Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/jptcp.v30i4.2443

MODIFIED LEMAIRE PROCEDURE COMBINED WITH ARTHROSCOPIC ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IN TREATMENT OF ANTEROLATERAL ROTATIONAL KNEE INSTABILITY

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Abstract

Background: Persistent anterolateral rotational knee instability (ALRI) with positive pivot shift test of varying grades is one of the commonest causes of ACL reconstruction (ACLR) failure even after adequate anatomic reconstruction, graft fixation and postoperative rehabilitation. So a lot of studies have discussed the role of anterolateral complex (ALC) reconstruction either non-anatomic by lateral extraarticular tenodesis (LEAT) or anatomic by anterolateral ligament reconstruction (ALLR) in addition to anatomic single bundle (SB) ACLR in controlling ALRI.

Aim: To evaluate the clinical and functional outcomes of combining LEAT using modified Lemaire procedure with arthroscopic anatomic SB-ACLR in treatment of ALRI.

Patients and methods: Between June 2019 and June 2022, a prospective study was conducted on 30 patients with high grade ALRI. All cases were operated by combined arthroscopic anatomic SB-ACLR and LEAT using modified Lemaire procedure. All cases were assessed pre- and postoperatively by clinical evaluation, IKDC subjective and objective scores and Lysholm scoring scale.

Results: All cases were followed for 18 months, re-evaluated and results compared at the end of follow-up. There was significant postoperative improvement regarding pain, ROM, stability, and scoring systems with p value <0.001.

Conclusion: Combined anatomic SB-ACLR and LEAT using modified Lemaire procedure exhibits good to excellent results in treatment of ALRI without considerable complications.

Keywords: ALRI, Pivot shift, ACL, Anterolateral complex, LEAT, Modified Lemaire

Introduction

Anterolateral rotational knee instability (ALRI) is a combined anterior translational and internal rotational movement of the proximal tibia. It occurs either due to acute combined injury to the anterior

cruciate ligament (ACL) and the anterolateral soft tissue structures of the knee or by progressive elongation of the other ligamentous restraints to internal rotation in chronic ACL deficiency.[1]

The anterolateral soft tissue structures (anterolateral complex, ALC) of the knee include from superficial to deep: the iliotibial band (ITB) with its superficial (sITB), middle (mITB), deep (dITB, including Kaplan fibers) and capsulo-osseous layers, the anterolateral ligament (ALL), the anterolateral capsule and the lateral meniscus.[2]

Persistent ALRI is considered one of the commonest causes of ACLR failure even after adequate anatomic single bundle (SB) or double bundle (DB) ACLR due to non-addressed anterolateral structures injuries[3] or other associated factors as younger ages, female sex, increased BMI, genu recurvatum, generalized ligamentous hyperlaxity, increased posterior tibial slope.[4] So a lot of studies have discussed the role of ALC reconstruction either non-anatomic by lateral extral articular tenodesis (LEAT) or anatomic by ALL reconstruction (ALLR) in addition to anatomic SB-ACLR in controlling ALRI.[2,5,6]

In 1967, Lemaire described the first extra-articular procedure to treat chronic ACL deficiency using a long strip of the ITB as a double bundle graft.[7] Later in 2002, Christel and Djian described a less invasive procedure using only a single bundle graft to simplify the original technique. This modification was the predecessor of the "Modified Lemaire Procedure" that is considered now the standard procedure of LEAT.[8]

Aim of the work

The aim of this study was to evaluate the clinical and functional outcomes of combining LEAT using modified Lemaire procedure with arthroscopic anatomic SB-ACLR in treatment of ALRI.

Patients and Methods

Patients

After approval of the Ethical Committee of Benha Faculty of Medicine and a written concent from each patient, a prospective study was conducted from June 2019 to June 2022 to evaluate the clinical and functional outcomes of combining LEAT using modified Lemaire procedure with arthroscopic anatomic SB-ACLR in treatment of ALRI.

The study included 30 patients with high grade ALRI operated and followed for 18 months. All cases had been operated in Benha University and El Helal Insurance Hospitals.

According to the pre-planned case sheet, patients' data included full detailed history, clinical and radiological evaluation (Knee x-rays, MRI and CT in cases of revision ACLR), laboratory investigations and the chosen scoring systems; International Knee Documentation Committee (IKDC) subjective and objective scores and Lysholm knee scoring scale.

