

Review Article

Functional Outcomes in the Management of ACL Rupture by ACL Reconstruction with Lateral Extra-articular Tenodesis Lemaire Procedure Versus MacIntosh Procedure: A Systematic Review

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Abstract

The purpose of this study was to systematically review the functional outcomes between lateral extraarticular tenodesis (LET) Modified Lemaire procedure and MacIntosh modified by Cocker-Arnold procedure other than ACL reconstruction (ACLR) alone in studies with high levels of evidence.

We performed a literature search for clinical studies comparing the LET Modified Lemaire procedure and MacIntosh modified by Cocker-Arnold procedure as an augmentation to ACLR with ACLR alone. The primary outcomes were the International Knee Documentation Committee (IKDC) score, the Lysholm score, and graft failures.

A systematic search on the literature was performed online from the inception dates to July 2022. Based on the screening of abstracts and titles, a total of 123 records were excluded. The authors independently based on the extracted full text. This selection process resulted in the final 6 articles for inclusion in the systematic review. The remaining 6 studies were eventually included, consisting of 2 randomized controlled trials, 2 retrospective studies and 2 prospective studies. ACLR with the LET provides better functional outcomes than ACLR alone, whereas between the two LET i.e. Lemaire and MacIntosh in the ACLR action do not give different functional outcomes.

ACLR with the LET provides better functional results than ACLR without the LET, the LET provides better rotational stability than ACLR alone, and also lower graft failures than ACLR alone. Meanwhile, between the two LET, namely the Lemaire and MacIntosh in ACLR, do not give different functional results because they can maintain rotational stability to reduce the incidence of graft failure and later will provide better functional outcomes.

Introduction

Despite a long history of differing surgical procedures, controlling anterolateral rotational laxity of the knee after anterior cruciate ligament (ACL) rupture remains a challenge. The results of a primary intraarticular anterior cruciate ligament reconstruction (ACLR) are excellent, with approximately 90% of patients achieving normal or near-normal knee function.

However, these results are not universal. Studies have reported 11%–30% recurrent and persistent instability.¹

Traditional, single-bundle anterior cruciate ligament reconstruction (ACLR) techniques have been demonstrated to provide good subjective results; however, multiple studies have shown that many patients continue to have complications related to the procedure. Failure of ACLR might be caused by anterolateral rotational instability due to the

inadequacy of the intraarticular graft to recreate normal knee kinematics. One of the proposed solutions is to use lateral-based soft-tissue reconstructive techniques in addition to ACLR.²

The structures that stabilize the lateral aspect of the knee are in a complex arrangement. Understanding the anatomy of this area may be crucial in determining whether any extra-articular reconstruction is likely to be desirable at the time of ACL reconstruction.³

David et al describe about advantage of the lateral extraarticular tenodesis (LET) procedure (1) Offers additional anterolateral rotary instability when used in conjunction with anterior cruciate ligament reconstruction. (2) Does not use soft tissue autografts that are commonly used for other knee ligament reconstructions. The disadvantage of the LET procedure is (1) Potentially overconstrains knee internal rotation. (2) Requires additional lateral incision and dissection.⁴

MacIntosh modified by Cocker-Arnold procedure. After the intraarticular reconstruction was fixed, the incision on the lateral side was extended to 10 to 12 cm in a hockey-stick fashion, extending from the Gerdy tubercle proximally to just inferior to the lateral epicondyle while the knee was flexed to 90°. The proximal extent of this incision parallels the midportion of the iliotibial tract. The fascia lata was exposed and incised along its fibers about 3 cm from the posterior border. With 1 cm of the iliotibial tract left intact posteriorly, a 1 cm-wide and 13-cm long strip of the iliotibial tract was detached proximally, leaving intact its distal attachment on the Gerdy tubercle. The lateral collateral ligament was identified, and the proximal part of the strip was passed under the ligament; the band was then reflected on itself and sutured under tension with periosteal absorbable stitches to the Gerdy tubercle while the tibia was held in maximal external rotation. Since we started using the described technique, we have always successfully used absorbable stitches (Vicryl) with no complication. Therefore, we consider their use suitable for the described procedure. The strip was also sutured to the fibular collateral ligament for additional stability. A combined reconstruction required an additional surgical time of 15 minutes.⁵

