15 Lateral Extra-articular Tenodesis in Revision Anterior Cruciate Ligament Reconstruction

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Case 1

A 21-year-old female soccer player initially suffered a non-contact knee injury resulting in an ACL tear. She underwent a successful ACL reconstruction with hamstring autograft, had an uneventful recovery and returned to sport at 8 months post-op. At 10 months post-op, she suffered a repeat non-contact injury with graft failure. Clinical examination demonstrated full range of motion with a grade 2 Lachman, grade 2 pivot shift, intact PCL and collateral ligament exams. No significant recurvatum was seen on the examination. Radiographs demonstrated appropriate tunnel placement with no widening. Given the patient's young age, activity level and role as an elite soccer player, the decision was made to augment the revision with an extra-articular tenodesis. She underwent a single-stage revision ACL reconstruction with BTB autograft and LET (Fig. 15.1). Her recovery was uneventful, and full return to sport was accomplished.

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Case 2

A 24-year-old male football player suffered a non-contact football injury, resulting in an ACL rupture and an irreparable medial meniscus tear. He underwent ACL reconstruction with hamstring autograft and a very small partial medial meniscectomy, removing less than 10% of the meniscal tissue and leaving a sufficient rim of more than 5 mm. The patient then suffered a second deceleration injury 6 months post-op, resulting in graft failure without a change in the status of the meniscus. He underwent revision ACL with BTB autograft. At 10 months post-revision ACL reconstruction, he was playing baseball and suffered another twisting injury resulting in a second re-tear.

Clinical examination at the time demonstrated neutral limb alignment, excellent muscle tone, grade 3 Lachman, grade 3 pivot shift, no external rotation laxity and intact collaterals. Lateral radiographs demonstrated an increased posterior slope of 14 degrees without significant recurvatum on exam (Fig. 15.2a). Given the multiple graft failures, the decision was made to address slope and ACL deficiency concurrently. The patient underwent anterior closing wedge high tibial osteotomy with revision ACL reconstruction with quadriceps tendon autograft and LET (Fig. 15.2b, c). LET in this case was especially helpful, given the potential for hyper-extension after anterior closing wedge high tibial osteot-

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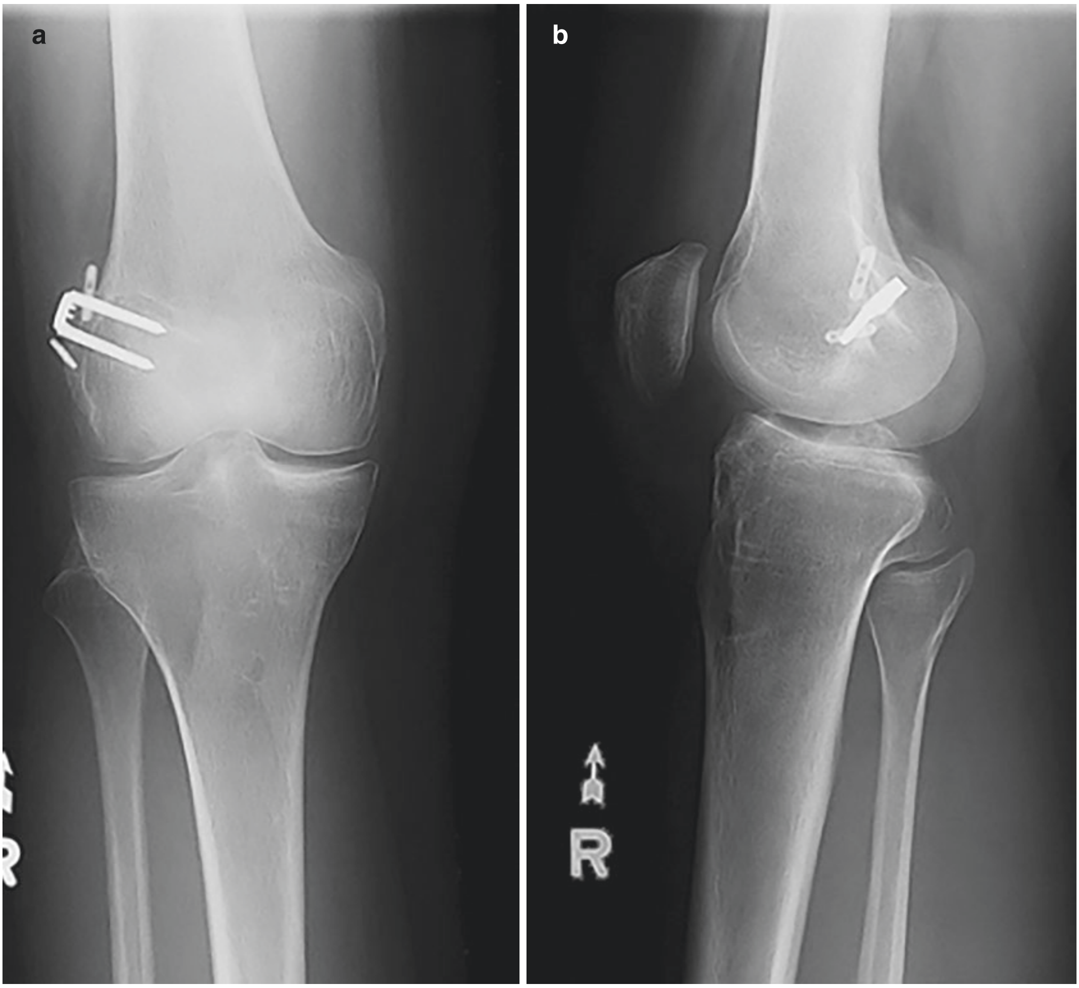

