Anterior Cruciate Ligament Reconstruction with Quadriceps Tendon—Patellar Bone Autograft and Dual Tibial Fixation
Shehan Abeyewardene, M.D., Tarra Geertman, A.T.C., Andrea Ganss, A.T.C., Kendall Hamilton, M.D., and Travis Menge, M.D.

Abstract: Anterior cruciate ligament ruptures are a relatively common injury in the athletic population, and surgical reconstruction is often indicated to restore knee stability. While hamstring tendon and patellar bone—tendon—bone autografts are a well-established graft choice in this population, there has been a growing body of literature supporting the benefits of quadriceps tendon autograft. Our technique illustrates a full-thickness quadriceps tendon—patellar bone autograft with dual tibial fixation using an interference screw and backup suspensory anchor fixation.

Although the use of the QT autograft has been increasing over the past decade, there are many different variations described in the literature of how the QT autograft is harvested as well as numerous fixation methods. This paper will aim to demonstrate a novel technique of ACL reconstruction using a full-thickness QT—patellar bone autograft with dual tibial fixation using an interference screw and backup suspensory anchor fixation to achieve an optimal biomechanical reconstruction.

Surgical Technique (With Video Illustration)
A demonstration of this technique in a right knee is provided in Video 1. The advantages and disadvantages of the procedure are shown in Table 1, whereas the pearls and pitfalls are summarized in Table 2.

Patient Positioning and Preparation
The patient is positioned supine on the operating table. Examination under anesthesia includes the Lachman test, pivot shift, anterior and posterior drawer test, and varus/valgus stress test at 0° and 30° to evaluate the collateral ligaments. The operative lower extremity is steriley prepped and draped. Skin markings are made along surgical landmarks, including the superior pole of the patella, lateral border of the vastus medialis, and standard anterolateral and far anteromedial portals (Fig 1).

Graft Harvest
With the knee at 90° of flexion, a 3-cm incision is made from the superior pole of the patella proximally. Full-thickness flaps are created down to the extensor fascia layer. Retractors are placed in the medial and
lateral aspects of the wound and the central portion of the tendon and borders of the vastus medialis and lateralis, respectively, are identified (Fig 2). The central third of the QT is harvested in a full-thickness manner with a double blade knife (Arthrex, Naples, FL) to a length of 60 to 65 mm aiming along the anatomic axis of the femur. The knee is then placed in 30\degree of flexion to harvest the patellar bone plug. An oscillating saw is used to harvest a 10-mm (width) × 20-mm (length) × 7-8 mm (depth) trapezoidal bone plug from the superior pole of the patella. Care is taken to avoid penetration of the patellar cartilage. An osteotome is used to gently free the bone plug from the patella and a 15-blade scalpel is used to free the soft tissue from the superior pole. A QT harvester (Arthrex) is placed over the bone plug and slid proximally along the tendon, and the graft is cut at the desired length (Fig 3).

**Graft Preparation**

The graft is brought to the back table for measurement and preparation (Fig 4). A rongeur is used to remove the excess bone to allow for a 10-mm cylindrical bone block. Next, 2 drill holes are made in the femoral bone block using a 1.5-mm drill. Two #5 ETHIBOND sutures are passed through these holes, and these sutures will be used to pull the bone block into the femoral tunnel at a later time. A locking looped stitch using a FiberLoop (Arthrex) is used to secure the distal 30 mm of the tendinous portion of the graft (Fig 5).

