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Does Anterior Cruciate Ligament Reconstruction Improve Functional and Radiographic Outcomes Over Nonoperative Management 5 Years After Injury?

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Abstract

Background: Current practice patterns for the management of anterior cruciate ligament (ACL) injury favor surgical reconstruction. However, long-term outcomes may not differ between patients completing operative and nonoperative treatment of ACL injury. Differences in outcomes between operative and nonoperative treatment of patients in the United States is largely unknown, as are outcomes in long-term strength and performance measures.

Purpose: To determine if differences exist in 5-year functional and radiographic outcomes between patients completing operative and nonoperative treatment of ACL injury when both groups complete a progressive criterion-based rehabilitation protocol.

Study Design: Cohort study; Level of evidence, 2.

Methods: From an original group of 144 athletes, 105 participants (mean $\pm$ SD age, 34.3 ± 11.4 years) with an acute ACL rupture completed functional testing (quadriceps strength, single-legged hop, and knee joint effusion testing; patient-reported outcomes) and knee radiographs 5 years after ACL reconstruction or completion of nonoperative rehabilitation.

Results: At 5 years, patients treated with ACL reconstruction versus rehabilitation alone did not differ in quadriceps strength ($P = .817$); performance on single-legged hop tests ($P = .234-.955$); activity level ($P = .349-.400$); subjective reports of pain, symptoms, activities of daily living, and knee-related quality of life ($P = .090-.941$); or presence of knee osteoarthritis ($P = .102-.978$).

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When compared with patients treated nonoperatively, patients treated operatively did report greater global ratings of knee function ($P = .001$), and lower fear ($P = .035$) at 5 years but were more likely to possess knee joint effusion ($P = .016$).

Conclusion: The current findings indicate that favorable outcomes can occur after both operative and nonoperative management approaches with the use of progressive criterion-based rehabilitation. Further study is needed to determine clinical algorithms for identifying the best candidates for surgical versus nonoperative care after ACL injury. These findings provide an opportunity to improve the educational process between patients and clinicians regarding the expected clinical course and long-term outcomes of operative and nonoperative treatment of ACL injuries.

Keywords

rehabilitation; osteoarthritis; knee function; fear; anterior cruciate ligament injury

Anterior cruciate ligament (ACL) rupture is a musculoskeletal knee injury that is common in sports. Patients frequently undergo ACL reconstruction with high but unrealistic expectations that prior knee function will be restored, prior activity levels attained, and further injury avoided.¹ Unfortunately, these goals are not often achieved after ACL reconstruction.² Previous systematic reviews highlighted that only 65% of patients return to their preinjury levels of sport and 36% develop knee osteoarthritis within 10 years of ACL reconstruction, a number that increases to 48% within the first 20 years after reconstruction. Suboptimal outcomes after ACL reconstruction warrant continued investigation into alternative management strategies after ACL injury.

Previous studies focused on patient-reported outcomes and radiographic outcomes, suggesting that long-term outcomes may not differ between patients completing operative treatment after ACL injury and those undergoing nonoperative treatment.³⁻⁵ A systematic review by Chalmers et al concluded that neither patient-reported knee function and activity level nor incidence of radio-graphic knee osteoarthritis differed between operative and nonoperative cohorts at a minimum 10-year follow-up. A systematic review and meta-analysis by Smith et al reported conclusions similar to those of Chalmers et al, finding no clinical superiority of ACL reconstruction over nonoperative management in outcomes, including patient-reported knee function and development of radio-graphic knee osteoarthritis. Frobell et al randomized active adults with ACL injury without significant concomitant knee injury to undergo early ACL reconstruction or rehabilitation with the option for delayed ACL reconstruction. Forty-nine percent of patients randomized to the rehabilitation group remained nonoperatively treated 5 years later. At 5 years, no differences were present in either patient-reported function on the Knee injury and Osteoarthritis Outcome Score (KOOS) or activity on the Tegner activity scale. Van Yperen et al compared 20-year outcomes of operative and nonoperative management of ACL injury. All patients completed 3 months of physical therapy initially after injury, and those who continued to experience symptomatic knee instability at that time underwent ACL reconstruction or eliminated cutting and pivoting activity from their lifestyle. At 20-year follow-up, no statistically significant differences existed in patient-reported functional outcomes, activity levels, or radio-graphic knee osteoarthritis.

