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Role of anterolateral reconstruction in ACL surgery. Why, When and How?

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Abstract

Ruptures of the anterior cruciate ligament (ACL) cause both abnormal anterior translation and anterolateral rotation of the tibia under the femur. Isolated intra-articular ACL reconstruction has evolved significantly over the past years, but in many cases it is insufficient to correct rotational laxity. There are several justifications for anterolateral plasty in the context of ACL surgery: The persistence of anterolateral laxity after some isolated ACL intra-articular reconstructions, the evidence of traumatic lesions of these anterolateral structures after ACL tear and the recent anatomical and biomechanical research on the anterolateral complex of the knee. One more justification is that some recent studies comparing the outcomes after isolated ACL reconstruction and those after ACL reconstruction combined with anterolateral reconstruction are in favor of the simultaneous procedures. The addition of an extra-articular procedure to the intra-articular reconstruction of the ACL can improve the outcomes particularly in these situations: Young age (<25 ans), sports with pivot contact particularly if high level, pivot-shift Grades 2–3, recurvatum of the knee and generalized hyperlaxity, posterior tibial slope superior to 12°, meniscus deficiency, and ACL revision. Different surgical techniques have been proposed and described. They can be classified in two groups: The techniques using an ilio-tibial band graft to perform a lateral tenodesis and the procedures aiming to reconstruct the anterolateral ligament. Both techniques intend to control the anterolateral displacement of the tibial plateau.

Keywords: Anterolateral ligament, anterior cruciate ligament, anterolateral reconstruction, lateral tenodesis, condylar strap.

1. Introduction

Ruptures of the anterior cruciate ligament (ACL) cause both abnormal anterior translation and anterolateral rotation of the tibia under the femur. These biomechanical abnormalities will present consequences on the dynamic stability of the knee as well as on the anatomical structures, in particular the menisci and cartilage, with development of osteoarthritis over time. Surgery must therefore correct these two biomechanical anomalies. Isolated intra-articular ACL reconstruction has evolved significantly over the past 10 years, but in many cases it is insufficient to correct rotational laxity. This explains interest in anterolateral reconstruction (ALR) procedures in association with intra-articular ACL reconstruction.

2. History

To understand the place that ALR can have in the treatment of ACL deficiency, it is interesting to recall the history of this type of surgery.

It was in the 1960s that Marcel Lemaire, a French surgeon, proposed to treat the ACL tears with an isolated lateral plasty using a band of the fascia lata [1]. The aim of this surgery was to restrict the translation of the lateral tibial plateau under the lateral femoral condyle. Lemaire had observed this abnormal movement in athletes with a ruptured ACL and described what he called the "ressaut." This surgical procedure actually dealt with the consequences and not the cause of the injury, but this needs to be highlighted in the context of the limited knowledge at this time about ACL rupture. With this technique, Lemaire obtained excellent results in athletes who could resume pivot sport activity without experiencing rotational instability and he enjoyed a great notoriety in the French sports community at the time. Unfortunately, the positive results only lasted a few years or months because the extra-articular procedure stretched in the absence of intra-articular reconstruction.

Almost simultaneously or shortly thereafter, Macintosh and Darby [2] in Canada described the "pivot shift"iand offered an equivalent anterolateral plasty. Others subsequently proposed plasties with the same principle: Losee et al. in 1978 [3], Ellison in 1979 [4], or Andrews and Sanders [5] in 1983.

The insufficient results of these

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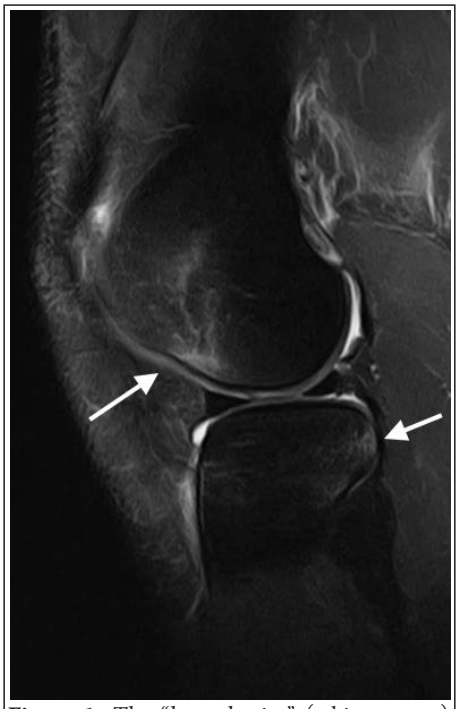

Figure 1: The "bone bruise" (white arrows) observed on the MRI performed after a recent rupture of the anterior cruciate ligament testifies the forced movement, which bring the posterior edge of the lateral tibial plateau into contact with the lateral condyle.

techniques with persistence or recurrence of laxity, meniscal lesions or secondary degenerative lesions led to the abandonment of isolated anterolateral techniques by most surgeons.

