Original Article

Good Surgical Outcomes After Concomitant Repair of Double Radial Tears of the Lateral Meniscus and Anterior Cruciate Ligament Reconstruction

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Purpose: To describe double radial tears of the lateral meniscus (LM), report early clinical treatment outcomes, and determine reoperation and failure rates. **Methods:** Twenty-one (N = 21) consecutive cases of arthroscopic-treated lateral meniscus double radial tears treated between 2012 and 2018 were reviewed, including 15 males (71.4%) and 6 females (28.6%). Meniscus repairs were all performed at the time of anterior cruciate ligament (ACL) reconstruction. Patients with associated fractures or prior surgeries were excluded. Concomitant injuries were reported, as were preinjury and postoperative Tegner scores, preoperative and postoperative visual analogue pain scale (VAS) scores, and postoperative International Knee Documentation Committee (IKDC) subjective scores. Reoperation and failure rates were documented. **Results:** Twenty-one (N = 21) tears were located in the posterior horn of the meniscus near the root attachment; 15 (71.4%) underwent all-inside repair, 4 (19.0%) underwent transtibial pull-through repair, 1 (4.8%) was partially debrided, and 1 (4.8%) was left untreated. Twenty-one tears (N = 21) were in the body of the meniscus; 7 (33.3%) were repaired, 7 (33.3%) were partially debrided, and 7 (33.3%) were left untreated. Thirteen patients (62%) had associated medial collateral ligament (MCL) injuries. Mean follow-up was 2.6 years. VAS at rest and with activity improved by 2.1 points ($P < .001$) and 3.1 points ($P = .017$) after surgery. The mean postoperative Tegner activity score was 6.4, and the mean IKDC score was 83.2 at final follow-up. Reoperation was required in 5 patients (23.8%), and the surgical treatment failed in 1 patient (4.7%). **Conclusions:** Double radial tears of the LM are uncommon injuries that occur in the setting of ACL tears, usually combined with MCL injury. The variety of surgical treatment techniques have a low failure rate at short-term follow-up. Patients tend to have good clinical outcomes with improvement in pain and overall function after surgically treating these injuries with simultaneous ACL reconstruction. **Level of Evidence:** Level IV, therapeutic study, case series

The lateral meniscus (LM) is vulnerable to injury with acute anterior cruciate ligament (ACL) and medial collateral ligament (MCL) tears, either in isolation or as combined injuries. The mechanism of the proposed injury is posterior subluxation of the femoral condyle on the tibia due to ACL disruption, and also the valgus mechanism with direct impact on the LM as a result of MCL failure.[1-3]

Various types of LM tears occur with ACL and MCL disruptions, but the posterior horn and meniscus body are the most commonly involved areas. A radial tear of the LM is often associated with a Grade III MCL tear.[4]

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Lateral meniscus radial tears or posterior horn root avulsions occur in up to 7% to 12% of ACL injured patients.[5,6] More recently, a lateral meniscus oblique radial tear (LMORT) near the root has been described in 18% of acute ACL injuries.[7] Avulsions or radial tears near the posterior meniscus root present unique diagnostic and surgical challenges.[8] Posterior root tears of the LM can be easily missed in preoperative magnetic resonance imaging (MRI) scanning, so it is critical to have a high suspicion in the setting of ACL injury.[9] In rare circumstances, it is possible to have coexisting radial tears of the posterior horn root *and* of the body of the LM, which have recently been termed "double radial tears of the lateral meniscus."[10]

Complete radial tears and root tears have significant biomechanical implications because of disruption of the circumferential fibers, resulting in complete dissipation of hoop stress resistance and meniscus extrusion. This injury is biomechanically comparable to complete meniscectomy.[11] The lateral compartment increased contact pressures and decreased contact area lead to detrimental effects on load transmission and increased risk of premature osteoarthritis. Meniscus repair can improve the aforementioned mechanical factors, restore contact pressures, and minimize the risk of arthritis.[12-14] Early root tear repair outcome studies demonstrate that both transtibial pull-through and suture anchor techniques are effective.[15,16]

Lateral meniscus double radial tear repair with an inside-out technique for the body tear and a transtibial pull-through technique for the posterior root tear has been previously described in a technical report.[10] However, there remains a lack of clinical information on injury patterns associated with these tears, and the results of operative management. Therefore the primary aims of this study were to describe double radial tears of the LM, report early clinical treatment outcomes, and determine reoperation and failure rates. We hypothesized that operative treatment of these injuries would result in sufficient pain control and functional outcomes at short-term follow up.