The 2 studies by Frobell et al and van Yperen et al compared operative and nonoperative outcomes after ACL injury in European countries. However, surgical practice patterns after ACL injury in the United States do not likely mimic surgical practice in Europe. The rate of ACL reconstructive procedures is higher in the United States (43 per 100,000 capita) than in countries such as Norway (34 per 100,000 capita) and Sweden (32 per 100,000 capita). One possible explanation for the higher US rate of ACL reconstruction as compared with European countries is an increased tendency for patients with ACL injury in the United States to be treated with surgery. In addition, previous studies comparing operative and nonoperative management of ACL injury did not focus on analyses of long-term outcomes in muscle strength or functional performance (eg, hop tests).

The purpose of this study was to determine if differences exist in 5-year functional outcomes (muscle strength, hop performance, patient-reported) and radiographic outcomes between patients completing operative and nonoperative treatment of ACL injury, in which both groups complete a progressive criterion-based rehabilitation protocol. This study expands on previous studies by including only patients treated within the United States who self-selected whether to have ACL reconstruction in a real clinic environment (with input from the physical therapy and orthopaedic surgeon team); it also includes long-term muscle strength and hop-test performance outcomes. The comprehensive analysis of 5-year outcomes after operative and nonoperative treatment strategies for ACL deficiency will provide further groundwork for improved education and decision making between patients and clinicians regarding anticipated outcomes after ACL injury.

METHODS

Participants

A total of 144 athletes with an acute unilateral ACL rupture (confirmed by a positive Lachman test result and 3-mm difference in anterior tibial excursion with instrumented arthrometry; KT1000, MEDmetric Corporation) who were 14 to 55 years old at the time of injury were enrolled from 2005 to 2011 as part of a completed randomized controlled trial or larger prospective cohort study (Figure 1). Those returning for 5-year testing were included in the current analysis (n = 105). Patients were initially categorized as nonoperative if they did not have ACL reconstruction for at least >6 months after injury. Two patients initially electing nonoperative treatment had ACL reconstruction 6 months after injury and were included within the operative group of this study. Confirmation of ACL injuries and subsequent rehabilitation was completed within an outpatient physical therapy clinic in a university setting. All patients participated in level 1 (eg, soccer, basketball) or level 2 (eg, tennis, downhill skiing) cutting and pivoting activities before injury. Exclusion criteria included a potentially repairable meniscus, symptomatic grade III injury to other knee ligaments, or articular cartilage lesions >1 cm² diagnosed at the time of ACL injury. This study was approved by the institutional review board at the University of Delaware, and all participants provided written informed consent.

Rehabilitation and Surgical Decision Making

All patients completed rehabilitation early after ACL injury to resolve initial impairments of pain, effusion, range of motion, and quadriceps muscle weakness. After impairment resolution, a patient was categorized as a potential coper if she or he demonstrated no more than 1 giving-way episode since injury, a score $\geq 80\%$ on the Knee Outcome Survey–Activities of Daily Living Scale (KOS-ADLS), a score $\geq 60\%$ on the Global Rating Scale of Perceived Function (GRS), and a score $\geq 80\%$ on the 6-m timed hop. Failure to meet any of these criteria resulted in classification as a noncoper. All patients completed an additional 10 sessions of progressive strength and neuromuscular training with protocols previously described.¹ Eighty-three patients underwent ACL reconstruction, and 22 completed nonoperative treatment of injury. No standardized process was used for surgical decision making. Patients self-selected treatment strategy using recommendations from the orthopaedic surgeon and physical therapy team. Patients treated nonoperatively were discharged to a home exercise program emphasizing strength and neuromuscular control after completion of their formal rehabilitation program and achievement of objective return-to-sport criteria,¹ if their goals included return-to-sports activities. Patients treated operatively underwent reconstruction by a board-certified orthopaedic surgeon using a 4-bundle semitendinosus-gracilis autograft or soft tissue allograft. Criterion-based postoperative rehabilitation was completed early after surgery and objective return-to-sport criteria was again implemented.¹

Clinical Measures of Knee Function

Functional testing consisted of quadriceps strength testing, single-legged hop testing, knee joint effusion assessment, and completion of patient-reported outcomes 5 years after ACL reconstruction or completion of nonoperative rehabilitation.

Quadriceps strength was tested during maximal voluntary isometric contraction (MVIC) with an electromechanical dynamometer (Kin-Com; DJO Global) with patients seated in 90° of hip and knee flexion. A quadriceps index was calculated as the quotient of the involved-limb MVIC to the uninvolved-limb MVIC multiplied by 100.

