Technical Considerations for Quadriceps Tendon Harvest

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12.1 Background

Graft options for anterior cruciate ligament reconstruction (ACL) is one of the most commonly studied topics in orthopedic sports medicine, yet controversy remains with regard to which graft is best. Cost, cosmesis, ease of harvest, infection, donor site morbidity, clinical outcomes, rerupture rates, fixation, and surgeon familiarity all factor into a surgeon's decision when choosing a graft. Bone-tendon-bone (BTB) grafts are considered to be the "gold standard" to which other autografts are compared. Proponents of BTB grafts cite bone-to-bone healing, rigid fixation, lower rerupture rates, and intact hamstrings which act as a secondary stabilizer to anterior tibial translation. Proponents of hamstring autografts cite lower donor site morbidity, an intact extensor mechanism, lower rates of late osteoarthrosis, and avoidance of graft-tunnel mismatch [12]. Autologous quadriceps tendon (QT) graft for ACL reconstruction was originally described in 1979 by Marshall et al. [9]. Despite decades of success with this graft, QT remains infrequently used compared to alternative autografts [17], although interest in this graft seems to be increasing [10, 17, 18]. Nevertheless, QT is an incredibly versatile graft option which can be used in the primary or revision setting for single-bundle or double-bundle reconstructions, via a transtibial, anatomic, or all-inside techniques. The QT is unique in the sense that it allows the surgeon to harvest only "what is needed" and leave the remaining anatomy intact. Additionally, the tendon can be harvested with or without a patellar bone plug making it an excellent choice for epiphyseal sparing techniques in skeletally immature patients. Histologic and biomechanical properties of QT make it a favorable choice for ACL reconstruction [1, 6, 7, 11, 13]. Clinical outcome studies demonstrate similar outcomes to alternative autografts, with low donor site morbidity [4, 5, 8, 13]. Graft size can easily be

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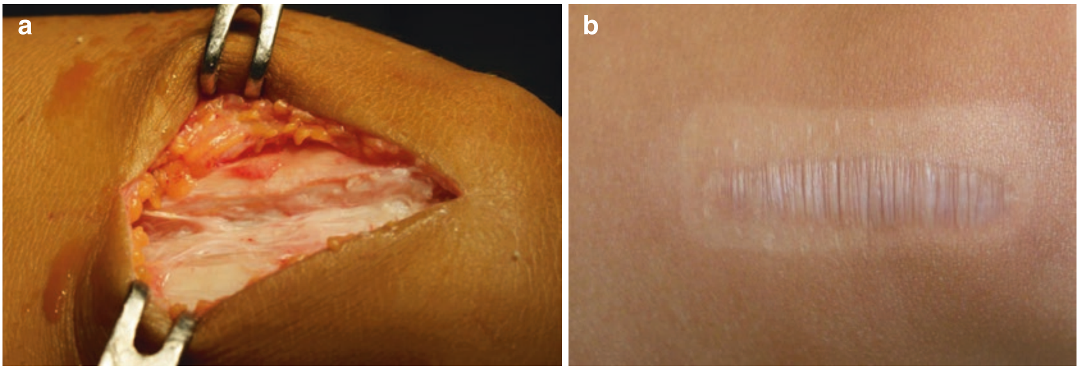

Fig. 12.1 (**a**) Incision and (**b**) scar following conventional quadriceps tendon harvest