Inclusion criteria: (1) 20 to 40 years old. (2) Both males and females. (3) Acute and chronic ACL injuries. (3) High grade ALRI (pivot shift test grades 2 and 3). (4) Participation in pivoting sports. (5) Generalized ligamentous hyper-laxity. (6) Genu recurvatum > 10º. (7) Segond fracture. (8) Revision ACLR.

Exclusion criteria: (1) < 20 and > 40 years old. (2) Malalignment: genu varum > 5º and genu valgum > 10º. (3) Multiligamentous knee injuries. (4) Radiological signs of knee OA (> Kellgren-Lawrence grade 2).

Cases were 27 males and 3 females. Mean age was 29.5 years. Mean BMI was 26.3 (21.3-38.2) kg/m^2. According to the IKDC scoring system, activity level of 14 cases (46.7%) were non-sporting, 7 cases (23.3%) were sporting sometimes, 8 cases (26.7%) were frequently sporting (recreational football) and only one case (3.3%) was sharing in high competitive sports (professional football).

The mean time elapsed between the index injury and surgery was 2.5 years (3 months-15 years).

There was **joint line pain and tenderness** in 9 cases (30%) with medial tenderness in 4 cases (13.3%), lateral in 2 cases (6.7%), medial and lateral in 3 cases (10%). Regarding **ROM**, there was 20º flexion deficit (the difference in degrees between maximum flexion of the injured and normal knees) in one case (3.3%), 25º in one case (3.3%) and 30º in one case (3.3%), with mean flexion deficit was 2.5 ± 7.7º (0-30º). There was 5º extension deficit in one case (3.3%) and 10º in 2 cases (6.7%), with mean extension deficit was 0.8 ± 2.7º (0-10º).

Regarding **stability**, **Lachman test** grade 2 (5-10 mm translation) with soft endpoint was found in 17 cases (56.7%), while grade 3 (>10 mm translation) with soft endpoint was found in 13 cases (43.3%). **Anterior drawer test** grade 2 (5-10 mm translation) was found in 17 cases (56.7%), while grade 3 (>10 mm translation) was found in 13 cases (43.3%). **Pivot shift test** grade 2 (clunk) was found in 23 cases (76.7%), while grade 3 (gross shift) was found in 7 cases (23.3%).

Three cases (10%) had medial and lateral meniscal injuries, 3 cases (10%) had medial and 2 cases (6.7%) had lateral meniscal injuries.

Mean **subjective IKDC score** was 55.4 (23-67), **objective IKDC score** was severely abnormal in 28 cases (93.3%) and abnormal in 2 cases (6.7%), while mean **Lysholm score** was 53.9 (30-62) with all cases (100%) had poor scores.

Methods

All cases were operated by combined arthroscopic anatomic SB-ACLR and LEAT using modified Lemaire procedure. 28 cases were primary, while 2 cases were revision.

Operative indications included high pivot shift test in all cases; grade 2 in 23 cases (76.7%), grade 3 in 7 cases (23.3%) with added indications for each patient. Ten cases (33.3%) had chronic injury > 12 months, 9 cases (30%) was sharing in pivoting sports (football), 5 cases (16.7%) were young age < 25 years, 5 cases (16.7%) had genu recurvatum > 10°, 3 cases (10%) had Segond fracture, 3 cases (10%) were active females, 2 cases (6.7%) were revision, 2 cases (6.7%) had generalized ligamentous hyperlaxity and one case (3.3%) was obese (BMI 38.2).

Pre-operative prophylactic antibiotics (1-2 grams of 4th generation cephalosporins, cefepime) were taken within 1 hour before the operation. All surgeries were performed under spinal anesthesia. All cases were positioned supine with a lateral side support to allow adequate valgus stress and a foot stopper to stabilize the leg during variable knee flexion degrees. Routine examination under anesthesia was performed by bilateral Lachman, anterior drawer, pivot shift, posterior drawer, varus and valgus stress tests to grade ACL injury and exclude associated ligamentous injuries. A tourniquet was secured over the proximal thigh followed by sterilization and draping.

Operative procedure . Arthroscopic anatomic SB-ACLR (Fig. 1)

Routine diagnostic arthroscopy was performed and any meniscal injuries were treated, either by performing partial menisectomy (3 cases; 2 medial and 1 lateral) or meniscal repair (5 cases; 3 medial and lateral, 1 medial and 1 lateral) with tightening of meniscal sutures before ACL graft tibial fixation.

