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Graft choices for anterolateral ligament knee reconstruction surgery: Current concepts

Chalidis *et al.* Review of ALLR grafts

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Abstract

The anterolateral ligament (ALL) is a primary structure of the anterolateral complex of the knee that contributes to internal rotational stability of the joint. Injury of the ALL is commonly associated with rupture of the anterior cruciate ligament (ACL). If left untreated, ALL lesions may lead to residual anterolateral rotational instability of the knee after anterior cruciate ligament reconstruction (ACLR), which is a common cause of ACL graft failure. The function of the ALL can be restored by lateral extraarticular tenodesis (LET) or anterolateral ligament reconstruction (ALLR). In the LET procedure, a strip of the iliotibial band is placed in a non-anatomical position to restrain the internal rotation of the tibia, while in ALLR, a free graft is fixed at the insertion points of the native ALL. Gracilis and semitendinosus grafts have mainly been utilized for ALLR, but other autografts have also been suggested. Furthermore, allografts and synthetic grafts have been applied to minimize donor-site morbidity and maximize the size and strength of the graft. Nevertheless, there has been no strong evidence to fully support one method over another thus far. The present review presents a detailed description of the graft choices for ALLR and the current literature available in regard to the effectiveness and outcomes of published surgical techniques.

Key Words: Anterolateral Ligament; Reconstruction; Lateral extraarticular tenodesis; Anterior Cruciate Ligament; Hamstrings; Gracilis; Semitendinosus

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Core Tip: There is no convincing evidence regarding the biomechanical and functional superiority of either LET or ALLR procedures during ACLR. Although hamstrings remain the most common graft choice for ALLR, other autografts, as well as allografts and synthetic grafts, have been also applied. Further research and comparative studies

should be carried out to identify the most effective graft material and technique for the restoration of rotational knee stability in the presence of residual instability after ACLR.

INTRODUCTION

The anterolateral ligament (ALL) is an independent structure of the anterolateral complex of the knee ⁸ along with the lateral collateral ligament (LCL), the iliotibial band (ITB) and the anterolateral joint capsule ⁴⁹. About its origin, there is no consensus so far on whether ALL bony attachment is located posterior and proximal ^{14,36} or anterior and distal ^{12,39} to the lateral femoral epicondyle or just on the lateral epicondylar together with the LCL attachment ⁵⁸. Its course is anterodistal and superficial to the LCL and its distal insertion midway between the anterior border of the fibular head and the Gerdy's tubercle of the tibia ¹⁷. ² The ALL is a nonisometric structure that tensions during knee flexion and internal tibial rotation and shows the greatest length change at 90° of flexion ⁷⁷. As a distinct structure of the anterolateral complex of the knee, the ALL seems to contribute to internal rotational stability of the joint ^{53,72} but its role in resisting rotational as well as anteroposterior instability in anterior cruciate ligament (ACL) deficient knee is still controversial ^{30,38}.

Anterolateral ligament lesion is presented as a midsubstance strain and tear or avulsion of its bony insertion on the tibia which is known as Segond fracture ²⁴. The injury is most commonly associated with ACL rupture ¹¹. Concomitant ACL and ALL deficiency may result in increased knee rotational instability, which may not be restored by isolated anterior cruciate ligament reconstruction (ACLR) ⁷¹. The incidence of positive pivot shift after ACLR could raise to 34% of operated cases ⁵⁵ and many studies have demonstrated that additional anterolateral ligament reconstruction (ALLR) decreases knee laxity ⁵¹ and ACL graft failure rate ⁵⁹ and improves patient-reported outcomes ^{43,57}. On the other hand, simultaneous ALLR has been associated with overconstrained internal rotation and subsequent knee joint stiffness ^{54,60}. Furthermore, there is some evidence that ALLR does not decrease the rotational laxity of the knee to a desirable degree and its role in improving the postoperative function is

limited^{18,70}. Thus, simultaneous ACLR and ALLR have been suggested mainly in cases of grossly unstable pivot-shift and revision ACL surgery^{41,52}. Moreover, indications for ALLR may include young patients who participate in pivoting activities as well as knees with chronic ACL-deficiency or concomitant meniscal tears requiring surgical repair⁶⁸.

