Anterior Cruciate Ligament Repair With Suture Tape Augmentation of Proximal Tears and Early Anterior Cruciate Ligament Reconstruction With Suture Tape Augmentation Result in Comparable Clinical Outcomes With Anterior Cruciate Ligament Reconstruction at 2-Year Follow-Up

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Purpose: To compare the postoperative side-to-side laxity and short-term clinical outcomes of patients who received primary anterior cruciate ligament (ACL) repair with suture tape augmentation, acute anterior cruciate ligament reconstruction (ACLR) with suture tape augmentation performed within 8 weeks of injury ($ACLR_{acute}$), or ACLR beyond 8 weeks of injury. **Methods:** After institutional review board approval was obtained, 100 patients were enrolled in this prospective trial: 34 primary ACL repair with suture tape augmentation, 33 ACLRs performed within 8 weeks of injury ($ACLR_{acute}$), and 33 ACLRs. Patients were allocated to ACL repair if a proximal avulsion was present with good tissue quality (Sherman type 1), confirmed by intraoperative diagnostic arthroscopy. Preoperative side-to-side anteroposterior knee laxity was assessed with KT-1000 arthrometer, and patient-reported outcomes (PROs) including the visual analog scale, Marx activity scale, Veterans RAND 12-item health survey (VR-12 physical & mental), Single Assessment Numeric Evaluation, Knee Injury and Osteoarthritis Outcome Score survey subscales, and range of motion were collected. These objective and subjective measures were repeated at regular intervals postoperatively through 2 years. Minimal clinically important difference calculations were performed assessing postoperative PRO changes at 2 years compared with preoperative. **Results:** The average time from injury to surgery was 5.03 ± 1.2 weeks for the ACL repair group, 5.09 ± 0.74 weeks for the $ACLR_{acute}$, and 43.22 ± 33.5 weeks for the ACLR group. Postoperatively, the KT-1000 side-to-side laxity difference for 30 lbs was determined to be 0.1 ± 0.37 (95% confidence interval [CI] −0.7 to 0.8) for ACL repair versus ACLR ($P < .0001$), −0.8 ± 0.35 (95% CI −1.5 to −0.1) for $ACLR_{acute}$ versus ACLR ($P < .0001$), and 0.8 ± 0.40 (95% CI 0.0-1.6) for ACL repair versus $ACLR_{acute}$ ($P < .0001$). The data reveal ACL repair and $ACLR_{acute}$ are noninferior to ACLR at 2-year follow-up. The postoperative difference from baseline for all PROs demonstrated improvement for all PROs. Magnetic resonance imaging at 1 year revealed tissue healing for the 3 ACL injury treatment groups. **Conclusions:** Patients who underwent ACL repair of proximal tears with suture tape augmentation or ACL reconstruction within 8 weeks from injury resulted in noninferior side-to-side knee laxity, comparable PROs, and similar range of motion at 2-year follow-up compared with ACLR. **Level of Evidence:** Level II, prospective comparative study.

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Anterior cruciate ligament (ACL) injuries consistently rank among the top orthopaedic procedures performed globally. Available estimates suggest more than 200,000 ACL injuries occur in the United States each year, with similar incidence reported globally.[1-3] Individuals experiencing ACL injuries are 5

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times more likely to progress to moderate or severe osteoarthritis (OA) compared with the uninjured knee. The risk of patients developing grade II or greater radiologic changes 10 years after injury, measured by the Kellgren-Lawrence classification, is greater in patients who underwent nonoperative treatment than anterior cruciate ligament reconstruction (ACLR).[4] Conservative and surgical treatments are continually advancing to meet patient demands of daily life and sport among the several age groups experiencing ACL injury.

Primary open ACL repair was the preferred technique for approximately 100 years; however, it was largely abandoned in the 1990s as the result of improved long-term outcomes of ACLR techniques.[5,6] Although mid- and long-term outcomes after ACLR have proved more favorable, the revision rate remains at 10% to 15%.[7] There is renewed interest in primary ACL repair as the result of arthroscopic techniques and material advancements. Surgical pearls of primary ACL repair include restoring natural anatomy, retaining proprioceptive fibers, and reducing donor-site morbidity.[7,8] Primary ACL repair outcomes success can be attributed to proper patient selection[8,9] and the incorporation of static augmentation, with suture tape acting as a "seatbelt."[6-8,10-14] The internal bracing technique introduces high-strength suture tape to the repair construct for native ligament reinforcement and excessive elongation protection.[7] The technique improvements and patient considerations have resulted in similar outcomes compared with traditional ACLR techniques.[15-20] Reported advantages of primary repair with suture tape augmentation over ACLR include an earlier range of motion, less pain, and decreased operative knee awareness.[20,21]

When ACLR is the preferred technique, surgeons must consider the optimal delay from injury to intervention. Controversy exists as the result of reports of stiffness, arthrofibrosis, and a reduced rate of return to work associated with early intervention.[22,23] Conversely, studies have described an increase in meniscus and cartilage injury if surgery is prolonged for more than 3 months from injury.[24,25] The American Academy of Orthopaedic Surgeons recommends ACLR be performed within 3 months of injury, after physical therapy, to increase preoperative range of motion.[26] Most recent systematic reviews suggest similar results in early versus delayed surgical intervention; however, definitive conclusions cannot be attained.[24,27,28]

The purpose of this study is to compare the postoperative side-to-side laxity and short-term clinical outcomes of patients who received primary ACL repair with suture tape augmentation, acute ACLR with suture tape augmentation performed within 8 weeks of injury ($ACLR_{acute}$), or ACLR beyond 8 weeks of injury. The authors' hypothesis was patients undergoing ACL repair or early intervention ACLR would demonstrate similar side-to-side laxity and clinical outcomes with those who underwent ACLR.

Methods

Subject Criteria

This study received institutional review board approval (2015-327-1). Patients with ACL injuries were seen in the clinic between 2016 and 2019 and approached for study participation if routine surgical treatment with either primary ACL repair or ACLR was required. Informed consent was obtained for all subjects. Eligibility for study inclusion was patients between the ages of 18 and 64 years, and clinical and radiologic (magnetic resonance imaging [MRI]) confirmation of ACL injury. Patients in poor health; with concomitant multiligament injuries of the medial collateral ligament, posterior cruciate ligament, lateral collateral ligament, posteromedial corner, or posterolateral corner requiring surgical treatment; previous major knee surgery; inadequate hamstring diameter or length; and chronic narcotic usage were excluded from involvement in this study. All patients within the enrollment period were considered for study participation. Patients were not randomized and stratified into 1 of 3 ACL surgical treatments (primary ACL repair, acute ACLR, ACLR) dependent on factors including ACL tear severity and time from injury.

Primary ACL Repair Inclusion

Patients considered eligible for primary ACL repair presented with an ACL tear at the femoral attachment with good tissue quality (Sherman type 1[29]). ACL tissue quality tear pattern was arthroscopically confirmed at the time of surgery. In addition, patients in this cohort had a maximum delay of 8 weeks from injury to surgery.

Acute ACL Reconstruction Inclusion ($ACLR_{acute}$)

Patients included in the acute ACLR cohort underwent surgery within 8 weeks of injury and did not possess the necessary tissue quality required for ACL repair.

ACLR Inclusion

Patients included in the ACLR cohort underwent surgical treatment more than 8 weeks from injury. This group served as the study control by which functional and patient-reported outcomes (PROs) of primary ACL repair and acute ACLR are compared. Eight weeks was determined on the basis of the average surgical timeline of the primary author during the enrollment period and includes conservative treatment before surgical intervention.

Surgical Technique

All surgeries were performed by the primary author (S.G.S.). The patient was examined to determine the

stability of the ACL, collateral ligaments, and the posterior cruciate ligament to ensure there were no concomitant injuries. Diagnostic arthroscopy was used to assess ACL tissue quality and determine eligibility for primary repair if patient was within 8 weeks of injury.