Hamstring tendons (HT) autografts were used in all cases except in revision cases, one with quadriceps tendon (QT) autograft and one with peroneus longus tendon (PLT) autograft. Visualization was optimized with a three-portal approach: anterolateral (AL), anteromedial (AM), and accessory anteromedial (AAM) portals.

The femoral tunnel was made in the I.D.E.A.L site of anatomic femoral tunnel that coincides with a distance of about 2 mm plus the planned tunnel radius from the posterior and proximal articular margins, while the tibial tunnel was made medial and in line or just posterior to the posterior border of the anterior horn lateral meniscus.

Grafts were fixed in all cases by femoral fixed buttons and tibial bioabsorbable interference screws except one revision case (in which QT was used) fixed by femoral and tibial bio-absorbable interference screws.

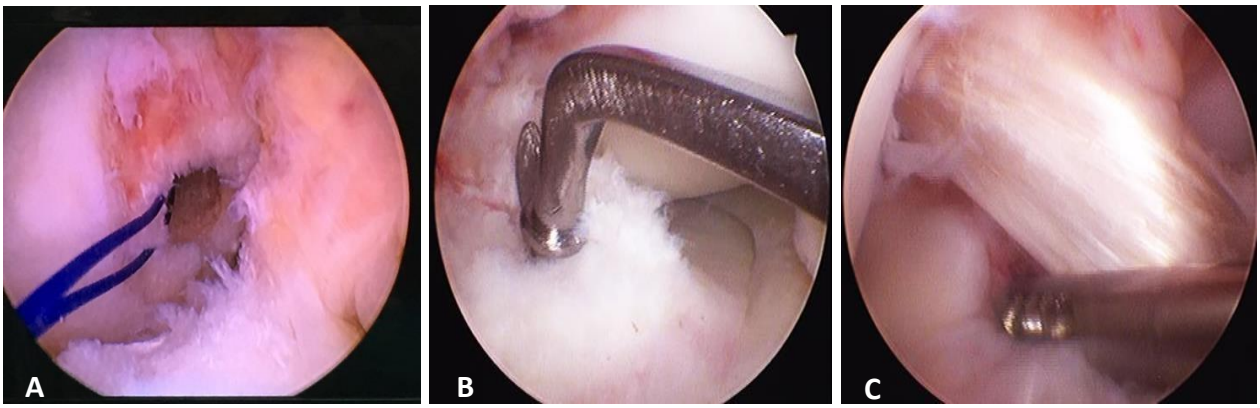

Fig. 1 A. Anatomic ACL femoral tunnel placement. B. Anatomic ACL tibial tunnel placement. C. ACL graft assessment after fixation.

Modified Lemaire procedure (Fig. 2)

While the knee was 60º flexed, landmarks were made as lateral femoral epicondyle (LFE), head of fibula (FH) and Gerdy's tubercle (GT). A 6-10 cm skin incision was made from the LFE to the GT, then subcutaneous tissues were dissected to the level of the ITB. ITB graft was harvested**,** 10-12 cm (randomly about 3 cm beyond the LFE) of the posterior half (central third), about 10 mm width leaving its distal attachment, most posterior fibers of the dITB and capsulo-osseous layer intact. The graft was released to be completely free then whip stitched and sized**.** The LCL was identified by hip flexion, abduction, and external rotation (FABER position) with knee flexion and varus stress then dissected and the graft was passed beneath it using a right angled forceps. The tunnel was marked at the point of insertion of the distal Kaplan fibers of the dITB into the femur which is a bony prominence on the supracondylar flare of the distal femur, called the distal ridge of Kaplan fibers, located 2-3 mm posterior and proximal to the LCL attachment. It should be directed anterior and proximal to avoid ACL femoral tunnel and not < 2-3 cm.

The graft was passed through the tunnel and fixed by a bio-absorbable interference screw with knee 60º flexion, neutral tibial rotation to avoid lateral joint over-constraint. The wound was irrigated and the ITB was partially closed to avoid constraint of the lateral patellofemoral joint followed by the subcutaneous tissue and skin. ACL graft harvest and tunnels preparation were done 1st then ITB graft harvest, passage and tunnel preparation followed by ACL graft passage, femoral fixation then tibial fixation and finally ITB graft fixation.

