8 Anterior Cruciate Ligament Reconstruction: Isolated or Combined with an Extra-Articular Procedure?

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8.1 Introduction

Some patients who undergo intra-articular anterior cruciate ligament reconstruction (ACLR) do not fully recover in terms of patient-reported outcomes (PROMs), knee kinematics, and return to sport. Technical factors only explain some of these failures. Residual anterolateral rotational instability (ALRI) associated with a positive pivot shift after surgery is a factor associated with poor functional outcomes.

Regardless of the technique used for ACLR, some retrospective reviews claim that up to 34% of patients continue to have excessive residual ALRI after surgery, as measured by the pivot shift test. Young patients (<25 years) have more flexible soft tissues and therefore a higher risk of residual instability. This can lead to worse long-term results and can influence the return to sports activities. It has been mentioned that this laxity could be improved by the addition of an extra-articular lateral procedure (LEAP) [1].

Another major concern is graft rupture after ACLR, which occurs in up to 28% of high-risk patients. To avoid this problem, combined procedures have been proposed to reduce stress on the anterior cruciate ligament (ACL) graft and protect it during ligamentization, with the expectation that this will result in less graft rupture and less need for revision surgery [2].

Current evidence shows that the anterolateral complex, composed of the iliotibial band (ITB) and its Kaplan fiber system, the anterolateral ligament (ALL), and the capsule, is an important stabilizing structure in the anterolateral part of the knee. Therefore, LEAPs are increasingly being added as concomitant procedures to primary intra-articular reconstruction and revision of the ACL [3].

LEAPs can be divided into the traditional lateral extra-articular tenodesis (LET) and the more modern technique of anatomic anterolateral ligament reconstruction (AALLR). Because of their important differences, the results between the LET and AALLR procedures should be considered separately.

8.2 Lateral Extra-Articular Tenodesis (LET)

LET is a non-anatomical procedure to restore anterolateral rotational stability and correct pivot shift. Lemaire described the use of a strip of ITB to make a lateral reinforcement. Since then, many variations of these procedures have been described. A better understanding of the anatomy and biomechanics of the anterolateral structures of the knee has led to the reappearance of LET as a combined procedure with ACLR.

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LET is performed using a strip of the ITB obtained from its central or distal part, without disinserting it from Gerdy's tubercle. The strip of ITB is passed under the lateral collateral ligament (LCL) and the posterior and proximal part is fixed to the lateral epicondyle with a clip, a suture anchor, or an interference screw [4] (Fig. 8.1). Postoperative overconstruction and stiffness are the most important historical concerns regarding the results of LET techniques.

8.3 Anatomic Anterolateral Ligament Reconstruction (AALLR)

The AALLR technique differs from ITB-based procedures in that it seeks to recreate the normal anatomy and biomechanics of the ALL. AALLR is most often performed with autografts, most often of gracilis tendons, which can be single or double braided, although allografts have also been used. There are three variants: single-bundle anatomic reconstruction, double-bundle anatomic reconstruction, and the combined intra- and extra-articular ACLR techniques.

8.3.1 Single-Bundle Anatomic Reconstruction

The femoral tunnel for the graft should be slightly posterior and proximal, or more precisely, 4 mm posterior and 8 mm proximal to the lateral femoral epicondyle; the tibial tunnel should be approximately 5–10 mm distal to the joint line, midway between the fibular head and Gerdy's tubercle [5] (Fig. 8.2).

8.3.2 Double-Bundle Anatomic Reconstruction

Tibial fixation can also be done with two tibial tunnels, in which an extra hole is made in the superolateral area of Gerdy's tubercle. In this method, the ALL grafts are positioned in the two tunnels as a "delta" or "inverted Y." An interference screw or a staple can be used to fix the graft in the tibial tunnel. The grafts will follow an anterior and inferior oblique orientation towards the tibia, below the ITB and superficial to the LCL.