At the same time, in the 1980s, intra-articular ACL plasties developed after a few unsuccessful attempts to perform a direct repair of the ligament [6].

Recently, anterolateral plasties have seen resurgence of interest but in combination with intra-articular plasties. This approach has more and more advocates but it is interesting to note that some surgeons, especially in Europe, have had this philosophy from the start as a result of Lemaire's experience and they have now long time follow-up.

Therefore, the purpose of this article is to describe the advantages of ALR when it is combined with an intra-articular reconstruction of the ACL and not in its isolated version.

3. Why

There are several justifications for anterolateral plasty in the context of ACL surgery: The persistence of anterolateral laxity after some isolated ACL intra-articular reconstructions, the evidence of traumatic lesions of these anterolateral structures after ACL tear and the recent anatomical and biomechanical research on the anterolateral complex of the knee. One more justification is that some recent studies comparing the outcomes after isolated ACL reconstruction and those after ACL reconstruction combined with ALR are in favor of the simultaneous procedures.

These different arguments are exposed in this chapter.

3.1) ACL Surgery Outcomes

The techniques of intra-articular ACL reconstruction have improved the clinical results of this surgery with better stability and better rate of return to sport. However, the critical analysis of the results does not allow us to be so enthusiastic.

The literature has now clearly demonstrated that after isolated intra-articular reconstruction of ACL, a pivot shift can persist in 10–20% of cases [7].

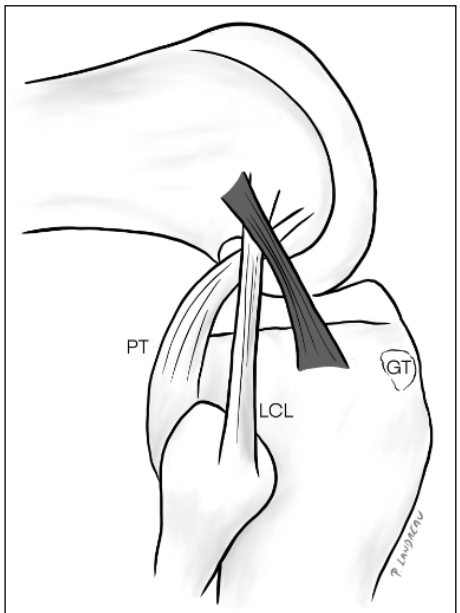

Figure 3: The proximal insertion of the anterolateral ligament (dark grey) is located on the lateral femoral epicondyle, posterior, and proximal to the lateral collateral ligament, it goes downward and forward to insert between the Gerdy's tubercle and the fibula head. PT: Popliteus tendon.

Figure 2: Paul Segond was the first to describe a lesion of the cortex of the lateral tibial plateau.

In their meta-analysis, Ardern et al. (48 studies evaluating 5770 participants at a mean follow-up of 41.5 months were included for review) demonstrated that while 82% of patients returned to some form of sports participation following ACL reconstruction surgery, only 63% of patients were able to return to their pre-injury level and only about half of patients returned to competitive sport after ACL reconstruction surgery [8]. In another study, the same group showed that while two-thirds of patients had attempted some form of sport by 12 months following their surgery, only one-third had returned to their pre-injury level of competitive sport participation [9].

