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ARTHROSCOPY AND SPORTS MEDICINE

Lateral extra-articular tenodesis with ACL reconstruction demonstrates better patient-reported outcomes compared to ACL reconstruction alone at 2 years minimum follow-up

F. E. Rowan[1,2] · S. S. Huq[1,2] · F. S. Haddad[1,2]

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Abstract

Purpose The role for extra-articular procedures in addition to ACL reconstruction to restore rotational stability is debated. We use lateral extra-articular tenodesis (LEAT) for patients that meet criteria. Our null hypothesis was that there would be no difference between two groups of patients that were treated with ACL reconstruction alone or ACL reconstruction with LEAT according to criteria.

Methods A prospectively collected database of patients that were treated primarily according to the presence of a high-grade pivot shift with LEAT at the time of ACL reconstruction was propensity-matched with a group of patients that underwent ACL reconstruction alone. Minimum follow-up was 2 years. Stratified variable analysis of the groups was also performed.

Results There were 218 and 55 patients in the ACL reconstruction group and ACL reconstruction with LEAT group, respectively. There were 125 patients and 46 patients after propensity matching with a median follow-up of 52 months and 27 months, respectively. Post-operative Lysholm score ($P = 0.005$), Tegner activity index ($P = 0.003$) and time to return to sport ($P < 0.001$) favoured ACL reconstruction with LEAT compared to ACL reconstruction alone. Sports with frequent change of direction maneuvers and higher rates of ACL injury (rugby, soccer, skiing) favoured ACL reconstruction with LEAT versus ACL reconstruction alone ($P = 0.001$). No significant difference in re-operation rate or type of surgery was found between the two surgical groups after propensity matching but 13 patients in the ACL reconstruction-only group re-injured their ACL, 8 of whom required supplementary LEAT at the time of revision surgery.

Conclusion Patient-reported outcomes and return to multi-directional sports after ACL reconstruction favour LEAT at the time of ACL reconstruction when narrow inclusion criteria are applied.

Keywords ACL · Anterior cruciate ligament · Lateral extra-articular tenodesis · Pivot shift test · Athlete

Introduction

The anterior cruciate ligament (ACL) limits internal rotation and anterior translation of the tibia [1]. Disruption to the ACL can create rotational and sagittal knee instability [2]. Recent interest in the anatomy and biomechanical role of the anterolateral ligament (ALL) of the knee has resulted in surgeons revisiting extra-articular methods to address rotational knee stability [3–8]. There has been a trend towards more horizontal femoral tunnels in ACL reconstruction to improve rotational stability of the knee after ACL reconstruction. The drawbacks to using a horizontal graft tunnel position include greater graft length change during knee arc of motion, compromised sagittal stability and high graft tension in extension [9]. This has prompted surgeons to re-explore extra-articular means to address rotational stability in the knee [10].

Lateral extra-articular tenodesis (LEAT) and ALL reconstruction in combination with ACL reconstruction has demonstrated mixed results and the indication for LEAT has not been well defined. Pooled prevalence of the ALL is 76.25% [8]. The authors of this meta-analysis also conducted anatomic dissection in paired cadaveric knees

✉ F. E. Rowan
fiachrarowan@rcsi.ie

[1] Department of Trauma and Orthopaedic Surgery, University College London Hospital, 235 Euston Road, London NW1 2BU, UK

[2] The Princess Grace Hospital, 42 Nottingham Place, London W1U 5NY, UK

and showed 80% unilateral ALL prevalence. Inconsistent ALL prevalence and bilaterality questions the importance of a singular anterolateral structure and suggests that combined factors may confer anterolateral rotatory stability to the knee. Multiple studies have not shown consistent benefit for ACL-deficient patients that are treated with an ACL reconstruction alone or in combination with LEAT [11]. There is debate regarding type of extra-articular reconstruction, tension applied, and position of the knee during tensioning [12, 13]. One surgical group reports better results with double bundle ACL reconstruction compared to LEAT with ACL reconstruction but also report using LEAT in high-risk individuals such as female soccer players [14, 15]. Concern has been raised about restricting lateral knee compartment motion when LEAT or variants are used [16]. A controlled cadaveric study showed significantly reduced tibial internal rotation compared with non-sectioned ACL knees when LEAT or ALL are performed [17]. In spite of this, a 20-year minimum follow-up study did not show lateral or patellofemoral arthritis in patients that underwent LEAT with ACL reconstruction [18].

