

Revision Anterior Cruciate Ligament Reconstruction With Nonirradiated Fresh-Frozen Patellar Tendon Allograft

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Purpose: To evaluate the effectiveness of a revision anterior cruciate ligament reconstruction with nonirradiated patellar tendon allograft used to salvage a failed index patellar tendon autograft procedure. **Type of Study:** Retrospective case series with minimum 2-year follow-up. **Methods:** Between 1993 and 1999, 39 patients underwent a revision reconstruction. Clinical, radiographic, arthrometric, and functional evaluations were performed. The Tegner, Lysholm, Noyes, Knee Injury and Osteoarthritis Outcome Score (KOOS), International Knee Documentation Committee (IKDC), and SF-12 rating scales were used. Statistical analysis was conducted with our Biostatistics Department. **Results:** Thirty-two of 38 patients (84%) were personally evaluated. The mean patient age was 28 years (range, 16 to 57 years); the mean follow-up was 4.8 years (range, 2.1 to 12.1 years). After revision, there were significant improvements in the Lachman and pivot-shift test results: 87% had a grade 0/1+ Lachman and a 0/1+ pivot-shift. However, 25% had a grade 1+ pivot-shift. Postoperatively, KT-1000 testing revealed that 84% had a maximum manual side-to-side difference of ≤ 3 mm and 6% had >5 mm. Functional testing revealed a mean 4% difference in side-to-side comparisons for a single-leg hop for distance and time, as well as vertical jump. The mean results of Noyes sports function (72), Lysholm (75), Tegner (6.3), KOOS sports activity scale (67), SF-12 physical component (48), SF-12 mental component (55), and IKDC (71) were obtained. The Noyes sports activity score showed a significant improvement from 55 preoperatively to 70 at follow-up. Subjectively, 87% of patients indicated that they were completely or mostly satisfied with the surgical outcome. One patient required another revision. **Conclusions:** The 2- to 11-year follow-up showed that the results of revision ACL reconstruction with a nonirradiated patellar tendon allograft were less favorable than those of a primary anterior cruciate ligament reconstruction, with a lower subjective satisfaction level and a higher percentage of patients with grade 1+ or higher pivot-shift results. However, when compared with previously published reports, our results were comparable and underscore that revision anterior cruciate ligament surgery should be approached with tempered enthusiasm and careful preoperative counseling, and considered as a salvage procedure. **Level of Evidence:** Level IV. **Key Words:** Anterior cruciate ligament—Reconstruction—Allograft—Revision—Nonirradiated.

There are estimates of nearly 100,000 primary skiing-related anterior cruciate ligament (ACL)

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injuries annually.¹ According to Garrett, a review of case logs of orthopaedic surgeons reviewed for the American Board of Orthopaedic Surgery, ACL reconstructive surgery is the seventh most commonly performed orthopaedic surgical procedure (W. G. Garrett, personal communication, July 2003). Analogous to the experience with total knee arthroplasty, it has been estimated that, nationally, 90% of ACL reconstructions are performed by surgeons who perform fewer than 10 reconstructions a year. Most clinical follow-up studies report a failure rate of between 10% and 20%.²⁻⁷ There are potentially 3,000 to 10,000 revision ACL surgeries to be performed each year in the United States.⁸ There have been few clinical follow-up studies evaluating the outcomes of revision ACL surgery. Most of those studies used irradiated allograft tissues. Revision ACL surgery is less suc-

cessful than index ACL reconstruction.⁹ Based on concerns about the potential deleterious effect of irradiation, the authors have exclusively used nonirradiated tissues for ACL index and revision surgery. Additionally, we prospectively decided to use a postoperative rehabilitation program after revision surgery identical to that for an index reconstruction. The purpose of this study was to evaluate the use of a fresh-frozen nonirradiated bone–patellar tendon–bone allograft for revision ACL surgery for a failed primary patellar tendon autograft procedure.

METHODS

The methodology used for this study was identical to that of several previously reported studies from our institution.¹⁰⁻¹² This study was a retrospective case series using a minimum 2-year follow-up interval and was approved by our Investigational Review Board.