Patients who met criteria underwent primary ACL repair with suture tape augmentation (ACL Repair TightRope with *Internal*Brace; Arthrex, Naples, FL).[30] Anchor sites of the ACL on the medial wall of the lateral femoral condyle were prepared by using a rasp and by creating microfractures. A tunnel was created for the fixation of the ACL on the femoral condyle. Subsequently, 2 looped sutures (FiberLink; Arthrex) were secured on the ACL to permit full contact of the proximal stump to the wall. A small incision was performed above the pes anserinus to create the tibial tunnel in an anatomical position, ensuring that the drill exited at the base of the stump of the ACL. The adjustable loop-length femoral cortical button and suture tape were passed through the femoral tunnel and secured on the femur. Distally, the tape was fixed with an anchor (SwiveLock; Arthrex) in 0° knee extension. The femoral fixation was retensioned at 10° knee extension after range of motion cycling.

Patients not meeting primary ACL repair criteria underwent all-inside ACLR (GraftLink; Arthrex) plus suture tape augmentation using hamstring autograft. A minimum 8-mm semitendinosus and gracilis tendon autograft was harvested and quadrupled. The graft was advanced through the femoral tunnel and fixated with a button, followed by tibial fixation at 10° of knee flexion. Intraoperative knee cycling was performed and the graft tensioned in knee extension. The time from injury to surgery was documented, and patients were allocated to $ACLR_{acute}$ if duration was less than 8 weeks or ACLR if greater than 8 weeks.

Postoperative Rehabilitation

The postoperative physical therapy program did not differ between the 3 investigated groups. Full weight-bearing was permitted on postoperative day 1. Patients were advised to wear a locked brace in full extension for 1 month while weight-bearing and use crutches as necessary. After 1 month postoperatively, an ACL brace was recommended for any activities outside the domicile for up to 6 months.

Physiotherapy commenced 48 hours postoperatively, with 2 to 3 visits per week for the initial 6 weeks, followed by 1 to 2 visits per week from 6 weeks to 3 months, and subsequently, 1 to 2 visits per month from 3 months to 6 months postoperatively. Return to normal physical activities, recreational sports, and manual labor was allowed at a minimum of 6 months postoperatively. At this time point, the patient was thoroughly evaluated by the physiotherapist. The evaluation consisted of successfully completing 3 hops test, strength greater than 90% of the contralateral leg, and restoration of range of motion.

Data Collection

After informed consent, the primary outcome of knee stability evaluated by arthrometric side-to-side knee laxity evaluation with the KT-1000 (15 lbs, 20 lbs, 30 lbs, Lachman) was recorded. KT-1000 data were collected by the primary author postoperatively at 6 weeks, 12 weeks, 26 weeks, 1 year, and 2-year intervals.

PROs included the visual analog scale, Marx activity scale, Veterans RAND 12-item health survey (VR-12 physical & mental), Single Assessment Numeric Evaluation (SANE), and Knee Injury and Osteoarthritis Outcome Score (KOOS) survey subscales. All PROs were independently completed by patients and collected electronically in a digital registry (Surgical Outcomes System; Arthrex). These subjective measures were repeated at 6 weeks, 12 weeks, 26 weeks, 1 year, and 2 years postoperatively. Minimal clinically important difference (MCID) calculations assessed postoperative PRO changes at 2 years compared with preoperative. MCID was calculated using the distribution method (1/2 standard deviation method),[31] and the change from surgery to 2-year outcome was compared to determine whether clinical improvement occurred. Preoperative and 2-year postoperative range of motion was collected. Range of motion measures were performed with a goniometer by a nurse and visually confirmed by the primary author (S.G.S.).

Patients underwent an MRI at 1 year to assess graft healing. Inflammation, ACL thickness, and contact with femoral insertion were evaluated. An ACL was assigned "good" if it was intact and "acceptable" if there was an observed periligamentous injury with superficial fluid collection, absence of displacement, thickening, and discontinuity of the ligament. The criteria for a "bad" observation included a large cyclops lesion, thickening of the ligament with intraligamentous hyperintense signal intensity on T2-weighted images, fibrillated edges, or re-rupture. The primary author (S.G.S.) and a radiologist assessed all postoperative imaging.

Statistical Analysis

An a priori power analysis was performed to detect an anteroposterior (AP) laxity side-to-side difference (compared with the contralateral knee) of 2.5 mm and standard deviation of 3.0. Results suggested a sample of 24 subjects per group were required to reach a power of 0.8 (alpha = 0.05). To account for attrition, a minimum of 86 patients were included in the study.

Differences between side-to-side AP laxity and range of motion were calculated at the patient level and then compared between groups. To assess the primary hypothesis that primary ACL repair and $ACLR_{acute}$ are clinically comparable with ACLR, a noninferiority test

was performed for KT-1000 knee AP laxity at the 2-year follow-up. A clinically relevant margin of less than 3 mm was used to assess noninferiority.[32] 95% confidence intervals (CIs) were calculated, and the upper bound was used to assess the hypothesis that ACL repair and $ACLR_{acute}$ would be noninferior to ACLR, which served as the control for this analysis. The numerical difference between the operated and contralateral knee for each cohort was calculated and used for noninferiority tests between the surgical groups to determine whether the difference was less than the cutoff value, 3 mm. Noninferiority to ACLR was achieved if the upper bound of the 95% CI for the surgical cohort difference was less than 3.

Descriptive statistics summarized patient demographics, operative data, and failure/retear frequency. The delayed ACL reconstruction group served as the control; PRO comparisons of interest were on the basis of primary ACL repair versus ACLR, $ACLR_{acute}$ versus ACLR, and ACL repair versus $ACLR_{acute}$. Continuous variables were summarized using the mean and standard deviation, and categorical variables were summarized using counts and percentages. Differences between groups were summarized with the mean and standard error, along with a 95% CI. Comparisons between groups were made using the Fisher exact test.

All *P* values are nominal, and no adjustment for multiple comparisons was made. A one-sided *P* value of $<.025$ was used to determine statistical significance for one-sided noninferiority tests. A 2-sided *P* value of $<.05$ was used to determine statistical significance for all