Recently we started adding LEAT to ACL reconstructions for patients that meet certain criteria [19]. These are either high-grade pivot shift test or ≥ two minor criteria (Table 1). Prior to this, we did not perform surgery to address anterolateral instability other than single-bundle anatomical ACL reconstruction. The aim of this study is to compare re-injury, re-operation, return to sport and patient-reported outcomes in patients that underwent ACL with or without LEAT at minimum 2 years follow-up. We hypothesized that adding LEAT to ACL reconstruction influences clinical outcome. To minimise baseline differences between the two treatment groups propensity matching analysis was performed. Our null hypothesis was that there would be no difference between both groups of patients.

Table 1 Indication for supplementary lateral extra-articular tenodesis (LEAT) with anterior cruciate ligament (ACL) reconstruction at our institution: one major criterion or ≥ 2 minor criteria

Major	Minor
High-grade pivot shift*	Hyperlaxity
Revision ACL reconstruction	Age < 20 years
	Failed contralateral ACL reconstruction
	Elite athlete

*As demonstrated in the office or under general anaesthesia. Elite athlete: professional or international standard. Hyperlaxity: Beighton score ≥ 4 or hypermobility syndromes

Methods

Patients

A consecutive series of patients that underwent ACL reconstruction prior to the introduction of LEAT at our institution (November 2014) was compared with a subsequent consecutive series of patients that underwent ACL reconstruction and LEAT. All surgeries were performed by the senior author at a single institution where a prospectively collected patient database is maintained by non-clinical data managers. Only those patients with minimum 2 year's follow-up were included. All patients had radiological evidence of ACL rupture. Patients were excluded from analysis if they underwent concomitant repair or reconstruction of posterior cruciate ligament, collateral ligament, corner injuries or were undergoing revision ACL surgery. Basic demographic detail was recorded including prior contralateral ACL injury. Sporting activity (elite: professional or international standard; sub-elite: national standard; recreational: non-representative amateur or none), chosen sport and working history (desk-based occupation; manual-labour occupation; full-time athlete) was also recorded.

Anterior cruciate reconstruction surgical technique

General anaesthesia and cephalosporin chemoprophylaxis was used. An anatomical single bundle doubled gracilis and semitendinosus hamstring graft (≥ 8 mm) was used in all cases. A cortical suspensory device (Endobutton®, Smith & Nephew, MA, USA) was used for femoral fixation and an interference screw (Intrafix® ACL Tibial Fastener System, DePuy Synthes, MA, USA) was used for tibial fixation. A 10 cm × 10 cm gauze soaked in 80 mg of diluted gentamicin was wrapped around the graft under tension (Acufex® Graftmaster, Smith & Nephew, MA, USA) during tunnel preparation. On occasion, trebled semitendinosus tendon grafts were used when the tendon was sufficiently wide upon inspection prior to harvest. Any concomitant intra-articular procedures were executed before notch preparation and tunnel drilling. Femoral drilling was performed through the anteromedial portal and an isometric entry point was centered posterior to the lateral intercondylar ridge. The tibial tunnel was drilled through the native ACL insertion.

