Original Article

Anterior Cruciate Ligament Reconstruction Using Bone—Patellar Tendon—Bone Autograft With Lateral Compartment Meniscectomy or Chondroplasty Does Not Lead to Decreased Return to Sport and Activity Compared With No Lateral Pathology

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Purpose: To investigate the influence of lateral meniscal and cartilage pathology on the outcome after anterior cruciate ligament (ACL) reconstruction in patients who participate in pivoting sports. **Methods:** Using a single-surgeon patient registry, patients undergoing an anterior cruciate ligament reconstruction (ACLR) using bone—patellar tendon—bone autograft were evaluated with minimum 2-year patient reported outcomes evaluated using Marx, Tegner, Lysholm, and International Knee Documentation Committee scales. Patients were divided into 3 groups: isolated ACL surgery, ACLR with a partial lateral meniscectomy, or a ACLR with partial lateral meniscectomy and lateral compartment chondroplasty. **Results:** A total of 98 patients met inclusion criteria. Using the isolated ACL reconstruction group as a control, we found that Marx scores were greater in patients who additionally underwent a partial lateral meniscectomy at 1 year ($P = .016$). There were no significant differences between the ACL-only group and the ACL with partial lateral meniscectomy and chondroplasty group. Within the partial meniscectomy cohort comparing the patients with red-white zone tears with the patients with white-white zone tear, we found there were no significant differences when compared with the ACL-only control. There were no significant differences appreciated between groups using the International Knee Documentation Committee, Lysholm, and Tegner scales. **Conclusions:** ACL reconstruction using bone—patellar tendon—bone autograft with anteromedial portal drilling technique does not have any significant short-term (2-year outcome) differences in return to activity and patient-reported outcomes compared with if patients additionally have a partial lateral meniscectomy and/or lateral compartment chondroplasty. Additional partial lateral meniscectomy showed significantly greater Marx scores at 1 and 2 years' postoperatively. **Level of Evidence:** Level III, retrospective cohort study.

Anterior cruciate ligament (ACL) injuries are commonly accompanied by meniscal injuries, which has been shown to change patient-reported outcomes but also the natural degeneration of the knee.[1-3] It is well known that the menisci are essential to the proper mechanical functioning of the knee joint and that injured or degenerated menisci can lead to an increased risk of posttraumatic osteoarthritis.[1-3] There have been studies that address the surgical strategies to address lateral and medial meniscus tears in conjunction with ACL tears, but there is a scarcity of literature that analyzes the outcomes of these repairs specifically looking at level of activity. Many sports, especially at the high school and collegiate level, require a significant amount of greater-impact and pivoting activities that put an increased amount of strain on the lateral compartment as the result of dynamic valgus stress and secondary lateral compartment compression. This study aims to identify whether lateral compartment pathology influences the short-term (2-year) outcomes after anterior cruciate ligament reconstruction (ACLR) using bone—patella tendon—bone (BPTB) autograft via

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anteromedial portal drilling technique on return to activities and patient-reported outcome measures (PROMs).

Lateral compartment pathology, especially for pivoting/change-of-direction individuals, has been thought to be a negative predictor of return to same level of those activities, given the amount of force placed on the lateral compartment during pivoting maneuvers. This may affect performance and satisfaction by the patient. Many individuals sustaining ACL injuries do so during sport, so lateral meniscus/articular cartilage issues occurring concomitantly may provide a further decreased chance at returning to similar level of activities or having similar satisfaction to an isolated ACL injury.

The purpose of this study is to investigate the influence of lateral meniscal and cartilage pathology on the outcome after ACLR in patients who participate in pivoting sports. Our hypothesis is that patients with greater activity levels (such that would be participating in lateral/cutting activities) would have lower patient-reported outcome scores if they had additional lateral compartment pathology compared with individuals who did not have lateral compartment pathology.

Methods

After institutional board approval, patients who underwent ACLR by a single surgeon (P.D.A.) between 2015 and 2018 were retrospectively identified in a patient registry. Inclusion criteria were the availability of pre- and postoperative patient-reported outcomes, including the Marx, Tegner, International Knee Documentation Committee (IKDC), and Lysholm scores, and a minimum 2-year follow-up. Exclusion criteria included non-BPTB autograft, lateral meniscus repair, any medial meniscectomy or medial meniscus repair, or any concomitant ligament surgery. Surgical indications included an ACL tear that was unstable on physical examination with associated subjective instability symptoms. Graft type was a shared decision-making model with patella tendon autograft recommended for individuals with greater activity level. All surgeries were performed via anteromedial portal flexible reamer femoral technique[4] with am absorbable interference screw fixation ("Milagro" interference screw, Depuy Synthes, Raynham, MA) on the femoral and tibial sides. Indications for meniscus repair were peripheral, longitudinal tears or radial tear in the vascular (red—red zone) or semivascular (red-white zone) regions of the meniscus judged intraoperatively and correlated with magnetic resonance imaging findings then dictated in operative note that was used for study registry reference.[5,6] Other meniscus tears in an avascular zone that were unstable were resected to a stable rim. Postoperatively, patients were weight-bearing as tolerated, with use of a long, double-hinged brace for ambulation for the first 6 weeks. Continuous passive motion machines were used for the first 10 days up to 100° of flexion. Outpatient physical therapy advised to start 3 to 5 days after surgery. Running was withheld until quadriceps strength was at least 80% symmetric with no pain or effusion. Return to cutting/pivoting sports advised to be withheld until >95% quadriceps strength symmetry with approved hopping and bounding by physical therapy and at least 9 months of time had passed since surgery.[7]

