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Combined ACL and ALL reconstruction reduces the rate of reoperation for graft failure or secondary meniscal lesions in young athletes

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Abstract

Purpose Graft failure and secondary meniscal tears are major concerns after anterior cruciate ligament (ACL) reconstruction in young athletes. The aim was to evaluate the link between ACL reconstruction with and without anterolateral ligament (ALL) reconstruction and outcomes in young patients participating in pivoting sports.

Methods This was a retrospective study of data collected prospectively. Patients less than 20 years, involved in pivoting sports and undergoing primary ACL reconstruction with a quadruple hamstring tendon (4HT) graft or 4HT graft combined with anterolateral ligament reconstruction (4HT + ALL) were included. Survival analysis was performed to identify the prognostic indicators for reoperation due to graft failure or secondary meniscal lesions. Knee laxity was assessed and patient reported outcome measures (PROMs) were collected.

Results A total of 203 patients (mean (± SD) age: 16.3 ± 2 years) with a mean follow-up of 4.8 ± 0.9 (range: 3.3−6.8) years were included. There were 101 4HT and 102 4HT + ALL grafts. Graft rupture rates were 11.9% for 4HT grafts and 5.8% for 4HT + ALL grafts (n.s.). There were 9.9% secondary meniscal procedures for 4HT grafts vs. 1.9% for 4HT + ALL grafts ($p = 0.02$). With reoperation for graft failure or secondary meniscal lesions at final follow-up as the endpoint, survival was better in the 4HT + ALL group (91.4% vs. 77.8%, respectively; $p = 0.03$). Absence of ALL reconstruction (HR = 4.9 [95%CI: 1.4–17.9]; $p = 0.01$) and preoperative side-to-side laxity > 3 mm (HR = 3.1 [95%CI: 1.03–9.1]; $p = 0.04$) were independently associated with an increased rate of reoperations. Mean (± SD) side-to-side laxity was 1.3 ± 1.3 mm (range: − 2 to 5) for 4HT grafts vs. 0.9 ± 1.3 mm (range: − 6 to 4.8) for 4HT + ALL grafts (n.s.) 6 months post-surgery. The rate of return to the same sport at the same level was 42.2% for 4HT grafts vs. 52% for 4HT + ALL grafts (n.s.). There was no significant difference in subjective outcomes including PROMs between the two groups.

Conclusion Combined ALL + ACL reconstruction reduced the rate of graft failure and secondary meniscal injury in young athletes when compared to ACL reconstruction alone. Subjective results were comparable, with a similar rate of complications. Combined reconstruction should be preferred in this young population.

Level of evidence Level IV.

Keywords Knee · Anterior cruciate ligament · Anterolateral ligament · Graft rupture · Return to sport

Introduction

Anterior cruciate ligament (ACL) injuries have become increasingly prevalent in adolescent athletes as sports training has increased in frequency and intensity [17]. Treatment of ACL injuries in this population may be challenging because of an unacceptably high rate of graft failure and reoperation [14, 34, 43, 53, 57].

Reported rates of graft failure vary from 1.4 to 18% [23, 30, 31, 50, 52], reflecting the fact that the causes of graft failure are multifactorial. This high risk was confirmed by the Norwegian ACL registry [37] showed that age is a significant risk factor for revision with a hazard ratio (HR) = 4.0 for the youngest age group (15−19 years) compared to subjects > 30 years of age. The Swedish ACL registry [2] found that adolescent patients (defined as between 13 and 19 years old) have the highest rates of early revision.

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It has also been shown that ACL reconstruction may fail to provide full control of laxity and restoration of normal knee kinematics which could therefore increase the risk of secondary meniscal injury [20, 41, 58].

For this reason, there is currently great interest in the role of the anterolateral structures of the knee in controlling laxity and their ability to share loads with the ACL graft and its effect on meniscal healing and return to sport [11, 26, 42, 47]. Ferretti et al. [15] found magnetic resonance imaging (MRI) abnormalities of the ALL in 88.2% of patients with ACL rupture. A systematic review of 29 articles by Ariel de Lima et al. [3] reported that the ALL was found in 100% of cases and that MRI was a good method to visualise the ALL. Mechanoreceptors have also been identified in the ALL, confirming its proprioceptive role [4]. Sonnery-Cottet et al. [50] demonstrated that combined HT + ALL reconstruction was associated with significantly lower rates of graft rupture and secondary meniscal tear [49, 50] in a high-risk population when compared to HT and bone–patellar tendon–bone (B-PT-B) grafts. In addition, Lee et al. [28] observed that adolescents with ACL rupture have greater rotational instability and a lower rate of healing of the ALL than adults.