Lateral extra-articular tenodesis surgical technique

LEAT was performed using a 12 cm lateral incision from Gerdy's tubercle in line with the posterior cortex of the femur (Fig. 1). The iliotibial band (ITB) was identified and a 10 mm × 100 mm strip of ITB was harvested from Gerdy's

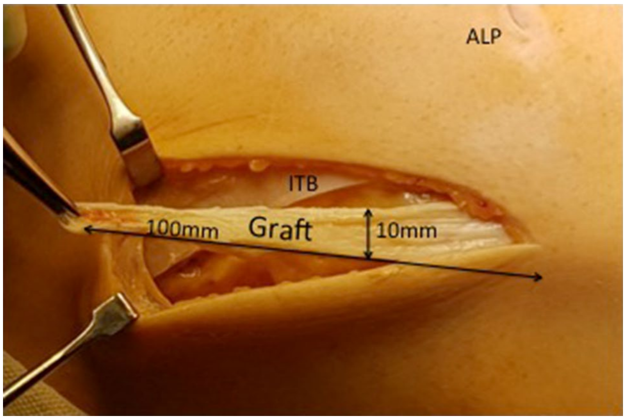

Fig. 1 Lateral extra-articular tenodesis (LEAT) is performed using autologous iliotibial band (ITB) graft. A lateral 12 cm incision is performed by extending proximally from the midpoint of Gerdy's tubercle in line with the posterolateral border of the femoral cortex. A graft of 10 mm × 100 mm is excised from the ITB but left attached to Gerdy's tubercle. The proximal end of the graft (forceps) is whip-stitched (No. 5 Ethibond [Ethicon, NJ, USA]) (not shown). *ALP* Anterolateral arthroscopic portal

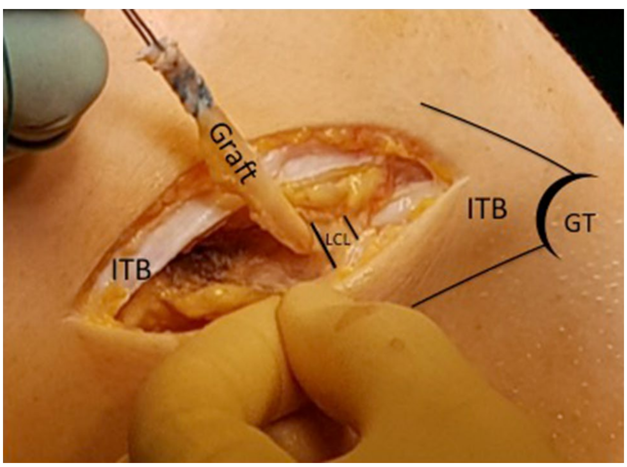

Fig. 2 Lateral extra-articular tenodesis (LEAT) autologous iliotibial band (ITB) graft is passed under the lateral collateral ligament (LCL). The graft is fixed under tension away from the cortical femoral suspensory fixation device, anterior to the posterolateral femoral cortical edge using a fixation staple (Smith & Nephew, MA, USA) and with the knee at 30° flexion and 0° tibial external rotation. *GT* Gerdy's tubercle

tubercle, proximally resected and whip-stitched (No. 5 Ethibond) (Fig. 2). The enveloping fibres of biceps femoris were split anterior and posterior to the lateral collateral ligament. The ITB graft was passed deep to the lateral collateral and with the knee in 30° flexion, neutral rotation fixed under tension to the lateral femoral just proximal and posterior to lateral epicondyle using a staple (Fixation staple with spike, X-small, 10.8 mm × 23 mm, Smith & Nephew, MA, USA) (Fig. 3).

Post-operative care

Patients were permitted to fully bear weight with unrestricted range of movement. Patients that underwent meniscal repair used braces with fortnightly 30° increased staged flexion from 0° to 90° until 6 weeks post-operatively. All patients received 150 mg aspirin thromboprophylaxis and thromboembolic deterrent stockings for 2 weeks. A standard physiotherapy protocol starting with achieving full active extension was commenced immediately.

Patient-reported outcome measures

Lysholm score, Tegner activity index and satisfaction were collected. Time to return to sport and level of return was recorded.