Tegner, Marx, International Knee Documentation Committee (IKDC), and Lysholm scores were selected preoperatively and postoperatively. Preoperatively, standard scoring questionnaires were distributed electronically via the SOS software platform (Arthrex, Naples, FL), with Marx evaluating greatest level of activity in the last year with the knee in a healthy state, Tegner evaluating greatest level of activity with current injured knee, and IKDC/Lysholm evaluating overall function of current injured knee. Tegner, IKDC, and Lysholm scores were recorded postoperatively at 6 months, 12 months, and 24 months. Marx scores were recorded at 12 and 24 months. Tegner and Marx scores were primary measures. IKDC and Lysholm scores were secondary measures. Patients were separated into 3 groups: ACLR without meniscal pathology, ACLR with partial lateral meniscectomy (PLM), and ACLR with PLM and lateral compartment chondroplasty.

Statistical Analysis

Statistical analysis was performed using RStudio, version 2023.06.0+421 (posit, Boston, MA). Continuous variables were reported as means, and categorical variables were reported as percentages. The significance level (α) was set at $P < .05$. Homogeneity of variance was assessed using the Levene test, and normality of PROMs for each of the 3 groups was assessed at each time point using the Shapiro-Wilk test. Univariate analyses of age, body mass index, and the 4 PROMs at baseline were performed using the nonparametric Kruskal-Wallis rank sum test. The Dunn (1964) Kruskal-Wallis multiple comparison test was used for post-hoc comparison, and P values were adjusted using the Holm method. Multivariate analysis was performed by creating linear mixed-effects models to compare PROMs for each group over time while controlling for differences in baseline scores. One-way analysis of variance was used to compare these linear models, and pairwise comparisons were made using the Tukey-Kramer post-hoc test. P values for these tests were adjusted using the Tukey method.

Results

A total of 98 patients (53 female, 45 male) met inclusion criteria with responses at 24 months. As only 2 patients who underwent meniscus repair were

Table 1. Patient Demographics

Group	ACLR Only (n = 60)	ACLR With PLM (n = 27)	*P* Value	ACLR With PLM and Lateral Chondroplasty (n = 11)	*P* Value
Age, yr	24.0 ± 7.6	20.6 ± 6.4	.046*	26.1 ± 4.7	.185
BMI	23.5 ± 4.1	25.1 ± 3.7	.055	25.8 ± 2.9	.034*,†
Sex					
Female	37 (62%)	13 (48%)		2 (18%)	
Male	22 (37%)	14 (52%)		9 (82%)	
Pretreatment PROMs					
Marx	11.83 ± 4.85	12.11 ± 5.73	1.000	11.73 ± 5.22	.868
Tegner	4.55 ± 2.92	4.67 ± 2.94	.847	5.36 ± 2.62	.794
IKDC	54.06 ± 12.22	55.89 ± 14.54	.566	50.06 ± 9.87	.593
Lysholm	67.30 ± 15.25	71.33 ± 16.26	.706	65.00 ± 13.62	.527

NOTE. *P* values show relationship with ACLR-only control group and were calculated using the Kruskal-Wallis rank-sum test. Age, BMI, and preoperative PROM scores are reported as mean ± SD; sex is reported as frequency and percentage of total group.

ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; IKDC, International Knee Documentation Committee; PLM, partial lateral meniscectomy; PROM, patient-reported outcome measure; SD, standard deviation.

*$P < .05$.

†$P < .01$.

available for 2-year follow-up, these were excluded from the cohort analysis. The average age was 23.3 years, and average body mass index was 24.2. Sixty patients (61%) underwent ACLR without meniscectomy or chondroplasty. In total, 27 patients (28%) underwent ACLR with PLM and 11 patients (11%) underwent ACLR with PLM and chondroplasty. Of the patients who underwent a PLM, 13 patients had tears extending to the red-white zone and 14 patients had tears extending to the white-white zone. Two patients had a tear extending to the red-red zone. A full breakdown of patient demographics by group is found in Table 1.

Using the ACLR only as a control group, patients who either underwent an ACLR with PLM or an ACLR with PLM and chondroplasty were compared using the Marx, Tegner, IKDC, and Lysholm scores (Table 2). There was a significant difference in patients who underwent a PLM at 1 year on Marx scales, going from pretreatment 12.11 to 1 year 11.20 (9.87-12.53) ($P = .016$) compared with the ACL-only group of pretreatment 11.83, 1 year 8.57 (7.70-9.43) (Figs 1 and 2). No significant differences in Tegner, IKDC, or Lysholm scores were found between the ACL-only group and the ACL with PLM group (Table 2, Figs 3-6).

