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How to cite

BILLIERES, Julien et al. Multiligament knee injuries treated by one-stage reconstruction using allograft : Postoperative laxity assessment using stress radiography and clinical outcomes. In: Orthopaedics & traumatology: surgery & research, 2020, vol. 106, n° 5, p. 937–944. doi: 10.1016/j.otsr.2019.08.001

This publication URL: https://archive-ouverte.unige.ch/unige:176961

Publication DOI: 10.1016/j.otsr.2019.08.001

Orthopaedics & Traumatology: Surgery & Research 106 (2020) 937–944

Contents lists available at ScienceDirect

Orthopaedics & Traumatology: Surgery & Research

journal homepage: www.elsevier.com

Original article

Multiligament knee injuries treated by one-stage reconstruction using allograft: Postoperative laxity assessment using stress radiography and clinical outcomes

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ARTICLE INFO

Article history:
Received 7 November 2018
Accepted 24 August 2019

Keywords:
Multiligament knee injury
Knee dislocation
Allograft
One-stage reconstruction
Stress radiography

ABSTRACT

Background: Surgical treatment of multiligament knee injuries (MLKIs) leads to better outcomes but there are controversies about optimal surgical strategies. Debates remain about timing of surgery: acute, staged or delayed and about graft choice: autograft, allograft or a combination of both. Therefore, we performed a retrospective study aiming to evaluate postoperative laxity using stress radiographs and clinical outcomes after one-stage reconstructions of injured ligaments using non-irradiated, fresh-frozen allografts.
Hypothesis: MLKIs treated by one-stage reconstructions using non-irradiated, fresh-frozen allograft may lead to satisfactorily postoperative laxity and clinical outcomes.
Methods: Between November 2013 and July 2015, 23 patients with MLKIs underwent one-stage reconstruction using allograft. Knee injuries were defined according Schenk classification of Knee Dislocation (KD). Patients were evaluated using the Knee injury and Osteoarthritis Outcome Score (KOOS), the Lysholm Knee Scoring Scale, and the International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form at a minimum follow-up of 24 months. Postoperative anterior, posterior, varus, and valgus laxities were assessed using stress radiographs and expressed as side-to-side differences (SSD) in millimeters.
Results: Three of 23 patients were lost to follow-up. There were 6 KD-I, 12 KD-III, and 2 KD-IV lesions, 12 lateral-side and 10 medial-side lesions, and 13 acute and 7 chronic cases. Three patients had associated neurovascular injuries. Mean follow-up was at 29.4 ± 6.1 months. Mean valgus SSD was 0.2 mm ± 1.4 mm (range, −2.1–2.2 mm), mean varus SSD was 1.4 mm ± 2.5 mm (range, −1.7 – 6.0 mm), mean posterior SSD was 7.2 mm ± 3.9 mm (range, 1.2 – 16.0 mm), mean anterior SSD was 3.6 mm ± 5.1 mm (range, – 4.8 – 16.8 mm). Overall IKDC ratings were: 4 grade A, 3B, 7C, and 6D. Three patients complained of postoperative instability, with an IKDC rating of D. The mean subjective IKDC score was 67.2 ± 19.6, the mean Lysholm Knee Scoring Scale was 77.3 ± 16.5, and the mean KOOS results were 78.5 ± 16.6 for pain, 67.7 ± 17.4 for symptoms, 86.5 ± 14.2 for daily activities, 56 ± 25.4 for sports, and 47.2 ± 28.6 for quality of life. Nineteen of 20 patients returned to sport—6 to the same level. One patient underwent an arthroscopic arthrolysis due to postoperative arthrofibrosis.
Conclusions: Using non-irradiated allografts for one-stage reconstructions of all the injured ligaments in MLKIs is effective and safe. Anteroposterior stability was difficult to restore, but patients returned to their daily activities and sometimes to their sports activity at the same preinjury level.
Level of evidence: Level IV, case series.

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https://doi.org/10.1016/j.otsr.2019.08.001

1. Introduction

Multiligament knee injuries (MLKIs) are complex lesions involving the disruption of at least two of the four major ligaments. The Schenk classification [1,2] is based on anatomical patterns of the ligaments involved and is widely used in the literature (Table 1). Another classification based on the injury mechanism and the ligament involved has been proposed by the French Society of Orthopedic Surgery and Traumatology [3]. Associated meniscal, chondral, neurological, and vascular injuries are frequent and contribute to the high morbidity of these serious injuries. Surgical treatment leads to improved outcomes [4–6], especially when associated with early rehabilitation [6]. To facilitate early knee motion and restore knee biomechanics, numerous authors have recommended a one-stage procedure of Anterior Cruciate Ligament (ACL) and Posterior Cruciate Ligament (PCL) reconstruction with simultaneous repair of the avulsed collateral ligaments or reconstruction of a mid-substance tear [7–9]. Many graft options are available as autograft, allograft, artificial ligament [10] or ligament bracing [11]. However, many surgeons advocate the use of allograft tissue because of the absence of donor site morbidity and multiple graft-size options [7,9,12,13]. Furthermore, good clinical results have been reported after bicruciate ligament [14–17] or collateral ligament [18–20] reconstructions using allograft tissues.