8.3.3 ACLR Combined Intra- and Extra-Articular Technique

AALLR in combination with ACLR can also be performed by passing the graft over the top of the lateral femoral condyle or using a single femoral tunnel (Fig. 8.3); this is called the combined intra- and extra-articular technique of ACLR. In this technique, the ALL and ACL grafts share the same femoral tunnel, which extends from the lateral wall of the lateral femo-

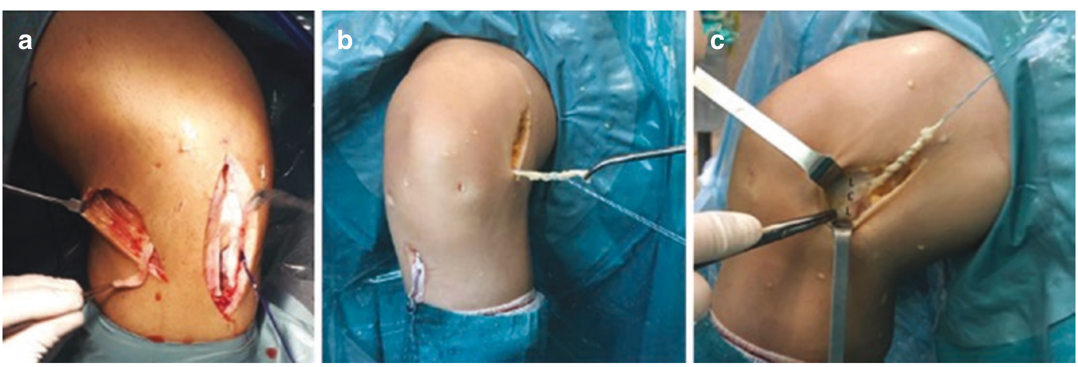

Fig. 8.1 (**a**) Combined anterior cruciate ligament reconstruction (ACLR) using bone to bone-patellar tendon-graft (BPTB) + lateral extra-articular tenodesis (LET). (**b**) Combined ACLR using hamstring tendon (HT) + lateral extra-articular tenodesis (LET). (**c**) Passage of the iliotibial band (ITB) under the lateral collateral ligament (LCL)

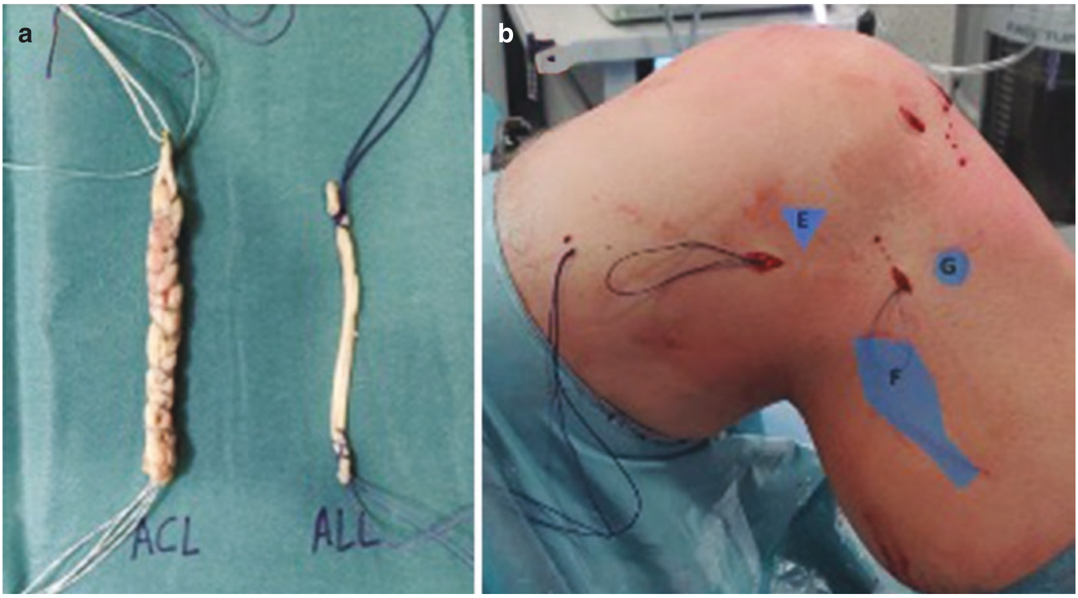

Fig. 8.2 (**a**) Graft preparation for combined ACL plus anatomical single-bundle anterolateral ligament (ALL) reconstruction with hamstring tendon (HT). (**b**) Anatomical references: lateral femoral epicondyle (E), fibula (F), and Gerdy's tubercle (G)

