

Clinical Results of Lateral Extra-Articular Tenodesis

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Summary: In the anterior cruciate ligament (ACL) deficient knee, excellent outcomes are achieved in many patients with an isolated, intra-articular ACL reconstruction. Some patients, however, have ongoing instability or suffer graft rupture. Failure after ACL reconstruction is multifactorial, but residual anterolateral rotatory laxity is 1 potential contributing factor. Lateral extra-articular procedures are a heterogeneous group of operations that were initially described as isolated treatments for the ACL deficient knee, and subsequently used in combination with intra-articular reconstructions. Initial observational studies were encouraging, however, comparative studies were less flattering and lead to a general abandonment of these procedures. With improved understanding of the anatomy and biomechanics of the anterolateral capsuloligamentous complex there has been a renewed interest in these procedures. Recent systematic reviews suggest efficacy of these procedures in improving rotational control, though data showing improved patient reported outcomes or reduced graft rupture rates are lacking. Preliminary results from ongoing clinical trials are supportive for lateral extra-articular tenodesis when used as an augment to modern, intra-articular ACL reconstructions in targeted, high-risk patients.

Key Words: lateral extra-articular tenodesis—ACL reconstruction—anterolateral rotatory instability.

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For many patients with an anterior cruciate ligament (ACL) deficient knee, an isolated intra-articular ACL reconstruction (ACLR) will lead to an excellent functional outcome. However, there remains a group of patients who have residual rotational instability,^{1–3} or go on to have graft rupture. Ongoing attempts have been made to better identify this patient population⁴ with the ultimate aim of developing treatments to improve their outcomes.

Recent descriptions of the anterolateral ligament (ALL)⁵ have rekindled interest in the role of anterolateral procedures in controlling rotational instability. Anterolateral rotatory instability (ALRI) is multifactorial, with the ALL, iliotibial band (ITB), anterolateral capsule, and lateral meniscus all contributing to internal rotational control. Given the spectrum of severity of ALRI, there are inherent challenges in assessing, grading, and treating this condition, and optimal management continues to be refined.

Despite the recent interest in the ALL complex and anterolateral rotational instability, these concepts are not new. Ségon⁶ described an association between injury to the anterolateral structures of the knee in conjunction with ACL disruption in 1879. The concept of rotational instability of the knee was introduced by Slocum and Larson.⁷ Further work by Hughston et al^{8,9} described ALRI, which he felt was primarily a

consequence of injury to the middle third lateral capsular ligament, and only accentuated by ACL deficiency.

Lateral extra-articular tenodesis (LET) procedures are a heterogeneous group of nonanatomic operations that were described to control this anterolateral rotational instability. Initially performed as isolated procedures and later used in combination with intra-articular ACLR, they fell from favor due to concerns regarding their efficacy and morbidity compared with modern, isolated intra-articular reconstructions. Today, the role for these procedures, particularly in high-risk populations, is again being examined.

TYPES OF LATERAL EXTRA-ARTICULAR PROCEDURES

Isolated Procedures

Early extra-articular procedures were performed as isolated operations for ALRI. Many of these techniques can, however, be combined with contemporary intra-articular ACLRs and modified to take advantage of advances in tendon-bone fixation techniques.

Lemaire¹⁰ described a technique using a 1.5×18 cm strip of ITB left attached distally to Gerdy's tubercle. This was passed deep to the lateral collateral ligament (LCL), through an osseous tunnel in the femur, and then back under the LCL to be anchored in a bone tunnel at Gerdy's tubercle. This technique forms the basis of many lateral extra-articular procedures. A single limb modification was described and popularized by Christel and Djian¹¹ where a 75 mm strip of ITB was anchored in a femoral bone tunnel after passing the graft superficial to the LCL.

Macintosh^{12,13} described an ITB-based reconstruction using a 20×2 cm strip from the midsection that is left attached distally and passed deep to the LCL, through a subperiosteal femoral tunnel immediately behind the LCL and then through a further tunnel at the distal lateral intermuscular septum. The graft was tensioned and sutured onto itself deep to the LCL (Fig. 1).

In 1979 Arnold et al¹⁵ described a modified Macintosh procedure. A 2 cm wide strip of ITB is fashioned with its distal attachment maintained. This is routed deep to the proximal LCL where it is sutured. The remaining graft is then reflected back down over the LCL to reach Gerdy's tubercle where it is secured to the tibia with a staple at 90 degrees of knee flexion and in external rotation.

The Ellison¹⁶ procedure differs from other ITB LET reconstructions in that a 1.5 cm strip of ITB is released distally from Gerdy's tubercle with a bone block. This is passed deep to the LCL and anchored into a bone trough in the region of the lateral patella tendon. This is combined with a capsular plication deep to the LCL, and was felt to create a dynamic reconstruction (Fig. 2).

Loose et al¹⁷ and Andrews and Sanders¹⁸ described further variations of isolated ITB-based LET procedures to treat ALRI.