LITERATURE SEARCH

We conducted a narrative review using the MEDLINE online database regarding the ALLR. The initial search applying the keywords “Anterolateral Ligament Reconstruction” led to 807 results. After abstract and full-text screening, 22 studies describing the results of ALLR in ACLR surgery were enrolled for further assessment. The extracted data were analyzed and organized to present the different reported methods of ALLR during ACLR in respect to graft choice, proximal and distal attachment location, stabilization technique and knee fixation angle. (Table 1).

GRAFT TYPES AND TECHNIQUES

So far, many grafts have been applied for the restoration of ALL function, but no consensus exists regarding the ideal graft type and fixation technique. Controversies are based on the anatomic parameters of ALL regarding its bony origin^{31,39} and its length changes during knee motion^{17,18} and they are referred to graft material choice^{29,74} as well as graft insertion site location and fixation angle^{2,33,40}. All the applied procedures aim to restore the knee kinematics in case of ALL deficiency and include either the lateral extraarticular tenodesis (LET) or anterolateral ligament reconstruction (ALLR) techniques. The main principle of LET procedure is the use of a strip of ITB which is stabilized proximally above the knee joint while its tibial insertion to Gerdy’s tubercle remains intact.⁶¹ On the other hand, the ALLR aims to restore the ALL native features, by fixing a free tendon graft between the anatomical femoral and tibial insertion points of the ALL⁶⁶.

The current graft types and techniques for reconstruction of ALL during ACL reconstruction include:

2.1 AUTOGRAFTS

2.1.1 Iliotibial band

The ITB is exclusively used for LET procedure. Lemaire⁴² was the first who described the LET technique in cases of chronic ACL injuries. In the original procedure, the ITB was identified and a strip of 1 cm wide and 18 cm long was harvested, leaving the attachment to Gerdy's tubercle intact. The graft was firstly passed in a distal to proximal direction under the LCL. Then, it was introduced to the distal femur through a bone tunnel above the lateral epicondyle and proximal to the LCL insertion. Consequently, it was passed again under the LCL in a proximal to distal direction and finally fixed to the tibia through a bone tunnel at Gerdy's tubercle and sutured on itself. Fixation was completed in 30° of knee flexion and some tibial external rotation. In case of combination with ACLR, LET allows for independent ACL graft choice. The authors also proposed a variation of the original technique by fixing the strip of ITB into the femoral tunnel which was created for bone-patellar tendon-bone graft ACLR.

Many modifications of the Lemaire procedure have been described referring to harvesting a shorter strip of tendon^{10,46}. In addition, the graft may be stabilized proximally with sutures to ITB, after passing through the lateral intermuscular septum¹³, or with either a staple⁴⁶ or an interference screw¹⁰. Andrews and Sanders⁴ described a technique where two strips of ITB were harvested and passed through two parallel lateral-to-medial femoral tunnels and sutured together.

Moreover, variable knee flexion angles have been recommended during fixation, including 30°¹, 60°⁴⁶, and 90°³. In respect to tibial rotation, older studies suggested that tibia should be maintained in external rotation, but no specific angle was defined^{4,7}. However, that position has been related to excessive restriction of internally rotatory movement and abnormal knee kinematics^{20,61}. This over-constraint along with the non-anatomic nature of LET procedure may lead to gradual elongation of the graft and

subsequent recurrent rotational instability^{20,21}. As a result, most recent studies have advocated a neutral rotation position for ITB graft fixation^{1,46}.

2.1.2 *Gracilis tendon*

Gracilis tendon (GT)¹ is a commonly used autograft for ALLR. The free tendon graft is fixed proximally on the lateral femoral epicondyle and distally between the fibular head and Gerdy's tubercle, after passing between the ITB and LCL⁴³. Most frequently, the graft is introduced proximal and posterior to lateral femoral epicondyle⁶⁵ but a more anterior position has been also described⁶². Femoral fixation can be performed with an interference screw²⁶ or an anchor⁶². The same principles are followed when concomitant ACLR is performed with either hamstrings graft^{62,65}, bone-patellar tendon-bone graft²⁶, or internal brace¹⁵.

