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Combined anterolateral ligament and anatomic anterior cruciate ligament reconstruction of the knee

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Abstract Although anatomic anterior cruciate ligament (ACL) reconstruction is established for the surgical treatment of anterolateral knee instability, there remains a significant cohort of patients who continue to experience post-operative instability. Recent advances in our understanding of the anatomic, biomechanical and radiological characteristics of the native anterolateral ligament (ALL) of the knee have led to a resurgent interest in reconstruction of this structure as part of the management of knee instability. This technical note describes our readily reproducible combined minimally invasive technique to reconstruct both the ACL and ALL anatomically using autologous semitendinosus and gracilis grafts. This method of ALL reconstruction can be easily integrated with all-inside ACL reconstruction, requiring minimal additional operative time, equipment and expertise.
Level of evidence V.

Keywords Knee · Anterolateral ligament (ALL) · Anatomy · Reconstruction · Anterior cruciate ligament (ACL) · Technique

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Introduction

Although the existence of the anterolateral ligament (ALL) was first described in anatomic studies over a century ago, a full appreciation of its functional importance in normal and sporting activities is still being established [3, 14, 19, 20, 29, 32, 35, 36]. Recent progress has been made in reconstructing the unstable knee, but this has mainly concentrated on restoring the mechanical constraints of the cruciate and collateral ligaments, with little consideration for the potential of the ALL itself as a key supportive structure [5, 26]. Cruciate ligament reconstruction alone can provide excellent clinical outcomes; however, a significant proportion of patients continue to suffer from rotational instability post-operatively, with many patients unable to return to their pre-injury level of sporting activity [2]. Furthermore, even when the cruciate ligaments are reconstructed anatomically, the procedure does not prevent the progression to early secondary osteoarthritis [21]. Although its function remains controversial, a new appreciation for the existence of the ALL as a distinct anatomic structure with the potential to confer rotational stability to the knee, has led several groups to advocate refinements to previous extra-articular ligament reconstruction techniques to more precisely restore the kinematics of the native knee [8, 15]. It is proposed that these procedures, when used in conjunction with arthroscopic anatomic anterior cruciate ligament (ACL) reconstruction, will be particularly beneficial to those patients who present with both anterolateral and rotatory knee instability or who remain unstable despite standard ligament reconstruction.

The senior author has developed a minimally invasive anatomic technique with which to reconstruct the anterolateral corner of the knee using gracilis tendon autograft, in conjunction with 'all-inside' quadrupled semitendinosus

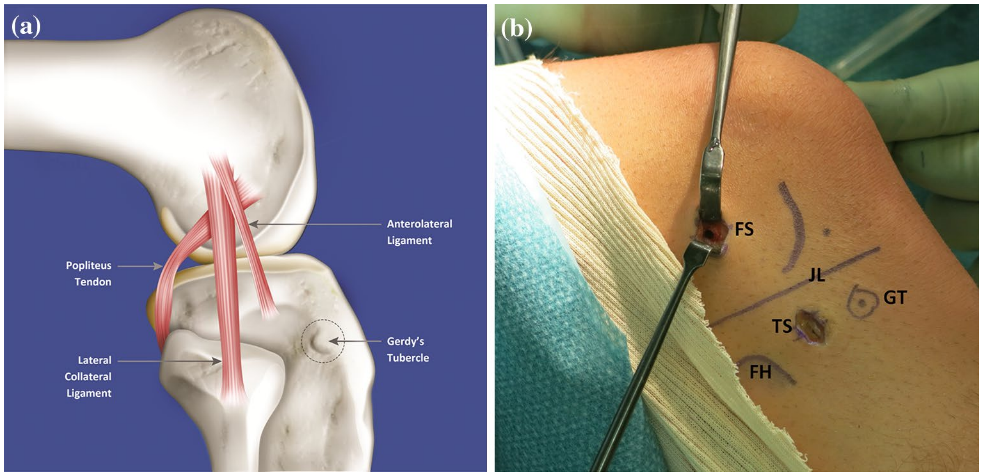

Fig. 1 **a** Schematic and **b** operative image of the lateral aspect of the right knee demonstrating the relationship of the anterolateral and lateral collateral ligaments to the joint. The joint line (*JL*) has been identified with a hypodermic needle, the femoral socket (*FS*) position is defined by the lateral femoral epicondyle, and the tibial socket (*TS*) position is defined by a point equidistant between the fibular head (*FH*) and Gerdy's tubercle (*GT*), 11 mm below the joint level

ACL reconstruction [24, 40]. Advantages of this combined technique include the requirement to harvest only a single set of hamstring tendons, as well as providing a consistent, facile method for identification of the anatomic position of the ALL using topographical landmarks. Consequently, this additional procedure only moderately increases tourniquet time in our practice.

