Range of Motion, Strength, and Function After ACL Reconstruction Using a Contralateral Patellar Tendon Graft

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Background: Regaining preinjury levels of activity and progressing rehabilitation factors after anterior cruciate ligament (ACL) reconstruction have shown mixed results.

Purpose: To evaluate the timing and rate of return for knee range of motion (ROM), stability, strength, and subjective scores after ACL reconstruction with contralateral patellar tendon graft (PTG).

Study Design: Case series; Level of evidence, 4.

Methods: Included were 2148 patients (1238 male patients, 910 female patients) who underwent primary ACL reconstruction with a contralateral PTG between 1995 and 2017 and had complete objective data through 3 months of follow-up. All patients participated in a rehabilitation program specific to goals for each knee. Patients were evaluated objectively with goniometric measurement of ROM, isokinetic quadriceps strength testing, and laxity with a KT-2000 arthrometer. Subjective data were collected at 2 and 5 years.

Results: Normal extension on the reconstructed knee was attained for 95% of patients at 1 week postoperatively; normal flexion on the reconstructed knee was reached by 77% of patients by 3 months. At 3 months postoperatively, mean limb symmetry index strength was 104%, and the strength on the ACL-reconstructed and graft-donor knees was 87% and 86% of their respective preoperative strength. Mean manual maximum side-to-side difference in laxity was 2.0 mm at 1 month. Most patients (90%) returned to level 8 sports or higher and did so at an average of 5.7 months. Mean International Knee Documentation Committee scores for the ACL-reconstructed and graft-donor knees were 89 and 91 at 2 years (n = 1015 patients) and 84 and 90 at 5 years (n = 1275 patients), respectively. Mean Cincinnati Knee Rating Scale scores for the ACL-reconstructed and graft-donor knees were 92 and 96 at 2 years (n = 1184) and 88 and 94 at 5 years (n = 1236), respectively.

Conclusion: For patients who underwent ACL reconstruction with a contralateral PTG, postoperative ROM and strength were restored quickly by splitting the rehabilitation into different goals between the two knees. Using a contralateral PTG, this structured rehabilitation plan can lead to a relatively quick return to sport and good subjective long-term outcomes.

Keywords: anterior cruciate ligament; rehabilitation; patellar tendon graft; long-term outcomes

Attaining preinjury function in regard to range of motion (ROM), strength, stability, and sports participation after an anterior cruciate ligament (ACL) reconstruction has, at times, shown to be difficult.[19,25] Studies show that ACL reconstructions can successfully restore stability in the long term, evident by adequate stability testing up to 20 years postoperatively.[8,17,28,46,59] However, patients can show a wide range of return to sports at the preinjury participation level, with rates ranging from 31% to 92%.[4,17,23,25] The reasons for this wide range have been related to graft type, surgical fixation, stiffness, quadriceps muscle weakness,[13,14,25,42] psychological readiness, and sex.[12,14,19,20,25,64] Given that 91% of patients expect to return to play at their preinjury level after surgery, determining strategies and factors that allow them to reach this

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goal should be the focus of orthopaedic surgeons and physical therapists treating patients with ACL tears.[16]

It is well known that loss of knee extension after an ACL reconstruction is one of the most debilitating complications after surgery, yet it continues to occur at a fairly high rate, with an incidence ranging from 1.9% to 10.9%.[21,35,38] Regaining quadriceps muscle strength has also been difficult regardless of graft source, and when the involved leg is asymmetrically weak compared with the contralateral limb, this can lead to low levels of return to sport.[25,39,43] Knowing the progression and the rate at which patients achieve normal levels for these objective measures will allow clinicians to properly treat and counsel patients throughout the postoperative rehabilitation process.

In postoperative rehabilitation, the goal is to attain symmetry between knees in terms of ROM, strength, and stability.[10] The senior author (K.D.S.) has used the patellar tendon graft (PTG) solely for all ACL reconstructions because of its strength obtained from bone-to-bone healing; its lower risk for subsequent ACL reinjury, especially with young athletes; and its ability to allow patients who rehabilitate fully to return to sports at a high rate.[46,54] Ipsilateral PTGs were consistently used between 1982 and 1995, and patients were doing fairly well overall; however, some problems occurred with the donor site, including poor strength recovery and anterior knee pain, that needed to be addressed. Although the PTG provided excellent stability, rehabilitating the donor site was difficult early in the rehabilitation process because any intensive strengthening conflicted with the goals of limiting swelling and achieving full ROM. Insufficient rehabilitation of the donor site after surgery can lead to suboptimal results like anterior knee pain and quadriceps weakness.[15,64] Consequently, many other surgeons chose to abandon the PTG for other graft sources.[6]

