

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

4  
5 **Background:** The prevalence of osteoarthritis after successful meniscal repair is significantly  
6 less than the rate that is observed after failed meniscal repair.

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

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

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

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

25 43 patients (11.2%) underwent re-operation for failure of the medial meniscus repair or a new  
26 tear. The survival rate of meniscal repair at 36 months in the ACLR+ALLR group was 91.2%  
27 (95% IC, 85.4%-94.8) and in the ACLR group it was 83.8% (95% CI, 77.1%-88.7%)  
28 ( $P= .033$ ). The probability of failure of medial meniscal repair was more than two times  
29 lower in patients with ACLR+ALLR compared to patients with isolated ACLR (hazard ratio,  
30 0.443; 95% CI, 0.218-0.866). No other prognosticators of meniscal repair failure were  
31 identified.

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

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

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

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

55 **Introduction**

56 The reported incidence of meniscal tears associated with an ACL rupture ranges from 16% to  
57 82 % for acute injuries and up to 96 % in chronic injuries.<sup>15</sup> Long-term studies of patients  
58 following anterior cruciate ligament reconstruction (ACLR) have demonstrated that medial  
59 meniscectomy is associated with higher rates of osteoarthritis (OA).<sup>3,5,32,40</sup> The importance of  
60 the medial meniscus as a secondary stabilizer for antero-posterior translation has been  
61 demonstrated by a number of biomechanical cadaveric studies.<sup>18,39,41</sup> Medial meniscectomy  
62 leads to increased tibial translation and abnormal knee kinematics.<sup>39,41</sup> It is therefore critical  
63 to try to repair the medial meniscus whenever possible. However, meniscal repairs have  
64 reported failure rates of up to 30%.<sup>27,52</sup> The high failure rate may, in part, explain why  
65 meniscectomy is performed 2 to 3 times more frequently than meniscus repair during  
66 ACLR.<sup>28</sup> Any technique which can increase the success of meniscal repair, performed at the  
67 time of ACL reconstruction, is therefore likely to be important in improving long-term  
68 outcomes.

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

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

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

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## 82 **Patients and Methods**

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

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

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

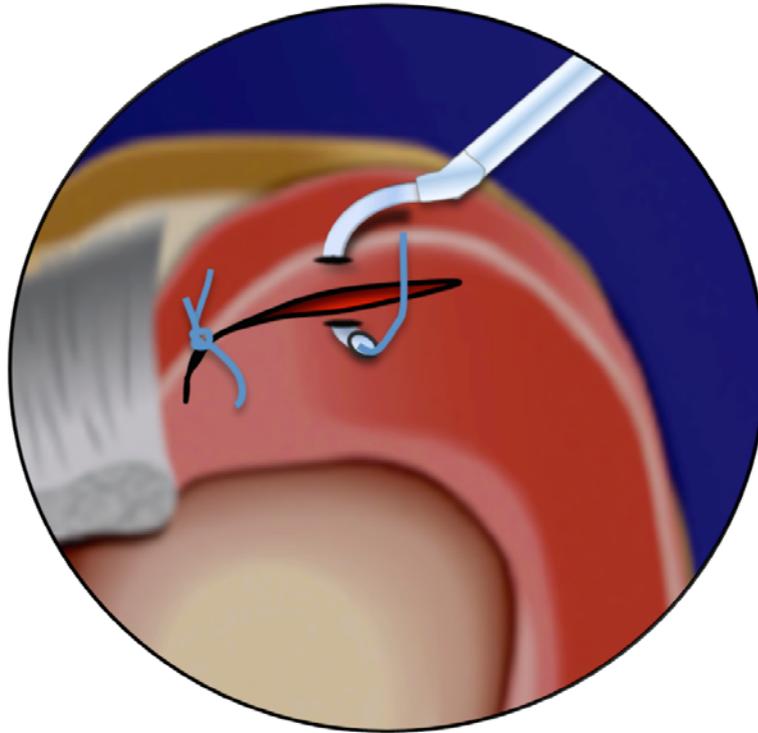
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### 111 Surgical Technique

#### 112 1) Medial Meniscus Repair:<sup>2,50</sup>

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



125

126 Figure 1. Suture repair of a posterior MM tear using a hook introduced through a  
127 posteromedial portal. Additional sutures can be placed if required, depending on the length of  
128 the tear. (Reproduced and modified with permission, M Thauat, Arthroscopy 2016,<sup>50</sup>  
129 Elsevier)

