Open Full-Thickness Quadriceps Tendon Autograft Harvest With Repair for Anterior Cruciate Ligament Reconstruction

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Abstract: Historically, one of the most common graft choices for anterior cruciate ligament (ACL) reconstruction in the pediatric population has been the hamstring autograft. Although pediatric ACL reconstructions with a hamstring autograft have allowed a majority of children and adolescents to return to athletics, it has been reported that anywhere between 6% and 38% of these patients will go on to experience subsequent graft rupture. The quadriceps tendon autograft is an alternative to the hamstring tendon autograft that demonstrates superior preliminary outcomes, and we currently recommend it for skeletally immature patients undergoing primary and revision ACL reconstruction. This paper aims to describe our technique for an open full-thickness quadriceps tendon harvest with repair.

Anterior cruciate ligament (ACL) tears in the pediatric and adolescent population are being recognized and treated with increasing frequency. Surgical techniques specific for this skeletally immature population have rapidly evolved to minimize the risk of growth disturbance and retear. However, incidence of graft failure is still high, with reported rates of retear ranging anywhere from 6% to 38%, largely dependent on the age and level of competition within the pediatric and young adolescent cohort as well as the type of graft used. When performing anterior cruciate ligament reconstruction (ACLR) in a growing adolescent athlete, the common graft options include hamstring tendon autograft versus quadriceps tendon autograft. The hamstring tendon autograft is more frequently used in the skeletally immature adolescent population, but recent investigations have focused on the quadriceps tendon as a potential superior alternative.

Numerous quad tendon graft harvest approaches have been described. Techniques include using either an open or minimally invasive approach, taking partial- or full-thickness graft, with or without a bone plug from the patella, and with or without quadriceps defect repair. A 2018 systematic review found that partial-thickness quadriceps tendon autograft with a bone plug for single-bundle reconstruction was the most used form of the quadriceps autograft.

Although the use of a quadriceps tendon autograft shows promising preliminary results, recently published data mainly involve ACLR using a quadriceps tendon autograft with a patellar bone block. In the skeletally immature patient, growth arrest following ACLR is more likely to occur when 3% to 5% of the physis is violated. For this reason, soft-tissue grafts are generally recommended over grafts that contain bone plug in patients with open physis. Literature describing harvest techniques of a soft-tissue quadriceps tendon autograft is limited to minimally invasive approaches and partial-thickness harvests. This paper describes a technique for an open approach to full-thickness...
soft-tissue quadriceps tendon harvest with subsequent defect repair for use in single-bundle ACLR.

Surgical Technique (With Video Illustration)

Patient Prep
The patient is placed in the supine position upon the operating room table. Following successful regional anesthesia, all bony prominences are well padded to avoid skin and neurovascular compromise. After performing an examination under anesthesia, the lower extremity is prepped and draped in the usual sterile fashion with the knee flexed to 90°.

Graft Harvest
Following Esmarch exsanguination of the lower extremity, the tourniquet is inflated, and a 5-cm incision is made longitudinally overlying the quadriceps insertion beginning 1 cm proximal to the superior pole of the patella and extending proximally (Fig 1). The incision is taken through the subcutaneous tissue to the level of the extensor mechanism. Once the quadriceps tendon is visualized, a surgical marker should be used to mark the proximal and central aspect of the quadriceps tendon where there is often an apex as the quadriceps musculature converges. The mark is carried distally to the superior pole of the patella (Fig 2). We typically will use either a double-bladed 11-mm or 10-mm scalpel (Parallel Graft Knife; Arthrex, Naples, FL) depending upon the size of the patient. The double-bladed scalpel is used to incise the tendon beginning at the superior pole of the patella extending proximally, straddling the previously marked central portion of the quadriceps tendon (Fig 3). Using a #15 blade scalpel, the graft is released directly from its insertion on the superior pole of the patella, freed from attachments along its length (Fig 4), and then amputated proximally (Fig 5) for a final length of either 60 to 65 mm for all-epiphyseal ACLR or 70 to 75 mm for complete transphyseal ACLR (Fig 6). A full-thickness graft is obtained including the rectus femoris and rectus intermedius components of the quadriceps tendon, leaving the synovial capsular layer intact if it is substantive (Fig 7). As stated previously, we prefer a full-thickness, all soft-tissue graft (without a bone plug from the superior pole of the patella) in this population of children and young adolescents. Particular care is necessary to avoid injury to the rectus femoris muscle tendon junction at the proximal aspect of the harvest.

Defect Repair
To begin, a #2 ETHIBOND suture (Ethicon, Somerville, NJ) is placed at the most proximal aspect of the defect and left long to provide traction and exposure by delivering the most proximal end of the defect for complete repair (Fig 8). Then, using #2 ETHIBOND sutures in an interrupted simple fashion, the remainder of the quadriceps defect is closed down to the superior pole of the patella. The repair included the synovial and capsular layers as well. The stitch used to close the distal most aspect of the quadriceps tendon defect may be placed in a buried fashion and in smaller patients, a #1 or #0 VICRYL may be used. The repair should be complete to limit extravasation of arthroscopy fluid for the remainder of the case (Fig 9). The tourniquet is released, and careful hemostasis is established.
Once passed to the back table, the quadriceps tendon should be prepared by first trimming nontendon or mechanically incompetent tissue. Using a modified Krakow technique, a combination of locking and running nonabsorbable #2 sutures should be passed through the distal 20 mm of the graft on both ends. Then, BTB TightRopes (Arthrex) must be secured to the graft proximally and distally. We prefer using FiberLink and TigerLink sutures (Arthrex) in a modified Krakow technique to secure the BTB TightRope to the graft (Fig 10). Other techniques are available as well; however, this has been an efficient and secure construct in our experience. The graft should then be passed using an all-inside technique (sockets not tunnels) with BTB TightRopes on both the femoral and tibial sides as previously described by McCarthy et al.27

**Closure**

At the conclusion of the procedure, the wound is copiously irrigated with antibiotic solution. The

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**Fig 3.** Right knee. Double-bladed scalpel is used to incise the central portion of the quadriceps tendon straddling the previously placed markings.