Methods

All consecutive, confirmed double radial tears of the LM with or without concomitant cruciate and collateral ligament rupture surgically repaired between 2012 and 2018 at two institutions (Mayo Clinic, Rochester, MN, and Columbia Orthopaedic Group, Columbia, MO) were eligible for inclusion in this institutional review board—approved study. All surgeries were performed by the senior authors (P.A.S., M.J.S., A.J.K.). Inclusion criteria included patients with double tears of the LM confirmed intraoperatively. Patients with associated fractures or prior surgeries were excluded.

Surgical technique

Figure 1 demonstrates a typical double radial LM injury on MRI. We begin with the body tear, as overtensioning of the posterior horn tear could make repair of the body tear difficult or impossible. An inside-out repair is preferentially used because it allows for smaller perforations and more sutures to be placed in a horizontal mattress fashion across the tear site, compared to all-inside repair[17] (Fig 2).

The posterior root repair is then performed using a transtibial pull-through technique using an adjustable meniscus root repair tibial guide (Arthrex, Naples, FL). The meniscus root cinch sutures are passed down through the tibial tunnel, and the knee is cycled to remove creep from the system. The sutures are tensioned with the knee in 90° of flexion, then secured to the anteromedial tibia with a biocomposite anchor (SwiveLock; Arthrex Naples, FL) (Fig 3). An all-inside technique is preferred for a LMORT near the root (Fig 4).[7]

Postoperative rehabilitation consisted of non-weightbearing for 6 weeks, with range of motion (ROM) limited from 0° to 90° for the first 4 weeks. Return to jogging was typically delayed until 4 to 6 months after surgery, and return to sport was typically achieved at 9 months from surgery.

Patient charts were reviewed for demographic information, including: age, gender, body mass index, tobacco use, and activity level. Intraoperative data, including concomitant and lateral femoral condyle cartilage injuries, were recorded. Knee ROM and outcome scores were measured after surgery, including visual analogue pain scale (VAS) at rest and with activity,[18] Tegner activity scale,[19] and International Knee Documentation Committee (IKDC) subjective scores.[20] All patients had VAS and Tegner activity scores obtained both before their injury and during the course of follow-up. IKDC scores were added to our knee preservation outcomes initiative at a later date and were limited to the postoperative period for all patients.

Failure was defined as reinjury of the previously operated LM by clinical or radiographic examination, by reoperation on the same meniscus with repair or meniscectomy, or by any further treatment/care sought for the injured meniscus.[21] Clinical success was defined as no reinjury, subsequent surgery, or further care to the injured meniscus.

Demographics and outcomes were reported using descriptive statistics, including means with standard deviations, ranges, and percentages, when appropriate. Continuous variables were compared using Wilcoxon/Kruskal-Wallis tests. Data were stored and analyzed using JMP Pro (v14.1.0, SAS Institute, Cary, NC). P values $< .05$ were taken to be significant. No power analysis was performed.