One way to restore symmetry after surgery is by performing an ACL reconstruction using a contralateral PTG.[10,45,56,57] We initially used a contralateral PTG with revision surgery, and our approach began to yield superior ROM and decreased swelling on the ACL-reconstructed knee as well as better quadriceps muscle strength return in the graft-donor knee when compared with the same measures for patients with an ipsilateral PTG.[55] However, the donor site on the contralateral side still showed some problems, and the rehabilitation on this side needed to be refined. It is possible for the patellar tendon donor site to regenerate to normal, but the donor site needs consistent stimulation for regrowth. More thought went into improving the rehabilitation on the graft-donor knee including attaining full ROM immediately after surgery and quickly starting low-resistance and high-repetition strength exercises to regenerate the patellar tendon. We consistently began using the contralateral PTG for primary ACL reconstruction in 1995. In an initial study of 434 patients by Shelbourne and Urch,[56] patients undergoing ACL reconstruction with a contralateral PTG were able to attain symmetric ROM and quadriceps muscle strength faster and returned to sports quicker compared with patients who received an ipsilateral PTG. Given the results found in this initial study, the senior author has performed primary ACL reconstructions predominantly using a contralateral PTG for >25 years.

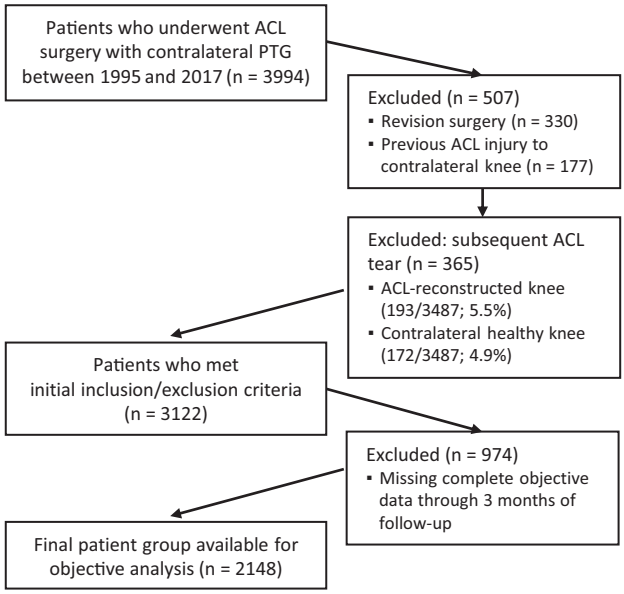

Figure 1. CONSORT (Consolidated Standards of Reporting Trials) flowchart of patient inclusion and exclusion process. ACL, anterior cruciate ligament; PTG, patellar tendon graft.

The purpose of this study was to evaluate, in a large group of patients, the timing and rate of return of normal knee extension and flexion, stability, and quadriceps muscle strength after ACL reconstruction with a contralateral PTG. We also sought to determine the postoperative outcomes regarding return to sport rates, activity level, and subjective scores on the International Knee Documentation Committee (IKDC) and Cincinnati Knee Rating Scale (CKRS).

METHODS

Primary ACL reconstruction with contralateral autogenous PTG was performed on 3994 patients between January 1995 and December 2017. All patients gave informed consent to participate in the study, and it was approved by the institutional review board at the institution where surgery was performed. Before undergoing surgery, patients were enrolled in a long-term prospective outcome study approved by the institutional review board at the participating hospital. We excluded patients who underwent revision ACL surgery (n = 330) and patients who had previous ACL injury to the contralateral knee (n = 177). Of the remaining 3487 patients, 193 experienced a subsequent ACL graft tear (5.5%) and 172 experienced a subsequent contralateral ACL tear (4.9%); these patients were excluded from the analysis. We required that patients have complete objective follow-up data through 3 months, of which 974 (31%) patients did not meet that requirement and were excluded. Ultimately, 2148 patients met the exclusion and inclusion criteria for analysis (Figure 1).