Four single-legged hop tests (single, crossover, and triple hop for distance; 6-m hop for time) were completed on each limb with a protocol previously described. The mean of 2 trials for each limb was used to calculate the quotient of the involved limb to the uninvolved limb multiplied by 100 for the single, crossover, and triple hops and the quotient of the uninvolved limb to the involved limb multiplied by 100 for the 6-m timed hop. Single-legged hop tests were not completed at 5 years if the quadriceps index was $<70\%$ for patients after nonoperative rehabilitation or $<80\%$ for patients after ACL reconstruction.

Knee joint effusion was measured with the modified stroke test, a reliable measurement scored on a 5-point scale. The presence of knee joint effusion was operationally defined by a grade of trace or greater.

Patients completed several patient-reported outcome measures to assess knee function, psychological response to injury, and activity levels at 5 years. The KOS-ADLS is a valid and reliable measure of impairment and functional limitation experienced during activities

of daily living secondary to knee injury. The GRS consists of a single reliable question asking the patient to rate one's current perceived level of knee function as compared with the perceived knee function before injury.⁶ The International Knee Documentation Committee (IKDC) Subjective Knee Form 2000 is a measure of knee-specific symptoms, function, and sports activities that is valid and reliable for a variety of knee conditions, including ACL injury.⁷ The KOOS is a reliable measure widely used in the ACL population.^{8,62} It consists of 5 sub scales assessing patient symptoms, complaints of pain, function in daily life, function during sports and recreational activities, and knee-related quality of life. The Marx Activity Rating Scale (Marx) is a reliable scale that assesses the frequency of 4 activities for patients with knee injuries: running, cutting, decelerating, and pivoting. The Tampa Scale for Kinesiophobia (TSK-11) is a valid and reliable modified version of the original TSK that measures fear of movement and reinjury. TSK-11 scores are elevated after ACL injury and related to lower self-report of knee function and rates of return to preinjury activity levels in this population.⁶³ The ACL–Return to Sports After Injury (ACL-RSI) is a reliable and valid patient-reported measure of emotions, confidence in performance, and risk appraisal associated with return-to-sport activities that is specifically designed for patients with ACL injury.⁶

Patients reported the levels of participating in cutting and pivoting activities as described by the IKDC 2000 activity scale,⁶⁴ which were compared with their reported levels before ACL injury on the same scale. Patients also reported current pain, worst pain, and best pain over the past week on a visual analog scale (VAS) from 0 to 10, with 0 indicating no pain and 10 indicating the worst pain imaginable.

Radiographs

Patients completed weightbearing posterior-anterior bent-knee (30°) radiographs 5 years after ACL reconstruction or completion of nonoperative rehabilitation, which were viewed with SigmaView software (Agfa HealthCare Corporation). Osteoarthritis in the medial and lateral tibiofe-moral compartments of each limb was graded with the Kellgren-Lawrence (KL) system. The presence of osteoarthritis was defined as a KL grade ≥ 2. Additionally, minimum joint space width measurements were manually measured within SigmaView software in the medial and lateral tibiofemoral compartments of each limb. Interlimb minimum joint space width differences were calculated (involved minus uninvolved). Excellent between-day intra-rater reliability for radiographic measures of interest was previously demonstrated with 20 radiographs of patients 5 years after ACL injury (graded by E.W.; Cohen κ for KL grades: 0.904, $P < .001$; all KL grades verified by a board-certified orthopaedic surgeon; intracorrelation coefficient for minimum joint space width: 0.981, $P < .001$).

Statistical Analyses

Statistical analyses were completed with PASSW 23.0 software (SPSS Inc). Independent t tests, Fisher exact tests (variables with 2 categories), and chi-square tests (variables with ≥ 3 categories) were used to test differences in baseline characteristics, baseline concomitant injuries, second ACL injuries, and 5-year cutting and pivoting activity levels between patients who underwent ACL reconstruction and those who received nonoperative ACL

treatment. Because differences were found between preinjury cutting and pivoting activity level (1 or 2) between the operative and nonoperative groups, analyses of variance were used to assess 5-year group differences in quadriceps strength and each single-legged hop test, patient-reported outcome, and pain level on a VAS, with preinjury activity level entered as a fixed factor in each model. Logistic regressions were used to assess 5-year group differences in knee effusion and if patients were currently at preinjury activity level (1 or 2), with preinjury activity level entered within the same block in each model. Previously reported minimal detectable changes (MDCs) (Table 1) and effect sizes (ESs) were used qualitatively to determine if meaningful differences existed in clinical measures between the patients treated operatively and those treated nonoperatively. A priori statistical significance was set at $\alpha = .05$, and values are presented as mean $\pm$ SD.