After return to sport, the risk of re-injury (graft rupture) ranges in the literature from 6% to 25% whereas the risk of contralateral ACL injury ranges from 2% to 20.5%. Wright et al. [10] conducted a systematic review of six levels I or II

prospective studies that evaluated the graft rupture and contralateral ACL injury rates in patients at least 5 years following ACL reconstruction surgery, using either a patellar tendon or hamstring tendon autograft. The results demonstrated that the ipsilateral ACL graft rupture rate ranged from 1.8% to 10.4%, with a pooled percentage of 5.8%. The contralateral injury rate ranged from 8.2% to 16.0%, with a pooled percentage of 11.8%. They concluded that the risk of ACL tear in the contralateral knee (11.8%) was double the risk of ACL graft rupture in the ipsilateral knee (5.8%). However, most studies do not clearly separate graft rupture and graft deficiency that may have been present from the early postoperative period. This may in turn influence the factors that are identified as predictors of graft rupture as opposed to failure. Young age is a factor of re-injury. Wiggins et al. [11] in a systematic review showed that athletes younger than 25 years who returned to sport have a secondary ACL injury rate of 23%. This systematic review and meta-analysis demonstrate that younger age and a return to high level of activity are predominant factors associated with secondary ACL injury. These combined data indicate that nearly 1 in 4 young athletic patients who sustain an ACL injury and return to high-risk sport will go on to sustain another ACL injury at some point in their career, and they will likely sustain it early in the return-to-play period.

The causes of failures and re-ruptures are multifactorial and not only related to the surgical technique. However, it cannot be denied that a percentage of patients who have had an isolated ACL reconstruction are still complaining rotational laxity after surgery and that this residual laxity partly explains the failures. This finding indicates that current intra-articular reconstructions are either imperfect or only address part of the problem or both.

To remedy this problem, much hope has been placed with the development of double-bundle techniques with the aim of reconstructing both the anteromedial and posterolateral bundles, the latter being primarily responsible for controlling the pivot shit. Although bio-mechanical studies have been promising, clinical results have not shown any clear superiority over conventional techniques. The concept of anatomical reconstruction is now quite consensual with a more oblique graft and tunnels located in the native ACL footprints, but there is still a percentage of imperfect results and re-ruptures especially in the young and athletic population. The ribbon-band concept, the concept of ACL augmentation and other technical variants did not revolu-tionize the results either.

3.2) Injuries of Anterolateral Structures

One of the most common mechanisms leading to ACL rupture is rotation with valgus, with the knee close to extension. In this valgus movement with forced internal rotation, the lateral tibial plateau slides forward and cause ACL rupture. The "bone bruise" observed on the MRI performed after a recent rupture of the ACL testifies this forced movement, which bring the posterior edge of the lateral tibial plateau into contact with the lateral condyle (Fig.1). This demonstrates that for a very short time, the lateral structures were put in tension during the injury. It is, therefore, logical to conceive that the lateral soft parts can be damaged during this mechanism. If they exist, these lesions cannot be repaired by simple reconstruction of the ACL.

Paul Segond was the first to describe a lesion of the cortex of the lateral tibial plateau (Fig. 2). He described a "pearly, resistant, fibrous band which invariably showed extreme amounts of tension during forced internal rotation" early.

Recently, traumatic lesions of the anterolateral structures and particularly

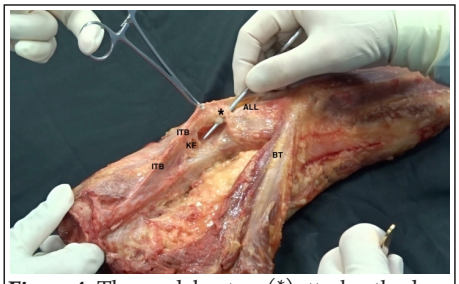

Figure 4: The condylar strap (*) attaches the deep surface of the iliotibial band to the lateral part of the distal femur and the lateral gastrocnemius tendon. The orientation of its fibers and its qualitative evaluation suggest that this structure may also have a role in the anterolateral stability of the knee through its tenodesis effect on the iliotibial band. Right knee.