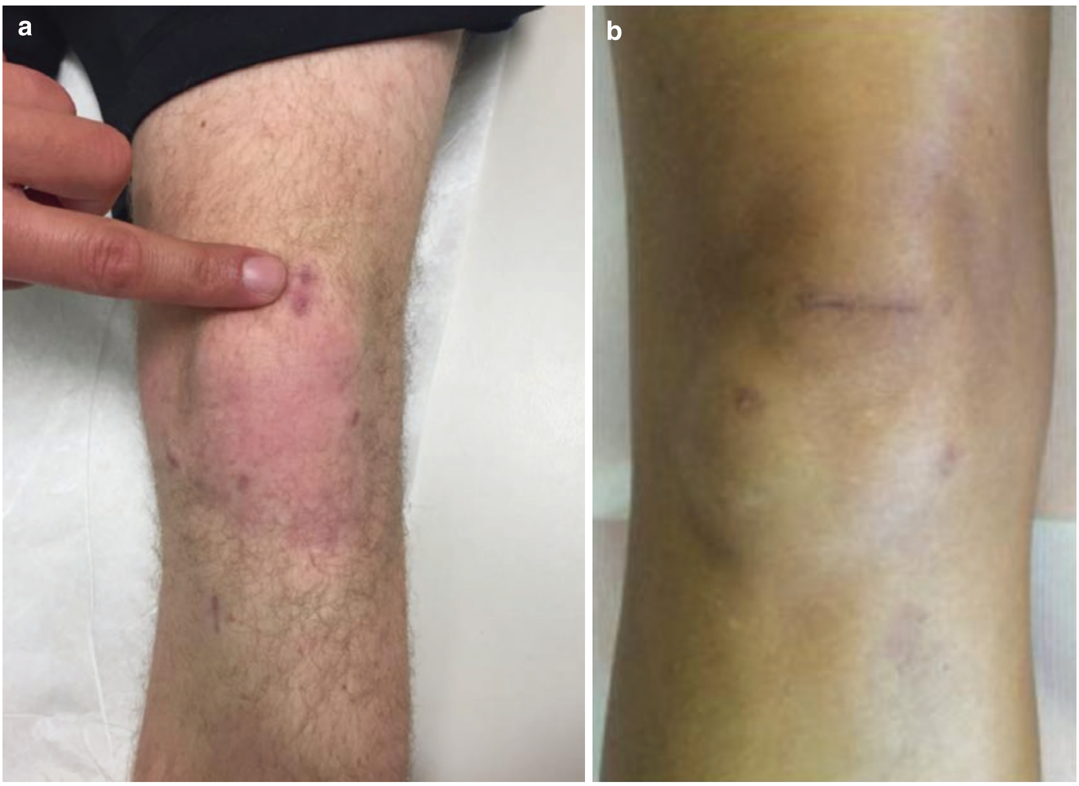

Fig. 12.2 Cosmetic appearance following minimally invasive quadriceps tendon harvest via (**a**) longitudinal or (**b**) horizontal incision

predicted from preoperative imaging studies [16, 20]. We think that the widespread use of QT has been limited by the historically cumbersome harvesting and less attractive cosmetic results compared to other autografts (Fig. 12.1).

The minimally invasive harvest techniques described in this chapter, in conjunction with recent development of specialized instrumentation, allow for a reproducible, safe, and easy graft harvest with improved cosmetic appearance (Fig. 12.2).

12.2 Indications and Contraindications

The QT is an appropriate choice for most patients undergoing ACL reconstruction. We have used QT as a primary graft option for several years in patients of all ages and activity levels, including elite athletes. Patients who perform a significant amount of kneeling for sport or employment and those with coexisting medial collateral ligament injury are excellent candidates for QT ACL reconstruction as the anterior knee pain associated with BTB harvest can be avoided and the dynamic stability provided by the medial hamstrings can be preserved. Graft-tunnel mismatch can be avoided in patients with longer patellar tendons. Contraindications for QT ACL reconstruction are few. These include prior quadriceps tendon surgery or injury, quadriceps tendinopathy, untreated coagulopathy, or large cavitary lesions in the revision setting.

12.3 Anatomy

The anatomy of the quadriceps tendon has traditionally been described as trilaminar, with the superficial fibers coming from the rectus femoris, the vastus medialis and vastus lateralis coalescing to form the middle layer, and the deepest portion extending from the vastus intermedius. In reality, this is a simplification of the great variation in contribution and pattern of fibers [19]. While the deeper fibers insert on the anterior edge of the superior pole of the patella, the most superficial fibers continue anterior to the patella and join the patellar tendon, and the most medial and lateral fibers contribute to the patellar retinaculum. The synovial tissue lines the deep surface of the quadriceps tendon as it forms the roof of the suprapatellar pouch extending approximately 5 cm above the superior pole of the patella [15].

The quadriceps tendon is thickest at the patellar insertion, on average 16 mm in female patients and 18 mm in male patients, and thins proximally as the contributing fibers separate from a common tendon at about 5–6 cm proximal to the insertion [20]. The average thickness of the central portion of this common tendon is 7–8 mm, and the average width is 27 mm [6, 20]. The average total length of the quadriceps tendon from the superior pole of the patella to the myotendinous junction of the rectus femoris is around 8 cm and correlates highly with patient height [20]. This allows for a graft of consistent length (7–8 cm), depth (6–7 mm), and width (9–10 mm) to be harvested [2] with an intra-articular volume 187.5% greater than that of a similar-width patellar tendon graft taken from the same subject [20]. The vascular supply to the quadriceps tendon includes contributions from medial, lateral, and peripatellar arcades [21]. The lateral perforating vessels tend to be at greatest risk of being encountered during harvest.

12.4 Preoperative Planning

The quadriceps tendon autograft has less variability in diameter when compared to hamstring autograft, and its thickness can be evaluated preoperatively on most routinely ordered knee MRIs. The quadriceps tendon should be measured at the midsagittal point of maximal thickness, 3 cm proximal to the superior pole of the patella (Fig. 12.3). It is unusual for the quadriceps tendon thickness to be inadequate for ACL reconstruction, as the intra-articular volume of

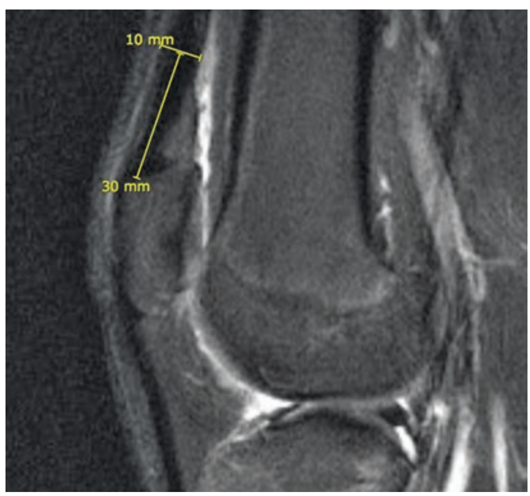

Fig. 12.3 Midsagittal measurement of quadriceps tendon thickness is performed 3 cm proximal to the proximal pole of the patella

graft tends to be larger and closer to anatomic than bone-tendon-bone reconstructions. Although partial-thickness grafts are preferred, a full-thickness graft should be planned if the tendon is less than 6 mm thick. We have not noticed any functional difference between patients who have received partial vs. full-thickness harvests if capsular rents are repaired.

