Anterolateral Ligament Reconstruction Protects The Repaired Medial Meniscus: A Comparative Study of 383 ACL Reconstructions from the XXX with a Minimum Follow Up of Two Years

Background: The prevalence of osteoarthritis after successful meniscal repair is significantly less than the rate that is observed after failed meniscal repair.

Study Design: Cohort study; Level of evidence, 2.

Purpose: The aim of this study was to determine whether the addition of anterolateral ligament reconstruction (ALLR) confers a protective effect on medial meniscal repair performed at the time of anterior cruciate ligament reconstruction (ACLR).

Methods: Retrospective analysis of prospectively collected data was performed to include all patients who had undergone primary ACLR with concomitant posterior horn medial meniscal repair between January 2013 and August 2015. ACLR autograft choice was either bone-patellar tendon-bone (B-PT-B), quadrupled hamstring tendon (4HT) or quadrupled semitendinosus tendon (4ST) graft with or without ALLR. At the end of the study period, all patients were contacted to determine if they had undergone re-operation. A Kaplan-Meier survival curve was plotted and Cox proportional hazards regression model was used to perform multivariate analysis.

Results: 383 patients (mean age 27.4 ± 9.2 years) with a mean follow-up of 37.4 months (range 24-54.9 months) were included. 194 patients underwent an isolated ACLR and 189 underwent a combined ACLR+ALLR. At final follow up there was no significant difference in postoperative side-to-side laxity (isolated ACLR group 0.9 ± 0.9mm (-1 to 3), ACLR+ALLR group 0.8 ± 1.0mm (-2 to 3) *P*= .2120) or Lysholm score (isolated ACLR group 93.0 (91.2-94.7), ACLR+ALLR group 93.7 (92.3-95.1), *P*= .556) between groups.

43 patients (11.2%) underwent re-operation for failure of the medial meniscus repair or a new tear. The survival rate of meniscal repair at 36 months in the ACLR+ALLR group was 91.2% (95% IC, 85.4%-94.8) and in the ACLR group it was 83.8% (95% CI, 77.1%-88.7%) (*P*= .033). The probability of failure of medial meniscal repair was more than two times lower in patients with ACLR+ALLR compared to patients with isolated ACLR (hazard ratio, 0.443; 95% CI, 0.218-0.866). No other prognosticators of meniscal repair failure were identified.

Conclusion: Combined ACLR and ALLR is associated with a significantly lower rate of failure of medial meniscus repairs when compared to those performed at the time of isolated ACLR.

Key words: Anterior Cruciate Ligament, Anterolateral ligament, Medial Meniscal Repair

What is known about the subject: Failure rates of meniscal repairs performed at the time of ACLR of up to 30% are reported. Failure of meniscal repair is associated with a significantly higher incidence of osteoarthritis at long term follow-up when compared to successful meniscal repair. Reducing the failure rate of meniscal repair is therefore an important objective in the management of these injuries. It is recently demonstrated that extra-articular tenodeses performed at the time of ACLR reduce residual instability and the rate of residual pivot shift. It is thought that this improvement in knee stability is responsible for the significant reduction in ACL graft rupture rates that is reported following combined ACLR + ALLR when compared to isolated ACLR. To the authors knowledge it has not been previously studied whether ALLR, and the reported improvement in knee kinematics, confers a protective effect on the repaired medial meniscus.

What this study adds to existing knowledge: This study demonstrates that the addition of anterolateral ligament reconstruction at the time of ACL reconstruction is associated with a significant reduction in the failure rate of medial meniscal repairs when compared to isolated ACL reconstructions. This finding is attributed to improved knee kinematics resulting from concomitant ALLR conferring a protective effect on the medial meniscal repair.

Introduction

The reported incidence of meniscal tears associated with an ACL rupture ranges from 16% to 82 % for acute injuries and up to 96 % in chronic injuries.[15] Long-term studies of patients following anterior cruciate ligament reconstruction (ACLR) have demonstrated that medial meniscectomy is associated with higher rates of osteoarthritis (OA).[3,5,32,40] The importance of the medial meniscus as a secondary stabilizer for antero-posterior translation has been demonstrated by a number of biomechanical cadaveric studies.[18,39,41] Medial meniscectomy leads to increased tibial translation and abnormal knee kinematics.[39,41] It is therefore critical to try to repair the medial meniscus whenever possible. However, meniscal repairs have reported failure rates of up to 30%.[27,52] The high failure rate may, in part, explain why meniscectomy is performed 2 to 3 times more frequently than meniscus repair during ACLR.[28] Any technique which can increase the success of meniscal repair, performed at the time of ACL reconstruction, is therefore likely to be important in improving long-term outcomes.

Concomitant reconstruction of the anterolateral ligament (ALL) of the knee with ACLR has recently been demonstrated to be associated with lower ACL graft failure rates than isolated ACLR.[45] The decrease in failure rates is attributed to increased rotational stability and load-sharing which protect the ACL graft from excessive forces.[36,45] This augmented stability may similarly protect the repaired medial meniscus, allowing a reduction in failure rates.

To the authors' knowledge, the impact of ALLR on the success of meniscal repair has not been previously investigated. The aim of this study was to report the clinical outcomes of repair of the medial meniscus in patients undergoing ACLR, with or without ALLR. The hypothesis of this study was that significantly decreased rates of failure of medial meniscal

repair would be observed in patients who underwent combined ACLR and ALLR when compared to those undergoing isolated ACLR.

Patients and Methods

Institutional review board approval was granted for this study and all patients gave valid consent to participate. There were no financial incentives for study participation. A retrospective analysis of prospectively collected data from the XXX database was conducted. All patients who underwent primary ACLR with concomitant medial meniscal repair through a posteromedial portal between January 1, 2013 to August 30, 2015 were included in the study. The rationale for including only repairs performed through a posteromedial portal was based on reports from several authors that different tear morphologies are associated with different failure rates.[16,25,33,37] In order to minimize any confounding effect of the tear pattern and location, only patients with vertical tears of the posterior horn of the medial meniscus, repaired through a posteromedial portal, including ramp lesions, were considered for study eligibility. Those who had meniscal root tears, horizontal or vertical tears more centrally located than the red-white zone were excluded.

Pre-operatively, all patients had sustained a knee injury resulting in an ACL tear diagnosed on the basis of clinical examination and magnetic resonance imaging (MRI). All procedures were performed by one of three experienced surgeons (XXX). Patients undergoing major concomitant surgery (e.g. high tibial osteotomy, multiligament reconstruction) and those whose ACLR was performed with a pediatric technique were not included in the study. The decision to use a particular graft type for ACLR was based on patient factors/choice and the authors' evolving indications for concomitant ALL reconstruction during the study period. This decision was taken preoperatively and was independent of the status of the medial

meniscus. During the study period, there was a trend towards more frequently performing combined ACLR and ALLR grafts with the progression of time. Indications included one or more of the following criteria: grade 3 pivot shift, high level of sporting activity, participation in pivoting sports, deep lateral femoral notch sign on radiographs, associated Segond fracture, chronic ACL rupture (>3 months after injury), and patients younger than 25 years old.