Technical note

Examination under anaesthesia is performed to confirm a significant rotatory instability and exclude collateral or posterolateral corner laxity. The patient is then positioned supine with the knee supported and flexed to 90°. A thigh tourniquet is inflated throughout the procedure. Both gracilis and semitendinosus tendons are harvested in the usual manner through an oblique incision over the pes anserinus. A whipstitch of high-tensile-strength non-absorbable suture (No. 0 Fiberwire, Arthrex, Naples, FL) is applied to the harvested end of the gracilis tendon to prepare this end for later insertion into the tibial socket. The attached distal gracilis is then excised from its insertion on the pes anserinus.

Positions for the graft fixation sockets on the femur and tibia are identified and marked on the skin: the femoral socket position is located immediately anterior to the lateral femoral epicondyle. The tibial socket position is defined by a point equidistant between the fibular head and Gerdy's tubercle (routinely this distance is approximately 22 mm from the centre of Gerdy's tubercle) and 11 mm below the joint level. The exact level of the joint can be located with a hypodermic needle (Fig. 1).

For the femoral socket, a small transverse skin incision is made over the lateral femoral epicondyle and the lateral collateral ligament (LCL) is identified. A 2.4 mm guidewire is advanced anteriorly and proximally from its entry point just anterior and superior to the LCL. A 4.5 mm cannulated drill is passed over the guidewire to a depth of approximately 25 mm to fully accommodate a bone anchor. Careful soft tissue clearance at the entrance of the socket ensures easy subsequent graft and anchor passage. A small longitudinal skin incision is made over the site of the tibial socket, and subcutaneous tissue is sharply dissected down to bone. The 2.4 mm guidewire is advanced medially and slightly inferiorly into the tibia, and the 4.5 mm cannulated drill is again passed to a depth of 25 mm. The prepared gracilis graft is kept moist, whilst the semitendinosus graft is prepared as a GraftLink construct for anatomic all-inside ACL reconstruction as previously described [24, 40]. Following ACL reconstruction, the ALL graft is secured into its bone sockets using an appropriate tap and either 4.75 or 5.5 mm diameter bioabsorbable fully threaded knotless anchors (SwiveLock BioComposite, Arthrex), depending on the diameter of the graft. Although we initially secured the graft into the distal (tibial) socket first (as seen in the video demonstration[1]), we have since found it is easier to tension the graft from the tibial end having first secured the whipstitched end into the femoral socket. The sutures are threaded through the hole at the tip of the graft fixation

[1] An online video demonstration of this combined technique can be viewed at: https://www.vumedi.com/video/combined-all-inside-acl-anterolateral-ligament-reconstruction/.

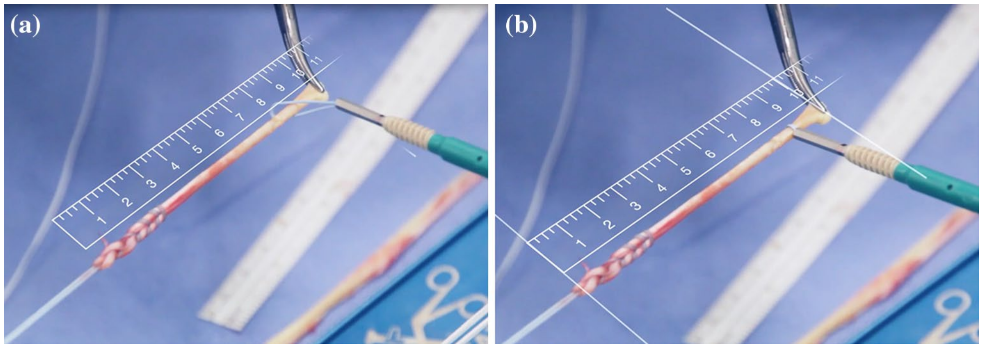

Fig. 2 A fixation anchor is modified by passing a loop of high-tensile-strength non-absorbable suture through the length of the anchor and its insertion tool, to act as a snare for subsequent attachment around the selected point of the graft. The snare suture is passed over the graft (**a**) so that the anchor can be locked into place (**b**) in the desired position along the graft, by applying tension to the snare loop

anchor so that the graft is held snug against the anchor, which is then secured within the femoral socket and deployed. The distal end of the ALL gracilis graft is then passed deep to the iliotibial band and delivered through the distal skin incision.