**Table 1. Advantages and Disadvantages of the Described QT Autograft Technique**

| Advantages | Disadvantages |
|------------|---------------|
| Greater average cross-sectional area compared with pbtb autograft of the same width | Can further weaken the quadriceps in those with pre-existing quadriceps weakness and unable to use in patients with previous quadriceps rupture |
| Greater load to failure compared with pbtb autograft | Risk of rectus femoris injury if harvest passes the myotendinous junction |
| Less donor-site morbidity compared with the pbtb autograft and better functional outcome scores compared with ht autograft | Larger incision compared with minimally invasive partial-thickness QT autograft |
| Less hamstring weakness compared with ht autograft | Greater risk for patella fracture compared with all soft-tissue QT autograft |
| More robust graft compared with a partial-thickness qt autograft | Requires flexible arthroscopic reamers |
| Reinforced dual tibial fixation increases pullout strength | Use of the patellar bone plug allows for bone-to-bone healing as opposed to an all soft-tissue qt autograft |

HT, hamstring tendon; PBTB, patella bone—tendon—bone autograft; QT, quadriceps tendon.

**Table 2. Pearls and Pitfalls**

| Pearls | Pitfalls |
|--------|----------|
| Avoid injury to the myotendinous junction during proximal dissection of quadriceps tendon while harvesting | Too large of bone block can increase risk of patellar fracture |
| Tension graft with knee in full extension to avoid loss of motion post-operatively | Inadequate graft size or length harvested |
| Visualize full width of quadriceps tendon when harvesting, allowing for 3- to 4-mm tissue on both sides for later side-to-side closure | |
| Aim along the anatomic axis of the femur when using the double blade knife when performing full-thickness quadriceps tendon harvest | |

**Fig 1.** Preoperative skin markings of a right knee demonstrating the quadriceps tendon harvest site and planned incision, located immediately proximal to the superior border of the patella.
ACL Reconstruction

Standard anterolateral and far anteromedial arthroscopy portals are established. A diagnostic arthroscopy is performed to assess the patellofemoral joint, medial, and lateral compartments, and any concomitant pathology is addressed. The native torn ACL is identified in the intercondylar notch and this is debrided using a shaver (Fig 6). The femoral tunnel is drilled first using a flexible reamer (Stryker, Kalamazoo, MI) through the medial portal (Fig 7). A 7-mm offset guide is placed on the backwall to help stabilize placement of the guide pin in the anatomic center of the ACL footprint and ensure a 2- to 3-mm backwall. The reamer is started and advanced 5 mm as an additional check to ensure that the integrity of the backwall is maintained. Once confirmed, a 20-mm socket is reamed, and the debris is

Fig 2. The quadriceps tendon of a right knee is exposed after skin incision and careful dissection through the underlying soft tissues allowing full visualization of the intended quadriceps graft harvest site.

Fig 3. A double-blade quadriceps tendon harvester is used to perform a full-thickness quadriceps tendon harvest on a right knee. The blade is advanced carefully from a distal to proximal direction, starting at the superior pole of the patella and centered over the quadriceps tendon.
removed with a shaver. A high-strength suture is then shuttled out the lateral aspect of the skin using the flexible guide pin and then clamped to facilitate graft passage later in the case (Fig 8A and B).

An accessory anteromedial incision is made over the tibia approximately 1.5 cm medial to the tibial tubercle and slightly proximal to the pes anserine tendons. An arthroscopic ACL aiming guide (Arthrex) is placed through the medial portal. The knee is positioned at 80° to 90° of flexion and the guide is set at a 55 to 60° angle. The tip of the guide is positioned 2 mm anterior to the posterior fibers of the lateral meniscus anterior horn, medial to the midline of the tibial footprint, and 15 mm anterior to the posterior cruciate ligament (Fig 9). A 2.4-mm guide pin is drilled up through the tibial footprint. The 2.4-mm guide pin is exchanged for a coring reamer guide pin. A 10-mm coring reamer (Arthrex) allows for precise tunnel placement in addition to capturing a core of the tibial autograft bone to be used for later grafting of the patellar harvest site (Fig 10).

