Clinical Outcomes Of Extra-articular Tenodesis / Anterolateral Reconstruction In The ACL Injured Knee

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Abstract

Purpose: The role of concomitant extra-articular procedures in improving the outcome of ACL reconstruction has experienced a recent resurgence in interest. The aim of this article is to highlight the differences in philosophies and outcomes of historical non-anatomic reconstructions and contemporary, anatomical anterolateral reconstruction.

Methods: A narrative review was performed using Pubmed/Medline using the key words “lateral extra-articular tenodesis”, and “anterolateral ligament reconstruction”.

Results: Results of search strategy:37 studies (13 reporting clinical outcomes of isolated lateral extra-artticular tenodesis (LET) in ACL deficient knees and 23 comparing isolated anterior cruciate ligament reconstruction (ACLR) with ACLR +LET and one study on anterolateral ligament (ALL) reconstruction were identified as relevant and included in the review. Results of literature review: Isolated extra-articular reconstructions are rarely performed in contemporary practice. They are associated with a high rate of persistent anterior instability and early degenerative change. Combined ACL reconstruction and lateral extra-articular tenodeses result in a significant reduction in the prevalence of residual pivot shift but the majority of studies do not demonstrate any significant difference with respect to patient reported outcome measures and return to sport. Although several authors report a trend towards decreased graft rupture rates, significant differences were not demonstrated in most studies. In a single clinical study, combined anatomic ACL and anterolateral ligament reconstruction was reported to be associated with a three-fold reduction in graft rupture rates and improved return to sport compared to isolated ACL graft choices.

Conclusion: Historical combined ACL reconstruction and lateral extra-articular tenodeses are associated with improved knee rotational stability. Although a trend towards decreased graft rupture rates is reported by several authors, the majority did not demonstrate a significant difference, likely as a result of small and underpowered studies using postoperative immobilisation and delayed rehabilitation protocols. More recently combined anatomic ACLR and ALL reconstruction has been shown to be associated with significant improvements in graft failure and return to sport rates when compared to isolated ACLR. However, these results are from a single clinical series with only medium term follow up.

Level of Evidence: IV

Key words: ACL, Anterolateral Ligament, Extra-articular Tenodesis, Graft Rupture, Return To Sport, Persistent Instability

Introduction

ACL reconstruction is associated with superior quality of life, sports function and knee symptoms when compared to non-operative treatment. [9] However, high rates of graft rupture (16-18% of young patients participating in pivoting, contact sports) [28], low rates of return to pre-injury levels of sport (55%) [8] and persistent rotatory instability (up to 30% of patients) [23,64], remain important post-operative clinical issues. Although the pathophysiology of these adverse outcomes is multifactorial, the rationale for considering a concomitant lateral extra-articular tenodesis (LET) is based on its ability to provide an increased lever arm for controlling rotation (due to its greater distance from the centre of rotation of the knee) than an isolated intra-articular reconstruction [5,19,65]. This is verified in studies that have demonstrated that the

addition of a LET results in an improvement in the kinematics of the knee and a reduction in forces transmitted to an ACL graft. [4,21,40]

Since the "rediscovery" of the anterolateral ligament of the knee by Claes et al. in 2013 [14], there has been considerable interest in the role of LET. However, this is not a new concept and it was perhaps Strickler in 1937 [56] who first described such a procedure but it was not until the 1970's and 80s that LET reached the height of its popularity with the MacIntosh [27] and Lemaire [31] techniques. These non-anatomical procedures were subsequently largely abandoned after a consensus at the American Orthopaedic Society for Sports Medicine (AOSSM) meeting in 1989, due to reports of poor results, overconstraint, early degenerative change [41,57] and a failure of prospective controlled studies to demonstrate a clinical advantage [1,6,37]. The recent resurgence in interest in the anterolateral structures of the knee has led to important advances in the understanding of their anatomy and biomechanics and this has allowed the development of anatomic anterolateral ligament reconstruction [53]. Although several authors have evaluated the risk of overconstraint with anatomic ALL reconstruction in cadaveric studies these have had several limitations [52] and in contrast clinical results have been promising with no evidence to support previous concerns regarding poor outcomes [54,55].