Our search of the literature found few studies reporting objective data on overall postoperative laxity after reconstruction of MLKIs. Most studies have reported on postoperative stability by using a physical examination, a manual arthrometer, or antero-posterior stress radiographs [6,16,21–26]. To the best of our knowledge, only two studies have reported on postoperative laxity measured by stress radiographs of all the planes (anterior, posterior, varus, and valgus) [27,28]. This technique provides objective, quantitative information on laxity, and some authors have advocated it to evaluate postoperative knee stability [7,13]. Furthermore, we did not find in the literature, reported clinical outcomes after one stage reconstruction of all injured ligament using fresh frozen non-irradiated allograft. Most of series were bicruciate reconstruction with collateral repair or reconstruction of all injured ligament with a combination of autograft and allograft.

Therefore we performed a retrospective study aiming to evaluate postoperative laxity using stress radiographs and clinical outcomes after one-stage reconstructions of injured ligaments using non-irradiated, fresh-frozen allografts. The hypothesis was that stability and knee function would be satisfactorily restored by this surgery.

2. Materials and methods

2.1. Patients

After ethics approval obtained from the SUD-EST II Ethics Committee, Lyon, France (N° ID-RCB: 2017-A01364-49), we retrospectively reviewed patients who were referred to our institution between December 2013 and July 2015 for MLKIs and treated using one-stage reconstruction.

Table 1
Schenk classification of Knee Dislocation (KD) [1,2].

Type	Description
KD I	Single cruciate injury with one collateral ligament injury
KD II	Bicruciate injury with collaterals intact
KD III	Bicruciate injury with one collateral ligament injury
KD IV	Bicruciate injury with both collaterals
KD V	Periarticular fracture dislocation

Additional letters "M" medial-sided injury, "L" lateral-side injury, "C" arterial injury, "N" nerve injury.

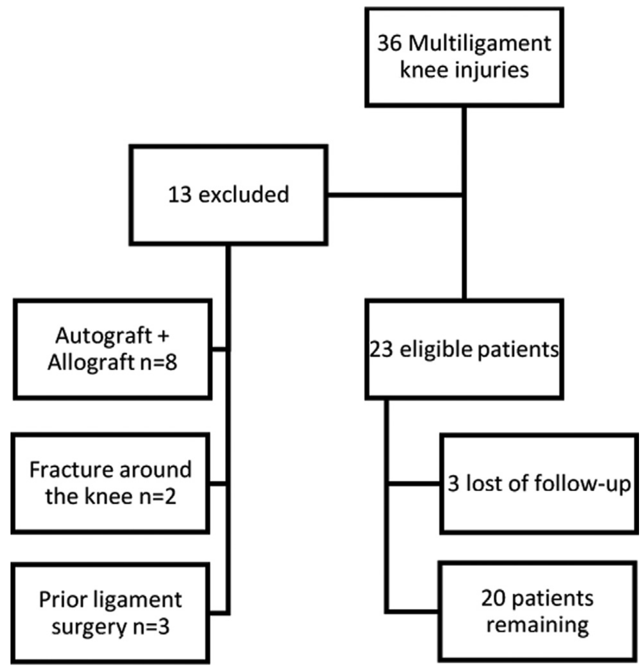

Fig. 1. Flowchart of the study.

In this period, 36 patients were managed using a standard surgical technique consisting of anatomical reconstruction of all the injured ligaments with non-irradiated, fresh-frozen allografts. Inclusion criteria were: two or more injured ligaments diagnosed clinically and by MRI and a minimum of two years of follow-up. Exclusion criteria were: use of an autograft reconstruction (used only when allografts were unavailable from the tissue bank), any prior knee surgery, concomitant ligament injury on the contralateral knee, or associated femoral or tibial fracture. Those criteria excluded 13 patients (Fig. 1), leaving 23 available for the study. Eight of the 13 patients were excluded for the use of autografts in addition to allografts, three for prior knee ligament surgery, and two for fracture around the knee. Patients who met the inclusion criteria were contacted and invited to participate in the study.

2.2. Surgical procedure

Surgery was done by senior orthopedic surgeons. Acute reconstruction was performed between 10 days and 4 weeks after injury. Chronic cases were defined as cases operated after four weeks (late diagnosis and referral).

The leg was elevated, and a tourniquet was inflated. Diagnostic arthroscopy was performed through standard inferomedial and inferolateral portal incisions. All associated cartilage and meniscus lesions were addressed and treated before ACL and PCL reconstruction. Arthroscopically assisted single-bundle anatomical reconstructions of injured cruciate ligaments were performed through independent tunnels (in–out technique for femoral tunnels). Graft fixation was done using interference screws ($n = 15$ or an endobutton ($n = 3$) for the ACL on the femoral side.