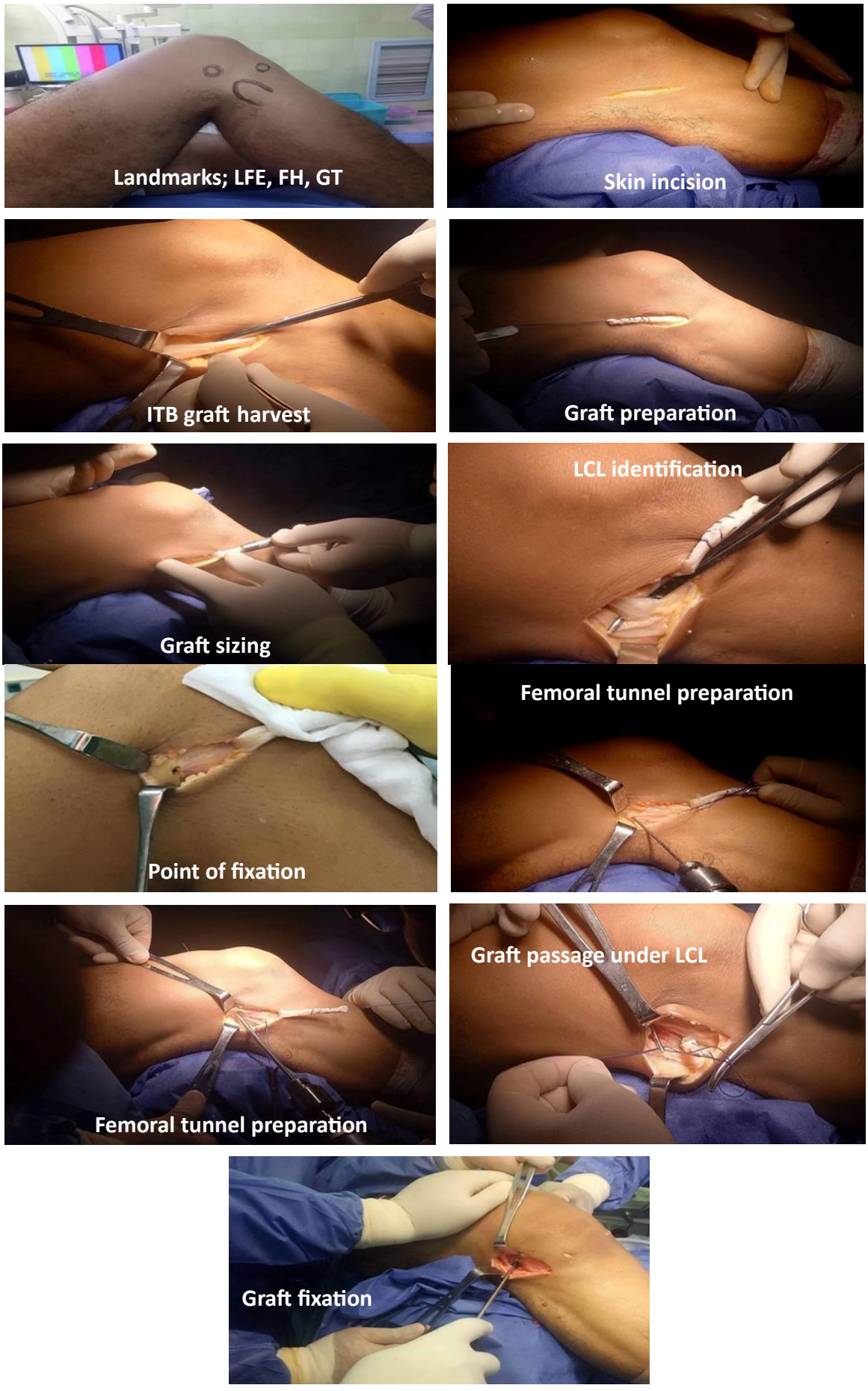

Fig. 2 Modified Lemaire procedure.

Postoperative protocol

Intravenous antibiotics (Cefepime 1gm/12 hours) were given for 2 days, then oral quinolones (ciprofloxacin 750 mg/12 hours) for further 5 days as well as analgesics, anti-oedema, anti-peptic ulcer drugs and prophylactic oral anticoagulant started 12 hours post-operative and continued till full mobilization and weight bearing, usually 4 weeks post-operative. Aggressive cryotherapy by ice packs was started immediately postoperative. Drain was removed within 24 hours postoperative. All cases were discharged from the hospital 24 hours postoperative. Dressings were changed after 1 week, and sutures were removed after 2-3 weeks.