Fig. 15.1 Case 1. Post-operative radiograph demonstrating the position of the staple on both (**a**) anteroposterior and (**b**) lateral radiographs

omy. As the meniscal deficiency was minute, we did not indicate the patient for medial meniscus allograft transplantation. He has subsequently returned to athletics with no residual instability.

Introduction

Anterior cruciate ligament (ACL) reconstruction (ACLR) has generally favourable outcomes. However, there remains a subset of patients who go on to fail [1, 2]. Graft failure can occur as a result of traumatic rupture, biologic factors (failure of graft to incorporate), technical errors of tunnel placement or unrecognized concomitant laxity [3]. Clinical failure may present with residual rotatory laxity resulting in instability, unacceptable stiffness or pain. A systematic review in 2011 suggested a 19% incidence of increased anterolateral rotatory laxity (pivot shift grade 2 and higher) after ACL reconstruction [4].

Undiagnosed concomitant injury to the anterolateral complex (ALC), which includes the iliotibial band (ITB) and anterolateral ligament (ALL), has been proposed to cause anterolateral rotatory instability (ALRI) that leads to increased failure of ACLR. ALRI is accentuated by other ligamentous deficiencies, particularly the ACL

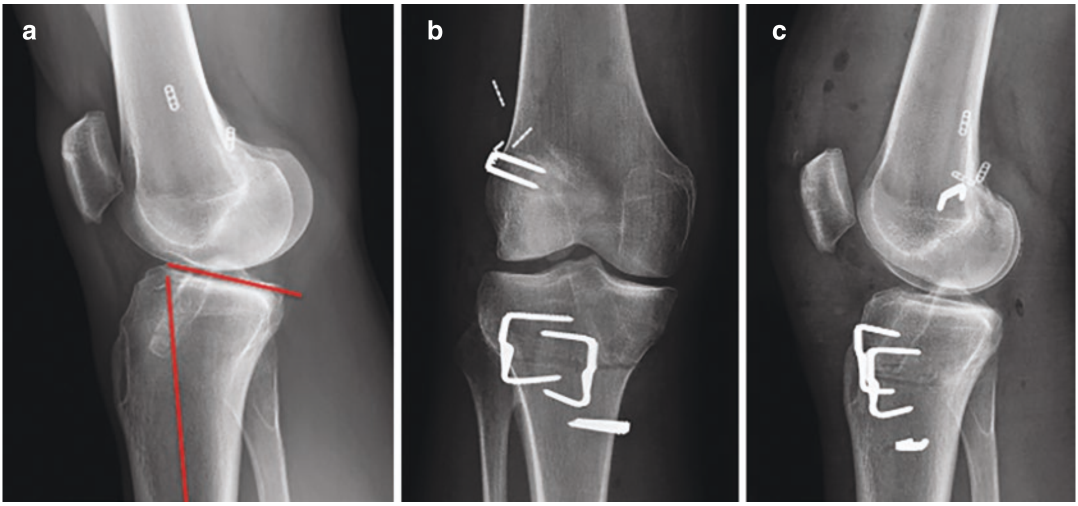

Fig. 15.2 Case 2. Radiographs demonstrate (**a**) pre-operative increased tibial slope of 14 degrees. Post-operative radiographs demonstrating reduced posterior slope and revision ACL reconstruction with LET (**b**, **c**)

