Minimally invasive anatomic reconstruction of the anterolateral ligament with ipsilateral gracilis tendon

Giovanni Felice Trinchese[1]
Francesco Oliva[2]
Nicola Maffulli[4]

[1] Department of Orthopaedics and Traumatology, "San Francesco d'Assisi" Hospital, Oliveto Citra (SA), Italy
[2] Department of Orthopaedics and Traumatology, University of Rome "Tor Vergata", Rome, Italy
[4] Department of Musculoskeletal Surgery, Azienda Ospedaliera San Giovanni di Dio e Ruggi d'Aragona, University of Salerno, Italy; Queen Mary University of London, Barts and the London School of Medicine and Dentistry, Centre for Sports and Exercise Medicine, Mile End Hospital, London, UK

Corresponding author:
Giovanni Felice Trinchese
Department of Orthopaedics and Traumatology,
"San Francesco d'Assisi" Hospital
Via Michele Clemente
84020 Oliveto Citra (SA), Italy
E-mail: giovtrin@libero.it

Summary

Background: **There has been much interest in understanding the anatomy and biomechanics of the anterolateral ligament (ALL). Several reconstruction procedures have been proposed to correct rotatory instability after Anterior Cruciate Ligament (ACL) and anterolateral soft tissues injuries.**
Methods: **We propose a new anatomic minimally invasive ALL reconstruction using the ipsilateral gracilis tendon. Through small skin incisions, the femoral attachment and the tibial insertion of the ALL can be identified, and half tunnels drilled. Then, the neo-ligament can be passed under the fascia lata into the tunnels. Fixation to the tibia is accomplished with a biotenodesis screw, and to the femur with a TightRope RT (Arthrex).**
Conclusion: **This procedure allows to reconstruct in a minimally invasive fashion the ALL in selected patients with chronic anterolateral instability in ACL deficient knees.**

Level of evidence: V.

KEY WORDS: anterolateral ligament, anterolateral knee capsule, rotatory instability, knee, ACL reconstruction, knee arthroscopy.

Background

The management of ACL tears is widely studied and debated[1], as, after an ACL reconstruction, many patients may still report residual rotational instability[2]. ACL reconstruction may not entirely restore normal rotatory control, leading to residual pathologic laxity[3]. In addition, untreated concomitant traumatic insufficiency of the anterolateral soft tissue structures may contribute to residual postoperative knee laxity[4], and extra-articular repair or reconstructions of the lateral knee anatomy[5-9] should therefore be considered. The ALL may be the key to restoring appropriate rotatory stability of the knee joint[10].
The anterolateral ligament of the knee was first described by the French surgeon Segond in 1879[11] as a "pearly, resistant, fibrous band". Hughston et al., 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 (ALRI)[12]. The concepts outlined by Hughston et al. were not exploited until 2007, when Vieira described the "capsulo-osseous" layer of the iliotibial band (ITB), naming it "the anterolateral-ligament"[13]. Vincent et al. during total knee arthroplasty procedures, observed a substantial tissue band on the lateral aspect of the knee; this band linked the lateral femoral condyle, the lateral meniscus and the lateral tibial plateau[14]. Finally Claes et al. described the anatomy of the anterolateral ligament in 41 cadavers[15]. Since 2013, the anatomy, radiographic appearance, biomechanics and clinical relevance of the ALL were explored[16-20]. Monaco et al., in a cadaver experiment, cutting the ALL, showed increasing tibial rotation which could be related to the pivot shift phenomenon[21]. Parsons et al. concluded that the ALL is an important stabilizer of internal rotation at flexion angles greater than 35°[22]. We have developed a new minimally invasive procedure to reconstruct anatomically the ALL. A duplicated ipsilateral gracilis tendon autograft is used to fully cover the femoral and tibial ALL footprints to restore physiologi-

Figure 1. Anatomical landmark: Gerdy's tubercle, fibular head, lateral epicondyle, and joint line.

cal rotational stability. A cortical suspension device with variable loop for femoral fixation allows optimal control of the tension of the neo-ligament.