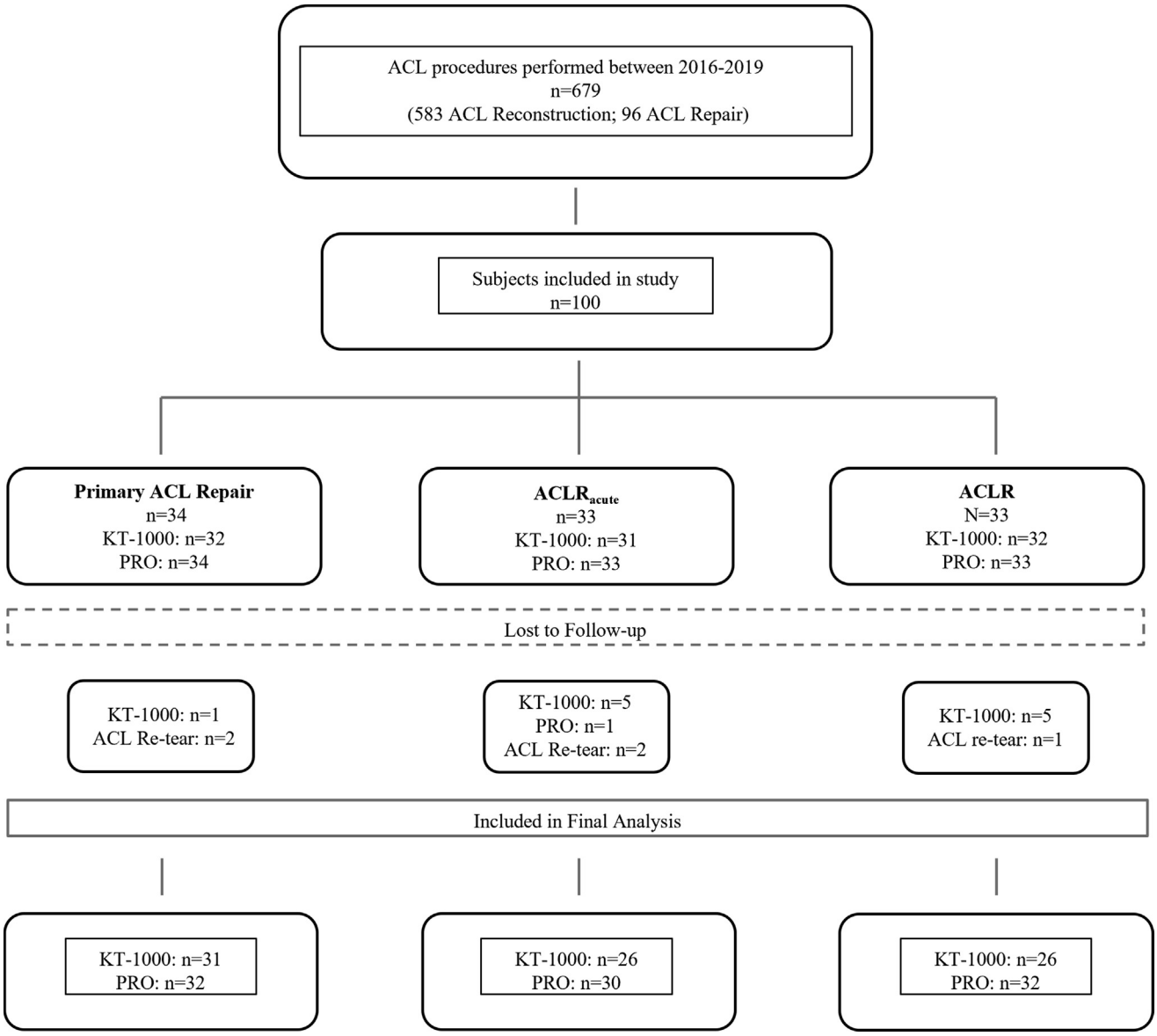

Fig 1. Subject inclusion and exclusion criteria flow diagram. (ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; PRO, patient-reported outcome.)

Table 1. Patient and Surgical Demographics

	ACL Repair (n = 34)	$ACLR_{acute}$ (n = 33)	ACLR (n = 33)	Repair Versus ACLR: *P* Value*	$ACLR_{acute}$ Versus ACLR: *P* Value*	Repair Versus $ACLR_{acute}$ *P* Value*
Age at treatment, yr	43.2 ± 9.9	35.6 ± 9.8	38.8 ± 11.7	.1017	.2214	.0022
Sex				.6799	.2163	.0971
Female	51.7% (15/29)	29.2% (7/24)	46.2% (12/26)			
Male	48.3% (14/29)	70.8% (17/24)	53.8% (14/26)			
Injury side (from objective data)				.2745	1.0000	.2745
Right	38.2% (13/34)	51.5% (17/33)	51.5% (17/33)			
Left	61.8% (21/34)	48.5% (16/33)	48.5% (16/33)			
Injury type				1.0000	.3192	.3725
With contact	20.8% (5/24)	5.9% (1/17)	20.0% (3/15)			
Without contact	79.2% (19/24)	94.1% (16/17)	80.0% (12/15)			
Surgical data						
Injury to surgery, wk	5.03 ± 1.2	5.09 ± 0.74	43.22 ± 33.5			
(min, max)	(2.71, 7.86)	(3.57, 6.43)	(12.86, 137)			
Surgical time (skin to skin), min	58.1 ± 11.4	53.1 ± 10.5	49.5 ± 11.8	.0728	.2070	.0728
Diagnosis						
Meniscus tear	76.5% (26/34)	87.9% (29/33)	93.9% (31/33)	.2234	.6724	.2234
Osteoarthritis	20.6% (7/34)	18.2% (6/33)	24.2% (8/33)	.8033	.5470	.8033
Insufficiency fracture	0.0% (0/34)	3.0% (1/33)	0.0% (0/33)	.4925	1.0000	.4925

NOTE. Data are displayed as mean ± standard deviation.

*P value from 2-sample t test (continuous data) or Fisher exact test (categorical data).

Table 2. Preoperative KT-1000 Side-to-Side Laxity

Measure	Side	ACL Repair Summary	$ACLR_{acute}$ Summary	ACLR Summary	Repair Versus ACLR Difference*	Repair Versus ACLR *P* Value†	$ACLR_{acute}$ Versus ACLR Difference*	$ACLR_{acute}$ Versus ACLR *P* Value†	Repair Versus $ACLR_{acute}$ Difference*	Repair Versus $ACLR_{acute}$ *P* Value†
15 lbs	Operated side	n = 32	n = 31	n = 32						
		8.1 ± 7.6	5.6 ± 2.0	6.3 ± 2.1						
	Contralateral side	32	31	31						
		5.7 ± 8.2	2.7 ± 1.7	3.4 ± 1.7						
	Difference‡	2.4 ± 3.6	2.8 ± 2.2	3.0 ± 2.7	−0.6 ± 0.81	.4641	−0.2 ± 0.62	.7965	−0.4 ± 0.75	.5681
		95% CI (1.1-3.7)	95% CI (2.0-3.6)	95% CI (2.0-4.0)	(−2.2 to 1.0)		(−1.4 to 1.1)		(−1.9 to 1.1)	
20 lbs	Operated side	32	31	32						
		9.2 ± 5.4	6.8 ± 2.0	7.8 ± 2.3						
	Contralateral side	32	31	31						
		6.4 ± 5.8	3.7 ± 1.8	4.3 ± 1.8						
	Difference‡	2.8 ± 4.1	3.1 ± 2.1	3.6 ± 3.0	−0.7 ± 0.91	.4190	-−0.5 ± 0.65	.4628	−0.3 ± 0.82	.7593
		95% CI (1.4-4.3)	95% CI (2.3-3.9)	95% CI (2.5-4.7)	(−2.5 to 1.1)		(−1.8 to 0.8)		(−1.9 to 1.4)	
30 lbs	Operated side	32	31	32						
		10.9 ± 5.1	8.5 ± 2.2	9.7 ± 2.7						
	Contralateral side	32	31	31						
		7.6 ± 5.6	4.8 ± 1.9	5.3 ± 2.0						
	Difference‡	3.3 ± 4.5	3.7 ± 2.5	4.5 ± 3.2	−1.2 ± 1.00	.2501	−0.8 ± 0.73	.2915	−0.4 ± 0.92	.6788
		95% CI (1.7- 5.0)	95% CI (2.8-4.6)	95% CI (3.3- 5.7)	(−3.1 to 0.8)		(−2.2 to 0.7)		(−2.2 to 1.5)	
Lachman	Operated side	32	31	32						
		9.0 ± 2.9	7.7 ± 2.0	8.4 ± 2.4						
	Contralateral side	32	31	32						
		5.6 ± 2.9	3.9 ± 1.8	4.3 ± 1.6						
	Difference‡	3.4 ± 4.3	3.8 ± 2.4	4.1 ± 2.8	−0.7 ± 0.92	.4458	−0.3 ± 0.66	.6245	−0.4 ± 0.88	.6712
		95% CI (1.9, 5.0)	95% CI (2.9, 4.7)	95% CI (3.1, 5.1)	(−2.5 to 1.1)		(−1.7 to 1.0)		(−2.1 to 1.4)	

NOTE. Data are displayed as mean ± standard deviation.

ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; CI, confidence interval.

*Data are displayed as mean ± standard error; (95% CI).

†*P* value from 2-sample *t* test.

‡Difference = operated side − contralateral side.