The aim of this study was to compare the reoperation rates for graft failure and secondary meniscal lesions in patients undergoing a quadruple hamstring tendon (4HT) graft versus a 4HT graft combined with anterolateral ligament reconstruction (4HT + ALL). The secondary aims were to evaluate the prognostic factors for graft failure, defined as reoperation for graft failure or secondary meniscal injury, and to determine the subjective outcomes and patient reported outcome measures (PROMs) between 4 and 4HT + ALL reconstruction. The hypothesis was that combined reconstruction of the ACL and ALL would reduce the rate of graft failure and secondary meniscal injury without causing more complications.

Materials and methods

Study population

This single-centre, single-surgeon, retrospective, cohort study was approved by our institutional review board (CE Clinique du Sport, Mérignac—12-2019-12). Patients undergoing ACL reconstruction with a minimum follow-up of 3 years were identified in our prospective surgical database. A total of 933 knees that underwent primary ACL reconstruction between 2015 and 2018 were reviewed. The inclusion criteria were: primary ACL reconstruction with an isolated 4HT (Group 1) or 4HT + ALL (Group 2); age < 20-years; and athlete practicing a pivoting sport. A pivoting sport was defined as a sport that involves rotational pivoting movements of the knee when the foot is on the ground (e.g. skiing or tennis); a contact pivoting sport is the same with the possibility of contact between players (e.g. football or rugby). Exclusion criteria included: age > 20-years; absence of practice of a pivoting sport; prior knee surgery; multi-ligament injury; other graft; refusal to participate. The flow of the patients is shown in Fig. 1. There were 240 ACL reconstructions fulfilling the inclusion criteria and 37 patients were lost to follow-up; 203 patients were included in the final analysis: 101 in Group 1 (4HT) and 102 in Group 2 (4HT + ALL).

Surgical technique

All patients underwent intra-articular reconstruction with a 4HT autograft with the semi-tendinosus tendon, according to the single antero-medial bundle biological augmentation (SAMBBA) technique [46], with two suspensory buttons, Pullup and Pullup XL (SBM, Lourdes, France).

ALL reconstruction was then performed with a gracilis graft [11], using a modification of the technique of Boutsiadis et al. [7] A femoral tunnel was drilled just posterior and proximal to the lateral epicondyle and another was drilled in the tibia just posterior to the Gerdy tubercle 7 mm below the joint-line (Fig. 2). The ALL graft was then fixed in the femur with a resorbable interference screw (Arthrex, Naples, Florida) and then fixed in the tibia with the ACL tight rope (Arthrex, Naples, Florida), tightened in extension and neutral rotation after ACL tensioning.

The decision to perform ALL reconstruction was based on ALL Expert Group recommendations [45]: pivot shift ≥ grade 2, hyperlaxity (knee recurvatum > 10°), high-level athlete (competing at regional or national level), Segond fracture (bony avulsion of the tibial ALL insertion on radiograph).

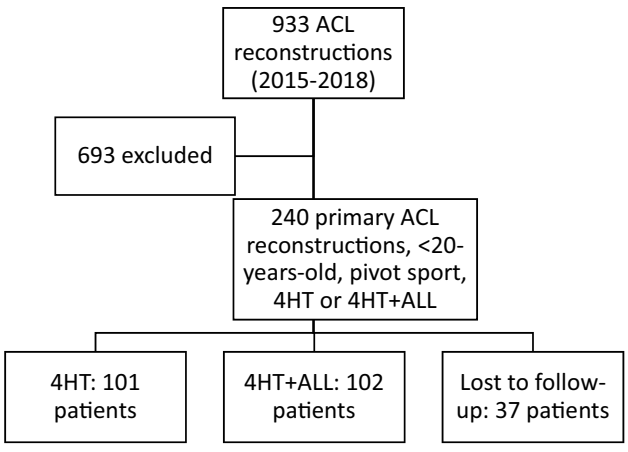

Fig. 1 Patient flow through the study. ACL, anterior cruciate ligament; 4HT, quadruple hamstring tendon; 4HT + ALL, quadruple hamstring tendon + anterolateral ligament reconstruction

