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Original article

ACL autograft reconstruction revisions with tendon allografts: Possibilities and outcomes. A one-year follow-up of 39 patients

Caroline Vincelot-Chainard [a,e,*], Xavier Buisson [b], Jean-François Taburet [c], Patrick Djian [d], Henri Robert [e]

[a] *Service de chirurgie osseuse, centre hospitalier universitaire (CHU) d'Angers, 4, rue Larrey, 49000 Angers, France*
[b] *Service de chirurgie orthopédique et traumatologique, centre hospitalier, 20, boulevard Général-Maurice-Guillaudot, 56000 Vannes, France*
[c] *Service de chirurgie orthopédique et traumatologique, hôpital André-Mignot, 177, rue de Versailles, 78150 Le Chesnay, France*
[d] *Cabinet de chirurgie orthopédique et traumatologique, 23, avenue Niel, 75117 Paris, France*
[e] *Service de chirurgie orthopédique et traumatologique, centre hospitalier du Haut Anjou, 1, quai du Dr-Lefèvre, 53200 Château-Gontier-sur-Mayenne, France*

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A B S T R A C T

Background: The number of anterior cruciate ligament (ACL) reconstructions is steadily rising in France. Re-tear rates of up to 25% have been reported and graft selection remains a notable challenge. Allografts, although rarely used in France, can be a viable option. The primary objective of this study was to demonstrate the benefits of ACL revision with allografts, by determining subjective scores (IKDC score and KOOS), measuring laxity, and evaluating the rate of return to sports.
Hypothesis: Tendon allografts are reliable and can be used in France for ACL reconstruction revision.
Material and methods: We conducted a retrospective study including 39 patients managed in two centres between 2004 and 2016 and followed up for at least a year. Patients were eligible if they had undergone tendon allograft reconstruction for ACL revision with or without rupture of a peripheral plane. We excluded underage patients and patients with a history of ligament injury in the contralateral knee. Mean age was 32 years. The allografts were extensor mechanisms, anterior or posterior tibial tendons, fascia lata tendons, hamstring tendons, and a short fibular tendon. They were obtained from French and Belgian tissue banks. They were used for the reconstruction of 39 ACLs and 11 collateral ligaments. The IKDC score and KOOS were determined in all patients. Laximetry was performed in 31 patients by an independent examiner.
Results: Mean follow-up was 3.5 years. Arthroscopic release was required in one patient, and 2 patients experienced re-tears. No deep surgical site infections were recorded. The subjective IKDC score and the KOOS improved significantly, from 53.6 to 80.7 and from 60.4 to 83.2, respectively. Mean postoperative differential laxity was 1.4 mm (KT 1000) and 1.6 mm (GNRB®). Of the 3 patients who were professional athletes, 2 had returned to sports at the same level one year later, and among the recreational athletes, 54% had resumed their previous sporting activities.
Conclusion: In the setting of complex ligament reconstruction revision, tendon allografts are reliable and can be used in France.
Level of evidence: IV; retrospective cohort study.

1. Introduction

Anterior cruciate ligament (ACL) surgery is commonly performed in France, with over 51,000 procedures in 2019 [1]. Primary ACL surgery usually confers good outcomes, allowing patients to return to their usual sports [2]. Nevertheless, after autograft ACL reconstruction, the 10-year re-tear rate can reach 25% and is highest in young patients with strong functional demands [3]. Revision of a reconstructed ACL is a major surgical challenge, with the outcomes of this complex procedure theoretically being less satisfactory than those of primary reconstruction [4]. The optimal type of graft to be used for revision of the reconstructed ACL remains a contentious topic [5–7]. In France, an autograft is generally used, because many

* Corresponding author at: Service de chirurgie osseuse, centre hospitalier universitaire (CHU) d'Angers, 4, rue Larrey, 49000 Angers, France.
E-mail address: vincelot.chainard.caroline@gmail.com (C. Vincelot-Chainard).

