State of the Art Review

Quadriceps tendon autograft for anterior cruciate ligament reconstruction: state of the art

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ABSTRACT

The ideal graft for anterior cruciate ligament reconstruction (ACLR) continues to be debated. Although first described in 1984, use of the quadriceps tendon (QT) autograft has only recently gained popularity. The biomechanical properties of the QT autograft are favourable compared to bone-patellar tendon-bone (BPTB) and doubled hamstring (HS) grafts with a higher load to failure and a modulus of elasticity that more closely approximates the native anterior cruciate ligament (ACL). The QT graft can be harvested with or without a bone plug, as either a full thickness or a partial thickness graft, and even through minimally invasive techniques. The surgeon must be aware of potential harvest risks including patellar fracture or a graft that is of insufficient length. Numerous short-term studies have shown comparable results when compared to BPTB or hamstring HS autografts with similar graft failure rates, patient-reported outcomes. A major advantage of QT ACLR is reduced donor site morbidity compared to BPTB. However, some persistent quadriceps weakness after QT ACLR has also been reported. The current literature shows that use of the QT autograft for ACLR provides equivalent clinical results compared to other autografts with less donor site morbidity. However, future studies with longer follow-up and higher level of evidence are needed to identify specific populations where the QT may have additional advantage.

Introduction

Since Hey Groves first described anterior cruciate ligament reconstruction (ACLR) in 1917 using a strip of fascia lata, the choice of graft selection has evolved over time [1]. Bone-patellar tendon-bone (BPTB) and hamstring (HT) autografts have been the mainstay of treatment for years. However, surgeon and patient dissatisfaction with harvest site morbidity has led to the search for alternative grafts. While the use of quadriceps tendon (QT) autograft has gained popularity in recent years, only a minority of surgeons currently use QT as their primary graft choice [2]. This state-of-the-art review will discuss the history, rationale, techniques, and outcomes of QT autografts for ACLR.

History

The use of QT autograft for ACLR was first described by Marshall et al. in 1979. He utilized an all soft-tissue graft beginning 5–6 cm proximal to the patella extending into the patellar tendon with incorporation of the prepatellar retinacular tissue. In 1984, Blauth described harvesting the QT with a proximal patella bone block [3,4]. Staubli in 1992 refined Blauth’s technique with anatomical studies [5]. In 1995, Fulkerson stated the “central QT graft is difficult to harvest” and described his technique for harvest of a QT-bone graft [6]. In 2003, he reported a case series of 29 ACLR (two revision) using QT autograft without a bone plug [7]. In 2007, he stated that QT autograft with or without bone offered a “reliable, pain-free, low-morbidity alternative to ACL reconstruction” [8]. Over the next decade (2000–2010), mixed clinical outcomes from various studies

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without large prospective or randomized controlled studies were available. While there were some reports of 93% success, other studies showed a 20% incidence of postoperative pivot shift, and there were reports of prolonged weakness of knee extension, especially in women [9]. These mixed results caused the QT autograft to be largely forgotten. However, as surgeons became more concerned with harvest site morbidity and as more encouraging biomechanical data appeared, there has been a resurgence in interest in QT autograft for ACLR. The last decade had seen a number of studies published with larger sample sizes and improved levels of evidence [10]. A survey of the ACL Study Group found increased usage of autograft QT since 2014, with it now making up about 10% of grafts used in ACLR from the most recent surveys [2].

In short, the QT autograft is not a new graft. For almost 40 years, it has been a valuable addition in revision ACLR and has been used by some surgeons as a reliable graft source for primary ACLR. The QT autograft has been proposed to be a suitable alternative to BPTB and hamstring autograft with the proposed advantages of a robust graft harvested either full or partial thickness, with or without a bone block, less anterior knee pain, decreased ham-tunnel weakness, improved cosmesis, and avoiding problems with graft-tunnel mismatch as sometimes occurs with BPTB grafts [9,10]. The increasing popularity of the QT autograft will continue to foster research in the controversial area of graft selection in ACLR.