Surgical Technique

1) Medial Meniscus Repair:[2,50]

A standard high lateral parapatellar portal for the arthroscope and a medial parapatellar portal for the instruments was utilized. Arthroscopic exploration of the medial meniscus was performed through the anterolateral portal and exploration of the posteromedial compartment was systematically performed by a trans-notch view. When posterior horn MM tears were identified, debridement and sutures of these lesions were performed through a posteromedial portal using a 25° hook (SutureLasso; Arthrex, Naples, FL) loaded with a No. 0 absorbable monofilament suture (PDS; Ethicon, Somerville, NJ) (figure 1). To improve exposure of more centrally located tears, internal rotation of the tibia was added. When the tear extended to the pars intermedia, in addition to the aforementioned posterior suture, a meniscal suture anchor (FasT-Fix; Smith & Nephew, Andover, MA) was also placed via a standard anterior portal in order to complete the repair. After suture placement an arthroscopic probe was used to evaluate and confirm satisfactory stability of the repair.

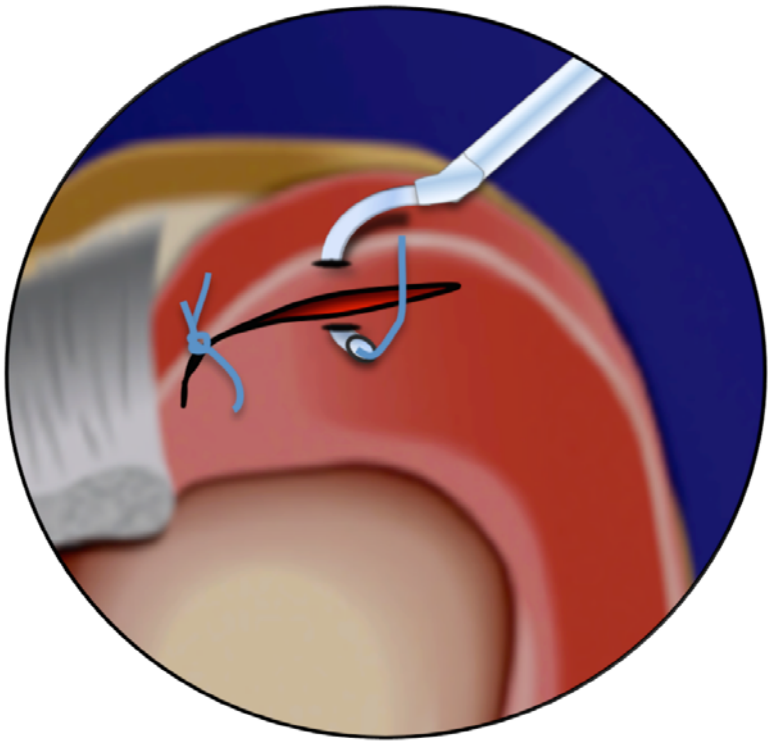


Figure 1. Suture repair of a posterior MM tear using a hook introduced through a posteromedial portal. Additional sutures can be placed if required, depending on the length of the tear. (Reproduced and modified with permission, M Thaunat, Arthroscopy 2016,[50] Elsevier)

2) ACLR with or without concomitant ALLR:

ACLR was performed using 3 different types of graft: bone-patellar tendon-bone (B-PT-B),[10] quadrupled hamstring tendons (4HT)[19] or quadrupled semitendinosus tendon (4ST).[43] For the ALLR, a gracilis tendon graft was used.[49]

Outcomes

Physical examinations were conducted by a sport medicine physician independent of the primary surgeons, preoperatively and at the following postoperative intervals: weeks 3 and 6 and months 3, 6, and 12. Preoperative demographic and clinical data were recorded at the

first clinical evaluation. Clinical evaluation including ligament testing and range of motion (ROM) evaluation were recorded at 3, 6 and 12-month follow-up. ~~An isokinetic test was performed at 6 months follow-up.~~ Side-to-side laxity evaluation was performed with the Rolimeter device (Aircast Europa, Neubeuern, Germany) at 12 months follow-up.

All patients ~~participated~~ were recommended to follow ~~in~~ the same postoperative rehabilitation protocol. This comprised brace-free mobilization, weight bearing as tolerated and a restricted range of motion from 0° to 90° for the first 4 weeks postoperatively.[31] Early rehabilitation was focused on obtaining full extension and quadriceps activation. A gradual return to sport activities was allowed starting at 4 months for non-pivoting sports, at 6 months for pivoting non-contact sports, and at 8 to 9 months for pivoting contact sports. ~~The return to pivoting non-contact sport was delayed if the aforementioned isokinetic testing showed a deficit greater than 20% in eccentric or concentric hamstring strength or any quadriceps deficit. In this situation, repeat testing was performed after a further 2 months of rehabilitation.~~

At the end of the study period, an author who was not one of the three primary surgeons, contacted all patients by e-mail and telephone in order to obtain Lysholm and Tegner scores and to determine whether the patient had undergone ipsilateral re-operation or contralateral knee surgery. If further surgery had been undertaken, then the operative records were obtained in all cases (including from other institutions) and reviewed. Failure of the MM repair was assumed when patients had a subsequent medial meniscal suture or meniscectomy.

Data Analysis

All calculations were made with SAS for Windows (Version 9.4; SAS Institute Inc) with the level of statistical significance set at $P < 0.05$. Descriptive data analysis (mean, standard deviation, range, 95% confidence interval and proportion) was conducted for the entire patient population. The baseline characteristics of patients and demographic variables were compared between the groups with the Student t-test for variables, and the chi-square test or exact Fischer test for proportions. A Kaplan-Meier survival curve, with failure of meniscal repair as the endpoint, was plotted. A Cox proportional hazards regression model was used to perform an adjusted analysis of time to failure of the repaired medial meniscus, in order to account for significant demographic differences between the groups.

Results

Patients

418 patients met the inclusion criteria. Thirty-five patients (8.4%) were lost to follow-up. The final study population comprised 383 patients (Figure 1), divided into two groups: 194 isolated ACLR (33 B-PT-B, 73 4HT, 88 4ST) and 189 ACLR + ALLR (176 HT, 6 B-PT-B, 7 4ST).

Patient characteristics are summarized in Table 1. There was no significant difference between the groups with respect to gender distribution, preoperative side-to-side laxity, time interval between the injury and surgery or the number of meniscal sutures placed. Significant differences were observed with respect to age, type of sports participation, Body Mass Index (BMI) and the incidence of co-existing lateral meniscal (LM) tears.

Table 1: Patients Demographics (N=383 patients). T-test for variables and chi-square test for proportions unless otherwise indicated.