Data analysis

To minimise baseline differences between the two treatment groups propensity matching analysis was performed. This method minimises baseline discrepancies in measured confounding factors through logistic regression modeling using treatment status as the dependent variable. For this study the ACL reconstruction with LEAT cases were assigned as the treatment group and the ACL reconstruction without LEAT cases were the controls. Potential confounding factors were assigned as covariates in this model and included age, sex, side on which operation was performed, previous contralateral ACL injury, sport(s) played, level of sport played, occupation type, and concurrent procedures performed at the time of ACL reconstruction. The model assigned a propensity score for any given case that represented the probability for the case to be assigned to the treatment group. The nearest neighbour method was used to match up control cases with corresponding treatment cases with similar propensity scores. To achieve well-matched groups with minimal data loss for final analysis, various models were evaluated with varying matching caliper values and matching ratios, respectively. Post-hoc diagnostic tests were then performed to evaluate the propensity model for good balance by inspecting standardized difference in mean values and inspecting for the presence of unbalanced covariates. Baseline characteristics were also compared using standard statistical techniques. Outcomes were then compared between the propensity-matched groups. Evaluated outcomes included between-group differences in post-operative satisfaction, Lysholm score and Tegner Activity Scale, time to return to sport, level of sport returned to relative to baseline, re-injury rate and rate of subsequent operations. Sub-set analysis was also performed by stratifying the data according to age, sex, level of sport played, occupation type, previous contralateral ACL injury and need for concurrent procedures at time of

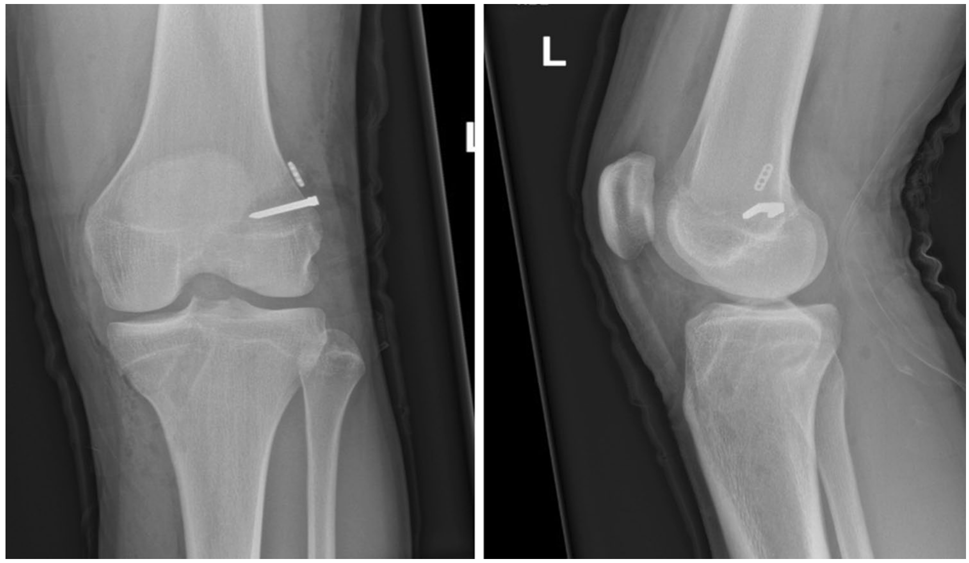

Fig. 3 Immediate post-operative anteroposterior and lateral radiographs showing location of staple for lateral extra-articular tenodesis (LEAT) fixation relative to suspensory femoral fixation

index ACL reconstruction ± LEAT. Time to return to sport was compared for athletes undergoing ACL reconstruction ± LEAT that participated in sports with change of direction maneuvers and higher rates of ACL injury: (rugby, soccer, and skiing) [20–23]. Propensity analyses and outcome measure analyses were performed for each strata. Categorical data were compared using χ^2 tests with Fisher's exact test used as an alternative when expected counts were < 5 in at least 25% of cells or < 1 in any cell. Normally distributed data were presented using mean values and standard deviations and comparisons were made using independent sample *t*-tests. Non-parametric data were presented using median and range and compared using the Mann–Whitney *U* test. Descriptive and comparative statistics were performed on SPSS Version 21.0 (IBM Corp, 2012). R Version 2.14.2 (R Development Core Team, 2012) functionality was used for propensity matching analysis via the R Essentials for SPSS and PS Matching for SPSS Version 3.0.4 (Felix Thoemmes, Wang Liao and Cornell University, 2015) extensions. All comparative tests were two-tailed with significance set at $p < 0.05$.