Anatomy

The QT anatomy is complex and anatomical differences exist. Most individuals have a trilaminar structure formed by the coalescence of four main tendon groups [11–13]. The most superficial layer is from the rectus femoris, while the middle layers are comprised of the vastus lateralis and the vastus medialis, and the deepest layer is from the vastus intermedius. However, there is tremendous anatomic variation as to how and where these structures come together to form the combined QT with some having bilaminar and quadrilaminar patterns in addition to the common trilaminar structure [14]. Most anatomic studies suggest that the proximal multilaminar tendon coalesces to form a cohesive structure 2–3 cm from the superior edge of the patella providing a consistent distal half of the QT graft [15–18]. Currently, there is no evidence that the variable proximal anatomical differences affect surgical outcome.

The QT has an average length of 6–8 cm and ranges in width from 2.5 to 3 cm [19]. A concern some surgeons express is the variable length of the QT. The length and size of the QT graft can be effectively assessed preoperatively utilizing anatomic consistencies. In a three-dimensional MRI study, Xerogeanes et al. found that standing height was the best predictor of available QT graft length. In patients over 1.5 m (5 feet), greater than 90% of the people in the study had a graft length of 7 cm or greater. This length was determined using the superior pole of the patella to the distal tip of the rectus femoris muscle. Since the optimal graft length is 6.5–7 cm, there is plenty of pure tendon available. In clinical practice, most preoperative MRIs only study 3–4 cm proximal to the patella. In such instances, ultrasound evaluation has been shown to accurately identify the available tendon length and thickness [17,20,21]. The QT runs 2–4 cm proximal to the distal tip of the rectus femoris muscle, so if additional length is needed, the harvest can be extended without significant loss of graft integrity [18]. However, harvesting into the muscle increases the risk of haematoma formation [22,23].

QT thickness has been shown to be very consistent over the distal 6 cm of tendon on mid sagittal MRI evaluation [18]. Recent studies utilizing cadaver and ultrasound evaluation further corroborated this data but showed that MRI may actually underestimate the thickness of the tendon [24]. These studies also showed that while the QT decreased in thickness in the proximal and lateral portions of the tendon, it was most consistent in the central–medial part of the tendon [13,25,26]. Therefore, it is recommended to harvest the QT graft in the central part of the tendon with the medial edge located 2–3 mm from the VMO muscle. QT thickness can also be assessed on mid-sagittal T2 MRI. The thickness measurements should be made perpendicular to the tendon fibers 2–3 cm above the superior patella. If a volume measurement is desired, then the corresponding axial cut is best utilized. The average thickness of the QT had been found to be almost double the size of the BPTB (8.4 ± 1.5 vs. 4.3 ± 0.8 mm) [27].

The ultrastructure of the QT has been more thoroughly defined. Hadjicostas evaluate the histology of the QT and found 20% more collagen and 30% more fibroblasts per mm² than with the matched patella tendon [28]. These are factors that may account for the superior structural properties of the QT versus the PT graft.

Biomechanics

Multiple variables are to consider in the biomechanics of the QT autograft including full or partial thickness, bone block or all soft tissue, and fixation methods used.

Full-thickness QT graft has undergone detailed biomechanical evaluation, and both the structural and material properties of the tendon have been characterized. The ultimate load to failure of a 10 mm wide QT graft is significantly greater (1.8×) than a similar width patellar tendon (PT) graft and also significantly higher than the native ACL [29,30]. Similar results have been reported by other authors [31,32]. However, most studies did not evaluate the material or mechanical properties of the graft types. Shani et al. evaluated the elastic modulus of the QT graft and found it to be very similar to the native ACL, whereas the elastic modulus of the PT graft was significantly higher [29,30]. Urchek et al. compared a 10 mm QT graft to a six-strand hamstring (HS) graft and found a similar ultimate load to failure, but again, found the HS graft to have a significantly higher elastic modulus than the QT graft or the native ACL [33]. It has been hypothesized that it is advantageous for the elastic modulus (or how the tissue responds to an applied force, independent of morphology) of a potential ACL graft to be similar to the modulus of the native ACL [30].

QT autograft can be harvested full-thickness (FT-Q) or partial thickness (PT-Q). Systematic reviews have shown no difference in clinical outcomes or complications [5,34]. When comparing full thickness to split thickness QT autograft, biomechanical data are limited. Split thickness biomechanical studies involve graft preparation for double bundle ACLR with the tendon split into a “Y-shape.” Miller et al. tested a single strand of either a sagittal or coronal split thickness QT from a full-thickness QT to determine differences in ultimate load, stiffness, and creep. They found no difference between halves with split tendons or among splitting planes after biomechanical testing. Ultimate load to failure of either limb was (445 ± 210 N) [35]. Despite systematic reviews showing no difference in clinical outcomes or complications, further biomechanical studies are needed to compare full and split thickness QT.