		All Patients N=383	**ACLR N=194**	**ACLR+ALLR N=189**	***p***
Follow-up (months)	mean ± SD (min ; max)	37.4 ± 9.0 24.0 ; 54.9	39.2 ± 9.4 24.0 ; 54.9	36.6 ± 8.2 24.1 ; 54.7	**< .0001**
Gender	Male	293 (76.5%)	153 (78.9%)	140 (74.1%)	.2688
Age (years)	mean ± SD (min ; max)	27.4 ± 9.2 14 ; 60	30.9 ± 9.9 15 ; 60	23.8 ± 6.8 14 ; 48	**< .0001**
BMI (kg/m^2)	mean ± SD (min ; max)	24.0 ± 2.6 17.3 ; 32.7	24.5 ± 2.6 18.5 ; 32.7	23.5 ± 2.5 17.3 ; 30.9	**.0002**
Injury to surgery interval (months)	mean ± SD (min ; max)	13.5 ± 31.7 0 ; 276	14.1 ± 36.4 0 ; 276	12.9 ± 26 0 ; 187	.7116
Preoperative side-to-side laxity (mm)	mean ± SD (min ; max)	7.2 ± 1.7 3 ; 16	7.0 ± 1.6 3 ; 14	7.5 ± 1.8 3 ; 16	.4451[a]
LM tear		140 (36.6%)	55 (28.4%)	85 (45%)	**.0007**
Type of sport[b]	Contact Non-contact	240 (62.7%) 143 (37.4%)	101 (52.1%) 93 (47.9%)	139 (73.5%) 50 (26.5%)	**< .0001**
Number of meniscal sutures[c]	mean ± SD (min ; max)	2.5 ± 0.8 1 ; 6	2.5 ± 0.8 (1-6) 1 ; 6	2.5 ± 0.8 1 ; 5	.6458

ACLR, anterior cruciate ligament reconstruction; ALLR, anterolateral ligament reconstruction; LM, lateral meniscus.

[a] Exact Fisher test between proportion of patients included in each IKDC laxity group (normal, nearly normal, abnormal, severely abnormal)

[b] Type of sport: pivoting sport with contact (soccer, handball, basketball, rugby, motocross) and pivoting sport without contact (alpine skiing,fitness, gymnastics, tennis).

[c] 27 repairs in the ACLR group and 20 in the ACLR +ALLR (*P* = .3199) group were completed with an additional FastFix suture via anteromedial portal.

Postoperative outcomes

Postoperative outcomes are summarized in Table 2. Side-to-side laxity was measured in 380 patients at 12 months follow-up. Three patients were excluded because of an ACL graft failure or a contralateral ACL injury before the one-year follow-up review.

Lysholm and Tegner scores and the rate of return to pre-injury level of sport were evaluated at the end of the study period, in 324 patients. Patients with failure of MM repair (n=43), ACL graft failure (n=15) and one patient with spinal cord tumor and lower limb neuropathy (n=1) were excluded.

Table 2 : Patients outcomes.
For scores and return to pre-injury sport, N=324 patients (154 ACLR, 170 ACLR+ALLR). For Postoperative side-to-side laxity, N=380 patients (193 ACLR, 187 ACLR+ALLR). T-test for variables or chi-square test for proportions unless otherwise indicated.

		All Patients	**ACLR**	**ACLR+ALLR**	***p***
Postoperative side-to-side laxity (mm)	mean ± SD (min ; max)	0.9 ± 0.9 -2 ; 3	0.9 ± 0.9 -1 ; 3	0.8 ± 1.0 -2 ; 3	.2120[a]
Lysholm score	mean (95%CI)	93.4 (92.3-94.5)	93.0 (91.3-94.7)	93.7 (92.3-95.1)	.5556
Tegner score	mean (95%CI)	6.9 (6.7-7.1)	6.5 (6.3-6.9)	7.2 (6.9-7.4)	**.0008**
Return to pre-injury sport		201 (62.0%)	97 (63.0%)	104 (61.2%)	.7374

ACLR, anterior cruciate ligament reconstruction; ALLR, anterolateral ligament reconstruction

[a] Exact Fisher test between proportion of patients included in normal or nearly normal IKDC laxity group

Re-operation

At latest follow-up, 74 patients (19.3%) underwent at least one re-operation after the index procedure (Table 3). 43 (11.2%) patients underwent re-operation for failure of MM repair and this occurred at a mean of 19.0 ± 11.5 months after initial procedure. All of these patients underwent a partial medial meniscectomy except for 2 patients who underwent a revision MM repair. However, both revision MM repairs failed, leading to meniscectomy. ACL graft

failure occurred in 15 patients (3.9%) at a mean of 24.4 ± 11.6 months after the index procedure. With respect to the contralateral knee, 24 patients (6.2%) presented with an ACL rupture at a mean of 24.9 ± 11.7 months after the index procedure.

Table 3 : Re-operations (N=383 patients)

	All Patients N=383
Overall	74 (19.3%)
Failure of MM repair	43 (11.2%)
ACL graft failure	15 (3.9%)
Arthrofibrosis	3 (0.8%)
Cyclops lesion	9 (2.3%)
Deep infection	2 (0.5%)
Hardware irritation	1 (0.3%)
Iterative lateral meniscus pathology	1 (0.3%)

ACLR, anterior cruciate ligament reconstruction; MM, medial meniscus.

Figure 2 shows the cumulative survivorship of MM repairs derived from Kaplan-Meier analysis when using re-operation for MM pathology as an endpoint. Analysis was performed on 367 patients; 15 patients with ACL graft failure and one with lower limb neuropathy secondary to spinal cord tumor were excluded. At both 24 months and 36 months of follow-up, rates of MM suture failure were significantly lower for patients who underwent ACLR+ALLR than for those who underwent isolated ACLR (*P*= .033) (Table 4).