Modified Lemaire procedure. To begin, with the patient positioned supine and the knee in 90° of flexion, a lateral incision is performed beginning at the level of the femoral insertion of the lateral collateral ligament (LCL) and extended proximally for 5 cm. Dissection is taken through sub-cutaneous tissues to the ITB. A central 8-cm x 1-cm strip of ITB is harvested and left attached distally to Gerdy's tubercle. Care is taken to avoid the important Kaplan's fibers posteriorly. The ITB graft is then whipped and stitched. After the LCL is identified, the graft is passed deep (medial) to the LCL. Intraoperative fluoroscopy (mini c-arm) is recommended to confirm the positioning of a drill guide directed distally to the distal femoral physis

with an anterior trajectory (to avoid convergence with the femoral socket of the ACLR) and just proximal and posterior to the femoral insertion of the LCL. In 30° of flexion and neutral rotation, the ITB graft is secured with an all-suture anchor. We currently prefer fixation with an all-suture anchor; however, PEEK (polyether ether ketone) or biocomposite suture anchors also may be used at the surgeon's discretion. The ITB graft is then passed lateral to the LCL and secured to itself using a nonabsorbable suture to complete the tenodesis. The ITB donor defect is then closed using nonabsorbable sutures in an interrupted simple fashion to complete the LET.⁶

Methods

Search Strategy

Focused literature searches were primarily conducted using Google Scholar and PubMed/MEDLINE, from their inception dates to July 2022. To optimize the sensitivity and specificity of the search method and identify all research, use the keywords listed below in combination with Boolean "AND" and "OR" phrases. Search terms: "Anterior Cruciate Ligament Rupture", "Anterior Cruciate Ligament Reconstruction", "Lemaire procedure", "MacIntosh procedure", and "outcomes".

Inclusion Criteria

One reviewer screened the search results. Operative management of patients with ACL rupture and planned to undergo ACL reconstruction with arthroscopy and combination with lateral extra-articular tenodesis Modified Lemaire procedure or MacIntosh Modified by Cocker-Arnold procedure and evaluation functional outcome in this systematic review. Patients with ACLR with ALL reconstruction, pharmacological treatment, nutrition treatment, and physical therapy or rehabilitation which stands alone were excluded. Patient ACL rupture with concomitant PCL was excluded in this systematic review. Other than studies using English were excluded in this systematic review.

Quality Evaluation

This was done, and based on inclusion criteria the authors filtered eligible studies through titles and abstracts. Then, the authors screened the complete studies from all the studies that were collected. The author is looking for publications that are very relevant to be included in this research. The author also assessed the quality of the study.

Result

The electronic search returned 123 records, after removing duplicate results. Based on duplicate records, screening of abstracts and titles, a total of 117 records were excluded. The authors independently based on the extracted full text. This selection process resulted in the final 6 articles for inclusion in the systematic review

Study Component	Inclusion	Exclusion
Population	Patients aged >18 years or older with primary ACL rupture and planned to undergo ACL reconstruction with arthroscopy.	<ul style="list-style-type: none"> • Animal studies. • Revision cases of ACL reconstruction. • Concomitant PCL. • Underlying congenital condition or neoplasm.
Intervention and Comparison	ACL reconstruction with lateral extra-articular tenodesis (Modified Lemaire procedure, MacIntosh Modified by Cocker-Arnold procedure)	<ul style="list-style-type: none"> • ACLR with (ALL) reconstruction. • Pharmacologic treatment. • Nutrition treatment. • Physical therapy or rehabilitation which stands alone.
Control	ACL Reconstruction alone	
Outcome	Measures clinical outcomes including the IKDC score, Lysholm score, report of graft failure	<ul style="list-style-type: none"> • Study is ongoing, and no results have been reported. • Outcome measures not reported in completion. • Other than a study using English
Publication	Studies published in English Listed in PubMed or Google Scholar Archives	Proceedings, Presentations Abstracts, Editorials, Letters Duplicate publications of the same study Studies published in languages other than English
Study Design	Retrospective study Prospective study Randomized control trial	Case reports, review articles

Abbreviations: PICO, Population-Intervention-Comparison-Outcome

Table 1. PICO Table Describing Inclusion and Exclusion Criteria

and is depicted in Figure 1. The remaining 6 studies were eventually included, consisting of 2 randomized controlled trials, 2 retrospective studies and 2 prospective studies. The details of this study are listed in Table 2.

