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Pullout Repair of Lateral Meniscus Posterior Root Tears Into the Posterolateral Tibial Tunnel During Anterior Cruciate Ligament Reconstruction: Meniscal Healing and Knee Stability

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Abstract

Introduction: To evaluate the impact of concomitant lateral meniscus (LM) posterior horn root tears (LMPHRT) on knee instability in anterior cruciate ligament (ACL) injuries and assess the outcomes of pullout repair into the tibial posterolateral (PL) tunnel.

Methods: Fifty-four patients who underwent ACL reconstruction (ACLR) were assessed for characteristics, meniscal repair status, pre- and postoperative clinical scores, side-to-side difference (SSD) in anterior tibial translation, and meniscal healing outcomes one year postoperatively. Statistical analyses were conducted to examine correlations between patient characteristics and SSD and compare SSD between the meniscal repair groups. Patient characteristics, change in SSD (Δ SSD), and clinical scores were compared between the groups with and without LMPHRT repair.

Results: Pre- and post-operative SSD did not significantly correlate with patient characteristics. Preoperative SSD was significantly larger in patients with LM (5.0 ± 1.3 vs. 4.0 ± 2.0 mm; $p = 0.029$) and LMPHRT repair (5.8 ± 1.1 vs. 4.0 ± 1.8 mm; $p = 0.005$) than in those without. No significant difference was observed in postoperative SSD between patients with and without each meniscal repair. Patients who underwent LMPHRT repair had a notable reduction in Δ SSD compared with those who did not (5.7 ± 1.5 vs. 3.9 ± 2.4 mm; $p = 0.049$). Among the eight patients, LMPHRT repair achieved complete healing in seven (87.5%) and partial healing in one (12.5%).

Conclusion: Concomitant LMPHRT was associated with greater preoperative anterior knee instability in patients with ACL injuries. Following ACLR combined with pullout repair of LMPHRT into the tibial PL tunnel, postoperative anterior stability was comparable to that in patients without LMPHRT who underwent ACLR alone, with favorable meniscal healing at one year. These findings suggest that pullout repair into the tibial PL tunnel may be a viable treatment option for LMPHRT concomitant with ACL injury.

Categories: Sports Medicine, Orthopedics

Keywords: anterior cruciate ligament, anterior tibial translation, anteroposterior knee laxity, lateral meniscus, posterior root tear

Introduction

The anterior cruciate ligament (ACL) plays an essential role in the anteroposterior and rotational stability of the knee joint [1]. The meniscus also plays an important role in knee joint stability [2]. Medial meniscus (MM) injuries, such as ramp lesions, and lateral meniscus (LM) injuries, concomitant with ACL injuries, have been reported to increase knee joint instability [3-5]. Among them, LM posterior horn root tear (LMPHRT) is a typical LM injury associated with ACL injuries and is known to occur relatively frequently, at approximately 14% [2]. As reported in biomechanical studies, knee instability occurs even in isolated LMPHRT without ACL injuries [6]. Moreover, concomitant ACL injury with LMPHRT causes increased knee joint instability [7]. Repairing the LMPHRT simultaneously with ACL reconstruction (ACLR) has been suggested to stabilize the knee joint and yield good clinical outcomes [8].

Forkel et al. reported surgical techniques of pullout repair for LMPHRT into the tibial posterolateral (PL) tunnel created during double-bundle ACLR [9]. Furthermore, in a biomechanical study, they reported that pullout repair for LMPHRT into the tibial PL tunnel is effective [10]. However, the extent to which pullout repair for LMPHRT into the tibial PL tunnel successfully improves clinical scores and knee instability in actual clinical practice remains unclear.

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Therefore, in this study, we aimed to evaluate the association between concomitant LMPHRT and knee instability in ACL injuries and to assess postoperative outcomes following pullout repair of LMPHRT into the tibial PL tunnel combined with ACLR, compared with ACLR alone in patients without LMPHRT. We hypothesized that pullout repair of LMPHRT into the tibial PL tunnel would yield a favorable meniscal healing rate and that patients with LMPHRT undergoing pullout repair combined with ACLR would demonstrate greater improvement in side-to-side difference (SSD) in anterior tibial translation (ATT) than patients without LMPHRT undergoing ACLR alone.

