled trials or retrospective case-control studies, they reported measures of postoperative stability and functional outcomes, they were published in the English language, and they were published from 2002-2022. Studies that analyzed animals or cadavers, those that did not directly compare patients who underwent ACL reconstruction with either BPTB or QT autograft (all soft tissue or B-QT), and those that used grafts other than quadriceps or BPTB (ie, Achilles tendon, allograft, or autologous hamstring) were excluded from this study. The online software program Covidence (Veritas Health Innovation, Melbourne, Australia) was used by 2 authors (U.D. and S.A.O.) to independently screen titles, abstracts, and then full article texts. Any disagreements were resolved through discussion between these 2 authors.

Data Extraction

The following data were extracted from each study: type of graft used (BPTB vs QT [all soft tissue or B-QT]); measures of postoperative knee stability (i.e., Lysholm score, IKDC score, Tegner score, or KT-1000 measurement [MEDmetric, San Diego, CA]); postoperative complications requiring reoperation; and measures of functional postoperative outcomes such as PRO measures, knee range of motion, return to sport, and level of performance. In addition, complications after ACL reconstruction were evaluated and extracted. This included graft failure requiring ACL revision, arthrofibrosis, infection, pain requiring removal of hardware, meniscal tear, cyclops lesion, patellar fracture, graft rupture, and pain with anterior kneeling. In this study, graft failure was defined as a recurrent ACL tear as confirmed by magnetic resonance imaging.

Assessment of Study Quality

Data quality assessment was performed with the Newcastle-Ottawa Quality Assessment Tool for nonrandomized trials.[11] Full texts were reviewed based on the inclusion and exclusion criteria. The aforementioned assessment tool was then used to grade study quality.

Results

A total of 348 studies were identified through the initial database searches, 63 of which were duplicates and were subsequently excluded. Titles and abstracts were screened for the remaining 285 studies, 277 of which were subsequently excluded. The remaining 8 studies were assessed for eligibility with full-text review. After 2 studies were excluded for having an incorrect study design, 6 studies were included for data extraction (Fig 1). Each of the included studies was a retrospective study.

Study Characteristics

The 6 studies included in this study are summarized in Table 1. In 2022, Hogan et al.[12] conducted a retrospective analysis of 119 patients who underwent ACL