Results

Baseline characteristics

There were 218 patients in the ACL reconstruction without LEAT group and 55 patients in the ACL reconstruction with LEAT group (Table 2). After propensity matching there were 125 patients and 46 patients in the ACL reconstruction group and ACL reconstruction with LEAT group, respectively, and the two groups were statistically similar (Table 3). Median follow-up was 52 months (range 24–96) in the ACL reconstruction without LEAT group and 27 (range 24–45) in the ACL reconstruction with LEAT group. Prior to propensity matching there were differences in age, standard of competition, occupation, and concomitant meniscal repair surgery after Bonferroni correction (Table 2): patients in the LEAT group were statistically younger (26 versus 33 years), more frequently elite level competitors (42% versus 16%), more frequently full-time athletes (40% versus 13%) and more frequently underwent meniscal repair at the time of ACL reconstruction (53% versus 27%).

Post-operative scores

Comparison of outcome variables between propensity-matched treatment groups showed statistically significant differences in post-operative Lysholm score (median: 98 versus 90) and Tegner activity index (mean: 8.04 versus 7.54) favouring ACL reconstruction with LEAT compared to ACL reconstruction alone (Table 4).

Return to sport

Time to return to sport (median: 8 months versus 6 months) favoured ACL reconstruction with LEAT ($P < 0.001$). Subset analysis of sports with frequent change of direction maneuvers and higher rates of ACL injury (rugby, soccer, and skiing) favoured ACL reconstruction with LEAT (mean 6.9 ± 2 months; $n = 34$) versus ACL reconstruction alone (mean 8.3 ± 2.2 months; $n = 122$) ($P = 0.001$).

Re-injury and re-operation

No patients that underwent ACL reconstruction with LEAT re-injured their ipsilateral ACL and therefore there were no

Table 2 Baseline characteristics prior to propensity matching

	ACLR ($n=218$)	ACLR + LEAT ($n=55$)	P value
Age, median (range) years	33 (14–56)	26 (16–64)	0.004*[#]
Male	120 (55%)	34 (62%)	0.365
Female	98 (45%)	21 (38%)	
Left knee	111 (51%)	23 (42%)	0.228
Right knee	107 (49%)	28 (58%)	
Football	53 (24%)	17 (31%)	0.317
Skiing	47 (22%)	8 (15%)	0.246
Rugby	25 (12%)	9 (16%)	0.326
Hockey	24 (11%)	4 (7%)	0.414
Basketball	19 (9%)	3 (6%)	0.583[§]
Others/unknown	54 (25%)	14 (26%)	0.917
Elite	35 (16%)	23 (42%)	< 0.001**
Sub-elite	27 (12%)	10 (18%)	0.262
Recreational	156 (72%)	22 (40%)	< 0.001**
Desk-bound occupation	135 (62%)	26 (47%)	0.048***
Manual-labour occupation	55 (25%)	7 (13%)	0.048***
Full-time athlete	28 (13%)	22 (40%)	< 0.001**
Previous contralateral ACL injury	49 (23%)	12 (22%)	0.917
Concurrent procedures at ACLR:			
Meniscal debridement	79 (38%)	11 (20%)	0.022***
Meniscal repair	59 (28%)	29 (54%)	0.003**
OCD microfracture	31 (15%)	1 (2%)	0.010***
OCD implantation	3 (1%)	0 (0%)	0.381
No concurrent procedure performed	37 (18%)	13 (24%)	0.254

ACLR anterior cruciate ligament reconstruction, *LEAT* lateral extra-articular tenodesis, *OCD* osteochondral defect

*Significant at $p < 0.05$ level

**Significance maintained after Bonferroni adjustment

***Not significant after Bonferroni adjustment

[#]Mann–Whitney *U* test used

[§]Fisher's exact test used

revision ACL reconstructions performed in this group of patients. Thirteen (5.9%) of the patients treated with ACL reconstruction alone sustained a re-injury of the reconstructed ACL. Eight (3.6%) patients underwent supplemental LEAT at the time of revision surgery. No significant difference in re-operation rate or type of surgery was found between the two surgical groups after propensity matching (Table 3). No patient in either group required either a manipulation or arthroscopic debridement for stiffness or arthrofibrosis. All arthroscopic re-operations related to meniscal pathology that may or may not have undergone repair or partial resection at index surgery.