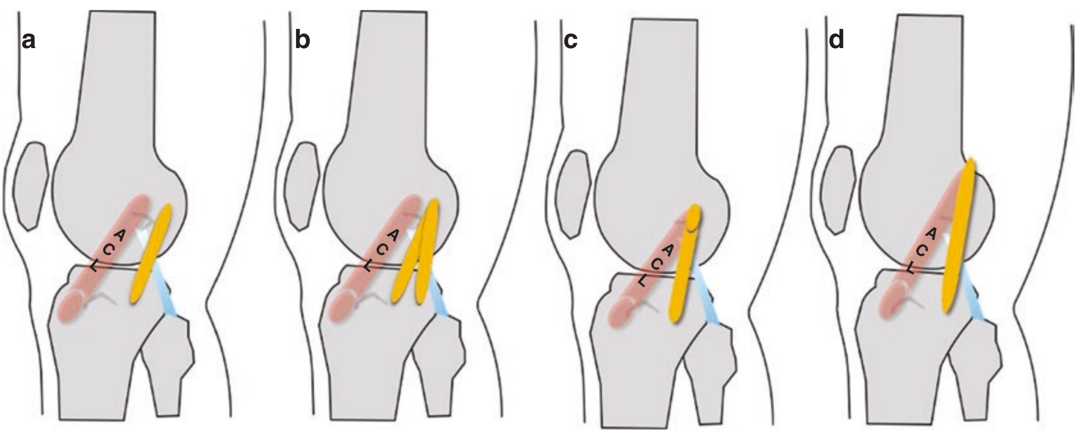

Fig. 8.3 (**a**–**d**) Types of anatomical reconstruction of anterolateral ligament: (**a**) single-bundle technique; (**b**) double-bundle technique; (**c**) combined intra- and extra-articular technique passing the graft using a single femoral tunnel; (**d**) combined intra- and extra-articular technique "over the top" of the lateral femoral condyle

ral condyle (ALL femoral insertion), slightly proximal and posterior to the lateral epicondyle, to the medial wall of the lateral femoral condyle (ACL imprint). The ACL portion of the graft is a combination of the semitendinosus and gracilis tendons and is passed intra-articularly from the tibia to the femur. The longest remnant of the gracilis tendon is pulled through the femoral tunnel or behind the femoral condyle and goes to the AALLR.

These procedures avoid a large lateral incision and do not require obtaining an ITB graft, which in itself may compromise the anterolateral stability of the knee or cause persistent lateral pain. The main disadvantage of this anatomical type of AALLR is that there are no published long-term series.

On the other hand, to date, no studies have compared clinical outcomes between LET and AALLR, when combined with ACLR. Delaloye et al. conducted a biomechanical study on six cadaver knees and found that in ACL-deficient and anterolateral knees, the combined ACL and anterolateral reconstruction restored native knee stability in the anterior socket and internal rotation as opposed to the isolated ACLR [6, 7]. In addition, both types of extra-articular reconstruction, AALLR or modified Lemaire LET, were similar in terms of restoration of knee kinematics. However, another study conducted on cadavers (20 knees) demonstrated superior biomechanical properties for LET than for AALLR [8]. In a recent systematic review the rotational stability and patient-reported outcomes (PROMs) were similar for ACLR combined with LET or with AALLR [8]. There is a significant cost difference between the two techniques: a LET only requires the addition of an implant for fixation compared to the use of ≥2 for most AALLRs.

8.4 ACL Reconstruction: Isolated vs Combined

Almost all recent clinical studies show benefits of combined ACLR versus isolated ACLR. The advantages that have been attributed to the combined reconstruction are the shared load with the ACL graft and the improved kinematics of the knee.