According to a study by Castoldi et al. (2020) they used the modified Lemaire procedure for lateral extraarticular tenodesis (LET). The research conducted with a total sample of 61 samples for the ACLR alone group and 60 samples for the ACLR group with lateral extraarticular tenodesis. Functional outcomes obtained from the 2 groups were followed up for 19.4 years (19–20.2 years) of follow-up for each group, for the IKDC score 81.1 (42.5–100) for the ACLR group alone, 82.4 (55.2–100) for the ACLR group with LET. Meanwhile, the Lysholm score was 86.6 (42–100) for the ACLR alone group, 90.3 (67–100) for the ACLR group with LET, as well as graft failure which was reported as 47.54% in the ACLR alone group, and 21.67% in the ACLR group with LET.⁷

Getgood et al. (2020) also explained in their research that were comparing 2 groups. The first group was ACLR alone and the second group was ACLR with modified Lemaire. From this study, the IKDC score for the first group was 86.6 ± 0.8, and for the second group 87.3 ± 0.8. The Lysholm score was not described in the study. As for graft failure, it obtained as much as 11.37% for the first group and 3.7% for the second group.⁸

Research conducted by Porter et al. (2020) also explained the same thing with the functional outcomes obtained from each group, namely the IKDC score with a value of 90.9 ± 10.7 for ACLR alone and 94.2 ± 11.2 for the ACLR group with the LET procedure. The Lysholm score was reported as 92.5 ± 4.8 for the ACLR alone group and 96.8 ± 8.0 for the ACLR group with LET. According to graft failure, it was reported that 14.8% occurred in ACLR alone and 0% in ACLR with LET. The LET procedure used in the study conducted by Porter et al was MacIntosh modified by Cocker-Arnold.⁹

Rowan et al. (2019) also conducted a study using a prospective design study, using 171 total samples and followed up for 2 years. Lysholm score for the ACLR alone group was 90 (70–100) and for the ACLR group with LET procedure using Modified Lemaire was 98 (75–100) and 5.9% for graft failure for the ACLR group alone and 0% for the ACLR group with the Modified Lemaire procedure.¹⁰

Based on research by Ferretti et al. (2016) which compared 2 groups, namely the ACLR group alone with the ACLR group with the LET procedure (MacIntosh modified by Cocker-Arnold). In a study conducted by Ferretti et al, was followed up for 10 years and 5 months (121–128 months) for each group with a total sample of 140. From the evaluated functional outcome, the IKDC score was 93.77 ± 6.63 for

