ACL Reconstruction Using Quadriceps Tendon

Nicola Santori, MD, PhD*
Ezio Adriani, MD†
Luigi Pederzini, MD‡

Quadriceps tendon has recently become a viable graft option for primary and revision anterior cruciate ligament reconstruction. It offers excellent biomechanical strength, a large cross-sectional area, and an appropriate length. Its advantages over bone-patellar tendon-bone and semitendinosus/gracilis tendon are presented.

Arthroscopic anterior cruciate ligament (ACL) reconstruction is one of the most commonly performed and most successful procedures in sports medicine. Various autograft choices have been used for ACL reconstruction, and the results in terms of stability and return to sports activities have been good. The ideal autograft should have optimal mechanical properties and low donor-site morbidity. The most recurring graft choices are the bone-patellar tendon-bone (BPTB) and the semitendinosus/gracilis tendon.

Unfortunately, BPTB autograft has been extensively associated with persistent donor-site morbidity, such as tenderness, anterior knee pain, pain on kneeling, infrapatellar contracture syndrome, patellar tendon rupture, and fat pad herniation. Of patients who have undergone arthroscopic ACL reconstruction using BPTB autograft, 40%–60% have one or more of the described complications. Hamstring autograft donor-site morbidity includes ACL agonist weakness and disruption of the protective ACL proprioceptive arc.

The quadriceps tendon graft has several potential advantages over BPTB and has recently gained attention as a promising option for primary and revision ACL reconstruction. The quadriceps tendon graft consists of four leaves of collagenous tissue running longitudinally and obliquely merging at the base of the patella. This method was discontinued after the biomechanical analysis performed by Noyes et al in 1984 and will not be addressed in this article.

The quadriceps tendon graft offers excellent biomechanical strength, large cross-section area, appropriate length, and the advantage of having a bone plug on one end harvested from the upper pole of the patella. Anterior knee pain associated with lower patella

Quadriceps Tendon-Bone Graft Properties

The quadriceps tendon-bone construct differs from the simple quadriceps tendon substitution reported by Marshall et al, which consists of the quadriceps tendon-prepatellar retinaculum-patellar tendon construct. This method was discontinued after the biomechanical analysis performed by

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bone block removal is eliminated with this grafting procedure.

Staubli et al.\textsuperscript{17,18} performed an extensive comparison of the quadriceps tendon graft and BPTB grafts. Mean quadriceps tendon graft lengths averaged 87 ± 9.7 mm for the right knee and 85.2 ± 4.8 mm for the left knee in addition to the bone block. The tendinous portion of the patellar tendon measured on average 51.6 ± 6.9 mm in the right knee and 52.2 ± 4.8 mm in the left knee. Cross-sectional area of a 10-mm wide quadriceps tendon graft averaged 64.4 ± 8.4 mm\(^2\). This value is significantly greater than the mean measurements of the patellar tendon, which measured 36.8 ± 5.7 mm\(^2\).

The ultimate tensile load of the intact ACL is approximately 2160 ± 157 N.\textsuperscript{19} A 10-mm quadriceps tendon graft has a similar ultimate tensile failure load, ie, 2173 ± 618 N compared to 1953 ± 325 N of the BPTB complex.\textsuperscript{17,18} In a similar study, Schatzmann et al.\textsuperscript{20} reported the ultimate tensile load of a 10-mm–wide, full-thickness central section of the quadriceps tendon to be as high as 2352 N. Harris et al.\textsuperscript{21} showed the ultimate tensile failure load of the quadriceps tendon to be 1.36 times that of a comparable BPTB graft.

Staubli et al.\textsuperscript{17,18} concluded that the evidence from anatomic, cryosectional, and structural properties analyses suggest that the quadriceps tendon graft may be a valuable and versatile adjunct to the surgeon’s armamentarium in cruciate ligament reconstruction. The multilayer structure of the quadriceps tendon allows this graft to be split, on one end, into two separate tails, making it an option in techniques that use two bundles to reconstruct the ACL or posterior cruciate ligament.

**Quadriceps Tendon Harvesting Technique**

A 3- to 4-cm transverse incision is made on the patella’s base. The quadriceps tendon is exposed through incising the fascia over the quadriceps tendon including multiple aponeurotic layers in front of the anterior patellar surface. Soft tissues are removed distally to proximally to visualize the insertion of the vastus medialis muscle in the quadriceps tendon. This is an important reference point for graft harvesting.