All patients who underwent a revision ACL reconstruction with nonirradiated patellar tendon allograft between March 20, 1990 and November 19, 1999 were identified from our computerized surgical database and reviewed. Exclusionary criteria included concomitant extra-articular reconstructions, high tibial osteotomy, associated multiligament pathologies, or contralateral knee ACL deficiency or reconstruction. All surgical procedures were performed by 2 senior surgeons (B.R.B., C.A.B.-J.). Thirty-nine patients were eligible for this study. Of these, 1 patient died, 3 lived outside the country, and 3 patients were lost to follow-up. Thirty-two of the 38 (84%) were personally evaluated. All but 2 patients were regional referrals to our center. A detailed questionnaire was filled out by each patient to eliminate interviewer bias. The evaluation consisted of a physical examination, KT-1000 arthrometric evaluation (MEDmetric, San Diego, CA), functional testing, and knee scoring scales. The knee scoring scales used included the Knee Injury and Osteoarthritis Outcome Score (KOOS),¹³ International Knee Documentation Committee (IKDC),¹⁴ Noyes Cincinnati rating scales,¹⁵ Tegner,¹⁶ Lysholm,¹⁷ and an SF-12.¹⁸

Surgical Technique

A single-incision arthroscopically assisted technique (24 patients), as described by Hardin et al.,¹⁹ or a 2-incision technique (8 patients) arthroscopically assisted technique¹¹ was performed. Hardware present from the index reconstruction was maintained when it did not obstruct ideal tunnel positioning (Fig 1).



FIGURE 1. Two-incision technique that was revised to an endoscopic technique. The previously placed hardware was maintained.

The principles of adequate notch preparation and revision notchplasty (when necessary), proper tunnel placement, rigid graft fixation using interference screws, and securing the tibial bone plug with the knee in extension were employed.²⁰ In general, a 10-mm, middle-third patellar tendon allograft was shaped with 25-mm bone plugs. Commercially available aiming devices were used for both femoral and tibial tunnel placement (Acufex Protrac Aimer; Smith & Nephew, Andover, MA). Determination of screw length and diameter were made intraoperatively, but in general a 7 × 25-mm cannulated metal interference screw was used on the femoral side and a 9 × 20-mm screw was used on the tibial side. The graft was placed with the cortical edge oriented posteriorly within the femoral tunnel and the screw was placed anteriorly to minimize potential soft-tissue injury to the graft. This orientation also placed the graft more posteriorly. After femoral fixation, the knee was cycled multiple times to assess femoral graft fixation and gross isometry. The tibial bone plug was rotated toward the lateral intercondylar wall, and the tibial interference screws were placed anteriorly on the cortical surface of the bone plug. All tibial screws were secured with the knee in complete extension or hyperextension while applying firm tension to the sutures on the tibial plug. Graft position, tightness, and notch clearance were inspected arthroscopically before closure. In fewer than 10% of cases, the tibial bone plug was secured to the tibia with staples or a screw and post if there was graft-tunnel mismatch. If meniscal repair was performed, the sutures were secured with the knee in complete extension.

Physical Examination

To avoid treating-surgeon bias, physical examination of both knees was performed independently by a sports medicine fellow. This evaluation included supine goniometric range-of-motion measurements, prone heel height differences measured to the nearest centimeter, and thigh circumference measurements (8 cm proximal to the patella). Varus-valgus stability at 0° and 30°, Lachman, anterior and posterior drawer, and pivot-shift tests were performed. Ligamentous laxity was graded as 1+ (0 to 5 mm), 2+ (6 to 10 mm), or 3+ (>10 mm). The pivot-shift phenomenon was graded as 1+ (slip), 2+ (jump), or 3+ (transient lock) in the position of thigh abduction and external rotation, which maximizes the pivot-shift phenomenon.²¹ Results were maintained on a standardized form.

Functional Examination

Thirty-one of 32 patients (1 patient was pregnant and did not complete functional testing) underwent bilateral knee functional testing at the follow-up examination conducted by an experienced athletic trainer (J.B., who had also conducted the functional examinations in several previous clinical studies).¹⁰⁻¹² The functional indices recorded were a timed single-leg 6-meter hop, measured single-leg hop, and single-leg vertical jump. All patients underwent 3 trials of each test for each leg; the trials were averaged and reported as side-to-side differences.