Table 3. Two-Year Postoperative KT-1000 Side-to-Side Laxity

Measure	Side	ACL Repair Summary	$ACLR_{acute}$ Summary	ACLR Summary	Repair Versus ACLR Difference*	Repair Versus ACLR *P* Value†	$ACLR_{acute}$ Versus ACLR Difference*	$ACLR_{acute}$ Versus ACLR *P* Value†	Repair Versus $ACLR_{acute}$ Difference*	Repair Versus $ACLR_{acute}$ *P* Value†
15 lbs	Operated side	n = 31	n = 26	n = 26						
		4.5 ± 2.0	3.2 ± 1.8	3.5 ± 1.3						
	Contralateral side	31	26	26						
		3.5 ± 1.8	3.0 ± 1.7	2.7 ± 1.8						
	Difference‡	31	26	26	0.2 ± 0.35	<.0001	−0.6 ± 0.34	<.0001	0.7 ± 0.37	<.0001
		1.0 ± 1.4	0.2 ± 1.3	0.8 ± 1.1	(−0.5 to 0.9)		(−1.3 to 0.1)		(−0.0 to 1.5)	
		95% CI (0.4-1.5)	95% CI (−0.3 to 0.8)	95% CI (0.4 to 1.3)						
20 lbs	Operated side	31	26	26						
		5.6 ± 2.0	4.2 ± 1.8	4.5 ± 1.4						
	Contralateral side	31	26	26						
		4.5 ± 1.8	4.0 ± 1.7	3.7 ± 1.9						
	Difference‡	31	26	26	0.2 ± 0.34	<.0001	−0.7 ± 0.34	<.0001	0.8 ± 0.37	<.0001
		1.0 ± 1.4	0.2 ± 1.3	0.8 ± 1.1	(−0.5 to 0.9)		(−1.3 to 0.0)		(0.1-1.6)	
		95% CI (0.5-1.6)	95% CI (−0.3 to 0.7)	95% CI (0.4-1.3)						
30 lbs	Operated side	31	26	26						
		6.7 ± 2.2	5.2 ± 1.9	5.7 ± 1.6						
	Contralateral side	31	26	26						
		5.7 ± 1.9	5.0 ± 1.7	4.7 ± 1.9						
	Difference‡	31	26	26	0.1 ± 0.37	<.0001	−0.8 ± 0.35	<.0001	0.8 ± 0.40	<.0001
		1.0 ± 1.6	0.2 ± 1.4	1.0 ± 1.1	(−0.7− 0.8)		(−1.5 to −0.1)		(0.0-1.6)	
		95% CI (0.5-1.6)	95% CI (−0.4−0.8)	95% CI (0.5-1.4)						
Lachman	Operated side	31	26	26						
		5.6 ± 2.2	4.1 ± 1.8	4.8 ± 1.3						
	Contralateral side	31	26	26						
		4.5 ± 1.8	3.8 ± 1.6	3.7 ± 1.8						
	Difference‡	31	26	26	0.0 ± 0.40	<.0001	−0.8 ± 0.38	<.0001	0.9 ± 0.41	<.0001
		1.2 ± 1.7	0.3 ± 1.4	1.1 ± 1.3	(−0.8 to 0.8)		(−1.6 to −0.1)		(0.1-1.7)	
		95% CI (0.6-1.8)	95% CI (−0.3 to 0.8)	95% CI (0.6- 1.6)						

NOTE. Data are displayed as mean ± standard deviation (N).

ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; CI, confidence interval.

*Data are displayed as mean ± standard error; (95% CI).

†*P* value from 2-sample noninferiority test on the basis of a noninferiority margin of 3.

‡Difference = operated side − contralateral side.

Table 4. Two-Year Postoperative KT-1000 Knee Anteroposterior Laxity Increases

KT-1000 Measure	Change Versus Contralateral	ACL Repair	$ACLR_{acute}$*	ACLR*	Repair Versus ACLR *P* Value†	$ACLR_{acute}$ Versus ACLR: *P* Value†	Repair Versus $ACLR_{acute}$: *P* Value†
15 lbs	Increase <3 mm	87.1% (27/31)	96.2% (25/26)	96.2% (25/26)	.3624	0.99	.3624
	Increase ≥3 mm	12.9% (4/31)	3.8% (1/26)	3.8% (1/26)			
20 lbs	Increase <3 mm	87.1% (27/31)	96.2% (25/26)	96.2% (25/26)	.3624	0.99	.3624
	Increase ≥3 mm	12.9% (4/31)	3.8% (1/26)	3.8% (1/26)			
30 lbs	Increase <3 mm	87.1% (27/31)	96.2% (25/26)	92.3% (24/26)	.6779	0.99	.3624
	Increase ≥3 mm	12.9% (4/31)	3.8% (1/26)	7.7% (2/26)			
Lachman	Increase <3 mm	83.9% (26/31)	96.2% (25/26)	88.5% (23/26)	.7153	.6098	.2046
	Increase ≥3 mm	16.1% (5/31)	3.8% (1/26)	11.5% (3/26)			

ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction.
*Data are displayed as % (n/N).
†*P* value from the Fisher exact test.

other evaluations. Analysis was performed using SAS, Version 9.4 (SAS Institute Inc., Cary, NC).

Results

Patient Demographics

A total of 100 patients met the specified follow-up criteria and were included for analysis in this study. Thirty-four patients underwent primary ACL repair with suture tape augmentation, 33 patients received $ACLR_{acute}$ within 8 weeks from injury, and the remaining 33 patients were allotted to the ACLR cohort (Fig 1). Strict inclusion criteria regarding tear propagation for the primary ACL repair cohort contributed to an extended enrollment duration.

The average time from injury to surgery was 5.03 ± 1.2 weeks for the ACL repair group, 5.09 ± 0.74 weeks for the $ACLR_{acute}$, and 43.22 ± 33.5 weeks for the ACLR group. The average autograft size for ACLR was 9.5 mm (range: 8-12 mm). There were no statistical differences in the demographics between the groups including injury side, injury type, body mass index, smoking status, diabetes, workman's compensation, and narcotic usage. For patients who reported their sex, there were no statistical differences between sex with a total of 43% female patients and 57% male patients. Primary ACL repair required an additional 8.6 minutes of operating time compared with ACLR (58.1 ± 11.4 vs 49.5 ± 11.8 minutes, $P < .07$). Meniscus tears were present in 76.5% of the primary ACL repair cases (26/34 patients), 87.9% of $ACLR_{acute}$ cases (29/33), and 93.9% of ACLR (31/33) (Table 1). In total, 94% (80/85) of meniscal tears among the 3 groups occurred in the posterior horn, and the remaining meniscal tears occurred at the external meniscus body. Treatment of meniscus injury was accomplished with partial meniscectomy (17 ACL repair, 17 $ACLR_{acute}$, 17 ACLR), meniscus repair (5 ACL repair, 7 $ACLR_{acute}$, 7 ACLR), combined partial meniscectomy and repair (3 ACL repair, 5 $ACLR_{acute}$, 7 ACLR), or debridement (1 ACL repair). OA was present in 21% of patients and graded according to the Kellgren-Lawrence classification. Grade 1 OA was observed in 1 ACL repair case, grade 2 OA was observed (2 ACL repair, 3 $ACLR_{acute}$, 1 ACLR), and grade 3 OA was observed (4 ACL repair, 3 $ACLR_{acute}$, 7 ACLR).

To assess the influence of age, sex, and meniscus injury on the primary objective at the 2-year postoperative follow-up, generalized linear multivariate regression models were fit to the KT-1000 side-to-side laxity outcomes. Models were adjusted by age (continuous), sex, and the presence of meniscus tear. The least square means estimates for the difference between groups were obtained, along with associated standard errors and 95% CIs. *P* values testing for noninferiority (margin of 3 mm) were obtained for each between-group comparison. Results from the multivariate analysis revealed age, sex, or the presence of meniscus pathology did not affect the 2-year side-to-side laxity outcomes of KT-1000 15 lbs, 20 lbs, 30 lbs, or Lachman tests when evaluating ACL repair or $ACLR_{acute}$ to ACLR ($P < .0001$).