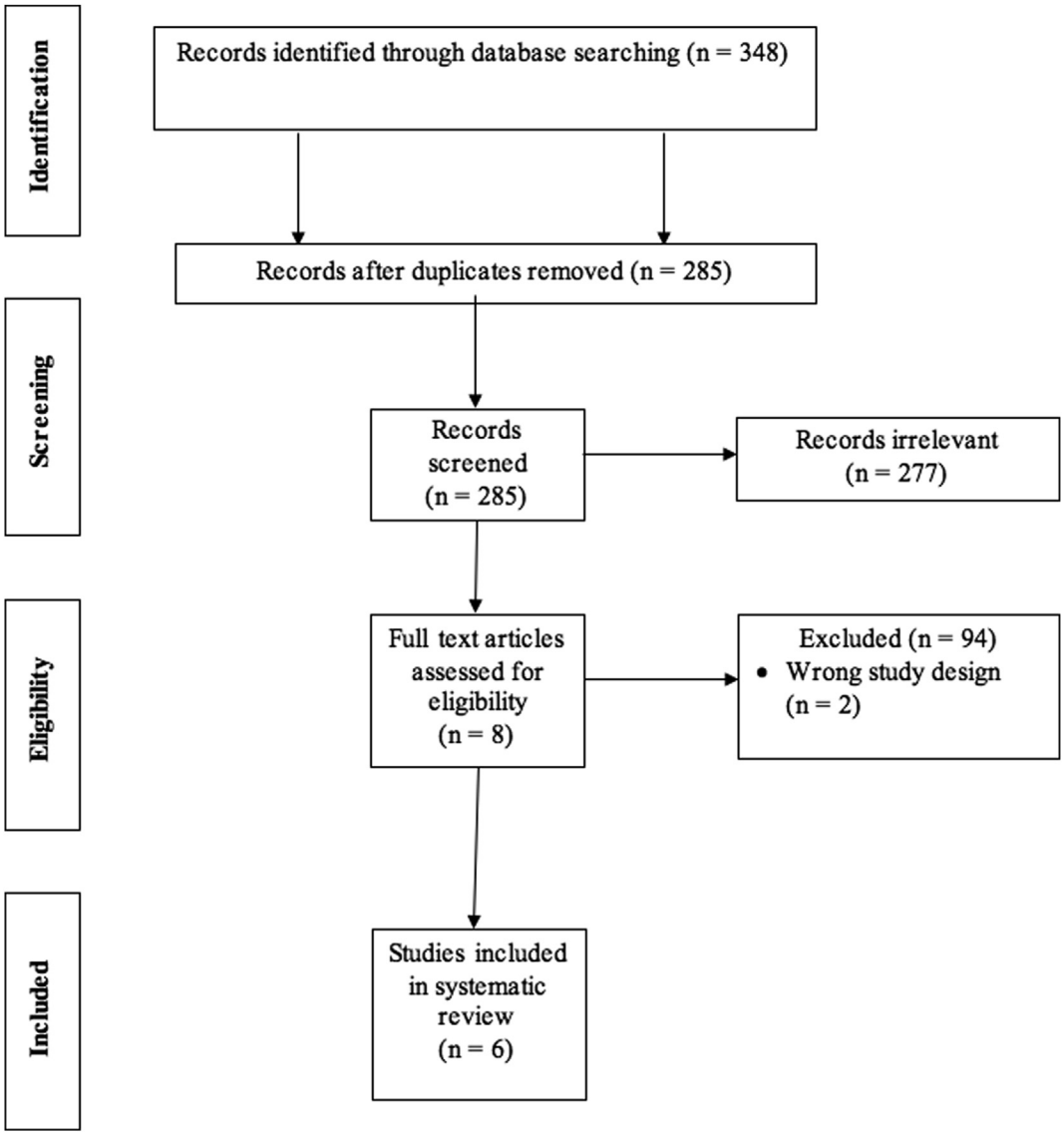

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) study selection flow diagram. The numbers of screened, excluded, and included studies are shown.

reconstruction with BPTB or QT autograft. They found no difference in performance outcomes between quadriceps or BPTB graft use through measurements such as the IKDC scale, Single Assessment Numeric Evaluation (SANE) scale, Tegner Activity Scale, Marx Scale, Knee Injury and Osteoarthritis Outcome Score (KOOS), and Patient-Reported Outcomes Measurement Information System (PROMIS) scale. Additionally, they found no statistically significant difference in the incidence of complications including arthrofibrosis, infection, pain causing removal of hardware, meniscal tear, cyclops lesion, and patellar fracture based on graft selection. The overall complication rates reported were 23.8% for BPTB autograft and 12.8% for QT autograft ($P = .2$).[12]

Walston and Barillas[13] conducted a retrospective observational study that examined the rehabilitation outcomes of 212 patients who underwent ACL reconstruction with either BPTB or QT autograft. They found no differences in flexion, extension, or pain improvement based on graft choice. However, there was a significant difference in knee Functional Status (FS) scores, with QT autograft patients experiencing an improvement in function of 48.293 points (out of a maximum of 100 points) compared with an improvement of 28.121 points for those with BPTB autograft ($P < .001$).[13]

A 2019 retrospective cohort study by Hughes et al.[14] compared the outcomes of quadriceps, hamstring, and BPTB autografts in 73 patients who underwent ACL reconstruction. This comparative study showed that patients who underwent ACL reconstruction with QT autograft had a significantly reduced Quadriceps Index

Table 1. Characteristics of Studies Included in Systematic Review

Authors	Year	Study Type	Patients, N	Autograft Types	Follow-Up Time	LOE	Outcome
Hogan et al.[12]	2022	Retrospective	119	BPTB and QT	12 mo	III	BPTB and QT are equivalent
Walston and Barillas[13]	2021	Retrospective	212	BPTB and QT	Discharge postoperatively	III	BPTB and QT are equivalent
Hughes et al.[14]	2019	Retrospective	73	Quadriceps, hamstring, and patellar tendon	9-15 mo	III	BPTB and QT are equivalent
Perez et al.[15]	2019	Retrospective	50	BPTB and QT	2 yr	III	BPTB and QT are equivalent
Han et al.[16]	2008	Retrospective	72	BPTB and QT	2 yr	III	BPTB and QT are equivalent
Gorschewsky et al.[17]	2007	Retrospective	260	BPTB and QT	2 yr	III	QT is superior