The aim of this article is to provide a review of the literature relating to LET in order to highlight the differences in philosophies and outcomes of historical reconstructions and contemporary anterolateral reconstruction.

Surgical Techniques

A large number of different LET procedures are described. It is beyond the scope of this article to describe all of the reported techniques in detail particularly when many are not

associated with published clinical results. However, a brief synopsis of the most frequently used reconstructions is provided here:

MacIntosh procedure. [27]

A strip of iliotibial band (ITB) is dissected from its mid-portion and turned down to its attachment at Gerdy's tubercle. It is then passed deep to the collateral ligament and looped behind the insertion of the intermuscular septum. It is then passed deep to the collateral ligament again, and fixed with the knee held at 90° flexion.

Ellison's distal ITT transfer.[20]

A distally detached strip of ITB with a bone flake is passed deep to the LCL and anchored in a bone trough slightly anterior to its original harvest site at the Gerdy tubercle with the knee flexed to 90° and held in external rotation.

Lemaire operation.[31]

A strip of ITB is detached proximally and passed deep to the LCL, and then through a femoral tunnel. The graft is then passed deep to the LCL a second time and fixed with sutures to the iliotibial band with the knee flexed to 30° and held in external rotation.

Marcacci/Zaffagnini technique.[34]

Semitendinosus and gracilis tendons are harvested proximally, sutured together, and passed through a tibial ACL reconstruction tunnel. The graft exits the tibial tunnel intra-articularly and is passed through the posterior aspect of the femoral notch and over the top of the lateral femoral condyle. The graft is then passed deep to the ITB and over the LCL and is then fixed distal to Gerdy's tubercle with the knee flexed to 90° and held in

external rotation

Combined Anatomic ACL and ALL reconstruction.[53]

The anatomic ACL/ALL graft is composed of a tripled semitendinosus tendon combined with a single strand gracilis tendon. The additional length of the gracilis forms the ALL graft. This exits the femoral tunnel at the anatomical footprint of the ALL on the lateral femoral cortex. It is routed deep to the ITB, through a tibial tunnel and then back proximally to the femur. The ALL graft is fixed in full extension.

Review of studies reporting outcome of isolated LET in ACL deficient knees

LET is most frequently performed in combination with ACLR. However, several authors have reported case series of patients undergoing isolated LET [3, 7, 10, 13, 18, 20, 24, 27, 30, 33, 35, 39, 61]. These have all been small retrospective non - controlled studies using predominantly the MacIntosh [3, 18, 27, 61] , Ellison [30, 35] or Lemaire [39] procedures and the majority have been published prior to 1995.

Although the majority of these studies described good outcomes in terms of patient reported outcome measures and the ability of LET to provide rotational control, several key findings were identified that limit the use of isolated LET in current practice. One of the main concerns is that high rates of persistent anterior laxity were reported at medium-term follow up, with 40-100% of patients having positive post-operative Lachman tests in multiple series [18, 24, 30, 39, 61]. In addition, several authors reported early degenerative change in the lateral compartment. This has been attributed to numerous factors including overconstraint by the LET [41, 46, 57], the non-anatomical nature of the reconstructions and also prolonged periods of post-operative

cast immobilisation rather than the aggressive early rehabilitation typical of contemporary practice.[15, 17, 37, 43, 44, 47] It is for these reasons that isolated, non anatomic LET procedures are rarely reported in the recent literature.

Review of studies comparing isolated ACLR versus combined ACLR and lateral extra articular tenodeses

Numerous studies report a comparison of the outcomes of isolated ACLR versus combined ACLR and non-anatomical LET. The vast majority of these are small retrospective series [2, 11, 12, 16, 25, 26, 29, 32, 41, 42, 46, 48-50, 55, 59, 62, 63]. However, prospective randomised controlled trials (RCTs) are also reported but contain small numbers only [1, 6, 37, 58, 60]. These have been the subject of several meta-analyses and the key findings are summarised here.