The distal anchor is modified by passing a loop of high-tensile-strength non-absorbable suture (No. 0 Fiberwire, Arthrex) through the length of the anchor and its insertion tool with a suture passer, to act as a snare for subsequent attachment along the distal end of the graft. This snare suture is passed over the graft and locked into place approximately 70 mm from the femoral insertion, by applying tension to the snare loop (Fig. 2).

Final graft tensioning is performed with the knee at 30° flexion and the foot in neutral rotation. The graft tension can be palpated and adjusted by sliding the snare suture along the graft and fully inserting the graft into the socket before committing with the graft fixation anchor. The fixation is assessed for tension and strength by cycling the knee several times before finally cutting the suture ends. The incisions and hamstring harvest tract are infiltrated with local anaesthetic [23], before closure with absorbable subcuticular sutures and application of impermeable skin dressings. Radiographs are taken post-operatively to verify fixation position (Fig. 3). Table 1 summarises the steps involved in the technique.

Discussion

Historically, the ALL was considered a condensation of capsule or fibrous tissue around the knee, being described by Segond in relation to the eponymous fracture associated with avulsion from its insertion into the lateral tibia [32] (Fig. 3). The identification of a Segond fracture has since been used as a diagnostic tool for its pathognomonic association with ACL rupture, although the benefits of anatomic reconstruction of this ligament had not been recognised [6, 11]. Reconstruction of the unstable knee has instead concentrated on restoring the mechanical constraints of the cruciate and collateral ligaments [26].

Before the advent of arthroscopic reconstructive knee surgery, several extra-articular lateral tenodesis techniques were employed to limit the pivot glide in the unstable knee [10, 14, 16, 22, 25]. These procedures were non-anatomic, required extensile approaches, frequently over constrained the lateral side of the knee and often left unacceptable residual instability [27], so were largely abandoned in favour of newer intra-articular ACL reconstruction techniques [5]. Early attempts to combine a modified lateral tenodesis with intra-articular ACL reconstruction to prevent persistent rotational instability had mixed outcomes, with many series unable to demonstrate an additional benefit of anterolateral tenodesis over intra-articular reconstruction in their patient groups [1, 34]. Consequently, there remains a significant 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 [5, 26]. We consider combined ACL and ALL reconstruction in such cases, as well as in elite athletes, or those with hypermobility. Several clinical studies have now demonstrated improved stability and outcomes in patients following ACL reconstruction with extra-articular lateral augmentation including: the MacIntosh modified Coker procedure with autologous iliotibial tract [38]; the over-the-top technique with a combined autologous semitendinosus and gracilis graft [41] and with various techniques in combination with revision ACL reconstruction [37]. Furthermore, a new appreciation for the existence of the ALL, as a distinct anatomic structure with the function to confer rotational stability to the knee, has led to refinement of these previous techniques in conjunction with anatomic arthroscopic ACL reconstruction, to more faithfully restore the kinematics of