8.4.1 Studies to Determine If the Combination ACLR + LEAP Can Improve Graft Survival

In a comparative study (cohort study; level of evidence, 2) on the results of combined ACLR + AALLR (using gracilis tendon with one femoral tunnel and two V-shaped tibial tunnels) versus isolated ACLR in high-risk patients (young athletes, participating in contact sports), Sonnery-Cottet et al. analyzed 512 patients aged 16–30 years, showing that after an average follow-up of 38.4 months the graft failure rate for patients undergoing combined ACLR + AALLR was 3.1 times less than in isolated ACLR with a four strand autologous hamstring tendon (HT) graft and 2.5 times less than in isolated ACLR with bone-patellar tendon-bone (BPTB) [9]. Graft rupture rates were 10.77% for the isolated hamstring ACLR group, 16.77% for BPTB, and 4.13% for HT graft combined with AALLR. In addition, Sonnery-Cottet et al. found a lower failure rate of medial meniscus repair in patients undergoing combined ALL reconstruction [10].

Castoldi et al. conducted a randomized controlled trial (level of evidence, 2.) with a minimum follow-up of 19 years. In 121 knees they compared isolated BPTB ACLR versus BPTB ACLR combined with AALLR with gracilis tendon using a delta tunnel arrangement in the tibia [11]. The study showed a trend toward decreased risk of graft rupture in the combined group (13%) versus the isolated group (29%; $P = 0.1$). However, the study was not powerful enough to confirm these results.

In a recent study (randomized controlled trial; level of evidence, 2) immediately following ACLR surgery, the authors repeated the pivot shift test. If the pivot shift was ≥1 greater than that recorded in the uninjured contralateral knee, patients were randomly assigned to have no further surgery or the addition of LET. ACLR combined with residual pivot shift knee LET after ACLR was found to reduce the risk of recurrence [14.8% vs 0.0% ($P < 0.001$)] and improve clinical outcomes, after 2 years of follow-up. The persistence of a residual pivot shift immediately after the ACLR may be considered a practical indication for combining a LET [12].

In the first multi-center, prospective, randomized clinical trial comparing an ACLR (with single-bundle HT) with or without LET (performed with an ITB strip), a total of 618 patients aged 14–25 years were randomized. At 2 years after surgery, 11% of patients in the ACLR group suffered graft rupture, compared to 4% in the ACL + LET group (RRR, 0.67; 95% CI, 0.36–0.83; $P < 0.001$). In the isolated ACLR group, 40% of patients had persistent rotational laxity (clinical failure) compared to 25% of ACLR + LET patients (RRR, 0.38; 95% CI, 0.21–0.52;

$P < 0.0001$). The addition of LET to an ACLR in young patients at high risk of failure resulted in a reduction of the relative risk (RRR) of graft rupture by 66% and an RRR of clinical failure (considered as graft rupture or persistent rotational laxity) of almost 40%. The authors of this study believe that this difference is clinically important and should probably change current practice [13].

8.4.2 Studies Trying to Determine If the Combination ACLR + LEAP Can Improve Residual Rotational Instability

Helito et al. retrospectively reviewed (level 3 evidence, case-control study) an AALLR using combined intra- and extra-articular ACLR versus isolated ACLR in chronic ACL ruptures (defined as ruptures more than 12 months old) [14]. Patients in whom the combined technique was used had better results in the KT-1000 with less residual pivot shift, presenting only 9.1% of positives versus 35.3% in the isolated ACLR group. The subjective International Knee Documentation Committee (IKDC) and Lysholm functional outcome scores were also significantly better. There was no re-rupture in the combined group versus 7.3% in the isolated ACLR group.

In another study, Lee et al. evaluated the effect of AALLR (single-bundle anatomic reconstruction with gracilis tendon allograft) on revision ACLR (with tibialis anterior tendon allograft) [15]. ACLR review in combination with AALLR significantly reduced rotational laxity. In fact, 90.5% of patients in the combined group and 53.5% of patients in the isolated group had a negative pivot shift ($P < 0.001$) and showed a higher rate of return to the same level of sports activity than the isolated revision ACLR (57.1% vs 25.6%, respectively; $P = 0.008$). Graft rupture requiring revision surgery was found in two patients (4.4%) in the isolated group, while no patients in the combined group suffered rupture.