Methods

Indication

1. Injury of the ALL identified by magnetic resonance imaging (MRI);
2. Segond fracture;
3. Pivot shift classified as grade III;
4. ACL revision surgery[23, 24].

Surgical Procedure

Under regional or general anaesthesia, the patient is supine with 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. After a routine arthroscopic examination of the knee, the hamstring tendons are harvested in the standard fashion.

The semitendinosus tendon is tripled or quadrupled and used for ACL reconstruction. The reconstructed ACL is not tensioned in this phase.

The anatomic landmark for the attachment and insertion of the ALL are identified[19]. The femoral lateral epicondyle, the fibular proximal head, the Gerdy's tubercle, the joint line, and the tibial insertion of the ALL are marked (Fig. 1). 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 in the middle 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 mm^2 each. The gracilis tendon is prepared with not absorbable stiches (FiberWire N.2) and double to a length of at least 80 mm. The tendon is assembled on a TightRope RT (Arthrex, Naples, FL, USA), which will fix into the femur the neo ligament (Fig. 2). A Kirschner wire is inserted through a small cutaneous incision from lateral to medial femoral side, at the anatomic attachment of the ALL (Fig. 3). Firstly, a 4 mm tunnel is drilled with a cannulated drill, and after that a half tunnel, wide enough to for the duplicated gracilis (usually 5 mm) and 25 mm deep, is produced at the femoral attachment (Fig. 4). A half tunnel (20 mm long; 5 mm wide) is produced at the tibial insertion of the ALL (Fig. 5). The neo ligament is fixed at tibia with a 6.25 x 15 mm Biotenodesis screw (Arthrex, Naples, FL, USA) (Fig. 6) and then passed under the fascia lata with a shuttle suture (Fig. 7). At this point, the TightRope RT is inserted into the femoral tunnel, and fixed on the femoral medial cortex, and tensioned at 30° of knee flexion (Fig. 8 a-c). After that, the ACL is tensioning

Figure 2. The gracilis tendon is prepared with non absorbable sutures and duplicated on a ThightRope RT.

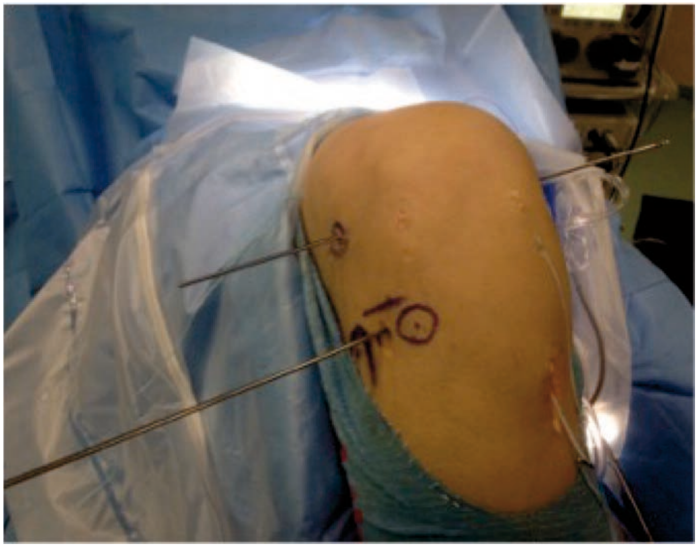

Figure 3. A Kirschner wire is inserted at the anatomic attachment and insertions of the ALL on the femur and tibia.

Figure 4. A half-tunnel 25 mm deep and 5 mm in diameter is drilled at the femoral site.

Figure 5. A half-tunnel 20 mm deep and 5 mm in diameter is drilled at the tibial site.