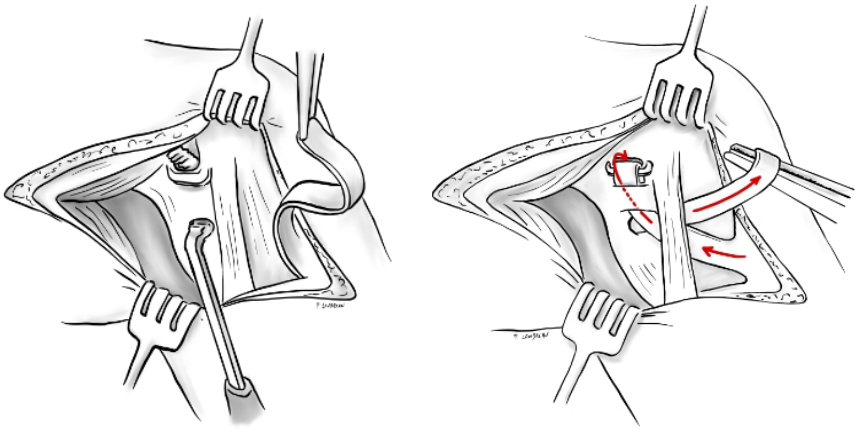

Figure 5: A strip of iliotibial band 12–15 cm long and 1 cm wide is taken, leaving its insertion on Gerdy's tubercle. A curved tunnel is performed with its inferior opening located just behind the femoral insertion of the lateral collateral ligament (LCL) (a). The strip is passed under the LCL, then under the periosteal detachment from bottom to top then in the tunnel in the opposite direction and finally passed again under the LCL to be sutured to itself (b).

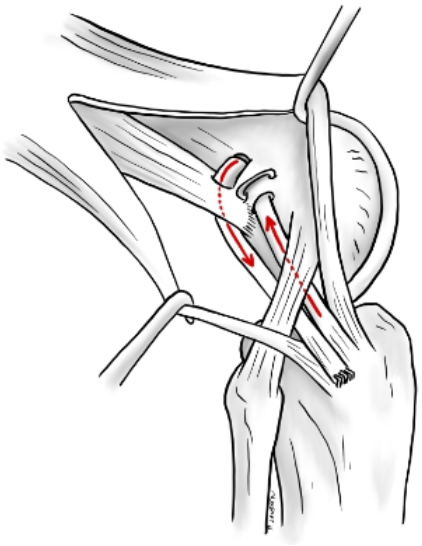

Figure 6: Macintosh technique for lateral tenodesis.

of the anterolateral ligament (ALL) have been documented and studied in imaging and during operative exploration [12, 13].

There is, therefore, in certain cases of rupture of the ACL, concomitant lesions of the anterolateral structures of the knee.

3.3)Anatomy

Vesalius, in his "De Humani Corporis Fabricaishad already described the fascia lata in the sixteenth century. He called it the sixth tibia muscle [14]. However, the first in-depth work on this muscle comes from Jacques Maissiat in 1843 when he devoted a monograph to this anatomical structure, hence sometimes used name of "bandelette de Maissiat." The term most widely used today is iliotibial band or iliotibial tract [15]. Kaplan's 1958 article is well known [15]. He showed the connections of the iliotibial-tibial tract with the inter-muscular septum and the supracondylar tubercle. Terry et al. in 1986 [16] provided a detailed analysis of the anatomy of the anterolateral structures of the knee. This work will be confirmed by Vieira et al. in 2007 [17].

Different terms have been used to describe one or more anatomical structures which could have a role in the rotary control of the knee at this level: Capsulo-osseous layer, mid-third lateral capsular ligament, lateral capsular ligament, or ALL.

There has been a marked resurgence of interest in recent years in the anterolateral anatomy of the knee. The ALL of the knee was originally described by Vincent et al. in 2012 [18], then Claes' article in the Journal of Anatomy [19] precisely described the anatomy of this "new"eligament. Despite several anatomical and biomechanical studies, the exact anatomy and role of the ALL are still debated. Nevertheless, ALL can be described as follows: The proximal insertion is located on the lateral femoral epicondyle, posterior, and proximal to the lateral collateral ligament (LCL), it goes downwards and forwards to insert itself between Gerdy's tubercle and the fibula head (Fig. 3). The Segond fracture could represent the avulsion of the distal insertion of the ALL [20].

The ALL has not been the only structure to be studied and identified. Kaplan fibers have been re-defined in their anatomy and biomechanical studies have been devoted to them [21]. Finally, more recently a deep structure in the iliotibial band (ITB) has been described, the condylar strap [22]. This anatomical structure attaches the deep surface of the ITB to the lateral part of the distal femur and the lateral gastrocnemius tendon

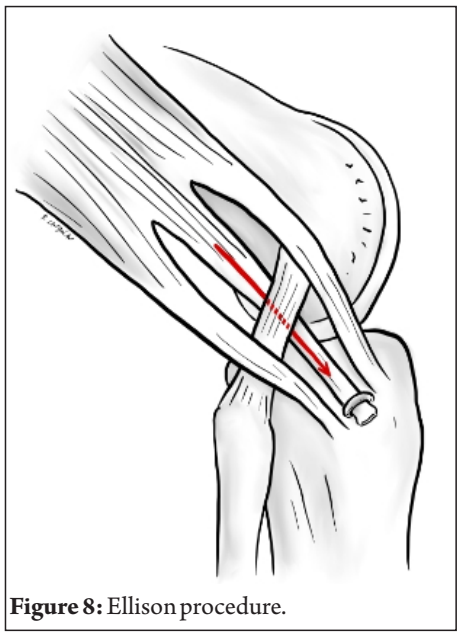

Figure 8: Ellison procedure.

