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# The scientific rationale for lateral tenodesis augmentation of intra-articular ACL reconstruction using a modified 'Lemaire' procedure

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**Abstract**
*Purpose* The purpose of this work was to develop the rationale for adding a lateral extra-articular tenodesis to an ACL reconstruction in a knee with an injury that included both the ACL and anterolateral structures, and to show the early clinical picture.
*Methods* The paper includes a review of recent anatomical and biomechanical studies of the anterolateral aspect of the knee. It then provides a detailed description of a modified Lemaire tenodesis technique. A short-term clinical follow-up of a case and control group was performed, with two sequential groups of patients treated by isolated ACL reconstruction, and by combined ACL plus lateral tenodesis.
*Results* The anatomical and biomechanical literature guide the surgeon towards a procedure based on the iliotibial band. The clinical study found a reduction in pivot-shift instability in the group of patients with the combined procedure.
*Conclusion* The evidence suggests that it should be appropriate to add a lateral extra-articular procedure to an ACL reconstruction in selected cases, but it was concluded that further data are required before definitive guidelines on the use of a lateral tenodesis can be established.
*Level of evidence* III.

**Keywords** Anterior cruciate ligament · Anterolateral ligament · Iliotibial band · Lateral tenodesis · Lemaire · Lateral collateral ligament

## Introduction

The anterior cruciate ligament (ACL) is the primary restraint to anterior tibial translation. It has an oblique orientation close to the centre of rotation of the knee, so it is lever arm to control rotation is small [2] and so an isolated intra-articular ACL reconstruction may be relatively ineffective for controlling internal rotation. Increasing the tension in an isolated ACL graft may lead to over-constraint of anterior translation laxity, yet allow residual rotational abnormality to persist [19]. Not all cases treated with an isolated intra-articular reconstruction are rotationally stable, with some having a residual pivot shift [18], and that may be related to damage to the extra-articular soft tissue structures. Patients with nominally successful ACL reconstructions may have persisting abnormally increased tibial internal rotation in gait [7, 23], and in squatting [20].

This, coupled with recent anatomical studies of the lateral soft tissues, has led to a resurgence of interest in lateral procedures to augment intra-articular reconstruction. It is recognised that ACL rupture is associated with subluxation of the lateral compartment of the knee and therefore an injury to the lateral soft tissue 'envelope' [24]. If these lateral structures do not heal, additional lateral surgery may be needed to assist with rotational control.

Lateral procedures were often used in isolation in the management of ACL rupture prior to the popularisation of the intra-articular reconstruction [5]. However, these procedures were historically thought to be associated with lateral osteoarthritis, but the knees receiving the lateral procedure

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at that time often had significant chondral and meniscal pathology by the time of surgery. Furthermore, the lateral procedure was used in isolation without concomitant intra-articular ACL reconstruction, and postoperatively the knees were often immobilised for an extended period [12]. Unsurprisingly, many suffered from fixed contracture, which in itself, as demonstrated in shoulder stabilisation surgery, is associated with osteoarthritic deterioration [8].

Recent clarification of the anatomy initially described the 'anterolateral ligament' [4, 6] (ALL), and that has led to the development of anterolateral surgical procedures, some of which have been promoted for clinical use without 'due diligence'. It would seem logical that once anatomy has been described it should be tested for biomechanics and then, based upon this, surgical options created. New surgical reconstructions should be subject to rigorous biomechanical evaluation. These experiments should be aimed at testing efficacy as well as potential unwanted effects, such as over-constraint, which could lead to osteoarthritis. Based upon a series of experiments in our laboratory [10, 11, 14, 15], considerable progress has been made in understanding the relevant anatomy and biomechanical roles of anatomical structures, and the impact of various surgical procedures. The purpose of this paper, therefore, is to describe the scientific basis on which a return to the use of lateral extra-articular procedures may be based.

Despite the recent interest in the ALL, laboratory results suggest that it is the ilio-tibial band (ITB), and its attachment to the distal femur via Kaplan's fibres, that provides the most important restraint to internal rotation of the tibia, with the ACL only significant at full knee extension [14]. Furthermore, the most isometric anatomical structure on the lateral side of the knee with regard to anterolateral control is the ITB via its deep and posterior fibres from Gerdy's tubercle to the Kaplan fibre attachment on the femur [15]. The ALL described by our group [6] attaches on the tibia midway between Gerdy's tubercle and the lateral (fibular) collateral ligament (LCL) attachment to the head of the fibula, and on the femur proximal and posterior to the LCL attachment. This description has since been confirmed [13]. In terms of isometry, the ALL tightens in extension and loosens in flexion [6, 15]. Some descriptions of the ALL, and even surgical procedures to reconstruct it, unfortunately place the femoral attachment at, or anterior and/or distal to the LCL attachment to the femur [4, 25]. Such reconstructions would inevitably loosen in extension and be ineffective. Remarkably some operative techniques for ALL reconstruction have indicated that the femoral attachment for the graft is at the femoral attachment of the LCL, but drilling a tunnel here would run the risk of serious damage to the LCL.