Surgical Procedure

The surgical technique for ACL reconstruction using a PTG from the contralateral normal knee has been described in detail previously.[56,57] A tourniquet was used on both knees during the surgery. The surgery was performed through a mini-arthrotomy to allow for the independent drilling of both the femoral and tibial tunnels. Of particular importance, the patellar and tibial defects caused by harvesting the graft were packed with bone graft that was obtained from drilling the femoral and tibial tunnels. When appropriate, a notchplasty was performed to accommodate the 10-mm graft. The patellar tendon defect was closed with a No. 1 vicryl suture, after which the ACL-reconstructed knee was put through full knee ROM, compared with the contralateral knee, from full hyperextension to flexion with the heel touching the buttock. Achieving full hyperextension at the time of surgery ensures that the patient can achieve full hyperextension the night of surgery. Patients stayed in the hospital overnight, and a perioperative pain management program was used, which has been described previously.[53]

Rehabilitation

A summary of the perioperative rehabilitation program that was prescribed is shown in Appendix Table A1; it has also been described in detail elsewhere.[10,48,52,56] The purpose of using a contralateral PTG was to divide conflicting rehabilitation goals between knees. The early goals for each knee were quite different; activities in the graft-donor knee were aimed at restoring strength, whereas the focus for the ACL-reconstructed knee was to control a hemarthrosis and recover full ROM.

Rehabilitation was provided by a staff of physical therapists who worked directly with the physicians, whose orthopaedic practice is limited to the knee only and has a high volume of ACL reconstructions. Patients were treated by the same physical therapist throughout the rehabilitation process before and after surgery for consistency and to control for any potential problems.

Data Collection

Patient demographic characteristics and details of surgery were prospectively collected and entered into a database. Patients were seen at routine intervals for patient care and rehabilitation, where objective data were collected. Evaluation was performed by physical therapists who had extensive experience with knee rehabilitation and testing procedures. Knee ROM was evaluated on both knees with the patient in a long-sitting position, and it was measured with a goniometer as described by Norkin and White.[37] Knee extension was evaluated with the patient's heel elevated on a bolster to allow the knee to go into hyperextension, if present. Knee flexion was measured with the patient in a long-sitting position and by having the patient bend the knee as far as possible toward the buttock. According to IKDC objective evaluation criteria, normal knee extension is considered to be within 2° of the opposite normal knee and normal flexion is considered to be within 5° of the opposite normal knee.[1] We evaluated for the percentage of patients who achieved normal knee extension and normal flexion at each time postoperatively. Objective knee stability was evaluated with a KT-2000 arthrometer (MEDmetric). The manual maximum difference, in millimeters, between knees was used for analysis.

TABLE 1
Formulas for Calculating Quadriceps Muscle Strength

Strength Evaluation	Calculation to Obtain Percentage Strength Value
% Strength of involved knee	$\left(\frac{\text{Reconstructed knee tor torque}}{\text{Graft knee torque}}\right) \times 100$
ACL-reconstructed knee strength	$\left(\frac{\text{Reconstructed knee torque}}{\text{Preoperative normal knee torque}}\right) \times 100$
Graft-donor knee strength	$\left(\frac{\text{Graft knee torque}}{\text{Preoperative normal knee torque}}\right) \times 100$

Quadriceps muscle strength was evaluated at 1, 2, 3, and 6 months postoperatively, using isokinetic testing (Cybex dynamometer; Lumex) at 60 deg/s and 180 deg/s. The mean postoperative isokinetic strength was calculated using 3 formulas as shown in Table 1. We also evaluated the percentage of patients who achieved $\geq 90\%$ strength compared with their preoperative normal value at each time postoperatively.

Subjective evaluation was performed using the CKRS and the IKDC subjective surveys.[1,7] An activity rating survey was sent to patients yearly after surgery, and we obtained the highest rating a patient achieved postoperatively.[50] For this activity rating scale, high-risk sports such as basketball, soccer, and football played at the professional or college level are defined as level 10, the school-age level is defined as level 9, and the recreational level is defined as level 8.[50] Patients were also sent a survey at 4, 6, 9, 12, and 13 months after surgery that asked, "At what time (in months) after surgery did you return to full sports/activities and at full capability?" If the survey was returned and the patient responded with the option of "I have not returned to sports at full capability yet," the survey was sent again at the next interval; the survey was stopped being sent when the patient confirmed a return to full sports activity.

