Combined anatomic reconstruction of the anterior cruciate and anterolateral ligaments

N. Maffulli1,2,3, F. Oliva1, A. Oliviero1

1 Department of Musculoskeletal Disorders, Faculty of Medicine and Surgery, University of Salerno, Salerno, Italy
2 Centre for Sports and Exercise Medicine, Barts and The London School of Medicine and Dentistry, Mile End Hospital, 275 Bancroft Road, London E1 4DG, UK
3 Institute of Science and Technology in Medicine, Keele University School of Medicine, Stoke on Trent ST4 8FB, England

SUMMARY
Despite the improvement of surgical techniques, up to 25% of all patients who undergo ACL reconstruction may experience residual rotational instability. The anterolateral ligament (ALL) of the knee is as a potential contributor to symptomatic residual anterolateral rotatory laxity in ACL-deficient patients. Indeed, combined ACL and ALL reconstruction significantly reduce the risk of ACL graft rupture, and prevents damage to the menisci and future knee osteoarthritis of the knee. Furthermore, complications are similar to those encountered when ACL reconstruction is performed alone. We report the procedure developed by the senior author to reconstruct the ACL and the ALL in a minimally invasive anatomical fashion.

KEY WORDS
anterolateral soft tissue structures of the knee; rotational instability; extra-articular reconstruction

BACKGROUND
The results of modern ACL reconstruction techniques are satisfactory and reliable, but a lack of rotational stability, confirmed by a positive pivot-shift test, often persists at clinical examination after ACL reconstruction (1). Indeed, up to 25% of all patients who undergo ACL reconstruction may experience residual rotational instability (2). In addition, untreated concomitant traumatic insufficiency of the anterolateral soft tissue structures may contribute to residual postoperative knee laxity (3). Extra-articular repair or reconstruction of the lateral knee anatomy (4) should therefore be considered.

Hughston et al. (5), in 1976, showed that acute and chronic anterolateral instability are both associated with damage at the mid-third of the lateral capsule and may be combined with a torn ACL. This combination may lead to anterolateral rotational instability.

In the past decade, combined intra- and extra-articular reconstruction procedures have been proposed to reduce anterolateral rotational instability (ALRI). Most extra-articular procedures collectively fall within the category of lateral extra-articular tenodesis (LET) procedures (6). Extra-articular procedures mechanically act on the peripheral soft tissues of the knee to prevent subluxation of the tibial plateau, and hence protect the ACL graft (7). However, concerns regarding the nonanatomic nature of LET procedures and the potential for overconstraint, resulting in early arthritis, and an increased risk of infections, led to a decrease in their popularity (8).

The anterolateral ligament (ALL) of the knee is as a potential contributor to symptomatic residual anterolateral rotatory laxity in ACL-deficient patients (1). Combined ACL and ALL reconstruction is currently the only type of lateral extra-articular procedure that has been demonstrated to significantly reduce the risk of ACL graft rupture and improve the rate of return to sports (9).

In 2007, Vieira (10) described the “capsulo-osseous” layer of the iliotibial band (ITB), naming it “the anterolateral ligament”. Claes et al. (11) described the anatomy of the ALL in 41 cadavers. They identified the ALL as a distinct ligamentous structure at the anterolateral aspect of the knee, with consistent origin and insertion sites. Specifically, the origin of the ALL was at the prominence of the lateral femoral epicondyle, slightly anterior to the origin of the lateral collateral ligament, and connecting fibres were observed between the two structures.
The ALL showed an oblique course to the anterolateral aspect of the proximal tibia, with firm attachments to the lateral meniscus, thus enveloping the inferior lateral genicular artery and vein. Its insertion on the anterolateral tibia was grossly located midway between Gerdy’s tubercle and the tip of the fibular head, definitely separate from the iliotibial band (ITB).

Since 2013, the anatomy, radiographic appearance, biomechanics and clinical relevance of the ALL were explored; Monaco et al. (12), in a cadaver experiment, cutting the ALL showed increasing tibial rotation which could be related to the pivot shift phenomenon. Parsons et al. (13) concluded that the ALL is an important stabilizer of internal rotation at flexion angles greater than 35°.

We report the procedure developed by the senior author to reconstruct the ACL and the ALL in a minimally invasive anatomical fashion.

**Indication**

1. Injury of the ALL and ACL diagnosed clinically and confirmed by magnetic resonance imaging (MRI) in the presence of grade III pivot shift;
2. Segond fracture;
3. ACL revision surgery.