RESULTS

Patient Characteristics

Of the 144 enrolled patients, 105 (72.9%) returned for 5-year testing (83 operative, 22 nonoperative) (Figure 1). The operatively and nonoperatively treated groups did not differ in age, body mass index, sex, mode of ACL injury, time to 5-year testing (calculated as time since ACL reconstruction or completion of nonoperative rehabilitation), classification as a noncoper or potential coper early after injury,¹³ concomitant injuries at the time of ACL injury, or second ACL injury rates (Table 2). A greater proportion of patients treated operatively were participating in level 1 cutting and pivoting activities before injury, as compared with a greater proportion of patients treated nonoperatively in level 2 activities ($P = .041$; operative: level 1, $n = 59$; level 2, $n = 24$; nonoperative: level 1, $n = 10$; level 2, $n = 12$).

Clinical Measures of Knee Function

Given the 5-year follow-up required by this study, a portion of patients who had moved out of the area completed patient-reported outcomes remotely but did not return for quadriceps strength, single-legged hop, and effusion testing. Ninety-four patients (operative, $n = 75$; nonoperative, $n = 19$) completed quadriceps strength testing, and 90 (operative, $n = 71$; nonoperative, $n = 19$) completed effusion testing. Twenty-four patients (operative, $n = 20$; nonoperative, $n = 4$) who completed quadriceps strength testing did not complete single-legged hop testing for reasons listed in Table 3, leaving 70 patients (operative, $n = 55$; nonoperative, $n = 15$) available for data analysis. After controlling for preinjury activity level, operatively treated patients did not differ in quadriceps strength or any of the 4 single-legged hop tests (single, crossover, triple, 6-m timed) at 5 years as compared with nonoperatively treated patients (Table 4). Forty-four percent of the patients treated with reconstruction demonstrated knee joint effusion at 5 years, as opposed to only 10% of patients treated nonoperatively, a difference that was statistically significant after controlling for preinjury activity level ($P = .016$).

Patient-reported outcomes were completed by 82 operatively and 22 nonoperatively treated patients. Some outcomes measures were not completed by all patients treated operatively (KOOS, $n = 80$; Marx, $n = 79$; TSK-11, $n = 81$; ACL-RSI, $n = 80$). After controlling for

preinjury activity level, patients treated operatively reported higher scores on the GRS than patients treated nonoperatively ($P = .001$; operative, $94.5\% \pm 6.9\%$; nonoperative, $87.2\% \pm 11.9\%$; ES, 0.89), and group differences exceeded the MDC of 6.5. The operative versus nonoperative group difference of 8.0 on the KOOS quality-of-life subscale exceeded the MDC of 7.2 but did not reach statistical significance ($P = .090$; operative, $85.9\% \pm 17.7\%$; nonoperative, $77.0\% \pm 21.7\%$; ES, 0.48). After controlling for preinjury activity level, patients treated nonoperatively reported higher levels of fear on the TSK-11 ($P = .035$; operative, 16.2 ± 5.5 ; nonoperative, 19.2 ± 5.0 ; ES, 0.56), and group differences met the MDC of 3.0. Nonoperatively treated patients also reported higher worst pain levels on the VAS ($P = .010$; operative, 0.6 ± 1.1 ; nonoperative, 1.5 ± 1.9 ; ES, 0.65), but group differences were less than one-third of the MDC of 2.8. No group differences were present in the KOS-ADLS, IKDC, Marx, ACL-RSI, current or best pain, cutting and pivoting activity levels at 5 years, return to preinjury activity level, or any of the other 4 sub-scales of the KOOS (pain, symptoms, activities of daily living, sport/recreation) (Table 4).

Radiographs were completed by 64 operatively treated and 20 nonoperatively treated patients. Tibiofemoral knee joint osteoarthritis (defined by KL grades) was present in 23.4% of patients treated operatively and 5.0% of patients treated nonoperatively (Table 5). No statistical group differences were present in the rate of medial or lateral compartment osteoarthritis in the involved or uninvolved limbs. Joint space width did not differ between patients treated operatively and nonoperatively in either tibiofemoral compartment.