12.5 Surgical Technique

12.5.1 Exposure of the QT

Examination of the injured knee is performed following induction of general anesthetic. A tourniquet is applied to the operative leg, which is then placed in a circumferential leg holder. The operative leg should rest at ninety degrees of knee flexion, putting tension on the extensor mechanism during graft harvest. The operative leg is then prepped and draped in a sterile fashion (Fig. 12.4).

Diagnostic arthroscopy can be performed before or after graft harvest according to surgeon preference. The distal vastus medialis obliquus and proximal pole of the patella are marked. A 1.5–2-cm mark is made at the planned incision site, starting just lateral to the midpoint of the superior pole of the patella, extending proximally along the length of the tendon longitudinally (Fig. 12.4). Alternatively, a 2–3-cm transverse incision over the superior boarder of the patella may be used. If arthroscopy is performed prior to graft harvest, it is important to suction all arthroscopy fluid from the knee, as capsular distention can make full-thickness violations more likely. Local anesthetic is injected into the planned incision site, which helps to distend the subcutaneous and areolar tissue. A 15-blade scalpel is used to

Fig. 12.4 Positioning with the operative leg in a circumferential leg holder and nonoperative leg in a lithotomy leg holder. The bony landmarks, arthroscopy portals, and harvest incision are marked

make the harvest incision, and the subcutaneous and areolar tissue is widely excised (Fig. 12.5). This step is critical for adequate visualization through the small incision. The paratenon is incised, and a RayTech sponge is used over a key elevator to sweep soft tissue off the anterior QT and anteriorly over the patella. An Army-Navy retractor or alternatively a long Langenbeck retractor is then placed. The arthroscope may be introduced into the wound with the fluid off, visualizing the tendon. The VMO, vastus lateralis, and distal rectus femoris musculotendinous junction are identified (Fig. 12.6). Crossing vessels should be coagulated with electrocautery or radiofrequency ablator to avoid postoperative hematoma at the harvest site. The arthroscope is advanced to the distal rectus femoris musculotendinous junction, and the arthroscope light source is used to transilluminate the skin over the anterior thigh. A mark is placed in the center of the point of maximum transillumination, which corresponds to the distal rectus femoris musculotendinous junction (Fig. 12.7). The distance from the proximal pole of the patella to the mark over the distal rectus femoris is measured. This distance represents the maximum length that is obtainable with an all soft tissue graft and usually measures over 8 cm.

Fig. 12.5 The subcutaneous tissue and areolar tissue are widely excised

Currently two different instrumentations for minimally invasive quadriceps tendon harvest are in clinical use:

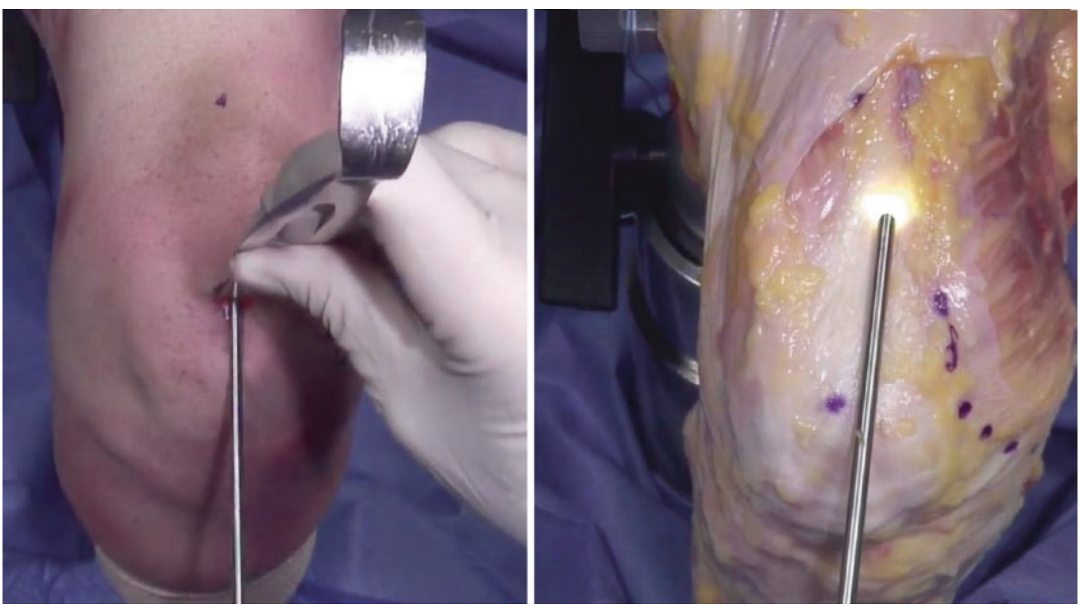

Fig. 12.6 The arthroscope (with fluid off) is used to view the quadriceps tendon, vastus medialis obliquus, vastus lateralis, and rectus femoris