Materials And Methods

Patients

This retrospective study was approved by the Ethics Committee of Committee of the Okayama University (K2410-012) and was performed according to the Declaration of Helsinki. Written informed consent was obtained from all patients.

Primary ACLR was performed on 77 patients between July 2020 and August 2023. We retrospectively surveyed the 72 patients who could be followed up for a year or more, excluding five patients who could only be followed up for less than one year postoperatively. Among these, 54 patients were finally included in the study, excluding one who underwent bone-patella tendon-bone reconstruction, two with re-ACL injuries, one with a postoperative knee infection, and 14 patients who did not undergo second-look arthroscopy.

Surgical technique of ACLR procedure

ACLR was performed using a double-bundle repair with anteromedial (AM) and PL bundles (Figure 1). Approximately 24 cm of the semitendinosus tendon was used to create two grafted tendons with a minimum diameter of 5 mm. The femoral and tibial tunnels were created using the outside-in technique with an ACL guide (Smith & Nephew, London, UK). The knee position and traction force for grafted fixation were 10° knee flexion and 20 N for the AM bundle and 0° knee flexion and 10 N for the PL bundle.

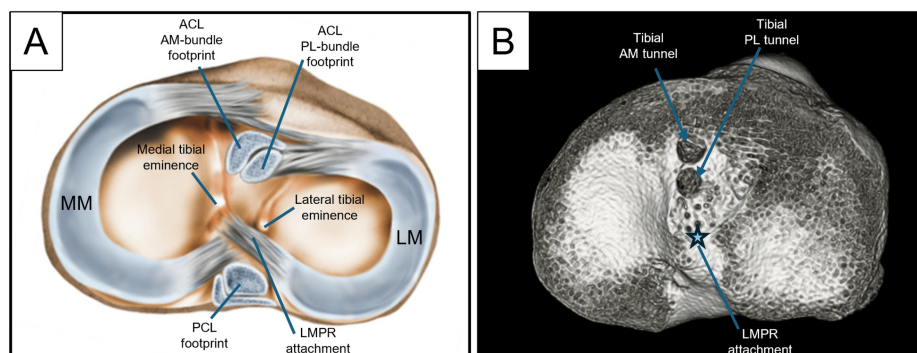


FIGURE 1: A schematic diagram of anatomy of the knee, and a 3D-CT showing technical tibial bone tunnel (right knee).

(A) Anatomy of ACL and LMPR attachment. Image Credits: Natsumi Hashiba (illustrator). The illustration was created using Adobe Photoshop (Adobe Inc., San Jose, CA, USA). (B) Technical tibial bone tunnel positions in double-bundle ACLR. Star mark indicates the LMPR attachment.

ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; AM, anteroposterior; LM, lateral meniscus; LMPR, lateral meniscus posterior root; MM, medial meniscus; PL, posterolateral; 3D-CT, three-dimensional computed tomography.

Surgical technique of pullout repair for LMPHRT into tibial PL tunnel

Pullout repair was performed for LMPHRT (Figure 2A). One or two FiberWires (Arthrex, Naples, FL, USA) were applied to the tear with a knee scorpion (Smith & Nephew) (Figure 2B). A simple suture was performed (Figure 2C) and then pulled into the tibial PL tunnel along with the PL grafted tendon for ACLR (Figure 2D), which was fixed simultaneously with the grafted tendon (Figure 2E).