DISCUSSION

Summary of Findings

The purpose of this study was to determine if differences exist in 5-year functional and radiographic outcomes between patients completing operative and nonoperative treatment of ACL injury. All patients completed progressive criterion-based rehabilitation and self-selected an operative or nonoperative treatment strategy using recommendations from the orthopaedic surgeon and physical therapy team. The findings of this study indicate that 5-year functional and radiographic outcomes are similar between operatively and nonoperatively treated patients. However, patients treated operatively did demonstrate more knee joint effusion, higher self-report in global knee function, and lower self-reported fear.

Baseline Characteristics

Patients treated operatively were more likely to participate in level 1 cutting and pivoting sports before ACL injury (71.1%) as compared with patients treated nonoperatively (45.5%). This discrepancy may be reflective of practice patterns in the United States to recommend ACL reconstruction to patients engaging in level 1 sports. However, a study completed in Norway demonstrated that 55% of nonoperatively treated patients were able to return to level 1 sports by 1 year, a rate similar to the 62% of operatively treated patients who were able to return.

The operative group consisted of higher proportions of men and potential copers than the nonoperative group, although neither difference reached statistical significance. Patients in

this study were directly involved in the surgical decision-making process with the aid of their physical therapist and orthopaedic surgeon. Knowledge of patient function, as measured within the classifications of potential copers and noncopers, likely affected the surgical decision. Although women are more likely than men to be noncopers, the proportion of women was greater in the nonoperative group than in the operative group. Further study is needed to determine the influence of sex on the decision to undergo reconstruction after ACL injury.

Clinically Measured Knee Function

Quadriceps strength and performance on single-legged hop testing did not differ between the operative and nonoperative groups. Scores on strength and hop measures were high, with both groups demonstrating >97% symmetry in quadriceps strength and all 4 hop tests. Furthermore, frequency of cutting and pivoting activities (as indicated by Marx scores) and participation in preinjury levels of cutting and pivoting activities at 5 years did not differ between patients treated operatively and nonoperatively, after controlling for preinjury activity level. Sixty-one percent of patients treated with reconstruction and 50% of patients treated with rehabilitation alone were engaging in their preinjury level of activity at 5 years.

The current findings further contradict the concept that ACL reconstruction is mandatory to achieve restoration of knee function and return to high-demand sports activities.²⁹ The ability to return to cutting and pivoting sports undoubtedly requires a stable knee joint. ACL reconstruction is superior to nonoperative management in reducing knee joint laxity.^{30,31} However, neuromuscular control mechanisms in some patients can overcome joint laxity and provide sufficient dynamic knee stabilization required for high-level activities. Similar return-to-sport rates between patients treated operatively and nonoperatively, after matching by age, sex, and cutting and pivoting activity levels, were reported at 1 and 2 years.³² The current findings suggest that with the implementation of progressive criterion-based rehabilitation, high levels of sports participation and knee performance can be achieved with both operative and nonoperative ACL management strategies.

Knee joint effusion is ubiquitous after ACL injury and reconstruction, present in 85% of patients at a mean 27 days after ACL injury. The rehabilitation protocols completed by participants in this study included effusion management techniques, with objective measures of effusion used as a marker for exercise progression and clearance to run and hop.³³ Despite attention to pre- and postoperative knee joint effusion, 43% of patients treated operatively (vs 10% of patients treated nonoperatively) demonstrated measureable effusion 5 years after reconstruction despite similarly low baseline rates of concomitant injuries (meniscus, articular cartilage) and similar 5-year sports activity levels to nonoperatively treated patients. The mechanisms leading to chronic knee joint effusion are not understood. However, the trauma induced by surgical reconstruction may result in negative long-term effects in knee joint effusion for certain individuals. Chronic knee joint effusion may be a precipitating factor in the development of knee osteoarthritis.³⁴ Further study is warranted to determine the influence of knee joint effusion on the development of posttraumatic osteoarthritis after ACL injury.

Patient-Reported Knee Function

Patient reports of knee function are important components for measuring success after ACL injury and reconstruction because they affect patient satisfaction levels. In the current study, patients treated nonoperatively scored 7.3% lower on the GRS and 8.9% lower on the knee-related quality-of-life subscale of the KOOS, both greater than the MDCs of 6.5% and 7.2%, respectively. However, non operatively treated patients were not different from patients treated with reconstruction in measures of knee symptoms or function as indicated by scores on the KOSADLS, IKDC, or the other 4 subscales of the KOOS.