BPTB, bone−patellar tendon−bone; LOE, level of evidence; QT, quadriceps tendon.

postoperatively compared with those who had BPTB autograft (69.5 vs 82.8, $P = .01$); however, no significant difference existed in the quadriceps strength summary measurement ($P = .13$). Notably, the authors also found that at 5 to 8 months, fewer patients with quadriceps autograft met the return-to-play criteria. Patients with QT autograft also had clinically meaningful quadriceps asymmetry at both 5 to 8 months and 9 to 15 months postoperatively.[14]

Perez et al.[15] performed a retrospective cohort study to evaluate outcomes in 50 patients who underwent ACL reconstruction using either BPTB or QT autograft. They found no statistically significant differences in performance outcomes between the 2 grafts through measurements such as the IKDC scale, Tegner Activity Scale, Lysholm scale, and patient satisfaction survey. Additionally, there were no statistically significant differences in the incidence of complications including arthrofibrosis, contralateral ACL injury, graft failure, anterior knee pain, and graft rupture.[15]

In 2008, Han et al.[16] performed a retrospective comparative study that directly compared BPTB and QT autografts in 72 patients. This study used the KT-1000 knee arthrometer to measure postoperative side-to-side differences in anterior knee laxity, and the authors found no statistically significant differences between BPTB and QT autografts. Additionally, no differences between graft cohorts were found in IKDC activity and side-to-side peak torque through Cybex II isokinetic testing (Cybex International). The rate of revision ACL reconstruction was 2.8% in patients who had quadriceps autograft versus 1.4% in those with BPTB autograft. Notably, 39% of BPTB patients reported anterior knee pain compared with 8.3% of QT patients.[16]

Gorschewsky et al.[17] retrospectively compared outcomes in 260 patients who underwent ACL reconstruction with either BPTB or QT autograft. They found that the overall IKDC score was reported as normal significantly more often in patients who had BPTB autograft (66%) than those who had QT autograft (11%, $P < .001$). Additionally, the rate of donor-site morbidity, which was defined as pressure-pain, irritation, or paresthesia, was significantly higher in patients with QT autograft (85% vs 50%, $P < .001$). Furthermore, 97% of BPTB patients reported no crepitus compared with only 45% of QT patients ($P < .001$). Patients subjectively reported higher satisfaction with BPTB autograft compared with QT autograft (62% vs 44%, $P < .04$). However, this study showed that the Lysholm and Noyes scores had comparable results across the 2 groups. Patients who had BPTB autograft had higher satisfaction and better knee joint function based on IKDC scoring.[17]

Discussion

Our study found that there are no significant differences in postoperative function, stability, or

complication rates in patients who received BPTB autograft and those who received QT autograft. Previous studies have shown that outcomes after ACL reconstruction using QT autograft are comparable to those using hamstring or BPTB autograft; however, there is a paucity of primary research regarding the biology of the QT and its functional qualities as a graft.[1,2,4,18] This study showed that both patients undergoing ACL reconstruction with BPTB autograft and those undergoing ACL reconstruction with QT autograft reported increased postoperative knee stability and functional outcomes. Both groups also performed better on functional tests such as the Lysholm scale, IKDC scale, Tegner scale, and KT-1000 evaluation postoperatively. Our study found that there was no statistically significant difference in complications requiring reoperation between the 2 groups, and complication rates as well as reoperation rates were low with both graft types.

Of the 6 studies that directly compared QT and BPTB autografts, 5 found that QT autograft yielded similar PRO measures compared with BPTB autograft, except in measures of pain. Hogan et al.[12] concluded that both BPTB and QT autografts showed improvement in PROs but that no difference in functional outcomes or complication rates existed between the 2 graft types. Similarly, Walston and Barillas[13] found that although graft choice may affect physical therapy and associated financial costs, there was no significant difference in outcomes based on the use of either BPTB or QT autograft. These findings were corroborated by Hughes et al.,[14] whose study showed that patients may have decreased strength in the areas from which their graft was harvested but that there was no significant difference in return to sport based on graft choice. Additionally, Perez et al.[15] suggested that there were no statistically significant differences in outcomes between QT and BPTB autografts. The takeaway of the study by Han et al.[16] was that the outcomes of QT and BPTB autografts for ACL reconstruction are equivalent but anterior knee pain is less severe when QT autograft is used. Similarly, Gorschewsky et al.[17] recommended QT autograft, especially for active patients, because it is associated with less restricted range of motion of the anterior knee joint and reduced donor-site morbidity.