[5]. The role of the ALC, and the ALL in particular, has been an area of intense controversy and recent study in regard to knee stability in recent years [6, 7].

Lateral extra-articular tenodesis (LET) procedures are a diverse group of nonanatomic operations that have been described to help control ALRI. Additionally, LET has been proposed to protect the ACL graft from strain during the initial healing period [5, 8]. Definitive evidence supporting the indications for LET procedures and long-term outcomes in revision ACLR are still emerging. The ALC Consensus Group, however, met in 2018 to discuss the available literature regarding the ALC and LET procedures. Based on the current evidence, they concluded that they were unable to make definitive recommendations on when to add LET to ACLR. The group suggested that LET procedures may be indicated in the context of revision ACLR and in primary ACLR in patients who present with a high-grade pivot shift and generalized ligamentous laxity and in young patients wishing to return to pivot sports [9]. Recent studies support these indications in the primary ACLR setting [10, 11]. The aim of the current chapter is to examine the relevant anatomy and biomechanics in ALRI and the role of LET in revision ACL reconstruction.

Relevant Anatomy

The ALC is comprised of the superficial iliotibial band (ITB), the deep ITB and its capsulo-osseous layer attachments from the distal femur to the proximal tibia and the ALL, a ligamentous structure within the anterolateral capsule [7, 9].

The anterolateral ligament (ALL) was first described by Segond in 1879 [12]. The ALL is a ligamentous structure within the anterolateral capsule of the knee. The ALL is best visualized with the knee flexed at 60 degrees and the tibia maximally internally rotated after sectioning the ACL [6]. In this position, the firm fibres can be seen running from the lateral epicondyle to the femur to the anterolateral portion of the tibia.

Differing dissection techniques and difficulty distinguishing the ALL from the anterolateral capsule can make the ALL challenging to identify [7, 9, 13]. Therefore, the prevalence of the ALL in the knee in cadaveric studies has ranged from 45% to 100% [13–16]. Additionally, authors have also described the ALL as being under the ITB and within the anterolateral capsule [17].

Histologically, there again is controversy observed in the literature. A 2020 cadaveric study in paediatric knees demonstrated that there was no discernible ligamentous tissue found within the ALC with histological, immunohistochemical or molecular analyses [18]. In adult cadaveric studies, however, others have found the ALL to be differentiated from the capsular tissue as it is comprised of dense connective tissue collagen bundles which are more consistent with ligamentous tissue [7, 19]. This band of connective tissues is often surrounded by loose synovial tissue [20]. Anti-human neurofilament protein stains have also revealed a large amount of peripheral nerves and mechanoreceptors suggesting a potential proprioceptive role of the ALL [21].

Biomechanical Rationale for Lateral Augmentation

Multiple cadaveric studies have investigated the role of the ALC on knee stability [22–26]. The anterolateral structures have been demonstrated to act as secondary stabilizers to anterolateral rotation in the knee. The ALL begins to load share beyond the physiological limits of the ACL [25, 26]. This indicates that the ALL has little role in controlling internal rotation in the ACL intact knee. A 2015 study demonstrated that sectioning of the ALL was observed to result in a statistically significant increase in anterior translation and internal rotation after the ACL was sectioned during an early-phase pivot shift [22].

In knees with combined ALL and ACL injury, ACL reconstruction alone has been shown to be inadequate at restoring anterolateral stability, resulting in significant residual rotational laxity [23, 27]. A 2016 in vitro robotic study examined the biomechanical effect of reconstruction of the ALL on rotatory stability when performed in combination with ACLR [23]. Kinematic differences between ACLR with an intact ALL, ACLR with ALL reconstruction using semitendinosus allograft and ACLR with a deficient ALL were compared with the intact state. In this study, combined anatomic ALL reconstruction and ACLR significantly improved the rotatory stability of the knee compared with isolated ACLR in the face of a concurrent ALL deficiency. Additionally, during pivot shift testing, ALL reconstruction significantly reduced internal rotation and axial plane tibial translation when compared with ACLR alone with an ALL deficiency [23].