The GRS asks patients to compare their current knee function versus their preinjury levels of knee function. The quality of life subscale of the KOOS addresses awareness of knee problems, modifications to lifestyle to avoid potential damage to the knee, and lack of knee confidence. The reported KOOS scores in both the operative and non-operative group should be viewed cautiously, as both were highly variable with large 95% CIs. As such, perhaps the lower GRS scores and KOOS quality of life scores of patients treated nonoperatively may indicate increased awareness and a more conscientious movement adaptation implemented by these patients. Patients completing rehabilitation alone are potentially more careful of how they move as compared with preinjury, but this heightened awareness may not change their physical ability to complete daily and sports activities when compared with their ACL-reconstructed counterparts. TSK-11 scores further corroborate this hypothesis. Patients treated nonoperatively reported higher levels of fear on the TSK-11 at 5 years than those treated operatively (difference matched the MDC of 3.0 points). It is unknown what score on the TSK-11 represents a “normal” or “healthy” level of fear. The higher level of fear reported by the patients treated nonoperatively may represent an implemented strategy to safely and successfully achieve high levels of knee function and long-term knee joint health without surgical intervention. Alternatively, the poorer GRS, KOOS quality of life, and TSK-11 scores could indicate negative consequences of choosing nonoperative rehabilitation over ACL reconstruction and affect knee function and activity levels. However, despite group differences in the GRS, KOOS quality of life, and TSK-11 scores, nonoperatively treated patients demonstrated similarly high levels of 5-year quad-iceps strength and single-legged hop scores as well as similar 5-year cutting and pivoting activity levels as compared with patients treated with ACL reconstruction.

Osteoarthritis

No statistically significant radiographic differences existed between patients treated operatively and those treated nonoperatively, although the incidence of osteoarthritis (defined by KL grades) was higher among patients treated operatively. Only 5% of patients treated nonoperatively had tibiofemoral osteoarthritis at 5 years, as opposed to 23% of patients treated operatively. A systematic review by Smith et al concluded that the risk for developing knee osteoarthritis was not different between operative and nonoperative groups during the first 10 years after injury, but patients with ACL reconstruction had a slightly higher likelihood of developing these sequelae after 10 years. Further follow-up of patients within our cohort is needed to determine if a similar pattern of osteoarthritis development emerges.

Additional Considerations

Frobell and colleagues reported outcomes of patients randomized to early ACL reconstruction or the option to have delayed ACL reconstruction at a similar 5-year testing point to that used in the current study. Forty-nine percent of patients in the latter group continued nonoperative treatment through 5 years. Frobell et al reported findings similar to those of the current study when comparing the early reconstruction group with those who remained nonoperatively treated at 5 years, including the absence of differences in any of the 5 KOOS subscales, 5-year sports and activity levels, and the presence of radiographic tibiofemoral osteoarthritis. Mean scores on each KOOS sub-scale were similar in magnitude between Frobell et al and the current study for both the operative and nonoperative groups. Frobell et al reported that 16% of patients treated with early ACL reconstruction and 12% of patients treated with rehabilitation alone demonstrated radio-graphic tibiofemoral osteoarthritis, as opposed to 23% and 5%, respectively, in the current study.

Seventy-three percent of the original cohort was included in the current analyses. Patients lost to follow-up may have provided additional insight in functional and radiographic differences between operatively and nonoperatively treated patients. Furthermore, the nonoperative group was considerably smaller than the nonoperative group. However, this is not unexpected, given the high rate of ACL reconstructions completed in the United States. In addition, it is not known whether outcomes at 5 years vary in alternative ACL populations. Our findings may not be generalizable to those who have more extensive concomitant injuries or are less active in sports activities. Also, the mean age of the cohort at 5-year testing was 34.3 ± 11.4 years. Therefore, caution is needed in applying the current findings directly to high school and college populations who are highly competitive in cutting and pivoting activities. In addition, giving-way episodes were not reliably tracked during follow-up data collection. This information would have been desirable to compare groups as well. A comprehensive study of 5-year outcomes comparing an operative versus nonoperative treatment strategy was presented in this study. Our findings indicate that favorable outcomes can occur after both treatment approaches with the use of progressive criterion-based rehabilitation. However, a tremendous hurdle remains in successfully screening and identifying the best candidates for ACL reconstruction and nonoperative rehabilitation. The ability for patients who initially have poor dynamic knee stability to eventually improve knee function and succeed with non-operative treatment may signal the need for extended periods of progressive rehabilitation to restore maximal knee function before surgical decision making. The current findings provide an opportunity for a better-informed educational process between patients and clinicians regarding the expected clinical course and long-term outcomes of operative and nonoperative treatment of ACL injuries.