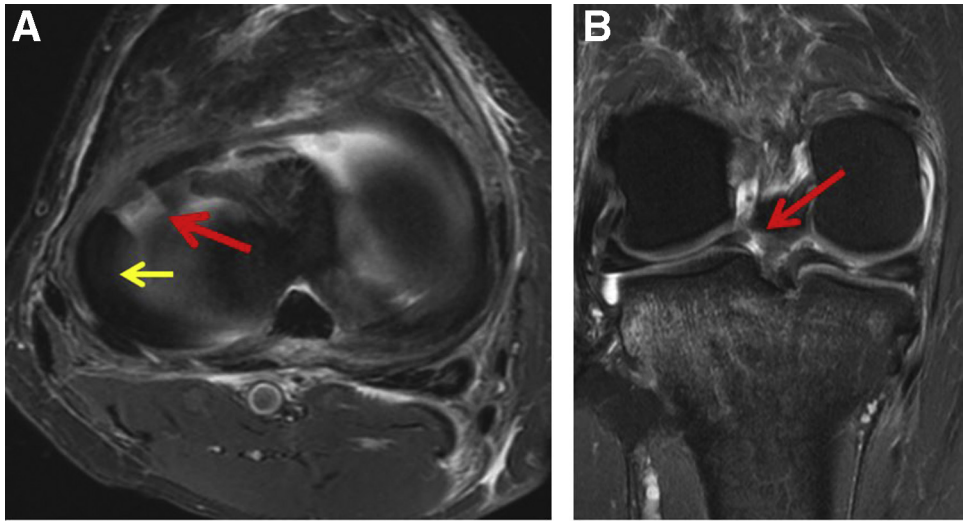

Fig 1. (A) T2-weighted axial magnetic resonance imaging (MRI) scan indicating a radial tear of the lateral meniscus body (*red arrow*) and extrusion of the meniscus (*yellow arrow*). (B) T2-weighted coronal MRI scan showing detachment of the posterior root of the lateral meniscus (*red arrow*).

Results

In total, 1,460 ACL reconstructions were performed by the senior authors between 2012 to 2018, of which 21 (1.4%) involved double radial tears of the LM meeting inclusion criteria. Twenty-one double radial tears were surgically treated in 21 patients with a mean age of 22 ± 10 years (range, 14-48) comprising 15 males (71.4%) and 6 females (28.6%) (Table 1). No patients were smokers. Patients were followed up for a mean 2.6 years. ACL injury and subsequent ACL reconstruction occurred in all patients. MCL injuries were identified in 13 patients (61.9%): four Grade III tears were treated with acute repair, and the remaining nine Grade II or lower tears were treated without surgery (Table 1). Lateral femoral condyle articular cartilage injuries were found in 18 of 21 patients (85.7%) patients, with Outerbridge grade II defects in 13 patients (72.2%).

A total of 21 meniscus radial tears near the root were diagnosed during surgery: 15 (71.4%) LMORTs were managed via all-inside repair, 4 radial tears within 5 mm of the root (19.0%) were repaired with a pull-through technique, 1 (4.8%) small incomplete oblique tear was partially debrided, and 1 (4.8%) incomplete radial oblique tear was left untreated (Table 2). Additionally, 21 meniscus body tears were diagnosed during surgery; 7 (33.3%) were repaired, 7 (33.3%) were partially debrided, and 7 (33.3%) were left untreated (Table 2).

Five patients (23.8%) underwent reoperation at a mean of 7.3 months from the index procedure. The reoperations included excision of fat pad fibrosis in 1 patient, notchplasty plus excision of scar tissue in 1 patient, lysis of adhesions in 2 patients, and excision of fat pad fibrosis plus partial lateral meniscectomy for a tear that was initially left untreated during index

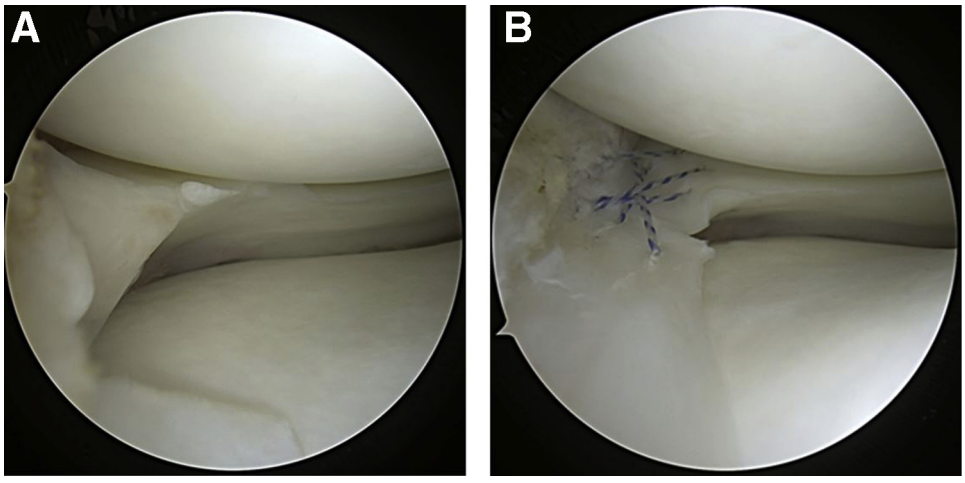

Fig 2. Arthroscopic views before (A) and after (B) the lateral meniscus body repair.