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surgeons feel that allografts are difficult to obtain or of limited reliability. Factors that influence the choice of the graft type include the initial reconstruction technique, the extent of the lesions, the expectations of the patient, the experience of the surgeon, and the availability of allografts. However, the use of each autograft is associated with a certain degree of morbidity that increases if several autografts are harvested [8]. For tendon-sparing purposes, we reasoned that the use of a tendon allograft deserved consideration for the treatment of re-tears after primary ACL reconstruction.

A considerable body of data exists regarding the use of allografts for primary ACL reconstruction but study results are conflicting [4,5,7,9]. Studies addressing the use of allografts for revising the reconstructed ACL are scarce and have only small numbers of patients [10,11].

The primary objective of this study was to demonstrate the benefits of ACL revision with allografts, by determining subjective scores (IKDC score and KOOS), measuring laxity, and evaluating the rate of return to sports. The secondary objective was to show that tendon allografts are available in France and that their use is legal and feasible.

2. Material and methods

2.1. Inclusion and exclusion criteria

We conducted a retrospective observational study in two centres. The included patients were managed between 2004 and 2016 and followed-up for at least one year. The functional, clinical, and laximetry results were analysed prospectively.

We included patients with a re-tear of a reconstructed ACL, whether isolated or accompanied with a tear of the collateral ligaments. All the procedures were performed by two surgeons specialised in the knee (HR and PD). Both surgeons deliberately chose to use an allograft. All patients signed a specific consent form. Patients who were unwilling to receive an allograft were managed with an autograft.

We excluded patients who were less than 18 years of age and patients with a history of ligament injury to the contralateral knee that would prevent the determination of differential laxity.

2.2. The allografts used

The allografts were obtained from tissue banks located in France (Paris, Tours and Clermont-Ferrand) and in Belgium. They were harvested from brain-dead patients, in the operating room, under optimal aseptic conditions. The grafts were validated then stored at −80° for 5 years. High-risk donors were eliminated by serological tests for the HIV, the hepatitis B and C viruses, HTML, and syphilis and by the examination of bacteriological samples. The grafts were delivered only after a quarantine to check that the recipient(s) of organs harvested from the same patient had not undergone seroconversion for any infectious agent.

Each tissue sample was subjected to the usual bacteriological and virological screening tests. The grafts were not subjected to secondary sterilisation, to avoid altering their biomechanical qualities. No immunosuppressants were given to the recipients, since tendon grafts contain no blood vessels or cells.

2.3. Operative technique

Imaging studies were obtained to evaluate the position of the tunnels, look for osteolysis, and assess the position of the fixation material. Testing under anaesthesia was performed to detect peripheral laxity associated with the ACL re-tear. All intra-articular reconstructions were performed arthroscopically.

All the main technical points regarding problems related to the tunnels and to the initial material left in place have been described in detail and will not be discussed again here [12].

The allografts were transported from the tissue banks in dry ice. They were thawed then soaked for 30 minutes in warm normal saline containing an antibiotic (80 mg of gentamicin). Isolated tendons (anterior and posterior tibial tendons, semitendinosus tendon, short fibular tendon) were cleared of muscle tissue debris, then prepared as for a hamstring autograft in bundles of two, three, or four strands, depending on their length. Extensor mechanism grafts were fashioned on a table to create either a bone–tendon–bone graft equivalent to a patellar tendon graft (Kenneth-Jones technique) or a bone–tendon graft equivalent to a quadricipital tendon (Fig. 1 a, b, c). For the tensor fascia lata, the tendinous sheet was rolled into a cigar shape with an intra-articular segment measuring 10 to 12 cm in length and 9 mm in width and an extra-articular segment (used to prevent knee snapping) measuring 9 to 12 cm in length and 7 mm in width (Fig. 2 a, b).

The grafts were threaded into the tunnels using a traction suture, then blocked in the tunnels by interference screws for the bone struts or, for the tendon ends; by staples, a suspended fixation, or some other technique. The tibial fixation was performed with the anterior shift reduced and the knee flexed at 10°, with no rotation.

The peripheral planes were repaired once the intra-articular reconstructions were finished.

To repair the lateral collateral ligament, the graft was threaded through a tunnel in the centre of the fibular head, then passed under the fascia lata, and finally blocked in a blind femoral tunnel with the knee extended.