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132 2) ACLR with or without concomitant ALLR:

133 ACLR was performed using 3 different types of graft: bone-patellar tendon-bone (B-PT-

134 B),<sup>10</sup> quadrupled hamstring tendons (4HT)<sup>19</sup> or quadrupled semitendinosus tendon (4ST).<sup>43</sup>

135 For the ALLR, a gracilis tendon graft was used.<sup>49</sup>

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137 Outcomes

138 Physical examinations were conducted by a sport medicine physician independent of the

139 primary surgeons, preoperatively and at the following postoperative intervals: weeks 3 and 6

140 and months 3, 6, and 12. Preoperative demographic and clinical data were recorded at the

141 first clinical evaluation. Clinical evaluation including ligament testing and range of motion  
142 (ROM) evaluation were recorded at 3, 6 and 12-month follow-up. ~~An isokinetic test was~~  
143 ~~performed at 6 months follow-up.~~ Side-to-side laxity evaluation was performed with the  
144 Rolimeter device (Aircast Europa, Neubeuern, Germany) at 12 months follow-up.  
145 All patients ~~participated~~ were recommended to follow in the same postoperative  
146 rehabilitation protocol. This comprised brace-free mobilization, weight bearing as tolerated  
147 and a restricted range of motion from 0° to 90° for the first 4 weeks postoperatively.<sup>31</sup> Early  
148 rehabilitation was focused on obtaining full extension and quadriceps activation. A gradual  
149 return to sport activities was allowed starting at 4 months for non-pivoting sports, at 6 months  
150 for pivoting non-contact sports, and at 8 to 9 months for pivoting contact sports. ~~The return to~~  
151 ~~pivoting non-contact sport was delayed if the aforementioned isokinetic testing showed a~~  
152 ~~deficit greater than 20% in eccentric or concentric hamstring strength or any quadriceps~~  
153 ~~deficit. In this situation, repeat testing was performed after a further 2 months of~~  
154 ~~rehabilitation.~~

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

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165 Data Analysis

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

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## 178 **Results**

### 179 Patients

180 418 patients met the inclusion criteria. Thirty-five patients (8.4%) were lost to follow-up. The  
181 final study population comprised 383 patients (Figure 1), divided into two groups: 194  
182 isolated ACLR (33 B-PT-B, 73 4HT, 88 4ST) and 189 ACLR + ALLR (176 HT, 6 B-PT-B, 7  
183 4ST).

184

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

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

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

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

<sup>a</sup> Exact Fisher test between proportion of patients included in each IKDC laxity group (normal, nearly normal, abnormal, severely abnormal)

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

<sup>c</sup> 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.

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## 196 Postoperative outcomes

197 Postoperative outcomes are summarized in Table 2. Side-to-side laxity was measured in 380

198 patients at 12 months follow-up. Three patients were excluded because of an ACL graft

199 failure or a contralateral ACL injury before the one-year follow-up review.

200

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

205

206 Table 2 : Patients outcomes.

207 For scores and return to pre-injury sport, N=324 patients (154 ACLR, 170 ACLR+ALLR).

208 For Postoperative side-to-side laxity, N=380 patients (193 ACLR, 187 ACLR+ALLR). T-test  
 209 for variables or chi-square test for proportions unless otherwise indicated.

210

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

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

<sup>a</sup> Exact Fisher test between proportion of patients included in normal or nearly normal IKDC laxity group

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213 Re-operation

214 At latest follow-up, 74 patients (19.3%) underwent at least one re-operation after the index

215 procedure (Table 3). 43 (11.2%) patients underwent re-operation for failure of MM repair

216 and this occurred at a mean of 19.0  $\pm$  11.5 months after initial procedure. All of these patients

217 underwent a partial medial meniscectomy except for 2 patients who underwent a revision