When examining the effects of LET on in vitro knee kinematics, a 2016 study demonstrated that both the modified Lemaire procedure and modified MacIntosh procedure restored rotational kinematics to the intact knee state [27]. Similar results were demonstrated in a 2019 study that examined multiple types of lateral augmentation procedures on the ACL- and ALC-deficient knee. In this study, the ACL and ALC (including ALL, capsule, and Kaplan fibres) were sectioned. After ACLR, the knees underwent five different lateral augmentation procedures. It was again noted that ACLR alone could not restore normal knee kinematics. The study found that ALL reconstruction and Ellison procedures were able to restore physiologic knee kinematics. Lemaire and MacIntosh procedures resulted in supra-physiologic constraint in this study [28].

Types of LET Procedures

Multiple different LET procedures have been described in the literature. Many were initially proposed for the treatment of ACL-deficient knees in isolation, without concomitant intra-articular ACLR [29–35]. Many of these techniques have also undergone modifications over the years. The original Lemaire technique forms the basis for many LET procedures [5]. The original Lemaire technique described using a 1.5 × 18 cm strip of ITB autograft [29]. This graft was left attached distally at Gerdy's tubercle and passed under the fibular collateral ligament (FCL) and through a femoral bone tunnel back under the FCL and anchored in a tibial bone tunnel at Gerdy's tubercle (Fig. 15.3a). The current modified Lemaire technique uses a single 7–8 cm strip of ITB left attached to Gerdy's tubercle, passed under the FCL and secured to the femur within a bone tunnel or via a staple/suture anchor (see author's technique and Fig. 15.4a–g) [30, 31].

The Ellison procedure uses an ITB graft that is detached distally from its insertion with the use of a bone block [32]. The graft is passed deep to

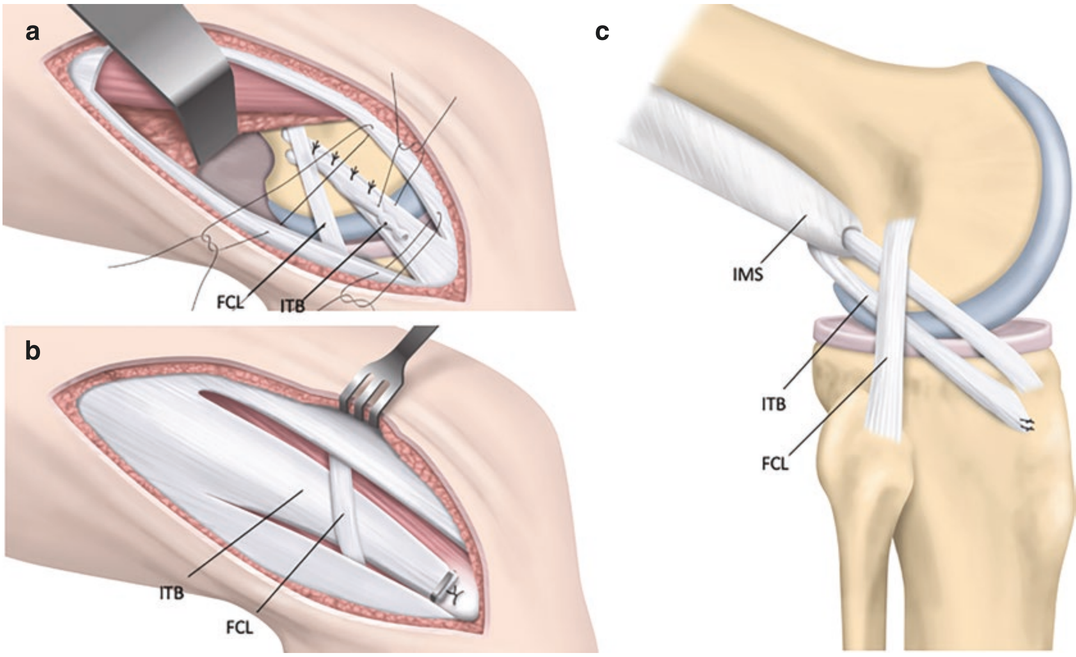

Fig. 15.3 LET procedures. (**a**) Lemaire technique; (**b**) Ellison technique; (**c**) MacIntosh technique (*FCL* fibular collateral ligament, *ITB* iliotibial band, *IMS* intermuscular septum)

the FCL and anchored just anterior to Gerdy's tubercle with a staple (Fig. 15.3b). A capsular plication is also performed in conjunction to the tenodesis deep to the FCL.