Lateral tenodesis procedures, such MacIntosh [1] and Lemaire [17], which leave a strip of ITB attached to Gerdy's tubercle, have a desirable pattern of isometry as long as they pass deep to the LCL: the length change is small, and it tends to elongate (that is: the graft tightens) as the knee is extended [15]. Whilst this is non-anatomical, the angle where the LCL attaches to the femur provides a pulley-effect for any ITB graft taken deep to it, and so a range of graft attachment points proximal/posterior to the LCL attachment may be used [15].

Based upon this knowledge, various reconstructive techniques were compared [11] in cadaveric knees that had been rendered ACL deficient and had a lesion of the anterolateral soft tissue complex, with division of the ALL/capsule anterior to the LCL and division of the ITB attachments to the femur. In this 'worst-case scenario' for anterolateral injury associated with ACL rupture, intra-articular ACL reconstruction alone did not restore normal kinematics. When an ALL reconstruction was added the performance of this procedure was relatively poor, leaving some residual abnormal rotational laxity. A MacIntosh procedure, in which a 1-cm-wide strip of ITB was elevated keeping it attached to Gerdy's tubercle and taken deep to the LCL to be attached to the distal lateral femur just proximal to the lateral femoral condyle, performed very well: the internal tibial rotation laxity did not then differ significantly from the laxity of the native knee [11]. A shorter strip of ITB taken deep to the LCL attached to the femur proximal and posterior to the LCL attachment on the femur, in the same position used for the Lemaire procedure, also performed well. If the same strip of ITB was taken superficial to the LCL and attached to the same 'Lemaire' point on the femur, its performance was inferior.

The early methods of lateral extra-articular tenodesis caused over-constraint of internal rotation, but that may have been the inevitable result of obsolete methods of treatment, such as immobilisation in external rotation [12]. It was believed widely that such procedures led to degenerative changes in the knee, although it is difficult to find evidence of that. Therefore, as part of 'due diligence' in the reintroduction of modern versions of lateral tenodeses, it is necessary to examine the hypothesis that modern methods may cause the articular surfaces to be subjected to elevated contact pressures resulting from graft tension and abnormal kinematics. Inderhaug et al. [10] found no increase in tibiofemoral contact pressures when the graft was tensed to 20 N tension and the tibia was held in neutral rotation at the time of tensioning and graft fixation. If the graft was tensed excessively, to 80 N, then a small but statistically significant rise of lateral compartment contact pressures was caused. If the tibia was also allowed to be pulled into external rotation by the graft when it was being fixed, then the 80 N tension caused a loss of tibial internal rotation.

A recent study [22] found that ALL reconstructions over-constrained the tibiofemoral joint, but they used a

high tension of 88 N. There is a risk that this work will be misinterpreted causing surgeons to fear over-constraint with all lateral procedures, whereas technically correct lateral tenodeses without over-tensioning and fixation in neutral rotation do not over-constrain. In this context, it is worth noting that surgeons typically tense ACL grafts to approximately 80 N when pulling the graft by hand, and so the lateral tenodesis requires a very much smaller tension than is often used.

Due to the laboratory results, a modified Lemaire type procedure has been chosen as our first-choice operative technique when undertaking a supplementary lateral procedure combined with intra-articular ACL reconstruction. The objective of this paper was to describe the results of adding a lateral tenodesis to an ACL reconstruction; it was hypothesised that there would be a reduction of rotatory instability after the combined procedure, when compared to a group of patients who had received an isolated ACL reconstruction.