218 MM repair. However, both revision MM repairs failed, leading to meniscectomy. ACL graft

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

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

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

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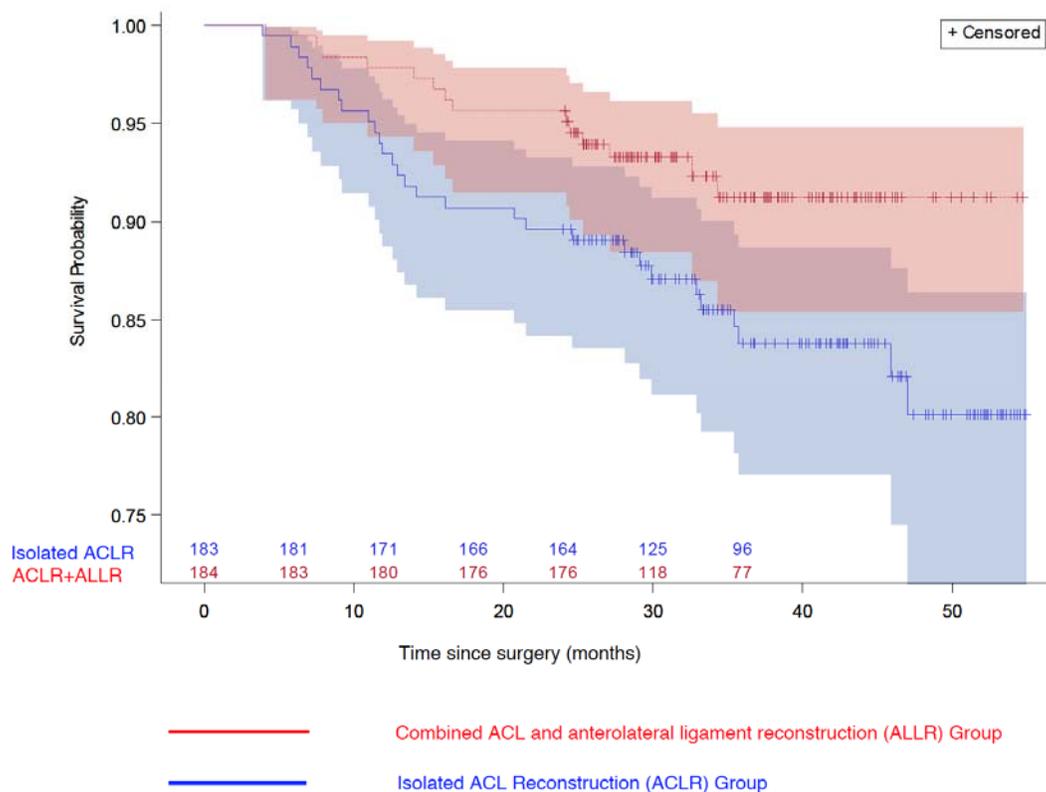
224 ACLR, anterior cruciate ligament reconstruction; MM, medial meniscus.

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

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

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

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Surgical Procedure	MM Repair Failure <sup>a</sup>		<i>P</i>
	mean (95% CI)		
<b>Overall</b>	mean (95% CI)	7.4 (5.1-10.6)      12.6 (9.4-16.9)	<b>.033</b>
<b>isolated ACLR</b>	mean (95% CI)	10.4 (6.8-15.8)      16.2 (11.3-22.9)	
<b>ACLR + ALLR</b>	mean (95% CI)	4.4 (2.2-8.5)      8.8 (5.2-14.6)	

<sup>a</sup> values expressed as percentage.

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

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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 ( $\leq$  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 characteristics<sup>a</sup>

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

<sup>a</sup>Bolded *P* values indicate statistical significance. Penalised adjusted Cox model.

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

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

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

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

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262 Table 6 : Kaplan-Meier Rates of MM Repair failure in ACLR group.  
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Graft type	MM Repair Failure <sup>a</sup>		P	
	24-month Follow-up	36-month Follow-up		
<b>Overall</b>	mean (95%CI)	9.4 (6.0-14.5)	15.3 (10.6-21.8)	.996
<b>B-PT-B</b>	mean (95%CI)	12.5 (4.9-30.0)	16.2 (7.0-34.6)	
<b>4HT</b>	mean (95%CI)	9.7 (4.7-19.2)	15.9 (9.1-26.9)	
<b>4ST</b>	mean (95%CI)	8.0 (3.9-16.1)	14.7 (7.5-27.7)	

<sup>a</sup> values expressed as percentage.