Non-accelerated rehabilitation program was followed for all cases. Hinged knee brace was applied with gradual increase of ROM till full ROM at 4 weeks. Partial weight bearing with crutches was started immediately and increased till full weight bearing at 4 weeks. Isometric static muscle strengthening exercises were started immediately followed by closed chain kinetic then open chain kinetic exercises. Running in a straight line was started at 4 months then in a zigzag line. Return to training (RTT) was started at 6 months, while return to play (RTP) was started at 9 months.

Criteria of RTP were absent pain and swelling, normal ROM, gait, stability, balance and proprioception, quadriceps and hamstrings strength ≥ 80% of the contralateral normal thigh, hop (single, triple, crossover and 6 meter timed) testing ≥ 90% of the contralateral normal side demonstrating good balance and landing mechanics and the ability to do sport-specific agility drills.[9]

All cases had been followed for 18 months and results scored and compared with the pre-operative status at the end of follow-up by **clinical evaluation** regarding pain, ROM and stability (lachman, anterior drawer tests for anterior instability and pivot shift test for lateral rotational instability) and using **IKDC** subjective and objective scores and **Lysholm** knee scoring scale.

Results

Mean operative duration was 118.3 (100-160) minutes.

Clinical outcomes

There was significant postoperative clinical improvement regarding pain, ROM (flexion and extension deficits) and stability (Lachman, anterior drawer and pivot shift test grades) (Table 1).

			Pre-operative		**Postoperative**		***P***
			N	**%**	**N**	**%**	
Pain			9	30%	1	3.3%	0.008
Flexion deficit	**Degree**	0◦	27	90.0%	28	93.3%	<0.001
		5◦	0	0%	2	6.7%	
		20◦	1	3.3%	0	0%	
		25◦	1	3.3%	0	0%	
		30◦	1	3.3%	0	0%	
	Mean ± SD		2.5 ± 7.7		.3 ± 1.3		<0.001
	Range		0-30◦		0-5◦		
Extension Deficit	**Degree**	0◦	27	90.0%	30	100.0%	<0.001
		5◦	1	3.3%	0	0%	
		10◦	2	6.7%	0	0%	
	Mean ± SD		.8 ± 2.7		0		<0.001
	Range		0-10◦		0		
Lachman test		Grade 0 (negative)	0	0%	21	70%	
		Grade 1 (<5 mm), firm endpoint	0	0%	9	30%	

	Grade 2 (5-10mm), soft endpoint	17	56.7%	0	0%	<0.001
	Grade 3 (>10mm), soft endpoint	13	43.3%	0	0%	
Anterior drawer test	Grade 0 (negative)	0	0%	21	70%	<0.001
	Grade 1 (<5 mm)	0	0%	9	30%	
	Grade 2 (5-10mm)	17	56.7%	0	0%	
	Grade 3 (>10mm)	13	43.3%	0	0%	
Pivot shift test	Grade 0 (negative)	0	0%	25	83.3%	<0.001
	Grade 1 (glide)	0	0%	5	16.7%	
	Grade 2 (clunk)	23	76.7%	0	0%	
	Grade 3 (gross)	7	23.3%	0	0%	

Table 1 Comparison between pre-operative and postoperative pain, ROM and stability among all studied cases.

Return to sports

Fourteen (87.5%) of sixteen cases sharing in sports returned to their pre-injury sport level and activity, while 2 cases (12.5%) couldn't return; one case (recreational football) due to anterior knee pain and tightness due to quadriceps myositis ossificans caused by QT graft and the other case (recreational football) due to associated lumbosacral disc prolapse. Mean time to return to sports (same pre-injury level) was 8.7 (7-12) months.

Scoring systems

Also there was significant postoperative improvement regarding IKDC subjective and objective scores and Lysholm scoring scale (Tables 2-4).

		Cases N=30		
		Pre-operative	**Postoperative**	***p***
Subjective IKDC score	**Mean ± SD**	55.4 ± 10.0	92.5 ± 5.5	<0.001
	Range	23-67	75-100	

Table 2 Pre-and postoperative subjective IKDC score among all studied cases.