Radiographs

Standing bilateral anteroposterior, standing bilateral 45° posteroanterior, lateral, and Merchant view radiographs were taken of all patients except the pregnant patient. Radiographs were graded based on the IKDC scale. A mild grade indicates minimal changes (small osteophytes, slight sclerosis, or flattening of the femoral condyle) and narrowing of the joint space that is just detectable. A moderate grade may indicate those changes plus joint space narrowing (a joint space of 2 to 4 mm side or up to 50% joint space narrowing). A severe grade indicates changes including a joint space of less than 2 mm or greater than 50% joint space narrowing. The radiographs were interpreted by a sports medicine fellow (J.F.).

Arthrometric Examination

Each knee was tested preoperatively and postoperatively with the KT-1000 arthrometer by an experienced independent examiner (J.B.). Testing was performed as

described by Daniel et al.²⁰ Anterior manual maximum and manual maximum side-to-side differences were calculated. An arthrometric failure was defined as a side-to-side difference >5 mm. Results were stratified into ≤3 mm, 3 to 5 mm, and ≥5 mm.

Questionnaire

A detailed questionnaire was developed that included the 2000 IKDC questionnaire,¹⁴ KOOS,¹³ Lysholm,¹⁷ Tegner,¹⁶ SF-12,¹⁸ and Noyes Cincinnati rating scales.¹⁵ The detailed questionnaire allowed us to develop a computer program that calculated the scores based on the questions that were asked and which ones fit into each scoring scale. The questionnaire also included a visual analog scale to assess pain and satisfaction level. The questionnaire was completed by the patients to eliminate interviewer bias. Subjective patient satisfaction was stratified by patients grading their satisfaction level as completely satisfied, mostly satisfied, somewhat satisfied, or dissatisfied.

Rehabilitation

Postoperatively, patients were seen in physical therapy where they underwent gait training, straight leg raising, prone heel hangs, and range-of-motion exercises. Full weight bearing was permitted immediately after surgery. A hinged knee brace locked in full extension was used postoperatively until the patient showed good quadriceps control. Patients were allowed to unlock or remove the brace for range-of-motion exercises. Patient comfort was used as a criterion for discontinuation of crutches, which usually occurred by 1 week after surgery. A formal supervised rehabilitation program was prescribed using a standard protocol so that patients could have their postoperative rehabilitation at outside facilities. This program was initiated within the first postoperative week. In general, bicycling was allowed by 2 weeks, use of stair climbing machines was permitted at 4 to 6 weeks, straight-ahead jogging was allowed at 12 to 16 weeks, and gradual return to sports was allowed between 4 and 6 months postoperatively if rehabilitation criteria were met. This rehabilitation protocol was identical to our primary patellar tendon autograft rehabilitation protocol. A custom ACL orthosis was used for sports from 6 months to 1 year after surgery.

Data Acquisition and Analysis

To eliminate surgeon bias, review of the chart and recording of the data were performed independent of the treating surgeons by the sports medicine fellow

TABLE 1. Chondromalacia Assessment by Compartment Involved and Severity

	Grade				
	0 (n/%)	1 (n/%)	2 (n/%)	3 (n/%)	4 (n/%)
Medial femoral condyle	20/63	4/13	2/6	5/16	0
Medial tibial condyle	26/81	3/9	1/3	0	0
Lateral femoral condyle	26/81	1/3	1/3	4/13	0
Lateral tibial condyle	24/75	7/22	0	8/25	0
Patellofemoral condyle	21/66	0	3/9	0	0

(J.F.) and orthopaedic resident (M.P.). Preoperative, intraoperative, and postoperative data were obtained to supplement the follow-up evaluation. All data were recorded on scannable Teleform sheets so that the data could be automatically input into a computer program (Cardiff Software, San Diego, CA). Descriptive statistics, analysis of variance testing, χ -square analysis, and Friedman tests were employed where applicable. Statistical analysis was performed using the SPSS software package (SPSS, Chicago, IL). Statistical consultation was obtained through the Department of Biostatistics. Statistical significance was established at $P < .05$ and $P < .01$.