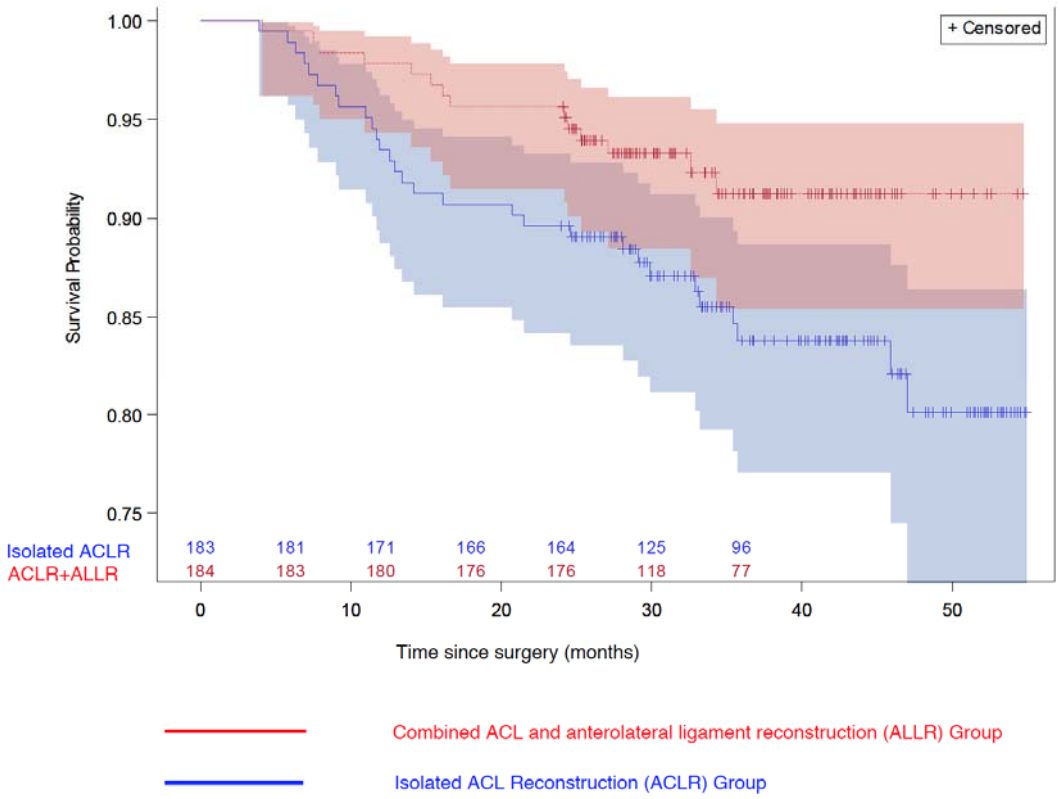


Figure 2. Kaplan-Meier survivorship using reoperation for medial meniscal pathology as an end point. Numbers at risks with 95% Confidence Interval

Table 4 : Kaplan-Meier rates of MM repair failure.

Surgical Procedure		MM Repair Failure[a]		*P*
		24 month Follow-up	36 month Follow-up	
Overall	mean (95%CI)	7.4 (5.1-10.6)	12.6 (9.4-16.9)	**.033**
isolated ACLR	mean (95%CI)	10.4 (6.8-15.8)	16.2 (11.3-22.9)	
ACLR + ALLR	mean (95%CI)	4.4 (2.2-8.5)	8.8 (5.2-14.6)	

[a] values expressed as percentage.

ACLR, anterior cruciate ligament reconstruction; ALLR, anterolateral ligament reconstruction; MM, medial meniscus

Cox proportional hazards regression model analysis showed that combined ACLR+ALLR was the only factor associated with a significant reduction in the risk of re-operation for failure of MM repair. Patients who underwent ACLR + ALLR had a greater than two-fold reduction in the risk of re-operation for failure of MM repair than patients who underwent isolated ACLR (hazard ratio, 0.443; 95%CI, 0.218-0.866; *P* = .021). In contrast, age (≤ 30 years or > 30 years), contact sports participation, BMI and the presence of a concomitant LM tear were not determined to be significant factors influencing the risk of re-operation for the MM (Table 5).

Table 5: Effect of ALLR on MM Repair Failure, adjusted on baseline characterics[a]

Variable	Adjusted Hazard Ratio N=367	95%CI	*P*
ALLR	0,443	0.218-0.866	**.021**
Age	0,665	0.327-1.296	.249
Type of sport	1,06	0.566- 2.034	.858
BMI[b]			.408
Normal vs underweight	1,061	0.008-7.548	
Normal vs overweight	0,967	0.464-1.885	
Normal vs obese	3,101	0.627-9.502	
LM tear	1,119	0.582-2.074	.730

[a]Bolded P values indicate statistical significance. Penalised adjused Cox model.

Covariates were selected by comparison between groups, and a threshold of 20%.

[b]WHO BMI classification: underweight (<18.5 kg/m^2), normal (18.5-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2), obese (30.0-34.9 kg/m^2).

MM, medial meniscus; ALLR, anterolateral ligament reconstruction;BMI, body mass index; LM, lateral meniscus; WHO, world health organization.

Within the isolated ACLR group, the choice of graft was not associated with a significant difference in the rate of reoperation for failure of MM repair at 24 and 36 months following the index procedure (Table 6).

Table 6 : Kaplan-Meier Rates of MM Repair failure in ACLR group.

Graft type		MM Repair Failure[a] 24-month Follow-up	36-month Follow-up	*P*
Overall	mean (95%CI)	9.4 (6.0-14.5)	15.3 (10.6-21.8)	.996
B-PT-B	mean (95%CI)	12.5 (4.9-30.0)	16.2 (7.0-34.6)	
4HT	mean (95%CI)	9.7 (4.7-19.2)	15.9 (9.1-26.9)	
4ST	mean (95%CI)	8.0 (3.9-16.1)	14.7 (7.5-27.7)	

[a] values expressed as percentage.

ACLR, anterior cruciate ligament reconstruction; B-PT-B, bone-patellar tendon-bone; 4HT, quadrupled hamstring tendons; 4ST, quadrupled semitendinosus tendon

Discussion

The main finding of this study is that the failure rate of MM repairs performed through a posteromedial portal was significantly lower after combined ACLR and ALLR than after isolated ACLR. The combined procedure was associated with a greater than two-fold reduction in the failure rate of MM repair, at a mean follow-up of 37.4 months (P= .033). This ~~demonstrates~~ suggests that ALLR has a protective effect on medial meniscal repairs performed at the time of ACLR. To the authors' knowledge, this is the first clinical study to assess meniscal repair failure rates after ACLR in the presence of an extra-articular tenodesis.

Numerous authors have investigated failure rates of meniscal repair performed at the time of ACL reconstruction. A systematic review of thirteen studies of meniscal repair outcomes reported a pooled rate of meniscal repair failure in ACL-reconstructed knees of 26.9% (18/67 knees) at greater than 5-years post-surgery.[27] Another systematic review of 21 studies evaluating all-inside and inside-out meniscal repair with concurrent ACL reconstruction, found pooled failure rates of 14.2% (140/1126 knees) at a mean follow-up of just over 5-years.[52] The failure rate for all-inside meniscal repair was significantly higher at 16% (121/744 knees) compared with 10% (39/382 knees) for inside-out repair (P= .016). It is important to note that both of these systematic reviews included a wide range of tear morphologies including those of the lateral meniscus. A number of trials have demonstrated higher failure rates of medial meniscus repair compared to lateral meniscal repairs.[13,20,21,29] This variability in the reported rate of failure demonstrates the importance of precisely defined inclusion criteria and caution in pooling results from different studies. Several authors have recently reported re-operation rates for failure of medial meniscal repairs performed at the time of ACLR. This has varied between 14%[53] and 26%.[14]

The importance of successful repair of the medial meniscus to long-term outcomes following ACLR, can be deduced from a number of trials. Claes et al. demonstrated that, at a minimum 10-year follow-up post-ACLR, 50% of patients that underwent meniscectomy had osteoarthritis (OA) compared to 16% of patients without meniscectomy (Odds ratio 3.54, 95 % CI 2.56–4.91).[5] Pernin et al. also reported that medial meniscectomy was a risk factor for development of OA in their long-term follow-up study (mean 24.5 years post-ACLR) with lateral extra-articular augmentation.[32] This finding was recently confirmed by Shelbourne et al. who reported a three times higher risk of developing OA in patients with medial meniscectomy at a mean 22.5 years after ACLR (Odds ratio 2.98, 95 % CI 1.91–4.66).[40] Two studies also assessed the difference in the prevalence of radiographic findings of OA between successful and failed meniscal repairs. Both reported higher rates of OA in failed repairs (56% compared with 14% and 57% compared with 15%).[6,35]