The original MacIntosh procedure is similar to the Lemaire in that it uses an ITB autograft left attached distally to Gerdy's tubercle [35]. The 20 × 2 cm graft is passed deep to the FCL, through a subperiosteal tunnel behind the FCL, then through a proximal tunnel in the intermuscular septum. The graft is then sutured back onto itself (Fig. 15.3c). A modification of this procedure has been described where a 2 cm strip of ITB is passed deep to the proximal FCL where it is sutured. It is then passed over top of itself and secured at Gerdy's tubercle with the use of a staple [33]. The MacIntosh technique has also been described as a combined intra- and extra-articular technique [34]. In this "over-the-top" procedure, a 25 × 4 cm strip of ITB is left attached distally to Gerdy's tubercle. It is passed deep to the FCL. It is then passed subperiosteally anterior to the intermuscular septum and then over the femoral condyle and into the knee to be used for ACLR.

Patient Assessment and Indications for LET in Revision ACLR

LET procedures should be considered in the revision setting when other factors predisposing a patient to graft failure have been excluded. Patients with primary graft failure should be investigated with complete history, physical examination and appropriate imaging.

History should include details of primary surgery including arthroscopic findings, postoperative rehabilitation course, time to return to sport and onset of recurrent instability (insidious versus acute traumatic rupture). Additionally, delineating the patients sporting and activity aspirations can help guide treatment.

Physical examination begins with assessment of weight-bearing alignment and gait abnormalities. In-depth assessment of collateral and cruciate ligaments including posterolateral, posteromedial, anterolateral and anteromedial corners should be completed to assess overall soft tissue integrity. When considering LET, particular attention should be paid to residual