The popliteal tendon was repaired using the Larson technique. A tunnel in the tibial epiphysis was drilled, starting posterior to Gerdy's tubercle and extending to the postero-lateral part of the tibia, 10 mm distal to the joint line. The graft was introduced into the tunnel in the anterior–to–posterior direction. When it exited the tunnel, it followed the trajectory of the popliteal tendon and was fixed in a tunnel drilled in the femoral epicondyle, anterior to the lateral collateral ligament [13].

For the antero-lateral reconstructions, when the allograft was long (quadricipital tendon and tensor fascia lata), this single graft was used intra- then extra-articularly. A lateral approach was used for outside–in drilling of the transverse femoral tunnel and for drilling of the tibial tunnel, which was positioned using a compass, posterior to Gerdy's tubercle, according to the Mac InJones technique [14]. If a single allograft was available, the procedure was performed to prevent knee snapping according to Lemaire's technique modified by Christel [15].

Repair of the medial plane involved reconstructing the medial collateral ligament and the oblique popliteal ligament using the technique described by Lind [16].

Four patients with pain from the medial compartment required correction of excessive varus by performing an open-wedge valgus tibial osteotomy before drilling the tibial tunnel.

Postoperative care involved wearing a hinged splint (0–90°) for 4 to 6 weeks when walking, immediate full weight-bearing if the procedure was strictly intra-articular, but elimination of weight-bearing for 45 days in the event of peripheral repair, and rapid rehabilitation therapy using a gentle protocol.

2.4. Data collection

Three independent examiners evaluated the patients more than one year after the surgical procedure. In addition to a physical examination, differential laxity was measured using the GNRB® (Genourob, Laval, France) or KT1000 (Medmetric Corporation, San Diego, CA, USA). To assess function, the patients then completed the subjective IKDC scale and the KOOS scale.

