Minimally Invasive Anterior Cruciate Ligament With Quadriceps Tendon Graft: A Proximal-to-Distal Harvest Technique

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Abstract: Recent systematic reviews have shown anterior cruciate ligament reconstruction using quadriceps tendon (QT) grafts to have superior clinical outcomes compared with traditional bone—patella tendon—bone and hamstring tendons grafts. Using minimally invasive techniques to harvest the QT graft can reduce postoperative pain and intraoperative surgical time. This technique is usually performed with a distal-to-proximal approach but often has issues of inadvertently harvesting a graft short of the desired length or causing a hematoma. As an alternative, we introduce a minimally invasive approach with a proximal-to-distal harvest technique that results in better visualization of tissue planes, more consistent graft sizes, lower risk of inadvertent arthrotomy, and reduced risk of hematoma. The minimally invasive QT graft harvest with a proximal-to-distal approach can offer unique advantages over the current standard distal-to-proximal approach.

Anterior cruciate ligament (ACL) reconstruction using a quadriceps tendon (QT) graft is becoming a more popular option for the typical, young, athletic patient. The bone—patella tendon—bone (BPTB) and hamstring tendon (HT) grafts are currently the 2 most widely used graft choices, with excellent short-to long-term outcomes. However, the QT has shown increased cross-sectional area, increased biomechanical properties, and residual strength of the extensor mechanism compared with the BPTB. A recent systematic review showed that superior clinical outcomes and reduced donor-site pain can be achieved after ACL reconstruction using the QT graft over the HT or BPTB grafts. The QT graft can be incorporated in various techniques during reconstruction. Several open and minimally invasive approaches have been described in the literature. The standard open quadriceps harvest for ACL reconstruction has traditionally been performed with a large longitudinal incision of approximately 7 to 8 cm to allow for adequate visualization of the rectus femoris (RF) tendon. However, advancements in minimally invasive techniques and instruments have reduced the need for these larger incisions, thereby decreasing postoperative pain and intraoperative surgical time. A distal-to-proximal QT harvest is most popular and currently the gold standard. Two common problems with the distal-to-proximal minimally invasive technique are inadvertent shortening of the graft and inadvertent arthrotomy.

This report is a detailed description of the minimally invasive approach incorporating a proximal-to-distal harvest technique. This technique was developed to address certain issues that occur with the distal-to-proximal technique. The minimally invasive QT graft using a proximal-to-distal harvest is a safe and reproducible approach for both primary and revision ACL reconstruction.

Anatomy and Biomechanics

The length of the QT graft is greatly influenced by the position at which the graft is initially harvested. Traveling proximally from the superior pole of the patella (SPP), the QT width gradually decreases from about...
43 mm at the insertion on the patella to 11 mm at 7 cm proximal (Fig 1). The point of maximal tendon length is 61%, on average, from the medial border of the QT insertion on the patella, to the lateral insertion but can be variable, making the central portion of the tendon difficult to find from a distal starting point. Angulation outside of the natural quadriceps (Q) angle can increase the risk for inadvertent short graft harvest. Surgeons often use direct visualization with the arthroscope in the distal-to-proximal technique to avoid poor trajectory and early truncation of the QT harvest. Adherent tissue, excess adipose, or large musculature also can make visualization difficult if starting distally.

The partial-thickness QT harvest allows for the vastus intermedius (VI) to serve as a robust structure preventing arthrotomy. The 4 QTs coalesce with one another and the retinaculum as they approach the SPP, creating less-definable tissue planes and leading to difficult dissection and inadvertent arthrotomy. However, proximally the RF and VI planes are more easily identifiable (Fig 2).

The vascular supply of the QT is formed by 3 arcades: medial, lateral, and peripatellar. Each arcade emerges from the periphery of the tendon and anastomoses with each other centrally in certain zones of the tendon. The density of vascularity is greatest near the SPP and decreases proximally. In the zone about 1 tp 2 cm proximal from the SPP, there is a relative watershed area where most QT ruptures occur. The areas adjacent to the musculotendinous junctions and the patella are all highly vascularized by their respective arcades and should be avoided to minimize risk of hematoma. Proximal-to-distal harvesting helps to address this complication.

**Surgical Technique for Proximal-to-Distal Harvest of QT (With Video Illustration)**

A demonstration of this procedure in a left knee is provided in Video 1. This procedure can be done with the leg hanging free or supine and with or without a tourniquet per the surgeon’s preference. The QT harvest should be performed with the knee flexed to 90°. A horizontal incision is made approximately 8.5 cm above the SPP before the arthroscope is introduced into the knee (Fig 3). This allows a graft harvest size of 7 to 7.5 cm. It is ideal to plan to truncate the graft about 1.5 cm proximal to the SPP as the QT and retinaculum begin to become confluent in this area. Relying on the distal 1.5 cm for a minimum graft length may make the harvest more difficult due to the confluence of tendons. Harvesting in the zone that becomes confluent may increase the risk of arthrotomy as well. Lastly, the SPP has a dense blood supply, and the QT is most avascular

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**Fig 1.** In a superior view with the knee flexed at 90°, the trapezoidal shape of the tendon is displayed (white lines). Proximally, the tendon is much narrower at the 70-mm mark. Line 3 depicts the ideal harvest angle in-line with the quadriceps angle. Line 1 is too medial. Line 4 is too lateral. Line 2 follows the mechanical axis.