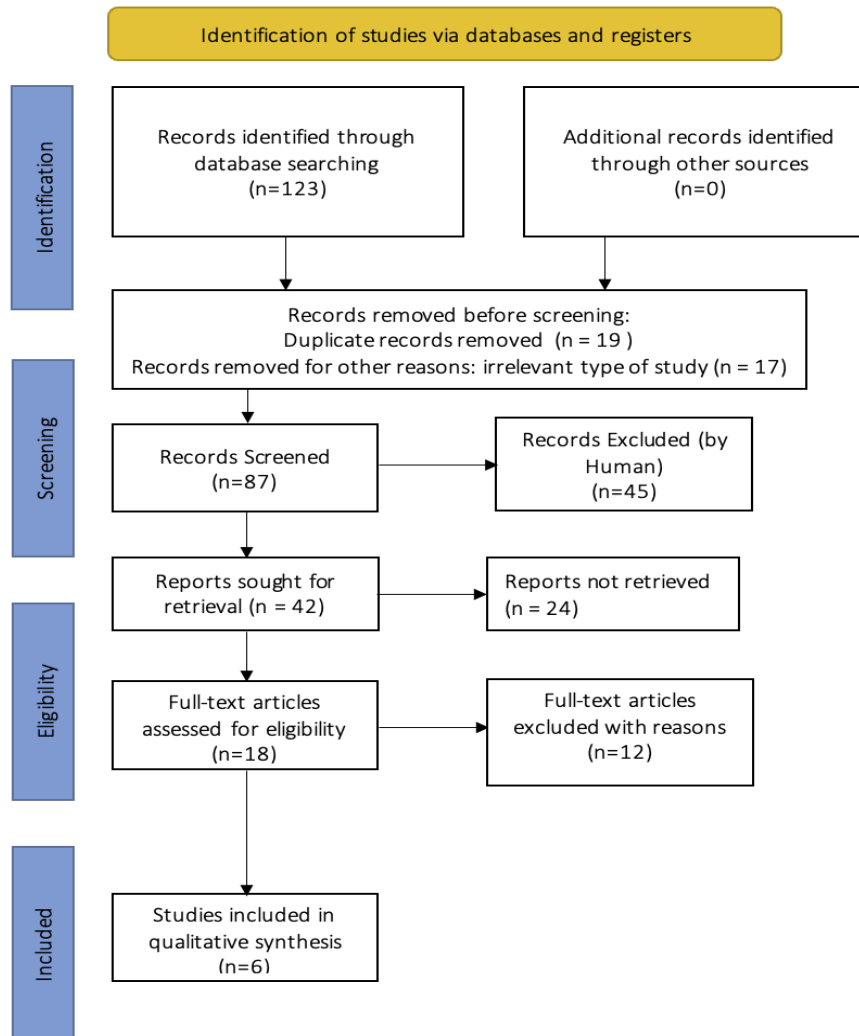


Figure 1. Flow chart showing article selection

the ACLR alone group and 96.19 ± 3.3 for the ACLR group with LET. Meanwhile, the Lysholm score was 95.46 ± 5.68 for the ACLR group alone and 96.24 ± 3.5 for the ACLR group with the LET procedure. From the graft evaluation, it was found that graft failure was 11.1% for the ACLR alone group and 0% for the ACLR group with the LET procedure.⁵

From the research conducted by Antonio et al. (2012) used a prospective study design comparing anterior cruciate ligament reconstruction (ACLR) alone with ACLR with lateral extraarticular tenodesis (LET) procedure. The LET procedure used is the MacIntosh modified by Cocker-Arnold. From the research conducted, the functional outcome of total samples was 55 patients, with an IKDC score of 87 ± 1.8 for the ACLR alone group, and 89 ± 1.5 for the ACLR group with LET. Meanwhile, the Lysholm score was 94.5 ± 6.65 for the ACLR group alone, and 95.8 ± 3.99 for the ACLR group with LET. The reported graft failure percentage was 6.2% for the ACLR alone group and 0% for the ACLR group with LET.¹¹

Discussion

Based on several studies that compared the ACLR procedure alone with the ACLR accompanied by the LET procedure, namely the Lemaire procedure and MacIntosh procedure, there was an increase in functional outcome between the ACLR alone group and the ACLR with the LET procedure assessed based on the IKDC score and Lysholm score, as well as the most graft failures, occurs in ACLR alone. Meanwhile, the Lemaire and MacIntosh procedure did not show any difference, they both produced better functional results compared to ACLR alone in ACL injury.

Residual instability, notch impingement, and graft re-tear in ACL-reconstructed knees is commonly associated with failure to return to sports. The residual pivot-shift phenomenon may lead to secondary meniscal injury or osteoarthritis development. Hence, controlling pivot shifts is one of the critical factors for improving outcomes after ACLR. The combined ACLR and LET reconstruction in patients with ACL injury is

No	Reference	Journal	Study Design	Level of Evidence
1.	Castoldi et al, 2020	The American Journal of Sports Medicine	Randomized Controlled Trial	II
2.	Getgood, et al, 2020	The American Journal of Sports Medicine	Randomized Controlled Trial	II
3.	Porter et al, 2020	The American Journal of Sports Medicine	Retrospective study	III
4.	Rowan et al, 2019	Archives of Orthopedic and Trauma Surgery; Springer	Prospective study	II
5.	Ferretti et al, 2016	Arthroscopy: The Journal of Arthroscopic and Related Surgery	Retrospective study	III

Table 2. Studies included in the analysis

Validity	Castoldi et al. (2020)	Getgood et al. (2020)	Porter et al. (2020)	Rowan et al. (2019)	Ferretti et al. (2016)	Antonio et al. (2012)
Same Population	●	●	●	●	●	●
Similar exposure	●	●	●	●	●	●
Exposure measurement	●	●	●	●	●	●
Confounding factors	●	●	●	●	●	●
Strategies to deal with confounding factors	●	●	●	●	●	●
Free of the outcome at the start	●	●	●	●	●	●
Outcome measurement	●	●	●	●	●	●
Follow up time	●	●	●	●	●	●
Follow up completeness	●	●	●	●	●	●
Strategies to address incomplete follow up	●	●	●	●	●	●
Statistical analysis	●	●	●	●	●	●

Note: Green, clearly stated; Blue, unclearly stated; Red, not stated.