Combined Procedures

Combined reconstructions can either be incorporated within the ACLR, where a single graft is utilized for both intra-articular and extra-articular procedures, or thought of as an augmentation to the ACLR with a separate graft is utilized.

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The authors declare that they have nothing to disclose.

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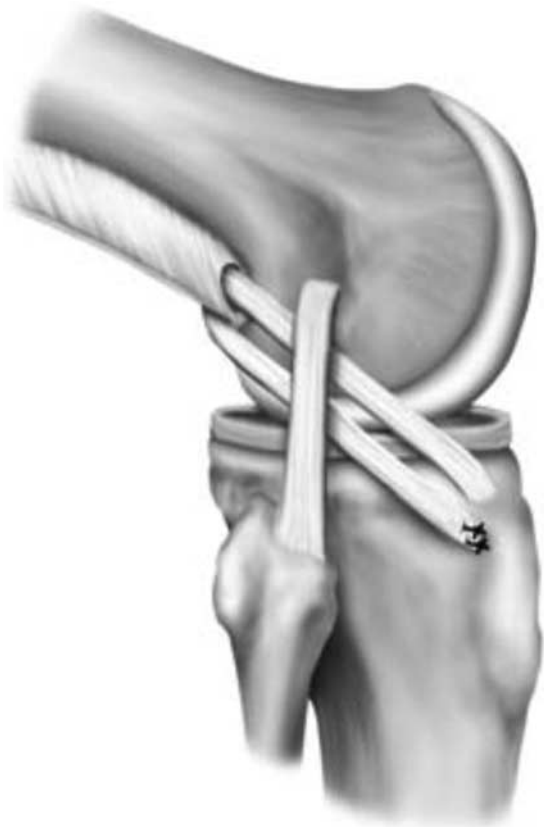


FIGURE 1. Macintosh 1. Lateral extra-articular reconstruction with a strip of iliotibial band passed through the intermuscular septum and under the lateral collateral. Reproduced from McCulloch et al.¹⁴

The Macintosh “over the top” reconstruction (1985)¹⁹ is an ITB based, combined intra-articular and extra-articular reconstruction (Fig. 3). A 25x4 cm long strip of ITB is left attached to Gerdy’s tubercle distally and passed deep to the LCL. It is then passed subperiosteally to the anterior aspect of the lateral intramuscular septum and then “over the top” and through the knee to reconstruct the ACL.

Marcacci et al²⁰ described a modification of this concept using a hamstring autograft (Fig. 4). The semitendinosus and gracilis tendons are harvested, left attached distally and sutured together, passed through a tibial tunnel into knee and then to the “over the top” position, where the extra-articular reconstruction was subsequently performed by passing the tendons superficial to the LCL and securing them distally at Gerdy’s tubercle.

The “MacInJones” procedure described by Lerat et al²² involves a bone-patella-tendon-bone (BPTB) intra-articular ACLR using the lateral third of the patella tendon. This was harvested in continuity with a 10 cm strip of quadriceps tendon that was used to create the extra-articular component. The quadriceps tendon was passed deep to the LCL and anchored into a tunnel at Gerdy’s tubercle.

CLINICAL RESULTS OF LATERAL EXTRA-ARTICULAR PROCEDURES

Isolated Lateral Extra-articular Procedures

Early literature describing isolated extra-articular procedures is heterogenous with various procedures, rehabilitation

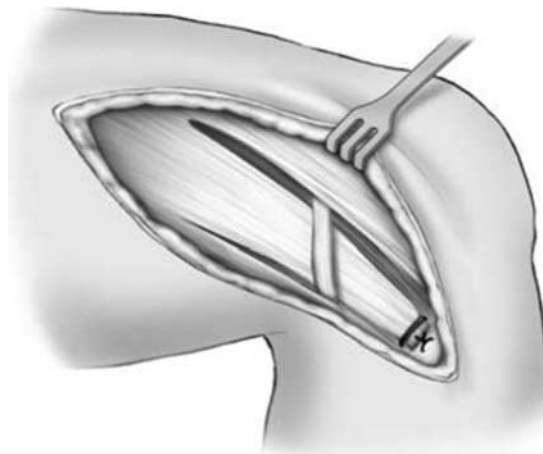


FIGURE 2. Ellison procedure. A “dynamic” lateral reconstruction where the iliotibial band was passed under the lateral collateral ligament, but was left intact proximally so that the tensor fascia muscle could help stabilize the knee during activity. Reproduced from McCulloch et al.¹⁴

protocols, and inconsistent outcome reporting. On the whole results are poor with high rates of residual instability and poor subjective outcome scores.