		Cases N=30				
		Pre-operative		**Postoperative**		***p***
		N	**%**	**N**	**%**	
Objective IKDC score	**Severely Abnormal (D)**	28	93.3%	0	0%	<0.001
	Abnormal (C)	2	6.7%	0	0%	
	Nearly normal (B)	0	0%	9	30%	
	Normal (A)	0	0%	21	70%	

Table 3 Pre- and postoperative objective IKDC score among all studied cases.

			Cases N=30				
			Pre-operative		**Postoperative**		***p***
Lysholm score	**Score**	**Mean ± SD**	53.9 ± 9		94.3 ± 2.7		<0.001
		Range	30-62		90-100		
	Poor	N, %	30	100%	0	0%	<0.001
	Good	N, %	0	0%	2	6.7%	
	Excellent	N, %	0	0%	28	93.3%	

Table 4 Pre-and postoperative Lysholm score among all studied cases.

Complications

Five cases (16.7%) had complications, one case (3.3%) had anterior knee pain and tightness and quadriceps myositis ossificans due to QT graft, one case (3.3%) had temporary post-tourniquet sensory manifestations for 2 weeks, one case (3.3%) had infrapatellar branch of saphenous nerve neuralgia spontaneously relieved within 3 months, one case (3.3%) had graft site superficial infection treated by dressings and short time antibiotics and one case had knee stiffness due to arthrofibrosis (delayed gradual rehabilitation due to medial and lateral bucket handle meniscal repair) leading to limited flexion to 90º treated by arthroscopic release and manipulation under anesthesia 4 months postoperative followed by aggressive physiotherapy with final 5º flexion deficit.

Discussion

During the last few decades, ACLR surgery has been significantly advanced with 75-90% of cases reporting good to excellent outcomes, while 10-25% will require revision due to ACLR failure.[10]

ACLR failure has been reported in a lot of cases without obvious causes despite adequate anatomic reconstruction, graft fixation and postoperative rehabilitation, leading to increased interest in detection of associated pathologies to avoid these failures. One of the most important causes was persistent ALRI with persistent positive pivot shift test of varying grades in 15-30%.[4]

A lot of surgical procedures have been reported to control ALRI as anatomic SB-ACLR with more horizontal graft, anatomic DB-ACLR or combined SB-ACLR and ALC reconstruction either non-anatomic by LEAT or anatomic by ALLR.[11] However, some SB and DB reconstructions do not restore normal kinematics under simulated pivot-shift loads in vivo and in vitro, even after successful reconstruction.[12] So several studies have profusely discussed the role of ALC reconstruction techniques in treatment of ALRI.[2,5,6]

Several studies compared LEAT to ALLR, combined with anatomic SB-ACLR for cases with high risk of ALRI and reported better results with LEAT producing more significant composite reduction of tibial anterior translation and internal rotation with easier technique and less cost, intra- and postoperative complications.[5,13]

The results of the current study were comparable to a lot of studies using similar technique and other studies using different techniques to control ALRI as isolated anatomic SB-ACLR and combined anatomic SB-ACLR and ALLR.

In comparison to studies using isolated anatomic SB-ACLR to manage ALRI as **Williams et al.**[14], **Rowan et al.**[15], **Getgood et al.**[16] **and Mahmoud et al.**[17], all studies reported non-significant flexion and extension deficits and great improvement on Lachman, anterior drawer and pivot shift testing without significant differences at the final follow-up .
Mean time to return to sports in the current study was earlier than in **Getgood et al.**[16], 11 (8-14) months and later than in **Rowan et al.**[15], 8 (4-14) months.

Mean postoperative subjective IKDC score was higher than in **Getgood et al.**[16] (86.6) and lower than in **Mahmoud et al.**[17] (96). Mean Lysholm score was higher than in **Rowan et al.**[15] (90) and **Mahmoud et al.**[17] (91.3).

This study reported less complications with only one re-operated case (3.3%) and no reported ACL graft failure or complications related to LEAT. Other studies had higher rate of graft failure and re-operation. **Williams et al.**[14] reported 4 cases (8.3%) with complications and all re-operated; graft failure at 8 months, cyclops lesion, haemoarthrosis and medial meniscus tear + arthrofibrosis. **Rowan et al.**[15] reported 13 cases (10.4%) with graft failure with 8 of them had supplemental LEAT during

revision. **Getgood et al.[16]** reported 34 cases (12%) with ACL graft failure. **Mahmoud et al.[17]** reported 15 cases (20.8%) with complications, 9 cases (12.5%) with graft failure, one case with DVT, one case with superficial wound infection and 4 cases with subsequent meniscus tear.