Acute lateral and medial-side injuries were repaired (using sutures, anchors, or staples) and augmented using allograft in the same way as for chronic cases, with the following techniques:

On the lateral side, the lateral collateral ligament, the popliteus tendon, and the popliteofibular ligament were reconstructed using an anatomical technique (Fig. 2) [29].

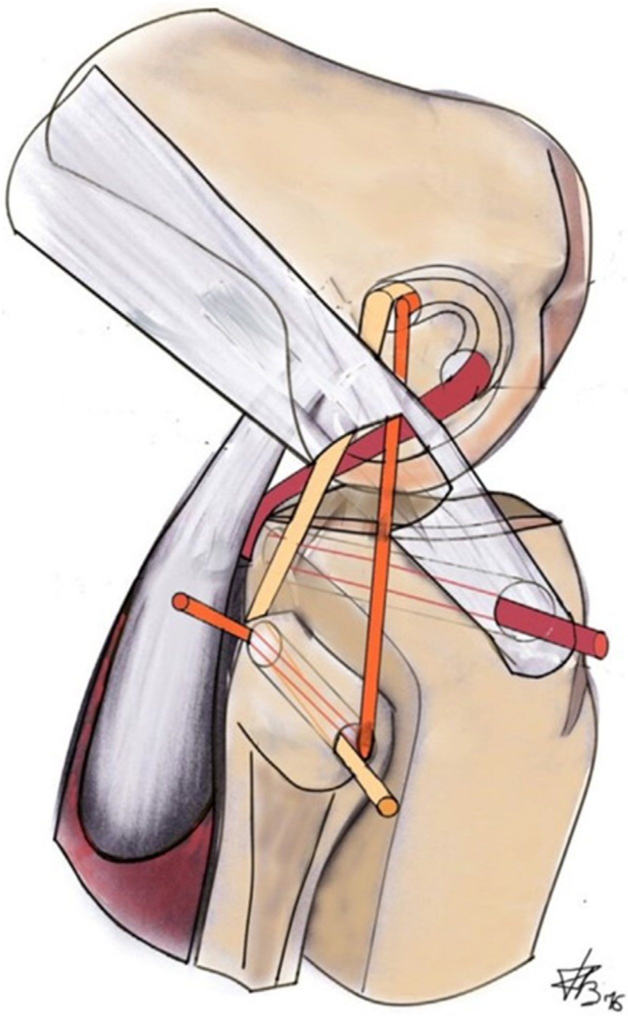

Fig. 2. Reconstruction of the three main posterolateral corner stabilizers (lateral collateral ligament, popliteus tendon, and popliteofibular ligament).

On the medial side, isometric techniques were used to reconstruct the superficial medial collateral ligament (MCL) and the posterior oblique ligament (POL) with a double-bundle allograft. A longitudinal medial incision was made, centered over the medial epicondyle and the medial tibial tubercule. A single femoral tunnel was made at the anatomical attachment point of the MCL [30] (3 mm proximal and 5 mm posterior to medial epicondyle). A POL tunnel was made at the posteromedial side, as described by La Prade [31], and the isometric MCL tibial tunnel was identified using a compass. The graft was placed under the sartorius fascia. First, the POL graft was fixed at full extension, and then the MCL graft was fixed at 20° of knee flexion using interference screws.

The type of allograft used for reconstruction depended on those available at the tissue bank. In our experience, one Achilles tendon can provide an adequate amount of tissue to reconstruct a KD-I injury (Fig. 3). KD-III injuries were reconstructed using either a whole patellar tendon with a quadriceps tendon ($n = 5$) or an Achilles tendon plus one soft tissue tendon ($n = 7$).

2.3. Rehabilitation

The postoperative rehabilitation protocol consisted of non-weight-bearing activities and limited flexion from 0° to 90° for six weeks. Knees were maintained in hinged-knee braces for three months. Physical therapy began in the first week and focused on quadriceps recovery and progressive restoration of the passive range of motion. If the PCL had been reconstructed, rehabilitation was done in the prone position and active knee flexion was not permitted for six weeks. Return to pivoting sports was allowed nine months after surgery. Knee motion flexion inferior to 100° was treated by arthroscopic arthrolysis between four to six months after the initial reconstruction.

2.4. Clinical and radiological evaluation

At a minimum follow-up of two years, bilateral and comparative stress radiographs were performed using the TELOS™ stress device (Metax, Hungen-Obbornhofen, Germany), with all patients undergoing the same protocol. An anterior drawer test was performed by applying a 25 kPa anterior load to the proximal tibia at 30° of knee flexion. A posterior drawer test was performed by applying a 15 kPa posterior load to the proximal tibia at 70° of knee flexion. Varus and valgus stress tests were performed by applying a 15 kPa load to the knee joint line at 20° of knee flexion. Anterior and posterior tibial translation, as well as varus and valgus opening, were measured using the same bony landmarks on both knees, as described by Jacobsen [32] (Fig. 4).