Neyret et al²³ recommended against an isolated Lemaire procedure in amateur skiers under 35 based on poor subjective



FIGURE 3. Macintosh over the top. Iliotibial band is detached proximally and passed over the top of the femur and through an intra-articular tunnel in the tibia. Reproduced from McCulloch et al.¹⁴

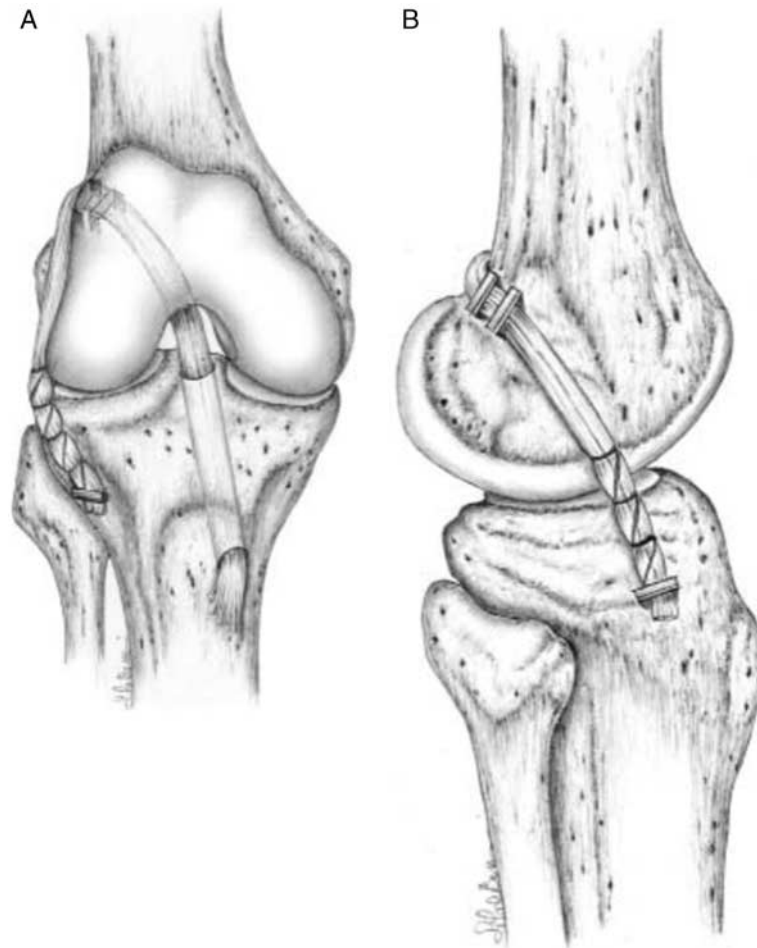


FIGURE 4. Marcacci procedure. Anterior cruciate ligament reconstruction with hamstring tendons plus extra-articular plasty. A, anteroposterior view; B, lateral view. Reproduced from Marcacci et al.²¹

satisfactions rates (16/31 satisfied) and high rates of residual instability. In their series 12 of 15 patients had a positive pivot shift at 4.5 years. The isolated Macintosh demonstrated better outcomes in terms of residual instability with negative pivot shift in 42 of 50 patients (84%) and a 74% return to sport rate at 2 years as reported by Ireland.²⁴ The authors reported a 75% good or excellent subjective outcome. This is in contrast to 52% good or excellent outcomes at 11 years reported by Amirault et al¹³ for the same procedure in 1988.

Ellison¹⁶ reported good outcomes with his procedure in 1979. There were 44% excellent and 39% good results in a series of 18 knees followed for between 31 and 44 months. There was, however, a 16.6% failure rate with 2 patients requiring reoperation. Kennedy et al,²⁵ however, demonstrated poor subjective results with an Ellison type reconstruction in 1978; only 16 of 28 (57%) patients reviewed at 12 months had “good” or “excellent” outcomes. There were high rates of residual instability as assessed by the pivot shift with only 4 of the 28 patients (14.3%) having a negative test at follow-up. Residual instability with an isolated Ellison procedure was also reported in a long-term follow-up study by Reid et al.²⁶ Of 32 patients, 24 (75%) had a positive pivot shift and 29 (91%) had a positive Lachman at a mean follow-up of 11 years. The authors abandoned the procedure citing poor subjective and objective scores and alarmingly high rates of radiologic degeneration.

The radiologic assessment was made using the modified Fairbank Criteria. Seven knees (22%) were normal, 8 knees (25%) had mild changes, 5 knees (16%) had moderate changes, and 12 knees (38%) had severe (grade 3 or 4) radiologic degeneration.

Combined Intra-articular and Lateral Extra-articular Procedures

Observational series for combined procedures were initially encouraging. In 1985 Bertoia et al¹⁹ reported 91% good or excellent results and a 97% return to preoperative activity at 37 months with a Macintosh over the top reconstruction. Zarins and Rowe²⁷ reported similar outcomes in 100 patients treated with a combined ITB and semitendinosus over the top reconstruction. There were 88% good or excellent results and a 0 or 1 + pivot shift in 91%. Dejour et al²⁸ augmented a BTB ACLR with a Lemaire procedure, achieving 83% good or excellent results at minimum 3-year follow-up in 1988.