A longitudinal incision is made on the quadriceps tendon approximately 3 mm lateral from this muscular insertion. It must be oriented parallel with the main body of the tendon and centered over the base of the patella. A parallel incision is made 10 mm laterally. Thus, it is possible to isolate a tendon strip approximately 10-mm wide and 7-mm thick, with a cross-section of approximately 70 mm\(^2\). An identical width of the patellar tendon gives a cross-section of approximately 36 mm\(^2\).

A 20 × 10-mm bone block is demarcated on the upper patella in line with the tendinous portion of the graft with the knee flexed to 60° (Figure 1). The knee is flexed to avoid patellar movement while performing the bone cuts. The bone block is harvested with a motorized oscillating saw, and hammering with chisels is avoided to prevent cracking or fissuring of the patella. The bone block is drilled and mounted with a single 2-0 Vicryl passing suture. The knee is extended, the incision is retracted proximally, and the quadriceps tendon is cut proximally at the preselected graft length (7-7.5 cm) by pulling the bone block distally (Figure 2). Two 2-0 Vicryl sutures are used in a Bunnell–Krackow fashion on the free tendon extremity (Figure 3).

The patellar defect is packed with autologous bone obtained while coring, instead of drilling, the tibial tunnel or with a conventional biodegradable gelatin sponge, according to surgeon preference. The anterior tension band bracing system is recreated closing the prepatellar bursa over the bony defect. The gap of the suprapatellar quadriceps tendon harvesting site is similarly closed.

**Technical Difficulties**

Fulkerson and Langeland\textsuperscript{11} first popularized the quadriceps tendon as an alternative for primary ACL recon-
struction and reported that dissection through the quadriceps tendon is difficult. They underlined the potential risk of opening the suprapatellar pouch and the resultant loss of intra-articular flow. This could result in a decreased intraoperative view, subcutaneous fluid distension, and increased operative time if an arthroscopic assisted procedure is used. Furthermore, if the pouch is opened, adhesions between the tendon and anterior aspect of the femur may occur with consequent restricted range of motion and poor scarring.

A potential solution consists of carefully dissecting the tendon and preserving the synovial layer of the suprapatellar pouch. Another option consists of maintaining the integrity of the vastus intermedius and using only three of the four leaves of the tendon. Both of these methods increase surgical time and require a learning curve.

In our experience, we try to save the synovial layer; however, the pouch is almost always opened (Figure 4). If accurate tendon defect closure is performed, this is not a problem (Figure 5). Knee flexion >120° and a temporary increase in intra-articular pressure guarantee a satisfactory arthroscopic view during graft insertion and fixation.

Another delicate step of this procedure is harvesting the upper patella bone block. The shape of the proximal extremity of the patella is more oblique than the distal extremity, therefore a risk of obtaining a short and oblique bone block exists. Because the soft-tissue layer over the patellar bone is thicker in this area than distally, a needle can be inserted through the quadriceps tendon to delineate the exact upper margins of the patella.

In our experience, harvesting the quadriceps tendon is more difficult than harvesting the BPTB. We recommend the surgeon begin with an appropriate (8-10 cm) skin incision and then as confidence with the procedure builds, the surgical access can be shortened.

**Graft Fixation**

The main surgical steps are the same ones used during every arthroscopic ACL reconstruction. Fullkerson and Langeland, Shelton, Pederzini et al., Staubli, Noronha, and Kim et al prefer to fix the patellar bone block in the femoral tunnel, whereas Slullitel et al and Randelli et al position the bone block in the tibial tunnel.

As previously stated, the anatomical features of the quadriceps tendon allow this graft to be used in a two-strand fashion (Figure 6). Pederzini et al described a technique featuring the bone block in a single half tunnel on the femur and a double tibial tunnel (Figure 7). Advantages are an increased bone-tendon interface, easier bone incorporation, and a more anatomical reconstruction with theoretically better long-term results.

Various fixation devices have been used, with interference screws remaining the most common. Randelli et al fix the tendinous portion in the femoral tunnel with two bioabsorbable pins and the patellar bone-block in the tibial tunnel with an interference screw. Noronha stabilizes the bone block in the femur with an interference screw and the tendinous extremity with a staple or screw in the anterointernal tibial cortex. Kim et al apply an alternative composite graft on the tibial side. Spongy bone obtained while coring the tibial tunnel is attached to the tendinous portion of the graft and used to refill the tibial tunnel.