Measurements of AP, medial, and lateral laxity were taken by the same bone radiologist. Laxity was expressed as the side-to-side difference (SSD) in millimeters and was graded according to the IKDC scale [33]: A (normal) = 0–2 mm, B (nearly normal) = 3–5 mm, C (abnormal) = 6–10 mm, and D (severely abnormal) > 10 mm. Patients were fully examined by an independent senior orthopedic surgeon (the author, who did not participate in these surgeries). Range of motion was measured using a goniometer. Postoperative rotatory knee laxity was evaluated during the physical examination using the pivot-shift test and the dial test at 30° and 90° flexion on both knees.

At the time of their study visit, all patients completed the following subjective scores: subjective IKDC forms [33], Lysholm Knee Scoring Scale [34], and KOOS [35]. Post-operative complications and sport activity levels were collected.

Fig. 3. Double-bundle allograft used for posterolateral corner reconstruction. The remaining Achilles tendon was sufficient for the reconstruction of the ACL.

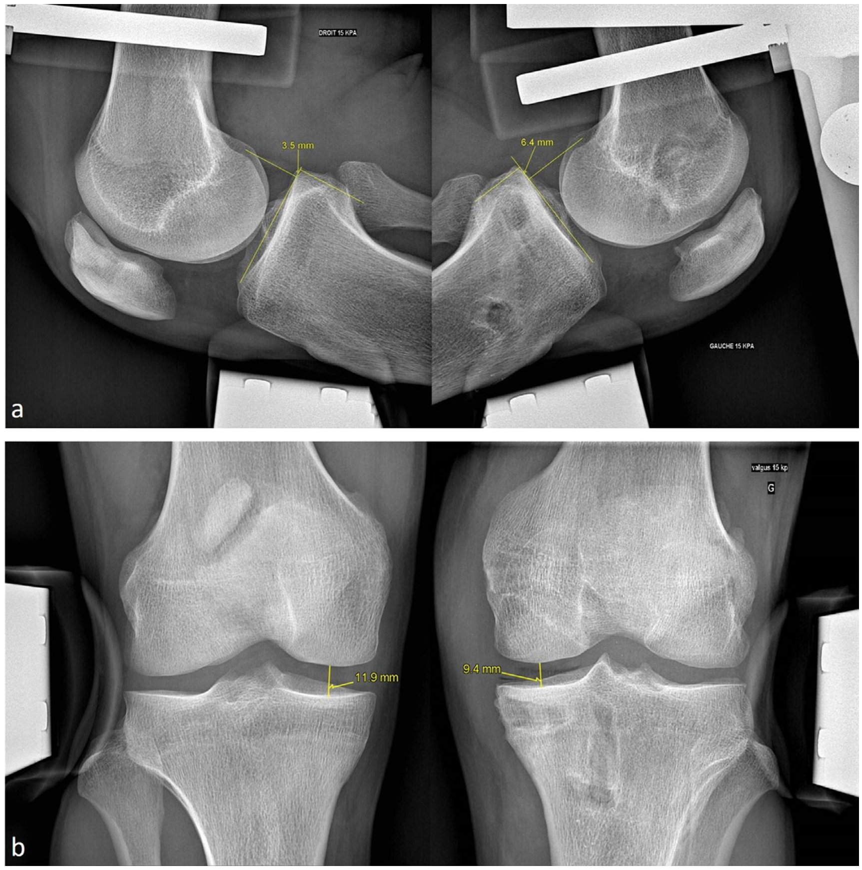

Fig. 4. Postoperative stress radiographs of the injured (PCL and medial side reconstructed, in this example) and non-injured knees. a: posterior drawer; b: valgus stress.

2.5. Statistics

For continuous variables the means and standard deviations were calculated for normal distributaed variables and median with interquartile range for non-normal destributed variables, for comparison Mann-Whitney test was used. Categorical variables were expressed as a proportion (%). Analyses were performed using the PASW statistical package, version 22 (SPSS Inc., Chicago). There were no missing values. Differences were deemed as significant when p values < 0.05.

3. Results

Three patients were lost to follow-up, leaving 20 patients for the final analysis. No patients declined to participate in this study. Mean follow-up was at 29.4 ± 6.1 months. Demographic data are presented in Table 2. On the 6 meniscal lesions, one was left in situ, three were repaired and two resected.

For the two patients with KD-IV, the medial-side injury was a tear of the deep MCL and these were treated conservatively. Three patients had initial neurovascular injuries, all of them with a bicruciate tear associated with a posterolateral injury. One of them had a residual foot drop at the last follow-up visit. Two of three had a popliteal artery injury—one needed a popliteal bypass and the other was treated using full anticoagulation therapy for three months.