Graft rupture rates

Combined procedures are proposed to reduce forces transmitted to the ACL graft and protect it during ligamentisation. There is therefore an expectation that this may result in reduced graft rupture rates. Rezende et al. [45] studied this in a meta-analysis including 8 RCTs (total of 682 patients) and found no difference in graft rupture rates between isolated ACLR and combined LET procedures. However, it should be noted that most of the included studies did not explicitly report graft rupture and overall numbers were therefore insufficient to draw clear conclusions. Table 1 summarises graft rupture rates from comparative series of isolated ACLR versus combined procedures. Several authors demonstrated a trend towards lower rates of re-rupture when concomitant LET was performed [1,2,22,59,60,40]. However, only Noyes and Barber

demonstrated a significantly lower rate when ACLR was combined with non-anatomical LET.[40]

Persistent laxity

Biomechanical studies have demonstrated that isolated ACL rupture does not result in high grade pivot shift but if the ALL is also transected then grades II and III pivot are demonstrable. [36] Song et al [51] reported a systematic review of studies evaluating persistent rotatory instability in patients who underwent combined ACLR and LET for high grade pivot shift. The authors evaluated 7 studies, including a total of 326 patients. The three types of LET used were anterolateral ligament (ALL) reconstruction, Marcacci and MacIntosh procedures. The authors reported that among the comparative studies included, the prevalence of residual pivot shift was significantly lower in patients treated with LET plus ACLR (13.3%) than those with ACLR only (27.2%). However, Song et al also highlighted that three previous randomised trials had not shown combined procedures to be superior [1, 6, 25] and attributed this to inclusion of patients with lower pre-operative grades of pivot shift where isolated ACLR was likely sufficient to provide rotatory control.

These findings are consistent with the results of the meta-analysis from Rezende at al, who demonstrated that the proportion of patients with normal or nearly normal pivot shift and Lachman tests was greater in the group treated with combined reconstructions. However, they also reported that the proportion of patients with a side-to-side difference greater than 3 mm (KT-1000 and KT-2000 arthrometer measurements) did not differ with the numbers available between groups and concluded that combined procedures afford only small improvements in knee stability. It is perhaps the stricter inclusion

criteria of the review by Song et al. (including high grade pivot only) that allowed them to draw stronger conclusions regarding the benefit of combined procedures in improving knee stability. However, Rezende et al [45] also highlighted that the pivot shift test is a subjective assessment and that confounding factors such as differences in methodology result in low reliability and a need for cautious interpretation of the results of such studies.

Patient reported outcome measures and return to sport

In the same meta-analysis Rezende et al [45] also evaluated patient reported outcome measures. They identified that IKDC subjective scores did not differ between patients who underwent isolated ACLR compared with patients who underwent a combined procedure. Furthermore, treatment groups did not differ regarding Tegner Lysholm activity scores or the proportion of patients able to return to their previous activity levels.

In contrast, Zaffagnini et al. [63] reported that a substantially greater proportion of patients who underwent LET plus ACLR achieved normal or nearly normal functional scores when compared with those who underwent isolated intra-articular ACLR using hamstring autograft.

One of the reasons for the difference in findings between studies is the considerable heterogeneity between them. However, it seems reasonable to conclude that patient reported outcome measures in those undergoing combined procedures do not appear to be dissimilar to those undergoing isolated procedures.

Rehabilitation protocols

As noted with isolated LET procedures the use of plaster cast immobilisation or bracing has been popular in the historical literature and is much less common in contemporary practice. Of the studies reporting combined procedures considered for this review, over half reported the use of bracing or immobilisation. Many of these studies were published prior to the popularisation of modern early aggressive rehabilitation. Some of the concerns with delayed rehabilitation relate to a predisposition to both early degenerative change and stiffness [22].