The significantly increased risk of OA associated with meniscal injury relates to the important role of the meniscus in the stability of the knee.[23] Cadaveric biomechanical studies have shown increased tibial anterior translation and external rotation after posterior meniscocapsular sectioning in the ACL-deficient knee.[1,30,46] Furthermore, they have demonstrated restoration of knee biomechanics only after both ACLR and repair of the meniscal lesion.[1,46] The medial meniscus also plays a stabilizing role in the ACL deficient knee, where it resists anterior tibial translation.[26,34]

It is therefore crucial to identify and repair meniscal lesions for successful long-term outcomes from ACLR. In this study, a standardized arthroscopic evaluation was performed in all patients in order to evaluate all MM lesions including hidden meniscal lesions - a substantial number of which may be missed with arthroscopic examination using only standard anterior portal examination.[42] The described surgical technique allows the ability to debride and repair lesions of the MM under direct visualization and as a result it has become

the authors standard practice for all MM lesions. Good clinical results have been reported at short term follow-up.[50]

Although isolated ACLR reliably restores anteroposterior stability, excessive tibial rotation may persist especially during more demanding activities. This persistent rotational instability can lead to repetitive micro-instability events that may contribute to failure of the meniscal repair.[34] It is therefore postulated that the higher failure rate of MM repair observed in the isolated ACLR group is due to failure to fully restore normal knee kinematics.

There has been a lot of interest recently in the role of the anterolateral structures of the knee in controlling rotatory laxity and their ability to share loads with the ACL graft.[5,8,36,44,12] Sectioning of the ALL in biomechanical cadaveric studies has resulted in greater rotational laxity in both the ACL-deficient knee[43] and the ACL-intact knee.[51] Augmentation of ACLR with an extra-articular tenodesis has been demonstrated to decrease rotational laxity and residual pivot shift.[11] Recently published clinical results demonstrate reduced failure of combined ACLR and ALLR when compared to isolated ACLR and this may be attributed to biomechanical load-sharing properties of the ALL graft.[45] Combined ACL and ALL reconstruction has been found to decrease the ACL graft failure rates by as much as 2.5 times compared to isolated ACLR.[45]

Some of the concerns regarding ALLR relate to the risk of late OA due to potential overtightening of the lateral compartment with extra-articular reconstruction. This overconstraint by ALLR was demonstrated in a recent cadaveric study using a supra-physiological 88N force for the ALL fixation.[38] In contrast several clinical series have not demonstrated a higher incidence of OA in those patients who underwent a lateral tenodesis when compared to isolated ACLR.[47,54] Similarly, a number of trials have reported excellent

results at long-term follow-up for combined ACLR and lateral tenodesis, with no increased risk of OA.[3,17,22] A systematic review of eight studies concluded that the addition of a lateral tenodesis to ACLR did not result in an increased rate of OA.[7] Furthermore, Ferretti, et al. demonstrated at a minimum 10-year follow-up that patients undergoing extra-articular reconstruction actually had a statistically lower risk (6 of 42; 14%) of OA than the standard ACL group (25 of 49; 51%) (p=0.003).[9] Although this finding is likely multifactorial it does support the concept of the current study which is that extra-articular procedures protect the repaired medial meniscus and therefore have the potential to reduce the rate of osteoarthritis following combined ACL rupture and medial meniscal tear.

A possible cause for the historical concerns regarding OA and extra-articular tenodesis may have been due to the now abandoned and overly cautious postoperative protocols which included toe-to-groin plaster cast immobilization for up to 2 months, rather than due to lateral overtightening from an extra-articular procedure.[8] Furthermore, concerns regarding complications after combined ACLR and ALLR reconstruction have also recently been assuaged with a study demonstrating the absence of any significant increase in reoperation rates after the combined procedure, in a series of over 500 patients.[49] Therefore, combined ACLR and ALLR can be considered to be a safe and effective surgical procedure.

Limitations

Limitations of our study include its retrospective nature and the absence of clinical evaluation at final follow-up. It is recognized that patients may minimize some symptoms or complaints during a telephone interview that a thorough examination may elucidate. Additionally, it is accepted that the use of re-operation as a definition for medial meniscal repair failure, rather than second look arthroscopy or MRI, would likely result in missed diagnoses of

asymptomatic failure. ~~the use of re-operation as a definition for medial meniscal failure rather than second-look arthroscopy or MRI~~. However, in previous studies, failure of meniscal repair has been defined as clinical failure based on patients who are clinically symptomatic or who underwent subsequent meniscal re-operation.[27,52] Second-look arthroscopy is rarely performed due to the unnecessary risk to the patient and some evidence that arthroscopic findings often do not correlate with patient symptoms.[4,48] A thorough clinical assessment including history and examination remains the gold standard for assessment of meniscal repair failure.[27,52] However, it should be noted that this may overestimate the meniscal healing rate.[24] A further limitation is that only vertical, posterior horn tears repaired through a posteromedial portal were included. The results cannot therefore be extrapolated to all medial meniscal tear types but the advantage of this approach has been to avoid confounding by the variable failure rates of different tear morphologies. In addition, this approach has permitted the utilization of a standardized surgical technique for all meniscal repairs which could otherwise also have been an important confounding factor.

Further limitations include the potential for selection bias due to the non-randomized study design and the fact that the indications for ALLR evolved during the study period. However, this is somewhat mitigated by the fact that only patients considered at high risk of ACL graft rupture underwent ALLR and that lesions of the medial meniscus did not influence graft choice. Finally, although the length of minimum follow-up may be considered as a potential limitation, it is important to note that the majority of meniscal repair failures are reported to occur within the first two years post-operatively. The minimum follow-up period in this study was therefore considered to be appropriate.[27,52]

Conclusions

Combined ACLR and ALLR is associated with a significantly lower rate of failure of medial meniscus repairs when compared to those performed at the time of isolated ACLR. It is recognized from previous studies that failure of medial meniscal repair is an important predictor of OA after ACLR. Further study is required to establish whether the protective effect of ALLR on medial meniscal repair is associated with decreased rates of OA at long term follow-up.