Postoperative knee laxity, as assessed by stress radiography, is presented in Table 3. After ACL reconstruction, 5 of 18 patients (28%) had abnormal or severely abnormal anterior laxity. One patient (5%) had a fixed posterior tibial subluxation with an SSD of − 4.8 mm on the anterior stress radiograph. The pivot-shift test was normal in 14 cases (grade A) and nearly normal in 4 more (grade B). Posterior laxity was abnormal (grade C) or severely abnormal (grade D) in 56% (9/16) of cases after PCL reconstruction. Varus laxity was graded abnormal in 2 (SSD of 5.4 and 6 mm) of 12 cases after reconstruction of posterolateral injuries. The dial test was normal in 11 cases (grade A) and nearly normal in one more (grade B). Valgus laxity

Table 2
Demographic data.

	Study group (n = 20)
Mean age, years (SD, range)	28.3 ± 11.8 (range, 16–52)
Sex, female/male	5/15
BMI, kg/m^2, (SD, range)	25.2 ± 5.3 (range, 18.7–39)
Left/right knee	10/10
Acute/chronic	13/7
Injury mechanism	12 sports trauma 8 motor vehicle accidents
Knee dislocations	9 (45%)
Type of injuries	3 KD-I L 3 KD-I M 7 KD-III L 5 KD-III M 2 KD-IV
Associated meniscal lesions	5 Medial (25%) 1 Lateral (5%)
Associated chondral lesions	5, max ICRS grade II
Other associated lesions	1 patellar tendon rupture 1 patellar dislocation 1 fibular nerve injury 2 popliteal artery and fibular nerve injuries
Type of allograft used for reconstruction or augmentation (Depending on availability)	8 Achilles' tendons 8 Knee extensor apparatus 3 Fibular tendons 3 Tibialis posterior tendons
Mean operative time, minutes (SD, range)	170.7 ± 37.9 (range, 101–241)

ICRS: International Cartilage Regeneration & Joint Preservation Society, KD: Knee Dislocation.

Table 3
Post-operative laxity as assessed by stress radiographs and classified according to IKDC (International Knee Documentation Committee). [33].

	Side-to-side difference in millimeters (SD, range)	Distribution of IKDC grades
Anterior laxity after ACL reconstruction ($n = 18$)	3.6 ± 5.1 (range, −4.8–16.8)	12A, 1B, 3C, 2D
Posterior laxity after PCL reconstruction ($n = 16$)	7.2 ± 3.9 (range, 1.2–16)	2A, 5B, 5C, 4D
Varus laxity after lateral reconstruction ($n = 12$)	1.4 ± 2.5 (range, −1.7–6)	10A, 2C
Valgus laxity after medial reconstruction ($n = 8$)	0.2 ± 1.4 (range, −2.1–2.2)	8A

Grade A laxity is a 0–2 mm side-to-side difference; grade B: 3–5 mm; grade C: 6–10 mm; and grade D: > 10 mm.

was almost normal in all medial reconstructions (maximum SSD of 2.2 mm). Valgus laxity was also normal for the two patients with a conservatively treated partial MCL injury.

Overall IKDC gradings based on stress radiographs were normal for four knees, nearly normal for three, abnormal for seven, and severely abnormal for six. Three patients complained of postoperative instability, with an IKDC grade D on stress radiographs, but they did not have revision reconstruction at their last follow-up. Two were graded D on the anterior drawer test, and one was graded D on the posterior drawer test.

Table 4
Knee function at follow-up for KD-I versus KD-III/IV [1,2].

	KD-I ($n = 6$)	KD-III/IV ($n = 11$)	p
Follow-up (months), SD	32.2 ± 6	26.1 ± 3.4	NS
Average ROM (°) (recurvatum/flexum/flexion)	6/0/136	2/1/129	
Average flexion deficit (°)	5 ± 4.5	13.6 ± 12.9	NS
Extension deficit (°)	0	1 patient (10°)	NS
Subjective IKDC [33]	73.8 ± 20.7	68.1 ± 19.2	NS
Lysholm [34]	85.5 ± 10.9	74.1 ± 18.6	NS

Patients with neurovascular injuries not included, $n = 3/20$. ROM: range of motion; KD: knee dislocation; NS: non significant.

Postoperative knee function is presented in Tables 4 and 5 and Fig. 5. Mean flexion deficit was 12.3 ± 11.4. The average VAS pain score was 3.3 ± 2.3/10. Nineteen of 20 patients (95%) had returned to sport—six at the same level, three at a lower level, and ten had adapted their sports activities. After the exclusion of patients with initial neurovascular injuries, there were no statistical differences in the subjective scores between acute and chronic injuries or, medial- and lateral-side injuries (Table 5).

Postoperative complications included one (5%) transient foot drop due to a temporary palsy of the common peroneal nerve, one (5%) arthrofibrosis treated by arthroscopic knee arthrolysis at four months, and five patients (25%) complained of painful hardware and needed partial removal. No surgical site infections were encountered.