Complications

No significant difference in the rate of complications (including infection, knee stiffness, and recurrent meniscal injury) between isolated ACLR and combined procedure groups has been demonstrated in meta-analysis.[45] However, the meta-analysis was limited by the low number of studies reporting complications. Similarly, a large proportion of the studies considered for this review did not explicitly report complications. Table 2 presents a summary of complications from included studies that reported adverse outcomes.

Secondary degenerative change

Concerns exist regarding the risk of secondary osteoarthritis (OA) due to potential overtightening of the lateral compartment with extra-articular reconstruction. However, Ferretti et al recently demonstrated that patients undergoing extra-articular reconstruction did not have an increased risk of OA at a minimum follow-up of 10 years [22]. The number of patients included in Kellgren-Lawrence grades II, III, and IV in the control group (25/49; 51%) was statistically higher than in the extra-articular

reconstruction group (6/42; 14%). These findings are in agreement with other authors [34], who also did not find an increased risk of OA with extra-articular tenodesis. Ferretti et al suggested that the previous concept of lateral overtightening causing degenerative changes in the lateral compartment is unlikely to be correct. They postulated that the previously reported increased incidence of OA may have been a result of the cautious postoperative protocol, which included immobilization in a plaster cast for up to 2 months postoperatively. [22] Additional potential causative factors include a combination of imperfectly anatomic ACL reconstruction, and a non-anatomic extra-articular lateral tenodesis, fixed in flexion and often with the tibia in external rotation.

Case Series Reporting Results of combined anatomic ACL and ALL reconstruction

Although there has been considerable recent interest in ALL reconstruction the vast majority of published studies relating to this topic are laboratory based. However, in 2015, Sonnery-Cottet et al [55] published the first prospective clinical series (n=83) of combined ACLR and ALL reconstruction with a mean follow-up of 32.4 months (range 24–39 months). Pre-operatively, patients were reported to exhibit the following grades of pivot shift (Grade 1, n=47; Grade 2, n=23; Grade 3, n=19). Post-operatively 76 patients had a negative pivot-shift and rest had grade 1 pivot-shift only. This is an important finding because previous authors have reported that regardless of the type of ACL graft used, most clinical series report a rate of residual pivot-shift of up to 15% [31, 46]. The authors reported no complications related to the surgical technique and only one patient had an ACL graft rupture that occurred one year after the index procedure, whereas six patients had a contralateral ACL rupture. Given the results of

combined ACL and ALL reconstruction compared to traditional ACL reconstruction in regards to re-rupture rate, return to play and rotational stability, it was concluded that the ALL has an important function concomitant to the ACL.

More recently, a large study has provided the first clinical comparison between isolated ACLR and combined anatomic ACL/ALL reconstruction in a high risk population of young patients engaged in pivoting contact sports. Sonnery-Cottet et al reported the outcomes of 105 B-PT-B, 176 4HT and 221 HT+ALL reconstructions [54]. The mean age for the study cohort was 22.4 ± 4.0 years (range 16-30), 72.5% (n=364) were male. The mean duration of follow-up was 38.4 ± 8.5 months (range 24-54). 39 professional athletes participated in this series: 6 in the HT group, 13 in the B-PT-B group and 20 in the HT + ALL group. The key findings of this study in relation to graft rupture, clinical outcomes and return to sport are reported below. It should also be noted that the limitations of this study included that it was a single surgeon, non-randomised, retrospective study.

Graft rupture rate

In contrast to previous meta-analyses comparing the outcomes of isolated ACLR and LET, Sonnery-Cottet et al. [54] demonstrated that combined anatomic ALL reconstruction was associated with significantly decreased graft rupture rates in a high risk population. At a mean follow up of 38.4 months, the graft rupture rates were as follows: isolated quadrupled hamstring tendon ACLR (4HT): 10.77% (6.60 to 17.32), isolated bone - patella tendon – bone ACLR (B-PT-B): 16.77% (9.99 to 27.40) and combined ACLR + ALL reconstruction (HT+ALL): 4.13% (2.17 to 7.80). When the differences in the demographics of the population relating to age and gender, and pre-operative side to side laxity differences were accounted for in multivariate analysis, the

rate of graft failure in HT+ALL was 3.1 times less than the 4HT group and 2.5 times less than the B-PT-B group. There was no significant difference in the graft failure rate between 4HT and B-PT-B groups.