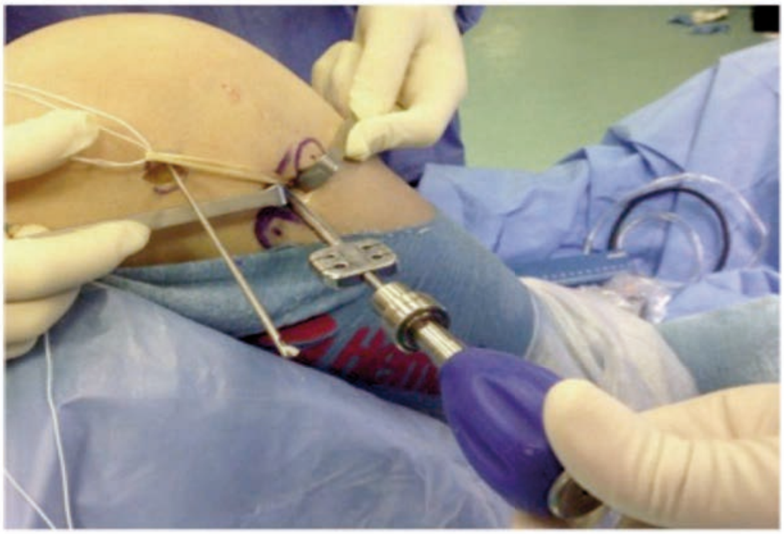

Figure 6. The graft is fixed at tibial site using a biotenodesis screw.

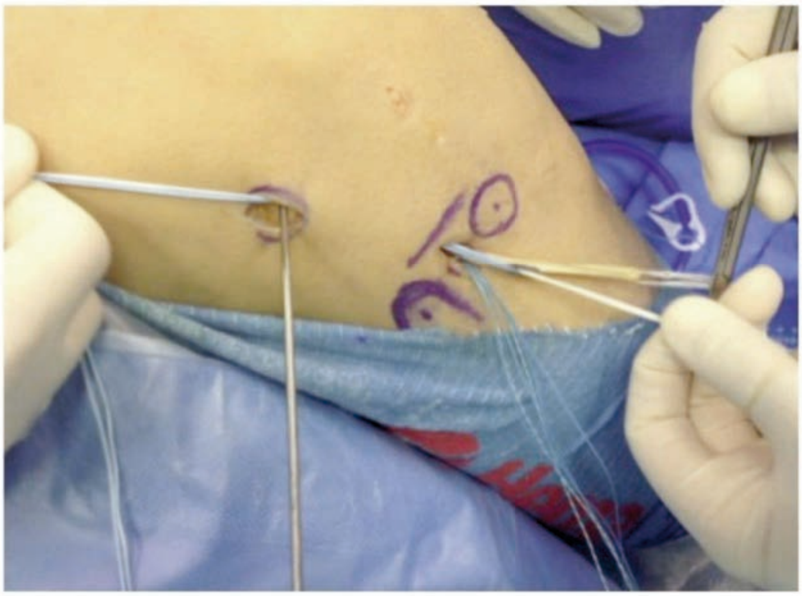

Figure 7. The TightRope RT and the graft are passed under the fascia lata.

with the knee near the extension. If the tension imparted by the TightRope RT to the neo-ALL is not adequate, it can be adjusted accordingly (Fig. 9).

Postoperative management

Rehabilitation begins as soon as possible, and does not differ from the protocol used for ACL reconstruction. In the early postoperative period, patients should be encouraged to keep the leg elevated when not weight-bearing. Cryotherapy is encouraged. The first step is quadriceps contraction with a straight leg rise without an extension lag. A continuous passive motion device can be helpful. The day after the procedure, the patient can start walking with crutches weight bearing as tolerated with the knee in a four point splint.

Risks

Complications are in line with ACL reconstruction. In addition, overconstraint of the knee joint should be avoided[25].

Discussion

It is necessary to restore the anatomy and the biomechanical properties of the ALL to optimise reconstruction procedures, including proper graft selection and