RESULTS

The mean interval from the initial injury to index reconstruction could not be reliably determined because we did not have access to many of the medical records from the initial treating physicians. Of note is that only 2 patients underwent their initial reconstruction by the senior surgeons. The mean interval from the initial ACL reconstruction to revision ACL reconstruction was 50 months (range, 9 to 101 months). The mean interval from revision surgery to follow-up was 4.8 years (range, 2.1 to 12.1 years; SD, 29.3). The average age of our patients at time of revision reconstruction was 28 years (range, 16 to 57 years; SD, 8). There were 14 male and 18 female patients and there were 20 right knees and 12 left knees reconstructed. The mean number of surgeries before the reconstruction was 2.8 (range, 2 to 5). Five patients had previously undergone a revision ACL reconstruction.

Associated Procedures and Surgical Findings

None of the patients had a posterolateral corner reconstruction at the time of our revision surgery or in the follow-up period. Chondromalacia of varying severity was observed in 70% (23 patients) in at least 1 of the 3 articular compartments (see Table 1 for compartment stratification). There was no statistical sig-

nificance when comparing those with chondromalacia and failure of the revision procedure. Fifty percent (16 patients) had undergone previous meniscal surgery on either the lateral and or medial meniscus. There was no statistical significance when assessing a relationship between previous meniscal surgery and subsequent revision failure.

Physical Examination

On preoperative Lachman testing, there were 3 patients with grade 1, 16 with grade 2, and 13 with grade 3 results. At revision follow-up, 18 patients (56%) had normal Lachman test results, 10 patients (31%) had a grade 1 Lachman with a firm endpoint, and 4 patients (13%) had grade 2 Lachman results (Fig 2). A significant reduction in postrevision Lachman grades was observed.

Preoperatively, 8 patients had grade 1 pivot-shift test results, 16 had grade 2, and 8 had grade 3. Postoperatively, 23 patients (71%) had negative pivot-shift results, 8 patients (25%) had grade 1, and 1 patient (3%) had grade 2. No patients had a grade 3 pivot-shift at follow-up (Fig 3). The reduction in the pivot-shift grades was statistically significant.

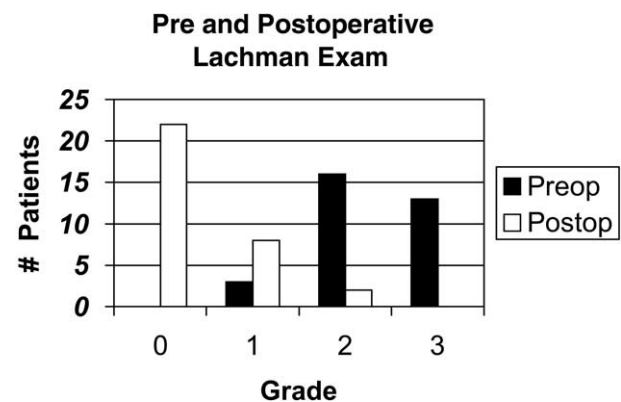


FIGURE 2. A statistically significant reduction in the postrevision Lachman grade is shown.

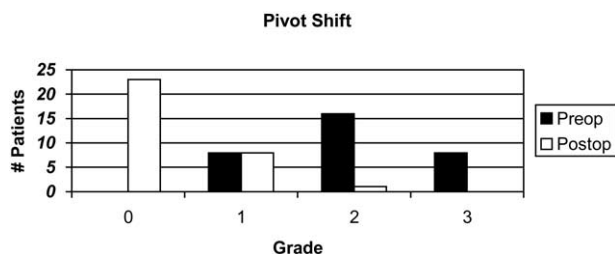


FIGURE 3. A significant reduction in the magnitude of the pivot-shift grade was observed after revision.

Postoperatively, the range of motion as measured by goniometer, was 2° of hyperextension (range, 11° of hyperextension to neutral; SD, 3) to a mean of 134° of flexion (range, 115° to 152°; SD, 8.23). Only 1 patient (3%) had a measured thigh girth atrophy of more than 1 cm when compared with the contralateral limb. The mean postoperative heel height difference in extension was 0.49 cm (range, 0 to 4.0 cm; SD, 0.83). The mean postoperative heel height difference in flexion was 1 cm (range, 0 to 12 cm; SD, 2.6).