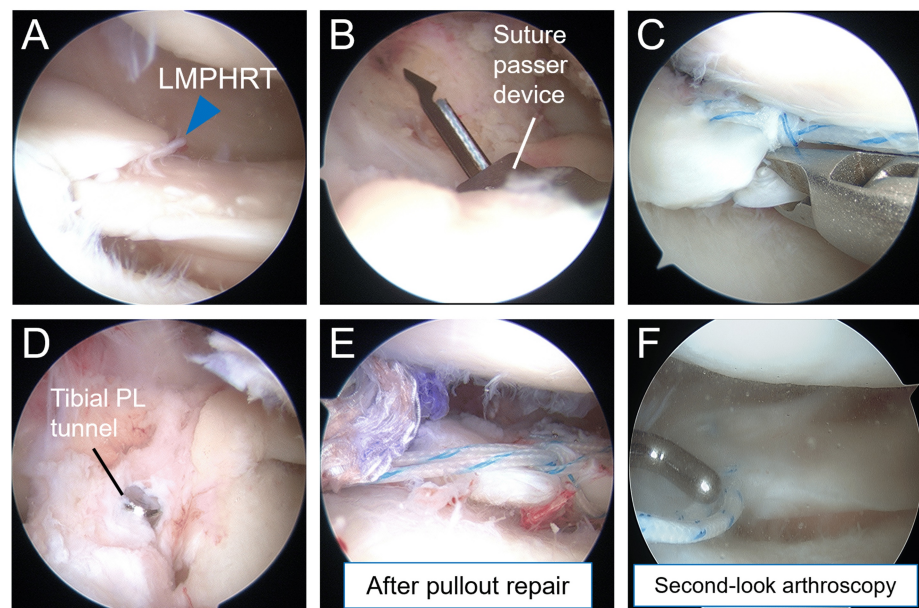


FIGURE 2: Arthroscopic findings at primary ACLR, LMPHRT repair, and second-look arthroscopy (left knee).

(A) LMPHRT (blue arrowhead) was observed. (B) A thread was passed through each end of the LMPHRT using the suture passer device. (C) Two simple stitches were applied to the LMPHRT. (D) The two sutures for LMPHRT were pulled out into the tibial PL tunnel of the ACLR. (E) Findings after primary ACLR and pullout repair of LMPHRT. (F) Findings of LMPHRT determined to be completely healing at second-look arthroscopy.

ACLR, anterior cruciate ligament reconstruction; LMPHRT, lateral meniscus posterior horn root tear; PL, posterolateral.

Surgical indication of meniscal repair

For meniscal injuries, the bucket handle and radial tears were sutured for repair. Flap tears of 2 mm or less in the white-white zone were only partially resected. Longitudinal tears of 1 cm or less and ramp lesions with no instability were rasped only. All other meniscal injuries were considered candidates for suture repair. For LMPHRT, pullout repair was indicated for complete tears, whereas rasping alone was performed for meniscal tissue damage without a complete tear or isolated longitudinal tears of 1 cm or less in the LM posterior horn root region.

Rehabilitation protocol

For ACLR alone, the patients were immobilized during knee joint extension and unloaded using a knee brace for the one-week postoperative period. An ACL brace was applied one week to three months postoperatively. The knee joint range of motion was 0-90° from one week postoperatively and 0-120° from two weeks to three months postoperatively. The loading was one-third partial body weight bearing at two weeks postoperatively, two-thirds partial body weight bearing at three weeks, and full body weight bearing at four weeks postoperatively.

For meniscal repair with ACLR, the patients were immobilized in knee extension and unloaded using a knee brace for two weeks postoperatively. An ACL brace was applied two weeks to three months postoperatively. The knee joint range of motion was 0-90° from two weeks postoperatively and 0-120° from three weeks to three months postoperatively. The loading was one-third partial body weight bearing at two weeks postoperatively, two-thirds partial body weight bearing at three weeks, and full body weight bearing at four weeks postoperatively.

Radiographic assessment

A lateral radiograph of the knee joint in the non-weight-bearing position was obtained preoperatively, and the posterior tibial slope angle (PTSA) was measured. The radiographic images of the lateral knee joint were unified so that the posterior condyles of the femur overlapped. The PTSA was defined as the angle between the line perpendicular to the tibial bone axis and the medial tibial plateau.

Clinical scores

Regarding clinical scores, the International Knee Documentation Committee [11], Visual Analog Scale pain, Knee Injury and Osteoarthritis Outcome [12], Lysholm [13], and Tegner scores [14] were evaluated preoperatively and one year postoperatively.

SSD in ATT measurements

ATT was measured on the affected and contralateral sides using the KS measure KSM-100 (SIGMAX, Tokyo, Japan) under general anesthesia preoperatively and one year postoperatively, and the SSD in ATT was calculated. A force of 100 N was applied during each anterior and posterior drawer test. The ATT measurements were performed independently twice by each of two orthopedic surgeons. The mean of the four measurements was used for the final analysis. Intraobserver and interobserver reliability were assessed using intraclass correlation coefficients, which were 0.89 and 0.86, respectively. Change in the SSD (Δ SSD) was defined as SSD preoperatively minus SSD at one year postoperatively.