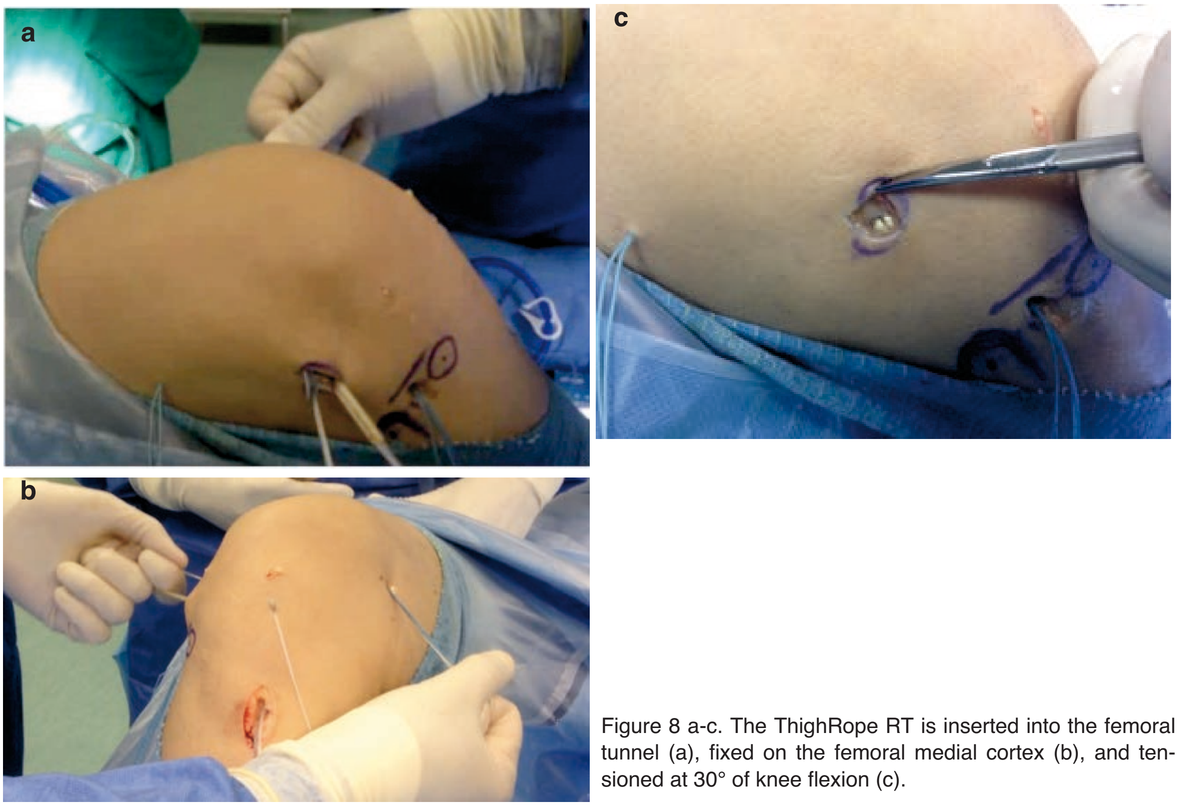

Figure 8 a-c. The ThighRope RT is inserted into the femoral tunnel (a), fixed on the femoral medial cortex (b), and tensioned at 30° of knee flexion (c).

Figure 9. The ThighRope's tension can be modulated as required.

fixation. In the procedure reported in this article, the anatomical attachment and insertion sites of the ALL are accurately reproduced[19].

The graft attachment and insertion points, and therefore the course of the graft, affect length change pattern during knee motion. A graft attached proximal to the lateral femoral epicondyle and running deep to the lateral collateral ligament will provide desirable graft behavior, without excessive tightening or slackening during knee motion[26].

The ALL does not maintain isometry, and exhibits different length change patterns during knee flexion and internal tibial rotation at 90°. An attachment proximal and posterior to the lateral femoral epicondyle is the only position with a favourable isometry, being 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° [27].

If the reconstructed ALL is attached 4 mm posterior and 8 mm proximal to the lateral epicondyle, it had the least tension change, with only a slight increase in tension as the knee extended. This site is recommended for ALL reconstruction to better control anterolateral rotational instability (ALRI)[28].

The gracilis tendon in our hands is appropriate; all 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[29, 30].