KT-1000 Arthrometric Side-to-Side Knee Laxity

No significant differences in KT-1000 AP knee laxity measurements were observed preoperatively for the margin of difference between the operated and contralateral side for the ACL repair versus ACLR, $ACLR_{acute}$ versus ACLR, and ACL repair versus $ACLR_{acute}$ groups (Table 2). Postoperatively, the KT-1000 side-to-side laxity difference for 30 lbs was determined to be 0.1 ± 0.37, 95% CI −0.7 to 0.8 for ACL repair versus ACLR ($P < .0001$), −0.8 ± 0.35, 95% CI −1.5 to −0.1 for $ACLR_{acute}$ versus ACLR ($P < .0001$), and 0.8 ± 0.40, 95% CI 0.0-1.6 for ACL repair vs $ACLR_{acute}$ ($P < .0001$) (Table 3). Data for all KT-1000 measures (15 lbs, 20 lbs, 30 lbs, and Lachman) are available in Tables 2 and 3. The data reveal ACL repair

Table 5. Range of Motion

	ACL Repair	$ACLR_{acute}$	ACLR	Repair Versus ACLR		$ACLR_{acute}$ Versus ACLR		Repair Versus $ACLR_{acute}$	
Side	Summary	Summary	Summary	Difference*	*P* Value†	Difference*	*P* Value†	Difference*	*P* Value†
Preoperative knee extension									
Operated side	n = 29	n = 28	n = 32						
	0.5 ± 1.5	1.5 ± 2.7	3.1 ± 3.3						
Contralateral side	1.0 ± 2.5	2.1 ± 3.2	3.9 ± 3.5						
Difference*	−0.5 ± 1.5	−0.6 ± 2.5	−0.8 ± 1.8	0.3 ± 0.44	.5496	0.2 ± 0.56	.7581	0.1 ± 0.55	.8716
	95% CI	95% CI	95% CI	(−0.6 to 1.1)		(−1.0 to 1.3)		(−1.0 to 1.2)	
	(−1.1 to 0.1)	(−1.6 to 0.4)	(−1.4 to −0.1)						
Postoperative knee extension									
Operated side	n = 31	n = 26	n = 25						
	0.5 ± 1.5	0.8 ± 1.8	1.6 ± 2.8						
Contralateral side	0.6 ± 1.7	1.2 ± 2.6	1.4 ± 2.7						
Difference*	−0.2 ± 0.9	−0.4 ± 1.4	0.2 ± 1.0	−0.4 ± 0.25	.1606	−0.6 ± 0.34	.0874	0.2 ± 0.31	.4774
	95% CI	95% CI	95% CI	(−0.9 to 0.1)		(−1.3 to 0.1)		(−0.4 to 0.9)	
	(−0.5 to 0.2)	(−0.9 to 0.2)	(−0.2 to 0.6)						
Preoperative knee flexion									
Operated side	n = 31	n = 31	n = 32						
	128.1 ± 5.6	126.9 ± 8.6	135.5 ± 6.1						
Contralateral side	139.5 ± 6.0	139.2 ± 5.3	137.5 ± 5.4						
Difference*	−11.5 ± 7.3	−12.3 ± 11.5	−2.0 ± 4.7	−9.4 ± 1.56	**.0001**	−10.2 ± 2.23	**<.0001**	0.8 ± 2.45	.7438
	95% CI	95% CI	95% CI	(−12.5 to −6.3)		(−14.7 to −5.7)		(−4.1 to 5.7)	
	(−14.1 to −8.8)	(−16.5 to −8.0)	(−3.7 to −0.3)						
Postoperative knee flexion									
Operated side	n = 31	n = 26	n = 25						
	138.2 ± 6.0	136.7 ± 4.9	135.4 ± 6.1						
Contralateral side	138.9 ± 6.3	138.8 ± 5.9	139.0 ± 6.3						
Difference*	-0.6 ± 3.1	-2.1 ± 3.5	-3.6 ± 4.5	3.0 ± 1.01	**.0050**	1.5 ± 1.12	.1915	1.5 ± 0.88	.0987
	95% CI	95% CI	95% CI	(0.9- 5.0)		(−0.8 to 3.7)		(−0.3 to 3.2)	
	(−1.8 to 0.5)	(−3.5 to −0.7)	(−5.4 to −1.8)						

NOTE. Data are displayed as mean ± standard deviation. Statistically significant findings are bold text. Difference = operated side − contralateral side.
ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; CI, confidence interval.
*Data are displayed as mean ± standard error; (95% CI).
†*P* value from 2-sample *t* test.

Table 6. Patient-Reported Outcomes

				Repair Versus ACLR		$ACLR_{acute}$ Versus ACLR		Repair Versus $ACLR_{acute}$	
	ACL Repair	$ACLR_{acute}$	ACLR	Difference*	*P* Value†	Difference*	*P* Value†	Difference*	*P* Value†
Visual analog scale									
Preoperative	n = 34 3.0 ± 2.2	n = 33 2.3 ± 2.1	n = 33 2.4 ± 2.4	0.5 ± 0.56 (−0.6 to 1.6)	.3492	−0.1 ± 0.56 (−1.2 to 1.0)	.8178	0.7 ± 0.53 (−0.4 to 1.7)	.2180
2-year	32 1.1 ± 1.9	30 0.8 ± 1.8	32 1.0 ± 1.3	0.1 ± 0.40 (−0.7 to 0.9)	.8814	−0.2 ± 0.39 (−0.9 to 0.6)	.6921	0.2 ± 0.46 (−0.7 to 1.1)	.6396
Δ at 2 years	−1.7 ± 2.1 95% CI (−2.5, −1.0)	−1.4 ± 2.6 95% CI (−2.4, −0.5)	−1.5 ± 2.2 95% CI (−2.2, −0.7)	−0.3 ± 0.54 (−1.4 to 0.8)	.5927	0.0 ± 0.60 (−1.2 to 1.2)	.9926	−0.3 ± 0.60 (−1.5 to 0.9)	.6256
Marx Activity Scale									
Preoperative	8.7 ± 4.6	10.6 ± 4.5	7.3 ± 5.8	1.4 ± 1.27 (−1.1 to 3.9)	.2740	3.3 ± 1.27 (0.8-5.9)	**.0108**	−1.9 ± 1.11 (−4.1 to 0.3)	.0867
2-year	5.6 ± 4.2	8.0 ± 4.6	6.9 ± 5.6	−1.3 ± 1.23 (−3.8 to 1.2)	.2913	1.1 ± 1.30 (−1.5 to 3.7)	.4167	−2.4 ± 1.11 (−4.6 to −0.1)	.0373
Δ at 2 years	−3.3 ± 5.5 95% CI (−5.3, −1.3)	−2.4 ± 5.6 95% CI (−4.5, −0.4)	−0.2 ± 7.4 95% CI (−2.9, 2.5)	−3.1 ± 1.64 (−6.4 to 0.2)	.0638	−2.2 ± 1.68 (−5.6 to 1.1)	.1918	−0.9 ± 1.41 (−3.7 to 1.9)	.5361
VR-12 Physical									
Preoperative	34.0 ± 11.7	33.3 ± 10.7	40.1 ± 10.6	−6.1 ± 2.73 (−11.5 to −0.6)	**.0293**	−6.8 ± 2.63 (−12.0 to −1.5)	**.0124**	0.7 ± 2.74 (−4.8 to 6.2)	.8058
2-year	52.6 ± 7.0	53.4 ± 6.2	51.2 ± 7.0	1.3 ± 1.76 (−2.2 to 4.8)	.4552	2.2 ± 1.68 (−1.2 to 5.5)	.2005	−0.9 ± 1.68 (−4.2 to 2.5)	.6141
Δ at 2 years	18.2 ± 11.2 95% CI (14.2, 22.3)	19.6 ± 10.8 95% CI (15.6, 23.6)	11.1 ± 10.1 95% CI (7.5, 14.7)	7.1 ± 2.67 (1.8-12.5)	**.0096**	8.5 ± 2.65 (3.2- 13.8)	**.0021**	−1.4 ± 2.80 (−7.0 to 4.2)	.6232
VR-12 Mental									
Preoperative	46.1 ± 11.2	50.3 ± 8.5	50.8 ± 11.9	−4.7 ± 2.82 (−10.3 to 1.0)	.1037	−0.5 ± 2.55 (−5.6 to 4.6)	.8517	−4.2 ± 2.43 (−9.0 to 0.7)	.0902
2-year	55.0 ± 8.1	54.9 ± 8.0	56.7 ± 7.7	−1.8 ± 1.97 (−5.7 to 2.2)	.3775	−1.8 ± 1.99 (−5.8 to 2.2)	.3651	0.1 ± 2.04 (−4.0 to 4.1)	.9754
Δ at 2 years	8.3 ± 10.3 95% CI (4.6, 12.1)	4.7 ± 10.8 95% CI (0.7, 8.7)	6.0 ± 12.4 95% CI (1.5, 10.5)	2.3 ± 2.85 (−3.3 to 8.0)	.4132	−1.3 ± 2.96 (−7.2 to 4.6)	.6535	3.7 ± 2.67 (−1.7 to 9.0)	.1737
SANE									
Preoperative	30.6 ± 17.9	37.4 ± 20.9	47.7 ± 25.3	−17.1 ± 5.34 (−27.7 to −6.4)	**.0021**	−10.3 ± 5.70 (−21.7 to 1.1)	.0763	−6.8 ± 4.75 (−16.3 to 2.7)	.1564