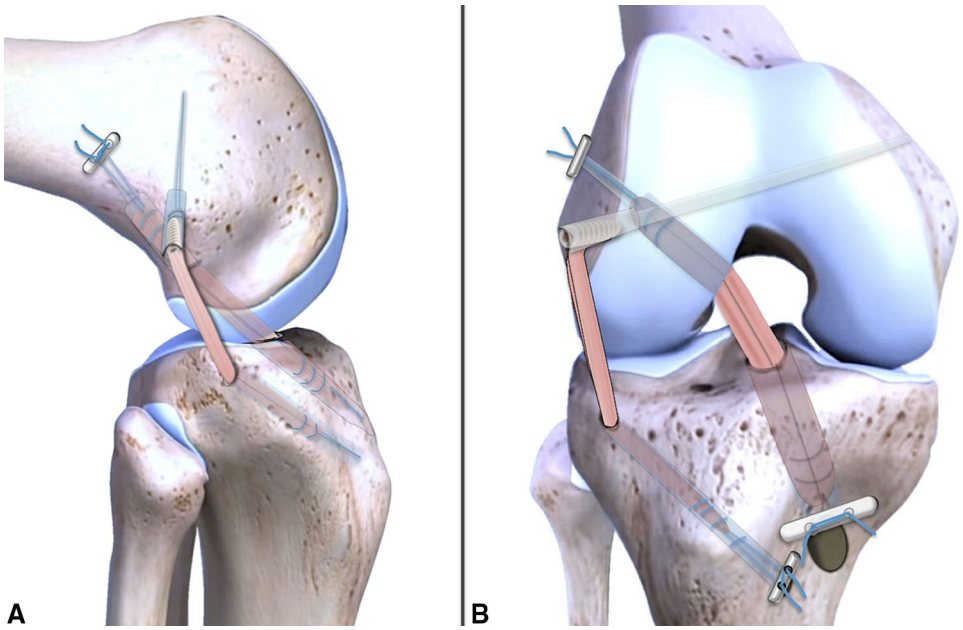

Fig. 2 **A** Lateral view and **B** anteroposterior view of the 4HT + ALL grafts. The intra-articular short ACL graft is fixed with two suspensory buttons (Pullup and Pullup XL; SBM, Lourdes, France). The ALL graft is fixed into an independent femoral tunnel with a resorbable interference screw (Arthrex, Naples, Florida) and in the tibia with an ACL tight rope (Arthrex, Naples, Florida)

Postoperative protocol

All patients had the same specific rehabilitation protocol to recover mobility, particularly in extension and contraction of the quadriceps [51]. Return to sport was only allowed after 6 months with validation of an isokinetic test, symmetrical jump test, ACL return to sport after injury (RSI) scale > 85% and teaching of a prevention program.

Outcome measures

Radiographic measurement of the tibial slope, measured in relation to the anatomical axis [59], was performed by two knee sport fellows (PL and AD) and showed excellent inter-observer reliability (intra class correlation) = 0.94 [95%CI: 0.92–0.95]. Antero-posterior side-to-side laxity using the GNRB® device [40] (whose threshold was evaluated, respectively, at 3 and 1.5 mm for complete and partial ACL rupture [28, 29]) was performed preoperatively. Intra-operative surgical data (duration of surgery, findings, other procedures, HT graft diameter) were collected.

Patients were assessed at 6 weeks (physical examination), 6 months (physical examination, side-to-side laxity with the GNRB®) and 3 years (physical examination, questionnaire and PROMs). The questionnaire included the following question: (1) about your operated knee, do you experience occasional pain, swelling, stiffness, instability or discomfort due to the surgical hardware? The PROMs collected were the subjective International Knee Documentation Committee (IKDC), ACL-RSI, Tegner activity scale and Lysholm knee score.

Graft failure was defined as recurrent instability requiring a revision procedure, a recurrent lesion with MRI confirmation of a graft lesion, or side-to-side laxity > 3 mm, while a secondary meniscal lesion was defined as meniscal pain with a confirmed MRI lesion requiring meniscal surgery, whether the meniscal lesion was new or a previous failed meniscal repair. Failure was defined as reoperation for graft failure or secondary meniscal lesions.

Study population

The demographic characteristics of the study population are summarised in Table 1. Mean (± SD) age was 16.3 ± 2 years (range: 11−20) and 119 patients (58.8%) were male. The majority of patients (n = 168, 82.8%) were involved in a pivot contact sport.

Statistical analysis

Quantitative variables are reported as mean ± standard deviation (SD) and range (min–max), while qualitative variables are reported as number and percentage.