Helito et al. compared (in a Level 3 study) functional outcomes, residual instability, and rupture rates in patients with ligament hyperlaxity (Beighton minimum of 5) undergoing ACLR alone or in combination with AALLR (the femoral tunnel used for ALL was the same one used for ACLR, using the remaining portion of gracilis for reconstruction, and fixation of the ALL in the femur and tibia was performed with an interference screw) [16]. At final evaluation, patients in the combined group showed better anteroposterior stability as assessed by KT-1000 ($P = 0.02$), better rotational stability as assessed by the pivot shift test ($P = 0.03$), and a lower rate of failure (21.7% in the single group vs 3.3% in the combined group; $P = 0.03$). The combined ACL and ALL reconstruction in patients with ligament hyperlaxity resulted in a lower re-rupture rate and better knee stability parameters than when the isolated ACLR was performed.

Getgood et al. compared in a randomized controlled trial the functional outcomes of isolated ACLR with the combination ACLR + LET at 6, 12, and 24 months post-operatively. Patients undergoing ACLR + LET did not have a lower functional outcome compared to those treated with ACLR alone. There were no clinically significant differences in PROMs between groups, nor in strength or function at 12 months. There was also no difference in the return to sport or in the percentage of reoperations [17].

Comparative studies have shown that combined reconstruction is associated with a significantly lower risk of ACL graft rupture and of need for subsequent meniscectomy; also, that it is associated with significantly better knee stability and better rates of return to pre-injury level of sporting activity compared to isolated ACLR. In addition, significant advantages were reported in some specific populations, including young patients participating in pivoting sports, patients with hyperlaxity, patients with chronic ACL injury, and patients undergoing revision ACLR.

There are no studies evaluating the cost-effectiveness of lateral extra-articular procedures in ACLR. These procedures result in an increase in cost: they require a little more surgical time and also increase the cost for the use of fixation materials such as sutures, screws, staples, or anchors; furthermore, depending on the technique, they may require additional grafts. LEAPs result in a lower degree of residual laxity and a lower risk of failure, which could contribute to reducing overall costs in the long term. In addition, the potential improvement in patient outcomes and reduction of the risk of failure could also allow for an earlier return to work and a reduction in lost productivity, which would also decrease indirect costs, and thus compensate for the higher initial resource use related to these procedures [18].

8.5 Indications for AALLR and LET

The indications for AALLR or LET remain controversial. The indications for combined ACL and ALL reconstruction are being expanded. Recent consensus papers published by the international Anterolateral Ligament Expert Group [19] and the International ACL Consensus Group Meeting [20] have reviewed their indications. Young patients (14–25 years) with ACL deficiency who have two or more of the factors shown in Table 8.1 are at greatest risk of re-injury. A combined ACL and ALL reconstruction would be indicated.

Table 8.1 Indications for combined anterior cruciate ligament reconstruction (ACLR) and lateral extra-articular procedure (LEAP)

Patients aged 14–25 years with ACL deficiency who have two or more of the following characteristics:	
1.	Participation in pivoting sports
2.	Elite athletes
3.	Presence of a grade 2 or higher pivot shift
4.	Generalized ligament laxity (Beighton score of 4 or greater)
5.	Genu recurvatum greater than 10°
6.	Preoperative side to side laxity >7 mm
7.	Associated Segond Fracture
8.	Chronic ACL rupture
9.	Lateral femoral notch signal on plain radiographs
10.	Patients undergoing revision ACLR
11.	Contralateral ACL reconstruction failure
12.	Biologically compromised patients, e.g., ACLR with allograft or patients with increased tibial slope in the sagittal plane because it may protect the ACL graft

ACL Anterior cruciate ligament

8.6 Complications of LEAPs

Despite the promising results and the fact that very few complications have been published following LEAPs, other authors have reported concerns about the addition of LEAPs. An ongoing randomized controlled trial is studying whether combined ACLR + AALLR reconstruction is associated with a higher rate of adverse outcomes compared to isolated ACL reconstruction. This study has shown no evidence of increased risk of complications or reoperations with the combined ACL + AALLR procedure (with HT graft) compared with the isolated ACLR (with BPTB graft) [21]. In a systematic review, the published rate of complications in patients treated with revision ACLR associated with LET is 8% [22].