(continued)

Table 6. Continued

	ACL Repair	$ACLR_{acute}$	ACLR	Repair Versus ACLR		$ACLR_{acute}$ Versus ACLR		Repair Versus $ACLR_{acute}$	
				Difference*	*P* Value†	Difference*	*P* Value†	Difference*	*P* Value†
2-year	84.6 ± 19.8	86.0 ± 12.8	81.9 ± 20.0	2.7 ± 4.98 (−7.3 to 12.6)	.5958	4.1 ± 4.24 (−4.4 to 12.6)	.3424	−1.4 ± 4.22 (−9.9 to 7.0)	.7400
Δ at 2 years	55.5 ± 25.9 95% CI (46.1- 64.8)	47.6 ± 24.9 95% CI (38.3, 56.9)	34.2 ± 33.4 95% CI (22.1- 46.2)	21.3 ± 7.47 (6.4-36.2)	**.0059**	13.4 ± 7.53 (−1.6 to 28.5)	.0791	7.9 ± 6.46 (−5.1 to 20.8)	.2282

NOTE. Data are displayed as mean ± standard deviation. Statistically significant findings are bold text.
ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; CI, confidence interval; SANE, Single Assessment Numeric Evaluation.
*Data are displayed as mean ± standard error; (95% CI).
†*P* value from 2-sample *t* test.

and $ACLR_{acute}$ are noninferior to ACLR at 2-year follow-up. In addition, ACL repair is noninferior to $ACLR_{acute}$ at 2-year follow-up. The operated and contralateral knee side-to-side laxity did not significantly increase more than 3 mm from baseline to 2-year follow-up for all comparative surgery groups (ACL repair vs ACLR, $ACLR_{acute}$ vs ACLR and ACL repair vs $ACLR_{acute}$) (Table 4).

Range of Motion

Patients who received primary ACL repair or $ACLR_{acute}$ reported a significantly greater difference in knee flexion preoperatively between the injured and contralateral side knee flexion compared with those who underwent ACLR (−9.4 ± 1.56°, 95% CI −12.5 to −6.3, $P < .0001$; −10.2 ± 2.23°, 95% CI −14.7 to −5.7, $P < .0001$, respectively). A difference of 0.8 ± 2.45° was observed between ACL repair and $ACLR_{acute}$ preoperatively and was not significant ($P = .74$). No significant differences were observed in knee extension range of motion at the 2-year follow-up; however, a significant difference between the operated and contralateral side in knee flexion was observed for the ACL repair versus ACLR group (−0.6 ± 3.1° vs −3.6 ± 4.5°, $P < .005$) (Table 5).

Patient-Reported Outcomes

PROs were collected throughout the study to evaluate patient pain and function from baseline through the 2-year postoperative time. There were no significant differences in the visual analog scale observed at the 2-year follow-up. The Marx activity preoperative score was lower for the ACLR group compared with the $ACLR_{acute}$ group (7.3 ± 5.8 vs 10.6 ± 4.5, $P < .01$), and no differences were observed at the 2-year time period between the groups. Patients in the ACLR group reported a significantly lower VR-12 physical score preoperatively compared with the ACL repair ($P < .02$) and $ACLR_{acute}$ ($P < .01$) groups. At the 2-year follow-up the ACL repair and $ACLR_{acute}$ patients resulted in a larger gain in the VR-12 Physical Score compared with the ACLR group ($P < .009$ and $P < .002$, respectively). No significant differences were observed for the VR-12 Mental Score. A lower SANE score was observed in the ACL repair group compared with the ACLR group ($P < .002$) and no significant differences were observed at the 2-year follow-up. Patients in the ACL repair group reported the largest increase in SANE score compared with the ACLR group ($P < .005$). No significant differences between ACL repair and $ACLR_{acute}$ were observed for any PROs (Table 6). Preoperative KOOS subscales, with exception of Quality of Life, were significantly lower in the ACL repair and $ACLR_{acute}$, compared with the ACLR group. All ACL repair and $ACLR_{acute}$ resulted in significantly greater postoperative