Adriani (unpublished data, 2001) achieves bone block fixation in the femoral tunnel with a transcondylar technique and a pin that passes through the previously drilled bone block. This method uses a U-shaped drill guide. The jaw of the guide is placed inside the femoral tunnel and a 3.2-mm Kirschner wire is drilled in the conventional transcondylar fashion through the lateral condyle. The wire is stopped at the margin of the femoral tunnel (Figure 8). Once the neoligament is positioned, the K-wire is advanced through the bone plug and medial femoral condyle for 2 cm. The K-wire is removed, and a 50- to 60-mm long, 50- to 60-mm long,
3-mm diameter bioabsorbable pin is implanted to stabilize the bone block (Figures 9 and 10). Trials of knee traction, extension, and flexion/extension are performed with the graft under tension. Tibial fixation is achieved with bioabsorbable interference screws.

**CLINICAL RESULTS**

One main concern regarding quadriceps tendon graft for ACL reconstruction is the paucity of literature and the lack of prospective studies and long-term results.

Shelton compared two groups of 50 patients undergoing either quadriceps tendon or BPTB ACL reconstruction and reported the 2-year follow-up results. Clinical results, KT-1000, Lachman, and pivot shift tests were similar in both groups with less harvest site morbidity in the quadriceps tendon group.

Chen et al reported a short series of 12 patients. Ten patients returned to the same or a higher level of preinjury sports activity at 15- to 24-month follow-up. According to the International Knee Documentation Committee rating system, 10 of 12 patients had normal or nearly normal ratings. Recovery of quadriceps muscle strength to 80% of the normal knee was achieved in 11 patients within 1 year.

Howe et al evaluated 83 patients with ACL reconstructions using quadriceps tendon with a mean 5.5-year follow-up. Ninety-six percent of patients were satisfied with their results, 4% were unsatisfied. Ninety-three percent of patients had no pain, and 95% had no giving way post-reconstruction. No increase in failure over time (1-10 years) was observed. The lack of a formal rehabilitation program >4 months postoperatively and repaired tears of the medial or lateral collateral ligaments were significant risk factors for poor recovery.

Noronha reported 203 primary and 37 revision reconstructions using quadriceps tendon graft. Results were similar to those obtained with the BPTB used in 434 cases, with less morbidity. Magnetic resonance imaging, performed post-reconstruction, provided compelling evidence of the effectiveness of this graft.

Slullitel et al performed 40 ACL reconstructions using an arthroscopic full-thickness quadriceps tendon technique. All knees appeared stable at follow-up and patients were back to normal activities of daily living in 20 days. A significant decrease in anterior knee pain was reported.

Theut et al reported high patient satisfaction with little associated morbidity, and objective data collected at follow-up were encouraging.

**DISCUSSION**

Three main autologous graft choices are currently used for ACL reconstruction: patellar, hamstring, and quadriceps tendon. Regardless of fixation technique, clinical studies do not show major differences in clinical outcome among these grafts. Therefore, other factors, such as graft harvest morbidity, are more important when comparing different grafts.

The quadriceps tendon-bone graft is gaining popularity for primary as well as revision ACL surgery in Europe. The main reason is the high rate of chronic patellofemoral problems with the patellar tendon graft. Treating this complication is frustrating, and suturing the tendon gap or bone grafting the patellar defect does not reduce anterior knee problems and kneeling complaints.

Local discomfort in the donor site region after quadriceps tendon autograft is rare. In a series of 12 patients, Chen et al reported mild harvest site tenderness at average 18-month follow-up in 1 patient. Fulkerson and Langeland reported no early quadriceps tendon morbidity in their series of 28 patients. Both studies regarded the quadriceps tendon as a low-morbidity graft.

Yasuda et al reported postoperative quadriceps weakness as the main disadvantage. They reported 85% quadriceps strength in men at final follow-up. In women, quadriceps strength at final follow-up was 70%, significantly lower than preoperative strength.
In our experience with the quadriceps tendon, which is similar to others, an aggressive rehabilitation program, despite soft-tissue fixation of the tendon end of the graft, promotes patient compliance and quicker return to sports activities. Quadriceps tendon autograft should be the treatment of choice for patients whose jobs require kneeling or long periods of knee flexion. It should also be used for ACL reconstruction in cases of low patella, after Osgood-Schlatter syndrome, patellar tendinities, ACL revision surgeries, and multiple knee ligament injuries. Relative contraindication is in poorly motivated female patients where postoperative quadriceps weakness could impair the final result.

Harvest site morbidity is becoming a central issue for surgeons. In this scenario, quadriceps tendon is a reasonable alternative for ACL reconstruction and may, in the future, replace the patellar tendon as the main graft source for primary ACL reconstruction. Additional long-term clinical studies and improvement in the understanding of the optimal rehabilitation programs will increase the popularity of this procedure in the future.

REFERENCES