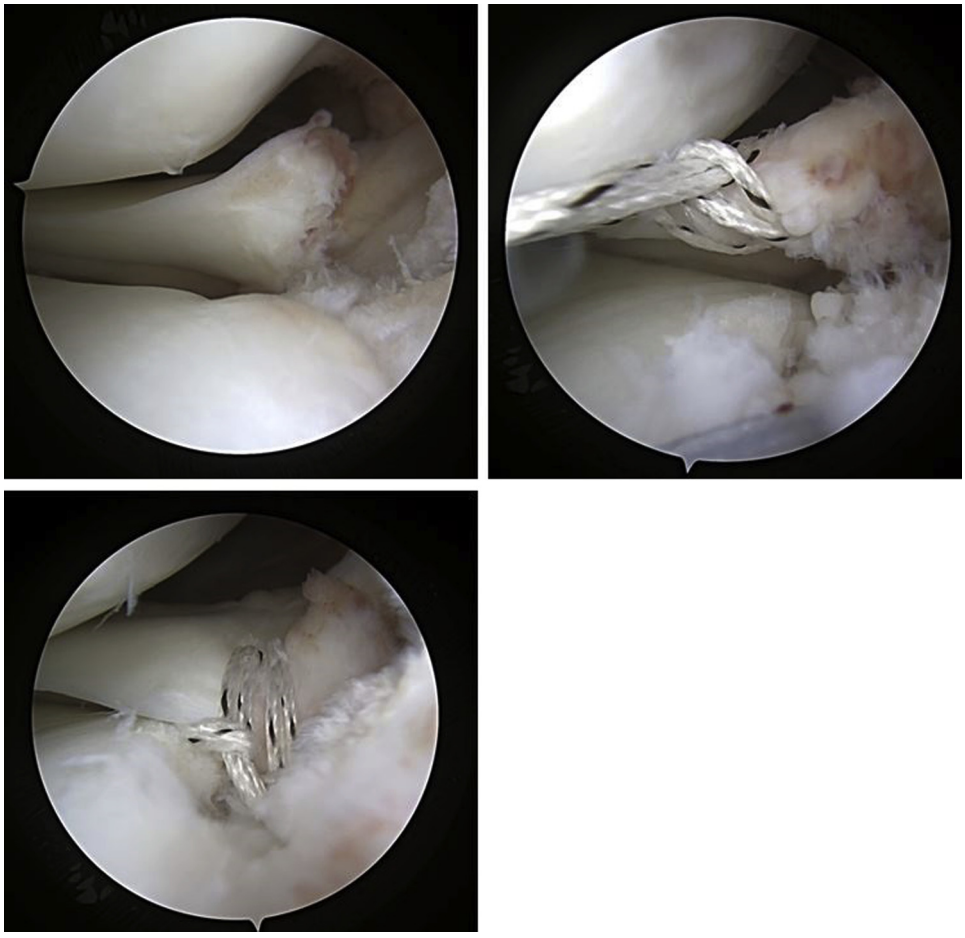

Fig 3. Arthroscopic images of the posterior root repair using two cinch sutures anchored through transtibial tunnel.

procedure in 1 patient. Lateral meniscus treatment failure rate was 4.7%.

Mean preoperative VAS at rest was 2.9 ± 1.8 and mean VAS with activity were 5.7 ± 3.0. The mean preinjury Tegner Activity Score was 5.7 ± 2.4 (Table 3). VAS scores at rest improved by 2.1 points (95% confidence interval [CI] 1.6-3.3; $P < .001$) (Table 3), and VAS scores with activity improved by 3.1 points (95% CI 2.5-5.9; $P = .017$) (Table 3) at final follow-up. Patients showed a slight improvement in activity level