There were no significant differences in Marx, Tegner, IKDC, and Lysholm scores between the ACL only group and the ACL with PLM and chondroplasty group (Table 2, Figs 1-6).

When further stratifying patients who had a PLM, we evaluated the maximum vascular zone of injury that required a resection to see whether it made any clinical difference how much meniscus was resected/injured (Table 3). Thirteen patients had a tear extending into the red-white zone, and 14 patients had a tear extending to the white-white zone. There were 2 patients who had a tear extending to the red-red zone, but because of this low number, we did not feel it was going to be clinically significant to compare it with the other 2 groups, so these patients were excluded from the meniscus zone breakdown. For both the red-white zone and white-white zone groups, no significant differences in Marx, Tegner, IKDC, and Lysholm scores were found compared with the control group of ACL-only. There were no significant differences between Marx, Tegner, IKDC, and Lysholm scores between the red-white zone group and the white-white zone group.

Discussion

This study compares the short-term outcomes regarding return to activity after ACLR based on lateral meniscus intervention at the time of the surgery. Of the estimated 200,000 people who tear their ACLs each year, approximately 55% to 65% of these people experience an accompanying meniscus tear.[1-3,8-11] The importance of the menisci in the proper functioning of the knee joint is widely described in literature, and meniscus deficiencies often are associated with increased chondrosis and an increased risk of developing osteoarthritis.[3,8] There are numerous studies that individually analyze the effect of ACLR and meniscus repair on return to activity, but there is a scarcity of information that directly compares the return to activity level of patients who underwent an ACLR and PLM and an ACLR and PLM with chondroplasty as it pertains to return to activity level of patients.

The primary results of the study show that there is not a significant amount of difference between patient-reported outcomes and return to activity in patients undergoing ACLR with and without lateral

Table 2. Patient-Reported Outcomes Based on Surgical Group

	ACL Only (n = 60)	ACL with PLM (n = 27)		ACL With PLM and Chondroplasty (n = 11)	
PROM	Estimated Marginal Mean (95% CI)	Estimated Marginal Mean (95% CI)	*P* Value*	Estimated Marginal Mean (95% CI)	*P* Value*
Marx					
1 yr	8.57 (7.70-9.43)	11.20 (9.87-12.53)	.016†	8.98 (6.63-11.33)	.999
2 yr	9.56 (8.62-10.50)	11.27 (9.82-12.72)	.380	9.45 (7.23-11.67)	1.000
Tegner					
6 mo	4.67 (4.24-5.10)	4.23 (3.57-4.89)	.974	4.68 (3.46-5.90)	1.000
1 yr	6.26 (5.83-6.69)	7.21 (6.58-7.84)	.262	5.48 (4.30-6.66)	.952
2 yr	6.59 (6.11-7.06)	7.19 (6.51-7.88)	.885	6.34 (5.20-7.48)	1.000
IKDC					
6 mo	68.4 (66.1-70.7)	70.2 (66.7-73.7)	.996	75.5 (68.9-82.0)	.549
1 yr	82.6 (80.2-84.9)	85.2 (81.8-88.6)	.944	82.1 (75.8-88.5)	1.000
2 yr	87.6 (85.1-90.1)	89.6 (86-93.3)	.993	86.5 (80.4-92.7)	1.000
Lysholm					
6 mo	83.7 (81.8-85.5)	86.4 (83.5-89.2)	.818	87.5 (82.2-92.8)	.913
1 yr	89.7 (87.9-91.6)	93.3 (90.6-96.1)	.438	93.5 (88.4-98.6)	.909
2 yr	91.3 (89.3-93.3)	93.7 (90.7-96.7)	.928	94.2 (89.3-99.2)	.976

ACL, anterior cruciate ligament; CI, confidence interval; IKDC, International Knee Documentation Committee; PLM, partial lateral meniscectomy; PROM, patient-reported outcome measure.

**P* values show relationship with ACL-only control at each time point. There were no significant differences between ACL with PLM and ACL with PLM and chondroplasty.