Clinical Outcomes

In keeping with previous reports of combined procedures there was no difference between groups with respect to the mean pre-operative subjective IKDC score or side-to-side laxity. The mean post-operative subjective IKDC score was 84.4 +/- 11.6 and there was no difference between groups with respect to delta subjective IKDC. The mean post-operative side-to-side laxity difference was 0.5 +/-0.9mm and again, there was no significant difference between groups in terms of delta Rolimeter. The mean Lysholm score at the last follow-up was 91.8 ± 9.6 (63;100) and the mean Tegner score was 7.0 ± 2.0 (1;9), with no significant difference between the groups. Complications were rare and are reported in Table 2 along with data from other included studies.

Return to sport

Overall, 93% of patients returned to sport at the latest follow-up. Return to self-described pre-injury level of sport (RPLS) was 64.6% (272/421). In the professional athlete population (n=39), five patients incurred a graft rupture (3 B-PT-B, 1 HT, 1 HT+ALL) and six incurred a contralateral ACL injury and were excluded from RPLS analyses. Of the remaining 28 professional athletes, all returned to their pre-injury level of sport. Combined ACL and ALL reconstruction was associated with higher odds of RPLS than 4HT but not compared to B-PT-B.

Conclusions

Historical combined ACL reconstruction and lateral extra-articular tenodeses are associated with improved knee rotational stability. Although a trend towards decreased graft rupture rates is reported by several authors, the majority did not demonstrate a significant difference, likely as a result of small and underpowered studies using postoperative immobilisation and delayed rehabilitation protocols. More recently combined anatomic ACLR and ALL reconstruction has been shown to be associated with significant improvements in graft failure and return to sport rates when compared to isolated ACLR. However, these results are from a single clinical series with only medium term follow up.

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Table 1. Summary of graft rupture rates reported in comparative series of isolated ACLR and combined procedures. Only data from studies that explicitly reported these outcomes are included. BTB – Bone Patella Tendon Bone, TFL – Tensor Fascia Lata, ITB – Iliotibial Band, BF – Biceps Femoris, HT – Hamstring Tendon, ALL – Anterolateral Ligament.

Author	Method (Follow up - months)	Number of patients in each study and group	Graft rupture rates at latest follow up: Isolated ALCR / ACLR and combined LET
1. Acquitter	Randomized study Min 30, mean 58	100 (50 BTB ; 50 BTB + LET with Quadriceps tendon graft)	12% ACLR / 4 % ACLR Combined LET
6. Anderson	Prospective randomised Min 24, Mean 34.4	105 (35 BTB; 35 Hamstring; 35 Hamstring + TFL)	2% BTB / 2 % Hamstring / 0% Hamstring + LET
22. Ferretti	Retrospective Min 10 years, Mean 25 years	140 (72 Quadrupled HT; 68 ACLR + LET with ITB)	1.4 % ACLR / 0% ACLR + LET
40. Noyes	Retrospective Min 23; Mean 35	100 (60 BTB; 40 BTB +LET with ITB)	16% ACLR / 3% ACLR combined LET $p<0.05$
46. Roth	Retrospective Min 24, Mean 38	93 (50 ACLR; 43 ACLR + BF advancement)	4% ACLR / 9% ACLR combined LET
54. Sonnery-Cottet	Prospective cohort , Min 24, Mean 38.4	502 (105 BTB; 176 Hamstring; 221 HT + ALL)	16.7 % BTB / 10,7 % 4HT / 4HT + ALL $p<0.05$
58. Trichine	Prospective randomised Min 6 , Mean 24.5	107 (52 BTB; 55 BTB + LET with ITB)	0% ACLR / 0% ACLR Combined LET
59. Trojani	Retrospective multicentre Series of ACL revision Min 24, Mean 44	189 revision ACLR (105 ACLR; 84 ACLR + LET with various grafts used for revision)	15% ACLR/ 7% ACLR Combined LET
60. Vadala	Prospective randomised Min 36, Mean 44.6	60 (32 Quadrupled HT; 28 Quadrupled HT + LET with ITB)	6.2 % ACLR / 0% ACLR Combined