Nominal variables were compared using the Chi^2 test or Fisher's exact test depending on the sample size. Variance was tested using the Student's *t* test or Mann–Whitney *U* test when a non-parametric test was required.

Kaplan–Meier survival curves were used to determine survival, with reoperation for graft failure or secondary meniscal tear as an endpoint. A Cox regression analysis was performed

Table 1 Characteristics of the study cohort

	All patients ($N=203$)	4HT ($N=101$)	4HT + ALL (N = 102)	p-value
Follow-up (years)				**< 0.01**
Mean ± SD	4.8 ± 0.9	5.4 ± 0.8	4.3 ± 0.7	
Range (min–max)	(3.3−6.8)	(3.5−6.8)	(3.3−6.1)	
Male sex, *n* (%)	119 (58.8)	57 (56.4)	62 (60.8)	n.s.
Age (years)				n.s.
Mean ± SD	16.3 ± 2	16.5 ± 2.2	16.8 ± 1.9	
Range (min–max)	(11−20)	(11−20)	(12−20)	
BMI (kg/m^2)				n.s.
Mean ± SD	21.9 ± 2.9	21.8 ± 3.0	22.1 ± 3.0	
Range (min–max)	(16−35)	(16−35)	(17−31)	
Time, injury to surgery (months)				n.s.
Mean ± SD	4.9 ± 6.5	4.3 ± 3.8	5.7 ± 8.2	
Range (min–max)	(1−60)	(1−24)	(1−60)	
Sport, *n* (%)				
Pivot contact	168 (82.8)	78 (77.2)	90 (88.2)	**0.04**
Pivot non-contact	35 (17.2)	23 (22.8)	12 (11.7)	
Tibial slope (°)				n.s.
Mean ± SD	7.7 ± 2.7	7.7 ± 2.7	7.6 ± 2.8	
Range (min–max)	(1−15)	(1−15)	(1−15)	
Side-to-side pre-surgical laxity (mm)				n.s.
Mean ± SD	3.1 ± 1.9	2.9 ± 1.9	3.4 ± 2.0	
Range (min–max)	(0−9)	(0−9)	(0−8)	
Meniscal tears, *n* (%)	113 (56)	55 (55)	58 (58.9)	n.s.
Suture, *n* (%)	93 (45)	48 (47.5)	45 (44.1)	n.s.
Meniscectomy, *n* (%)	20 (9.9)	7 (6.9)	13 (12.8)	n.s.
Chondral lesions, *n* (%)	43 (21)	22 (21.8)	21 (20.6)	n.s.
Diameter of the ST graft (mm)				n.s.
Mean ± SD	8.7 ± 0.7	8.6 ± 0.7	8.7 ± 0.6	
Range (min–max)	(7−10)	(7−10)	(7−10)	
Duration of surgery (min)				< 0.01
Mean ± SD	32.8 ± 8.4	28.4 ± 6.9	37.1 ± 7.5	
Range (min–max)	(16−76)	(16−50)	(17−76)	

Significance was set at p<0.05

HT, hamstring tendon; HT + ALL, hamstring tendon + anterolateral ligament; BMI, body mass index; SD, standard deviation; NS, not significant

to the determine factors associated with failure. The variables included in the analysis were selected based on statistically significant results of univariate analysis ($p < 0.05$). Post hoc analysis on the sample size (203 patients) calculation found a power of 84.5% to find a difference in combined graft failure or secondary meniscal injury between the two groups. All statistical analyses were performed using IBM SPSS (Statistical Product and Service Solutions) software for Windows (version 27).

Results

Reoperations

At a final follow-up of 4.8 ± 0.9 years (range: 3.3−6.8), there was a lower rate of graft failure in the 4HT + ALL group compared to the 4HT group, but the difference was not statistically significant (5.8% vs. 11.9%; n.s.). The

rate of secondary meniscal lesions was also lower in the 4HT + ALL group (1.9% vs. 9.9%; $p = 0.02$). There were more secondary meniscal procedures in patients who underwent meniscal repair compared to those who did not (7.5% [7/93] vs. 1.8% [2/110] of knees, respectively; $p = 0.04$). The details of the reoperations are summarised in Table 2.

Predictors of failure

At the final follow-up, mean (± SD) overall survival was 83.3 ± 3% (Fig. 3). Survival was 77.8 ± 4.3% in the 4HT group vs. 92.2 ± 2.7% in the 4HT + ALL group ($p = 0.04$) (Fig. 4). The predictors of failure are summarised in Tables 3 and 4.