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 gracilis and 39.9 N mm^{-1} 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[31]. We prefer to use a duplicate ipsilateral gracilis tendon because it does not weaken the iliotibial band, which represents another important anatomical structure of the anterolateral anatomy of the knee in controlling rotational stability. Regarding graft fixation, appropriate biomechanical tests are still necessary to evaluate which device is the best for ALL reconstruction. A biotenodesis screw at the tibia and a TightRope RT at the femur produce a suspension and sliding effect, allowing to modulate the strenght until the optimal tension is reached. The study meets the ethical standards of the journal[32].

Conclusion

ALL reconstruction should be performed in concert with ACL reconstruction, to restore rotational stability of the knee and prevent damage to the menisci and future knee osteoarthritis. The procedure described is safe and reproducible. A duplicate ipsilateral gracilis tendon allows to better cover the femoral attachment and tibial insertion areas of the native ALL, and to have a graft that better resists to the rotational forces. Furthermore, the use of a cortical suspension sliding device for femoral fixation allows optimal control of the tension of the neo-ligament. Obvioulsy, longitudinal studies are necessary to evaluate the long-term outcome after this procedure.

References

1. Mall NA, Chalmers PN, Moric M, et al. Incidence and trends of anterior cruciate ligament reconstruction in the United States. Am J Sports Med. 2014;42(10):2363-2370.
2. Sonnery-Cottet B, Thaunat M, Freychet B, Pupim BH, Murphy CG, Claes S. Outcome of a combined anterior cruciate ligament and anterolateral ligament reconstruction technique with a minimum 2-year follow-up. Am J Sports Med. 2015;43(7):1598-1605.
3. Chambat P, Guier C, Sonnery-Cottet B, Fayard JM, Thaunat M. The evolution of ACL reconstruction over the last fifty years. Int Orthop. 2013;37:181-186.
4. Vadalà AP, Iorio R, De Carli A, et al. An extra-articular procedure improves the clinical outcome in anterior cruciate ligament reconstruction with hamstrings in female athletes. Int Orthop. 2013 Feb;37(2):187-192.
5. Saragaglia D, Pison A, Refaie R. Lateral tenodesis combined with anterior cruciate ligament reconstruction using a unique semitendinosus and gracilis transplant. Int Orthop. 2013;37(8):1575-1581.
6. Lutz C, Sonnery-Cottet B, Imbert P, Barbosa NC, Tuteja S, Jaeger JH. Combined Anterior and Anterolateral Stabilization of the Knee With the Iliotibial Band. Arthrosc Tech. 2016 Apr;5;2:e251-e256.
7. Chahla J, Menge TJ, Michell JJ, Dean CS, LaPrade RF. Anterolateral ligament reconstruction technique: An anatomical-based approach. Arthrosc Tech. 2016;5:e453-e457.
8. Helito CP, Bonadio MB, Gobbi RG, et al. Combined intra- and extra-articular reconstruction of the anterior cruciate ligament: The reconstruction of the anterolateral ligament. Arthrosc Tech. 2015;4:e239-e244.
9. Sonnery-Cottet B, Barbosa NC, Tuteja S, Daggett M, Kajetanek C, Thaunat M. Minimally invasive antero-lateral ligament reconstruction in the setting of anterior cruciate ligament injury. Arthrosc Tech. 2016;5:e211-e215.
10. Spencer L, Burkhart TA, Tran MN, Rezansoff AJ, Deo S, Caterine S, Getgood AM. Biomechanical analysis of simulated clinical testing and reconstruction of the anterolateral ligament of the knee. Am J Sports Med. 2015 Sep;43(9):2189-2197.
11. Segond P. Recherch scliniques et experimentales sur les èpanchements sanguins du genou par entorse. Progrès Mèdical (Paris). 1879;85.
12. Hughston JC, Andrews JR, Cross MJ, et al. Classification of knee ligament instabilities. Part I. The medial compartment and cruciate ligaments. J Bone Joint Surg Am. 1976;58:159-172.
13. Vieira EL, Vieira EA, da Silva RT, Berlfein PA, Abdalla RJ, Cohen M. An anatomic study of the iliotibial tract. Arthroscopy. 2007 Mar;23(3):269-274.
14. Vincent JP, Magnussen RA, Gezmez F, et al. The anterolateral ligament of the human knee: an anatomic and histologic study. Knee Surg Sports Traumatol Arthrosc. 2012;20:147-152.
15. Claes S, Vereecke E, Maes M, Victor J, Verdonk P, Bellemans J. Anatomy of the anterolateral ligament of the knee. J Anat. 2013;223(4):321-328.
16. Caterine S, Litchfield R, Johnson M, Chronik B, Getgood A. A cadaveric study of the anterolateral ligament: re-introducing the lateral capsular ligament. Knee Surg Sports Traumatol Arthrosc. 2015 Nov;23(11):3186-3195.
17. Dodds AL, Halewood C, Gupte CM, Williams A, Amis AA. The anterolateral ligament: Anatomy, length changes andassociation with the Segond fracture. Bone Joint J. 2014;96-B:325-331.
18. Helito CP, Demange MK, Bonadio MB, et al. Anatomy and Histology of the knee anterolateral ligament. Orthop J Sports Med. 2013 Dec 9;1(7):2325967113513546.
19. Kennedy MI, Claes S, Fuso FAF, et al. The Anterolateral Ligament: an Anatomic, Radiographic, and Biomechanical Analysis. Am J Sports Med. 2015;43:1606-1615.
20. Daggett M, Ockuly AC, Cullen M, et al. Femoral origin of the anterolateral ligament: an anatomic analysis. Arthroscopy. 2016;32(5):835-841.
21. Monaco E, Ferretti A, Labianca L, et al. Navigated knee kinematics after cutting of the ACL and its secondary re-