## Materials and methods

Lemaire [17] described an operation in which a strip of iliotibial band was left attached to Gerdy's tubercle and attached through interconnecting drill holes to create a bone tunnel in a position proximal to and posterior to the LCL attachment to the femur. In reference to this procedure and to also make the point that lateral tenodeses are not a new phenomenon, we have called the procedure below a 'modified Lemaire procedure':

A 1-cm-wide strip of iliotibial band is elevated keeping it attached to Gerdy's tubercle (Fig. 1). This needs to be long enough to pass deep to the LCL and has an extra 2–3 cm to fold back upon itself. It is usually 6–8 cm long depending on patient size. It is taken deep to the LCL (Fig. 2) and fixed to the lateral femur with the knee at 30° flexion and with neutral rotation using a suture anchor and two sutures (Fig. 3). The site of attachment is raw bone created by a periosteal elevator. The remaining graft is doubled back upon itself and sutured to itself (Fig. 4). The defect in the iliotibial band is closed with interrupted one vicryl sutures. No excess tension is placed on

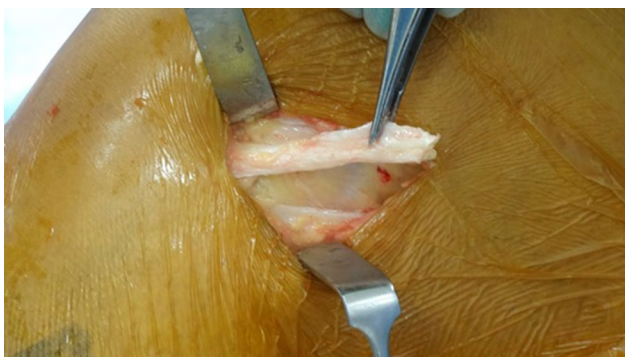

**Fig. 1** A 10-mm-wide strip of ITB is elevated leaving it attached to Gerdy's tubercle. Incisions in the ITB are made just anterior and posterior to Gerdy's tubercle. The strip is from the mid-ITB. The LCL is palpated to judge the appropriate length to harvest

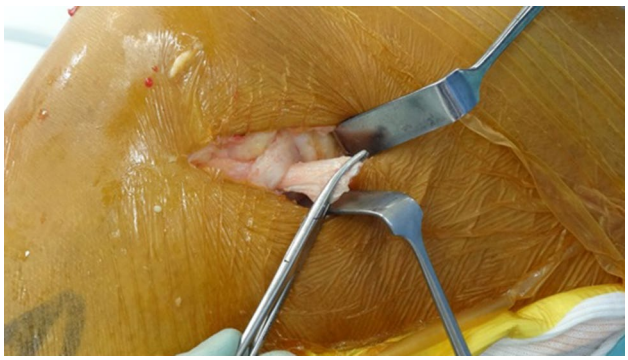

**Fig. 2** The ITB graft is taken deep to the LCL

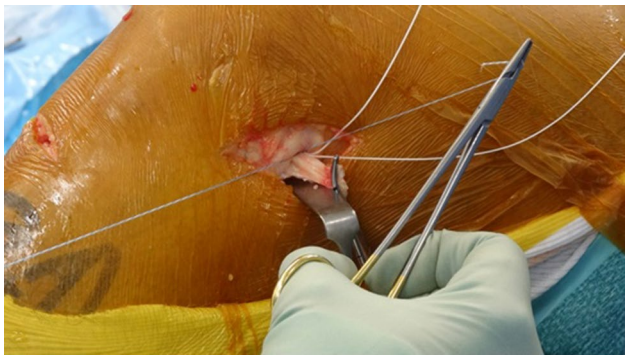

**Fig. 3** The graft is attached to the lateral femur, at a site of raw bone created by a periosteal elevator, with a suture anchor and two sutures

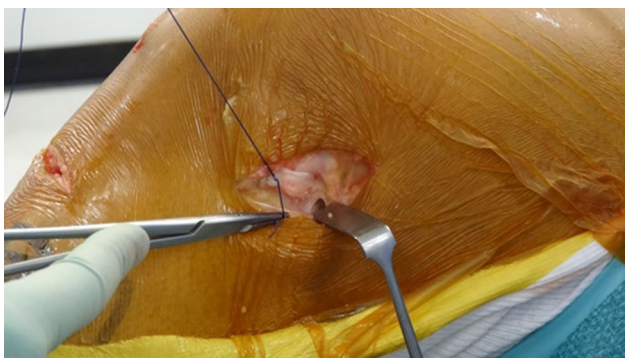

**Fig. 4** The excess length of the ITB graft is turned back on itself and the two layers of graft are sutured together

**Table 1** Patient demographics

| | ACL reconstruction only | ACL reconstruction + tenodesis |
|---|---|---|
| Time period | January 2013–January 2015 | January 2015–October 2016 |
| Number | 48 | 49 |
| Gender | 35 male | 38 male |
| Mean age (range) | 29 years (15–55) | 23 years (14–55) |
| Side | 27 right side | 30 right side |
| Elite sports participation | 23 (14 = football, 6 = rugby) | 38 (15 = football, 11 = rugby) |
| Graft | 29 = ipsilateral hamstring | 30 = ipsilateral hamstring |
| | 1 = contralateral hamstring | 1 = contralateral hamstring |
| | 18 = patellar tendon | 18 = patellar tendon |

the graft to avoid over-constraint—it is useful to think of a tenodesis as behaving like a check-rein, analogous to medial patellofemoral ligament reconstruction.