**Fig 2.** In a superomedial view with the knee flexed at 90°, the natural plane between the RF and VI is shown approximately 7 cm proximal to the patella. The arrow shows the confluence of the 4 tendons and retinaculum as they approach the superior pole of the patella. (QT, quadriceps tendon; RF, rectus femoris; VI, vastus intermedius.)
in the zone 1 to 2 cm proximal to the SPP. Therefore, terminating the harvest 1.5 cm proximal to the SPP decreases the likelihood for postoperative hematoma and, at the same time, iatrogenic arthrotomy.

Through the 1.5-cm horizontal incision, the subcutaneous layer is bluntly separated from the QT with a blunt tool per the surgeon’s preference such as a Cobb elevator and lap sponge. The central aspect of the RF tendon is identified deep to the subcutaneous layer and superficial fascia (Fig 4). Sometimes the vastus medialis obliquus must be gently swept medially to adequately visualize the tendon in its entirety, especially in muscular patients. This is crucial to identify the most central aspect of the tendon. Once the central aspect of the tendon is identified, a U-shaped incision in the RF corresponding to the desired tendon width is performed carefully to only cut the RF muscle and not the deeper VI (Fig 5). The size of the RF tenotomy should be large enough to pass a blunt tool or finger deep to the tendon in the plane between the RF and VI. A blunt tool is then used to gently develop the plane deep to the RF toward the patella. Two to three whipstitches with a FiberLoop (Arthrex, Naples, FL) are used to allow passage of the start of the QT graft into the Arthrex Quadriceps Harvest Tool (Fig 6). The harvester is pointed at the central part of the patella while using a deep retractor to visualize the path as distal as possible.

**Fig 3.** In a superior view with the knee flexed at 90°, the superior pole of the patella, vastus medialis, and the proximal direction of the quadriceps tendon are marked. An incision (demonstrated by arrow) is made approximately 8.5 cm proximal to the superior pole of the patella. (VMO, vastus medialis obliquus.)

**Fig 4.** In a superior view with the knee flexed at 90°, retractors are placed proximal and distal to visualize the RF tendon from the incision site. A shortened ruler has been placed on top of the tendon to demonstrate the width to be slightly greater than 10 mm. (RF, rectus femoris.)

**Fig 5.** In a superior view facing distally with the knee flexed at 90° and retractors placed proximally and distally, an incision is performed to the proximal RF tendon according to the desired width. (RF, rectus femoris; VI, vastus intermedius.)
Direct visualization 2 cm distally should allow safe harvest as the tendon begins to widen in this region. The tendon is then removed, tensioned, and fixation is added per the surgeon’s preference. One to two tranexamic acid–soaked sponges can be placed into the horizontal incision to accelerate hemostasis, and the diagnostic arthroscopy is performed. The sponges may be removed later at the surgeon’s preference. Figure 8 shows an arthroscopic view of the tendon harvest path confirming avoidance of an inadvertent arthrotomy. A recent systematic review showed no clear consensus on closure of the QT harvest defect and can be left to the surgeon’s preference. We currently perform a closure of the defect through an endoscopic technique described by Lavender et al. The overlying skin and subcutaneous tissue are closed with absorbable suture.

Discussion
The QT graft was originally described in 1979, and the modern approach was described by Blauth. The QT harvest has become a popular, safe, and reliable method of use for the autograft in ACL reconstruction. Recent systematic reviews have shown superior or comparable results compared with BPTB without the risk for anterior knee pain or patella fracture, although persistent quadriceps weakness is still a
**Table 1. Proximal-to-Distal Quadriceps Autograft Harvest**

| Advantages | Disadvantages |
|------------|---------------|
| - Improved cosmesis with minimally invasive approach | - Learning curve with this new technique |
| - Reduced surgical time | - Unfamiliarity with QT graft harvest among surgeons |
| - Equal or superior clinical outcomes vs BPTB and HT grafts | - Risk of rectus femoris retraction if harvest passes the myotendinous junction |
| - Decreased likelihood for postoperative hematoma and iatrogenic arthroscopy | - Postoperative hematoma and iatrogenic arthroscopy |
| - Decreased chance for short graft harvest compared with distal-to-proximal harvest | - Lack of bone-to-bone healing |
| - More durable graft | - Quadriceps weakness |
| - Maintains hamstring stability on the knee joint | - May require proprietary equipment |
| - Less anterior knee pain compared to B TB | - Short and unusable graft harvest with improper technique |

BPTB, bone—patellar tendon—bone; HT, hamstrings; QT, quadriceps tendon.

A recent systematic review and meta-analysis has shown no significant difference in knee strength between QT and B TB grafts but did show decreased knee extension strength compared with an HT graft. The QT has 20% more collagen, is 1.8 times thicker, on average, and has greater ultimate strength when compared with the B TB autograft.

The minimally invasive technique has certain advantages over the traditional open harvest technique, including lower donor-site morbidity, reduced surgical time, and improved cosmesis. The proximal-to-distal QT harvest also can reduce the risk of inadvertently shortened graft size. There is currently no consensus on the need to repair the QT after partial-thickness harvest. An inadvertent arthroscopy would necessitate closure before arthroscopic ACL reconstruction, a risk that our technique minimizes. The bleeding risk is increased as the harvest approaches the robust blood supply near the musculotendinous junctions and patella. The proximal-to-distal harvest also minimizes this risk. Advantages and disadvantages are addressed in Table 1. There have been advancements to ACL reconstruction using a QT autograft, and the proximal-to-distal harvest is one more addition to ensure safe reproducibility of a proven surgical concept. We believe this new harvest technique will help to improve patient outcomes and reduce harvest site morbidity.

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