straint. Knee Surg Sports Traumatol Arthrosc. 2012;20: 870-877.
22. Parsons EM, Gee AO, Spiekerman C, Cavanagh PR. The biomechanical function of the anterolateral ligament of the knee. Am J Sports Med. 2015;43:669-674.
23. Ferreira M, Zidan F, Miduati FB, Fortuna CC, Mizutani BM, Abdalla RJ. Reconstruction of anterior cruciate ligament and anterolateral ligament using interlinked hamstrings - technical note rev bras ortop. 2016;51(4):466-470.
24. Daniel DM, Fithian DC. Indications for ACL surgery. Arthroscopy.1994;10(4):434-441.
25. Schon JM, Moatshe G, Brady AW, et al. Anatomic Anterolateral Ligament Reconstruction of the Knee Leads to Overconstraint at Any Fixation Angle. Am J Sports Med. 2016 Oct;44(10):NP58-NP59.
26. Kittl C, Halewood C, Stephen JM, et al. Length change patterns in the lateral extra-articular structures of the knee and related reconstructions. Am J Sports Med. 2015;43:354-362.
27. Imbert P, Lutz C, Daggett M, Niglis L, Freychet B, Dalmay F, Sonnery-Cottet B. Isometric characteristics of the anterolal ligament of the knee: a cadaveric navigation study. Arthroscopy. 2016;32(10):2017-2024.
28. Katakura M, Koga H, Nakamura K, Sekiya I, Muneta T. Effects of different femoral tunnel positions on tension changes in anterolateral ligament reconstruction. Knee Surg Sports Traumatol Arthrosc. 2016 May 25. [Epub ahead of print].
29. Zens M, Feucht MJ, Ruhhammer J, ET AL. Mechanical tensile properties of the anterolateral ligament. J Exp Orthop. 2015 Dec;2(1):7.
30. Helito CP, Bonadio MB, Rozas JS, et al. Biomechanical study of strength and stiffness of the knee anterolateral ligament. BMC Musculoskeletal Disorders. 2016 Apr 30;17:193.
31. Wytrykowski K, Swider P, Reina N, et al. Cadaveric Study Comparing the Biomechanical Properties of Grafts Used for Knee Anterolateral Ligament Reconstruction. Arthroscopy. 2016 Nov;32(11):2288-2294.
32. Padulo J, Oliva F, Frizziero A, Maffulli N. Muscles, Ligaments and Tendons Journal - Basic principles and recommendations in clinical and field science research: 2016 update. MLTJ. 2016;6(1):1-5.