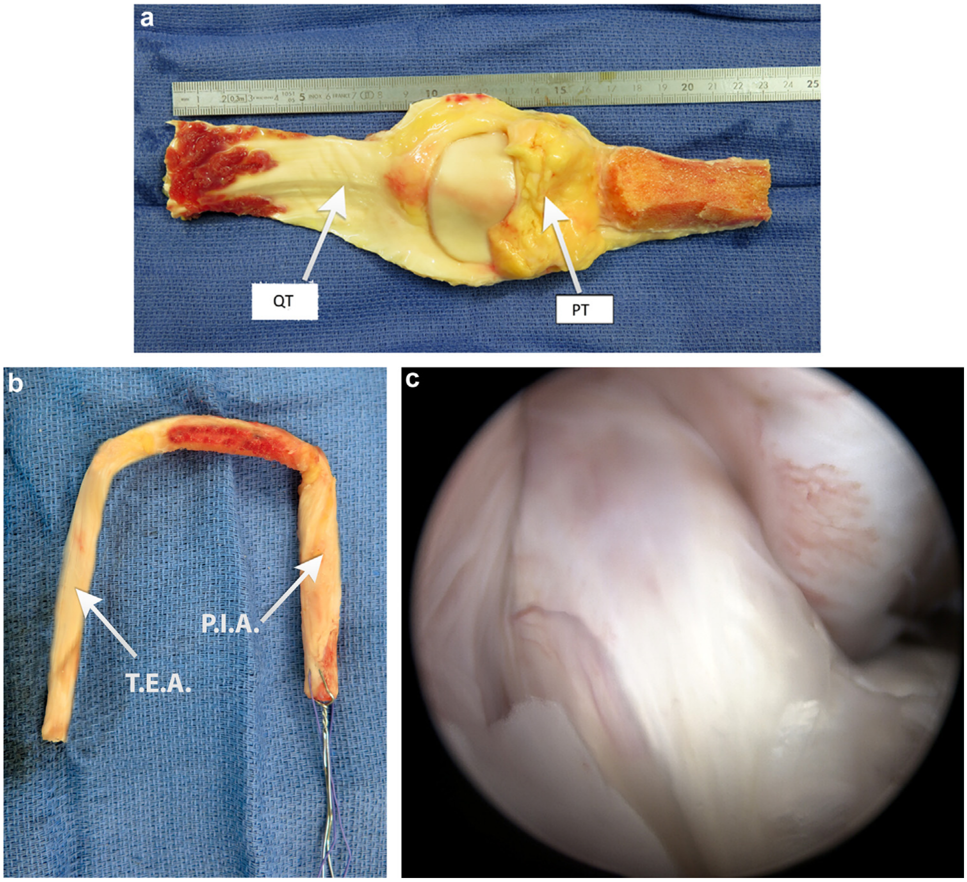

Fig. 1. a: Complete extensor apparatus before preparation. QT: quadriceps tendon; PT: patellar tendon. b: Extensor apparatus graft after preparation according to the Mac InJones technique. EAT: extra-articular tenodesis; IAP: intra-articular plasty. c: Right knee: second look one year after surgery.

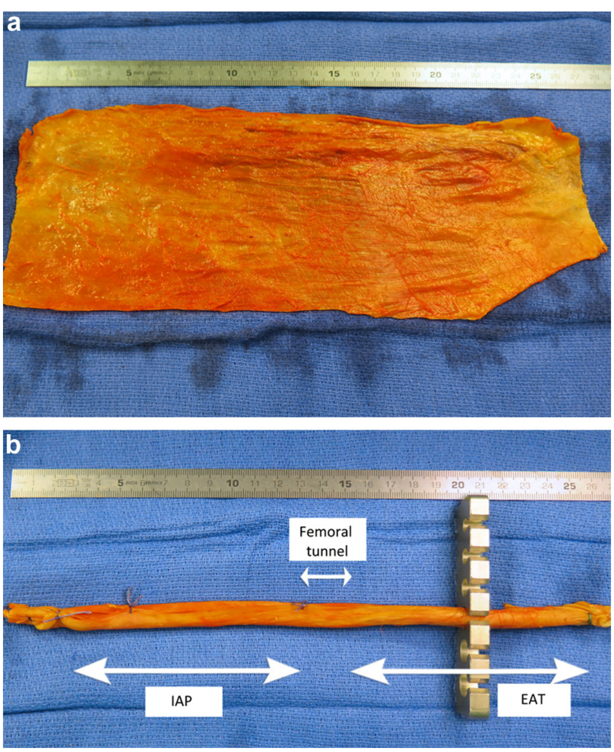

Fig. 2. a: Fascia lata aponeurosis before preparation. b: Tubular fascia lata graft after preparation. EAT: extra-articular tenodesis; IAP: intra-articular plasty.

2.5. *Statistical analysis*

The statistical analysis of the study data was performed using the BiostaTGV site (biostatgv.sentiweb.fr).

The non-parametric Mann–Whitney test was applied to compare the IKDC scores and KOOS before and after surgery. Analysis of variance was performed to compare the impact on the IKDC score of cartilage or meniscal lesions, age, or number of previous surgeries on the same knee.

For the KOOS, we used a threshold of 10 points to define the minimal clinically important difference for the six items (symptoms, stiffness, pain, function and daily living, sports, and quality of life), in order to confirm a significant improvement [17].

Values of p below 0.05 were considered statistically significant.

3. Results

3.1. *Epidemiological data*

We included 39 patients with a mean postoperative follow-up of 3.5 ± 3 years (range, 1–13.7 years). Mean age at surgery was 32 ± 10 years (range, 18–54 years). There were 32 males and 7 females. The left knee was affected in 20 patients and the right knee in 19 patients.

The mechanism of the re-tear was a pivot-contact sport in 25 patients, a pivot sport without contact in 5 patients, and a traffic accident in 6 cases; the mechanism was unknown in 3 patients. Of the 39 patients, 3 were professional athletes, 32 were recreational athletes, and 4 did not engage in sports, but had knee instability during their daily activities.