Descriptive statistics were obtained, and objective data were analyzed for all patients at 1, 2, and 3 months after surgery as well as at 6 months for those available. Any available subjective data for patients meeting the criteria for objective follow-up were used for analysis.

RESULTS

Of the 2148 patients meeting criteria for this study, the mean age was 24.3 ± 10.1 years (range, 12.0-71.0 years). The mean age for female patients (n = 910) was 22.1 ± 9.8 years (range, 12.4-71.0 years). The mean age for male patients (n = 1238) was 25.9 ± 9.9 years (range, 12.0-64.2 years).

The mean ROM for extension, flexion, and difference between knees for extension and flexion through 6 months postoperative is shown in Table 2. Normal extension

TABLE 2
Range of Motion From 1 Week Through 6 Months Postoperatively[a]

	Time Postoperatively					
	1 wk	2 wk	1 mo	2 mo	3 mo	6 mo[b]
Extension[c]	5 ± 3	5 ± 3	5 ± 3	5 ± 2	5 ± 3	5 ± 2
Flexion	109 ± 14	121 ± 12	132 ± 11	139 ± 8	144 ± 7	146 ± 7
Difference: extension	0 ± 1	0 ± 1	0 ± 1	0 ± 2	0 ± 1	0 ± 1
Difference: flexion	–31 ± 16	–23 ± 14	–15 ± 11	–8 ± 8	–4 ± 5	–2 ± 5

[a]Data are reported as mean ± SD.
[b]n = 1503.
[c]Positive value represents degree of hyperextension.

TABLE 3
Objective Stability Values as Measured With KT-2000 Arthrometer

	Time Postoperatively				
	1 mo	2 mo	3 mo	6 mo[a]	2 y[b]
Laxity, manual maximum difference, mean ± SD	2.0 ± 1.4	1.9 ± 1.3	2.0 ± 1.5	2.0 ± 1.5	1.9 ± 1.4
Laxity, % of patients					
≤3 mm	91	92	90	90	90
4-5 mm	8	7	8	8	8
>5 mm	1	1	2	2	2

[a]n = 1471.
[b]n = 674.

(within 2° of normal knee) was achieved for 95% of patients at 1 week, 96% at 2 weeks, and 98% at 1 month postoperatively. Normal flexion (within 5° of noninvolved knee) was achieved by 49% of patients at 2 months, 77% at 3 months, and 89% at 6 months postoperatively.

The manual maximum difference in laxity between knees, as measured with the KT-2000 arthrometer, was 2.0 ± 1.4 mm at 1 month postoperatively, and stability was maintained through time (Table 3).

Isokinetic testing of quadriceps muscle strength showed that the mean percentage strength of the involved knee compared with the noninvolved knee at 3 months postoperatively was 104% for the 180 deg/s speed and 115% for the 60 deg/s speed. More important, when compared with the preoperative normal baseline measurement, the mean strength of the ACL-reconstructed knee was 87% for the 180 deg/s speed and 79% for the 60 deg/s speed and the mean strength of the graft-donor knee was 86% for the 180 deg/s speed and 71% for the 60 deg/s speed at 3 months after surgery (Table 4). The percentage of patients who achieved strength ≥90% of their preoperative normal value by 6 months postoperatively was 64% for the ACL-reconstructed knee for the 180 deg/s speed and 47% for the 60 deg/s speed. For the graft-donor knee at the same time point, 61% achieved strength ≥90% for the 180 deg/s speed and 30% for the 60 deg/s speed.

Results of the activity rating survey showed that 90% of patients (1643/1830) returned to jumping and pivoting sports at the recreational level (level 8) or higher after surgery. Overall, 81% of patients (1486/1830) were able to return to their preinjury activity level after surgery. For patients involved in jumping and pivoting sports, the percentage who were able to return to their preoperative sport level was 67% for college and professional athletes, 70% for school-age athletes, and 88% for recreational athletes (Table 5). Of the 1222 patients responding to the survey regarding time of return to sport, the mean time patients reported that they returned to full sports at full capability was 5.7 ± 2.3 months after surgery. The mean subjective CKRS and IKDC scores at 2 and 5 years after surgery are shown in Table 6.

DISCUSSION

The results of this study showed a clear progression for the timing and rate of return for normal knee extension and flexion, stability, and quadriceps muscle strength after ACL reconstruction using a contralateral PTG. Patients returned to jumping and pivoting sports at a high rate at around 6 months after surgery. Furthermore, subjective results showed that patients achieved normal values for both the ACL-reconstructed and graft-donor knees at 2 and 5 years postoperatively.