Table 7. Knee Injury and Osteoarthritis Outcome Score (KOOS) Subscales

				Repair Versus ACLR		$ACLR_{acute}$ Versus ACLR		Repair Versus $ACLR_{acute}$	
	ACL Repair	$ACLR_{acute}$	ACLR	Difference*	*P* Value†	Difference*	*P* Value†	Difference*	*P* Value†
Pain Subscale									
Preoperative	n = 34	n = 33	n = 33	−10.7 ± 4.57	**.0233**	−9.6 ± 4.93	.0558	−1.1 ± 4.02	.7924
	60.0 ± 14.8	61.1 ± 18.0	70.7 ± 21.8	(−19.8 to −1.5)		(−19.4 to 0.2)		(−9.1 to 7.0)	
2-year	32	30	32	−2.3 ± 3.07	.4653	2.0 ± 2.07	.3297	−4.3 ± 3.08	.1699
	88.0 ± 15.3	92.3 ± 8.1	90.3 ± 8.2	(−8.4 to 3.9)		(−2.1 to 6.2)		(−10.5 to 1.9)	
Δ at 2 years	26.9 ± 14.6	30.6 ± 18.3	20.0 ± 21.1	6.9 ± 4.54	.1318	10.7 ± 5.03	**.0379**	−3.7 ± 4.19	.3761
	95% CI	95% CI	95% CI	(−2.2 to 16.0)		(0.6- 20.7)		(−12.1 to 4.6)	
	(21.6- 32.2)	(23.8-37.5)	(12.4-27.6)						
Symptoms subscale									
Preoperative	57.4 ± 18.4	59.1 ± 13.9	71.0 ± 20.3	−13.6 ± 4.73	**.0053**	−11.9 ± 4.28	**.0074**	−1.7 ± 4.00	.6650
				(−23.1 to −4.2)		(−20.5 to −3.3)		(−9.7 to 6.2)	
2-year	82.8 ± 16.5	83.7 ± 10.1	81.4 ± 17.2	1.5 ± 4.21	.7315	2.3 ± 3.55	.5146	−0.9 ± 3.45	.8003
				(−7.0 to 9.9)		(−4.8 to 9.5)		(−7.8 to 6.0)	
Δ at 2 years	24.9 ± 20.4	24.8 ± 15.4	10.6 ± 21.7	14.3 ± 5.26	**.0086**	14.2 ± 4.80	**.0046**	0.1 ± 4.61	.9782
	95% CI	95% CI	95% CI	(3.8-24.8)		(4.6- 23.8)		(−9.1 to 9.4)	
	(17.5-32.2)	(19.0- 30.5)	(2.8-18.4)						
Activities of Daily Living Subscale									
Preoperative	59.7 ± 17.1	65.4 ± 20.4	78.5 ± 22.1	−18.8 ± 4.83	**.0002**	−13.1 ± 5.24	**.0150**	−5.7 ± 4.60	.2169
				(−28.5 to −9.2)		(−23.6 to −2.6)		(−14.9 to 3.4)	
2-year	93.5 ± 13.6	96.5 ± 6.3	94.9 ± 6.6	−1.4 ± 2.68	.5975	1.6 ± 1.65	.3437	−3.0 ± 2.67	.2679
				(−6.8 to 4.0)		(−1.7 to 4.9)		(−8.4 to 2.4)	
Δ at 2 years	32.6 ± 16.6	29.6 ± 17.3	16.9 ± 22.0	15.7 ± 4.87	**.0021**	12.6 ± 5.04	**.0148**	3.0 ± 4.30	.4850
	95% CI	95% CI	95% CI	(5.9-25.4)		(2.6-22.7)		(−5.6 to 11.6)	
	(26.6-38.6)	(23.1-36.0)	(9.0-24.8)						
Sport and Recreation Subscale									
Preoperative	n = 30	n = 31	n = 33	−24.0 ± 6.81	**.0008**	−18.8 ± 7.02	**.0096**	−5.3 ± 6.31	.4080
	17.5 ± 23.3	22.8 ± 25.8	41.5 ± 30.0	(−37.6 to −10.4)		(−32.8 to −4.7)		(−17.9 to 7.4)	
2-year	27	26	28	3.6 ± 6.27	.5633	12.5 ± 4.96	.0153	−8.9 ± 5.30	.1020
	78.4 ± 24.1	87.2 ± 13.1	74.7 ± 22.4	(−8.9 to 16.2)		(2.5-22.5)		(−19.6 to 1.8)	
Δ at 2 years	23	25	28	29.3 ± 8.32	**.0009**	35.4 ± 7.46	**<.0001**	−6.1 ± 6.40	.3441
	62.1 ± 24.2	68.2 ± 20.0	32.8 ± 33.3	(12.6-46.0)		(20.4-50.4)		(−19.0 to 6.8)	
	95% CI	95% CI	95% CI						
	(51.6, 72.5)	(59.9, 76.5)	(19.9, 45.7)						
Quality of Life Subscale									
Preoperative	n = 34	n = 33	n = 33	−7.6 ± 6.36	.2380	−0.2 ± 6.10	.9753	−7.4 ± 6.45	.2563
	25.0 ± 27.5	32.4 ± 25.2	32.6 ± 24.4	(−20.3 to 5.1)		(−12.4 to 12.0)		(−20.3 to 5.5)	
2-year	32	30	32	5.7 ± 6.72	.4024	10.3 ± 5.91	.0858	−4.7 ± 6.20	.4551
	73.0 ± 27.8	77.7 ± 20.1	67.4 ± 25.9	(−7.8 to 19.1)		(−1.5 to 22.1)		(−17.1 to 7.7)	
Δ at 2 years	48.2 ± 32.3	44.6 ± 29.1	34.0 ± 24.0	14.3 ± 7.11	**.0493**	10.6 ± 6.76	.1223	3.7 ± 7.82	.6417
	95% CI	95% CI	95% CI	(0.0-28.5)		(−2.9 to 24.1)		(−12.0 to 19.3)	
	(36.6, 59.9)	(33.7, 55.5)	(25.3, 42.6)						

NOTE. Data are displayed as mean ± standard deviation. Statistically significant findings are bold text.
ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; CI, confidence interval.
*Data are displayed as mean ± standard error; (95% CI).
†*P* value from 2-sample *t* test.

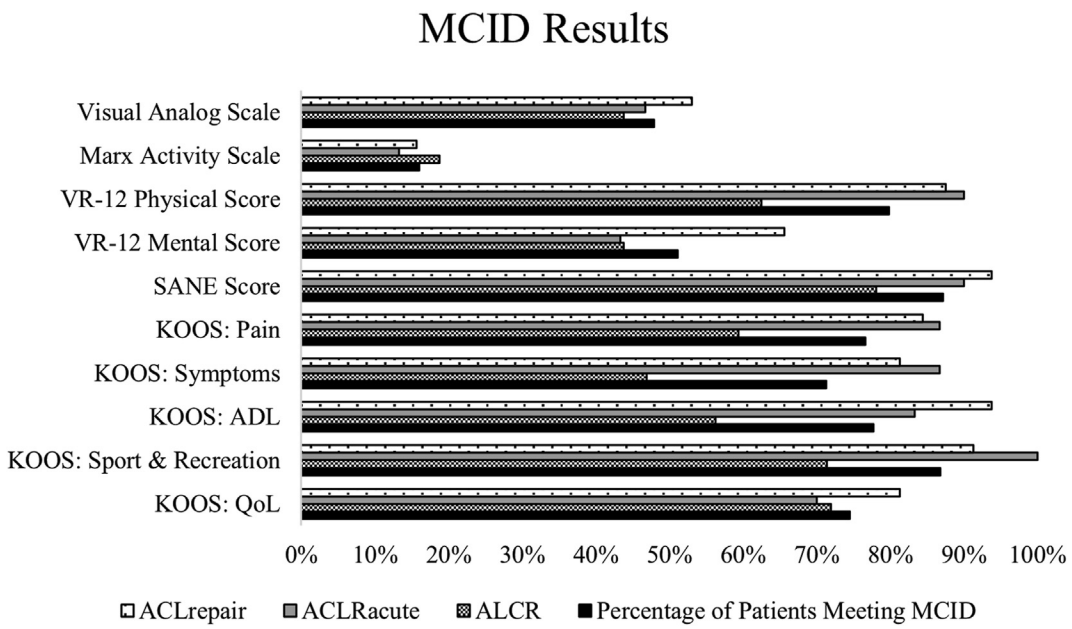

Fig 2. Minimal clinically important difference (MCID) results. The percentage of patients in each anterior cruciate ligament (ACL) surgery cohort who achieved the MCID at minimum 2-year follow-up for all outcome measures included is presented. The MCID was determined for each outcome measure: visual analog scale (1.1), Marx Activity Scale (3.1), VR-12 Physical Score (5.6), VR-12 Mental Score (5.5), Knee Injury and Osteoarthritis Outcome Score (KOOS) Pain subscale (9.2), KOOS Symptoms subscale (10.1), KOOS Activities of Daily Living subscale (9.9), KOOS Sport and Recreation Function subscale (15.4), and KOOS Knee-related Quality of Life (QoL) subscale (14.5). (ACLR, anterior cruciate ligament reconstruction.)

improvements compared with ACLR for all KOOS subscales (Table 7).

Minimal Clinically Important Difference

MCID was calculated for the 2-year outcome on the basis of the distribution method (1/2 standard deviation),[33] and improvement from baseline is reported in (Fig 2).

Postoperative MRI Findings

All MRI scans available at the 1-year visit reported healing. ACL repair MRI was classified "good" in 77.7% (21/27), "acceptable" in 14.8% (4/27), and "bad" in 7% (2/27) of the cohort. In total, 84% of patients in the $ACLR_{acute}$ group had "good" healing (21/25 patients) and 16% had "acceptable" healing. Patients who underwent ACLR had "good" healing at 81.4% (22/27) and "acceptable" at 18.5% (5/27).