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Figure 1.

Flow diagram of study cohort. Two patients electing and completing at least 6 months of nonoperative treatment had delayed anterior cruciate ligament (ACL) reconstruction and were included in the operative group at 5 years, resulting in 83 operatively treated and 22 nonoperatively treated patients in this analysis.

TABLE 1.Minimal Detectable Changes for All Clinical Measures Between Operative and Nonoperative Groups^a

Minimal Detectable Change	
Single-legged hop test, %	
Single	8.1
Crossover	12.3
Triple	10.0
6-m timed	13.0
KOS-ADLS	11.4
GRS ^c	6.5
IKDC	12.8
KOOS subscale	
Pain	6.1
Symptoms	8.5
ADL	8.0
Sport/recreation	12.0
QoL	7.2
TSK-11	3.0
ACL-RSI	1.9
Pain (VAS)	2.8

^a ACL-RSI, ACL–Return to Sports After Injury; ADL, activities of daily living; GRS, Global Rating Scale of Perceived Function; IKDC, International Knee Documentation Committee Subjective Knee Form 2000; KOOS, Knee injury and Osteoarthritis Outcome Score; KOS-ADLS, Knee Outcome Survey–Activities of Daily Living; QoL, quality of life; TSK-11, Tampa Scale for Kinesiophobia; VAS, visual analog scale.

Baseline, Concomitant, and Second ACL Injury Characteristics Between Patients Who Underwent ACL Reconstruction and Nonoperative Management of ACL Injury^a

TABLE 2.

	Operative (n = 83)	Nonoperative (n = 22)	P Value
Age at 5-y testing, y	33.6 ± 11.0	36.8 ± 13.0	.248
Body mass index, kg/m ²	26.6 ± 4.3	26.5 ± 4.5	.862
Sex, male:female	56:27	10:12	.082
Preinjury activity level, 1:2	59:24	10:12	.041
Mode of ACL injury, noncontact:contact	58:25	14:8	.611
Time from ACL reconstruction/nonoperative rehabilitation to 5-y testing, y	5.4 ± 0.8	5.1 ± 0.6	.092
Nonoper:potential coper	47:36	8:14	.100
Concomitant, yes:no			
Meniscus tear	35:48	6:16	.229
Chondral injury	3:80	3:19	.105
Bone bruise ^b	59:11	15:4	.730
Second ACL injury, yes:no			
Ipsilateral	10:73	—	—
Contralateral	5:78	0:22	.581

^aValues are presented as n or mean ± SD. Boldface indicates statistically significant group differences, $P < .05$. ACL, anterior cruciate ligament.

^bBone bruise data include 89 of 105 patients.

TABLE 3.

Primary Reasons Why Single-Legged Hop Testing Was Not Completed During 5-Year Testing

	Operatively Treated Patients, ^a n
Knee joint effusion	2
Quadriceps index <80%	2
Knee joint effusions and quadriceps index <80%	2
Knee pain with hopping	4
Contralateral lower extremity pain with hopping	1
Recent additional lower extremity injury	3
Patient safety	3 (1)
Patient refusal	2 (3)
Unknown	1

^aNumber of nonoperatively treated patients in parentheses.

Clinical Measures of Knee Function Between Patients Who Underwent ACL Reconstruction and Nonoperative Treatment of ACL Injury^a

TABLE 4.