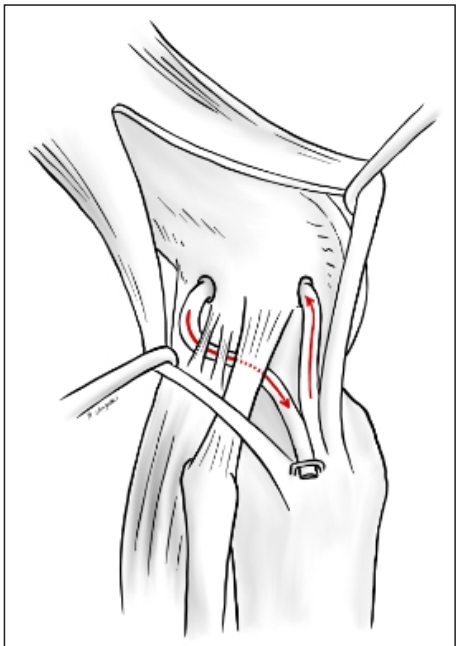

Figure 7: Loose's procedure.

(Fig. 4). The orientation of its fibers and its qualitative evaluation suggest that the condylar strap may also have a role in the anterolateral stability of the knee through its tenodesis effect on the ITB.

We can, therefore, see that the precise anatomical evaluation of the antero-lateral structures of the knee is still a controversial subject and it is probable, in view of the various current anatomical studies that several anatomical structures act in synergy.

3.4)Biomechanics

Several biomechanical cadaveric studies have evaluated the effect of the section of the ALL and the anterolateral capsule on internal tibial rotation with contradictory results. It is, therefore, difficult to draw conclusions at this time and more studies are needed in the future. Regarding the biomechanical effect of lateral tenodesis (LET), the results seem more consistent. Engebretsen has shown that adding an extra-articular lateral plasty to an ACL reconstruction can reduce the stress on the intra-articular plasty by 43% [23]. More recently, Monaco et al. [24], in a computer navigation study, showed that ALR was more effective than intra-articular reconstruction in reducing axial

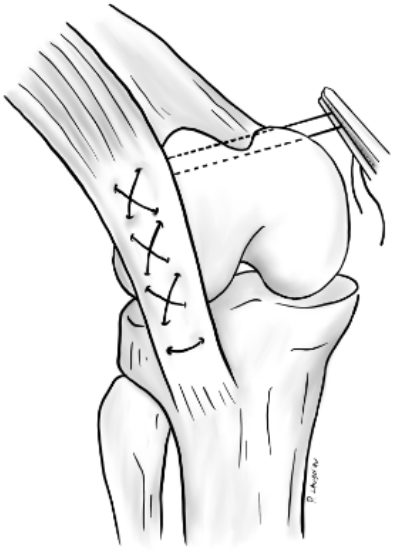

Figure 9: Andrews tenodesis technique.

tibial rotation and that anatomic ACL reconstruction and ALR were synergic in controlling the pivot-shift phenomenon. In a cadaveric model, Marom et al. [25] demonstrated that the LET in combination with ACL reconstruction transferred loads from the ACL graft to the tenodesis and reduced the anterior tibial draw with applied pivoting loads and during the simulated anterior drawer test.

3.5) Results

Noyes, in 1991, had shown that the addition of an extra-articular plasty to an intra-articular allograft statistically reduced failures at 2 years' follow-up [26]. At the same time, another study, comparing bone – patellar tendon –abone autograft ACLR with or without ALR in 80 patients concluded that there was no benefit from ALR and suggested that it could be responsible for osteoarthritis lesions [27]. This paper certainly made some surgeons suspicious of the benefit of ALR for several years. Other more recent studies, some with a follow-up of 20 years, have shown the absence of greater osteoarthritis in ALR [28, 29, 30].