**Surgical procedure**

We performed our investigation ethically according to international standards and as required by the journal (14). Under regional or general anaesthesia, the patient is supine with the knee flexed to 90° with a lateral upper thigh support and a sand bag under the foot, allowing the surgeon to mobilise the knee fully.

The anatomic landmark for the attachment and insertion of the ALL are identified (15). The femoral lateral epicondyle, the fibular head, Gerdy’s tubercle, the joint line, and the tibial insertion of the ALL are marked. The femoral origin of the ALL is about 5 mm posteriorly and proximally to the lateral collateral ligament (LCL), while the tibial insertion is located midway between the centre of Gerdy’s tubercle and the anterior aspect of the fibular head, about 25 mm posterior to the centre of the Gerdy’s tubercle, and 10 mm below the joint line. The length of the ALL is about 40 mm, and its tibial and femoral insertional areas are about 65 mm² each.

A single-incision endoscopic technique is used with anteromedial and anterolateral arthroscopy portals and a gravity saline irrigation of the joint.

After a routine arthroscopic examination of the knee, the gracilis and semitendinosus tendons are harvested in the standard fashion, through a vertical 2 cm long incision centred 2.5 cm medial and 2 cm distal to the medial margin of the anterior tibial tuberosity, with an open tendon stripper. Before using the tendon stripper, the hamstring tendons are carefully dissected from bands which may divert the tendon stripper and result in premature graft truncation. The semitendinosus tendon is tripled and the gracilis tendon is left long. The proximal portion of the graft, which includes the triplicate semitendinosus and the first part of the gracilis, is sutured using n. 1 Ethibond sutures (Ethicon, Edinburgh, United Kingdom). The proximal 25 mm of the free end of the gracilis tendon graft is whip-stitched using n. 1 Ethibond sutures suture (figure 1).

The femoral tunnel is drilled prior to drilling the tibial tunnel. The femoral tunnel is produced in an outside-inside fashion, using a standard guide for PCL through the anterolateral portal, just posterior and distal to the lateral epicondyle, about 5 mm posterior and proximal to the lateral collateral ligament (LCL). The femoral tunnel enters the knee joint in the posterior third of Blumensaat’s line, in the middle of the area of femoral origin of the ACL. The tibial tunnel is produced in an outside-inside fashion with a 55° angled tibial guide, entering the knee joint in the anterior half of the middle third of the tibial plateau.

Figure 1 - The proximal portion of the graft includes the triplicate semitendinosus and the first part of the gracilis, while the distal portion includes the remaining part of the gracilis tendon.
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On the AP view, the lateral margin of the tibial tunnel is at the centre of the intercondylar notch, which is the highest point of the intercondylar notch.

A suture loop is used by passing a n. 2 Ethibond suture (Ethicon, Edinburgh, United Kingdom) in a retrograde fashion from the femoral tunnel to the tibial tunnel, and used for graft passage;

The graft is passed, without detaching its tibial insertion, thereby improving its fixation and vascularization, through the tibial and femoral tunnel, so that the part of the graft constituted by the tripled semitendinosus and the distal portion of the gracilis reconstruct the ACL, while the remaining part of the gracilis tendon is used to reconstruct percutaneously the ALL (figure 2).

The graft is secured into the tibial tunnel under tension as it exits the femoral tunnel, using a non-metallic round-head, cannulated 8 x 25 mm interference screw (RCI, Smith and Nephew Endoscopy, Andover, Massachusetts, USA). Then, with the knee at 30° of flexion and in external rotation the graft is tensioned again, and subsequently the femoral side is secured using a non-metallic round-head, cannulated 7 x 25 mm interference screw (RCI, Smith and Nephew Endoscopy, Andover, Massachusetts, USA).

The part of the gracilis tendon which emerges from the femoral tunnel will constitute the new ALL ligament. For the ALL reconstruction, a tunnel (30 mm long) is produced at the site of the tibial insertion of the ALL.

A small incision is performed on the tibial insertion of the ALL about 20 mm posterior to the centre of the Gerdy’s tubercle, and 10 mm below the joint line. The guidewire is inserted in the tibia from postero-lateral to antero-medial. A reamer is inserted, to just breach the tibial cortex taking care to avoid the tibial tunnel of the ACL reconstruction. This step can be checked using the image intensifier. Following successful breach, the tunnel is sequentially enlarged, if necessary, using the same careful technique, with larger diameter drills until a tunnel of the correct diameter, equivalent to the graft diameter, is produced.