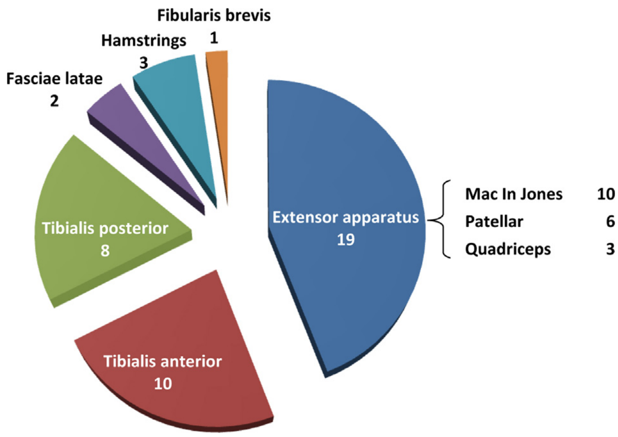

Fig. 3. Types of grafts used (44 in all).

Table 1
Types of lesions and procedures on ligaments, menisci, and cartilage.

Interventions		
Lesions	*n*	Procedures
ACL only	39	–
ACL + medial plane	3	Hamstring tendon (1)
ACL + lateral plane ± popliteal tendon	8	Leg tendons (5) Hamstring tendons (3)
LCA + antero-lateral plasty	18	Mac InJones technique (10) Christel technique (8)
Lesion of the medial meniscus	16	Sutures (8) Meniscectomies (8)
Lesion of the lateral meniscus	9	Sutures (5) Meniscectomies (4)
Tibial osteotomy	4	Including 3 with a postero-lateral plasty
Isolated chondral lesions Grade 1: 2 Grade 2: 8 Grade 3: 2	12	Abstention (12)

The grafts used for the primary reconstruction were the patellar tendon in 11 patients, the hamstrings in 25 patients, the fascia lata with the MacIntosh technique in 2 patients, and the quadricipital tendon in one patient. In 4 patients, antero-lateral repair using the Lemaire technique was also been performed. In addition, 7 patients had already had revision surgery using a tendon autograft. In all, 13 patients had had surgery at least once on the knee after the primary reconstruction (new reconstruction or procedure on the meniscus).

3.2. Operative data

The mean time from primary to revision surgery was 5.6 ± 5.8 years (range, 1–27 years). In all, 44 tendon allografts were used for the intra-articular reconstruction of the 39 ACLs. In addition, repair of the lateral collateral ligament and popliteal ligament was performed in 8 patients and repair of the medial collateral ligament in 3 patients (Fig. 3). In 18 patients, a procedure to prevent knee snapping was performed in addition to the intra-articular reconstruction.

One patient underwent isolated ACL reconstruction and an open-wedge valgus osteotomy due to degenerative disease in the medial knee compartment. Finally, 3 patients underwent ACL reconstruction, repair of the postero-lateral corner, and an open-wedge valgus osteotomy to correct anterior, posterior, and lateral laxity (Table 1).

Table 2
IKDC scores before and after surgery (the maximum score is 100).

IKDC	Before surgery	After surgery	*p* value
Mean	53.6	80.7	0.002
SD	10.4	12	
Minimum	34	47	
Maximum	71	93.5	

The two re-tears were excluded.

4. Results

Tables 2–4 report the subjective evaluations by the subjective IKDC score and the KOOS. The overall functional scores showed significant improvement. The 10-point cut-off for the minimal clinically important difference was reached for the "daily living" item and exceeded for the other five items. The "quality of life item" improved but had the lowest value of all items.

Of the 3 professional athletes, 2 returned to their sport at the same level and one at a lower level. Of the 32 recreational athletes, 17 (53%) returned to their sport at the same level or at a lower level.

The mean postoperative subjective IKDC score was not associated with the number of previous surgical procedures, but was associated with the presence of chondral or meniscal lesions and by age at the time of the allograft surgery (Tables 5 and 6).

Table 7 reports the preoperative and postoperative differential laxities. In 34 patients, significant gains were noted irrespective of the method used to record laxity. Residual laxity was < 3 mm in 25

Table 3
KOOS values before and after surgery (the maximum score is 100).

KOOS before surgery	Global	Symptoms	Stiffness	Pain	Daily living	Sports	Quality of life
Mean	60.4	60.9	70.2	66.7	72.4	49.7	45.6
SD	8.9	13.6	13.6	10.1	11.7	12.2	17.4
Minimum	45	35	50	40	60	30	19
Maximum	70	80	100	75	97	70	70

Table 4
KOOS values after surgery (the maximum score is 100).