Surgeons have the option to harvest the QT with a bone plug (QT-bone) or QT-all soft tissue. Clinically, no significant differences have been seen between QT-bone and QT-all soft tissue graft in either the primary or revision settings [15,36]. When comparing the biomechanics of QT-bone and QT-all soft tissue, the type of fixation used is paramount for comparison. Arakgi et al. compared three types of suspensory fixation with QT-all soft tissue against QT-bone with cyclic loading and amount of displacement. No difference was seen in displacement among the types of fixation between QT-bone and QT-all soft tissue, but there was significant greater displacement than for QT-bone [37]. How this is clinically significant is unknown and requires more biomechanical studies looking at the differences in fixation choice and QT-bone versus QT-all soft tissue autografts.

The structural properties of the remaining QT complex have also been reported. Adams et al. showed that after the harvest of a 10 mm thick QT graft, the remaining QT has a significantly greater ultimate load to failure (2430 ± 680 N) compared to the intact patellar tendon (1920 ± 330 N) [38]. Although reports of QT or PT rupture following harvest are extremely rare, the increased strength of the remaining QT may play a role in improving extensor mechanism strength recovery after ACLR.
Surgical technique

Graft harvest

The QT can be harvested with a variety of techniques. These include traditional open or minimally invasive techniques. Also, the QT can be harvested with or without a bone plug and can be a full thickness or partial thickness graft. Graft harvest is done after exsanguination and inflation of the tourniquet. The patient is supine with the knee flexed to around 80–90°, supported by a foot stop and a lateral thigh support. Arthroscopy of the knee is performed prior to graft harvest. This has the advantage of leaving some fluid in the knee which aids in detecting breaches of the deep layer of the tendon.

Traditionally, a 4–6 cm longitudinal incision starting at the superior pole of the patella is made (Fig. 1). Soft tissue is cleared from the QT using a periosteal elevator. It is also helpful to be able to see the distal muscle fibers of rectus femoris proximally so that these are not inadvertently cut. There is usually a small artery entering the tendon medially and this can be cauterized. After exposing the QT, the vastus medialis oblique (VMO) is identified with the graft being taken 2–3 mm lateral to

Fig. 1. Left knee with 5–6 cm longitudinal incision centred over the proximal patella exposing the quadriceps tendon.

Fig. 2. 1 cm full thickness QT graft is measured and incised. Notice the electrocautery was used to score the tendon in the image on the right which helps provide a cutting guide for the saw.

Fig. 3. Minimally invasive harvesting technique with a transverse skin incision approximately 2–3 cm long, over the superior border of the patella.
its border. A 10–12 mm wide graft is measured, and parallel longitudinal incisions are made (Fig. 2).

A more cosmetically acceptable, minimally invasive technique can also be utilized [39]. A transverse skin incision approximately 2–3 cm long is made over the superior border of the patella (Fig. 3). The bursal layer is then dissected to expose the QT, and a long Langenbeck retractor is introduced. Next a tendon knife (Karl Storz) (Fig. 4) with two parallel blades (9, 10, or 12 mm apart) is used to define the width of the graft. The blades are advanced to the 6-cm mark (measured from the superior patellar border) (Fig. 5). The thickness of the graft is then defined with a tendon separator (Karl Storz) (Fig. 4), which is set to a depth of 5 mm and is also advanced to the 6-cm mark. Finally, the graft is freed proximally using the QT cutter (Karl Storz) (Fig. 4), a punch-action instrument that is introduced 1–2 cm proximal to the superior–patellar border. It is advanced to the desired length (minimum 6 cm) and activated to cut the proximal end of the graft (Fig. 6). Distally, an all soft-tissue graft or QT-B graft can be performed through this small incision. Alternative instrumentation for minimal invasive graft harvest is also available from Medacta and Arthrex.