The tibial attachment of the graft is placed between the fibular head and Gerdy's tubercle approximately 5 to 13 cm distal to the lateral joint line^{23,28}. Fixation is accomplished using an interference screw¹³ or an anchor²⁸. Some authors have described ALLR in an inverted V-shaped fashion. Specifically, the graft is introduced in a tibial bone tunnel extending anterior to the fibular head and posterior to Gerdy's tubercle and then is fixed at the femoral side with an anchor¹⁵ or with sutures around the graft⁵⁹. Sonnery-Cottet et al.⁶⁵ completed tibial fixation of the graft with two suture anchors. The first one was placed on the superolateral margin of the Gerdy's tubercle and the other one midway between the fibular head and Gerdy's tubercle.

During combined ALLR and ACLR using hamstring tendons autograft, a single graft is usually used for both procedures. After ACLR, the remaining graft is passed through a bone tunnel to the lateral surface of the distal femur, proximally and posteriorly to the lateral epicondyle^{23,59}. Helito *et al*²⁸ identified the ALLR femoral tunnel location using fluoroscopy, aiming approximately 3-4 mm below the halfway point of the Blumensaat's line in the anteroposterior direction³. Furthermore, Ferreira *et al*²³ used a triple semitendinosus tendon (ST) graft for ACLR and a double GT graft for ALLR. Another combination is a four-strand ACL graft formed by a triple ST bundle and a

single GT bundle while the remaining GT is used for ALLR²⁸. Colombet¹³ also described the use of a quadruple ACL graft composed of two ST and two GT bundles. A double-bundle graft for ALLR was created from the excess tendon tissue of the bundles.

There is no consensus regarding the ideal fixation angle of GT graft. Several different knee angles have been reported so far including full extension¹⁵, 30°⁶², 45° to 60°²³, 60° to 90°²⁸, and 90°¹³. In contrast, it has been generally accepted that the tibia should be maintained in neutral rotation at the time of graft stabilization^{59,62,65}.

Semitendinosus tendon

Apart from GT, the ST has been also widely used for ALLR²⁶. Kim *et al*³⁷ harvested the contralateral ST for ALLR, as the ipsilateral ST had been already used for ACLR during the same or previous procedure. The double-bundle graft was firstly attached on the tibia (midway between the fibular head and Gerdy's tubercle) using an adjustable length loop button, then passed deep to ITB and finally fixed posterior and proximal to the lateral femoral epicondyle with an interference screw, while the knee was positioned in 30° of flexion and neutral rotation. Additionally, Zarins and Rowe⁷⁶ proposed simultaneous ACLR and ALLR using only the ipsilateral ST. After proximal release, the ST was passed through the knee joint for ACLR, then exerted through a lateral femoral bone tunnel and tied to ITB keeping the knee in 60° of flexion and tibial external rotation.

2.1.4 Peroneus longus

Escudeiro de Oliveira *et al*²² reconstructed the ALL with an ipsilateral peroneus longus (PL) tendon graft and the ACL with a quintuple graft composed of a double-bundle ST, a double-bundle GT, and a single-bundle PL. Specifically, the quintuple graft was initially used for ACLR and the excess PL material was passed through a femoral tunnel, proximal and posterior to the lateral epicondyle, and was attached distally between the fibular head and Gerdy's tubercle at 15 mm from the joint line. An

interference screw was used in each attachment site and during fixation the knee was kept at mild valgus and 30° of flexion. The authors supported the option of PL graft for ALLR as it could be easily harvested with minimal invasiveness, it was associated with low donor site morbidity and allowed adequate concomitant ACLR in combination with hamstring tendons autograft.