Table 3. Eligibility Assessment of Included Studies

an effective and safe solution and leads to good functional outcomes with no increase in complications and aids in early return to preinjury activities with a surviving healthy graft. We recommend its application in indicated cases, especially when MRI documents ALL injuries.¹²

The most important finding of the present study is that the combination of LET. to ACLR is a safe and effective surgical option in young patients with ACL rupture. Clinical scores at follow-up were satisfactory in the study group, and 86% of patients could return to their pre-injury sports level. Furthermore, in this study, no case of graft failure occurred. The most common complication of ACLR in skeletally immature patients is graft failure, observed in up to 25% of patients undergoing ACLR. The absence of graft failure cases in

our series could be attributable to the combination of LET to ACLR. Indeed, extra-articular augmentation between the tibia and femur on the lateral side of the knee could prevent internal rotation of the tibia, stabilize the knee, and protect the reconstructed ligament.¹³

In their metaanalysis, Rezende et al found no significant differences in functional outcome between ACL reconstruction with or without LET, though there was a clear reduction in high-grade pivot-shift test in the LET-treated groups. This observation is shared in a systematic review by Song et al, which noted that isolated ACL reconstruction is sufficient to handle only low-grade pivot shift. Dutton et al, found that, besides improving rotational control of the knee, LET, also reduced by more than 40% the stress of intra-articular reconstruction, which is especially useful in ACL revision. Noyes and Barber²¹ reported a significantly lower re-rupture rate when ACL reconstruction was combined with LET.¹⁴

The rationale of combining intra and extra-articular procedures in ACL reconstruction is to restrict the internal rotation of the reconstructed knee, thus providing more stability in the knee in the rotational axis and preventing the ACL graft from undergoing further excessive stress. Many studies have already investigated the role of such extra-articular procedures. Anderson et al, as well as Roth et al, showed no improvement with the addition of an extra-articular procedure. Completely different conclusions were shown by Lerat et al. and Noyes et al., which showed the results of two prospective studies with significantly better results in patients with an extra-articular procedure. In conclusion study Vadala et al., the combination of an extra-articular MacIntosh procedure modified by Cocker-Arnold with ACL reconstruction seems to significantly reduce the rotational instability of the knee.¹¹

David et al. also describe when performed in addition to an ACL reconstruction, LET procedures have been demonstrated to significantly reduce anterior tibial translation and anterolateral rotary instability in addition to reducing the force experienced by the graft when an anteriorly directed load was applied. This does come at the cost of over-constraint of the knee, with decreased tibial internal rotation across various flexion angles from 0° to 90°. However, persistent anterolateral rotary instability occurring after ACL reconstruction leads to poor patient outcomes and increased risk of graft failure; thus, LET procedures may be able to help improve patient outcomes when used as an adjunct to ACL reconstruction by helping to restore normal rotational stability.⁴

Finally, this study has several limitations: (1) The studies included are of level II and III evidence; (2) The heterogeneity of some analyses is high; (3) Due to the