The surgeon can elect to harvest a full thickness or partial thickness graft. Harvesting a full thickness graft is technically easier and yields a thicker tendon, but it may allow fluid extravasation with arthroscopy, even after donor site closure. When a partial thickness graft is preferred, it is important to remember that there is a consistent fatty layer between the rectus femoris and vastus intermedius tendon components and to progress deep to this layer to maximize graft thickness (Fig. 7) (Be aware the tendon is thinner laterally than medially). A separator device (Karl Storz) (Fig. 4) is then used to create a coronal plane incision that joins the

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**Fig. 4.** Tendon knife, tendon separator, tendon cutter (Karl Storz).

**Fig. 5.** Tendon knife with two parallel blades (9, 10, or 12 mm apart) is used to define the width of the graft. The blades are advanced to the 6-cm mark (measured from the superior patellar border).

**Fig. 6.** Quadriceps tendon cutter, a punch-action instrument that is introduced 1–2 cm proximal to the superior–patellar border. It is advanced to the desired length (minimum 6 cm) and activated to cut the proximal end of the graft.

**Fig. 7.** Partial thickness graft harvesting showing the fatty layer between the rectus femoris and vastus intermedius tendon components. It is important to progress deep to this layer to maximize graft thickness.
two parallel sagittal incisions in the tendon. This can be enhanced by sliding the tips of a Metzenbaum scissor both proximally and distally in the same plane. A cutting device (Karl Storz) (Fig. 4) can then be used to cut the proximal end of the graft 6.5–7.0 cm from the proximal pole of the patella. If the surgeon is electing not to use a bone plug, the distal graft is then sharply elevated from the deep layer of the tendon from proximal to distal. As an alternative to a bone plug, a periosteal strip equal to the graft width and 1.5–2 cm thick can be dissected from the anterior-patellar surface. The strip is then folded over and whipstitched with two nonabsorbable No. 2 sutures. This yields a rounded end that will facilitate later graft passage.

Harvesting a bone plug with the QT allows for interference screw fixation in the femoral tunnel and is helpful when the QT is short and in revision ACL cases. If the surgeon elects to use a QT-B graft, a 1.5–2 cm long proximal patella bone block is outlined with a width conforming to graft geometry. A narrow sagittal saw (0.5–0.7 cm) and an osteotome are used to harvest a bone plug to form a trapezoidal shaped bone plug. To avoid patellar fractures, it is advisable to finish by sawing parallel to the anterior patellar surface in a proximal-to-distal direction with the narrow saw blade (Fig. 8). At that point, the bone plug is easily mobilized with a chisel. Making the bone cut in full knee extension allows a smaller skin incision to be utilized. The graft is then incised to the end of the tendon proximally and sharply transected. The total length of the QT-B graft is approximately 85 mm.

**Graft preparation**

When utilizing a QT-B graft, the bone plug is fashioned to the appropriate size and made into a rectangular graft or be crimped to size to form a “bullet-like shape” (Fig. 9) Rounding the proximal corners of the bone plug will facilitate later graft passage into the femoral tunnel. Two 1.5-mm holes are drilled through the bone plug. These drill holes can be made parallel or perpendicular to each other depending on author preference. Heavy nonabsorbable sutures are passed through the drill holes; these can be attached to a cortical suspensory fixation device.

The graft is cleaned by removing any remaining muscle tissue and sized for appropriate tibial and femoral tunnel drilling. The soft tissue part of the graft (or both ends if using a QT graft) is then sutured using two #2 high-strength synthetic sutures in a whip stitch configuration. These sutures can be attached to a cortical button or used to tension the graft if interference screw fixation is chosen. The proximal end of the graft is marked 2 cm from the tip or at the bone tendon interface to later help with identification of when the graft is adequately seated in the femoral tunnel (Fig. 10). Once graft preparation is completed, we prefer to place our graft in a vancomycin impregnated sponge until ready for passage.

**Donor site closure**

The donor defect in the tendon is closed superficially with 0 or 2–0 absorbable sutures, but definitive wound closure is delayed until after graft passage. A Scorpion Suture passing device (Arthrex Naples, FL) can facilitate complete closure of the defect proximally (Fig. 11). A dry scope of the incision can be done at the conclusion of closing the QT defect to ensure water tight closure (Figs. 12 and 13). Packing the donor
A site with a subcutaneous gauze sponge can provide good haemostasis and reduce any extravasation that may occur (from opening the suprapatellar pouch). If a QT-B graft has been procured, the most distal aspect of the incision is left open for bone grafting at the conclusion of the case. Autograft can be collected from drilling of the femoral and tibial tunnels, or crushed cancellous allograft can be used to bone graft the patella defect and then the incision is closed in a standard layered closure.