†$P < .05$.

compartment pathology. There was a difference in the Marx activity level of the group that received an ACLR with PLM compared with the control group that only received an ACLR at 1 year (Table 2) where the PLM had greater activity scores than the group whose lateral menisci were intact. It was hypothesized that the addition of the meniscectomy procedure to this group would lead to a decreased activity level compared with

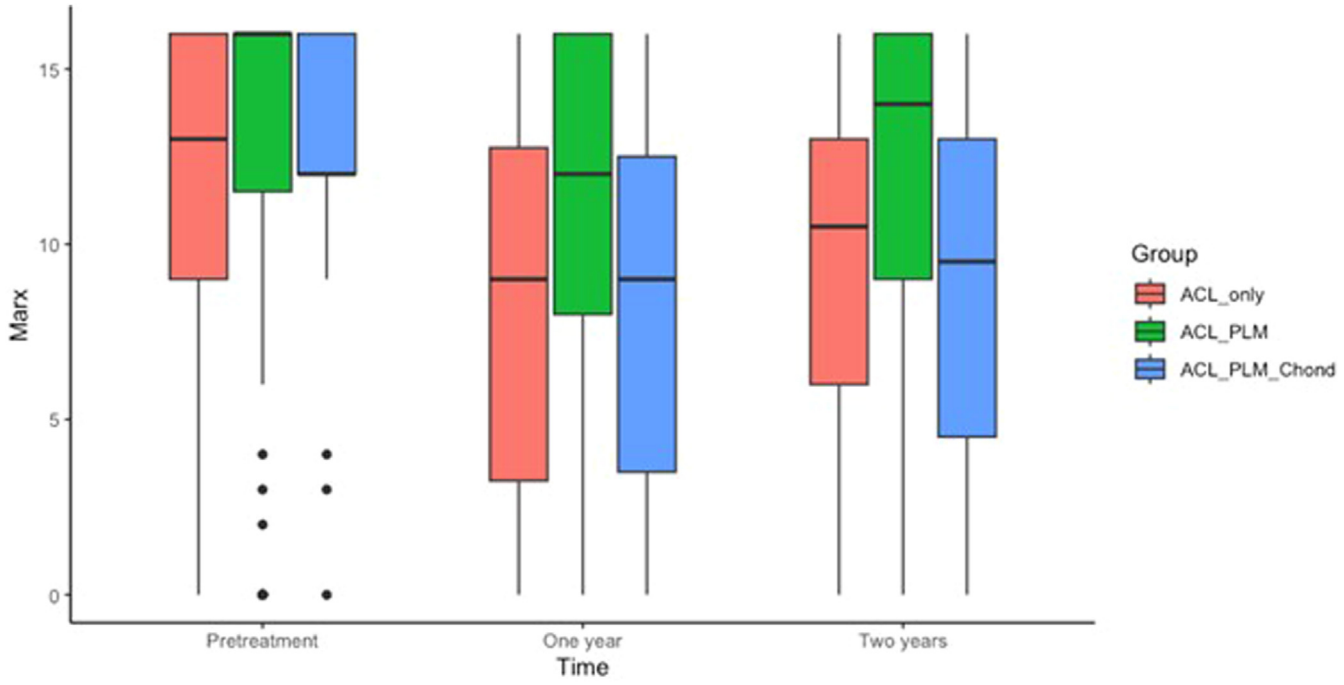

Fig 1. Marx scores by surgical group. (ACL, anterior cruciate ligament; Chond, chondroplasty; PLM, partial lateral meniscectomy.)