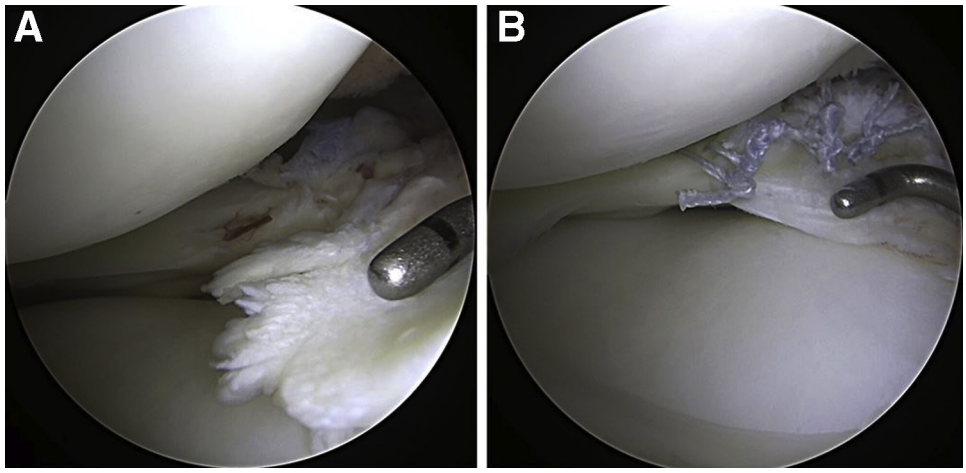

Fig 4. Before (A) and after (B) arthroscopic images of an all-inside repair of a lateral meniscus oblique radial tear.

Table 1. Patient Demographics and Injury Characteristics

Age at Surgery (y)	22 ± 10 (14-48)
Gender	
Male	15 (71.4%)
Female	6 (28.6%)
BMI	26.7 ± 4.6 (22.1-38.5)
Smoking status	
Nonsmoker	21 (100%)
Current smoker	0 (0%)
Former smoker	0 (0%)
Activity level	
Sedentary	0 (0%)
Recreational	5 (23.8%)
Competitive	16 (76.2%)
Unknown	0 (0%)
Laterality	
Right	16 (76.2%)
Left	5 (23.8%)
Concomitant Injuries	
MCL	13 (61.9%)
LCL	0 (0%)
ACL	21 (100%)
PCL	0 (0%)
ALL	2 (9.5%)
Medial meniscus	12 (57.1%)
Tibial cartilage	12 (57.1%)
Femoral cartilage	18 (85.7%)
LFC injury	
Yes	18 (85.7%)
Grade I	2 (11.1%)
Grade II	13 (72.2%)
Grade III	1 (5.5%)
Grade IV	2 (11.1%)
No	3 (14.3%)

BMI, body mass index.

after surgery, with an overall increase in Tegner activity levels by 0.7 points (95% CI −1.7 to 0.63); however, this was not statistically significant ($P = .334$). Mean IKDC score at final follow-up was 83.2 (Table 3).

Discussion

The presence of concomitant intraarticular and ligamentous injuries in the setting of acute ACL tears is well established. Meniscus tears occur in 60% to 75%, articular cartilage injuries in up to 46%, bone bruises in approximately 80%, and collateral ligament tears in 5% to 24% of cases.[22-29] In the current study, we found that double radial tears of the LM are uncommon injuries that occur in the setting of an acute ACL tear. A concomitant MCL injury occurred in 13 patients (62%), 4 of which were Grade III lesions (31%), requiring acute repair. It can be inferred that the valgus and rotational forces created by this combined ligamentous injury may lead to the development of multiple tears as opposed to an isolated tear of the LM. Femoral cartilage injuries were present in 18 patients (85%), with Grade II lesions representing the majority (72%). There were concurrent medial meniscus tears in 12 patients (57%). These findings are consistent with previously reported data.[22,23]

Surgical outcomes were good to excellent, with low failure rates and a high level of postoperative function. Reoperations were performed on 5 patients (23.8%). This reoperation rate is not surprising given the extent and severity of the initial injuries and the complexity of the index procedures. Four of the reoperations were for non-meniscus-related issues: excision of fat pad fibrosis, notchplasty, excision of scar tissue, and lysis of adhesions. At the time of reoperation, the LM was found to either be healing or healed in each of these cases. The other reoperation was a partial lateral meniscectomy for a tear that was initially left untreated during the index procedure, thus making the overall failure rate of LM treatment 4.7%. No reoperations were performed for re-tears, either of the ACL or of the meniscus. Wu et al.[30] previously reported a 20.8% reoperation rate at 5-year follow-up after concomitant radial meniscus repair and ACL reconstruction. This is comparable to our overall reoperation rate. Meniscus repair failure rates after concomitant ACL reconstruction have been reported at 26% to 40%.[31-33] Studies in adults have found meniscus healing rates of 55% to 90% after combined ACL reconstruction and meniscus repair.[34-36]

Our cohort included primarily sport-related injuries, occurring in both competitive and recreational athletes. Postoperative Tegner scores averaged 6.4, which was not significantly different from preinjury scores. VAS scores had improved significantly at final follow-up, with a mean 2.1-point improvement in VAS at rest from 2.9 to 0.8 ($P < .001$) and a 3.1-point improvement in VAS with activity, from 5.7 to 2.6 ($P = .017$). The postoperative IKDC scores averaged 83.2, which is comparable to previously reported outcomes in patients with meniscus tears and cartilage injuries noted at the time of ACL reconstruction,[37] and within the range of 82 to 92 reported in other radial repair series.[12,30,38,39] Postoperative knee ROM was excellent in all but 2 patients who had restricted flexion of 90° and 100° at 3- and 4.5-year follow-up, respectively. Excluding those patients, average ROM arc was 0.5° to 137° for the remainder of the cohort.