References

1. Ahn JH, Bae TS, Kang KS, Kang SY, Lee SH. Longitudinal tear of the medial meniscus posterior horn in the anterior cruciate ligament-deficient knee significantly influences anterior stability. *Am J Sports Med.* 2011;39(10):2187-2193.
2. Ahn JH, Wang JH, Yoo JC. Arthroscopic all-inside suture repair of medial meniscus lesion in anterior cruciate ligament--deficient knees: results of second-look arthroscopies in 39 cases. *Arthroscopy*. 2004;20(9):936-945.
3. Ait Si Selmi T, Fithian D, Neyret P. The evolution of osteoarthritis in 103 patients with ACL reconstruction at 17 years follow-up. *Knee*. 2006;13(5):353-358.
4. Asahina S, Muneta T, Yamamoto H. Arthroscopic meniscal repair in conjunction with anterior cruciate ligament reconstruction: factors affecting the healing rate. *Arthroscopy.* 1996;12(5):541-545.
5. Claes S, Hermie L, Verdonk R, Bellemans J, Verdonk P. Is osteoarthritis an inevitable consequence of anterior cruciate ligament reconstruction? A meta-analysis. *Knee Surg Sports Traumatol Arthrosc.* 2013;21(9):1967-1976.
6. DeHaven KE, Lohrer WA, Lovelock JE. Long-term results of open meniscal repair. *Am J Sports Med.* 1995;23(5):524-530.
7. Devitt BM, Bouguennec N, Barfod KW, Porter T, Webster KE, Feller JA. 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(4):1149-1160.
8. Dodds AL, Gupte CM, Neyret P, Williams AM, Amis AA. Extra-articular techniques in anterior cruciate ligament reconstruction: a literature review. *J Bone Joint Surg Br.* 2011;93(11):1440-1448.

9. Ferretti A, Monaco E, Ponzo A, et al. Combined Intra-articular and Extra-articular Reconstruction in Anterior Cruciate Ligament-Deficient Knee: 25 Years Later. *Arthroscopy.* 2016;32(10):2039-2047.

10. Garofalo R, Mouhsine E, Chambat P, Siegrist O. Anatomic anterior cruciate ligament reconstruction: the two-incision technique. *Knee Surg Sports Traumatol Arthrosc*. 2006;14(6):510-516.

11. Hewison CE, Tran MN, Kaniki N, Remtulla A, Bryant D, Getgood AM. Lateral Extra-articular Tenodesis Reduces Rotational Laxity When Combined With Anterior Cruciate Ligament Reconstruction: A Systematic Review of the Literature. *Arthroscopy.* 2015;31(10):2022-2034.

12. Inderhaug E, Stephen JM, Williams A, Amis AA,. Anteroateral Tenodesis or Anterolateral Ligament Complex Reconstruction: Effect of Flexion Angle at Graft Fixation When Combined With ACL Reconstruction. *Am J Sports Med*. 2017 Sep 1 (E.pub ahead of print) PMID: 28898106

13. Johnson MJ, Lucas GL, Dusek JK, Henning CE. Isolated arthroscopic meniscal repair: a long-term outcome study (more than 10 years). *Am J Sports Med.* 1999;27(1):44-49.

14. Karl Eriksson ER, Bjorn Barenius and Bjorn Engstrom Meniscal Sutures are Superior to Bioabsorbable Arrows: Results After 918 Consecutive Meniscal Repairs in a Dual Center Analysis. *Orthop J Sports Med.* 2017;5.

15. Kilcoyne KG, Dickens JF, Haniuk E, Cameron KL, Owens BD. Epidemiology of meniscal injury associated with ACL tears in young athletes. *Orthopedics.* 2012;35(3):208-212.

16. Laurendon L, Neri T, Farizon F, Philippot R. Prognostic factors for all-inside meniscal repair. A 87-case series. *Orthop Traumatol Surg Res.* 2017. Aug 2. pii: S1877-0568(17)30204-9. doi: 10.1016/j.otsr.2017.05.025.

17. Lerat JL, Chotel F, Besse JL, et al. [The results after 10-16 years of the treatment of chronic anterior laxity of the knee using reconstruction of the anterior cruciate ligament with a patellar tendon graft combined with an external extra-articular reconstruction]. *Rev Chir Orthop Reparatrice Appar Mot.* 1998;84(8):712-727.

18. Levy IM, Torzilli PA, Warren RF. The effect of medial meniscectomy on anterior-posterior motion of the knee. *J Bone Joint Surg Am.* 1982;64(6):883-888.

19. Locherbach C, Zayni R, Chambat P, Sonnery-Cottet B. Biologically enhanced ACL reconstruction. *Orthop Traumatol Surg Res.* 2010;96(7):810-815.

20. Logan M, Watts M, Owen J, Myers P. Meniscal repair in the elite athlete: results of 45 repairs with a minimum 5-year follow-up. *Am J Sports Med.* 2009;37(6):1131-1134.

21. Majewski M, Stoll R, Widmer H, Muller W, Friederich NF. Midterm and long-term results after arthroscopic suture repair of isolated, longitudinal, vertical meniscal tears in stable knees. *Am J Sports Med.* 2006;34(7):1072-1076.

22. Marcacci M, Zaffagnini S, Giordano G, Iacono F, Presti ML. 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(4):707-714.

23. Messner K, Gao J. The menisci of the knee joint. Anatomical and functional characteristics, and a rationale for clinical treatment. *J Anat.* 1998;193(Pt 2):161-178.

24. Miao Y, Yu JK, Ao YF, Zheng ZZ, Gong X, Leung KK. Diagnostic values of 3 methods for evaluating meniscal healing status after meniscal repair: comparison

among second-look arthroscopy, clinical assessment, and magnetic resonance imaging. *Am J Sports Med.* 2011;39(4):735-742.

25. Morgan CD, Wojtys EM, Casscells CD, Casscells SW. Arthroscopic meniscal repair evaluated by second-look arthroscopy. *Am J Sports Med.* 1991;19(6):632-637; discussion 637-638.

26. Musahl V, Citak M, O'Loughlin PF, Choi D, Bedi A, Pearle AD. The effect of medial versus lateral meniscectomy on the stability of the anterior cruciate ligament-deficient knee. *Am J Sports Med.* 2010;38(8):1591-1597.

27. Nepple JJ, Dunn WR, Wright RW. Meniscal repair outcomes at greater than five years: a systematic literature review and meta-analysis. *J Bone Joint Surg Am.* 2012;94(24):2222-2227.

28. Noyes FR, Barber-Westin SD. Treatment of meniscus tears during anterior cruciate ligament reconstruction. *Arthroscopy.* 2012;28(1):123-130.

29. Noyes FR, Chen RC, Barber-Westin SD, Potter HG. Greater than 10-year results of red-white longitudinal meniscal repairs in patients 20 years of age or younger. *Am J Sports Med.* 2011;39(5):1008-1017.

30. Peltier A, Lording T, Maubisson L, Ballis R, Neyret P, Lustig S. The role of the meniscotibial ligament in posteromedial rotational knee stability. *Knee Surg Sports Traumatol Arthrosc.* 2015;23(10):2967-2973.

31. Perkins B, Gronbeck KR, Yue RA, Tompkins MA. Similar failure rate in immediate post-operative weight bearing versus protected weight bearing following meniscal repair on peripheral, vertical meniscal tears. *Knee Surg Sports Traumatol Arthrosc.* 2017.