	Operatively Treated		Nonoperatively Treated		P Value
	Mean $\pm$ SD	95% CI	Mean $\pm$ SD	95% CI	
Quadriceps index, %	104.7 $\pm$ 17.9	100.6–108.9	103.1 $\pm$ 17.9	94.6–111.8	.817
Single-legged hop test, %					
Single	101.1 $\pm$ 10.8	98.2–104.0	101.8 $\pm$ 7.4	97.7–105.9	.463
Crossover	102.2 $\pm$ 10.4	99.4–105.0	97.8 $\pm$ 7.8	93.5–102.1	.234
Triple	101.2 $\pm$ 9.4	98.6–103.7	100.9 $\pm$ 6.3	97.4–104.4	.930
6-m timed	101.2 $\pm$ 8.1	99.0–103.3	100.5 $\pm$ 5.5	97.4–103.5	.955
KOS-ADLS, %	96.7 $\pm$ 4.5	95.7–97.7	95.5 $\pm$ 5.5	93.1–98.0	.404
GRS	94.5 $\pm$ 6.9	93.0–96.0	87.2 $\pm$ 11.9	81.9–92.5	.001^b
IKDC	92.1 $\pm$ 9.7	90.0–94.3	87.8 $\pm$ 11.9	82.5–93.1	.195
KOOS subscale					
Pain	95.8 $\pm$ 6.6	94.3–97.3	94.2 $\pm$ 9.3	90.0–98.3	.658
Symptoms	90.6 $\pm$ 10.0	88.4–92.8	92.0 $\pm$ 10.8	87.2–96.8	.396
ADL	98.1 $\pm$ 4.4	97.1–99.0	97.5 $\pm$ 5.4	95.1–99.9	.941
Sport/recreation	91.1 $\pm$ 12.8	88.3–94.0	89.5 $\pm$ 17.7	81.7–97.4	.892
QoL	85.9 $\pm$ 17.7	82.0–89.9	77.0 $\pm$ 21.7	67.4–86.6	.090 ^b
Marx	8.7 $\pm$ 4.8	7.6–9.7	7.0 $\pm$ 4.2	5.1–8.9	.366
TSK-11	16.2 $\pm$ 5.5	15.0–17.4	19.2 $\pm$ 5.0	17.0–21.4	.035^b
ACL-RSI	8.0 $\pm$ 2.5	7.4–8.5	6.7 $\pm$ 3.1	5.3–8.1	.100
VAS Pain					
Current	0.2 $\pm$ 0.5	0.1–0.3	0.3 $\pm$ 0.6	0.0–0.6	.464
Worst	0.6 $\pm$ 1.1	0.4–0.9	1.5 $\pm$ 1.9	0.7–2.3	.010
Best	0.1 $\pm$ 0.5	0.0–0.2	0.0 $\pm$ 0.2	0.0–0.1	.987
Effusion (yes), %	43.7	31.8–55.5	10.5	4.7–25.7	.016
Activity level at 5 y, n (1:2:3:4)	42:13:24:3	—	7:6:8:1	—	.400
Currently at preinjury activity level (yes), %	61.0	50.0–72.0	50.0	27.0–73.0	.349

^aValues are presented as mean $\pm$ SD unless noted otherwise. Boldface indicates statistically significant group differences after controlling for preinjury activity level (1 or 2), $P < .05$. ACL, anterior cruciate ligament; ACL-RSI, ACL-Return to Sports After Injury; ADL, activities of daily living; GRS, Global Rating Scale of Perceived Function; IKDC, International Knee Documentation Committee Subjective

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Knee Form 2000; KOOS, Knee injury and Osteoarthritis Outcome Score; KOS-ADLS, Knee Outcome Survey-Activities of Daily Living; Marx, Marx Activity Rating Scale; QoL, quality of life; TSK-11, Tampa Scale for Kinesiophobia; VAS, visual analog scale.

^b Group difference exceeds minimal detectable change value in Table 1.

TABLE 5.
Radiographic Characteristics Between Patients Who Underwent ACL Reconstruction and Nonoperative Treatment of ACL Injury^a

	Operatively Treated (n = 64)	Nonoperatively Treated (n = 20)	P Value
Involved OA (yes), %			
Medial compartment	15.6 (6.5 to 24.8)	5.0 (–5.5 to 15.5)	.447
Lateral compartment	12.5 (4.2 to 20.8)	5.0 (–5.5 to 15.5)	.679
Medial or lateral compartment	23.4 (12.8 to 34.1)	5.0 (–5.5 to 15.5)	.102
Uninvolved OA (yes), %			
Medial compartment	6.3 (0.2 to 12.3)	0.0 (0.0 to 0.0)	.568
Lateral compartment	6.3 (0.2 to 12.3)	5.0 (–5.5 to 15.5)	>.999
Medial or lateral compartment	9.4 (2.0 to 16.7)	5.0 (–5.5 to 15.5)	>.999
Minimum JSW difference, ^b mm			
Medial compartment	0.0 (–0.3 to 0.3)	0.0 (–0.5 to 0.4)	.978
Lateral compartment	–0.5 (–0.8 to 20.2)	–0.3 (–0.9 to 0.4)	.439

^aValues within parentheses are 95% CIs. ACL, anterior cruciate ligament; JSW, joint space width; OA, osteoarthritis.

^bJSW data include 82 of 84 patients.