**Graft Passage and Graft Fixation**

An arthroscopic grasper is passed up the tibial tunnel and used to retrieve the shuttle suture from the femoral tunnel. The passing sutures of the ACL graft are placed through the loop of the shuttling suture and gently pulled out the lateral thigh. A 7 × 20-mm titanium interference screw is placed to secure the femoral bone plug. Once seated, the knee is cycled to evaluate for impingement against the posterior cruciate ligament, roof of the notch, and lateral wall. The knee is then placed in 0-10° of flexion to avoid loss of knee extension while fixing the tibial side of the graft. A 10 × 30-mm soft-tissue bio-composite interference screw is placed anterior to the graft and seated in placed. The arthroscope is placed back into the knee joint to remove debris, perform an arthroscopic lavage, and to perform a final ACL graft check (Fig 11). Finally, backup suspensory fixation is used to further support our tibial interference fixation. Approximately 1 cm distal to the tibial tunnel aperture a 4.5-mm unicortical tunnel is drilled into the tibial cortex. A tap is used to create threads in the tunnel, and the tibial sided graft sutures are passed through the eyelet of a 4.75-mm SwiveLock anchor (Arthrex). The anchor is secured by screwing the threads into the bone until it is flush with the cortex (Fig 12). An examination under anesthesia is performed at this time to confirm restoration of excellent knee stability.

**Wound Closure**

The autograft that was obtained during tibial tunnel reaming is removed from the coring reamer. Any soft tissue is removed, and the bone graft is shaped with a
rongeur to fit appropriately in the patellar harvest site. The fascia of the patella is closed over the top with 0-VICRYL suture. Subcutaneous tissue is closed over the harvest site. Arthroscopy portals and skin closure is performed meticulously with monofilament suture. Sterile bandages are used to dress the wound and a hinged knee brace is placed locked in full extension.

Postoperative Rehabilitation
Patients may begin immediate postoperative weight-bearing with knee range of motion from 0 to 90° of flexion. Progressive eccentric closed chain strengthening and isokinetic hamstring strengthening beginning 3 weeks after ACL reconstruction results in improved function, strength, and muscle mass compared with starting at 2 weeks after surgery.4

Discussion
Although the QT autograft has been traditionally overlooked as a leading graft choice for ACL reconstruction, multiple studies in the past 2 decades have shown that it is an excellent option compared with the historically popular PBTB and HT autografts. Stäubli et al.5 demonstrated that a 10 mm-wide QT had an average cross-sectional area nearly twice that of a PBTB graft of the same width, while Xerogeanes6 reported the QT histologically has 20% more collagen fibrils per cross-sectional area than the patellar tendon. This significant increase in cross-sectional area decreases the risk of windshield wiper effects as well as tunnel-graft mismatch. Biomechanical studies also show that when compared with a patellar tendon of the same width, the QT is 1.8 times thicker and has a 1.36 times greater load-to-tendon failure.7 Mouarbes et al.8 found that there were no differences in functional outcomes between those who had ACL reconstruction with QT autograft versus PBTB autograft; however, those who had QT autograft had less donor-site pain (risk ratio for QT vs BPTB, 0.25). When comparing QT autograft with HT autograft, they found no differences in donor-site

Fig 7. Arthroscopic view of a right knee while viewing through the anterolateral portal demonstrates guide pin position against the lateral wall for femoral tunnel drilling.

Fig 8. (A) and (B) Arthroscopic views of a right knee while viewing through the anteromedial portal demonstrating the femoral tunnel with suture in place to aid in quadriceps tendon–patellar bone graft passage.
pain, but patients treated with QT autograft had an average 3.81 times greater Lysholm functional outcome score versus HT autograft. A general concern when using a QT autograft is residual quadriceps weakness. Letter et al. showed that there was an 11.6% decrease in peak torque and 18.4% decrease in average torque when comparing the operative and nonoperative legs in patients undergoing ACL reconstruction, however they found that patients treated with QT autograft and PBTB autograft both showed similar isometric strength deficits. Furthermore, no significant differences were found in quadriceps muscle electromyography ratios between patients treated with QT autograft and PBTB autografts. An advantage of using a QT autograft as opposed to a HT autograft is the ability to preserve hamstring strength. Hamstring weakness is associated with increased risk of ACL injury; therefore, using a QT autograft could decrease the risk of ACL re-rupture, especially in the athletic female population.