**Tunnel drilling, graft passage, and fixation**

Tunnel preparation and drilling is similar to any ACL reconstruction. The femoral tunnel can be drilled in an antegrade or retrograde fashion to a depth of 20–25 mm. Passing sutures attached to the graft or fixation device are used to shuttle the graft into position. At least 20 mm of the QT graft or the entire bone plug of a QT-B graft should be placed into the femoral tunnel. Femoral fixation is commonly done with a cortical...
suspensory button but a $7 \times 20$ interference screw can also be used for QT-B grafts.

Current literature on fixation methods shows no difference in failure between suspensory versus interference fixation among QT ACLR [40]. Three different methods of suspensory QT-all soft tissue fixation have been compared: (1) Cortical button alone; (2) Cortical button with rip-stop suture; and (3) Continuous loop cortical button. There was no significant difference in displacement after cyclic loading between these different methods [37]. When looking at interference screws, no differences have been observed with displacement or load to failure between different types of screws [41]. However, the biomechanics and clinical outcomes of different fixation methods are an area that needs further study. With the knee near full extension, the graft is tensioned and fixed on the tibial side using a soft tissue interference screw or cortical button. Back-up fixation can also be performed by passing the graft sutures into a 4.75 mm knotless suture anchor placed just distal to the tibial tunnel.

Rehabilitation

Early postoperative rehabilitation should focus on decreasing postoperative pain and swelling. Zhang et al. recently performed a systematic review of postoperative rehabilitation for QT ACLR. Their study included 31 studies using QT-bone and 26 studies using QT-soft tissue. Most studies permitted full weight-bearing and ROM within the first 12 postoperative weeks. Isometric exercises were typically initiated with 1 week after surgery and closed-chain exercises within 12 weeks. Progression to open-chain and sports-specific exercises occurred within 36 weeks. Postoperative complications such as graft failure, cyclops syndrome and arthrofibrosis were similar regardless of graft type. The recommended that protocols after QT ACLR should emphasize early range of motion with an emphasis on full extension, early weight bearing, and early isometric quadriceps exercises. Progression to closed and open-chain exercises and to sports specific training should follow a gradual progression similar to other ACL graft protocols [42]. Good quadriceps strength should be achieved before initiating running, agility drills and sport-specific training.

Outcomes

Randomized controlled studies and meta-analyses have compared QT autograft to bone patellar bone and hamstring autografts, looking at differences of graft rupture rates, patient reported outcomes, return to sport, and morbidity of various ACL grafts [43–45]. Although, several randomized controlled trial (RCTs) exist comparing QT to BPTB or HT, it should be noted that these studies are limited by small sample sizes (≤50/group). To date, most studies are observational, have relatively short-term follow-up, and are level III-IV evidence.

Graft rupture rates

Runer et al. in their study of 875 patients showed significant higher rates of ipsilateral graft ruptures versus contralateral ACL injuries in HT group compared to the QT group (odds ratio 2.1; $P < 0.01$). This was even more pronounced in highly active patients treated with HT versus QT autograft (odds ratio 2.6; $P = 0.01$) [46]. Conversely, Lind et al. showed a higher revision rate in the Danish Knee Ligament Registry for QT autograft (4.7%) versus BPTB (1.5%) and HT (2.3%) at 2-year follow-up ($P < 0.002$) [43]. In a follow-up study, they showed the higher rate of QT graft failure was limited to lower volume centres (<100 QT over an 8-year period) [44]. This demonstrates that there is probably a learning curve associated with transition to QT autograft for ACL reconstruction.

A systematic review and meta-analysis of QT autograft including 21 studies showed a graft failure rate of 2.1% (95% CI, 1.4%–2.8%) [45]. When looking at comparative studies between QT and BPTB, they found no significant difference in anterior translation or the presence of a pivot shift. Comparative studies between QT and HT, again no significant difference in laxity. Crum et al. performed a systematic review comparing all soft tissue QT to bone QT and found no differences in graft rupture rates between the different graft preparations, but they did note higher risk of a positive pivot shift in the B-QT group [47]. Most recently, Dai et al. reported a systematic review and meta-analysis that showed no difference in graft failure between QT and BTB among 10 studies (two RCTs and eight observational studies). Additionally, nine studies (1 RCT and eight observational studies) showed no significant difference in graft failure between HT and QT rupture risk [48]. Although most of the studies on QT versus BTB are Level III and IV and have only mid-term follow-up periods, the evidence available shows no significant difference in graft rupture rate between QT, HT, and BPTB autografts.