Comparative studies were less flattering and concerns arose about the surgical morbidity associated with LET, including potential lateral compartment over-constraint and the development of osteoarthritis. O’Brien et al’s²⁹ retrospective series of 80 patients with 4-year follow-up showed no improvement in stability when a modified Macintosh procedure was performed in addition to a BPTB ACLR. The extra-articular procedure was used routinely during part of the study period and

not in selected cases. Forty percent had chronic pain or swelling attributed to the extra-articular procedure. Strum et al³⁰ also found no benefit to extra-articular augmentation in 127 patients undergoing intra-articular reconstruction. Again, this study was retrospective, and no indication is given for those in whom the additional extra-articular procedure was performed. In a prospective, randomized trial published in 2001, Anderson et al³¹ compared BPTB, hamstring, and hamstring plus Losee LET reconstructions with a minimum of 2 years follow-up and found no benefit to the additional extra-articular procedure.

The procedures fell out of favor in North America following an American Orthopaedic Society for Sports Medicine consensus conference in 1989, where it was felt the greater morbidity and higher risk of complications outweighed any potential biomechanical benefits. There was, however, significant regional variation in the utilization of LET augmentation and its use in many European centers continued.

Long-term follow-up reports have recently been published. Zaffagnini et al³² recently reported minimum 20-year outcome data on 52 patients undergoing the Marcacci procedure. Objective International Knee Documentation Committee (IKDC) scores were good or excellent in 86% of patients (31%, A; 55%, B). One patient (2%) had a graft rupture and a positive pivot shift was seen in only 3 of 26 patients (12%) assessed

using the KiRA inertial sensor system. The combined procedure was not associated with development of lateral compartment or patellofemoral osteoarthritis. It is important to note there was no control group (isolated intra-articular ACLR) in this case series. The same group reported 11-year results for high-level athletes undergoing double-strand hamstring ACLR with LET in 2009.²¹ IKDC scores were good or excellent (A and B) in 90.7% of patients and only 2 patients >5 mm manual maximum side-to-side difference in laxity.

Randomized Trials of ACLR Augmented With Lateral Extra-articular Procedures

A growing body of randomized trials examine the effect of LET as an augment to intra-articular ACLR (Table 1). The trials differ in the type of LET and intra-articular reconstruction, outcome measures and definitions of failure. Patient inclusion and exclusion criteria also differ, with some enrolling patient perceived to be at high risk for failure with a grossly positive preoperative pivot shift.³⁸ Drawing firm conclusions about the safety, efficacy, and indications for LET augmentation is difficult based on this current data set.

Zaffagnini et al³⁵ has been the only author to demonstrate improved patient reported outcome measures associated with LET. In this 2006 study, 75 patients were randomized evenly to 3 treatment groups. These consisted of: (1) The Marcacci technique,

TABLE 1. Randomized Trials of Lateral Extra-articular Procedure Augmentation of Intra-articular Anterior Cruciate Reconstruction

References	Control	LET Intervention	Mean Follow-up (mo)	Failure Rate	Residual Pivot Shift ++/+++	KT-1000/2000	IKDC A/B	Comments/Conclusion
Anderson et al ³¹	PT (n = 35)	HS+Losee ITB LET (n = 35)	35.4	1/35 (2.9%) PT 0/35 (0%) HS+LET 1/32 (2.9%) HS	7/35 (20%) PT 7/35 (20%) HS +LET 8/35 (22.9%) HS	5.2 mm PT 5.7 mm HS +LET 6.0 mm HS*	97% PT 68% HS+LET 79% HS	No significant difference between groups
Ait Si Selmi et al ³³	PT (n = 60)	PT+HS LET (n = 60)	18	NR	2/60 (3.3%) PT 0/50 (0%) LET	NR 6.0 mm HS*	82.4% PT 79.3% LET	In French No significant difference between groups
Acquitter et al ³⁴	PT (n = 50)	“MacInJones” PT+Quads Tendon LET (n = 50)	58	6/52 (12%) PT 2/52 (4%) LET	4/50 (10%) PT 2/50 (5%) LET	7.2 mm PT 7.3 mm LET*	80% PT 88% LET	In French No significant difference between groups
Zaffagnini et al ³⁵	PT (n = 25) HS (n = 25)	Marcacci HS LET (n = 25)	60	NR	0/25 (0%) PT 4/25 (16%) HS 0/25 (0%) HS+LET	1/25 (5%) PT 5/25 (5%) HS 1/25 (5%) HS +LET (b > 5 mm)	76% PT 72% HS 84% HS+LET	
Giraud et al ³⁶	PT (n = 34)	“MacInJones” PT+Quads Tendon LET (n = 29)	84	NR	9.5% PT 5.3% LET	10.5 mm PT 11.4 mm LET†	52.3% PT 55.5% LET	In French
Zaffagnini et al ³⁷	DBHS (n = 37)	Marcacci HS LET (n = 35)	47	0/37 (0%) DBHS 0/35 (0%) HS+LET	0% DBHS 0% HS+LET	1.1 mm DBHS 0.7 mm HS +LET†	97.5% DBHS 94.3% HS+LET	Better subjective, objective and functional outcomes in DBHS group
Vadala et al ³⁸	HS (n = 32)	HS+Cocker-Arnold LET (n = 28)	44.6	2/32 (6.3%) HS 0/28 (0%) LET	14.2% HS 0% LET	2.8 mm HS 2.7 mm LET*	28 (100%) HS 27 (100%) LET	Selection of high-risk patients: females with 2+/3+ pivot shift
Trichine et al ³⁹	PT (n = 60)	PT+Modified Lemaire LET (n = 60)	24	0/60 (0%) PT 0/60 (0%) PT+LET	(4.4%) PT (1.4%)PT+LET	NR	79.7% PT 82.5% PT+LET	Radiologic analysis also No significant difference between groups