KOOS after surgery	Global	Symptoms	Stiffness	Pain	Daily living	Sports	Quality of life
Mean	83.2	84.3	89	85	83.4	77.2	69.3
SD	11.5	10.4	16.7	11.6	7.5	17.5	23
Minimum	53	60	56	60	60	30	44
Maximum	98	98	100	100	100	100	98
Gain versus preoperative value	22.8	23.4	16.8	18.3	10	27.5	23.7

The two re-tears were excluded.

Table 5
Mean subjective IKDC scores according to the number of previous surgical procedures.

Number of previous procedures	IKDC, mean ± SD	*p* value
One (24 patients)	75.2 ± 21	
Two (6 patients)	77.5 ± 10.5	0.8
Three (7 patients)	75 ± 11.9	

Table 6
Mean postoperative IKDC scores according to the presence of chondral lesions, presence of meniscal lesions, and age (< 25 or ≥ 25 years).

	IKDC, mean ± SD	*p* value
No chondral lesions (27)	78.05 ± 18.47	
Chondral lesion grade 1, 2, 3 (12)	69	0.82
Chondral lesion grade 2	80.9 ± 10.9	
Chondral lesion grade 3	75.25 ± 25.1	
Meniscal lesion (25)	73.74 ± 22	0.03
No meniscal lesion (14)	82.6 ± 10.1	
Age < 25 years (12)	83.4 ± 11.25	0.02
Age ≥ 25 years (27)	75.9 ± 19	

Table 7
Laximetry results before and after surgery in 34 patients.

	Before surgery (mm)	After surgery (mm)	Gain (mm)	*p* value
KT-1000 (13)	7.1 ± 1.9	1.4 ± 1.3	5.7	0.03
GNRB (21)	5.4 ± 1.9	1.6 ± 1.38	3.8	0.04

(73%) patients, between 3 and 5 mm in 7 (21%) patients, and > 5 in 2 (6%) patients.

No cases of deep surgical site infection or thromboembolic events were recorded. Arthroscopic release was required in one patient whose flexion was limited at 95°. At last follow-up, flexion was 125°. Re-tears occurred in 2 (5.1%) patients, during a fall after 3 years of follow-up and during a skiing accident after 4 years of follow-up, respectively.

5. Discussion

The findings from this study demonstrate that the use of allografts is feasible and reliable in France. To our knowledge, this is the largest French cohort study reporting the medium-term outcomes of ACL reconstruction revision using allografts. All patients were significantly improved, and the mean residual differential laxity was 1.4 mm and 1.6 mm. We reserved allograft reconstructions primarily for recreational athletes who could accept longer times off sports than those achieved with autografts. Our 54% return-to-sports rate is lower than the 67% reported by Legnani et al. but higher than the 43% reported by Andriolo et al. [18,19].

The main limitations of our study are the retrospective design, the absence of a control group managed with autografts, and the absence of randomisation. These limitations do not allow the production of a higher level of scientific evidence.

The strong points of our study are the large number of patients ($n = 39$) managed using a rarely performed technique in France, the long 3.5-year follow-up, the subjective evaluation using standardised and validated scales (IKDC and, KOOS), and the differential laximetry performed by 3 independent examiners.

The literature contains an abundance of studies of primary ligament reconstruction using allografts, but only few studies addressing revision reconstruction. We will discuss only this latter group. The multicentre international MARS group study [20] of revision ligament reconstruction found that, after 2 years, the number of re-tears was twice as high with allografts than with autografts. However, 53% of the allografts were sterilised by irradiation. Autograft reconstruction was followed by significantly better results on the subjective KOOS, WOMAC and IKDC evaluations. The MARS group, together with Fox et al. and Maletis et al. concluded that "revision of an ACL reconstruction with an allograft should be considered as a salvage procedure" [20–22].