**Fig 4.** Right knee. The quadriceps tendon is freed from remaining surrounding tissue attachments with a #15 blade.

**Fig 5.** Right knee. Once proper length is obtained, the proximal end of the graft is amputated with a #15 blade.

**Fig 6.** Harvested 73-mm quadriceps tendon autograft for use in complete transphyseal anterior cruciate ligament reconstruction.
subcutaneous tissues of the quadriceps incision are closed with 2-0 VICRYL in an interrupted simple fashion and the skin is closed with a running 3-0 PROLENE or 3-0 MONOCRYL in a subcuticular fashion depending on patient factors and surgeon preferences. Steri strips and padding should be applied over the closed wound before wrap and brace application.

A video detailing the technique is shown in Video 1. Pearls and pitfalls and advantages and disadvantages of this technique for ACLR with a soft tissue quadriceps autograft are described in Tables 1 and 2, respectively.

Discussion

The quadriceps tendon autograft is an excellent alternative to the hamstring tendon autograft, as cadaveric studies have reported comparable or superior load to failure strength.\(^2^8,^2^9\) In addition, the quadriceps tendon is able to consistently provide a graft of robust size. In an anatomic study by Lippe et al.,\(^3^0\) the size of the native quadriceps tendon was found to be 88.3 ± 8.4 mm in length (range, 78.3-99.7 mm) and 43.3 ± 5.8 mm in width (range, 34.3-54.1 mm). The large size of the native tendon allows for a dependable harvest from the center third to yield a graft size of 10 to 11 mm in width and 70 to 75 mm in length. Contrary to hamstring tendon harvest, which requires harvesting the entire tendon and detaching the muscle, harvesting

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**Fig 7.** Right knee. View of the quadriceps tendon defect after completion of full-thickness graft harvest.

**Fig 8.** Right knee. Repair of the remaining quadriceps defect using #2 ETHIBOND sutures in an interrupted simple fashion.

**Fig 9.** Lateral view of the right knee. Finished quadriceps tendon repair extending to the superior pole of the patella.

**Fig 10.** Quadriceps tendon autograft prepared with a modified Krakow technique and BTB TightRopes on both the femoral and tibial ends.
Advantages and Disadvantages of a Using a Quadriceps Tendon Autograft for ACL Reconstruction

### Table 1. Pearls and Pitfalls of ACL Reconstruction Using a Quadriceps Tendon Autograft

| Harvest a Full-thickness Graft including Both the Rectus Femoris and Rectus Intermedius. | Avoid compromise of the proximal muscle tendon junction during the harvest by limiting the proximal extent to avoid injury of the muscle and proximal migration. We prefer using link sutures with a modified Krakow technique on the 2 sides of the graft to secure the BTB TightRope constructs proximally and distally. Ensure the quadriceps tendon defect is fully repaired after autograft harvest to inhibit extravasation of arthroscopy fluid. |

ACL, anterior cruciate ligament.

Table 2. Advantages and Disadvantages of a Using a Quadriceps Tendon Autograft for ACL Reconstruction

| Advantages | Disadvantages |
|------------|--------------|
| - Preliminary results show lower rates of graft retear with quadriceps autograft compared with hamstring autograft. |
| - Full-thickness graft is consistently larger and more robust than a partial-thickness graft. |
| - A 5-cm incision allows for direct visualization and facilitates full-thickness harvest and secure closure. |
| - All-soft tissue graft avoids the potential of patella fracture postoperative and the diminishes the risk of a physeal bar in the pediatric and young adolescent patient. |
| - Open full-thickness harvest requires a slightly larger (5 cm) incision compared with a partial-thickness "minimally invasive" 2-cm approach. |
| - There is potential for injury at the muscle–tendon junction during the proximal aspect of the quadriceps harvest. |

ACL, anterior cruciate ligament.
proximal aspect of the quadriceps autograft where the rectus femoris and rectus intermedius begin to separate. An interval of adipose tissue between these tendon layers is noted on occasion and requires care in securing the suspensory fixation mechanism. Fourth, in smaller patients who are undergoing a complete transphyseal reconstruction, obtaining 70 mm of an all-soft tissue quadriceps autograft can be challenging. Some investigators have incorporated a portion of the superior pole of the patellar to address this. We have not found this to be necessary, as a 65-mm autograft length will suffice in these unusual circumstances. Fifth, theoretically there is the potential for quadriceps weakness in the early phases of rehabilitation. We have not found this to be of clinical significance, as these patients develop the ability to perform a straight leg raise on par with our patellar tendon autograft patients. Finally, this experience and series represents the patient population of the 2 senior authors and therefore may not be generalizable.

As growing literature supports the use of a quadriceps tendon autograft, this article describes a technique that can be used in younger patients undergoing ACLR that produces superior short-term outcomes. We currently recommend the use of a soft-tissue quadriceps tendon autograft in adolescents undergoing primary or revision ACLR.

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