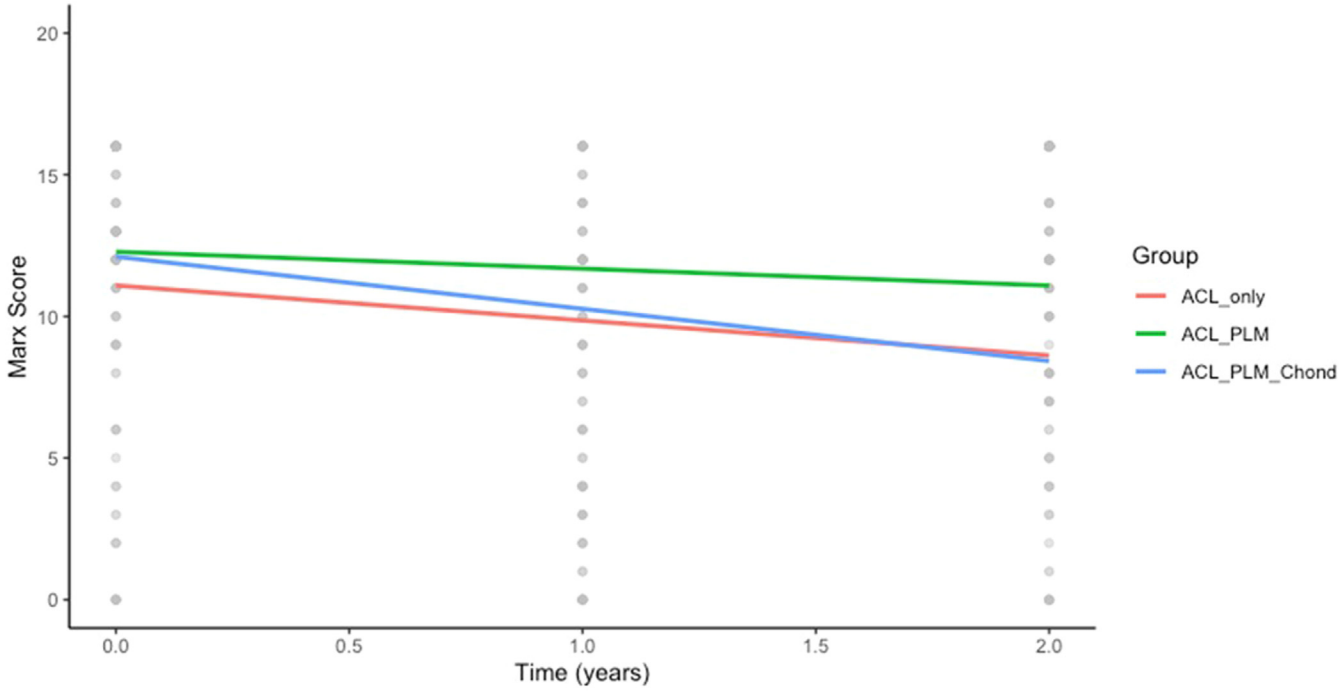

Fig 2. Marx scores linear model. (ACL, anterior cruciate ligament; Chond, chondroplasty; PLM, partial lateral meniscectomy.)

the control group (with an intact meniscus) because of previous literature.[1,2] However, we found that in some cases the patients regained similar or greater activity levels after the additional meniscectomy (Fig 1). Activity level outcomes were patient reported and measured primarily with the Marx and Tegner activity scales and secondarily with the IKDC and Lysholm scales to account for variation. Tegner, IKDC, and Lysholm scores showed no significant differences between groups including between groups that had PLM.

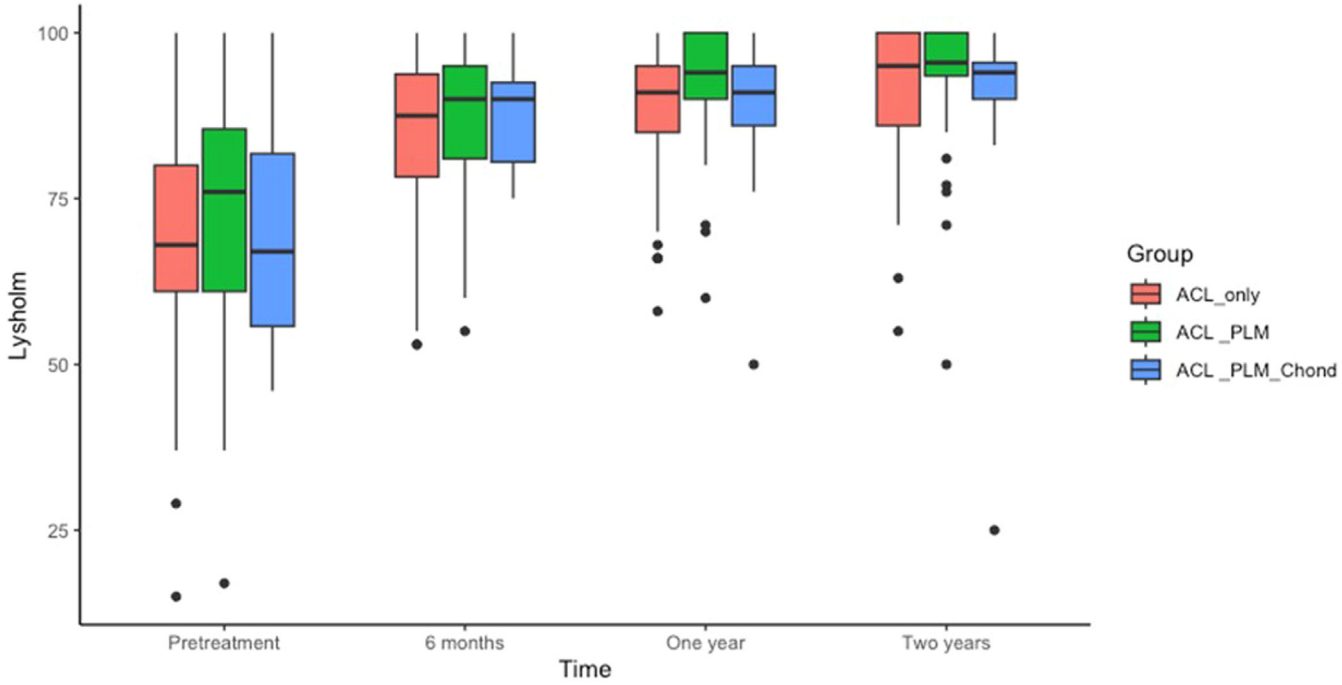

Fig 3. Lysholm scores by surgical group. (ACL, anterior cruciate ligament; Chond, chondroplasty; PLM, partial lateral meniscectomy.)