Several other studies obtained results similar to ours. In a study by Legnani et al. with a mean follow-up of 5.2 years, the functional scores and laximetry measurements were comparable after revision with autografts and with allografts [18]. These findings are paralleled by reports from Pascual-Guarrido et al. and Mayr et al., provided the allografts used are not sterilised by irradiation or by chemical means [23,24]. Reverte-Vinaxia et al. reported a 21% failure rate and a mean subjective IKDC score of 63%, i.e., lower than in our cohort [25]. In a non-randomised cohort study comparing patellar tendon autografts and allografts, the risk of re-tear was higher with the allografts (4.1% vs. 1.7%); however, the allografts were irradiated [22]. Chougule et al. reported a 6-year failure rate of 5% [11] and concluded that "revision of an ACL reconstruction using semitendinosus allograft is a safe procedure that improves the function of the patient" [11].

The subjective and objective outcomes of our cohort are comparable to those of autograft revisions presented at the 2006 symposium of the French Society for Arthroscopy (*Société française d'arthroscopie*) [26]. In a multicentre study, Colombet et al. found that lateral repair significantly improved laxity, without however modifying the global IKDC score [26]. Laximetry decreased from 7.1 to 2.8 mm at last follow-up in the retrospective cohort and from 7 to 2 mm in the prospective cohort. In this study, the mediocre functional outcomes correlated with the presence of chondral lesions or previous performance of meniscectomy. In our study of allografts, we also found a significantly adverse impact of chondral and meniscal lesions. In the MARS group study of 583 autograft revisions, the IKDC scores and KOOS were very similar to those in our cohort, although the re-tear rate was lower (2.2% versus 5.1% in our cohort) [20]. Regardless of the type of graft, the rate of return to sports was lower after revision surgery than after primary surgery, due to the age at surgery and to the time elapsed between the two procedures [20]. In a study by Keizer et al., the rate of return to sports was 51.4% in the 34 patients managed using an allograft compared to 62.8% in the patients managed with a patellar tendon autograft [27].

The two disadvantages of allografts that are often brought up are the longer time to ligamentisation and the risk of infection. Maturation of the allograft involves several phases that unfold more slowly than with autografts, thus delaying the return to sports [3,28]. Extra-articular plasty, which is widely used, protects the intra-articular plasty during its ligamentisation. Extra-articular plasty was not performed in all our patients, notably in those who did not engage in sports or had only minimal laxity.

The risk of bacterial infection is not higher with allografts than with autografts [29,30]. The risk of viral transmission is even lower [31]. Gamma radiation to sterilise the grafts, even when used in low doses, produces no benefits and impairs the mechanical properties of the graft. In the four French tissue banks that do not use imported material, soft tissue grafts are not subjected to delipidation, proteination, viral inactivation, or irradiation and are cryopreserved between −196° and −40° [32].

One of the obstacles to using allografts today is their limited availability in France, which relies heavily on grafts imported from Belgium (88% in 2016) [32]. The demand for and distribution of tendons increases year on year (+316% between 2012 and 2016). Allografts are used for ACL revision in up to 20% of cases in Italy and in 54% of cases in the US [19,20]. In France, as revision procedures have no specific code in databases; it is difficult to know the number of allografts used for revisions. This number is probably low, accounting for less than 5% of revisions per year.

The reasons for choosing an allograft for ACL revision must be clearly explained to the patient. The advantages and risks must be described. If the recipient accepts, he/she must sign a specific consent document (Bioethics law of 1994).

6. Conclusion

The findings from this study demonstrate that the use of allografts is feasible and reliable in France for the revision of complex ligament reconstructions and when tendon sparing is paramount. The quality of the reported results should motivate orthopaedic surgeons to harvest more tendon and meniscus allografts, in order to diminish our dependency on tissue banks in other countries.

Disclosure of interest

Djian Patrick is a consultant for Smith & Nephew. Robert Henri designed the GNRB®, but receives no royalties. Caroline Vincelot-Chainard, Xavier Buisson, and Jean-François Taburet declare that they have no competing interest.

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Contributions of each author

Vincelot-Chainard Caroline is co-author, and contributed to the writing and reviewing; Buisson Xavier, Taburet Jean-François, to the data collection; Djian Patrick and Robert Henri are also co-authors and contributed to the data collection and study referring surgeons.

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