A review of clinical data from the senior surgical author examined a sequential series of 48 isolated ACL reconstructions with no other ligament injury requiring surgical repair performed during 2013–2015, versus a series of 49 cases with combined ACL reconstruction plus lateral extra-articular tenodesis performed during 2015–2016. The patient demographics are in Table 1, which shows that both groups were comparable: both groups included a large proportion of elite athletes (mostly footballers), and most of the patients in each group had an ipsilateral hamstrings tendon autograft for the ACL reconstruction. For the purpose of this paper, the patients were reviewed at short term after their surgery, with the emphasis on loss of range of motion (which might indicate that adding the tenodesis led to loss of motion, or over-constraint) and grading the laxity by anterior draw and Lachman tests, and pivot shift. Complications were also noted. Descriptive statistics only were used, in view of the very short and different lengths of follow-up between the two groups.

## Results

Both groups of knees had similar pathology at surgery: 65% required additional chondral and/or meniscal procedures in each group. Both groups had similar rates and types of complications post-surgery, with four re-operations in each group (Table 2). The isolated ACL reconstruction group had one graft rupture at 8 months, whilst there were none in the combined procedures group.

There was no evidence of loss of knee flexion–extension in either group: both groups had extension of the operated knee within ±5°–7° at review, compared to the contralateral knee, and both groups had a mean loss of 3° flexion at a mean of 6.3 months post-surgery (range 0.8–29 months).

There was a similar prevalence of residual anterior translation laxity in both groups post-surgery, but with a different pattern: the isolated ACL group had grade 1 laxity in 10% for anterior draw and 26% for Lachman test, whereas the combined group had 19% for anterior draw and 6% for the Lachman test, and thus tended to be more stable near knee extension (Table 3). This was reflected in the pivot-shift test results, with 9% of the isolated ACL group having a pivot-glide and 2% of the combined group. It was also recorded that 9% of the combined group who had a negative pivot-shift test on their operated knee had a pivot-glide in the undamaged contralateral knee, indicating knees of patients especially predisposed to ACL insufficiency, so demonstrating the efficacy of the combined procedure.

## Discussion

The most important finding of this study was that the group of knees treated with a combined ACL plus lateral tenodesis had a reduced prevalence of rotational instability (pivot-glide) than did the group which had only had an isolated ACL reconstruction and that this restraint of laxity was not associated with any loss of motion. The clinical data

**Table 2** Intra-operative findings

| | ACL reconstruction only | ACL reconstruction + tenodesis |
|---|---|---|
| Time to surgery | 7.9 months (22 days–29 months) | 4.6 months (1.5–12 months) |
| Additional meniscal ± chondral procedure | 31 | 31 |
| Chondral damage | 22 | 18 |
| Meniscal repair | 18 | 21 |

**Table 3** Clinical Findings; changes of range of motion (ROM) are the difference from the value for the contralateral knee

| | ACL reconstruction only | ACL reconstruction + tenodesis |
|---|---|---|
| Mean change of extension pre-op | 1° loss ($n = 41$; range: 0°–5° loss) | 1° loss ($n = 49$; 0°–10° loss) |
| Mean change of flexion pre-op | 2° loss ($n = 40$; range: 0°–20° loss) | 3° loss ($n = 49$; 0°–35° loss) |
| Mean change of extension post-op | 1° loss ($n = 42$; gain 5°–loss 7°) | 1° loss ($n = 49$, gain 5°–loss 5°) |
| Mean change of flexion post-op | 3° loss ($n = 40$; 0°–20° loss) | 3° loss ($n = 48$; 0°–10° loss) |
| Anterior drawer | 4 × Grade 1 ($n = 42$) | 9 × Grade 1 ($n = 47$) |
| Lachman | 1 × Grade 1 ($n = 42$) | 3 × Grade 1 ($n = 47$) |
| Pivot shift (operated leg) | Pivot-glide: 4 ($n = 44$) | Pivot-glide: 1 ($n = 47$) |
| Pivot shift (non-operated leg) | Pivot-glide: 0 ($n = 44$) | Pivot-glide: 4 ($n = 47$) |
| Re-rupture of ACL graft | 1 | 0 |
| Other complications | 1 = cyclops, 1 = haemarthrosis, 1 = medial meniscus/fibrosis | 1 = cyclops + medial meniscus tear, 1 = fat pad debride, 1 = medial meniscus tear, 1 = MUA for flexion stiffness |

from the authors in this paper are not intended to show that these procedures should be used routinely, but are simply a marker to indicate that—in the early stage post-surgery—the data do not indicate over-constraint of the knee and do suggest reduced prevalence of pivot-shift laxity. Thus, they act to support the idea of performing a longer-term study to provide stronger data.