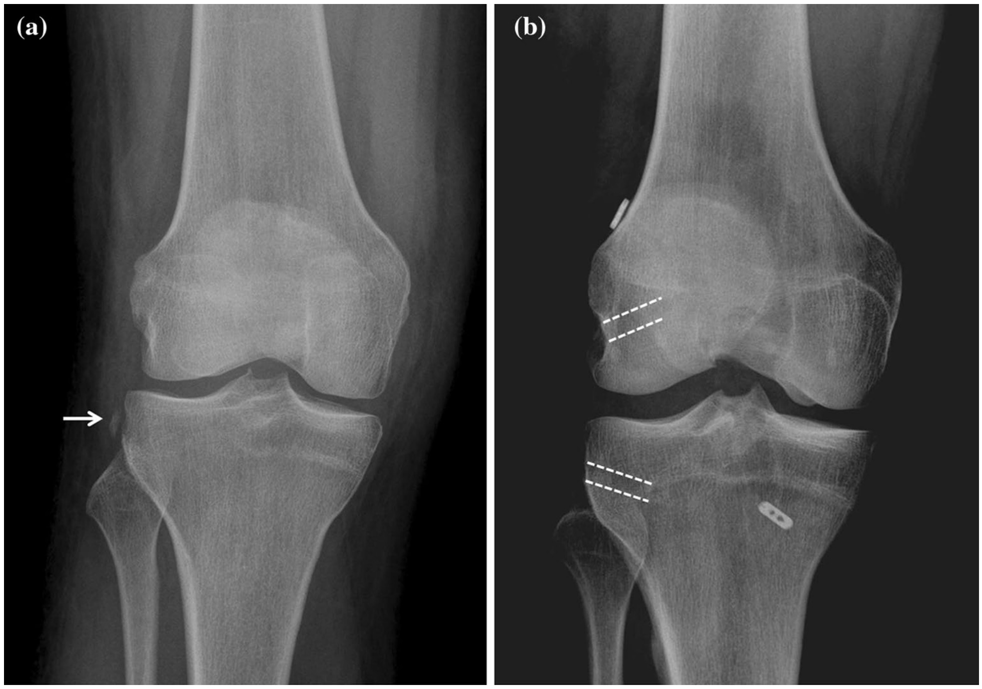

Fig. 3 AP radiographs of a right knee following a twisting injury, **a** demonstrating a Segond avulsion fracture at the insertion of the ALL (*arrow*), **b** post-operatively, following combined ALL and all-inside ACL reconstruction (ALL fixation sockets marked by *dashed lines*)

Table 1 Key steps involved in the combined anterolateral ligament and anatomic anterior cruciate ligament reconstruction technique

Step	Procedure	Notes
1	Examination of knee under anaesthesia	To confirm indication and exclude concomitant injury
2	Hamstring harvest	Ipsilateral gracilis tendon is used
3	Whipstitch free end of gracilis tendon graft	No. 0 non-absorbable suture
4	Distal end of graft detached at pes anserinus	Ensure all muscle is removed from graft, keep moist
5	Fixation points identified and marked on skin	See Fig. 1 for landmarks
6	Transverse incision for femoral socket	Careful preservation of LCL and soft tissue clearance
7	Femoral socket prepared	4.5 mm drill over 2.4 mm guidewire, to 25 mm depth
8	Longitudinal incision for tibial socket	4.5 mm drill over 2.4 mm guidewire, to 25 mm depth
9	ACL reconstruction is performed	Ipsilateral semitendinosus tendon is preferred
10	Whipstitched end of graft secured into femur	Bioabsorbable fully threaded knotless anchors used
11	Distal end of graft delivered through tibial incision	Graft should pass deep to iliotibial band
12	Distal anchor modified to include snare suture	See Fig. 2
13	Snare suture locked over graft and secured	Secured at approximately 7 cm from origin
14	Distal graft anchor fixation	Performed at 30° flexion, in neutral rotation
15	Assessment of fixation and appropriate tension	Cycle knee several times
16	Wound closure	Consider infiltration of local anaesthetic
17	Post-operative radiographs	To verify fixation position

ACL anterior cruciate ligament, *LCL* lateral collateral ligament

the native knee. This has already been demonstrated efficacious in a clinical series of 92 patients at a minimum of 2-year follow-up [33].

Recent studies have precisely characterised the location, structure and biomechanical properties of the native ALL in cadaveric [4, 7, 9, 13, 31] and live specimens [39]. Newly published data demonstrate the femoral origin of the ALL to be posterior and proximal to the lateral femoral epicondyle, so our exact reconstruction technique is likely to evolve further to take advantage of the improved isometric property afforded by this position [17]. Additionally, consistent radiographic landmarks for the origin and insertion of the ALL have been defined for accurate surgical reconstruction [12, 17, 30]. Although the ultimate tensile strength of the ALL is modest when compared to the cruciate ligaments [17, 42], its lateral position with respect to the ACL provides a mechanically favourable lever arm with which to resist rotatory moments. Furthermore, its relatively anterior insertion with respect to the LCL contributes to anterior and rotational stability [9] particularly at higher flexion angles [28]. These properties can be clearly demonstrated in cadaveric specimens by comparing rotational laxity prior to and following section of the ALL or by measuring length change patterns of grafts with modified attachment points during knee flexion [18].

Conclusion

Using the knowledge gained by recent detailed anatomic and biomechanical studies and combining this with the surgical expertise and specialist implants available in the modern healthcare environment, a relatively simple, minimally invasive procedure has been designed to replicate and restore the function of the native ALL in combination with ACL reconstruction.

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Compliance with ethical standards

Conflict of interest A.J.W. is a consultant for Arthrex.

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