Complications

One patient had persistent numbness of the infrapatellar branches of the saphenous nerve. The same patient was dissatisfied with a prominent tibial fixation device. There were no intra-articular infections or wound complications that required treatment.

Stratified variable analysis

Lysholm score and Tegner activity index was higher for patients undergoing LEAT and ACL reconstruction with a concomitant procedure ($P=0.017$ and $P=0.008$, respectively) or male sex ($P=0.001$ and $P=0.009$, respectively) compared to those patients undergoing ACL reconstruction alone (Table 5). Patients without a previous contralateral ACL injury positively influenced Lysholm scores in patients undergoing LEAT and ACL reconstruction compared to ACL reconstruction alone.

Time in months to return to sport was shorter for patients that underwent LEAT and ACL reconstruction that were

Table 3 Baseline characteristics after propensity matching

	ACLR ($n=125$)	ACLR + LEAT ($n=46$)	P value
Age, median (range) years	29 (15–56)	27 (16–64)	0.260#
Male	67 (54%)	27 (59%)	0.553
Female	58 (46%)	19 (41%)	
Left knee	61 (49%)	23 (50%)	0.889
Right knee	64 (51%)	23 (50%)	
Football	33 (26%)	15 (33%)	0.423
Skiing	24 (19%)	8 (17%)	0.788
Rugby	15 (12%)	7 (15%)	0.577
Hockey	14 (11%)	4 (9%)	0.783§
Basketball	12 (10%)	2 (4%)	0.357§
Others/unknown	27 (22%)	10 (22%)	0.984
Elite	30 (24%)	16 (35%)	0.184
Sub-elite	21 (17%)	8 (17%)	0.927
Recreational	74 (59%)	22 (48%)	0.159
Desk-bound occupation	74 (59%)	25 (54%)	0.569
Manual-labour occupation	28 (22%)	7 (15%)	0.302
Full-time athlete	23 (18%)	14 (30%)	0.090
Previous contralateral ACL injury	29 (23%)	9 (20%)	0.612
Concurrent procedures			
Meniscal debridement	38 (32%)	10 (22%)	0.264
Meniscal repair	52 (44%)	23 (51%)	0.326
OCD microfracture	3 (3%)	1 (2%)	0.931
No concurrent procedures performed	26 (22%)	11 (24%)	0.661

ACLR anterior cruciate ligament reconstruction, *LEAT* lateral extra-articular tenodesis, *OCD* osteochondral defect

#Mann–Whitney U test used

§Fisher's exact test used

Table 4 Comparison of outcome variables between propensity-matched treatment groups

	ACLR ($n=125$)	ACLR + LEAT ($n=48$)	P value
Post-op Lysholm score, median (range)	90 (70–100)	98 (75–100)	0.005*#
Post-op Tegner activity index, mean ± SD	7.54 ± 1.35	8.04 ± 1.35	0.003*$^{\Phi}$
Time to return to sport, median (range) months	8 (4–14)	6 (5–12)	< 0.001*#
Level of sport returned to after ACLR:			
Higher/same level	110 (88%)	42 (91%)	0.542
Lower level/did not return to sport	15 (12%)	4 (9%)	
Post-op satisfaction	115 (92%)	44 (96%)	0.518§
ACL re-injury rate	6 (5%)	0 (0%)	0.193§
Revision surgery:			
Revision ACLR	6 (5%)	0 (0%)	0.130
LEAT performed	5 (4%)	0 (0%)	0.169
Arthroscopic surgery excl. ACLR	20 (16%)	6 (13%)	0.929