2.1.5 *Plantaris longus*

Josipovic *et al*³⁵ presented a technique of ALLR using the ipsilateral plantaris longus tendon. A quintuple graft composed of a three-strand ST and a two-strand GT was used for ACLR and a two-strand plantaris longus graft, which substituted the ALL, sutured to the quintuple graft. After the ACL graft fixation, the plantaris longus tendon was passed through a bone tunnel posterior and proximal to the lateral femoral epicondyle and fixed with an interference screw 10 mm distally from the joint line and midway between the fibular head and Gerdy's tubercle, while the knee was fully extended. Although the authors reported good short-term results there is a lack of data regarding the effectiveness of the technique.

2.1.6 *Quadriceps and patellar tendon grafts*

Historically, Marshall *et al*⁴⁵ presented the Marshall-MacIntosh procedure using an autograft of quadriceps tendon-prepatellar retinaculum-patellar tendon for concomitant ACL and ALL reconstruction. The distal attachment of the extensor apparatus to the tibial tubercle ⁵ was preserved and the graft was passed through a tibial and femoral bone tunnel over the top of the lateral femoral condyle and fixed on Gerdy's tubercle. Dupont *et al*¹⁹ presented a modification of the technique by harvesting a free graft including the bony attachment of the quadriceps tendon-prepatellar retinaculum-patellar tendon on the tibial tubercle. Additionally, Benum ⁴ ⁷ reported the use of the lateral one-third of the patellar tendon with a proximal bone block for ALLR. The distal attachment on the tibial tubercle was preserved and the graft was fixed with staples to the femoral origin of LCL.

2.2 ALLOGRAFTS

Some authors have recommended the application of allografts for ALLR, even in primary surgery, emphasizing the advantages of no donor site morbidity and availability of larger and longer grafts ⁴⁷. However, the use of allografts has been mainly suggested in revision surgery, where autografts may be not available in sufficient quantity ⁹. Lee *et al* ⁴¹ used a GT allograft for ALLR in combination with tibialis anterior allograft for ACLR in the setting of revision surgery. Comparing ACLR with and without ALLR, they reported better outcomes after at least three years in terms of residual pivot shift, subjective IKDC score and Tegner score, return to the preinjury level of sports activity and possibility of revision surgery when ALLR was additionally performed. Chahla *et al* ⁹ underwent also ALLR using an ST allograft mainly in cases requiring revision ACL surgery. However, they did not present any postoperative outcomes. Fernández *et al* ⁴⁴ used an Achilles tendon allograft for both ACLR and ALLR in patients with previously failed ACLR and significant bone loss. They performed a two-stage procedure to fill the bone defect with a bone graft and to subsequently reconstruct the ACL and ALL. Still, no postsurgical outcome was reported.

2.3 SYNTHETIC GRAFTS (POLYESTER TAPE)

Wagih and Elguindy ⁷³ reported an ALLR technique using polyester tape. The synthetic ligament was attached proximally anterior and distal to the lateral femoral condyle with a cortical suspensory button. Distally, the graft was inserted between the Gerdy's tubercle and the fibular head and stabilized *via* sutures that tied on the medial side of the tibia through two bone tunnels. During fixation, the knee was placed in 30° of flexion. The authors suggested that polyester tape ALLR might be worth further investigation as it was a minimally invasive technique without donor site morbidity. Furthermore, the material could offer adequate strength with minimal possibility of laxity and postoperative failure. However, no details about the postoperative outcome were provided.

BIOMECHANICAL EVALUATION

The combination of ACLR with LET or ALLR can restore residual rotational laxity after isolated ACLR³⁴. However, the LET procedure has been related to postoperative overconstrain of the internal rotation of the knee⁶¹. In a cadaveric study, Smith *et al*⁶⁴ reported similar results and equivalent restoration of knee kinematics between ALLR and LET after ACLR. Regarding knee position during graft fixation, Inderhaug *et al*³² in a controlled ACLR laboratory study found that knee laxity was equally restored when ITB graft tenodesis was performed at 0°, 30°, or 60° of knee flexion. On the other hand, ALLR using GT graft achieved normal kinematics only when fixation was performed in full extension. Conversely, in another cadaveric study, Geeslin *et al*²⁵ found that both LET and ALLR were effective in reducing internal tibial rotation independently of the knee fixation angle or graft tension.