32. Pernin J, Verdonk P, Si Selmi TA, Massin P, Neyret P. Long-term follow-up of 24.5 years after intra-articular anterior cruciate ligament reconstruction with lateral extra-articular augmentation. *Am J Sports Med.* 2010;38(6):1094-1102.

33. Pujol N, Panarella L, Selmi TA, Neyret P, Fithian D, Beaufils P. Meniscal healing after meniscal repair: a CT arthrography assessment. *Am J Sports Med.* 2008;36(8):1489-1495.

34. Robb C, Kempshall P, Getgood A, et al. Meniscal integrity predicts laxity of anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc.* 2015;23(12):3683-3690.

35. Rockborn P, Gillquist J. Results of open meniscus repair. Long-term follow-up study with a matched uninjured control group. *J Bone Joint Surg Br.* 2000;82(4):494-498.

36. Roessler PP, Schuttler KF, Heyse TJ, Wirtz DC, Efe T. The anterolateral ligament (ALL) and its role in rotational extra-articular stability of the knee joint: a review of anatomy and surgical concepts. *Arch Orthop Trauma Surg.* 2016;136(3):305-313.

37. Rubman MH, Noyes FR, Barber-Westin SD. Arthroscopic repair of meniscal tears that extend into the avascular zone. A review of 198 single and complex tears. *Am J Sports Med.* 1998;26(1):87-95.

38. Schon JM, Moatshe G, Brady AW, et al. Anatomic Anterolateral Ligament Reconstruction Leads to Overconstraint at Any Fixation Angle: Response. *Am J Sports Med.* 2016;44(10):NP58-NP59.

39. Seon JK, Gadikota HR, Kozanek M, Oh LS, Gill TJ, Li G. The effect of anterior cruciate ligament reconstruction on kinematics of the knee with combined anterior cruciate ligament injury and subtotal medial meniscectomy: an in vitro robotic investigation. *Arthroscopy.* 2009;25(2):123-130.

40. Shelbourne KD, Benner RW, Gray T. Results of Anterior Cruciate Ligament Reconstruction With Patellar Tendon Autografts: Objective Factors Associated With the Development of Osteoarthritis at 20 to 33 Years After Surgery. *Am J Sports Med.* 2017 Aug 1:363546517718827. doi: 10.1177/0363546517718827.

41. Shoemaker SC, Markolf KL. The role of the meniscus in the anterior-posterior stability of the loaded anterior cruciate-deficient knee. Effects of partial versus total excision. *J Bone Joint Surg Am.* 1986;68(1):71-79.

42. Sonnery-Cottet B, Conteduca J, Thaunat M, Gunepin FX, Seil R. Hidden lesions of the posterior horn of the medial meniscus: a systematic arthroscopic exploration of the concealed portion of the knee. *Am J Sports Med.* 2014;42(4):921-926.

43. Sonnery-Cottet B, Freychet B, Murphy CG, Pupim BH, Thaunat M. Anterior Cruciate Ligament Reconstruction and Preservation: The Single-Anteromedial Bundle Biological Augmentation (SAMBBA) Technique. *Arthrosc Tech.* 2014;3(6):e689-693.

44. Sonnery-Cottet B, Lutz C, Daggett M, et al. The Involvement of the Anterolateral Ligament in Rotational Control of the Knee. *Am J Sports Med.* 2016;44(5):1209-1214.

45. Sonnery-Cottet B, Saithna A, Cavalier M, et al. Anterolateral Ligament Reconstruction Is Associated With Significantly Reduced ACL Graft Rupture Rates at a Minimum Follow-up of 2 Years: A Prospective Comparative Study of 502 Patients From the SANTI Study Group. *Am J Sports Med.* 2017;45(7):1547-1557.

46. Stephen JM, Halewood C, Kittl C, Bollen SR, Williams A, Amis AA. Posteromedial Meniscocapsular Lesions Increase Tibiofemoral Joint Laxity With Anterior Cruciate Ligament Deficiency, and Their Repair Reduces Laxity. *Am J Sports Med.* 2016;44(2):400-408.

47. Strum GM, Fox JM, Ferkel RD, et al. Intraarticular versus intraarticular and extraarticular reconstruction for chronic anterior cruciate ligament instability. *Clin Orthop Relat Res.* 1989(245):188-198.

48. Tachibana Y, Sakaguchi K, Goto T, Oda H, Yamazaki K, Iida S. Repair integrity evaluated by second-look arthroscopy after arthroscopic meniscal repair with the FasT-Fix during anterior cruciate ligament reconstruction. *Am J Sports Med.* 2010;38(5):965-971.

49. Thaunat M, Clowez G, Saithna A, et al. Reoperation Rates After Combined Anterior Cruciate Ligament and Anterolateral Ligament Reconstruction: A Series of 548 Patients From the SANTI Study Group With a Minimum Follow-up of 2 Years. *Am J Sports Med.* 2017:363546517708982.

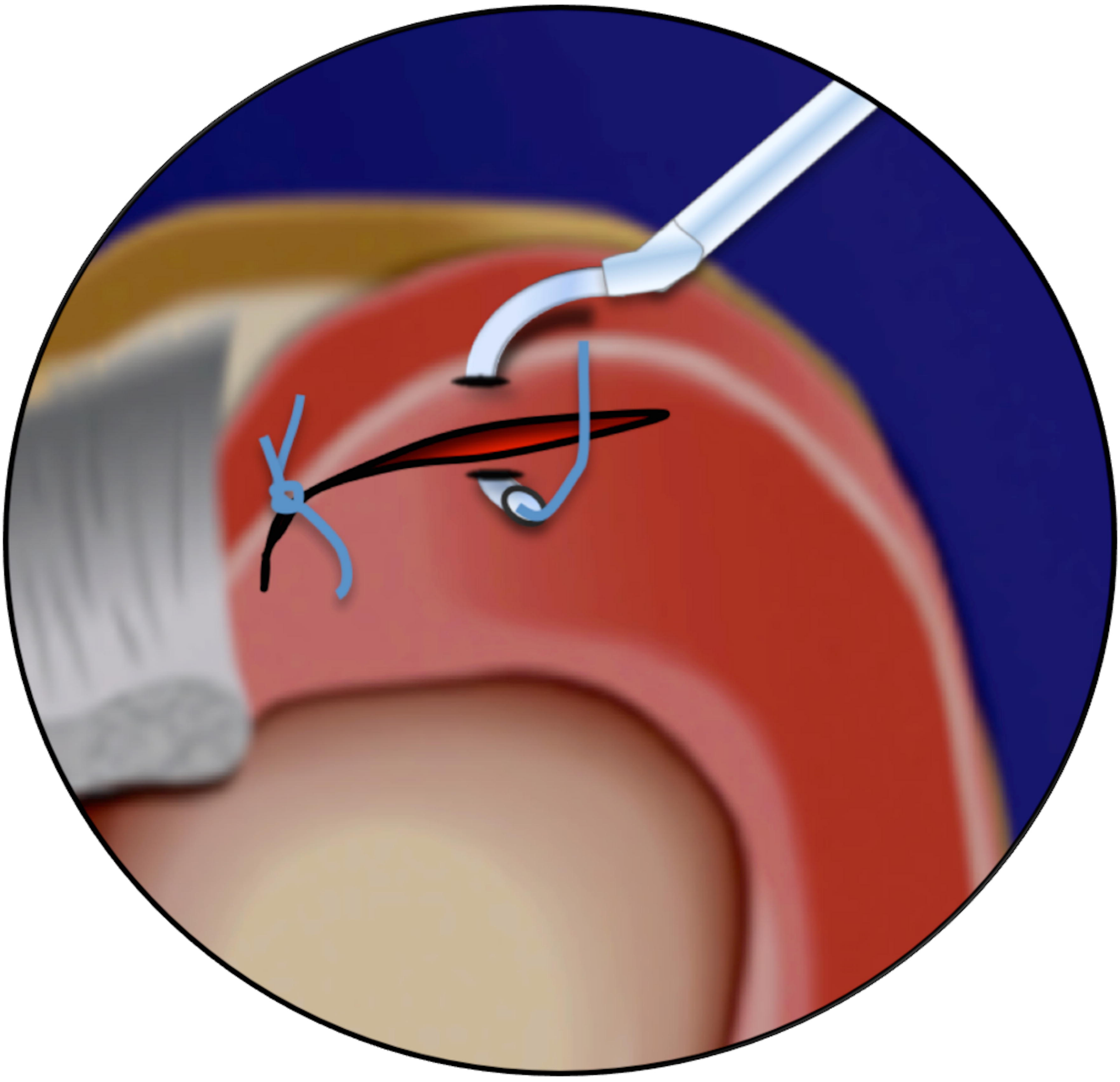
50. Thaunat M, Jan N, Fayard JM, et al. Repair of Meniscal Ramp Lesions Through a Posteromedial Portal During Anterior Cruciate Ligament Reconstruction: Outcome Study With a Minimum 2-Year Follow-up. *Arthroscopy.* 2016;32(11):2269-2277.