ACLR anterior cruciate ligament reconstruction, *LEAT* lateral extra-articular tenodesis, *SD* standard deviation

*Significant at $p < 0.05$ level

#Mann–Whitney U test

$^{\Phi}$Independent sample t test

§Fisher's exact test

Table 5 Summary of stratified analyses

Stratified variables (*n*)	*P*-values for differences between ACL reconstruction alone and ACL reconstruction + LEAT						
	Lysolm score	Tegner index	RTS[a] time	RTS[a] level	% Satisfied	% Re-injured	% Re-operated
Age							
< 30 (67)	0.317[b]	0.537[c]	0.653[c]	–[e]	1.000[f]	0.288[f]	0.044*[f,g]
≥ 30 (93)	0.407[b]	0.152[c]	0.038*[c,d]	0.762[f]	1.000[f]	1.000[f]	1.000[f]
Sex							
Male (91)	0.001*[b,h]	0.009*[c,i]	0.003*[b,h]	0.262[f]	1.000[f]	0.172[f]	0.017*[f]
Female (72)	0.496[b]	0.370[c]	0.891[b]	0.699[f]	0.327[f]	1.000[f]	0.423
Occupation type							
Athlete (21)	0.219[b]	0.655[c]	0.754[b]	–[e]	–[j]	1.000[f]	1.000[f]
Non-athlete (149)	0.253[b]	0.251[c]	0.056[b]	1.000[f]	1.000[f]	0.359[f]	0.247
Sporting level							
Elite (58)	0.089[b]	0.655[c]	0.777[c]	–[e]	–[j]	–[l]	0.144[f]
Non-elite (135)	0.185[b]	0.165[c]	0.020*[c,k]	0.517	1.000[f]	0.344[f]	0.274
Previous contralateral injury							
Yes (38)	0.107[b]	0.129[c]	0.807[c]	1.000[f]	0.233[f]	1.000[f]	1.000[f]
No (102)	0.023*[b,h]	0.200[c]	0.034*[c,m]	0.749[f]	0.174[f]	1.000[f]	0.163
Concomitant procedure							
Yes (157)	0.017*[b,h]	0.008*[c,n]	0.001*[c,o]	0.805	1.000[f]	0.338[f]	0.340
No (22)	0.441[b]	0.583[c]	0.493[c]	–[e]	1.000[f]	1.000[f]	0.273[f]

*Significant at $p < 0.05$ level

[a]Return to sport

[b]Mann–Whitney *U* test

[c]Independent sample *t* test

[d]Mean difference 1.207 in favour of tenodesis group

[e]100% of sample returned to same/higher level of sport

[f]Fisher's exact test

[g]26% vs 4% in ACLR and tenodesis groups, respectively

[h]Mean rank difference in favour of tenodesis group

[i]Mean difference 0.779 in favour of tenodesis group

[j]100% satisfaction rate in whole sample

[k]Mean difference 1.107 in favour of tenodesis group

[l]No re-injuries in whole sample

[m]Mean difference 1.043 in favour of tenodesis group

[n]Mean difference 0.670 in favour of tenodesis group

[o]Mean difference 1.274 in favour of tenodesis group

> 30 years of age ($P = 0.038$), males ($P = 0.003$), non-elite athletes ($P = 0.02$) and that underwent concomitant procedures ($P = 0.001$) compared to ACL reconstruction alone. A history of no contralateral ACL injury favoured the LEAT group for return to sport ($P = 0.034$) but did not influence the ACL reconstruction alone group ($P = 0.87$). Re-operation rate was higher for male patients and those < 30 years of age undergoing ACL reconstruction alone compared to LEAT and ACL reconstruction.

Standard of return to sport, post-operative satisfaction and re-injury rate were not influenced by any of the stratified variables tested for ACL reconstruction with or without LEAT. Clinical scores, return to sport, satisfaction, re-injury or re-operation rates did not differ between elite or recreational athletes.