Complications/Failures

No significant differences were observed for retear between the investigate groups. There was a 5.9% retear rate for ACL repair (2/34), 6.1% for $ACLR_{acute}$ (2/33), and 3.0% for ACLR (1/33). All retears occurred within 1 year of surgery. Failures in the $ACLR_{acute}$ and ACLR were caused by poor compliance with postoperative protocols. The 2 ACL repair retears were the result of participation in sports and trauma. These patients received revision ACLR and were excluded from the statistical analysis.

Discussion

Results from this study suggest side-to-side laxity differences for ACL repair and $ACLR_{acute}$ were statistically noninferior to patients who undergo ACLR, and all laxity measures were well within the clinically meaningful threshold of 3 mm. All PROs improved from baseline, and no statistically significant differences were observed between the investigated groups at the 2-year follow-up. An MRI at 1 year revealed healing had occurred. No significant difference between failures was observed for either investigated group.

The high failure rate of historical primary ACL repair can be attributed to patient selection (e.g., nonproximal tear with poor tissue quality), a large arthrotomy performed, and postoperative casting.[7,9,10,29] The resurgence of interest in primary ACL repair instigated a retrospective examination of patients with successful outcomes and revealed patient selection is a critical factor.[6] Indications for successful primary ACL repair include proximal avulsion tears of sufficient tissue quality, patients older than 35 years, surgery performed within 28 days of injury, and a body mass index less than 26.[8-10] Success of modern primary ACL repair incorporates the advanced understanding of patient selection and the addition of suture tape augmentation,[34] which functions as a "seatbelt"[35] in the early postoperative period. Clinical results of suture tape augmented ACL repair display good short-[13,14,36] to midterm outcomes,[11] and return to sport.[37] The

successful outcomes of ACL repair observed in the present cohort are attributed to the selection protocol and intraoperative diagnostic visualization of the avulsion site (proximal detachment). Preoperative PRO scores of ACL repair were significantly lower than the reconstruction cohorts, indicating less severe injuries and less concomitant pathologies. However, this group attained similar, if not superior, postoperative outcomes at 2 years.

Clinical stability of primary ACL repair with suture tape augmentation and early ACLR intervention at 2 years was revealed to be noninferior to ACLR, as determined by side-to-side anteroposterior laxity. A mean difference of 0.1 ± 0.37 mm between the operated and contralateral side was observed between primary ACL repair and ACLR, and −0.8 ± .35mm was observed between $ACLR_{acute}$ and ACLR for an applied load of 30lbs. All 2-year postoperative differences between the operated and contralateral side measured less than 1.2 mm for the 15 lbs, 20 lbs, 30 lbs, and Lachman test, with $ACLR_{acute}$ resulting in the smallest differences with a mean of 0.22 mm. The findings are within the clinically accepted side-to-side difference of 3 mm[32] and comparable with clinical literature evaluating the outcomes of primary ACL repair and ACLR. Douoguih et al.[38] reported a significant difference in AP laxity for 20 lbs applied load between a primary ACL and ACLR cohort; however, the findings were well below the 3-mm threshold. A systematic review by Wilson et al.[7] reported a mean 1.2-mm Lachman difference in 4 studies. Similarly, Vermeijden et al.[14] reported a mean difference of 1.3 mm for KT-1000 measurements reported in 6 studies. The results of the presented prospective evaluation suggest there are no differences in clinical laxity for either primary ALC repair with suture tape augmentation or $ACLR_{acute}$, compared with ACLR.

Several investigations have assessed ACL repair with suture tape augmentation to ACLR and observed comparable findings.[14,18] Recently, Müller et al.[39] reported comparable 2-year patient-reported and isokinetic muscle strength of patients who underwent ACL repair and ACLR. Hopper et al.[16] reported a retrospective analysis of 272 ACLR and 134 ACL repair patients and discovered comparable rates of secondary surgery between the groups. Comparative investigations of both techniques by Vermeijden et al.[20,21] suggest patients prefer ACL repair and have less daily awareness of the repaired knee compared with reconstruction. These findings were observed in the presented study where retear rates and PROs resulted in similar 2-year follow-up outcomes for ACL repair and ACLR.

The injury-to-surgery timing is an essential consideration for ACLR. Historically, ACL injury treatment was delayed because of early intervention, resulting in stiffness and arthrofibrosis. Technological and rehabilitation advancements now suggest early intervention may be more beneficial to avoid the increased risk of meniscal and chondral damage in addition to posttraumatic OA.[27] A meta-analysis of 8 studies reporting injury-to-surgery timing described no differences in PRO, range of motion, complications, risk of retear, or residual laxity between a 3-week and 10-week cutoff period.[28] These findings were also observed in meta-analyses performed by Vermeijden et al.[27] and Kim et al.[24] For patients younger than 40 years of age, Agarwal et al.[40] reported a 65% reduction of arthrofibrosis if ACLR was delayed 6 weeks from injury. Results from the presented study suggest $ACLR_{acute}$ is noninferior to ACLR, as assessed with KT-1000, and results in similar PRO at short-term follow-up. Although a statistically significant difference was observed between ACL repair and ACLR for postoperative knee flexion range of motion between the operated and contralateral knee, this finding is likely clinically irrelevant. Patients in the ACL repair group displayed comparable postoperative knee range of motion, whereas a deficit in flexion range of motion in the ACLR was observed compared to the contralateral leg. Postoperative range of motion between the operated and contralateral knee was comparable for the $ACLR_{acute}$ and ACLR cohorts. These findings are in agreement with the most recent literature regarding injury-to-surgery time, and are attributed to modern surgical techniques and patient selection criteria.

The etiology of ACL injury is multifactorial.[41,42] The surgical technique and intervention timeline should consider patient-specific symptoms such as range of motion, presence of an effusion, pain, and gait.[2] The presented prospective study described successful outcomes attributed to ACL repair or reconstruction techniques and is consistent with the scientific literature supporting surgical ACL intervention. In addition, the comparative results of $ACLR_{acute}$ and ACLR demonstrate a low risk of arthrofibrosis after $ACLR_{acute}$, which is contrary to established literature.

Limitations

This study is not without limitations. The presented findings are from a single surgeon operating at a private clinic and a community/academic hospital, and the results may not be generalized to a global population. Although the presented study would have benefited from a randomization procedure, this process was unattainable on the basis of an intraoperative diagnostic assessment of the proximal ACL stump. Knowledge of the repair technique may introduce bias, which may be reduced by using independent examiners and additional surgeons. The acute injury protocols of the primary authors' country health service may have contributed to the extended enrollment time and ACLR

cutoff determination. Upon injury, patients seek care from a primary physician, who then refers the patient to physiotherapy. The patient may not see an orthopaedic surgeon until several weeks of physiotherapy are completed. The authors chose an 8-week cutoff to differentiate the standard-of-care ACLR groups because of the standard of care physiotherapy pathway in the primary authors' country. In addition, the extended study duration is attributed to the stringent inclusion criteria necessary for primary ACL repair. The range of motion measurements were performed with an analog goniometer. More accurate measurements can be performed with dedicated fixtures and digital measurement devices. The distribution method used to calculate MCID is a function of the preoperative PRO score standard deviation and is affected by patient enrollment numbers. Lastly, the results of this 2-year prospective study may require longer-term study durations to detect differences between the operative groups.

Conclusions

Patients who underwent ACL repair of proximal tears with suture tape augmentation or ACLR within 8 weeks from injury resulted in noninferior side-to-side knee laxity, comparable PROs, and similar range of motion at 2-year follow-up, compared with ACLR.

Disclosures

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: S.S. reports financial support was provided by Arthrex. A.N.K. reports a relationship with Arthrex that includes employment. The other author (C.J.G.) declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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