Table 2 Reoperations in whole cohort and two sub-groups at the final follow-up

Reoperation	All patients ($N = 203$)	4HT ($N = 101$)	4HT + ALL ($N = 102$)	p-value
Graft failure	18 (8.9)	12 (11.9)	6 (5.8)	n.s.
Time to graft failure (years)				n.s.
Mean ± SD	1.9 ± 1.0	2.0 ± 1.2	1.8 ± 0.5	
Range (min–max)	(0.8–4.5)	(0.8–4.5)	(1.2– 2.5)	
Secondary meniscal lesion	12 (5.9)	10 (9.9)	2 (1.9)	**0.02**
Medial meniscus	9 (4.4)	8 (3.4)	1 (0.5)	**0.03**
Lateral meniscus	3 (1.5)	2 (1)	1 (0.5)	n.s.
Cyclops	18 (8.9)	10 (9.9)	8 (7.8)	n.s.
Hardware removal	3 (1.5)	0 (0)	3 (2.9)	n.s.
Infection	2 (1))	2 (2)	0 (0)	n.s.

Significance was set at $p<0.05$

All values shown are *n* (%) unless stated otherwise

HT, hamstring tendon; HT + ALL, hamstring tendon + anterolateral ligament; SD, standard deviation; NS, not significant ($p > 0.05$)