12.5.2 Quad Tendon Harvesting System [Arthrex (Naples, FL)] [14]

With the knee at 90° of flexion, the Arthrex (Naples, FL) triple-blade harvest knife is used to incise the tendon starting just proximal to the superior pole of the patella, advancing toward the musculotendinous junction of the rectus femoris, which is identified by the mark previously placed on the anterior skin (Fig. 12.8). Markings on the knife handle allow for measurement of the QT incision. A 15 blade is used to extend the distal parallel incisions to the proximal pole of the patella, tapering the graft slightly, as graft diameter will increase slightly with later suture addition and graft preparation. The transverse limbs are connected, subperiosteally dissecting the tendon off of the patella. Proximal dissection is continued with metzenbaum scissors or scalpel. Tendon harvest depth is referenced off of the vertical limbs created by the triple-blade harvest knife. A layer of fat usually exists between the tendon and capsule. If fat is encountered, avoid deeper dissection or risk capsular violation if planning for a partial-thickness harvest. An Allis clamp can be placed on the distal tendon, which facilitates control and tension on graft as dissection is carried out proximally.

Once 3 cm of tendon has been dissected free, an Arthrex Fiberloop (Naples, FL) suture is used to place 4 throws in the tendon, starting 1.5–2 cm proximal to the dissected tendon end, continuing distally, locking the last stitch, which exits the central portion of the tendon. The needle is left in place for later graft preparation. Tension is placed on these sutures during further proximal dissection, which is continued with metzenbaum scissors. Once 4–5 cm of tendon has been elevated, the Arthrex (Naples, FL) stripper/cutter is used to first strip and then cut the tendon, with firm tension on the previously placed sutures (Fig. 12.9). Currently, we harvest grafts 6.5–7 cm in length when performing anatomic

Fig. 12.7 The arthroscope is advanced to the level of the distal musculotendinous junction of the rectus femoris and light source turned to transilluminate the skin over the anterior thigh, and a mark is placed in the center of transillumination

Fig. 12.8 The triple-blade harvest knife (Arthrex, Naples, FL) is used to incise the tendon longitudinally, starting proximal to the patella and advancing in the direction of the previously placed mark on the skin identifying the distal rectus femoris musculotendinous junction

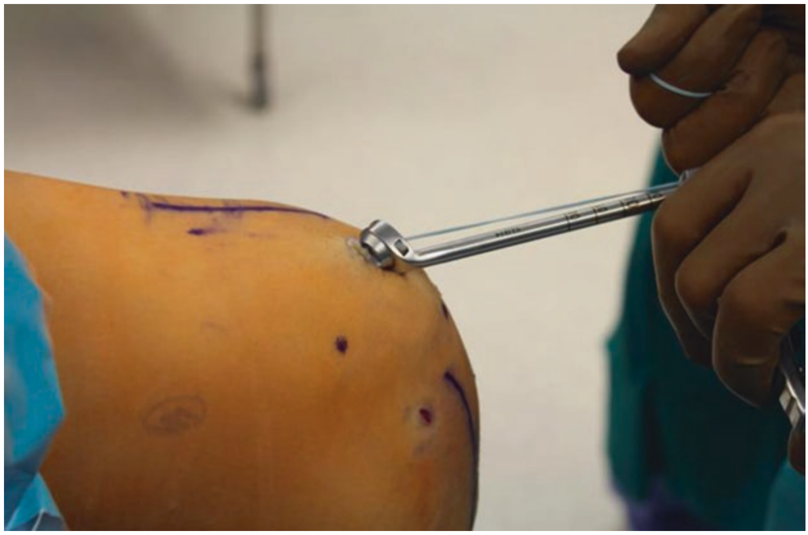

Fig. 12.9 The stripper/cutter device (Arthrex, Naples, FL) is used for proximal dissection and final transection of the graft proximally

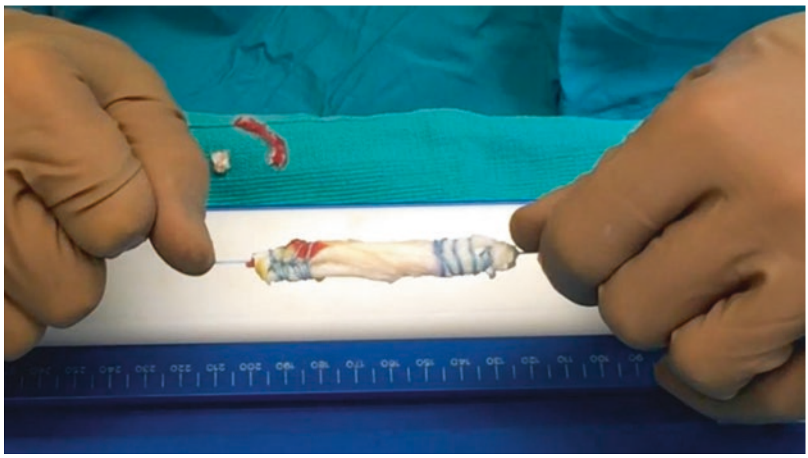

Fig. 12.10 The soft tissue quadriceps tendon graft is then prepared and sized

ACL reconstruction with an accessory medial portal technique and suspensory fixation. The harvested graft is delivered from the wound and brought to the back table for graft preparation and sizing (Fig. 12.10).