Discussion

We conducted a retrospective review of a prospectively gathered single-surgeon database to assess clinical outcome of patients that undergo LEAT at the time of ACL reconstruction. Propensity-matched comparison of patients that underwent ACL reconstruction with or without LEAT from this series showed that concomitant LEAT resulted in improved clinical scores and earlier overall return to sport. Return to sport was also earlier in those patients participating in sports with high rates of directional changes and ACL injuries that underwent supplementary LEAT. We disproved our null hypothesis that there would be no difference between patients treated with or without concomitant LEAT at the time of ACL reconstruction.

In recent years, we have introduced an algorithmic approach to treating patients with ACL insufficiency. We do not routinely augment ACL reconstruction with LEAT. We use major and minor criteria to determine those patients that should receive concomitant LEAT at the time of ACL reconstruction. Patients that have high-grade pivot shift test or undergoing revision ACL surgery, are treated with LEAT at the time of ACL reconstruction. Patients that have two or more minor criteria (Table 1) are also treated with LEAT. A risk to lateral extra-articular procedures is the introduction of lateral compartment constraint. This may manifest as early post-operative stiffness or late post-operative compartment degeneration. We cannot comment on long-term effects of LEAT in our cohorts but we do not report early re-operation for stiffness. All revision arthroscopies were for meniscal pathology of a previously repaired tear or propagation of a previously partially resected meniscal tear.

A confounding factor in the comparison of our two groups prior to propensity matching is the prevalence of elite athletes. There were significantly more elite athletes and significantly less recreational athletes in the LEAT group. This has implication for recovery whereby professional and international level athletes that are often full-time athletes have considerably more resources and time for rehabilitation. Conversely, elite athletes are more demanding of the body's performance and may have lower post-operative satisfaction or Lysholm scores and this was not the case. In spite of these factors, whether the patient was a full-time athlete or not had no influence on clinical scores, return to sport, satisfaction, re-injury or re-operation.

The limitations of a retrospective analysis apply to our study. The main criticisms of our study are related to the method of anterolateral stabilisation and objective post-operative assessment: Our surgical technique is a modified Lemaire ALL reconstruction as previously described [12]. Recent biomechanical testing shows adequate restoration of internal rotation and valgus laxity using this technique [24]. A common criticism of this technique is that inconsistent tension of the re-routed ITB strip prior to femoral fixation may result in overconstraint of the lateral compartment. ACL graft tension is still debated despite decades of arthroscopic ACL reconstruction experience [25]. An experienced surgeon will tension both ACL graft and re-routed ITB using limb position and feedback resistance from the graft. Until efficient, real-time computational or navigational techniques demonstrate better results, graft tensioning will continue in a pragmatic manner as described in our methodology. We do not present objective mechanical assessment of sagittal or rotational knee stability after ACL reconstruction with or without LEAT using a KT2000 or rolimeter. While this represents incomplete assessment of ACL reconstruction, our research question was whether there is a difference in clinical outcome and we have shown a difference favouring LEAT at the time of ACL reconstruction, particularly in patients that partake in cutting field sports. We have failed to demonstrate pre-operative Tegner activity indices and Lysholm scores for either patient group as not all data were complete. Instead, we present post-operative scores with no patient lost to follow-up. Time to surgery can influence outcome after ACL reconstruction [26]. We do not have accurate data for time from ACL injury to ACL reconstruction and we suspect that the higher standard of athlete will have presented for surgery earlier than the recreational athlete although this is conjecture. Finally, we do not present radiographic data following ACL reconstruction with or without LEAT. Dejour et al. [27] demonstrated lower anterior translation of the tibia in the lateral compartment in patients undergoing combined LEAT and ACL reconstruction compared to ACL reconstruction alone. The significance of this radiological finding is unclear as there was no difference in clinical findings between groups in their study.

In conclusion, this propensity-matched case control study shows that clinical results after ACL reconstruction favour LEAT at the time of surgery when certain criteria are applied. A prospective controlled study using the criteria we apply would test our surgical algorithm for patients presenting with ACL injury.

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Compliance with ethical standards

Conflict of interest The senior author is a paid speaker and consultant and receives royalties from Smith and Nephew.

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

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