In comparison to studies using similar technique as **Williams et al.[14], Rowan et al.[15]**, **Getgood et al.[16]**, **Mahmoud et al.[17]**, **Alm et al.[18]**, **Ahn et al.[19]**, all studies reported non-significant flexion and extension deficits and great improvement on Lachman, anterior drawer and pivot shift with negative results in most cases and grade 1 in the rest of cases, while **Alm et al.[18]** reported 2 cases (3.4%) and **Ahn et al.[19]** reported one case (2.1%) with grade 2 pivot shift test.

Mean time to return to sports was earlier than in **Getgood et al.[16]**, 11 (8-17) months, and later than in **Rowan et al.[15]**, 6 (5-12) months.

All studies reported significantly improved scores. Mean postoperative subjective IKDC score was higher than in **Mahmoud et al.[17]** (78), **Getgood et al.[16]** (87.3) and **Alm et al.[18]** (90) while was lower than in **Ahn et al.[19]** (93.3). Mean Lysholm score was higher than in **Mahmoud et al.[17]** (84.2), while was lower than in **Rowan et al.[15]** (98) and **Alm et al.[18]** (95).

Other studies reported higher incidence of re-operation, ACL graft failure and complications related to LEAT. **Williams et al.[14]** reported 4 cases (8.2%) with complications and all re-operated, one case with cyclops lesion and medial meniscus tear, one case with retropatellar fat pad syndrome, one case with medial meniscus tear and one case with flexion stiffness did MUA. **Alm et al.[18]** reported 3 cases (5%) with ACL graft failure. **Mahmoud et al.[17]** reported 7 cases (9.7%) with complications, 4 cases (5%) with graft failure, 3 cases with meniscal tears did subsequent arthroscopy.

Getgood et al.[16] reported 11 cases (4%) with graft failure and some complications related to LEAT, one case with intraoperative iatrogenic LCL injury did immediate repair, 3 cases with immediate postoperative haematoma, 14 cases with LEAT staple irritation with 10 cases re-operated for removal, 2 cases with ITB snapping and one case with lateral compartment over-constraint. **Ahn et al.[19]** reported one case (2.1%) with delayed protrusion of the LEAT screw with limited flexion and pain treated by screw removal with complete recovery.

In comparison to studies using combined anatomic SB-ACLR and ALLR to manage ALRI as **Sonnery-Cottet et al.[6]** and **Abdelrazek et al.[21]**, **Abdelrazek et al.[21]** reported more flexion and extension deficits, with one case (5%) with 15º and one case (5%) with 25º flexion deficit, while 2 cases (10%) with 10º extension deficit. Regarding stability, all studies reported good results without grade 2 Lachman or pivot shift tests.

Mean postoperative subjective IKDC score was higher than in **Sonnery-Cottet et al.[6]** (84.4). Mean Lysholm score was higher than in **Sonnery-Cottet et al.[6]** (91.8) and **Abdelrazek et al.[21]**

Sonnery-Cottet et al.[6] reported 40 cases (8%) with ACL graft failures (37 underwent revision) and 51 cases (10.2%) underwent re-operation for non-failure causes.

Limitations

However there are some limitations in this study; small number of cases were included, there was no pre- and postoperative instrumental clinical and radiological assessment of ALRI, depending only on subjective measures and objective manual testing, the follow-up was limited to 18 months and longer follow-up would be necessary for better evaluation of the benefits and the potential long-term complications of this surgical procedure as OA changes especially the lateral compartment due to over-constraint that may result from LEAT and finally comparative studies with control groups would

be more useful in evaluating the results of this surgical procedure with respect to either isolated anatomic SB- or DBACLR or combined with ALLR technique.

Conclusion

Combined anatomic SB-ACLR with LEAT using modified Lemaire procedure exhibits good to excellent results for treatment of ALRI regarding postoperative stability and return to the same pre-injury level of activity and sports within adequate time without considerable complications of LEAT and less incidence of ALCR failure than reported after isolated anatomic SB- and DB-ACLR.

Less postoperative complications were reported after neutral tibial rotation during LEAT fixation and with using bio-absorbable interference screws for fixation rather than bone staples.

Larger number of cases, longer clinical and radiological follow-up duration and comparative studies with control groups are recommended for better evaluation of the benefits and the potential long-term complications of LEAT using modified Lemaire procedure.

Funding This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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