Treatment for the body tear and the posterior horn/root tear was guided by preoperative imaging and clinical examination but ultimately was made during

Table 2. Operative Details

	Meniscus Root Tears	Meniscus Body Tears
Repair		7 (33.3%)
All-inside	15 (71.4%)	
Root repair	4 (19.0%)	
Partial meniscectomy	1 (4.8%)	7 (33.3%)
No intervention	1 (4.8%)	7 (33.3%)

Table 3. Surgical Outcomes

	Preoperative	Final Follow-Up	*P* Value
VAS at Rest	2.10 ± 1.8	0.8 ± 1.0	<0.001
VAS with Activity	5.7 ± 3.0	2.6 ± 2.2	0.017
Tegner Activity Score	(Pre-injury) 5.7 ± 2.4	6.4 ± 2.0	0.334
IKDC	—	83.2 ± 14.0	—
Postoperative knee ROM (Arc of motion)	—	0.5°-133°(132°)	—

surgery. It has been reported that radial tears up to 60% of the central zone have no effect on pressure magnitude in the medial or lateral compartments, and thus partial meniscectomy can be considered.[14] However, tears involving ≥90% of the meniscus width clearly benefit from repair by returning contact pressures back to near-normal levels.[14,40] Full-thickness radial tears of the meniscus body and root render the meniscus nonfunctional due to loss of hoop stress resistance, which is biomechanically comparable to complete meniscectomy. Repair of these tears can return peak contact pressures and contact area of the affected compartment back to their normal state, which may delay the onset of arthritic changes.[41-45] It is important to maintain or restore meniscus integrity whenever possible, particularly in the younger, active patient. Following the "ABCs" of meniscus repair(anatomic reduction, biologic augmentation, and circumferential compression across the tear site), our preference is to use an inside-out LM body repair whenever possible because of its more anatomic reduction and low clinical failure rate with equivalent healing compared to all-inside repairs.[30,46,47]

Transtibial pull-through repair and suture anchor repair of posterior root tears are both supported in the literature. In the setting of concurrent ACL reconstruction, clinical success rates and functional outcomes are similar between techniques.[48] There is no consensus on meniscus healing rates and postoperative meniscus extrusion between groups. Seo et al.[48] found better healing status with suture anchor repairs on second-look arthroscopy, whereas others have observed complete healing rates >90% on postoperative MRI or second-look arthroscopy with transtibial pull-through repair.[49,50] Moon et al.[50] reported an increase in postoperative meniscal extrusion with transtibial repair, whereas Kim et al.[15] found no difference in meniscus extrusion. Several studies have found that the pull-through technique improves lateral compartment contact pressures and clinical outcomes.[12,41,42,51] Advantages of the pull-through technique are that it can be completed without the need for a posterior portal, the tibial guide allows for accurate drilling, and the cinch sutures provide robust capture of the root with single suture passage.[52]

Limitations

There are limitations to this retrospective case series with a relatively small number of patients since double LM injuries are uncommon. We included LM injuries of varying morphologies and severities, which necessitated different surgical treatments. Our cohort is not homogenous in that regard, but one of our aims was to describe the various concomitant injuries that occur. The small case numbers precluded subgroup analysis by stratifying the patients into particular types of treatment (i.e., transtibial pull-through repair vs all-inside repair of the LM root). This could potentially be performed in the future with a larger group of patients. Longer follow-up would also be beneficial in analyzing how patients with these injuries perform over time. Last, it is difficult to determine the degree to which patients' improvements were attributed to ACL reconstruction versus the lateral meniscus treatment.

Conclusions

Double radial tears of the LM are uncommon injuries that occur in the setting of ACL tears, usually combined with MCL injury. The variety of surgical treatment techniques have a low failure rate at short-term follow-up. Patients tend to have good clinical outcomes with improvement in pain and overall function after surgically treating these injuries with simultaneous ACL reconstruction.

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