A grasper is placed underneath the ITB from the tibial incision to the femoral incision (femoral emergence of the ACL tunnel) and is used to retrieve the suture ends from the whipstitched end of the gracilis tendon and used to shuttle the graft under the ITB (figure 3).

A suture loop is employed by passing a n. 2 Ethibond suture (Ethicon) in a retrograde fashion from the antero-medial part of the tibial tunnel for the ALL to the postero-lateral portion.

The suture tails from the whipstitched end of the gracilis tendon are passed into this loop to allow the passage of the ALL graft through the tunnel.

The graft is tensioned with the knee in full extension and neutral rotation, and fixed at tibia, with a non-metallic interference screw 7 x 30 mm (RCI, Smith and Nephew Endoscopy, Andover, Massachusetts, USA). The excess part of the graft is eliminated. Combined ACL and ALL reconstruction is shown in figure 4.

Post-operative management

Rehabilitation begins as soon as possible with the same protocol used for ACL reconstruction. In the early postoperative period, patients should be encouraged to keep the leg elevated and to move every joint of the lower limb when not weight-bearing. Cryotherapy is encouraged. Isometric quadriceps contraction with a straight leg and rise with the knee extended are performed as soon as the patient is able.

Patients can start walking with crutches, weight bearing as tolerated immediately after the procedure. We do not use post-operative splinting of the operated knee.
Extra-articular reconstruction provides additional reduction of the pivot shift as compared with intra-articular reconstruction alone. This procedure allows the combined anatomical reconstruction of the ACL and the ALL, reproducing the anatomical attachment and insertion sites of the ALL (15).

The aim of surgical reconstruction of the ACL and ALL is to restore normal joint kinematics, thereby eliminating rotational instability and the potential for associated damage to the menisci and chondral surfaces.

The ALL is not isometric, exhibiting different change patterns during knee flexion and internal tibial rotation at 90°. An attachment proximal and posterior to the lateral femoral epicondyle is the only favourable position, so that will be tight in extension and in internal rotation at 20°, and then relaxed when the knee goes to flexion at 120° and during internal rotation at 90° (19).

If the reconstructed ALL is attached 4 mm posterior and 8 mm proximal to the lateral epicondyle, it exhibits the least tension change, with only a slight increase in tension as the knee extends. This site is recommended for ALL reconstruction to better control anterolateral rotational instability (ALRI) (20).

The gracilis tendon is appropriate; other autologous and artificial graft choices provide a sufficient load to failure to replace the ALL, but the ultimate tension of the gracilis tendon matches the ALL (22).

The maximum load to failure for the ALL was 141 N, 200.7 N for the duplicated gracilis, and 161.1 N for the ITB; the stiffness was 21 N mm⁻¹ for the ALL, 131.7 N mm⁻¹ for the ITB.
mm\(^4\) for the gracilis and 39.9 N mm\(^4\) for the ITB; the elongation at failure was 6.2 mm for the ALL, 19.9 mm for the gracilis and 20.8 mm for the ITB. Therefore, the tendon of gracilis had the highest maximum load to failure, while the mechanical properties of the ITB most closely resemble those of the ALL (22).

Combining a modified lateral tenodesis with intra-articular ACL reconstruction to prevent persistent rotational instability produces mixed outcomes, with many series unable to demonstrate any additional clinical benefits of anterolateral tenodesis over intra-articular reconstruction (23). Consequently, there remains a healthy scepticism regarding the utility of ALL reconstruction. Despite this, a combined procedure is still considered a useful option for revision ACL cases and in patients with high-grade rotational instability (2). We consider combined ACL and ALL reconstruction in such patients, as well as in elite athletes, or those with hypermobility. Several clinical studies demonstrate improved stability and outcomes in patients following ACL reconstruction with extra-articular lateral augmentation, including the MacIntosh modified Coker procedure with autologous iliotibial tract (3); the over-the-top technique with a combined autologous semitendinosus and gracilis graft (24), and various techniques in combination with revision ACL reconstruction (25).

The procedure described uses the ipsilateral gracilis tendon. In this way the iliotibial band, another important structure in controlling rotational stability, is not weakened.

**CONCLUSION**

ALL reconstruction performed in concert with ACL reconstruction allows to restore the rotational stability of the knee and prevent damage to the menisci and future knee osteoarthritis of the knee. Furthermore, it is associated with a significant reduction in ACL graft rupture rates, no increase in the risk of reoperation, and a very low rate of complications. The procedure described is safe and reproducible.

**REFERENCES**