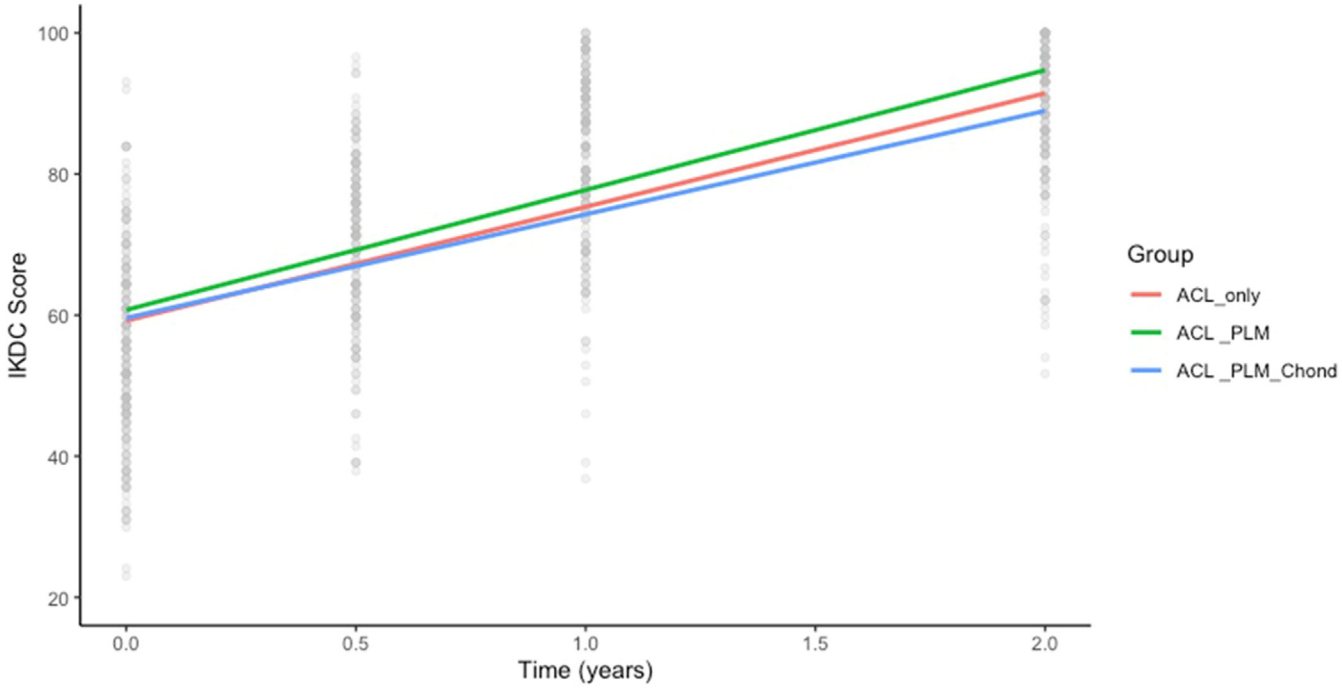

Fig 4. Lysholm scores linear model. (ACL, anterior cruciate ligament; Chond, chondroplasty; PLM, partial lateral meniscectomy.)

This result is unexpected because of the volume of literature that supports meniscus repair versus meniscectomy to maintain knee function.[1-3,8-13] The results obtained in this study could be the result of variety of factors including surgical technique. Previous bone-drilling techniques, like traditional transtibial technique, did not provide as biomechanically similar postoperative result to traditional anatomic drilling techniques such as anteromedial portal techniques and retrograde reaming techniques.[14] A biomechanical