The arthroscope is then reinserted (fluid off) into the incision with an Army-Navy retractor at the proximal apex. The harvest site is inspected for full-thickness rents. Any capsular violation or areas of full-thickness harvest are closed with 2.0-Vicryl suture. If a partial-thickness harvest is confirmed, no deep closure is needed. A strip of gelfoam is placed in the harvest site, and the subcutaneous tissue and skin is closed.

Graft preparation The smaller end of the graft (usually the patellar side) is usually used on the femoral side for reconstruction. The needle left in places from earlier tendon whipstitch is placed through the loop of the Tightrope RT, and three or four whipstitches are then placed back in the tendon, starting 5 mm from the end, and proceeding toward the middle of the graft. The needle is then cut off, and suture limbs are wrapped around the graft and tied. The knot can be shuttled into the substance of the graft with a free needle. A second Fiberloop is used to whipstitch the multilaminar proximal of the graft in a similar fashion as

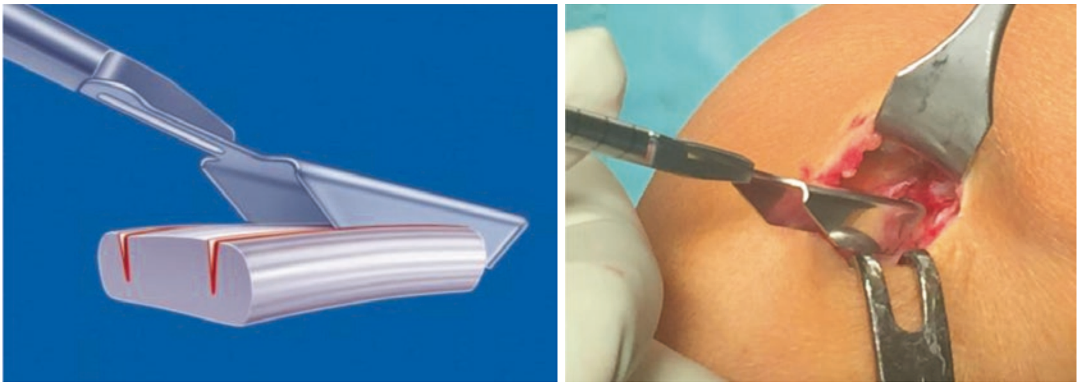

Fig. 12.11 The double knife (Karl Storz, Tuttlingen) is then introduced starting centrally on the superior patella boarder and pushed proximally

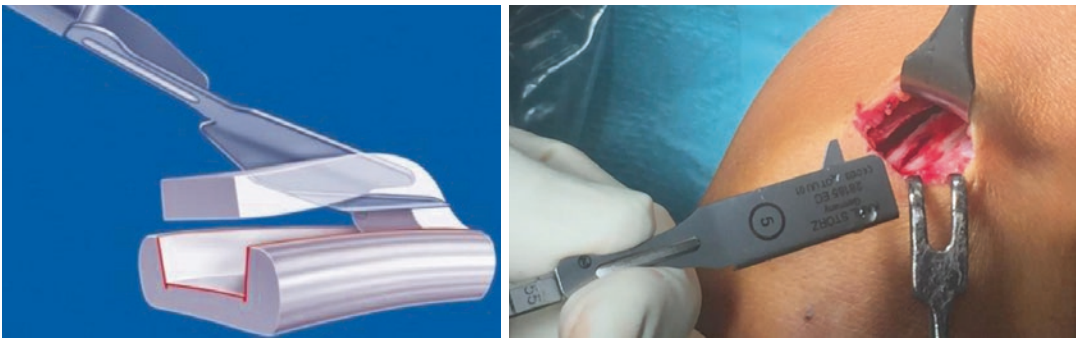

Fig. 12.12 The tendon separator of 5 mm (Karl Storz, Tuttlingen) is introduced and advanced proximally

previously used, with four throws placed, locking the last stitch before the suture exits the central portion of the graft.

12.5.3 QuadCut System [Karl Storz (Tuttlingen, Germany)] [3]

A double knife (Karl Storz, Tuttlingen) in 8–12-mm width is then introduced starting over the middle or slightly lateral to the middle of the superior patella boarder and pushed up to a minimum of 6 cm if used with a bone block or 7 cm if used as a soft tissue graft (Fig. 12.11). The thickness of the graft is then determined using a 5-mm tendon separator (Karl Storz, Tuttlingen). The separator is then pushed proximal to the same length mark (Fig. 12.12). Using a 5-mm tendon separator commonly leaves the recess closed and avoids fluid leakage during arthroscopy in most cases. A 5 × 10 mm graft approximates an 8-mm graft diameter of a round graft and a 5 × 12 mm graft approximates a 9-mm round graft. Finally, the tendon strip is cut subcutaneously using a special tendon cutter (Karl Storz, Tuttlingen) (Fig. 12.13), and the graft is retrieved through the skin incision.