Failure is defined by each paper, typically graft rupture and/or persistent instability.

KT-1000/2000—*Maximal manual side-to-side difference.

†Maximum manual displacement.

++/+++ indicates 2+ or 3+, or grade 2 or 3.

DBHS indicates double bundle hamstring anterior cruciate reconstruction; HS, hamstring anterior ligament reconstruction; IKDC, International Knee Documentation Committee; ITB, iliotibial band; LET, lateral extra-articular tenodesis; NR, not reported; PT, patella tendon anterior cruciate ligament reconstruction.

as described above,²⁰ (2) a 4 strand, single bundle hamstring ACLR, or (3) a BPTB ACLR. At 5-year follow-up the LET group had higher subjective IKDC scores and also had a quicker return to sport. Zaffagnini et al³⁷ reported on 35 patients treated with the Marcacci procedure compared with 37 patients randomized to a double bundle ACLR and followed for 3.9 years. The double bundle group performed better in terms of IKDC scoring and pivot shift. Higher return to sport rates were seen in the double bundle group (100% vs. 91%), with the Marcacci cohort returning to sport more quickly (3.8 vs. 6.4 mo).

The concept of LET as an augmentation in selected high-risk patients was explored by Vadala et al³⁸ who studied only female patients with ACL deficient knees who had a preoperative grade 2 or 3+ pivot shift. They randomized 60 patients to 4SHS ACLR with or without an extra-articular Coker-Arnold procedure. At mean follow-up of 44.4 months, a residual positive pivot shift was found in 57.1% of patients with an isolated ACLR and in 18.6% of patients with a combined ACLR and LET ($P < 0.05$). Logistic regression models demonstrated the postoperative pivot shift was highly correlated ($P = 0.0001$) to treatment group. Functional outcome measures including IKDC, Tegner, Lysholm scores were not significantly different between groups, however, this study was likely underpowered to detect a statistically different clinical difference in these outcome measures.

RECENT SYSTEMATIC REVIEWS

Five recent systematic reviews⁴⁰⁻⁴⁴ have examined LET augmentation of ACLR. Rezende et al,⁴³ Hewison et al,⁴² and Song et al⁴⁴ all found LET to be associated with improved stability as assessed by pivot shift. The Rezende paper also found ACLR augmented with LET improved anteroposterior stability as measured by Lachman and KT-1000 testing. The 4 reviews investigating patient reported outcome measures did not find any improvement in pooled IKDC scores. Rezende reported comparable failure rates for isolated intra-articular ACLR and ACLR augmented with LET. Hewison and Song did not report on this outcome. The focus of the first review by Devitt et al⁴¹ was on the development of osteoarthritis. The authors found LET augmentation of ACLR was not associated with an increased rate of osteoarthritis of the knee. Low rates of OA were reported at 11 years, but the authors found rates increased thereafter. Meniscal injury at the time of surgery was the greatest predictor of OA. A further meta-analysis published by Devitt and colleagues investigated the effect of LET augmentation in early (≤ 12 mo) and delayed ACLR. Interestingly LET augmentation was not effective in reducing residual pivot shift in early ACLR group, however, there was statistically significant reduction in residual pivot shift in delayed ACLR. These systematic reviews all highlight limitations of the existing evidence base, but on the whole they suggest LET is associated with increased stability as measured by pivot shift, without a demonstrated improvement in patient reported outcome measures.

LATERAL EXTRA-ARTICULAR PROCEDURES IN REVISION ACLR

The concept of LET augmentation in revision ACLR is appealing, especially if there is no obvious cause identified for the initial failure. LET may protect the revision graft from excessive stress during incorporation in the early postoperative period^{45,46} but more importantly it may address residual rotational instability as an underlying cause for failure.