Second-look arthroscopy

One year postoperatively, all included patients underwent second-look arthroscopy and anchor screw removal (Figure 2F). The healing status after meniscal repair was evaluated using an arthroscopic probe and classified into three categories: complete healing, partial healing, and unhealed [15]. Complete healing was defined as complete coverage of the tear site by healing tissue without probe penetration. Partial healing was defined as incomplete coverage of the tear site by healing tissue with slight probe penetration. Unhealed was defined as minimal coverage of the tear site by healing tissue with complete probe penetration.

Statistical analyses

Statistical analysis was performed using the EZR software (Saitama Medical Center, Saitama, Japan). Normality of distribution was assessed using the Shapiro-Wilk normality test, which revealed a parametric distribution for height, PTSA, and Δ SSD, and a non-parametric distribution for age, body weight, body mass index (BMI), SSD in ATT, and clinical scores.

Preoperative clinical scores were compared to those at one year postoperatively using the Wilcoxon signed-rank test because these were paired, non-normally distributed data. Correlations between patient characteristics and SSD in ATT were evaluated using Spearman's rank correlation coefficients. Comparisons of SSD in ATT between the two groups with and without meniscal repair were performed using the Mann-Whitney U test. Comparisons were made between the ACLR alone and the ACLR and LMPHRT repair groups and between groups with and without LMPHRT repair using Fisher's exact test for sex, Mann-Whitney U test for non-normally distributed continuous variables (age, body weight, BMI, SSD in ATT, and clinical scores), and unpaired t test for normally distributed continuous variables (height, PTSA, and Δ SSD). No adjustment for multiple comparisons was performed. Statistical significance was set at $p < 0.05$.

Results

The characteristics of patients included in this study were as follows: a mean age of 28.0 ± 14.1 years, 31 males and 23 females, a mean BMI of 24.6 ± 4.7 kg/m², and a mean preoperative PTSA of $9.2 \pm 3.2^\circ$.

Meniscal repair was performed in 28 patients (51.2%): MM repair was performed in 18 (33.3%) patients, LM repair in 16 (29.6%), MM and LM repair in six (11.1%), and LMPHRT repair in eight (14.8%). All clinical scores showed significant improvements from the preoperative to one year postoperatively ($p < 0.001$; Table 1).

	Preoperative	Postoperative	V-value	p-value
IKDC score [11]	62.7 ± 14.5	89.5 ± 8.6	0	< 0.001*
VAS pain score	16.3 ± 19.4	4.4 ± 6.9	1152.5	< 0.001*
KOOS [12]				
Pain	82.5 ± 13.2	94.9 ± 6.2	12	< 0.001*
Symptoms	80.2 ± 14.4	91.2 ± 8.8	100	< 0.001*
ADL	89.4 ± 13.4	98.0 ± 4.3	17	< 0.001*
Sport/Rec	49.3 ± 26.7	87.2 ± 16.5	20	< 0.001*
QOL	52.8 ± 22.5	80.6 ± 15.1	38.5	< 0.001*
Lysholm score [13]	74.8 ± 13.9	95.8 ± 5.8	16	< 0.001*
Tegner activity score [14]	3.0 ± 1.4	5.9 ± 1.4	14.5	< 0.001*

TABLE 1: Clinical scores preoperatively and one year postoperatively.

Data are presented as mean ± standard deviation. Preoperative and one-year postoperative clinical scores were compared using the Wilcoxon signed-rank test. The V statistic and p-value are reported. *Statistically significant at $p < 0.05$.

ADL, activities of daily living; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; QOL, quality of life; Sport/Rec, sports and recreational function; VAS, Visual Analog Scale.

Meniscal healing status on second-look arthroscopy is shown in Table 2. Among the 28 patients who underwent meniscal repair, three (10.7%) were unhealed, five (17.9%) had partial healing, and 20 (71.4%) had complete healing. Among the eight patients who underwent LMPHRT repair, one (12.5%) had partial healing, and seven (87.5%) had complete healing.