QT *with* a bone block:

The tendon strip is elevated and then followed distally until its bony attachment. The dimensions of the bone block (1.5–2-cm length and respective graft width) are outlined. The bone cuts are made with an oscillating saw, starting with the longitudinal cuts. The graft is then elevated, and the final cut

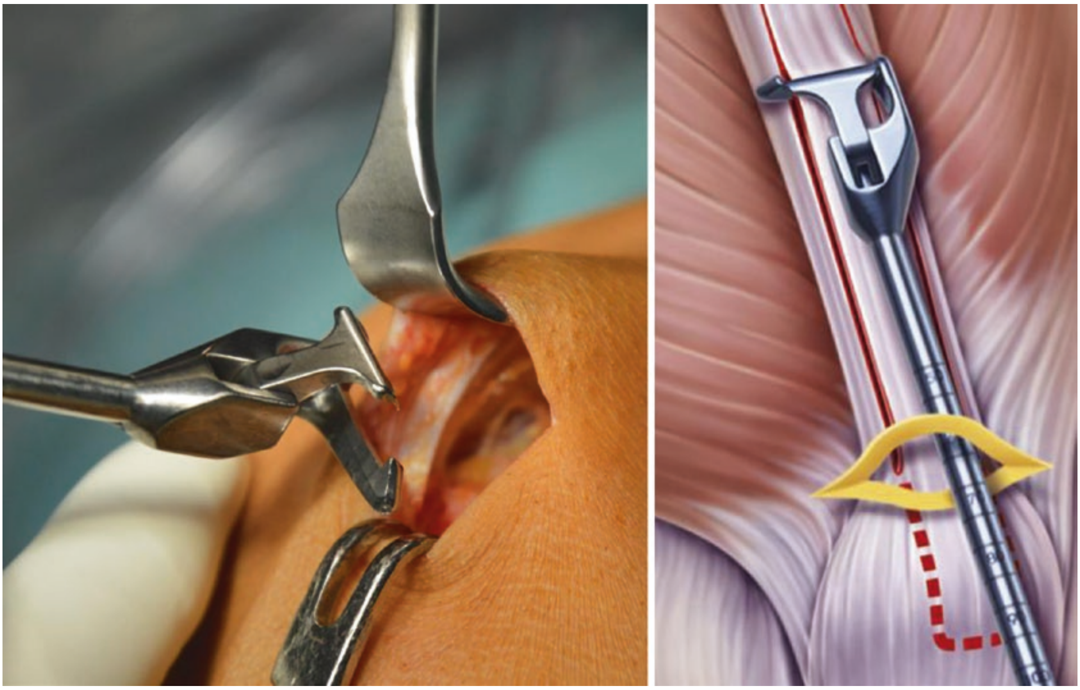

Fig. 12.13 The tendon strip is cut subcutaneously by a special tendon cutter (Karl Storz, Tuttlingen)

determining the thickness of the bone block is made from proximal to distal. The bone block is then easily elevated with a chisel (Fig. 12.14). To minimize the risk of patella fracture, forceful use of chisel and hammer to remove the block should be avoided. Finally, the tendon defect is closed, and the prepatellar bursal tissue layers are carefully closed over the bony defect.

Graft preparation The bone block is prepared to the appropriate diameter, and one or two 1.5-mm holes are drilled through. The bone block can then be mounted to a flip button (e.g., EndoButton® [Smith & Nephew], Flipptack® [Karl Storz, Tuttlingen]) by strong non-resorbable sutures (e.g., No. 2 FibreWire® [Arthrex, Naples, FL]) or a resorbable pull-out suture if the graft will be fixed with an interference screw on the femur. Two whipstitch sutures are placed in the distal end of the graft using non-resorbable No. 2 suture material (Fig. 12.15).

QT *without* a bone block:

The tendon strip is elevated and then followed distally until its bony attachment. The parallel longitudinal cuts are continued about 2 cm distally with a 15-blade scalpel. The QT graft is then subperiosteally elevated from the surface of the patella (Fig. 12.16) and detached. Finally, the tendon defect is closed.