Patient-reported outcomes

In their series, Runer et al. showed no difference in Lysholm, Tegner activity scores and visual analogue scale between QT and HT autografts at 2-year follow-up [46,49]. Lind et al. had no significant difference in IKDC or KOOS scores between QT and HT in their randomized controlled trial [50]. Both meta-analyses found no difference between QT and HT in IKDC scores [46,49,50]. In a RCT with 10-year follow-up, Barie et al. found no difference in IKDC, Lysholm, or Tegner activity scores between QT and BPTB grafts [51]. The meta-analyses showed no difference in IKDC and Lysholm scores between QT and BPTB grafts [45,48]. The available evidence shows equal patient-reported outcomes when comparing QT to BPTB and HT autografts.

Return to sport

When comparing HT and BPTB autografts, 70.6% versus 81% were able to return to sport. Looking at return to preinjury level of performance BPTB is 50.0% compared to 48.5% with HT autografts [52]. Currently, we are not aware of any literature that exists comparing return to sport rates for QT compared to BPTB or HT. Barie et al. did report similar Tegner activity scores in their RCT between QT and BPTB, but they did not report return to play rates [51]. Similarly, Lind et al. reported similar KOOS sports scores between QT and HT autografts, but they also did not report return to play rates [50]. Panos et al. compared HT and QT graft signal intensity on MRI showing decreased signal intensity of the QT graft between 3 and 9 months, compared to no change of the HT autograft. This sign of earlier graft maturity seen with QT can potentially be used to aid in return to sport time [53]. Among adolescent patients with QT ACLR at 36 months 87.9% return to sport [54]. Further randomized controlled studies and multicentred studies with higher level of evidence are needed to help better understand the effect of QT graft choice on return to sport.

Morbidity

A major advantage of QT autograft is a decrease in donor site morbidity. QT autograft harvesting is associated with decreased donor site morbidity (i.e., anterior knee or kneeling pain) compared to BPTB. Barie et al. compared QT to BPTB autograft and showed decreased kneeling pain and squattting pain in the QT group up to 10 years post-operative [51]. The meta-analysis by Mourabes et al. showed a significant difference in donor site pain in favour of QT autograft (risk ratio for QT versus BPTB group, 0.25; $p < 0.000001$) [46]. Lind et al. showed a 50% lower incidence of graft site morbidity in QT patients compared to HT [50]. The meta-analyses by Dai et al. showed the QT autograft was associated with a significant reduction in the donor site morbidity rate compared with HT (risk ratio 0.60; $P = 0.02$) [48]. QT also appears to have a decreased risk of infection, injury to the infrasaphenous branch and quadriceps strength deficits [55]. Overall, QT is associated with decreased acute and chronic morbidity than HT and BPTB [56].
Complications

Despite the comparable outcomes of QT ACLR, complications do occur and have been reported in various studies over the years. Many are minor complications and fortunately, most major complications occur only in a small percentage of patients. These include the typical risks associated with ACLR of any graft type including venous thromboembolism, infection, and graft failure [9,10,15,22]. Lind et al. found a much higher revision rate following QT ACLR in the Danish Knee Ligament Registry compared to BTF or HS ACLR [43]. However, on subsequent analysis, they discovered that the increased revision rate only occurred in centres that perform fewer than 100 surgeries over an 8-year period [44]. This emphasizes that there is a learning curve associated with QT-ACLR and as with many surgical procedures, more repetition leads to better outcomes.

However, the surgeon should be aware of the unique complications that can occur with QT ACLR. Patella fractures have been reported to occur with a higher frequency in QT-B ACLR compared to BTF ACLR. Lee et al. followed 139 QT ACLR patients for 7 years and found an overall 4% risk of patella fracture [57]. Fu et al. found a 3.5% intraoperative and 8.8% 2-year postoperative patella fracture risk in 57 patients [58]. Special attention to harvest technique of the proximal patella bone plug can reduce the risk of fracture. Such techniques include harvesting from the central region of the superior pole of the patella, bone grafting the defect, and harvesting a bone plug less than 50% of the patella depth [58]. Complications with knee extension have also been examined showing weakened knee extension torque for at least 24 months (similar to that of BPTB) [59,60]. Lee et al. showed persistent quadriceps weakness compared to the contralateral knee up to 7 years following QT ACLR [57]. No difference in strength differences have been seen between QT and QT-B grafts or between full thickness and partial thickness grafts [15,61]. It appears that the effects do not significantly affect performance or return to play times, but the potential for quadriceps weakness should be discussed with patients.