Table 5
Knee function at follow-up for Acute versus Chronic and Medial versus Lateral.

	Acute ($n = 11$)	Chronic ($n = 6$)	p	Medial ($n = 8$)	Lateral ($n = 9$)	p
Follow-up (months), SD	29.8 ± 5.9	25.3 ± 1.6	NS	26.3 ± 4.2	30 ± 5.7	0.036
Average ROM (°)(recurvatum/flexum/flexion)	4.1/0.9/132.7	2.5/0/128.3		3.1/1.3/126.9	3.9/0/135	
Average flexion deficit (°)	11.4 ± 12.5	9.2 ± 9.7	NS	12.5 ± 15.4	8.9 ± 6.5	NS
Extension deficit (°)	1 patient (10°)	0	NS	1 patient (10°)	0	NS
Subjective IKDC [33]	66.6 ± 21	76.6 ± 15.1	NS	69.8 ± 22.6	70.4 ± 17.2	NS
Lysholm [34]	76.7 ± 17.9	80.7 ± 16.1	NS	72 ± 21.9	83.6 ± 8.9	NS
KOOS [35]						
Pain	77.5 ± 17.3	81 ± 15.6	NS	76.7 ± 19.6	80.6 ± 13.7	NS
Symptom	68.8 ± 18.1	67.9 ± 12.4	NS	66.5 ± 19.3	70.2 ± 13.1	NS
ADL	85.6 ± 16.2	92.2 ± 11	NS	83.7 ± 18.8	91.7 ± 9	NS
Sport/Rec	60 ± 22.2	63.3 ± 19.4	NS	57.5 ± 25.2	64.4 ± 16.7	NS
QoL	50 ± 29.3	58.3 ± 23.9	NS	55.5 ± 32.5	50.7 ± 23.1	NS

Patients with neurovascular injuries not included. ROM: range of motion; NS: not significant.

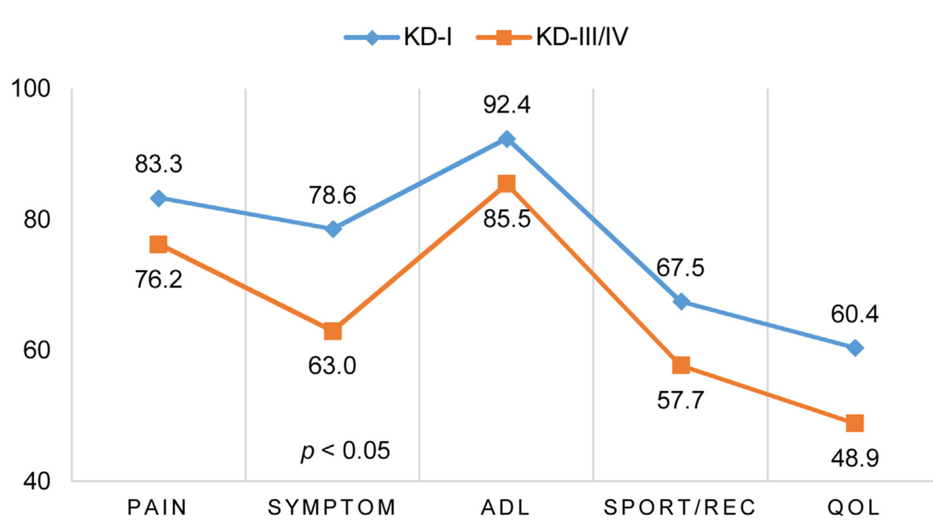

Fig. 5. KOOS at follow-up for KD-I versus KD-III/IV (KD: knee dislocation according to Schneck [1,2]).

Table 6
Published series of postoperative laxity assessed by stress radiography after surgical treatment of MLKIs.