Graft preparation The periosteal part of the graft is folded in the middle, and whipstitch sutures are placed on each side of the graft using a strong No. 2 suture (e.g., No. 2 FibreWire® [Arthrex, Naples, FL] (Fig. 12.17). This will result in a smooth round end of the graft, which allows easier graft passage. The sutures are then passed through a flip button (e.g., EndoButton® [Smith & Nephew], Flipptack® [Karl Storz, Tuttlingen]) for later fixation. Alternatively resorbable sutures may be used if a soft tissue interference screw is planned for femoral graft fixation. Two

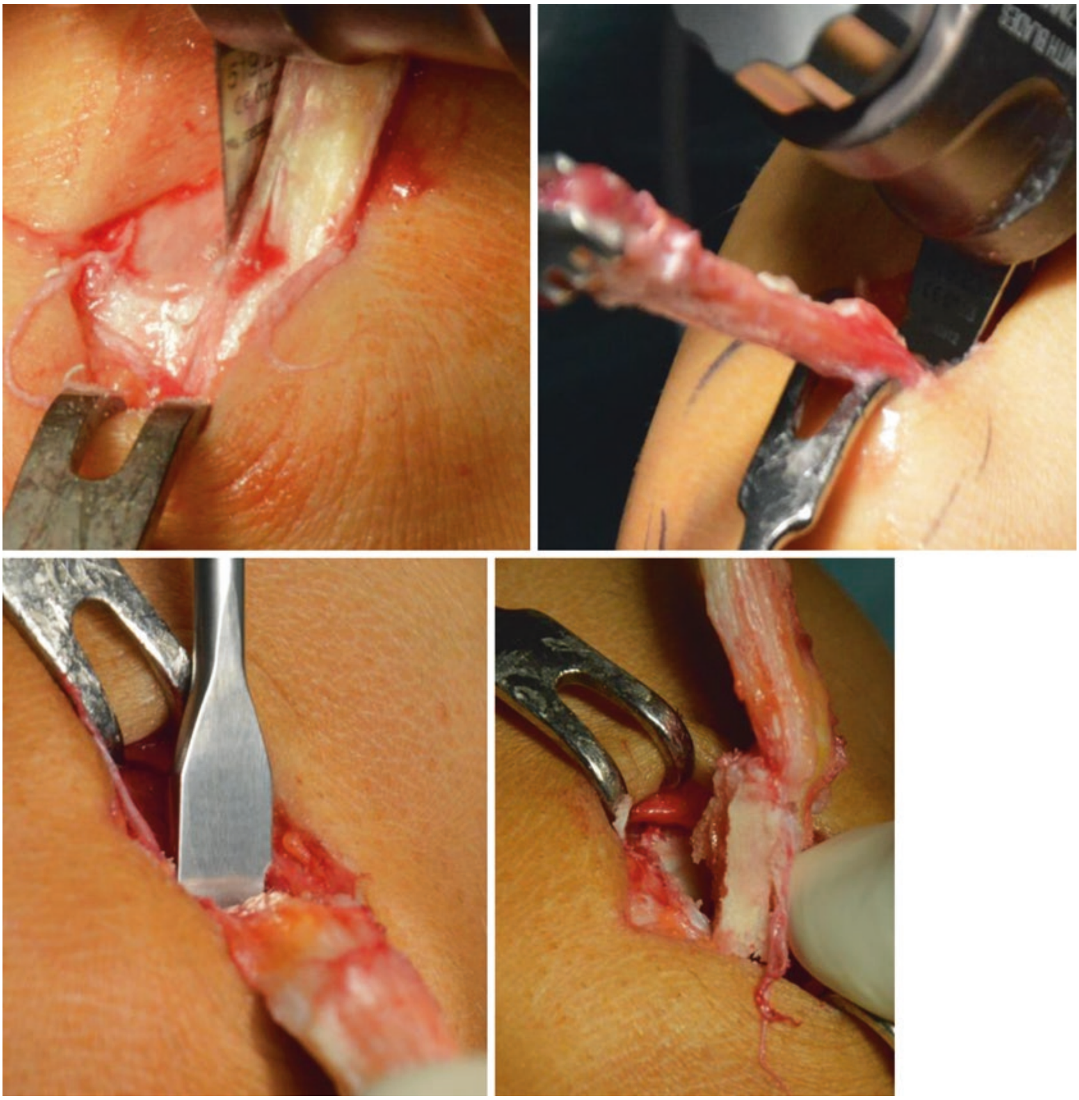

Fig. 12.14 The bone block is harvested using an oscillating saw

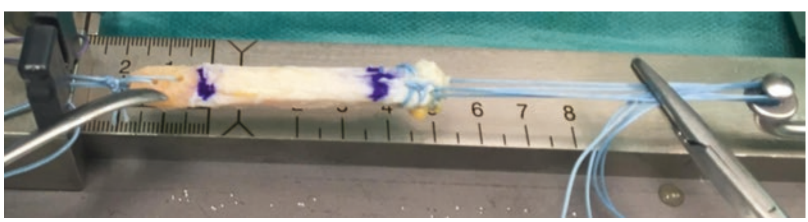

Fig. 12.15 The final QT graft with bone block mounted to a FlippTack (Karl Storz, Tuttlingen)

whipstitch sutures are placed in the distal end of the graft using non-resorbable No. 2 suture material (Fig. 12.18).

12.6 Rehabilitation

Rehabilitation following quadriceps tendon autograft ACL reconstruction is similar to other autograft techniques. It is important to maintain terminal extension with full early motion stretching and exercises. Weight bearing may begin when quadriceps function returns, and in-line jogging can be safely permitted at 3 months. As with any ACL reconstruction technique, functional testing is recommended prior to return to sports.