	Meniscal healing status		
	Unhealing	Partial healing	Complete healing
Meniscus repair (n = 28), n (%)	3 (10.7%)	5 (17.9%)	20 (71.4%)
MM repair (n = 18) ^a , n (%)	2 (11.1%)	2 (11.1%)	14 (77.8%)
LM repair (n = 16) ^b , n (%)	1 (6.2%)	4 (25.0%)	11 (68.8%)
MM+LM repair (n = 6) ^c , n (%)	0 (0.0%)	1 (16.7%)	5 (83.3%)
LMPHRT repair (n = 8), n (%)	0 (0.0%)	1 (12.5%)	7 (87.5%)

TABLE 2: Meniscal healing status in second-look arthroscopy at one year postoperatively.

Data are presented as numbers (%). ^aIncludes six patients with MM+LM repair. ^bIncludes six patients with MM+LM repair and four patients with LMPHRT repair. ^cIncludes four patients with LMPHRT repair.

LM, lateral meniscus; LMPHRT, lateral meniscus posterior horn root tear; MM, medial meniscus.

The SSD preoperatively and at one year postoperatively did not correlate significantly with patient characteristics (Table 3). A comparison of the SSD preoperatively and one year postoperatively between the two groups, with and without meniscal repair, is shown in Table 4. In terms of preoperative SSD, patients who underwent LM repair ($p = 0.029$) and LMPHRT repair ($p = 0.005$) were significantly larger than those who did not. There was no significant difference in the postoperative SSD between patients with and without meniscal repair.

	Preoperative SSD		Postoperative SSD	
	r	p-value	r	p-value
Age	-0.066	0.634	0.169	0.221
Height	-0.218	0.113	0.122	0.381
Weight	-0.128	0.358	-0.009	0.946
Body mass index	-0.050	0.722	-0.033	0.814
Preoperative PTSA	-0.075	0.589	0.230	0.095

TABLE 3: Correlation of patient characteristics with SSD preoperatively and one year postoperatively.

Correlations between patient characteristics and SSD in ATT were evaluated using Spearman's rank correlation analysis. Spearman's rank correlation coefficient (r) and p-value are reported. *Statistically significant at $p < 0.05$.

PTSA, posterior tibial angle slope; SSD, side-to-side difference in anterior tibial translation; ATT: anterior tibial translation.

	Meniscus repair		MM repair ^a		LM repair ^b		MM+LM repair ^c		LMPHRT repair	
	repair (+); n = 28	repair (-); n = 26	repair (+); n = 18	repair (-); n = 36	repair (+); n = 16	repair (-); n = 38	repair (+); n = 6	repair (-); n = 48	repair (+); n = 8	repair (-); n = 46
Preoperative SSD in ATT (mm)	4.5 ± 2.0	4.1 ± 1.6	4.3 ± 2.3	4.3 ± 1.6	5.0 ± 1.3	4.0 ± 2.0	5.3 ± 0.9	4.2 ± 1.9	5.8 ± 1.1	4.0 ± 1.8
Test statistic (W)	332.5		342		189.5		79		69.5	
p-value	0.586		0.745		0.029*		0.072		0.005*	
Postoperative SSD in ATT (mm)	0.2 ± 1.5	0.0 ± 1.1	0.4 ± 1.2	0.0 ± 1.3	0.0 ± 1.5	0.2 ± 1.2	0.2 ± 0.9	0.0 ± 1.5	0.1 ± 0.9	0.1 ± 1.4
Test statistic (W)	301		262		306.5		147.5		192	
p-value	0.265		0.245		0.969		0.932		0.851	

TABLE 4: SSD in ATT preoperatively and one year postoperatively with and without meniscal repair.

Data are presented as mean ± standard deviation. Comparisons between groups with and without meniscal repair were performed using the Mann–Whitney U test. The W statistic and p-value are reported. ^aIncludes six patients with MM+LM repair. ^bIncludes six patients with MM+LM repair and four patients with LMPHRT repair. ^cIncludes four patients with LMPHRT repair. *Statistically significant at $p < 0.05$.

ATT, anterior tibial translation; LM, lateral meniscus; LMPHRT, lateral meniscus posterior horn root tear; MM, medial meniscus; SSD, side-to-side difference in anterior tibial translation.

There were no significant differences in patient characteristics and clinical scores between the groups with and without LMPHRT repair (Table 5). Meanwhile, patients with LMPHRT repair showed significantly greater ΔSSD than those without repair ($p = 0.049$, Table 5).