First author/year	Number and type of MLKIs	Type of surgery	Type of graft	Mean follow-up time	Postoperative laxity				Remarks
					Anterior	Posterior	Varus	Valgus	
Our series	3 KD-I L 3 KD-I M 7 KD-III L 5 KD-III M 2 KD-IV	One-stage reconstructions of injured ligaments	Non-irradiated, fresh-frozen allografts: Achilles' tendons, knee extensor apparatus, fibular tendons, tibialis posterior tendons	29.4 ± 6.1 mos	3.6 ± 5.1 mm range, −4.8–16.8 mm	7.2 ± 3.9 mm range, 1.2–16 mm	1.4 ± 2.5 mm range −1.7–6.0 mm	0.2 mm ± 1.4 mm range −2.1–2.2 mm	
Bin et al., 2007 [27]	7 KD-III M 5 KD-III L 3 KD-IV	Fist stage: medial side injury repair, lateral side injury repair or reconstruct Second stage: PCL or ACL reconstruction if laxity was present	Achilles allograft and/or BPTB allograft	88.9 mos	12 A, 3B	3A, 8B, 4C	5A, 2B, 1C	7A, 3B	SSD not expressed in mm
Hongwu et al., 2018 [28]	13 cases of irreducible posterolateral knee dislocation	One-stage arthroscopic reduction combined with multiligament reconstruction or repair	PCL: Artificial ligament ACL: Hamstring autograft Medial and lateral side injuries: repair of contralateral hamstring	32.6 mos	2.23 ± 0.92 mm range 1–4 mm	3.23 ± 1.16 mm range 2–5 mm	0.46 ± 0.52 mm range 0–2 mm	1.77 ± 1.87 mm range 0–7 mm	
Mariani et al., 2001 [38]	8 KD-II 5 KD-III M 2 KD-III L	Arthroscopic bicruciate reconstruction	PCL: BPTB autograft ACL: Hamstring autograft	36 mos range, 24–56	3.3 ± 0.4 mm	7.3 ± 1.5 mm			
Strobel et al., 2006 [26]	17 KD-III L	One-stage arthroscopic bicruciate reconstruction and reconstruction of PLC structures	Ipsilateral and controlateral hamstring	Minimum 24 mos range 24–66.3	1.59 ± 3.50 mm	7.12 ± 3.37 mm			
Ranger et al., 2011 [24]	3 KD-II 28 KD-III L 29 KD-III M 11 KD-IV	Open one-stage reconstructions of injured ligaments	Artificial ligaments (LARS)	54 ± 19.9 mos. range 24–96	2.4 ± 5.8 mm	7.6 ± 4.1 mm			
Heitmann et al., 2019 [11]	24 KD-III M 37 KD-III L 8 KD-IV	Acute one-stage anatomic repair and ligament bracing of injured ligaments by open approach	Pull-out suture with braided non-absorbable suture # 2	14.0 ± 1.6 mos.	3.2 ± 1.3 mm	2.9 ± 2.1 mm			
Rios et al., 2010 [39]	4 KD-I L (ACL) 10 KD-I (PCL) 7 KD-III L	One-stage arthroscopic bicruciate reconstruction and reconstruction of PLC structures	Variable Allograft and/or autograft	39 mos. range 24–81		3.2 ± 4.5 mm	0.2 ± 1.9 mm		Anterior translation not evaluated by stress radiography
Yoshiya et al., 2005 [40]	12 KD-I M (ACL) 7 KD-I M (PCL) 3 KD-III M	One-stage arthroscopic cruciate reconstruction and reconstruction of medial collateral ligament	Hamstring autograft for medial collateral ligament Controlateral BPTB and/or quadriceps tendon for cruciates	27 mos. range 24–48				0.2 ± 0.5 mm	Anterior and posterior translation not evaluated by stress radiography
Liu et al.2013 [18]	15 MLKIs 1 Patellar dislo-cation + medial side injury	One-stage reconstruction of sMCL + repair or reconstruction of other injuries	Achilles allograft for sMCL	34 mos. range 24–67				1.1 ± 0.9 mm	

KD: Knee Dislocation, Schenck classification [1,2], BPTB: Bone-patellar tendon-bone, PLC: Posterolateral corner, sMCL: superficial Medial collateral ligament, SSD: Side-to-side difference, IKDC grading system: Grade A laxity is a 0–2 mm side-to-side difference; grade B, 3–5 mm; grade C, 6–10 mm; and grade D, > 10 mm.

4. Discussion

The present study's most important finding was that one-stage reconstruction of all injured ligaments using non-irradiated, fresh-frozen allografts leads to satisfactorily knee function despite the difficulty to restore a normal post-operative laxity, especially in sagittal plan. However, patients returned to their daily activities and sometimes to their sports activity. Complications rate was low, in particular the rate of postoperative arthrofibrosis. Furthermore, frontal laxity assessment of MLKIs undergoing reconstructions by allografts is a new issue adding significant data over the existing knowledge.

First objective of this study was to evaluate postoperative laxity after one-stage reconstruction using allograft. It was assessed using comparative stress radiographs made in all planes and expressed as an SSD in millimeters. This technique was chosen over manual arthrometers because it is an objective and reliable measurement [36]. Furthermore, arthrometers tend to underestimate posterior residual laxity [37]. In addition, some authors [6] advocate stress radiographs to assess postoperative laxity. To the best of our knowledge, few studies used this modality to assessed postoperative laxity after surgical treatment of MLKIs and the results are summarized in Table 6. Only two studies have reported on postoperative laxity measured by stress radiographs of all the planes (anterior, posterior, varus, and valgus). First, Bin et al. [27] have reported their results of 15 knees treated using a two-stage strategy. Medial-side lesions were repaired, lateral-side lesions were repaired and/or reconstructed using allografts or bicep tenodesis, and the ACL and PCL were reconstructed in cases of instability over grade 1 + and over grade 2 +, respectively. In their study, the stress radiograph methodology was not described, and residual laxity was not expressed as SSD in millimeters but graded using the IKDC scale. Posterior translation was abnormal (grade C) in 27% (4/15) of cases.