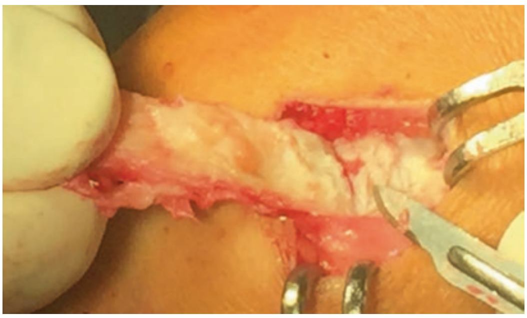

Fig. 12.16 The QT graft is pulled distally, and a 2-cm strip of periosteum in the appropriate width is elevated

12.7 Complications

There is limited data on complications of quadriceps tendon harvest in the literature, but the rate of complications appears to be similar to other autograft choices, with equivalent incidence of graft rerupture and arthrofibrosis [13]. In our experience with over 600 ACL reconstructions using minimal invasive quadriceps tendon harvest, an uncommon complication is the development of a harvest site hematoma. This may occur if the quadriceps muscle is violated to a significant degree during graft harvest, especially laterally where the perforating vessels exist, and cause extensive bleeding after release of the tourniquet. Alternatively, if a full-thickness harvest is performed, the extravasation of intra-articular bleeding through a rent in the synovium may form a similar hematoma anterior to the remaining quadriceps tendon. Patients with hematomas generally present with pain 2–3 days

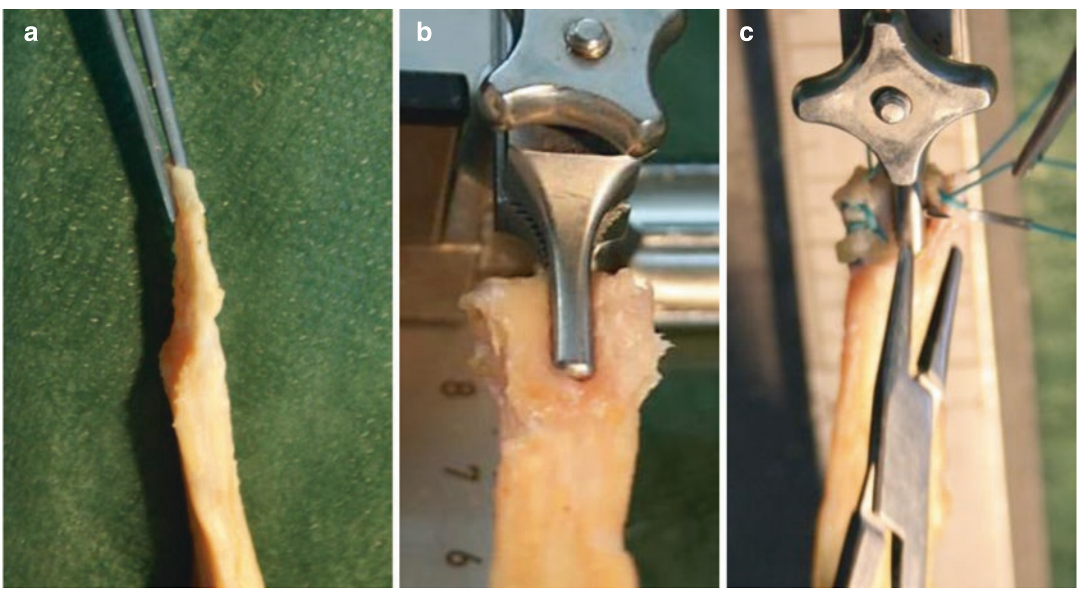

Fig. 12.17 (**a**) The periosteum is folded in the middle and (**b**) fixed in the clamp of a preparation board. (**c**) Whipstitch sutures are placed on each side of the graft using non-resorbable No. 2 suture material

Fig. 12.18 The final soft tissue QT graft mounted to a FlippTack (Karl Storz, Tuttlingen)

after surgery, swelling directly under the harvest site wound if seen. Once identified, it should be evacuated immediately and hemostasis assured. The risk of graft site hematoma formation can be reduced by centralizing the graft harvest within the quadriceps tendon, preferentially harvesting partial-thickness grafts, and terminating the proximal tendon harvest at or distal to the myotendinous junction of the rectus femoris (7–8 cm proximal to the tendon insertion on the patella). Another rare complication that has occurred is a retraction of the rectus femoris muscle after quadriceps tendon harvesting crossed the myotendinous junction. Despite the cosmetic deformity, there were no functional consequences.

12.8 Summary

While many knee surgeons have used the QT as a graft for ACL revision surgery, it has not yet achieved universal acceptance for primary ACL reconstruction. A main reason in our opinion is that conventional QT graft harvest has been technically demanding and has led to cosmetically less favorable results. However, with the development of new instrumentations and minimally invasive harvesting technique, the cosmetic outcome can be markedly improved and surgical time reduced. We think that with these improvements QT has become an attractive graft not only for revision but also for primary ACL reconstruction.

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