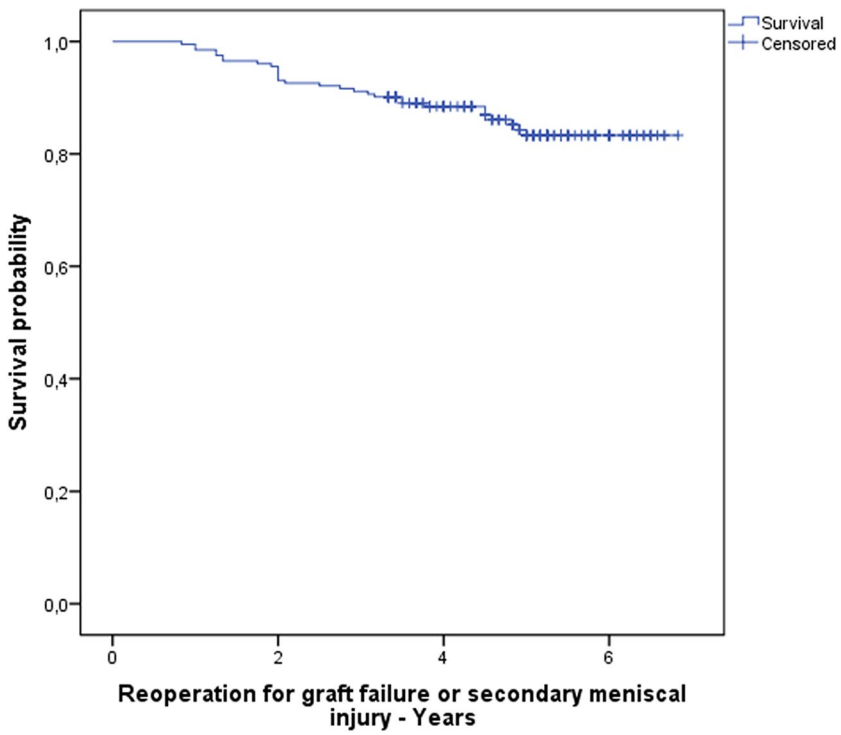

Fig. 3 Kaplan–Meier analysis of overall graft survival

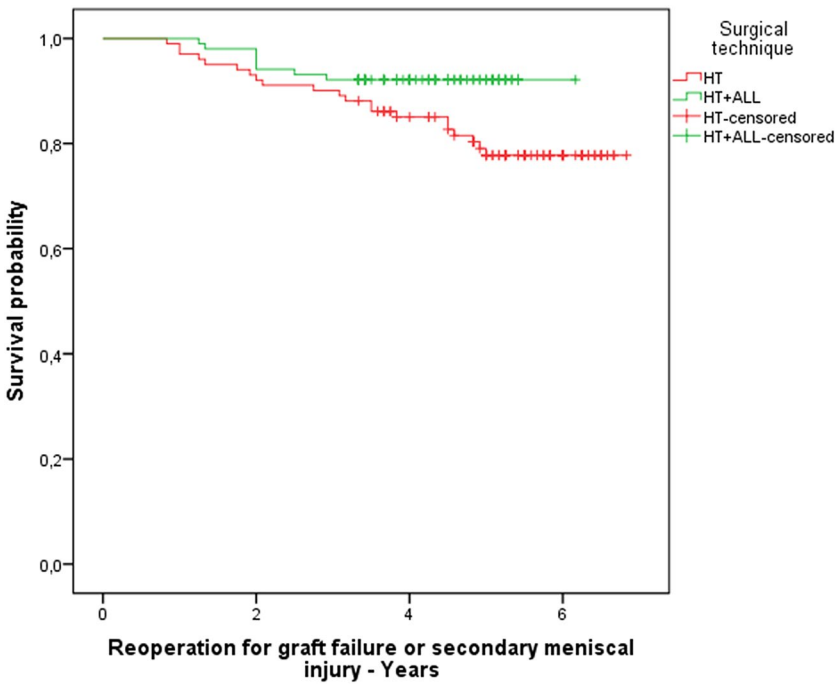

Fig. 4 Kaplan–Meier analysis of survival based on the surgical procedure

Outcomes

Mean (± SD) post-surgical side-to-side laxity was similar in the two groups: 1 ± 1.3 mm in the 4HT + ALL group vs. 1.3 ± 1.3 mm in the 4HT group (n.s.). The answers to the questionnaire and PROMs at 2 years were also similar in the two groups (n.s.) (Table 5).

Discussion

The most important finding of this study is that the combined rate of reoperation for graft failure or secondary meniscal tear was decreased significantly by the addition of ALL reconstruction in young athletes. ALL reconstruction was associated with a 4.9-fold reduction in reoperation for graft failure or secondary meniscal lesions at a mean follow-up of 4.8 years. Recently, several studies have highlighted the role of the anterolateral structures of the knee in the control of rotatory laxity [10, 19, 21, 36, 42]. Song et al. [44] carried out a systematic review of 326 patients in 7 studies evaluating persistent rotatory instability after ACL reconstruction and found a significantly lower prevalence of residual pivot shift in patients treated by lateral extraarticular tenodesis (LET) + ACL reconstruction (13.3%) than in those with ACL reconstruction only (27.2%). It is possible that this better control of rotational laxity protects the knee and consequently reduces the load on both the graft and the menisci (repaired or not). Furthermore, postoperative sagittal side-to-side laxity was similar in the two groups, which is consistent with the findings of Sonnery-Cottet et al. [50]; thus, it could be argued that ALL reconstruction plays a primary role in the control of rotational laxity.

It has not been proved conclusively that ALL reconstruction can decrease graft failure rates. A recent meta-analysis of 6 studies including 683 patients with a mean age of 27 years by Rhatomy et al. [39] found no difference in the rate of graft failure between isolated ACL reconstruction vs. combined ACL + ALL reconstruction. However, the current results are similar to those of Sonnery-Cottet et al. [50] who found a graft failure rate of 4.1% in a group of 16−30-year-olds who had undergone 4HT + ALL, while Lee et al. [27] did not observe any graft failure among 42 ACL revisions with ALL reconstruction. Another recent study by Balendra et al. [5] found an ACL reconstruction failure rate of 8.2% at 2 years in a population of professional footballers with an average age of 23 years, with a decrease in risk of graft failure to 2% when a B-PT-P graft was associated with a LET. In the setting of ACL revision surgery, Rayes et al. [38] also compared HT + ALL to the supposed gold standard B-PT-TB + LET and found the same outcomes regarding graft failure and reoperation, thus demonstrating the strength of this reconstruction.

Concerning the adolescent population studied here, the most interesting comparison is with the meta-analysis of Wiggins et al. [57], who found that the pooled rate of ipsilateral ACL reinjury across 11 studies was 10% in patients < 25-years-old, at a mean follow-up of 51 months. Not only is the graft failure rate of the 4HT + ALL group lower, but the age of the patients was also lower. The rest of the literature reports graft failure rates of between 9 and 25% in the same young population with different types of grafts