Previous studies have looked at ROM after an ACL reconstruction and its importance on outcomes; however, few have discussed its significance in the early postoperative phase and how this progresses over time.[11,36,44,47] One major benefit of using a contralateral PTG is allowing the patient to work on 2 different goals simultaneously,

TABLE 4
Isokinetic Testing of Quadriceps Muscle Strength[a]

	Time Postoperatively			
Isokinetic test	1 mo	2 mo	3 mo	6 mo[b]
180 deg/s speed				
% Strength of involved knee[c]	113 ± 37	105 ± 25	104 ± 24	104 ± 20
ACL-reconstructed knee strength	60 ± 18	76 ± 21	87 ± 24	99 ± 29
Graft-donor knee strength	56 ± 18	75 ± 21	86 ± 21	97 ± 23
60 deg/s speed				
% Strength of involved knee[c]	150 ± 59	123 ± 39	115 ± 33	114 ± 27
ACL-reconstructed knee strength	55 ± 18	70 ± 20	79 ± 22	90 ± 26
Graft-donor knee strength	40 ± 15	60 ± 17	71 ± 19	82 ± 21
Patients within 10% difference between knees, %				
180 deg/s speed	30	38	47	52
60 deg/s speed	15	25	33	40
Patients with ≥90% strength vs preoperative normal value, %				
ACL-reconstructed knee				
180 deg/s speed	5	22	42	64
60 deg/s speed	3	13	27	47
Graft-donor knee				
180 deg/s speed	3	19	39	61
60 deg/s speed	0	5	15	30

[a]Data are reported as mean ± SD or % of patients.
[b]n = 1480.
[c]Calculated as % strength of involved knee.

TABLE 5
Preoperative Sport or Activity Level Compared With Maximum Activity Rating Achieved After Surgery

	Postoperative Level Achieved, n				
	10	9	8	≤7	Achieved Preoperative Level or Higher, n (%)
Preoperative level					
10 (n = 137)	92	5	31	9	92 (67.2)
9 (n = 736)	153	365	191	27	518 (70.4)
8 (n = 684)	38	43	522	81	603 (88.2)
≤7 (n = 273)	6	19	178	70	273 (100)
Total (n = 1830)	289	432	922	187	

TABLE 6
Subjective Survey Results[a]

	2 y Postoperatively		5 y Postoperatively	
	ACL-Reconstructed Knee	Graft-Donor Knee	ACL-Reconstructed Knee	Graft-Donor Knee
	n = 1015		n = 1275	
IKDC	88.6 ± 12.5	91.4 ± 11.4	84.3 ± 17.3	89.5 ± 14.4
	n = 1184		n = 1236	
CKRS	92.4 ± 9.6	95.6 ± 7.2	88.3 ± 14.6	94.1 ± 9.9

[a]Data are reported as mean ± SD. ACL, anterior cruciate ligament; CKRS, Cincinnati Knee Rating Scale; IKDC, International Knee Documentation Committee.

separated between the ACL-reconstructed knee and the graft-donor knee.[56] The main goal for the ACL-reconstructed knee is to achieve full ROM quickly, which was evident in this study as 95% of patients reached normal knee extension by 1 week after surgery. For knee flexion, patients progressed slowly due to joint swelling, although steadily, as 49% were normal at 2 months (139°) and 89% were normal at 6 months (146°). Similar to our study,

Shelbourne and Urch[56] looked at the postoperative objective differences between patients having an ACL reconstruction with an ipsilateral PTG versus a contralateral PTG and found similar knee extension between the 2 groups; however, results showed better knee flexion in the contralateral group.

Stiffness after an ACL reconstruction has shown to be a relatively common and devastating complication, with an incidence rate ranging from 1.9% to 10.9%.[35] A recent systematic review found 2 risk factors for developing postoperative stiffness, one being extension loss in the early postoperative phase and the other being poor quadriceps muscle control.[35,58] Our results indicate that full knee hyperextension can be accomplished early, as 95% of the patients achieved normal extension by 1 week after surgery, which is higher than reported by previous studies on the topic.[31,35,36,44] Furthermore, this study compared knee extension loss to the high standard of within 2° of knee extension of the opposite normal knee, in line with established IKDC criteria.[1] Current studies use much less stringent criteria of achieving 0° extension, without regard to hyperextension, or 5° extension loss compared with the opposite normal knee.[38,60] Having less stringent criteria means that the true incidence of extension loss is likely much worse in other reports if it were compared with the IKDC criteria, as in our current study.