Hongwu et al. [28] have reported on 13 cases of irreducible posterolateral knee dislocation treated by one-stage arthroscopic reduction combined with multiligament reconstruction or repair. Hamstring autograft was used to reconstruct ACL and collateral ligament, artificial ligament for PCL reconstruction. Postoperative laxity was graded normal or nearly normal (grade A or B) in all planes except one knee with an abnormal (grade C) medial joint gapping.

In our consecutive series of patients with MLKIs reconstructed using allografts, residual postoperative laxity was frequent, especially in the sagittal plane, but it was rare in the frontal plane. Our results were within the ranges of the studies mentioned in Table 6.

In terms of postoperative scores, our results were similar to other series of MLKIs treated by surgery [41–43]. The mean Lysholm Knee Scoring Scale and the mean subjective IKDC score varied from 75–93.3 and from 58–77, respectively. Compared to a previous study reporting outcomes after medial and lateral reconstructions for MLKIs [8], we found no significant differences between medial- and lateral-side injuries. Statistical analysis was limited by the number of cases and the heterogeneity of lesions. We therefore found no statistically significant difference between the clinical scores of acute and chronic cases or between patients with medial- and lateral-side injuries. Patients with initial neurovascular injuries were not included in this analysis because lower scores were expected in this subgroup [44]. Most patients were able to return to sporting activities, but only 32% did so at their pre-injury level. This finding was consistent with a study reporting outcomes after the one-stage reconstructions of 18 KD-I and 21 KD-III patients using autografts (31%) [8].

Surgery was delayed for a minimum of ten days after cases of acute injury, and immediate postoperative rehabilitation was started to minimize the occurrence of knee stiffness. Range of motion was similar to other studies [41], and we observed a mean flexion deficit of 14° in patients with KD-III and KD-IV scores. Our rate of postoperative arthrofibrosis was 5%; this was lower than our similar series of one-stage reconstructions using autografts with 18 KD-I and 21 KD-III (18%) [8]. This lower rate of arthrofibrosis may be explain by using allograft instead of autograft. Further comparative studies are needed to confirm this hypothesis. In two large series of more severe injuries (KD-III and KD IV) treated by acute one-stage combined repair and reconstruction using artificial ligament [24] or ligament bracing using non-absorbable sutures [11], arthrofibrosis rate was 19.7% and 11.6% respectively. Allografts have been available at our institution since 2013 and have been used for MLKIs in order to avoid donor-site morbidity of the injured knee (and of the contralateral knee). Successful surgical treatment of MLKIs using allografts has been reported previously, and many authors recommend this technique [9,14,15,17,45,46]. Cook et al. [47] reported similar revision rates for autografts and allografts after the reconstruction of 133 MLKIs over a ten-year period. Irradiated allografts were not used because of their altered biomechanical properties [48].

The present study has limitations. It included chronic and acute cases, with the same technique, but depending on the type of allograft available. Lateral and medial MLKIs were included. Cases with vascular and nerve injuries were included because it does not change results of the main criteria of assessment of the study: objective laxity measurement. Subgroup analysis was probably not conclusive because of their small size. These limitations were inherent to all case-series studies of MLKIs available in the literature as it used a retrospective design involving a small group and heterogeneity in injury patterns. Preoperative scores and laxity assessed using stress radiography were not available for chronic cases, so the improvement of knee function could not be assessed. Furthermore, functional recovery was not entirely assessed because isokinetic and functional tests were not performed at last follow-up. However, that was not the study's purpose.

5. Conclusion

In conclusion, one-stage reconstruction using non-irradiated, fresh-frozen allografts for MLKIs provides satisfactory results in terms of subjective knee function at a two-year follow-up despite anteroposterior stability was difficult to restore with an abnormal posterior laxity in more than half of patients. The complication rate was low despite the severity of the initial injury and the complex nature of the surgical technique. Further studies are needed to compare allograft and autograft for treating MLKIs.

IRB and RCT information

Ethics approval was obtained from the SUD-EST II Ethics Committee, Lyon, France. N° ID-RCB: 2017-A01364-49.

Disclosure of interest

The authors declare that they have no competing interest.

Outside the current study, Camille Steltzlen, Philippe Boisrenoult and Nicolas Pujol have occasional consultancy for Smith & Nephew and Zimmer-Biomet. Nicolas Pujol declares being occasional consultant for Lima. Philippe Beaufils declare being Editor In Chief of Orthopaedics & Traumatology: Surgery & Research Journal.

Funding

None.

Contributions

Julien Billières: Drafting the article, acquisition, analysis and interpretation of data.

Charlotte Labruyère: Acquisition of data.

Camille Steltzlen: Surgery performance.

Amanda Gonzalez: Statistics, analysis and interpretation of data.

Philippe Boirenoult: Surgery performance.

Philippe Beaufils: Surgery performance.

Nicolas Pujol: Surgery performance, conception and design of the study, final approval and corrections of the version to be submitted.

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