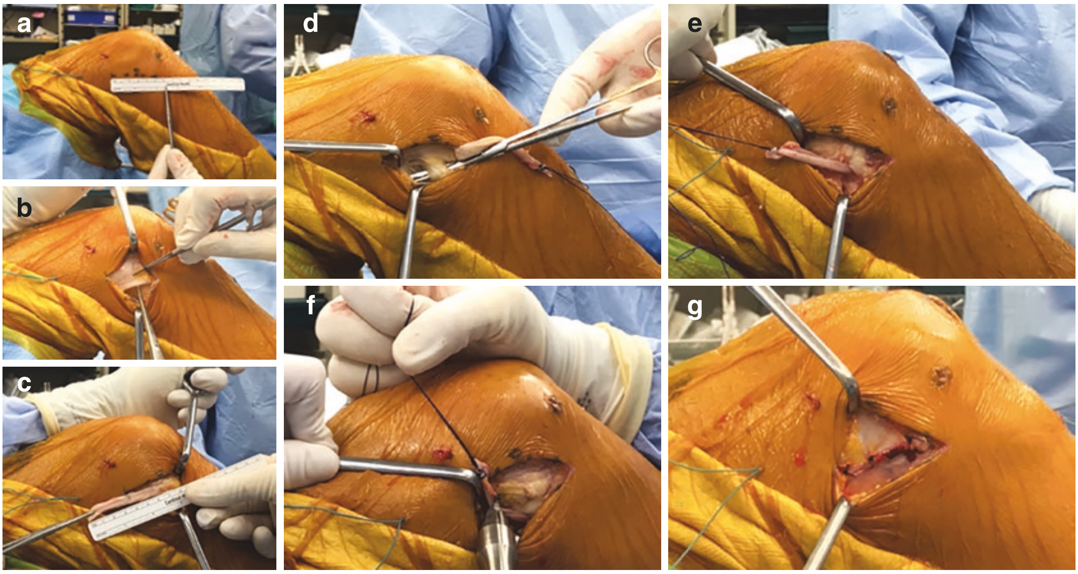

Fig. 15.4 Senior author's technique of modified Lemaire LET. (**a**) A 6 cm longitudinal skin incision is made just posterior to the lateral epicondyle, stopping 2 cm from Gerdy's tubercle. (**b**) The subcutaneous tissue is dissected down to the ITB. (**c**) A 1-cm-wide by 8-cm-long strip of the posterior half of the ITB is harvested, leaving intact the distal attachment at Gerdy's tubercle as well as the Kaplan fibre complex. (**d**) The fibular collateral ligament (FCL) is located and dissected. A Kelly is passed beneath the FCL. (**e**) The graft is tunnelled deep to the FCL. (**f**) Fixation of the tenodesis is performed with a staple, with the graft tensioned to no more than 20 N with the knee held at 60° of flexion and neutral rotation of the tibia. (**g**) The ITB is tacked closed with number 1 Vicryl suture. (Ethicon Inc., Somerville, NJ)

ALRI. Evidence of high-grade pivot shift test is indicative of ALRI [36, 37].

Appropriate imaging should include plain radiographs (weight-bearing films including hip-to-ankle alignment films), MRI and CT scan. Plain radiographs provisionally assess tunnel position and size and existing hardware. Alignment radiographs can also identify bony malalignment that can contribute to graft failure such as increased tibial slope or coronal malalignment with particular attention paid to asymmetry [38]. MRI can further reveal ligamentous or meniscal deficiency that contributes to residual instability. CT is regarded as the gold standard to evaluate tunnel widening and tunnel position [39]. Stress radiographs can augment clinical examination in the assessment of concomitant ligamentous injury such as the posterolateral corner.

Once other factors contributing to the index ACL failure have been identified and addressed, the authors suggest the following possible clinical scenarios where addition of LET would be appropriate:

1. Traumatic graft rupture in a young patient with previously well-functioning graft and well-positioned tunnels where the patient has a desire to return to multidirectional sports
2. Clinical graft failure with non-modifiable risk factors including meniscal deficiency, unresponsive to appropriate rehabilitation program, generalized ligamentous laxity or high-grade pivot shift
3. Graft failure with no clear cause for failure
4. Residual ALRI with intact graft

Outcomes of LET in Revision Surgery

Initial studies examining LET procedures in isolation showed variable outcomes and failed to definitively demonstrate the efficacy of the procedure [40, 41]. With the renewed interest in the ALL and its modern use in combination with ACLR and revision ACLR, the outcomes have been more promising. Recent studies have demonstrated improved patient-reported outcomes and decreased rates of failure with combined ACLR and LET compared to ACLR alone in both the primary and revision setting [42–47].

A study in 2006 evaluated revision ACLR with hamstring autograft combined with modified MacIntosh LET [43]. Thirty patients were evaluated at a mean 5 years post-operatively. A graft was considered to have failed when a revision was done or when the side-to-side difference on KT-1000 arthrometer testing was >5 mm and/or the pivot shift test grade was greater than a trace. At the time of final follow-up, one patient had undergone repeat revision for graft failure at 3 years post-operatively. Pivot shift was normal in 15 patients (50%), slightly positive in 11 patients (37%) and positive in 2 patients. Overall rate of failure was 10%. There were no degenerative changes noted on radiographs.

Similarly, a 2019 study examined the functional results of combined LET and ACLR in professional soccer players. In the retrospective review, 24 professional soccer players were analysed at a mean of 42 months post-operatively [42]. ACLR revision was performed with an autologous bone–patellar tendon–bone autograft or a hamstring graft. LET was performed using a MacIntosh procedure. At the time of final follow-up, AP laxity was significantly reduced ($p < 0.0001$). Twenty-two patients (92%) had a negative pivot shift, and two had a residual glide (8%). The mean subjective IKDC and Lysholm score improved from 69.5 ± 11.1 (range: 56–90) to 88.4 ± 8.9 (range: 62.1–100) and from 58.1 ± 11.7 (range: 33–72) to 97.4 ± 3.2 (range: 88–100), respectively, with significant improvement ($p < 0.0001$) over pre-operative values. There was a 92% return to sport at the same level. Failure rate was reported as 8% [42].