Various other complications unique to QT autograft have been reported in the literature. One study found decreased proprioception at 15 degrees of flexion with QT ACLR compared to HS or allograft ACLR [61]. Arthrofibrosis in paediatric ACLR has also been found to be more common with a QT graft than HS (odds ratio 2.6) but lower than BPTB [62]. We could only find a single case report of a donor site QT rupture which occurred 10 years after a QT-ACLR [63].

Future perspectives

With new knowledge about the biomechanics of QT graft and with multiple short-term studies showing good outcomes and low morbidity with QT ACLR, the popularity of QT ACLR has increased. However, additional investigation still needs to be done on both the basic science of QT graft and the clinical results of QT ACLR. We still need a better understanding of the biomechanical differences in QT-bone versus QT-all soft tissue and full and split thickness QT grafts. Additionally, the optimal method of fixation for QT grafts has not been determined.

Clinically, studies comparing different QT graft preparations and fixation are needed. Larger comparative studies are also needed to see whether there are specific populations where QT autograft has an advantage over other autografts. For example, QT may be useful in smaller females where HS autografts are often <8 mm. QT may also have a significant advantage over BPTB in athletes whose sports require kneeling. More information is needed on the effect of QT harvest on extensor mechanism strength and whether the reported strength deficits result in functional deficits. Finally, the current literature lacks long term follow up studies and higher level of evidence studies are also needed.

Conclusion

Currently, only a small percentage of surgeons use QT for ACLR. However, the QT has been shown to have excellent biomechanical properties that are equal or possibly better than other autografts. The QT can be harvested as a full thickness or partial thickness graft and with or without a bone plug. These differences in harvest technique don’t appear to greatly affect the outcomes. QT harvest can also be done with a minimally invasive technique. Short-term studies suggest that the QT autograft has equal failure rates and patient reported outcomes when compared to BPTB or HT with less donor site morbidity.

Larger comparative studies are needed to see whether there are specific populations where QT autograft has a clear advantage over other autografts. QT may also have a significant advantage over BPTB in athletes whose sports are require kneeling. More information is needed on the biomechanics of different QT graft preparations and on the clinical outcomes between graft preparations. Additionally, how QT compares to other ACLR grafts will only be answered as more studies with longer time

Box 1

Key articles on quadriceps tendon autograft for anterior cruciate ligament reconstruction


Major pitfalls of quadriceps tendon autograft ACL reconstruction

- Can be split or full thickness
- Can have a bone block or soft tissue only
- MRI may actually underestimate the thickness of the tendon
- QT decreased in thickness in the proximal and lateral portions of the tendon, it is most consistent in the central-medial part of the tendon.
- Less anterior knee pain compared to BPTB

Tips and tricks for quadriceps tendon autograft ACL reconstruction

- For thickest graft, harvest the QT graft in the central part of the tendon with the medial edge located 2-3 mm from the VMO musculature
- Harvesting the medial aspect of the QT also decreased the risk of patella fracture.
- Rehabilitation emphasis is on restoring full motion and decreasing swelling. Early weight-bearing and isometric quadriceps exercises should be encouraged.

Major pitfalls of quadriceps tendon autograft ACL reconstruction

- Potential high learning curve, leading to higher revision rates in low volume centres/surgeons
- Persistent quadriceps weakness has been shown in some studies.
- Not taking the central region of the superior pole of the patella, not grafting the defect or harvesting a bone plug >50% depth can lead to a patella fracture.

Future directions

- Understanding biomechanical difference of full thickness versus partial thickness QT graft
- Biomechanical studies to determine optimal fixation methods
- Long-term data for QT ACLR outcomes
- Identifying specific populations where QT may have additional benefit.
- Need for higher-level studies comparing different QT graft preparations/fixation and QT versus other grafts.

References