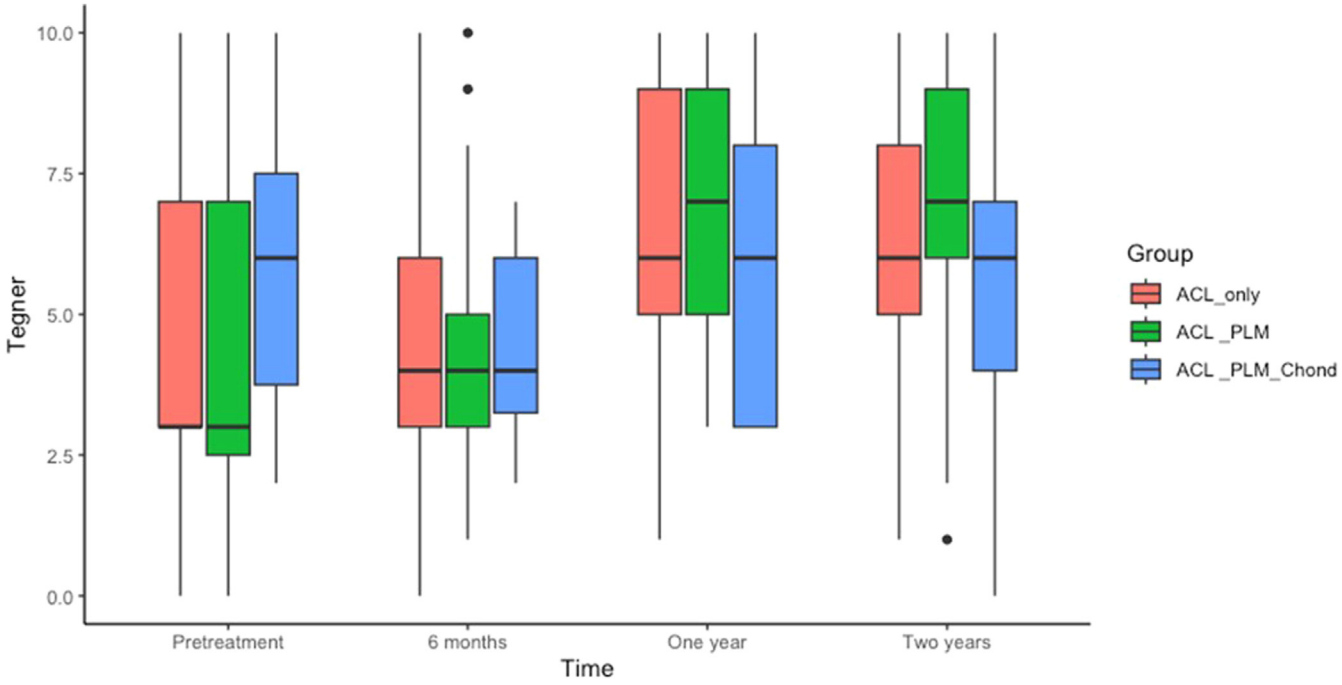

Fig 5. Tegner scores by surgical group. (ACL, anterior cruciate ligament; Chond, chondroplasty; PLM, partial lateral meniscectomy.)

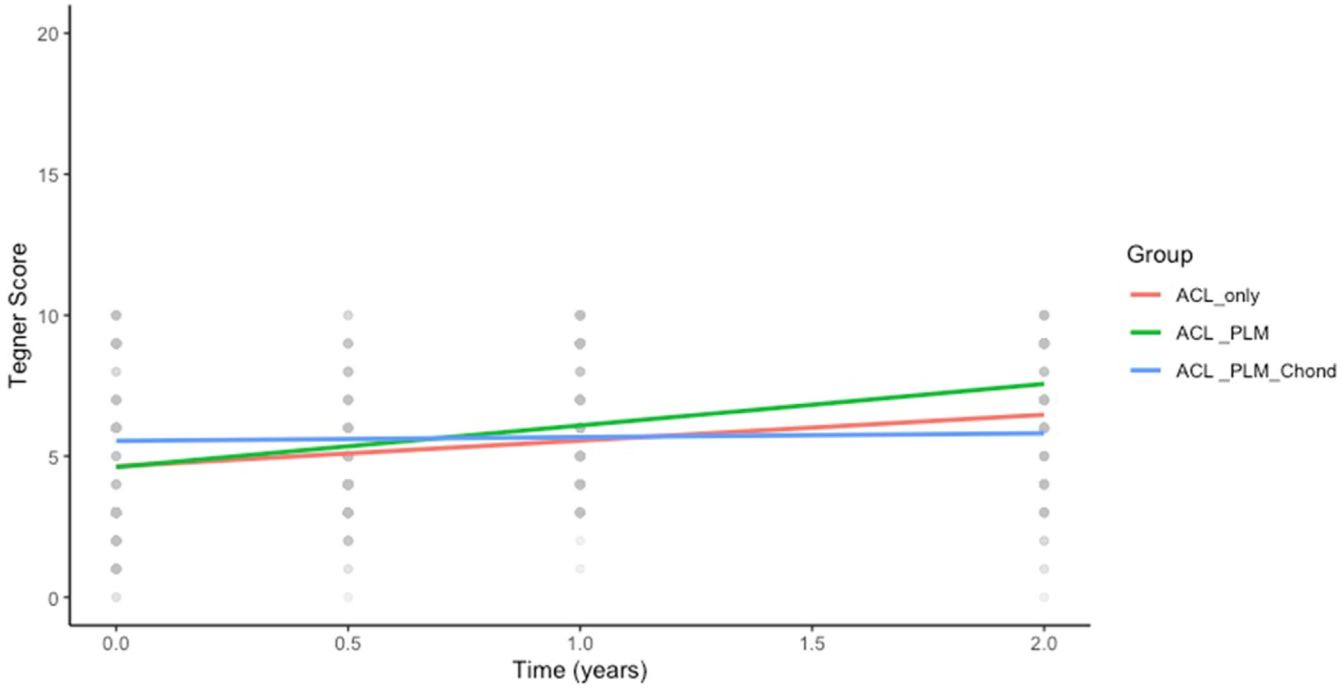

Fig 6. Tegner scores linear model. (ACL, anterior cruciate ligament; Chond, chondroplasty; PLM, partial lateral meniscectomy.)

study by Petrigliano et al.[14] in 2011 showed the significant differences in Lachman and pivot shift physical examination maneuvers with nonanatomic ACL drilling and progressive meniscectomy that was notably tempered when anatomic ACL drilling was performed. This study showed that with more nonanatomic drilling, there was more force directed on the meniscus respectively. Kocher at al.[15] showed that lateral meniscus integrity was one of the main influencers on patient satisfaction in their ACL reconstruction cohort