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

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265 **Discussion**

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

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274 Numerous authors have investigated failure rates of meniscal repair performed at the time of  
275 ACL reconstruction. A systematic review of thirteen studies of meniscal repair outcomes  
276 reported a pooled rate of meniscal repair failure in ACL-reconstructed knees of 26.9% (18/67  
277 knees) at greater than 5-years post-surgery.<sup>27</sup> Another systematic review of 21 studies  
278 evaluating all-inside and inside-out meniscal repair with concurrent ACL reconstruction,  
279 found pooled failure rates of 14.2% (140/1126 knees) at a mean follow-up of just over 5-  
280 years.<sup>52</sup> The failure rate for all-inside meniscal repair was significantly higher at 16%  
281 (121/744 knees) compared with 10% (39/382 knees) for inside-out repair ( $P = .016$ ). It is  
282 important to note that both of these systematic reviews included a wide range of tear  
283 morphologies including those of the lateral meniscus. A number of trials have demonstrated  
284 higher failure rates of medial meniscus repair compared to lateral meniscal repairs.<sup>13,20,21,29</sup>  
285 This variability in the reported rate of failure demonstrates the importance of precisely  
286 defined inclusion criteria and caution in pooling results from different studies. Several  
287 authors have recently reported re-operation rates for failure of medial meniscal repairs  
288 performed at the time of ACLR. This has varied between 14%<sup>53</sup> and 26%.<sup>14</sup>

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290 The importance of successful repair of the medial meniscus to long-term outcomes following  
291 ACLR, can be deduced from a number of trials. Claes et al. demonstrated that, at a minimum  
292 10-year follow-up post-ACLR, 50% of patients that underwent meniscectomy had  
293 osteoarthritis (OA) compared to 16% of patients without meniscectomy (Odds ratio 3.54,  
294 95 % CI 2.56–4.91).<sup>5</sup> Pernin et al. also reported that medial meniscectomy was a risk factor  
295 for development of OA in their long-term follow-up study (mean 24.5 years post-ACLR)  
296 with lateral extra-articular augmentation.<sup>32</sup> This finding was recently confirmed by  
297 Shelbourne et al. who reported a three times higher risk of developing OA in patients with  
298 medial meniscectomy at a mean 22.5 years after ACLR (Odds ratio 2.98, 95 % CI 1.91–  
299 4.66).<sup>40</sup> Two studies also assessed the difference in the prevalence of radiographic findings of  
300 OA between successful and failed meniscal repairs. Both reported higher rates of OA in  
301 failed repairs (56% compared with 14% and 57% compared with 15%).<sup>6,35</sup>  
302 The significantly increased risk of OA associated with meniscal injury relates to the  
303 important role of the meniscus in the stability of the knee.<sup>23</sup> Cadaveric biomechanical studies  
304 have shown increased tibial anterior translation and external rotation after posterior  
305 meniscocapsular sectioning in the ACL-deficient knee.<sup>1,30,46</sup> Furthermore, they have  
306 demonstrated restoration of knee biomechanics only after both ACLR and repair of the  
307 meniscal lesion.<sup>1,46</sup> The medial meniscus also plays a stabilizing role in the ACL deficient  
308 knee, where it resists anterior tibial translation.<sup>26,34</sup>  
309 It is therefore crucial to identify and repair meniscal lesions for successful long-term  
310 outcomes from ACLR. In this study, a standardized arthroscopic evaluation was performed in  
311 all patients in order to evaluate all MM lesions including hidden meniscal lesions - a  
312 substantial number of which may be missed with arthroscopic examination using only  
313 standard anterior portal examination.<sup>42</sup> The described surgical technique allows the ability to  
314 debride and repair lesions of the MM under direct visualization and as a result it has become

315 the authors standard practice for all MM lesions. Good clinical results have been reported at  
316 short term follow-up.<sup>50</sup>

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

322

323 There has been a lot of interest recently in the role of the anterolateral structures of the knee  
324 in controlling rotatory laxity and their ability to share loads with the ACL graft.<sup>5,8,36,44,12</sup>