Attaining normal knee hyperextension early after surgery plays a large role in the patient achieving a good outcome, and this can be done only with proper fit and positioning of the graft. Given that the ACL is an intra-articular ligament, the relationship between the graft and the intercondylar notch needs to be understood and appreciated. When the knee is in full hyperextension, the ACL fits perfectly in the intercondylar notch, without impingement, allowing for full function including normal gait and the ability to gain strength. To accommodate a 10-mm graft, a notchplasty is often done to allow the graft to fit in the notch and allow full hyperextension, thus avoiding any postoperative complications like stiffness.

Attaining good quadriceps muscle strength has been shown to be linked to the ability to return to sport, proper biomechanics, and overall quality of life after an ACL reconstruction, yet this parameter is difficult to regain.[8,22,39-41,43,63,65] Using a contralateral PTG provides a unique advantage for regaining strength by splitting the rehabilitation between the two knees and allowing the patient to exclusively focus on strength for the graft-donor knee. In our current study, patients showed a consistent progression of quadriceps muscle strength through time (Table 4). Attaining symmetry early, followed by getting both knees back to preoperative normal values, is thought to allow for a quicker return to normal function and eventually sports.

Regaining quadriceps muscle strength is a variable that is difficult to normalize after surgery, regardless of graft choice.[15,24,26,41] Kobayashi et al[26] assessed isokinetic quadriceps muscle strength (180 deg/s) for patients undergoing ACL reconstruction with an ipsilateral PTG and showed a limb symmetry index of 69% and 82% at 6 months and 12 months, respectively. Feller and Webster[15] looked at the difference in isokinetic quadriceps muscle strength between hamstring tendon grafts and PTGs 4 months after surgery and found a significant deficit for both groups; however, patients who received a PTG had a larger deficit (hamstring tendon graft 27%; PTG 36%). Shelbourne and Urch[56] compared strength return between patients receiving an ipsilateral versus a contralateral PTG, and the results showed statistically significantly better strength return with the contralateral graft. Properly rehabilitating the donor site continues to be a problem, evident by significant strength deficits in the literature, further justifying the individual and focused attention to the donor site that the contralateral PTG approach can provide.[15,26] Studies are finding asymmetric quadriceps strength at the time when most athletes are returning to sport, 4 to 12 months, which appears to affect function negatively in the long-term.[15] Some studies have found long-term deficits in strength compared with the contralateral limb for up to 2 years, potentially providing a reason to delay a return to sport past this time.[29,34] Normalizing strength early on can give the patient a better chance at returning to sports successfully and in a timely manner.

Postoperative laxity is an important component of an ACL reconstruction that cannot be overlooked when determining success and failure of the surgery. Our study indicated that knee laxity, measured by a manual maximum KT arthrometer difference, was within normal limits at 1 month after surgery (2.0 mm) and was maintained through 2 years (1.9 mm). In terms of postoperative laxity, surgical success and failure are often defined as a manual maximum KT arthrometer difference of >5 mm between the surgical and nonsurgical side.[1,18] Our current study showed that 98% of patients had normal laxity, ≤5 mm manual-maximum difference between knees, when measured by the KT arthrometer at 6 months after surgery. As shown in our current study, as well as in previous studies by Shelbourne et al,[51] knowing that almost all patients have normal postoperative laxity in all stages, the physical therapy staff is able to confidently progress them through rehabilitation without the fear of a surgical failure.

A high percentage of patients in the current study (90%) were able to return to at least a recreational level (level 8) or higher after surgery. Of those involved in jumping and pivoting sports before surgery, many were able to attain this same level after surgery, 67% for college and professional athletes, 70% for school-age athletes, and 88% for recreational athletes. The average time to return to full sports participation was 5.7 months after surgery. Successful return to sports at 5.7 months after surgery appears to be faster than previously reported, as a recent systematic review on the topic showed that 14 of the 15 studies included reported a return to sport time of 6 months or longer.[27] Although faster than reported by most of the studies in the systematic review, 5.7 months is slower than previously reported data on ACL reconstructions that used a contralateral PTG; a study by Shelbourne and Urch[56] showed a return to sport time of 4.9 months for the population overall and 4.1 months in the young and highly active population. A main concern for early return to sport after surgery is a subsequent ACL injury to either knee;

however, Shelbourne et al[49] showed that the rates of ACL injury in both knees were the same for patients returning before and after 6 months, with all rates ranging from 4.0% to 5.4%. In the study by Shelbourne and Urch, published in 2000, the investigators learned that athletes could get back to sports safely and quickly after surgery; however, their performance was not where they wanted it to be. Therefore, over the years, patients have been advised to take more time getting back to sport so that this aspect of the rehabilitation process could be improved.