	ACLR □ LMPHRT repair (+); n = 8	ACLR + LMPHRT repair (-); n = 46	Test statistic	p-value
Patient characteristics				
Age (years)	27.6 ± 14.8	28.1 ± 14.0	W = 199	0.724
Sex, male/female, n	2/6	29/17		0.060
Height (m)	1.64 ± 0.05	1.67 ± 0.06	t = 1.385	0.172
Weight (kg)	66.0 ± 11.9	69.0 ± 14.2	W = 202	0.670
Body mass index (kg/m ²)	24.4 ± 4.0	24.6 ± 4.8	W = 196.5	0.770
Preoperative PTSA (°)	9.0 ± 3.1	9.3 ± 3.2	t = 0.224	0.824
ΔSSD (mm)	5.7 ± 1.5	3.9 ± 2.4	t = 2.018	0.049*
Preoperative clinical scores				
IKDC score [11]	54.7 ± 18.8	64.1 ± 13.0	W = 217	0.364
VAS pain score	17.4 ± 20.0	16.1 ± 19.2	W = 176.5	0.940
KOOS-Pain [12]	75.0 ± 17.3	83.9 ± 11.8	W = 236.5	0.164
KOOS-Symptoms [12]	74.5 ± 18.9	81.2 ± 13.2	W = 201	0.610
KOOS-ADL [12]	84.5 ± 17.1	90.2 ± 12.4	W = 202.5	0.583
KOOS-Sport/Rec [12]	46.3 ± 32.2	49.9 ± 25.6	W = 177	0.950
KOOS-QOL [12]	52.6 ± 28.2	52.8 ± 21.3	W = 168	0.775
Lysholm score [13]	67.4 ± 19.4	76.1 ± 12.3	W = 222.5	0.296
Tegner activity score [14]	2.8 ± 1.0	3.0 ± 1.4	W = 186.5	0.878
Postoperative clinical scores				
IKDC score [11]	85.7 ± 7.6	90.2 ± 8.6	W = 247	0.128
VAS pain score	3.0 ± 4.0	4.6 ± 7.2	W = 183.5	1.000
KOOS-Pain [12]	95.5 ± 5.8	94.8 ± 6.3	W = 166	0.659
KOOS-Symptoms [12]	92.2 ± 6.9	91.1 ± 9.1	W = 189.5	0.961
KOOS-ADL [12]	97.9 ± 3.4	98.0 ± 4.5	W = 183.5	1.000
KOOS-Sport/Rec [12]	81.9 ± 26.8	88.1 ± 13.7	W = 189.5	0.901
KOOS-QOL [12]	81.3 ± 10.4	80.4 ± 15.8	W = 195	0.797
Lysholm score [13]	98.6 ± 2.4	95.3 ± 6.1	W = 110.5	0.064
Tegner activity score [14]	5.8 ± 1.3	5.9 ± 1.4	W = 198.5	0.725

TABLE 5: Comparison of patient characteristics and ΔSSD with and without LMPHRT repair.

Data are presented as mean ± standard deviation or number, as appropriate. Sex was compared using Fisher's exact test; age, weight, body mass index, and clinical scores were compared using the Mann–Whitney U test; and height, preoperative PTSA, and ΔSSD were compared using the unpaired t-test. W and t statistics are reported for the Mann–Whitney U test and unpaired t-test, respectively. No test statistic is reported for Fisher's exact test.

*Statistically significant at $p < 0.05$.

ACL, anterior cruciate ligament reconstruction; ACLR, anterior cruciate ligament; ADL, activities of daily living; IKDC, International Knee Documentation Committee; KOOS, Knee Injury, and Osteoarthritis Outcome Score; LMPHRT, lateral meniscus posterior horn root tear; PTSA, posterior tibial slope angle; QOL, quality of life; Sport/Rec, sports and recreational function; VAS, Visual Analog Scale; ΔSSD, change in the side-to-side difference in anterior tibial translation from preoperative to one year postoperative.

Discussion

The most important finding of this study was that although concomitant LMPHRT was associated with

greater preoperative anteroposterior instability, patients who underwent LMPHRT pullout repair combined with ACLR demonstrated comparable anterior knee stability at one year postoperatively to patients without LMPHRT who underwent ACLR alone. Second, LMPHRT combined with ACL injury was successfully repaired using pullout repair into the tibial PL tunnel, with complete healing in seven of eight patients (87.5%) and partial healing in one of eight patients (12.5%).