A recent study by Bowman et al. reported QT autograft as one of the preferred graft choices among orthopaedic surgeons in younger patients and those in pivoting sports. In our technique, a full-thickness QT autograft with patellar bone plug is obtained, which is felt to be a more robust graft when compared with a partial-thickness QT autograft. In addition, this graft construct offers the benefits of accelerated healing by achieving bone-to-bone healing, similar to a PBTB autograft. We also use an anchor in addition to an interference screw to achieve dual tibial fixation, with the anchor backup thought to help attain a more biomechanically superior construct and increase the pullout strength of the fixation construct.

As with any technique, there are potential pitfalls to using our technique for ACL reconstruction. First,
patients who have sustained previous ipsilateral QT ruptures are not eligible to undergo this procedure. It is also recommended that patients with pre-existing quadriceps weakness use either a PBTB or HT autograft due to the risk of further weakening the quadriceps. When compared with the PBTB or HT autograft, there is also risk to the quadriceps when obtaining the graft if the surgeon dissects too proximal and violates the myotendinous junction. Although the risk is low, our technique carries a greater risk of physeal bar formation in the pediatric population as well as greater risk of patella fracture when compared with an all-soft tissue QT autograft. In addition, our technique requires the use of arthroscopic flexible reamers, which may not be readily available to all surgeons.

References
1. Filbay SR, Grindem H. Evidence-based recommendations for the management of anterior cruciate ligament (ACL) rupture. Best Pract Res Clin Rheumatol 2019;33:33-47.
2. Widner M, Dunleavy M, Lynch S. Outcomes following ACL reconstruction based on graft type: Are all grafts equivalent? Curr Rev Musculoskelet Med 2019;12:460-465.
3. Hwang MD, Piefer JW, Lubowitz JH. Anterior cruciate ligament tibial footprint anatomy: Systematic review of the 21st century literature. Arthroscopy 2012;28:728-734.
4. Gerber JP, Marcus RL, Dibble LE, Greis PE, Burks RT, LaStayo PC. Effects of early progressive eccentric exercise on muscle size and function after anterior cruciate ligament reconstruction: A 1-year follow-up study of a randomized clinical trial. Phys Ther 2009;89:51-59.
5. Stäubli HU, Schatzmann L, Brunner P, Rincón L, Nolte LP. Mechanical tensile properties of the quadriceps tendon and patellar ligament in young adults. Am J Sports Med 1999;27:27-34.
6. Xeroygeanes JW. Quadriceps tendon graft for anterior cruciate ligament reconstruction: The graft of the future! Arthroscopy 2019;35:696-697.
7. Harris NL, Smith DA, Lamoreaux L, Purnell M. Central quadriceps tendon for anterior cruciate ligament reconstruction. Part I: Morphometric and biomechanical evaluation. Am J Sports Med 1997;25:23-28.
8. Mouarbes D, Menetrey J, Marot V, Courtot L, Berard E, Cavaignac E. Anterior cruciate ligament reconstruction: A systematic review and meta-analysis of outcomes for quadriceps tendon autograft versus bone—patellar tendon—bone and hamstring-tendon autografts. Am J Sports Med 2019;47:3531-3540.
9. Letter M, Baraga MG, Best TM, et al. Comparison of neuromuscular firing patterns of the superficial quadriceps in soft tissue quadriceps tendon versus bone—patellar tendon—bone ACL autografts. Orthop J Sports Med 2019;7:2325967119887674.
10. Myer GD, Ford KR, Barber Foss KD, Liu C, Nick TG, Hewett TE. The relationship of hamstrings and quadriceps strength to anterior cruciate ligament injury in female athletes. Clin J Sport Med 2009;19:3-8.
11. Bowman EN, Limpisvasti O, Cole BJ, ElAttrache NS. Anterior cruciate ligament reconstruction graft preferences among orthopaedic surgeons [published online February 1, 2021]. Arthroscopy. https://doi.org/10.1016/j.arthro.2021.01.042.