Table 3. Patient-Reported Outcomes Between ACLR-Only Compared With PLM Involving White-White and Red-White Zones

	ACL-Only (n = 60)	ACL With PLM, Red-Red Zone (n = 13)		ACL With PLM, White-White Zone (n = 14)	
PROM	Estimated Marginal Mean (95% CI)	Estimated Marginal Mean (95% CI)	*P* Value*	Estimated Marginal Mean (95% CI)	*P* Value*
Marx					
1 yr	8.61 (7.74-9.48)	10.29 (8.12-12.46)	.719	11.05 (9.11-13.00)	.216
2 yr	9.61 (8.66-10.55)	11.25 (9.82-12.72)	.782	10.62 (8.44-12.81)	.960
Tegner					
6 mo	4.65 (4.23-5.07)	4.52 (3.49-5.55)	1.000	3.74 (2.77-4.70)	.743
1 yr	6.24 (5.81-6.67)	7.61 (6.60-8.62)	.255	6.62 (5.72-7.53)	.998
2 yr	6.57 (6.10-7.03)	7.46 (6.52-8.49)	.832	6.30 (5.28-7.32)	.999
IKDC					
6 mo	68.6 (66.3-71.0)	71.6 (65.9-77.2)	.990	67.6 (62.3-72.8)	1.000
1 yr	82.8 (80.4-85.1)	87.2 (81.6-92.7)	.885	82.4 (77.4-87.3)	1.000
2 yr	87.8 (85.3-90.4)	88.2 (82.6-93.9)	1.000	90.9 (85.4-96.5)	.986
Lysholm					
6 mo	83.9 (82.0-85.8)	86.2 (81.5-90.9)	.993	84.7 (80.4-89.1)	1.000
1 yr	90.0 (88.0-91.9)	93.7 (89.1-98.2)	.866	92.3 (88.2-96.4)	.984
2 yr	91.6 (89.5-93.7)	91.7 (87.0-96.4)	1.000	95.4 (90.8-100.0)	.851

ACL, anterior cruciate ligament; CI, confidence interval; IKDC, International Knee Documentation Committee; PLM, partial lateral meniscectomy; PROM, patient-reported outcome measure.

**P* values were calculated by comparing estimated marginal means generated from linear mixed-effects models, and they show relationship with ACL-only control at each time point.

published in 2002. This is one of the reasons we wanted to be sure to clarify that the technique involved in this cohort was anteromedial flexible reamer drilling that should reproducibly decrease load on the menisci and therefore should be distinguished from previous studies that may have used more nonanatomic techniques. A similar biomechanical study by Tang et al.[11] showed that partial lateral root meniscectomy and total meniscectomy had no effect on ACL stability at 30° of flexion or less. This study ultimately challenges the current knowledge of the efficacy of meniscectomies, particularly lateral meniscectomies, with concurrent ACLR regarding the level of activity patients who undergo these procedures can expect to return to.

The strengths of this study include that the same surgeon and surgical team performed each surgery with the same graft source. There is no variation to account for surgical technique. In addition, all patients followed the same postoperative protocols. The high return to activity levels in patients who had a PLM compared with those with an intact meniscus (Figs 1-6) based on various PROMS at 2-years postoperatively was an unexpected finding. It is challenging to ascertain why this would be; our hypothesis is that this was related to age and associated sports that were played. The ACL with PLM mean age was 20.6 years ($P = .046$) whereas isolated ACLR was 24.0 years and ACLR with PLM and chondroplasty was 26.1 years. This would imply that a notable number of the ACL with PLM group is college-aged and therefore may have a year or more of sports remaining on their eligibility, with a 2019 National Collegiate Athletic Association cohort athlete cohort analysis having an investigated age range of 13 to 26 years of age.[16]

Limitations

This study is not without imitations. To begin, without a power analysis, it is unknown whether our sample size was sufficient. Therefore, the results may be due to a type II error. A notable limitation of the study is lack of lateral meniscal repair subjects to assess. Our quantity of patients who met criteria was small, especially compared with our other cohorts and thus not felt to be appropriately representative of this procedure outcome. An additional limitation of the study is that PROMs were only collected up until 2 years after the operation. The specific level of sports that individuals returned to was not documented in our investigation and is a limitation of the study. Further, the lateral meniscectomy as well as the lateral meniscectomy with chondroplasty cohorts were relatively low volume, and this could underplay the outcomes.

Conclusions

ACLR using BPTB autograft with anteromedial portal drilling technique does not have any significant short-term (2-year outcome) differences in return to activity and patient-reported outcomes compared with if patients additionally have a PLM and/or lateral compartment chondroplasty. Additional PLM showed significantly greater Marx scores at 1 and 2 years postoperatively.

Disclosures

All authors (S.H., S.C., B.F., P.A.) report no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

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