Additionally, Monaco *et al*⁴⁸ noticed that ALLR with GT showed superior biomechanical properties than LET while the native ALL had lower failure load and stiffness compared to both grafts. Ra *et al*⁵⁶ found that LET resulted in similar rotational stability but worst anterior instability compared to ALLR. On the contrary, Spencer *et al*⁶⁹ reported that ALLR was less effective in reducing anterolateral rotational laxity than the LET procedure. Deviadri and [van der Veen](#)¹⁶ used LET in four patients with residual rotational instability after ACLR and reported significant improvement of knee kinematics.

In a recent meta-analysis, Yin *et al*⁷⁵ reported superior knee kinematics after combined ACLR and ALLR or LET compared to isolated ACLR in ACL deficient knees. Similarly, Littlefield *et al*⁴³ in a systematic review identified that supplementary ALLR during ACLR improved anterior tibial translation and internal knee rotation and resulted in a lower incidence of graft failure.

CLINICAL EVIDENCE

Current literature suggests that combined ACLR with ALLR or LET can improve clinical outcomes and decrease the possibility of ACL graft failure compared to isolated ACLR⁴³. Beckers *et al*⁶ observed that both LET and ALLR during ACLR provided superior Lysholm Score and reduced ACL re-rupture rate. Na *et al*⁵⁰ in a systematic review found that ALLR or LET along with ACLR were related to superior subjective IKDC, Tegner and Lysholm scores than isolated ACLR. However, the LET was associated with higher postoperative stiffness and complications than ALLR. Sonnery-Cottet *et al.*⁶⁷ using data from 270 patients noticed that combined ACLR with ALLR led to a lower reoperation rate, better long-term graft survivorship but similar overall complication risk compared to isolated ACLR. The authors reported a 5-fold increase in the risk of ACL graft failure after a mean of 104 mo in case of isolated ACLR. Similarly, in a systematic review of de Lima *et al*⁵ the simultaneous ALLR and ACLR were related to better clinical outcomes than single ACLR, including higher success in return to sport and lower ACL graft rupture rate. The advantages and disadvantages of each technique are summarized in Table 2.

DISCUSSION

Restoration of rotational stability is of paramount importance in the ACL injured knee. Apart from intraarticular ACLR, additional extraarticular procedures may be required to improve knee function and stability and minimize the risk for ACL graft failure. These include the LET and the ALLR with variable modifications of each procedure regarding the graft choice and fixation technique. Semitendinosus and gracilis are the main tendon grafts for ALLR but other autografts such as peroneus longus, plantaris longus, and quadriceps-patellar tendons have been also applied. Allografts and synthetic grafts are usually preferred in revision ACLR procedures where there is limited availability of autograft material for both ACLR and ALLR. Although all the available grafts for LET and ALLR may improve knee rotational stability, few studies with a relatively short follow up and a small number of patients have been published so far. Therefore, there is inconclusive evidence to favor one method over the others in

terms of biomechanical properties and clinical outcomes. Further large-scale studies are required to clarify the benefit of ALLR during primary or revision ACLR procedures. Particularly, future randomized control trials should compare ACLR with or without ALLR in young, active, and high-demand patients by using different graft types. The research should focus also on the subgroup of patients with large pivot-shift and operated meniscal tears aiming to find a potential correlation between ALLR and failure of ACLR under these conditions.

CONCLUSION

According to the current review and existed literature, there is no convincing evidence regarding the biomechanical and functional superiority of either LET or ALLR procedures during ACLR. Although hamstrings remain the most common graft choice for ALLR, other autografts, as well as allografts and synthetic grafts, have been also applied with satisfactory results and low complication rate. However, a pooled analysis of all published raw data would further improve the quality of the review and related evidence despite the heterogeneity of the studies.

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