325 Sectioning of the ALL in biomechanical cadaveric studies has resulted in greater rotational  
326 laxity in both the ACL-deficient knee<sup>43</sup> and the ACL-intact knee.<sup>51</sup> Augmentation of ACLR  
327 with an extra-articular tenodesis has been demonstrated to decrease rotational laxity and  
328 residual pivot shift.<sup>11</sup> Recently published clinical results demonstrate reduced failure of  
329 combined ACLR and ALLR when compared to isolated ACLR and this may be attributed to  
330 biomechanical load-sharing properties of the ALL graft.<sup>45</sup> Combined ACL and ALL  
331 reconstruction has been found to decrease the ACL graft failure rates by as much as 2.5 times  
332 compared to isolated ACLR.<sup>45</sup>

333

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

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

349

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

358

### 359 **Limitations**

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

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

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

387

## 388 **Conclusions**

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

395

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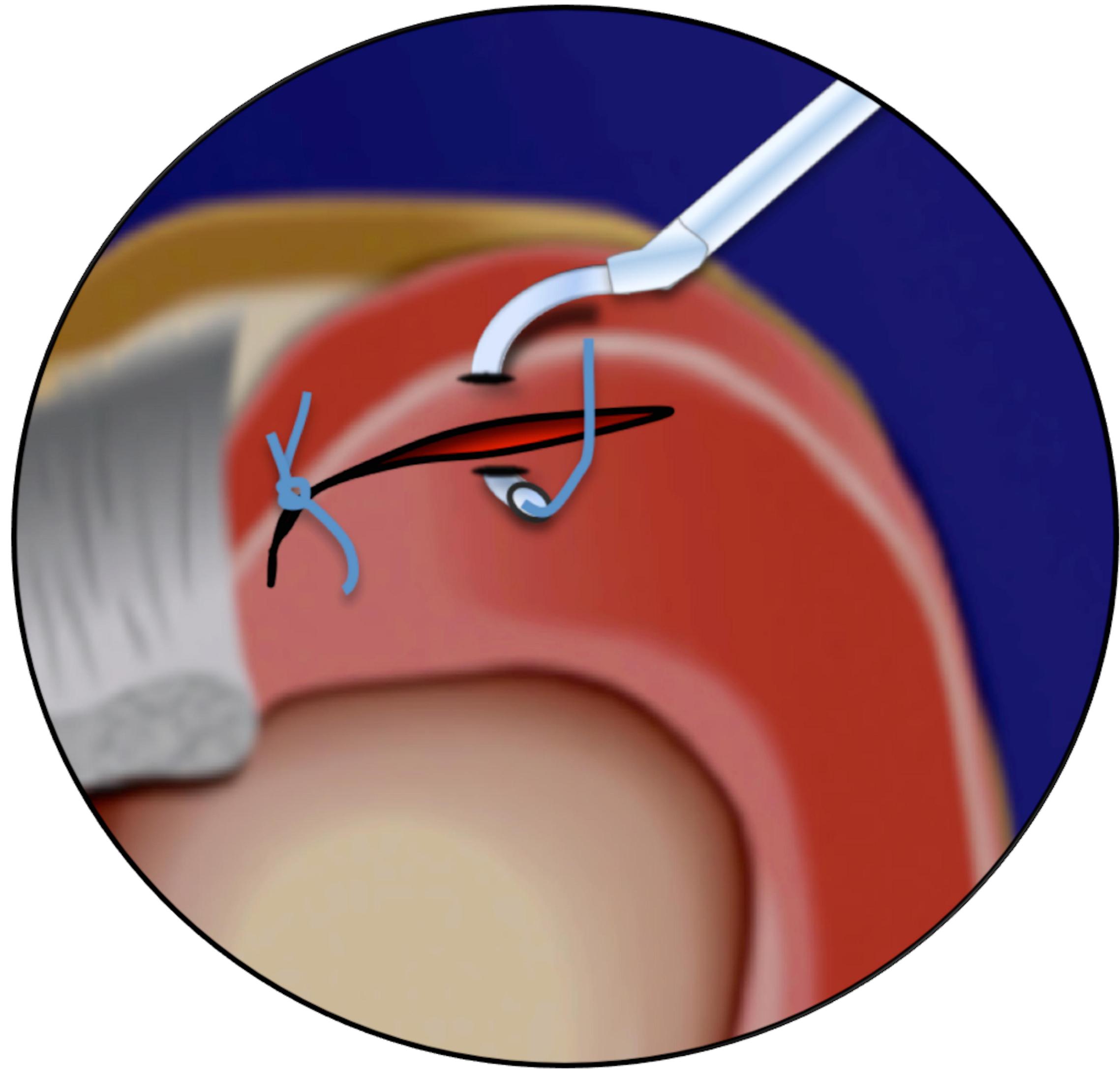
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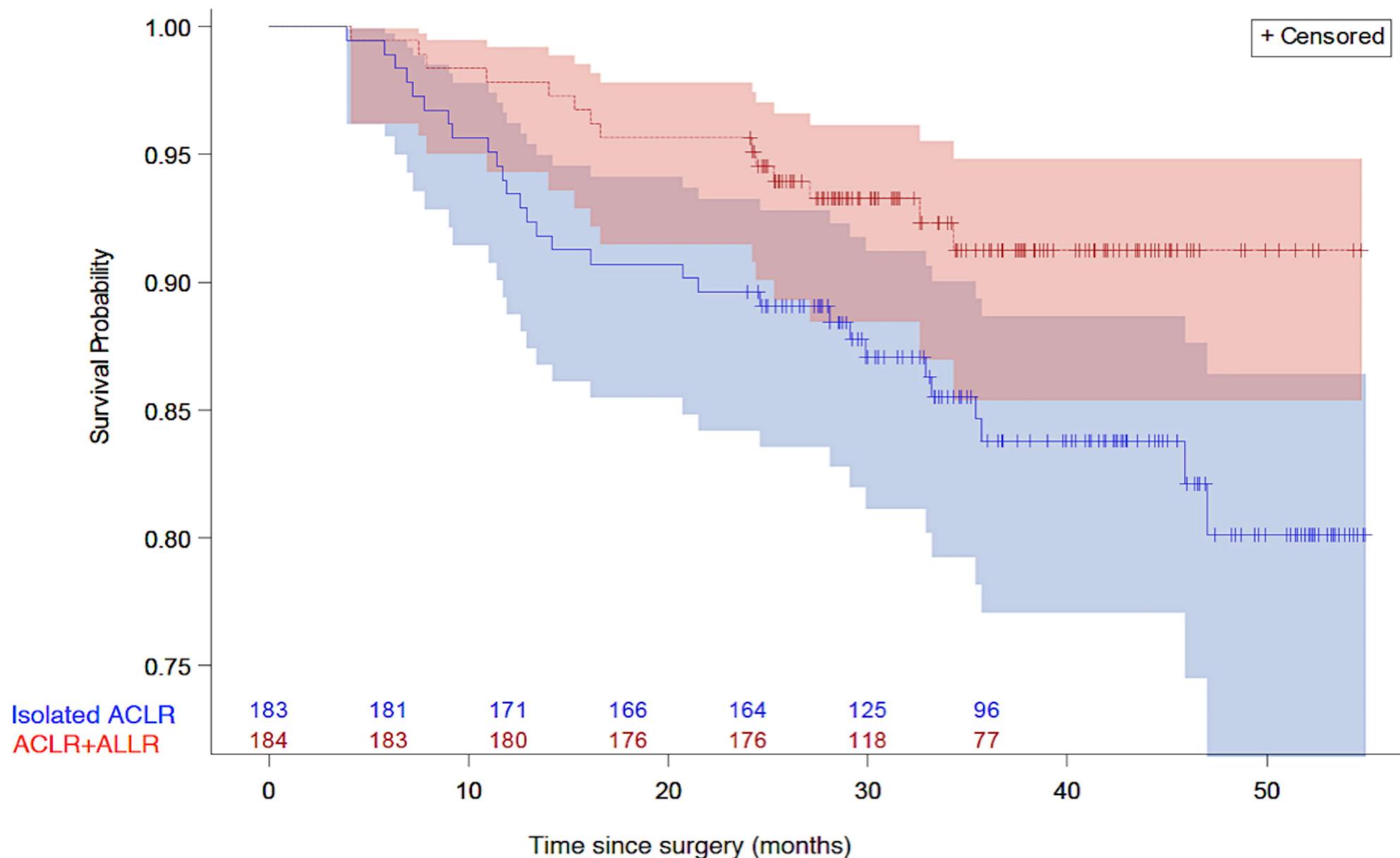
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Combined ACL and anterolateral ligament reconstruction (ALLR) Group

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Isolated ACL Reconstruction (ACLR) Group