In a recent randomized controlled trial, Getgood et al. concluded that the addition of a lateral extra-articular tenodesis to a single-bundle hamstring tendon autograft ACLR in young patients at high risk of failure results in a statistically significant, clinically relevant reduction in graft rupture and persistent rotatory laxity at 2 years after surgery [31].

Thus, there are nowadays many arguments to grant a place to a complementary anterolateral procedure next to the intra-articular reconstruction of the ACL.

4. When

There is currently some evidence concerning the risk factors for re-rupture after ACL reconstruction: Young age, pivot-contact sports in particular if practiced at high level, constitutional laxity and recurvatum, excessive posterior tibial slope (>12°), meniscal deficiency, and graft with a diameter of <8 mm [7, 10, 11, 31].

There is no current support to justify a systematic anterolateral plasty during intra-articular ACL reconstruction. Nevertheless, the current results of the literature and the personal experience of the author conclude that the addition of an extra-articular procedure to the intra-articular reconstruction of the ACL can improve the outcomes particularly in these situations:

- Young age (<25 ans)
- Sports with pivot contact particularly if high level
- Pivot-shift grade 2–3
- Recurvatum of the knee and generalized hyperlaxity
- Posterior tibial slope superior to 12°
- Meniscus deficiency
- And the majority of the ACL revision whatever if previous factors are existing [32].

5. How

Different surgical techniques have been proposed and described. They are either a modification of Lemaire/Macintosh

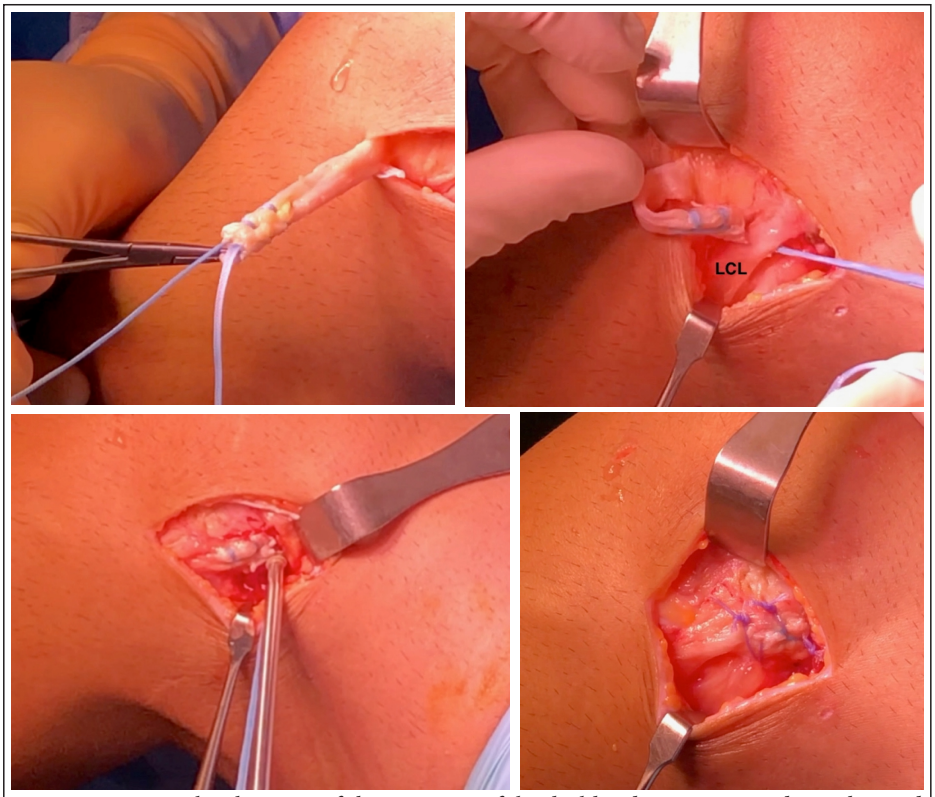

Figure 10: Personal technique. Left knee. A strip of iliotibial band 10–12 mm wide is taken and immediately prepared using a back and forth tape with Krackow points (a). The graft is passed under the lateral collateral ligament (b). With the knee at 40° of flexion and foot in external rotation, the graft tape is fixed to the condyle with an anchor (c) then the graft itself is secured by four sutures fixing the graft on the condylar periosteum and the fibers of the gastrocnemius muscle (d).

using the ITB and can be grouped under the common term of LET, or they are procedures aiming to reconstruct ALL. The choice is mainly related to beliefs about the real role of ALL in controlling tibial rotation and whether or not it is the only one responsible. The biomechanical role of anterolateral structures seems complex, as does its anatomy, and to summarize the control of anterolateral laxity with ALL alone is undoubtedly an oversimplification of the biomechanics of the knee.