Gorschewsky et al.[17] found that 62% of patients reported satisfaction with BPTB autograft as opposed to 44% of patients with quadriceps autograft ($P = .04$). Patient satisfaction was also evaluated by Han et al.,[16] who observed that anterior knee pain was less common in the QT autograft group (5.5% vs 35% in BPTB group). Conversely, Walston and Barillas[13] found that there was no significant difference in pain after ACL reconstruction with either BPTB or QT autograft. Similarly, Hogan et al.[12] found no statistically significant difference between the 2 groups based on the Knee Injury and Osteoarthritis Outcome Score (KOOS) subscales for pain, activities of daily living, sport, symptoms, and quality of life. In addition, no significant difference in measures of stability was found in the included studies that examined KT-1000 scores, flexion and extension range of motion, and side-to-side stability between QT and BPTB autografts. This finding suggests that both QT and BPTB autografts can result in favorable postoperative stability.

Revision rates owing to graft failure were not statistically significant between patients undergoing ACL reconstruction with BPTB autograft and those undergoing ACL reconstruction with QT autograft. Notably, the studies that examined revision rates owing to graft failure had contrasting findings. It is important to note that the mean age of patients at the time of surgery in the study of Hogan et al.[12] was lower in both the BPTB and QT autograft groups (21.0 years and 18.7 years, respectively) as compared with the study by Han et al.[16] (27.8 years and 27.8 years, respectively). Hogan et al. showed that although 7.5% of patients with BPTB autograft underwent revision surgery as compared with 5.1% of patients with QT autograft, this difference in revision rates was not statistically significant ($P = .6$). The mechanisms of injury that led to graft failure and revision surgery were not discussed by Hogan et al. In this study, the mean time to revision for the BPTB and QT autograft groups was 25.2 months and 12.0 months, respectively.[12]

Conversely, Han et al.[16] found that graft failure occurred in 1 patient who underwent ACL reconstruction with BPTB autograft as compared with 2 patients with QT autograft, which was not deemed to be clinically significant. Additionally, Han et al. reported that the 1 patient with BPTB autograft who underwent revision surgery did so because of indirect trauma, and the 2 patients in the QT group underwent revision owing to traumatic rupture while playing sports and owing to graft failure without a distinct injury. The mean time to revision was 64 months for BPTB autograft and 37.5 months for QT autograft. The studies by Hogan et al.[12] and Han et al.[16] illustrate that overall there were no objective differences in revision rates between BPTB and QT autografts and that multiple variables can influence revision rates. Our systematic review compares postoperative function and stability in patients undergoing ACL reconstruction with either BPTB autograft or quadriceps autograft. Both BPTB and QT autografts improve postoperative stability and function compared with the preoperative state. QT autograft is associated with a reduced postoperative Quadriceps Index compared with BPTB autograft, whereas BPTB autograft is associated with more anterior knee pain than QT autograft. Orthopaedic surgeons can use this information to educate patients when selecting a graft for ACL reconstruction.

Limitations

This study is not without limitations. First, the retrospective study design of the 6 included studies does not allow for as high quality of data as a study including only randomized controlled trials with a higher level of evidence. Second, it is possible for relevant studies to have been omitted owing to the search terms used. Furthermore, only studies written in English were included in our literature search, which could have led to pertinent studies being excluded. Finally, data were not available to stratify our results with factors such as recurrent ACL injuries; therefore, we were unable to account for differences in outcomes in patients with first-time ACL tears versus patients with recurrent ACL tears.

Conclusions

Patients undergoing ACL reconstruction with either BPTB or QT autograft reported improved postoperative knee stability and functional outcomes. There is no significant difference in complications between quadriceps autograft use and BPTB autograft use.

Disclosures

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: M.K.M. reports board membership with American Academy of Orthopaedic Surgeons, *American Journal of Sports Medicine* Electronic Media, American Orthopaedic Association, American Orthopaedic Society for Sports Medicine, *Arthroscopy*, Arthroscopy Association of North America, Association of Bone and Joint Surgeons, International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine, Ortho Info, and Ruth Jackson Orthopaedic Society; has a consulting or advisory relationship with Arthrex; and receives speaking and lecture fees from Arthrex. All other authors (U.D. S.A.O. V.K.I. A.P-C.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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