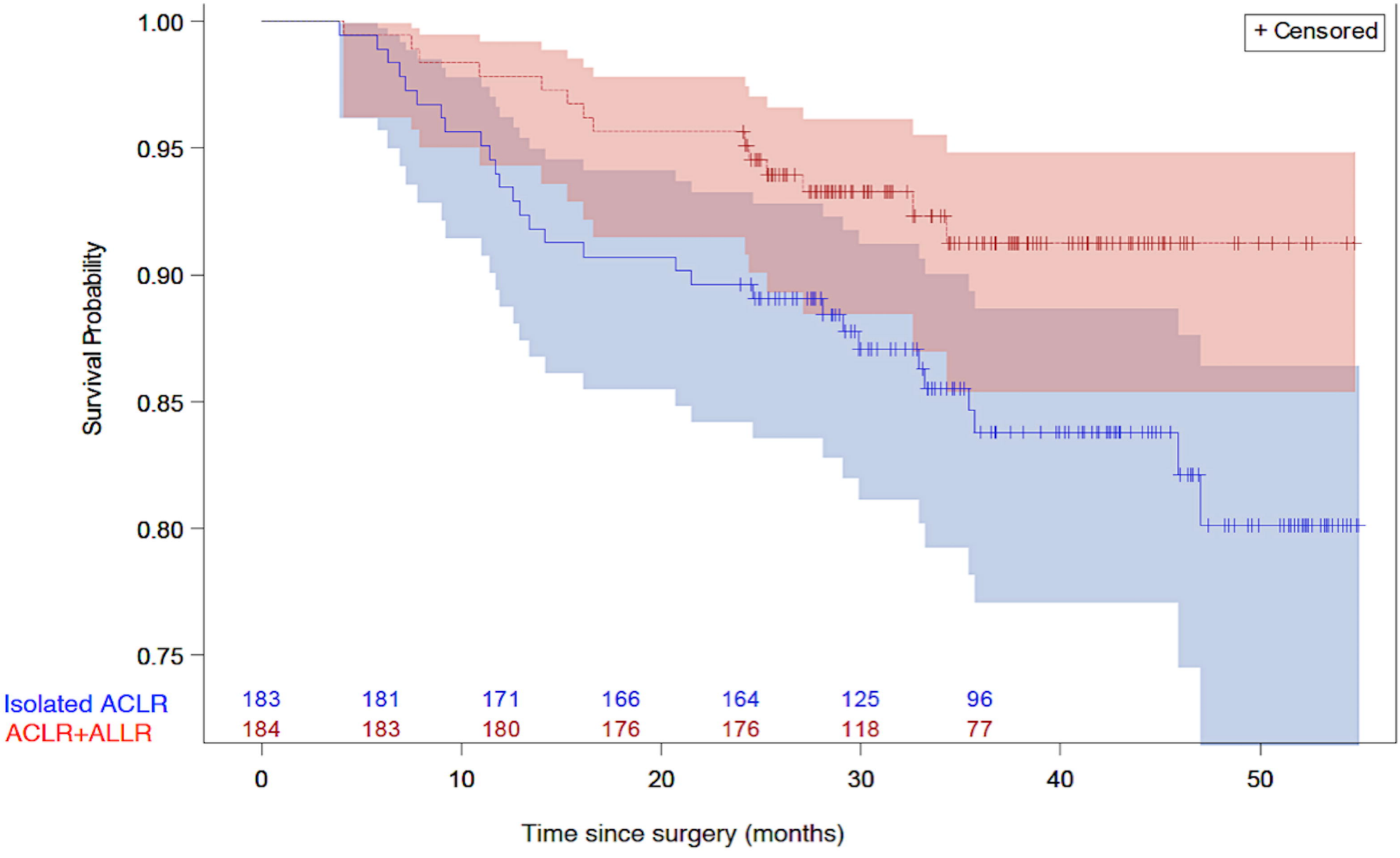
51. Vap AR, Schon JM, Moatshe G, et al. The Role of the Peripheral Passive Rotation Stabilizers of the Knee With Intact Collateral and Cruciate Ligaments: A Biomechanical Study. *Orthop J Sports Med.* 2017;5(5):2325967117708190.

52. Westermann RW, Duchman KR, Amendola A, Glass N, Wolf BR. All-Inside Versus Inside-Out Meniscal Repair With Concurrent Anterior Cruciate Ligament Reconstruction: A Meta-regression Analysis. *Am J Sports Med.* 2017;45(3):719-724.

53. Westermann RW, Wright RW, Spindler KP, Huston LJ, Group MK, Wolf BR. Meniscal repair with concurrent anterior cruciate ligament reconstruction: operative success and patient outcomes at 6-year follow-up. *Am J Sports Med.* 2014;42(9):2184-2192.

54. Zaffagnini S, Marcacci M, Lo Presti M, Giordano G, Iacono F, Neri MP. 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(11):1060-1069.





Combined ACL and anterolateral ligament reconstruction (ALLR) Group

Isolated ACL Reconstruction (ACLR) Group