No	Study (year)	LET Technique	LET Graft	ACLR Technique	ACLR Graft	Age		Gender		Sample		Mean follow up	
						ACLR alone	ACLR + LET	ACLR alone	ACLR + LET	ACLR alone	ACLR + LET	ACLR alone	ACLR + LET
1.	Castoldi et al. (2020)	Modified Lemaire	Gracilis	N/A	Bone patellar tendon bone graft	26 years (15-40 years)	26 years (15-40 years)	Male: 43(70%) Female: 18(30%)	Male: 47 (78%) Female: 13 (22%)	61	60	19.4 years (19-20.2 years) follow up	19.4 years (19-20.2 years) follow up
2.	Getgood et al. (2020)	Modified Lemaire	Iliotibial band	Various	Semitendinosus and/or gracilis.	26 years (15-40 years)	18.9 years (14-25 years)	Male: 151 (48%) Female: 161(52%)	Male: 151 (49%) Female: 155 (51%)	312	306	24 months follow up	24 months follow up
3.	Porter et al. (2020)	MacIntosh modified by Cocker-Arnold	Iliotibial band	Standard knee arthroscopy surgery	Doubled autologous hamstring tendon graft	22.3 ± 3.7 years	21.8 ± 4.1 years	Male: 12(44.4%) Female: 15(55.6%)	Male: 11 (39.2%) Female: 17 (60.8%)	27	28	2 years follow up	2 years follow up
4.	Rowan et al. (2019)	Modified Lemaire	Iliotibial band	Single bundle	Doubled gracilis and semitendinosus hamstring graft	29 years (15-56 years)	27 years (16-64 years)	Male: 67 (54%) Female: 58 (46%)	Male: 27 (59%) Female: 19 (41%)	125	46	2 years follow up	2 years follow up
5.	Ferretti et al. (2016)	MacIntosh modified by Cocker-Arnold	Iliotibial band	Single Bundle	Semitendinosus and gracilis	27.3 years (18-50 years)	25.7 years (18-46 years)	Male: 51 (71%) Female: 21 (29%)	Male: 56 (82%) Female: 12 (18%)	72	68	10 years 5 months (121-128 months) follow up	10 years 5 months (121-128 months) follow up
6.	Antonio et al. (2012)	MacIntosh modified by Cocker-Arnold	Iliotibial band	Anatomical Out-In technique,	Hamstring tendon graft	28 years (15-40 years)	27 years (15-40 years)	N/A	N/A	28	27	44.6 months (36-50)	44.6 months (36-50)

Abbreviations: LET, Lateral Extraarticular Tenodesis; ACLR, Anterior Cruciate Ligament Reconstruction; N/A, Not Available

Table 4. Sample characteristics of included studies

No	Study (year)	IKDC			Lysholm			Graft failure (%)		
		ACLR alone	ACLR + Modified Lemaire Technique	ACLR + MacIntosh Modified by Cocker-Arnold Technique	ACLR alone	ACLR + Modified Lemaire Technique	ACLR + MacIntosh Modified by Cocker-Arnold Technique	ACLR alone	ACLR + Modified Lemaire Technique	ACLR + MacIntosh Modified by Cocker-Arnold Technique
1.	Castoldi et al. (2020)	81.1 (42.5–100)	82.4 (55.2–100)	N/A	86.6 (42–100)	90.3 (67–100)	N/A	47.54%	21.67%	N/A
2.	Getgood et al. (2020)	86.6 ± 0.8	87.3 ± 0.8	N/A	N/A	N/A	N/A	11,37%	3,7%	N/A
3.	Porter et al. (2020)	90.9 ± 10.7	N/A	94.2 ± 11.2	92.5 ± 4.8	N/A	96.8 ± 8.0	14,8%	N/A	0%
4.	Rowan et al. (2019)	N/A	N/A	N/A	90 (70–100)	98 (75–100)	N/A	5,9%	0%	N/A
5.	Ferretti et al. (2016)	93.77 ± 6.63	N/A	96.19 ± 3.3	95.46 ± 5.68	N/A	96.24 ± 3.5	11,1%	NA	0%
6.	Antonio et al, (2012)	87 ± 1.8	N/A	89 ± 1.5	94.5 ± 6.65	NA	95.8 ± 3.99	6,2%	NA	0%

Abbreviations: IKDC, International Knee Documentation Committee; ACLR, Anterior Cruciate Ligament Reconstruction; N/A, Not Available

Table 5. Outcomes discussed in included studies

scarcity of studies, single and multilevel pathologies were all included into the analysis, where this may cause bias in the overall analysis; (4) there is no study comparison between Lemaire and MacIntosh procedure the study just comparison between ACLR alone with ACLR with LET procedure (Lemaire and MacIntosh procedure). However, to our knowledge, this study is the first to formulate a systematic review on this matter thoroughly. It is hoped that this study might be beneficial as a guideline in choosing appropriate methods of treatment for patients with anterior cruciate ligament rupture, while further inspiring other researchers to conduct well-designed trials with a bigger number of samples and performing subgroup analysis.

Conclusion

ACLR with the LET procedure provides better functional results than ACLR without the LET procedure, the LET procedure provides better rotational stability than ACLR alone and also lower graft failures than ACLR alone. Meanwhile, between the two LET procedures, namely the Lemaire and MacIntosh procedures in ACL reconstruction, they do not give different functional results because they can maintain rotational stability to reduce the incidence of graft failure and later will provide better functional outcomes.

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