In the face of widespread evidence of persistence of residual tibiofemoral rotatory instability in some knees post-ACL reconstruction, there is a growing body of anatomical and biomechanical work which supports the concept of adding a lateral extra-articular procedure to an intra-articular ACL reconstruction in order to better control the rotation. This evidence has led the present clinical authors to choose to introduce a modified Lemaire procedure into their practice for cases identified as being at increased risk of residual rotatory instability. However, although there are some published clinical studies to support the addition of a lateral procedure to an ACL reconstruction, such data are not yet available to support their routine use.

This paper has described some of the history of lateral extra-articular procedures, either in isolation or in combination with an intra-articular ACL reconstruction. The literature shows clearly that, when the extra-articular procedure was used alone to treat instability following ACL injury, there was a high failure rate. Neyret et al. [21] used the Lemaire tenodesis in its original form, which entailed the use of a strip of ilio-tibial tract 160 mm long, taken through bone tunnels, and found that it failed to control instability in 17 of 33 cases at a mean 4.5 years post-surgery. They noted that the lateral procedure was designed to control the pivot shift and that it never controlled tibial anterior translation. Therefore, they recommended that the isolated lateral procedure should not be used.

A less-invasive version of the Lemaire tenodesis was described by Christel and Djian [3], who used a strip of ITB 12 mm wide and 75 mm long. This was attached to the femur at Krackow's point K9 [16], either using a screw plus spiked washer, or else a bone tunnel with interference screw. This procedure was a predecessor of that used by the present authors.

Of course, whilst laboratory testing is seductive, producing clear objective measurements analysed pairwise within each knee, the realism must always be doubted and it does represent only a 'time-zero' scenario. The effect of potential stretching of grafts with rehabilitation, or the restabilisation by healing of pericapsular tissues post-surgery cannot be assessed. It is therefore essential that prolonged clinical outcome studies be performed to assess the effect of these procedures not only on graft survivorship and patient function but also on the risk of stiffness and osteoarthritis. A review of clinical studies [9] found eight randomised clinical series which had compared isolated ACL reconstruction versus combined ACL plus lateral extra-articular procedures. They found little evidence to suggest better clinical outcome scores, but did find a significant reduction in the rate of pivot-shift instability with the combined procedure.

Unfortunately, it is impossible to be clear regarding the absolute indications for additional anterolateral surgery when ACL reconstruction is undertaken. Furthermore, there are no clinical tests or radiological investigations that will indicate that an additional lateral extra-articular procedure is necessary. As a result, we have to apply the logic of using it in patients who we believe are at a high risk of ACL graft re-rupture and/or rotational instability. This includes revision cases, juveniles (in whom fixation of the graft can be made distal to the growth plate when intra-operative X-ray is used), those with abnormal laxity and even a positive pivot shift in the normal limb, those with a strong family history of problems, significantly abnormal posterior tibial slope in the sagittal plane and malalignment in the coronal plane.

## Conclusion

There has been an accumulation of evidence to support the addition of a lateral extra-articular procedure to an intra-articular ACL reconstruction from laboratory studies of the restraint provided by the lateral anatomical structures and the measurement of reduction of rotational laxity. It has been shown that low graft tensions are needed, so that internal rotation will not be over-constrained, and excessive articular contact stresses will not be caused. These data have been supported by a review of clinical data which reported significant reduction of the prevalence of pivot-shift instability at short term. However, it may be concluded that further studies are required in order to ascertain the correct indications for adding the lateral procedure to an ACL reconstruction.

#### Compliance with ethical standards

**Conflict of interest** The authors' biomechanical studies which support this article were supported by fellowship grants from Smith & Nephew (Endoscopy) Co, by the AGA (The German-speaking Arthroscopy Association) and the Bergen Regional Health Authority.

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**Ethical approval** This article does not contain any studies with human participants or animals performed by any of the authors.

**Informed consent** None.

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