Study	Graft type	Mean follow up (Months)	n	Range of motion/ Stiffness (% of patients)	Persistent pain (% of patients)	Persistent instability (% of patients)	Other complications
Acquitter[1]	BTB	60	50	Ext. deficit 4% Flex. deficit0%	42%	12%	NR
	BTB + QT		50	Ext. Deficit 4% Flex. deficit O%	54%	6%	NR
Anderson[6]	BTB	35.4	35	Ext. deficit 8.6% Flex. Deficit 2.8%	NR	NR (20% PS)	1 (2.9%) staple and plica removal
	Hamstring + ITB		35	Ext. deficit 20% Flex. Deficit 23%	NR	NR (20% PS)	2 (5.7%) mobilisation for flexion deficit, 3 staples removal
	Hamstring		35	Ext. deficit 2.8% Flex. Deficit 5.7%	NR	NR (23%PS)	4 (11.4%) staples removal
Dejour[16]	Double bundle Hamstring	24	25	NR	24%	NR	44% patients with Hypoaesthesia
	BTB		25	NR	36%	NR	68% patients with Hypoaesthesia
	BTB+ Modified Lemaire with Gracilis		25	NR	36%	NR	76% patients with Hypoaesthesia
Giraud [25]	BTB	84	34	No difference between the two groups for flexion recovery (139° / 140°)	NR	NR	NR
	BTB + QT (MacIntosh)		29		NR	NR	NR
Lerat [32]	BTB	48	50	No difference between the two groups for flexion recovery and extension recovery	0%	NR	1 (2%) Arthrolysis
	BTB + QT (MacIntosh)		60		5%	NR	3 (5%) Arthrolysis
O'Brien [41]	BTB	48	31	NR	NR	NR	Swelling in LET group (friction of ITB graft on lateral collateral ligament)
	BTB+ ITB		48	NR	42% pain on LET	NR	
Sgaglione [50]	ST Graft	38 .5	21	NR	NR	NR	2 staple removals and debridement at lateral femoral condyle in ST graft + ITB group
	ST Graft + ITB		51	NR	15.7% pain on LET	NR	

Study	Graft type	Mean follow up (Months)	n	Range of motion/ Stiffness (% of patients)	Persistent pain (% of patients)	Persistent instability (% of patients)	Other complications
Sonnery-Cottet [54]	BTB	38.4	105	NR	NR	No persistent instability reported. No differences in side to side laxity	1 (0.9%) tibial screw removal. 1(0.9%°) Septic arthritis+ 11(10.4%) arthrolysis (Cyclops)
	Quadrupled Hamstring		176	NR	NR		1 (0.5%) tibial screw removal + 1 (0.5%) mobilisation (stiffness)+ 5 (2.8%) arthrolysis (Cyclops)
	Tripled ST + ALL reconstruction with Gracilis		221	NR	NR		1(0.4%) tibial screw removal +1 (0.4%) mobilisation for Stiffness)+ 1 (0.4%) lavage for haemarthrosis + 6 (2.7%) arthrolysis (Cyclops)
Vadala[60]	Quadrupled Hamstring	44.6	28	Full ROM in both group at final evaluation	No differences between groups	No persistent instability reported. (PS better result in LET group)	NR
	Quadrupled Hamstring + ITB		27				NR

Table 2. Summary of complications reported in comparative studies of isolated ACL reconstruction versus combined procedures. Only data from studies that explicitly reported complications are included. BTB – Bone Patella Tendon Bone, QT – Quadriceps Tendon, ITB – Iliotibial Band, ST – Semitendinosus, ALL – Anterolateral Ligament, PS – Pivot shift, NR – Not reported.