Table 3 Univariate analysis of predictors of failure at final follow-up

Factor			Mean ± SD survival (%) at final follow-up (4.8 ± 0.9 years)	*p-value
Demographics pre-surgical	Age (years)	≤ 15	81.8 ± 4.8	n.s.
		> 15	83.4 ± 3.9	
	Sex	Male	80.6 ± 4.2	n.s.
		Female	87.1 ± 3.9	
	BMI (kg/m^2)	≤ 25	81.1 ± 3.4	n.s.
		> 25	93.8 ± 4.2	
	Tibial slope [12]	≤ 11	82.8 ± 3.2	n.s.
		> 11	85.7 ± 7.6	
	Pivot contact sport	Yes	83.6 ± 3.3	n.s.
		No	82.3 ± 6.6	
	Side-to-side laxity (mm) at 6 months	≤ 3	93.0 ± 3.0	**0.05**
		> 3	80.3 ± 6.0	
	Injury to surgery (months)	≤ 6	82.8 ± 3.4	n.s.
		> 6	83.0 ± 6.7	
Surgical details	Surgical group	HT	77.8 ± 4.3	**0.04**
		HT + ALL	92.2 ± 2.7	
	Meniscal lesion	Yes	77.4 ± 4.5	**0.02**
		No	90.7 ± 3.5	
	Meniscectomy	Yes	73.2 ± 10.4	n.s.
		No	84.5 ± 3.0	
	Meniscal repair	Yes	78.6 ± 4.9	n.s.
		No	87.4 ± 3.5	
	HT graft diameter (mm) [1]	≤ 8	77.2 ± 6.3	n.s.
		> 8	85.6 ± 3.3	

Significance was set at p<0.05

*Log rank test

HT, hamstring tendon; HT + ALL, hamstring tendon + anterolateral ligament; BMI, body mass index; SD, standard deviation; NS, not significant ($p > 0.05$)

Table 4 Multivariate analysis of predictors of failure at final follow-up

Predictor	Hazard ratio ± SD [95% CI]	*p*-value
Surgical group—HT	4.9 ± 0.7 [1.4–17.9]	**0.01**
Pre-surgical side-to-side laxity > 3 mm	3.1 ± 0.5 [1.03–9.1]	**0.04**
Presence of meniscal lesion	2.5 ± 0.6 [0.8–7.8]	n.s.

Significance was set at p<0.05

HT, hamstring tendon; SD, standard deviation; CI, confidence interval, NS, not significant ($p > 0.05$)

(HT, B-PT-B, Fascia Lata) [6, 18, 24, 52], which are higher than those in the present 4HT + ALL group. The recent stability experience study [16] found that adding a LET to hamstring ACL reconstruction in young active patients significantly decreased the rate of graft failure.

Focusing more closely on secondary meniscal injuries, we found a rate of 1.9% in the 4HT + ALL group versus 9.9% in the 4HT group. Secondary meniscal lesions after ACL reconstruction have been investigated thoroughly. Sonnery-Cottet et al. [49] found that the probability of failure of medial meniscal repairs was > 2 times lower patients undergoing ACL + ALL reconstruction compared to ACL reconstruction alone (HR = 0.443 [95% CI: 0.218−0.866]). Two systematic reviews of 13 and 21 studies [33, 56] found a reoperation rate for secondary meniscal lesions of 26.9% and 14.2%, respectively, 5 years after ACL reconstruction, which is higher than the two groups of this study. Another study by Balendra et al. [5] found a rate of secondary meniscal injury of 16.4% in professional football players, 2 years after ACL reconstruction.

Table 5 Return to sport, subjective outcomes and PROMs among the whole cohort and the two surgical groups at final follow-up

Outcome	Total population ($N=203$)	HT ($N=101$)	HT + ALL ($N=102$)	p-value
Return to same sport	140 (75.3)	68 (75.6)	72 (75)	n.s.
Return to same sport at the same level	88 (47.3)	38 (42.2)	50 (52)	n.s.
Occasional pain	68 (38.6)	34 (37.8)	34 (35.4)	n.s.
Stiffness	41 (22)	20 (22.2)	21 (21.9)	n.s.
Instability	33 (17.7)	15 (16.7)	18 (18.7)	n.s.
Hardware discomfort	14 (7.5)	8 (8.9)	6 (6.3)	n.s.
Swelling	24 (13)	11 (12.3)	13 (13.6)	n.s.
IKDC score				n.s.
Mean ± SD	82.7 ± 14.3	83.3 ± 14.3	82 ± 14.4	
Range (min–max)	(37−100)	(37−100)	(42−100)	
ACL-RSI score				n.s.
Mean ± SD	68.6 ± 22.9	69.8 ± 23.5	67.4 ± 22.4	
Range (min–max)	(8−100)	(8−100)	(16−100)	
Tegner activity scale				n.s.
Mean	7	7	7	
Range (min–max)	(3−10)	(3−10)	(4−10)	
Lysholm knee score				n.s
Mean (± SD)	85.8 ± 15.9	86.4 ± 15.2	86 ± 16.8	
Range (min–max)	(44−100)	(44−100)	(46−100)	