Although athletes expect to return to their sport after surgery, and at a high level, some are unable to do so.[3,5,16,61] The overall rate of return to preinjury levels in the current study was 81%, which is on the high end of the range typically reported in the literature.[4,23] In the literature, return to preinjury levels of sport has a wide range, from 31% to 92%[3,5,23,27,62]; therefore, it is important to note the differences in studies when assessing these rates, as many reasons, including age, sex, graft selection, lifestyle choices, psychological factors, and a host of rehabilitation factors, have been linked to having both high and low rates of return.[8,22,24,27,61,62]

Many of the patients in the current study were able to maintain these positive outcomes long-term, as the average CKRS score at 2 years was 92 on the ACL-reconstructed knee and 96 on the graft-donor knee. At 5 years, on the same CKRS, the ACL-reconstructed knee was 88 and the graft-donor knee was 94. For the IKDC, our results at 2 years were 89 on the ACL-reconstructed knee and 91 on the graft-donor knee, and scores stayed relatively high at 5 years, at 84 on the ACL-reconstructed knee and 90 on the graft-donor knee. Our postoperative IKDC results are in line with the normative IKDC values for the general population for those around the average age of patients in our study, with normal values being 89 for men and 86 for women in the 18- to 35-year age bracket.[2] McCarthy et al[32] examined a sample of which the majority received PTGs, and Mohtadi et al[33] measured a group with hamstring tendon grafts; 2-year IKDC scores were 84 in both studies. The graft-donor knees from our study consistently scored higher on subjective scores long-term, further justifying the importance of properly rehabilitating the graft-donor knee. Splitting the rehabilitation between knees and independently working on different goals for the ACL-reconstructed knee and the graft-donor knee is thought to play a large role in returning each knee back to a normal level.

The clinical setting for this study entailed orthopaedic surgeons and in-house physical therapists whose practice was limited to knee treatment only. Over the years, the clinicians have seen a high volume of ACL reconstructions and have collected and continually analyzed data, with the goal of making incremental changes to improve outcomes. Among the benefits of a contralateral PTG, having an office setup like ours most likely helped make these outcomes possible.

Limitations

One of the main limitations of this study is that the results apply only to those undergoing ACL reconstruction with a contralateral PTG, as no other graft was used on our patients. Although not the aim of our study, donor site morbidity was not assessed with a donor site-specific questionnaire, which may be of concern for clinicians choosing a PTG, given that Mastrokalos et al[30] showed similar levels of pain in the graft-donor site for contralateral and ipsilateral PTG. Our study had long-term follow-up on 69% of patients initially enrolled, lower than the ideal 80%, thus possibly skewing our results. From a subjective standpoint, we received data regarding time to return to sport from only 57% of the patients, potentially skewing these results as well. Regarding follow-up, we had to exclude 974 patients for not having data at every time point through 3 months. Many patients had data at some time points during this 3-month period, as well as beyond, yet still had to be excluded for this study. The current study excluded those who sustained an ACL graft tear or contralateral ACL tear, thus not allowing us to determine the effects that a contralateral PTG would have on this type of outcome. Complications were not reported in this particular study; however, they have been reported extensively in previous publications.[9] We did not include long-term radiographs, in particular patellofemoral views from the graft-donor knee, which would help in determining long-term arthritic changes, if any, although this outcome was not an aim of the study. Last, the results from this study are a product of a unique practice setting, thus limiting the generalizability of the findings to other practice settings unlike ours. Simply performing an ACL reconstruction using a contralateral PTG is not the only factor in successful outcomes; instead, it must be accompanied by the specific rehabilitation principles described here.

CONCLUSION

For patients having an ACL reconstruction with a contralateral PTG, postoperative ROM and strength can be progressed quickly and effectively by splitting the rehabilitation into two different goals, with ROM being the focus on the ACL-reconstructed knee and strength being the focus on the graft-donor knee. Performing the surgery in this way, followed by a structured rehabilitation plan, can allow patients to return to their desired activity level in a timely manner and achieve good subjective results at 2 and 5 years postoperatively.