8.6.1 Difficulties with Grafting

It is advisable to prepare the ends of the graft with a No. 2 non-absorbable suture in a running-locked pattern to avoid tearing when the graft is fixed.

8.6.2 Injury to LCL

The proximity between the femoral insertion of the ALL and the LCL predisposes to iatrogenic LCL lesions during femoral tunnel reconstructions. Helito et al. observed in 8.3% of fresh cadaver knees an injury of at least 50% of the LCL fibers when the femoral tunnel was perforated for ALL grafts. The percentage of LCL injury rose to 41.6% when 8 mm diameter drills were used [23].

8.6.3 Wound Hematoma

It is the most frequently reported complication following LET procedures. Superior geniculate vessels are at risk during surgical approach Therefore, it is important to identify them and coagulate them to avoid post-surgical hematomas. Drains may also be placed in the area to prevent hematomas.

8.6.4 Persistent Lateral Pain

Getgood et al. observed that, both in patients operated for isolated ACLR and those operated for ACLR + LET, pain was minimal in the early postoperative phase (3 months): overall, pain was approximately 8/40 in the four-item pain intensity measure (P4: pain in the morning, afternoon, night and with activity during the last 2 days), although it was lower in the isolated ACLR group than in the ACLR + LET group (adjusted mean difference, −1. 6; 95% CI, −2.7 to −0.6; $P = 0.003$) [17]. This difference was not observed 3 months after the operation.

8.6.5 Discomfort Caused by Fixation Devices

This can happen especially if staples are used to fix the graft and may require removal of the fixing material (hardware).

8.6.6 Over-Constraint of the Lateral Compartment

This is due to the fixation of the graft with the tibia in external rotation and the over-tensioning of the graft.

8.6.7 Loss of Knee Mobility or Stiffness

No patient in the recently published series required manipulation under anesthesia or arthroscopic debridement for loss of knee mobility or stiffness.

8.6.8 Patellofemoral Crepitus

Distally, in the anterior aspect of the superficial layer of the ITB, curved fibers are identified that are anchored to the lateral aspect of the patella and patellar tendon, which are called the iliopatellar band. The distal edge of this portion of the iliopatellar band constitutes the lateral patellotibial ligament [24]. Tensioning the window at the ITB during a LET can lead to patellofemoral problems. We recommend not to close the ITB under tension or even to leave the distal part of the window unclosed.

8.6.9 Osteoarthritis of the Lateral Compartment

O'Brien et al. (in a small, non-randomized retrospective review) compared ACLR with BPTB autograft with or without LET in 80 patients. They found no clinical differences in KT-1000 and concluded that the addition of LET did not provide any benefit; in addition, 40% of patients had chronic pain and/or inflammation in the lateral area [25].

Marcacci et al. found no increase in degenerative changes in the lateral compartment after more than 10 years of follow-up in patients without lateral meniscal tears undergoing combined intra- and extra-articular ACL reconstruction [26]. Two other European studies with more than 20 years of follow-up have not shown a higher rate of development of osteoarthritis with the addition of LET [27, 28].

In addition, a recent meta-analysis also found no correlation between LET and osteoarthritis. The incidence of osteoarthritis was low up to 11 years post-surgery, but increased thereafter. The presence of meniscal injury at surgery was reported to be a major predictor of the development of osteoarthritis [29]. Previously reported osteoarthritis could probably have been the result of a combination of imperfectly anatomical ACLR and non-anatomic LET, fixed in flexion, and often with the tibia in external rotation and delayed rehabilitation due to immobilization in a cast for up to 2 months after the operation. Based on this study, it can be stated that the addition of extra-articular reconstruction to anatomic intra-articular ACLR followed by a modern rehabilitation protocol does not increase the risk of osteoarthritis [30]. Although there has been concern about the possible increased risk of osteoarthritis, there is no clinical evidence that lateral reinforcing procedures lead to it.

8.6.10 Malposition of the Fixation Devices

The fixing screws can migrate out of the tunnel and be located in the supracondylar area. Fixation devices can also migrate intra-articularly in tibial fixation and can damage the articular cartilage of the tibial plateau [31].