Anyway, if we take a pragmatic view, the debate loses some of its interest; the different techniques currently used all have the same principle, which aims to limit the translation of the lateral tibial plateau under the femoral condyle. We will describe the current anterolateral plasties which all have a concept similar to the Lemaire and Macintosh techniques and the ALL reconstruction techniques.

5.1) Lateral tenodesis

5.1.1) Lemaire technique

We will start with the description of Lemaire's technique because, to the best of our knowledge, it was described before others including the MacIntosh one. The first publication in 1967 [1] was in French and circulated very little in the English-speaking world (Fig. 5).

A strip of ITB 12–15 cm long depending on the size of the patient and 1 cm wide was taken, leaving its insertion on Gerdy's tubercle. A curved tunnel was performed with its inferior opening located just behind the femoral insertion of the LCL. This tunnel was made with two awls then with a special curved instrument developed by Lemaire, the "rifloir." A Dujarier staple was placed at the lower edge of the upper tunnel opening to prevent progressive section of the bone by the plasty. Periosteal detachment was carried out on the surface of the tunnel. The strip was passed under the LCL, then under the periosteal detachment from bottom to top then in the tunnel in the opposite direction and finally passed again under the LCL to be sutured to itself. At the time of fixation, Lemaire advised to position the knee at 35–40° of flexion, in strong external rotation of the tibia.

5.1.2) Variants

Macintosh and Darby [2] described his first isolated LET technique in the 1970s (not to be confused with his intra and extra-articular plastic surgery described later). It also used a strip of ITB passed through a tunnel but with a passage also in the intermuscular septum (Fig. 6).

Losee's procedure [3] also used an ITB strip passed under the LCL, through a tunnel, and into the posterolateral capsule (Fig. 7).

Ellison [4] detached the distal insertion from the ITB, passed it under the LCL, and re-attached it over the Gerdy's tubercle (Fig. 8).

Andrews and Sanders [5] performed a "real"etenodesis with transosseous stitches (Fig. 9).

It should be noted that some authors, such as Macintosh, have proposed a technique using the same graft to perform intra-articular surgery and LET with passage through a femoral tunnel or according to the so-called "over-the-top" over-the-top sing the ITB, the extensor apparatus or the hamstrings [33, 34, 35, 36].

The LET technique has recently been simplified with shorter grafts and the use of modern fixation systems such as interference screws or fixation anchors.

5.1.3) Personal technique

A slightly curved 5–6 cm skin incision is made, centered on the lateral epicondyle (Fig. 10). A strip of ITB 10–12 mm wide is taken with a variable length and width depending on the patient. The upper landmark is the lateral epicondyle, the proximal section of the future graft being performed 2 cm proximal to the perceptible protrusion of the epicondyle to harvest sufficient length. The transplant is immediately prepared using a back and forth tapes with Krackow points. The anterior and posterior edges