The French Arthroscopic Society⁴⁷ conducted a retrospective multicenter study of isolated revision ACLR versus revision ACLR augmented with LET. The study included a

variety of different reconstruction techniques. Of 189 patients, LET was performed in 84 (51%) according to the surgeon's preference. No further details on how surgeons decided to allocate patients to LET augmentation were provided. Patients were followed for a minimum of 2 years. Failure was defined as a grade 2 or 3 pivot shift test and a KT-1000 test showing a difference over 5 mm. There was a 15% failure rate (12/79) in the isolated ACL revision group and 7% rate for the combined LET group (6/84), however, this difference did not reach statistical significance. Lateral tenodesis was associated increased knee stability with 80% having a negative pivot shift versus 63% without tenodesis. This difference reached significance, however, IKDC scores were not different between groups.

Ferretti et al⁴⁸ published results of 30 patients treated with LET augmentation in revision ACLR. The primary operations were patella tendon ($n = 26$) or synthetic ($n = 4$) reconstructions, and the revision procedure was a 4 strand hamstring autograft with the Coker-Arnold modification of the Macintosh LET. At a mean 5-year follow-up, 2 patients had a side-to-side difference of > 5 mm with a 2+ pivot shift and 1 patient had a revision at another institution resulting in a 10% failure rate overall. There was a significant reduction in both the Lachman ($P = 0.00001$) and the pivot-shift test ($P = 0.0013$) at follow-up with the pivot shift being negative in 15 patients, 1+ in 11, and 2+ in 2. Fifteen of the 28 patients were IKDC A, 11 B, and 2 group C. There were high rates of radiologic arthritis at final follow-up.

CURRENT TRIALS

The "Standard ACL Reconstruction versus ACL and Lateral Extra-Articular Tenodesis" (STAbiLiTY)⁴⁹ study is an ongoing prospective randomized control trial of over 600 patients coordinated by the University of Western Ontario. The study focuses on high-risk patients, with inclusion criteria being patients 14 to 25 years old with an ACL deficient knee who play competitive pivoting sports, have a grade 2 pivot shift or generalized ligamentous laxity. Participants are randomized to hamstring ACLR or ACLR with an ITB-based LET (modified Lemaire). The primary outcome measure is graft failure at 2 years, with secondary outcomes being patient reported outcome scores (ACL-QOL, KOOS, MARX Activity Rating Scale, IKDC, Euro QoL), knee range of motion, and radiologic markers of arthritis. One-year results of the trial have been presented, and while the interim results should be interpreted with caution, they appear favorable for LET. Failure rates in the LET group are 4 from 199 (2.0%) and in the isolated ACLR group 11 from 211 (5.2%, $P = 0.10$). The rates of asymmetric pivot shift are also significantly different between the groups in favor of the LET procedure (37.0% vs. 21.6%, $P = 0.001$). However, this appears to come at the cost of increased early morbidity, with increased pain and reduced lower limb function at 3 months. The estimated study completion date is March 2019.

The Pittsburgh group have also registered a prospective, randomized trial comparing anatomic single bundle hamstring ACLR with or without an extra-articular tenodesis using a Marcacci technique.⁵⁰ Outcomes assessed will include biomechanical and patient reported outcome measures with the estimated study completion date in 2020.

CONCLUSIONS

The role of extra-articular procedures continues to be defined. Improved understanding of the anatomy and biomechanics of the anterolateral capsuloligamentous complex, combined with ongoing high-quality clinical trials will

hopefully provide definitive evidence about the safety and efficacy of this procedure and identify the subgroup of patients who are most likely to benefit. This will in turn better inform the decision making of surgeons.