A 2012 study directly compared revision ACL alone to revision ACL with the addition of LET [47]. The retrospective multicentre study included patients operated on from 1994 to 2003 at ten different centres with a minimum of 2 years follow-up. There were 163 patients included in the study. An associated LET was performed in 84 patients (51%). Type of LET performed and specific indications for the procedure were not disclosed by the authors. Failure was defined as grade 2 or 3 pivot shift or KT-1000 test showing a difference of greater than 5 mm. Failure rate was 15% in the revision ACLR group and 7% in the revision ACLR with LET group. At final follow-up, 63% of patients in the revision ACLR alone group had a negative pivot shift compared to 80% in the revision ACLR with LET ($p = 0.03$). There was, however, no statistical difference between groups with respect to IKDC scores.

A 2018 study investigated radiographic changes in patients who underwent ACLR with semitendinosus autograft combined with LET. Patients were evaluated at a mean of 10 years follow-up. There was a 7.6% failure rate based on side-to-side KT-1000 evaluation, >2 or higher pivot shift or patient-reported instability. Severe degenerative changes were seen in 25% of patients. The only risk factor that correlated with degenerative changes was previous meniscectomy [48].

The French Society of Arthroscopy investigated the rate of complications associated with combined primary ACLR and LET [46]. Thirteen surgical centres prospectively studied 392 cases of ACLR with LET with a minimum of 1-year follow-up. Multiple techniques for LET were used including both single continuous grafts and separate grafts for each procedure. Outcome measures included range of motion, time to return to normal gait, Lachman testing, adverse events and re-tear. Two patients (0.5%) required manipulation under anaesthesia for flexion deficit, and four patients (1%) underwent arthroscopic lysis of adhesions for extension deficit. At the time of arthroscopy, this was found to be related to cyclops lesion and not the LET. During the first year, there was 1.7% rate of revision surgery specific to LET (three tibial screw and three femoral screw removal). Overall re-tear rate was 2.8% at 2 years follow-up. This study indicates the low morbidity associated with the lateral extra-articular procedures and highlights the increased post-operative stability and reduced failure rate.

Senior Author's Preferred Surgical Technique

The modified Lemaire technique is used by the senior author (AG) [30]. The leg is positioned in 80 degrees of flexion. A 6 cm longitudinal skin incision is made just posterior to the lateral epicondyle, stopping 2 cm from Gerdy's tubercle (Fig. 15.4a). The subcutaneous tissue is dissected down to the iliotibial band (Fig. 15.4b). A 1-cm-wide by 8-cm-long strip of the posterior half of the ITB is harvested, leaving intact the distal attachment at Gerdy's tubercle as well as the Kaplan fibre complex (Fig. 15.4c). The free end of the tendon is whipstitched with a number 1 Vicryl suture (Ethicon Inc., Somerville, NJ). The fibular collateral ligament (FCL) is located and dissected. A Kelly is passed beneath the FCL (Fig. 15.4d). The graft is tunnelled deep to the fibular collateral ligament (FCL) (Fig. 15.4e). The graft is then attached to the femur just proximal to the metaphyseal flare of the lateral femoral condyle, proximal and posterior to the FCL femoral attachment and just anterior to the insertion of the distal Kaplan fibres of the ITB. Care must be taken during dissection at this point to avoid compromise of the ACL femoral fixation which is in the vicinity of this area. Fixation of the tenodesis is performed with a staple (Fig. 15.4f), with the graft tensioned to no more than 20 N with the knee held at 60° of flexion and neutral rotation of the tibia. The graft is then sutured back onto itself over the staple using the remainder of the whipstitched number 1 Vicryl suture [30]. The ITB is tacked closed with number 1 Vicryl suture (Fig. 15.4g). There is no change in the postoperative rehabilitation protocol with the addition of the LET. Generally, LET is completed at the end of the case (i.e. after ACL reconstruction is completed).

Conclusion

Though ACLR has generally favourable outcomes, there remains a subset of patients who go on to clinical graft failure or re-rupture. Multiple factors can lead to ACLR failure. ALRI or excessive residual laxity can contribute to ACLR failure. Modern LET procedures add minimal morbidity and have been shown to be effective in addressing ALRI in revision ACLR and decreasing graft failure rates.

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