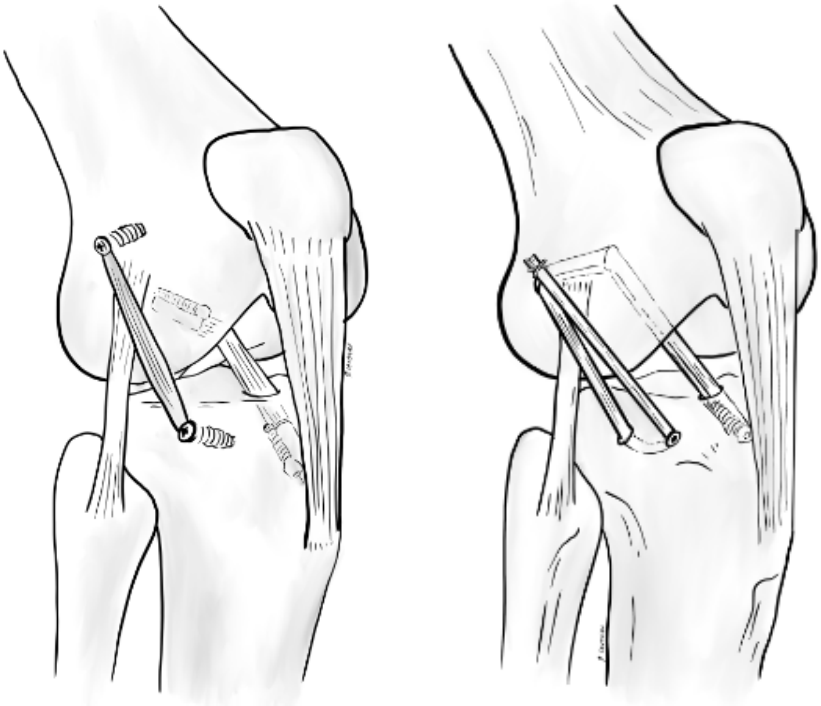

Figure 11: The anterolateral ligament (ALL) reconstruction can be performed separately to the intra-articular procedure (a) or using the same femoral tunnel ending in the area of the ALL femoral insertion with triple or quadruple semitendinosus for anterior cruciate ligament and double or single gracilis for the ALL reconstruction (b).

of the LCL are marked and a passage under the LCL is prepared using scissors and Kelly forceps. Proximal to the upper insertion of the LCL, the lateral aspect of the condyle is dissected with identification of the traction wire of the intra-articular graft left in place to identify the position of the femoral tunnel to avoid any risk of conflict. The graft is passed under the LCL then tensioned, knee at 40° of flexion and foot in external rotation. The proximal point of the graft is marked on the lateral condyle and then the preparation for the fixation system is carried out by drilling. The position of this last point is optimally proximal and posterior to the proximal insertion of the LCL but it is important to notice that, in this technique, the control of the translation of the tibial plateau depends on the passage of the graft under the LCL. On the other hand, the orientation of the drilling must be anterior to avoid interference between the femoral tunnel of the intra-articular plasty and the proximal fixation system of the extra-articular graft. The graft tape is fixed to the condyle with the anchor then the graft itself is secured by four sutures fixing the graft on the condylar periosteum and the fibers of the gastrocnemius muscle. The ITB is then closed with simple stitches, avoiding excessive tension at its lower part to avoid a risk of excessive lateral traction on the patella. The subcutaneous layer and the skin are closed without drainage after careful hemostasis. Performing an extra-articular gesture in no way modifies the post-operative protocol in our daily practice: Immediate full weight-bearing, full motion if no combined meniscus repair, hinge brace for protection during the first 3 weeks during walking.

5.2) ALL Reconstruction

Besides, LET techniques are non-anatomic and whose principle is to perform a plasty controlling the anterior translation of the tibia, several authors have recently described techniques aiming to reconstruct ALL anatomically. These techniques have as a prerequisite and as an assumption that ALL is the only or main element in the control of the translation of the tibial plateau. They are based on recent anatomical and biomechanical studies.

A hamstring autograft is most often used which allows for minimally invasive surgery with two short incisions. In general, the semi-tendinosis is used for intra-articular grafting and the gracilis for reconstruction of the ALL. The two grafts can be performed separately with an all-inside technique for ACL and an ALL graft secured by interference screws or anchors [37]. Other authors have described techniques using the same femoral tunnel ending in the area of the ALL femoral insertion with triple or quadruple semitendinosus for ACL and double or single gracilis for the ALL reconstruction [7,38] (Fig. 11).

6. Conclusion

The literature, whether it concerns anatomy, biomechanics, imaging, or the analysis of clinical outcomes, supports the value of anterolateral procedures in ACL surgery.

The addition of an extra-articular procedure to the intra-articular reconstruction of the ACL can improve the outcomes particularly in these situations: Young age (<25 ans), sports with pivot contact particularly if high level, pivot-shift grade 2–3, recurvatum of the knee and generalized hyperlaxity, posterior tibial slope superior to 12°, meniscus deficiency, ACL revision.

There are still uncertainties about the superiority of one technique over another and future studies will certainly give us more insight, particularly on long-term results.

Clinical relevance

This article is intended to summarize the current knowledge concerning the role of the ALL and in general the ALR in ACL reconstruction. The rationale, the current indications and the technical concepts are exposed and should help the reader to understand the place of this surgery in the context of ACL reconstruction.

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