REFERENCES

- Chambat P, Guier C, Sonnery-Cottet B, et al. The evolution of ACL reconstruction over the last fifty years. *Int Orthop*. 2013;37:181–186.
- Tashman S, Collon D, Anderson K, et al. Abnormal rotational knee motion during running after anterior cruciate ligament reconstruction. *Am J Sports Med*. 2004;32:975–983.
- Ristanis S, Stergio N, Patras K, et al. Excessive tibial rotation during high-demand activities is not restored by anterior cruciate ligament reconstruction. *Arthroscopy*. 2005;21:1323–1329.
- Musahil V, Seil R, Zaffagnini S, et al. The role of static and dynamic rotatory laxity testing in evaluating ACL injury. *Knee Surg Sports Traumatol Arthrosc*. 2012;20:603–612.
- Claes S, Vereecke E, Maes M, et al. Anatomy of the anterolateral ligament of the knee. *J Anat*. 2013;223:321–328.
- Ségon P. Clinical and experimental research into bloody effusions in knee sprains. *Prog Méd*. 1879;7:297–341.
- Slocum DB, Larson RL. Rotatory instability of the knee: its pathogenesis and a clinical test to demonstrate its presence. *J Bone Joint Surg Am*. 1968;50:211–225.
- Hughston J, Andrews J, Cross M, et al. Classification of knee ligament instabilities. Part II: The lateral compartment. *J Bone Joint Surg Am*. 1976;58:173–179.
- Hughston J, Andrews J, Cross M, et al. Classification of knee ligament instabilities. Part I. The medial compartment and cruciate ligaments. *J Bone Joint Surg Am*. 1976;58:159–172.
- Lemaire M. Chronic knee instability. Technics and results of ligament plasty in sports injuries. *J Chir*. 1975;110:281–294.
- Christel P, Djian P. Antero-lateral extra-articular tenodesis of the knee using a short strip of fascia lata. *Rev Chir Orthop Reparatrice Appar Mot*. 2002;88:508–513.
- Macintosh D. Lateral substitution reconstruction. In proceedings of the Canadian Orthopaedic Association. *J Bone Joint Surg*. 1976;58:142.
- Amirault J, Cameron J, MacIntosh D, et al. Chronic anterior cruciate ligament deficiency. Long-term results of MacIntosh's lateral substitution reconstruction. *Bone & Joint Journal*. 1988;70:622–624.
- McCulloch P, Latterman C, Boland A, et al. An illustrated history of anterior cruciate ligament surgery. *J Knee Surg*. 2007;20:95–104.
- Arnold J, Coker T, Heaton L, et al. Natural history of anterior cruciate tears. *Am J Sports Med*. 1979;7:305–313.
- Ellison A. Distal iliotibial-band transfer for anterolateral rotatory instability of the knee. *J Bone Joint Surg Am*. 1979;61:330–337.
- Loose RE, Johnson TR, Southwick W. Anterior subluxation of the lateral tibial plateau. A diagnostic test and operative repair. *J Bone Joint Surg Am*. 1978;60:1015–1030.
- Andrews JR, Sanders R. A “mini-reconstruction” technique in treating anterolateral rotatory instability (ALRI). *Clin Orthop Relat Res*. 1983;172:93–96.
- Bertoia J, Urovitz E, Richards R, et al. Anterior cruciate reconstruction using the MacIntosh lateral-substitution over-the-top repair. *J Bone Joint Surg Am*. 1985;67:1183–1188.
- Marcacci M, Zaffagnini S, Iacono F, et al. Arthroscopic intra- and extra-articular anterior cruciate ligament reconstruction with gracilis and semitendinosus tendons. *Knee Surg Sports Traumatol Arthrosc*. 1998;6:68–75.
- Marcacci M, Zaffagnini S, Giordano G, et al. Anterior cruciate ligament reconstruction associated with extra-articular tenodesis: A prospective clinical and radiographic evaluation with 10- to 13-year follow-up. *Am J Sports Med*. 2009;37:707–714.
- Lerat J, Dupre La Tour L, Herzberg G, et al. Review of 100 patients operated on for chronic anterior laxity of the knee by a procedure derived from the Jones and MacIntosh methods. Value of dynamic radiography for the objective analysis of the results. *Rev Chir Orthop Reparatrice Appar Mot*. 1987;73:201.
- Neyret P, Palomo R, Donell S, et al. Extra-articular tenodesis for anterior cruciate ligament rupture in amateur skiers. *Br J Sports Med*. 1994;28:31–34.
- Ireland J, Trickey E. Macintosh tenodesis for anterolateral instability of the knee. *Bone Joint J*. 1980;62:340–345.
- Kennedy J, Stewart R, Walker DM. Anterolateral rotatory instability of the knee joint. An early analysis of the Ellison procedure. *J Bone Joint Surg Am*. 1978;60:1031–1039.
- Reid J, Hanks G, Kalenak A, et al. The Ellison iliotibial-band transfer for a torn anterior cruciate ligament of the knee. Long-term follow-up. *J Bone Joint Surg Am*. 1992;74:1392–1402.
- Zarins B, Rowe CR. Combined anterior cruciate-ligament reconstruction using semitendinosus tendon and iliotibial tract. *J Bone Joint Surg Am*. 1986;68:160–177.
- Dejour H, Walch G, Neyret P, et al. Results of surgically treated chronic anterior laxities. Apropos of 251 cases reviewed with a minimum follow-up of 3 years. *Rev Chir Orthop Reparatrice Appar Mot*. 1988;74:622–636.
- O'Brien S, Warren R, Pavlov H, et al. The iliotibial band lateral sling procedure and its effect on the results of anterior cruciate ligament reconstruction. *Am J Sports Med*. 1991;19:21–25.
- Strum G, Fox J, Ferkel R, et al. Intraarticular versus intraarticular and extraarticular reconstruction for chronic anterior cruciate ligament instability. *Clin Orthop Relat Res*. 1989;245:188–198.
- Anderson AF, Snyder RB, Lipscomb AB Jr. Anterior cruciate ligament reconstruction: a prospective randomized study of three surgical methods. *Am J Sports Med*. 2001;29:272–279.
- Zaffagnini S, Muccioli G, Grassi A, et al. Over-the-top ACL reconstruction plus extra-articular lateral tenodesis with hamstring tendon grafts: prospective evaluation with 20-year minimum follow-up. *Am J Sports Med*. 2017;45:3233–3242.
- Ait Si Selmi T, Fabié F, Massouh T, et al. Greffe du LCA au Tendon Rotulien Sous Arthroscopie Avec ou Sans Plastie Antero-Externe. In: *Le Genou Du Sportif-10èmes Journées Lyonnaises De Genou*. Sauramps Medical; 2002:221–224.
- Acquitter Y, Hulet C, Locker B, et al. Intérêt d'une plastie extra-articulaire dans le traitement des laxités antérieures chroniques du genou par une autogreffe de tendon rotulien. *Rev Chir Orthop Reparatrice Appar Mot*. 2003;89:413–422.
- Zaffagnini S, Marcacci M, Presti M, et al. Prospective and randomized evaluation of ACL reconstruction with three techniques: a clinical and radiographic evaluation at 5 years follow-up. *Knee Surg Sports Traumatol Arthrosc*. 2006;14:1060–1069.
- Giraud B, Besse JL, Cladiere F, et al. Intra-articular reconstruction of the anterior cruciate ligament with and without extra-articular supplementation by quadriceps tendon plasty: seven-year follow-up. *Rev Chir Orthop Reparatrice Appar Mot*. 2006;92:788–797.
- Zaffagnini S, Bruni D, Russo A, et al. ST/G ACL reconstruction: double strand plus extra-articular sling vs double bundle, randomized study at 3-year follow-up. *Scand J Med Sci Sports*. 2008;18:573–581.
- Vadala A, Iorio R, De Carli A, et al. An extra-articular procedure improves the clinical outcome in anterior cruciate ligament reconstruction with hamstrings in female athletes. *Int Orthop*. 2013;37:187–192.