The significance of ATT in ACL injury has been reported in several studies. Large preoperative ATT is a risk factor for ACL injuries after ACLR [16]. A large postoperative ATT is also a risk factor for meniscal injury after ACLR [17]. Therefore, it is important to identify the factors that influence preoperative and postoperative ATT in ACL injuries.

Regarding factors affecting preoperative ATT, PTSA is greater, and ramp lesions are coexistent [3]. LM injuries are reportedly more influential on the preoperative ATT than MM injuries [18]. In particular, ATT is increased by LMPHRT concomitant with ACL injury rather than ACL injury alone [7]. However, other studies have reported no increase in the ATT with or without concomitant LMPHRT [19]. In this study, the preoperative ATT was significantly greater in patients who underwent LM or LMPHRT repair concomitant with ACLR. This finding emphasizes the importance of the LM, especially the LMPHRT, as a second stabilizer for the anteroposterior stability of the knee joint following the ACL.

As a factor affecting postoperative ATT, meniscal repair, rather than meniscectomy, provides more anteroposterior stability to the knee joint for meniscal injuries consistent with an ACL injury [20]. Moreover, even in the presence of LMPHRT, pullout repair can provide a postoperative ATT equivalent to that in the absence of LMPHRT [21]. In this study, the presence or absence of meniscal repair, including LMPHRT repair, had no apparent effect on the postoperative ATT. At our institution, if meniscal repair was indicated, a suture or pullout repair procedure was performed. Consequently, it is possible to achieve good meniscal healing and restore the anteroposterior stability of the knee joint provided by the meniscus.

Conservative treatment is often used for LMPHRT associated with ACL injury because of the high rate of meniscal healing in meniscal injuries concomitant with ACL injury [22]. Recently, repair of the LMPHRT has become the preferred choice due to its better clinical outcomes in the mid-term and higher meniscal healing rates [23]. In addition, side-to-side suturing, suture anchor repair, and pullout repair have been reported as repair techniques for LMPHRT with favorable healing rates, supported by their clinical scores [24–26]. A method for simultaneously pulling out the sutures of the LMPHRT into the bone tunnel for ACLR has also been reported [27]. In this study, the repair method for LMPHRT was simultaneous pullout repair of the PL bone tunnel for ACLR. Complete healing was achieved in seven of eight cases (87.5%) and partial healing in one of eight cases (12.5%), with a good healing rate. The postoperative clinical scores were equally favorable in patients with and without LMPHRT repair. Although our surgical approach involved non-anatomical repair of the LMPHRT, it may be an effective method to avoid overlap of the bone tunnel.

This study has several limitations. First, this was a retrospective study with a relatively small sample size, particularly in the LMPHRT repair group, which included only eight patients. Furthermore, 14 patients who did not undergo second-look arthroscopy were excluded, which may have introduced selection bias and limited the generalizability of the findings. Second, the follow-up period was limited to one year, and longer-term evaluation of ACL re-injuries and meniscal healing is warranted. Third, although all patients had negative pivot shift tests at one year postoperatively, rotational knee instability was not quantitatively assessed. Fourth, two patients with re-ACL injuries were excluded, which may have affected the evaluation of SSD and meniscal tears. In addition, small meniscal tears deemed ineligible for repair were included in the group without LMPHRT. Fifth, the comparison group consisted of patients without LMPHRT rather than patients with untreated LMPHRT; therefore, the independent effect of LMPHRT repair on postoperative knee stability could not be determined. Furthermore, the significant difference in preoperative SSD between the groups may have influenced the observed difference in Δ SSD. Finally, no adjustment for multiple comparisons was performed, which may have increased the risk of type I error. Therefore, the findings should be interpreted with caution. Future studies with larger sample sizes and longer follow-up periods are warranted to address these limitations.

Conclusions

Concomitant LMPHRT was associated with greater preoperative anterior knee instability in patients with ACL injuries. Following ACLR combined with pullout repair of LMPHRT into the tibial PL tunnel, postoperative anterior stability was comparable to that in patients without LMPHRT who underwent ACLR alone, with favorable meniscal healing at one year. These findings suggest that pullout repair into the tibial PL tunnel may be a viable treatment option for LMPHRT concomitant with ACL injury.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Okayama University issued approval K2410-012. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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