Values shown are n (%) unless stated otherwise

HT, hamstring tendon; HT + ALL, hamstring tendon + anterolateral ligament; IKDC, International Knee Documentation Committee score; ACL-RSI, anterior cruciate ligament-return to sport after injury scale; SD, standard deviation

p value was not significant for any of the outcomes ($p > 0.05$)

Regarding the postoperative outcomes and PROMs, these were not significantly different between the two surgical procedures and this is consistent with the results of Sonnery-Cottet et al. [50] who found no difference in IKDC, Lysholm knee score and Tegner activity score between three grafts: 4HT, HT + ALL and B-PT-B.

No difference in return to sport was found between the two groups (42.2% of patients in the 4HT group returned to the same sport at the same level versus 52% of patients in the 4HT + ALL group). Webster et al. [55] reported that 88% of patients < 20-years-old returned to high-risk sports 60 months after surgery, while Balendra et al. [5] reported that 96.1% of professional footballers returned to play and 90.1% returned to the same level of play. In a systematic review of ten studies including patients < 15-years-old, Morvan et al. [32] found that a return to sport was possible for 91.7% of individuals, and in four of these studies, 61−89% of patients returned to the same level and 42% returned to a competitive level, after a mean follow-up of 7.9 years. The rate of patients returning to sport in the current study cohort is lower than that in the literature, but according to Kyritsis et al. and Webster et al. [25, 54], we authorised a return to sport 6 months after surgery only if there was 100% muscular recovery, no difference in the jump test, an ACL-RSI score > 85% and side-to-side laxity < 5 mm. It is possible that the strict criteria for a return to sport used in this study were responsible for the low rate of return to sport. In addition, Coquard et al. [13] observed that adding an ALL reconstruction to a HT ACL graft does not delay functional recovery and return to sport.

Some surgeons are concerned about doing ALL reconstructions because of a presumed higher risk of complications. In the current study, there was no difference in subjective outcomes such as occasional knee pain, hardware problems, stiffness and swelling 2 years after surgery. Furthermore, there was also no difference regarding cyclops syndrome.

Although the operating time was significantly longer in the 4HT + ALL group, it did not lead to more infections; there were only two infections, both in the 4HT group, which occurred prior to 2017 and before the use of the vancomycin-soaked compresses [22, 35]. However, there were three cases of hardware removal in the 4HT + ALL group, all related to ALL fixation, versus none in the 4HT group. According to previous experience, these hardware discomforts originate essentially from the femoral-ALL fixation screw, which must be well buried in the bone in order not to rub against the iliotibial band. These results

are, therefore, reassuring when it comes to the supposed risks of anatomic ALL reconstruction and are in accordance with the results of Sonnery-Cottet et al. [48].

The ideal indication for 4HT + ALL has yet to be established, namely which patients could benefit from it and which can do without it? In our opinion, the indication for ALL reconstruction is specific to each patient and should be based on clinical examination and laxity findings. According to Cavaignac et al. [9], it is possible to screen an ALL lesion by ultrasound in the operating room before making the first incision. This may be a way forward to refine the indications and would also allow a more reproducible placement of the femoral tunnel according to Castoldi et al. [8].

This study has several limitations. First, it was retrospective in design and the lack of randomisation prevents us from ruling out selection bias. Follow-up was only 3 years, but the majority of graft failures occur during the first 2 years after surgery and the mean time to failure of 1.9 years is consistent with the literature [57]. Follow-up was also longer in the 4HT group, which may account for some of the differences in failure rates, but the mean time to failure was not different between the two groups. Further multicentre, randomised, controlled studies are needed to refine the indications for anterolateral extraarticular procedures and to confirm the current results, which demonstrate better outcomes with combined ACL + ALL reconstruction in this high-risk population.

Conclusion

In young athletes, ALL reconstruction reduces the graft failure rate by half and significantly reduces the incidence of secondary meniscal lesions. The two independent risk factors for reoperation due to graft failure or secondary meniscal lesions were the absence of an ALL graft and preoperative side-to-side laxity > 3 mm. Combined ACL and ALL reconstruction should be preferred in young patients who participate in pivoting sports.

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Declarations

Conflict of interest The authors have no conflicts of interest to declare that are relevant to the content of this article.

Ethical approval This retrospective study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the local Institutional Review Board (No. 12-2019-12).

Informed consent All patients gave informed consent to participate to the study.

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