39. Trichine F, Alsaati M, Chouteau J, et al. Patellar tendon autograft reconstruction of the anterior cruciate ligament with and without lateral plasty in advanced-stage chronic laxity. A clinical, prospective, randomized, single-blind study using passive dynamic X-rays. *Knee*. 2014;21:58–65.
40. Devitt B, Bell S, Arderm C, et al. The role of lateral extra-articular tenodesis in primary anterior cruciate ligament reconstruction: a systematic review with meta-analysis and best-evidence synthesis. *Orthop J Sports Med*. 2017;5:2325967117731767.
41. Devitt B, Bouguennec N, Barford K, et al. Combined anterior cruciate ligament reconstruction and lateral extra-articular tenodesis does not result in an increased rate of osteoarthritis: a systematic review and best evidence synthesis. *Knee Surg Sports Traumatol Arthrosc*. 2017;25:1149–1160.
42. Hewison C, Tran M, Kaniki N, et al. Lateral extra-articular tenodesis reduces rotational laxity when combined with anterior cruciate ligament reconstruction: a systematic review of the literature. *Arthroscopy*. 2015;31:2022–2034.
43. Rezende F, Moraes V, Martimbianco A, et al. Does combined intra- and extraarticular ACL reconstruction improve function and stability? A meta-analysis. *Clin Orthop Relat Res*. 2015;473:2609–2618.
44. Song G, Hong L, Zhng H, et al. Clinical outcomes of combined lateral extra-articular tenodesis and intra-articular anterior cruciate ligament reconstruction in addressing high-grade pivot-shift phenomenon. *Arthroscopy*. 2016;32:898–905.
45. Draganich L, Reider B, Miller P. An in vitro study of an intraarticular and extraarticular reconstruction in the anterior cruciate ligament deficient knee. *Am J Sports Med*. 1990;18:262–266.
46. Engebretsen L, Lew W, Lewis J, et al. The effect of an iliotibial tenodesis on intraarticular graft forces and knee joint motion. *Am J Sports Med*. 1990;18:169–176.
47. Trojani C, Beaufils P, Burdin G, et al. Revision ACL reconstruction: influence of a lateral tenodesis. *Knee Surg Sports Traumatol Arthrosc*. 2012;20:1565–1570.
48. Ferretti A, Conteduca F, Monaco E, et al. Revision anterior cruciate ligament reconstruction with doubled semitendinosus and gracilis tendons and lateral extra-articular reconstruction. *J Bone Joint Surg Am*. 2006;88:2373–2379.
49. Standard ACL reconstruction vs ACL + Lateral Extra-Articular Tenodesis Study (STAbLiTY). Available at: <https://clinicaltrials.gov/ct2/show/NCT02018354>. Accessed January 2018.
50. Anderst W. ACL-reconstruction vs ACL-reconstruction With EAT. 2016. Available at: <https://clinicaltrials.gov/ct2/show/NCT02913404>.