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APPENDIX

TABLE A1
Rehabilitation Program for ACL Reconstruction With Contralateral Patellar Tendon Graft

Goals	Exercises
	Preoperative
ACL-reconstructed knee	
Reduce swelling	Cold/compression; elevation
Obtain full ROM	Hyperextension device/heel slides 3×/day
Good leg control	Active terminal extension
Achieve normal gait	Gait training
Mental preparedness	Patient education of program and goals
Graft-donor knee	
Maintain leg strength	Practice step-up exercise used postoperatively for graft knee
	Surgery
ACL-reconstructed knee	
Maintain full ROM	Passive motion from full hypertension to full flexion (heel touches buttocks)
Prevent pain and swelling	Intravenous ketorolac pain prevention program[54]
Graft-donor knee	
Bone graft the defects in the patella and tibia	—
Close patellar tendon defect	—
	Phase 1 (immediate postoperative through 1 wk postoperative)
ACL-reconstructed knee	
Minimize hemarthrosis	Cold/compression to remain on the knee except during exercises; elevation
Full passive hyperextension	Heel prop, 10 min, 4×/day
Flexion to 125°	CPM set at highest flexion possible; leave leg in maximal flexion for 3 min, 3×/day
Gentle ROM	Heel slides; use measuring stick to monitor progress
Independent leg raise	CPM machine set to move from 0° to 30° continually when not doing exercises; knee is elevated above the heart in the CPM machine
Weightbearing as tolerated	Active quadriceps contractions; straight-leg raises; active terminal extension
Normal gait	Gait training
Graft-donor knee	
Minimize swelling	Cold pack; leg elevated on pillow
Full passive hyperextension	Heel prop exercise to allow for full hyperextension
Full flexion	Heel slides; pull heel to buttocks; use measuring stick to monitor progress
Donor site strengthening	Shuttle machine; set resistance so able to do 25 repetitions, 3×/day; progressively increase repetitions and resistance
	Phase 2 (1 wk through 1 mo postoperative)
ACL-reconstructed knee	
Maintain full extension	Heel prop
Be able to lock knee straight with full weightbearing	Single-leg stance; locking knee in extension
Increase flexion equal to opposite knee	Heel slide
Maintain minimal swelling	Cold/compression
Normal gait	Gait training in front of a mirror
Progress to light strengthening	Active terminal extension; progress to stationary bicycling
Graft-donor knee	
Maintain full extension and flexion	Heel prop; heel slide
No swelling	Ice after exercise
Donor site strengthening	▪ Shuttle exercise: up to 100 repetitions 3×/day (through 2 wk postoperative) ▪ Step-box exercise at height to allow for 50-100 repetitions; perform 3-4×/day ▪ Progress to single-leg weight training exercises (still high repetition/low resistance): leg press, leg extension

(continued)

Table A1 (continued)

Goals	Exercises
Phase 3 (after 1 mo postoperative as patient is able to progress)	
ACL-reconstructed knee	
Maintain full ROM	Heel props as needed; sit on heels
Control swelling	Cold/compression; adjust activities to keep swelling to a minimum
Quadriceps strengthening	Bicycle; Stairmaster; can progress to leg press, leg extension, squats once strength symmetry is within 10%
Return to light sports	Functional progression from agility drills, sport-specific agility drills, to controlled practice drills
Graft-donor knee	
Donor site strengthening	Single-leg strengthening; increase weight and decrease repetitions for weight training exercises; can progress to double-leg strengthening once symmetry is within 10%
Phase 4 (after 3 mo postoperative as patient is able to progress)	
ACL-reconstructed knee	
Maintain full ROM	Exercises as needed; watch for motion loss and decrease activities if needed; monitor daily
Control swelling	Adjust activities to keep swelling to a minimum; continue using cold/compression
Return to full sports	Continue sport-specific and controlled practice drills and progress first to part-time competition and then full-time competition
Graft-donor knee	
Return donor site functional strength	▪ Continue with weight training 3-4×/wk ▪ Increase functional strength through sport-specific activities; alternate intensity with hard and easy days

[a]ACL, anterior cruciate ligament; CPM, continuous passive motion; ROM, range of motion.