8.6.11 Convergence of Tunnels

On the femoral side, tunnel convergence represents a potential problem during a combined reconstruction. The tunnel orientations in the combined ACL-ALL reconstructions need careful intraoperative care to avoid convergence between the tunnels. This could compromise the fixation and integration of the graft, leading to the failure of the combined reconstruction or even causing lateral femoral condyle fractures. The most commonly used techniques require femoral fixation independent of the ACL. Among the many suggested femoral fixation methods, some require a bone tunnel.

In a study of ten cadaver knees, Jaecker et al. observed that tunnel convergence occurred in seven of ten cases (risk, 70%) using the Lemaire technique and in no case using the MacIntosh technique [32]. They concluded that tunnel convergence was most frequently observed in combined ACL and LET reconstruction using the Lemaire technique, regardless of knee size. The positioning of the LET femoral tunnel according to the MacIntosh reconstruction was not associated with the tunnel convergence.

In another study on ten cadaver knees, Jette et al. showed that tunnels with a 0° angle in the axial plane had a high risk of contact and disruption of the posterior femoral cortex; therefore, these angles should be avoided [33]. They recommended that when simultaneous ACL and AALLR reconstruction is performed, the femoral tunnel should be drilled at an angle of 30° anterior in the axial plane and 30° proximal in the coronal plane.

In an in vivo study, Smeets et al. have shown that the risk of tunnel convergence increases significantly when the AALLR tunnel is drilled at 0° in the axial plane [34]. The convergence of the tunnels can be avoided by pointing the AALLR tunnel 40° anteriorly and perpendicularly to the anatomical axis of the femur. A more horizontal orientation of the ACL, as in the anteromedial portal technique, is an additional risk factor for the tunnel coalition with respect to the use of the transtibial technique.

In an in vivo study Perelli et al. demonstrated 100% risk of tunnel convergence when the axial inclination of the LET tunnel was less than 15°, and a 92% chance of an unsafe bone bridge (<5 mm) between the tunnels for an axial inclination of 15°–20° [35]. The inclination in the axial plane seems to influence the possibility of convergence, while the inclination in the coronal plane does not seem to have the same effect. They recommended that to avoid any interference between an anatomical ACL femoral tunnel and a modified LEAP Lemaire femoral tunnel, the femoral tunnel should be drilled at an angle of at least 20° anteriorly.

The use of an inside-out ACL femoral tunnel drilling technique instead of an outside-out or the use of anchors for lateral brace fixation instead of bone tunnel can avoid this complication. In general, the number of complications or adverse events in LEAPs is low. Based on the current studies there is no evidence to support the concerns of high rates of adverse events reported following historical extra-articular lateral procedures. Table 8.2

Table 8.2 Complications/adverse effects of lateral extra-articular procedures (LEAPs)

INTRAOPERATIVE
Difficulties with the graft
Injury to LCL
POSTOPERATIVE
Wound hematoma
Cosmetic problems
Persistent lateral pain
ITB snapping
Muscular hernia in the lateral approach
Discomfort caused by fixing devices
Over-constraint of lateral compartment
Stiffness
Patellofemoral crepitus
Lateral compartment osteoarthritis
Malposition of fixing devices
Convergence of tunnels

LCL Lateral collateral ligament, *ITB* Iliotibial band summarizes the complications/adverse effects of lateral extra-articular procedures (LEAPs).

8.7 Conclusions

The rate of graft failure after isolated ACLR remains a concern for knee surgeons despite the development of reconstructive techniques (transtibial, anatomic, or double-bundle techniques). This situation has led researchers to take a renewed interest in the role of anterolateral augmentation procedures. There is currently a great deal of interest in the role of the anterolateral structures of the knee in controlling rotational laxity and their ability to share loads with the ACL graft. Clinical results show that combined ACL and LEAP reconstruction is a safe procedure, reducing the rate of graft failure and increasing the rate of return to pre-injury sports levels. Research has shown that these procedures do not overconstrain the knee, nor do they increase lateral tibiofemoral contact pressure or cause loss of internal rotation.

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