Radiographic Results

Radiographs were obtained for 31 patients (97%) (Fig 4). The grading was based on the IKDC scoring system outlined in the Methods section. The medial compartment was most commonly affected, with degenerative changes present 47% of the time.

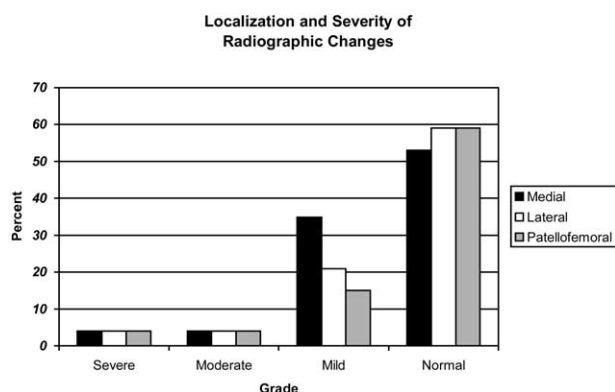


FIGURE 4. The IKDC Rating Scale: The medial compartment was normal in 17 patients (53%), mild medial compartment changes were present in 12 patients (38%), moderate changes in 1 patient (3%), and severe changes present in 1 (3%). In the lateral compartment, 22 patients (67%) had normal radiographs, 8 patients (26%) had mild changes, 1 patient (3%) had moderate changes, and none had severe changes. The patellofemoral articulation was normal in 20 patients (68%), mild changes were present in 8 patients (26%), moderate changes in 1 (3%), and severe changes present in 1 (3%).

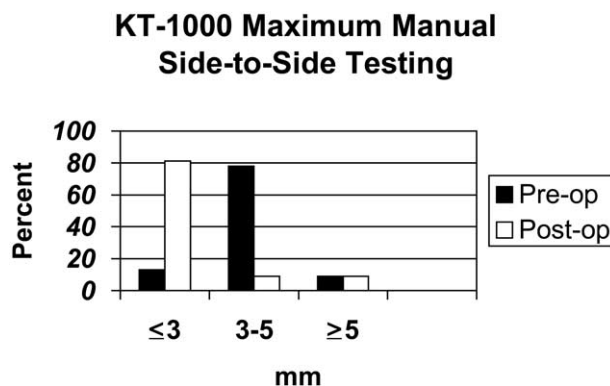


FIGURE 5. A significant reduction in the maximum manual side-to-side differences was observed after revision.

Functional Examination

The functional parameters measured included a timed single-leg 6-meter hop, a single-leg hop for distance, and a vertical jump. The single-leg hop for the affected knee was 96% of the nonaffected (range, 78% to 107%; SD, 7.7). The timed hop for the affected knee was 102% of the nonaffected knee (range, 81% to 138%; SD, 15). The mean difference for the vertical jump was 98% of the nonaffected knee (range, 35% to 232%; SD, 33.2). The small mean deficits were affected by wide ranges and standard deviations. For the 3 functional tests, 88%, 85%, and 66% of patients, respectively, had less than 10% side-to-side deficits. Ten of 31 patients (32%) tested better on the affected knee than on the contralateral knee on the timed single-leg hop, single-leg hop for distance, and on the vertical jump test. They were not the same 10 patients and they did not have pathology in the contralateral extremity.

Arthrometric Examination

Preoperative: KT-1000 arthrometric testing was recorded on all patients. The mean manual maximum translation was 14 mm (range, 8 to 21 mm; SD, 3.8) for the affected knee and the mean manual maximum translation was 6.5 mm (range, 2.5 to 13 mm; SD, 2.3) for the unaffected knee. These differences were significant ($P = .001$). Four patients (13%) had side-to-side differences ≤3 mm, 25 patients (78%) had differences between 3 and 5 mm, and 3 patients (9%) had differences ≥5 mm (Fig 5).

Postoperative: KT-1000 arthrometric testing was performed on all patients postoperatively. The mean manual maximum translation was 9.4 mm (range, 6 to 18 mm; SD, 2.9) for the affected knee and the mean manual maximum translation was 7.8 mm (range, 5 to 10 mm; SD, 1.4) for the unaffected knee. KT-1000

TABLE 2. Knee Scoring Scales

Scale	Mean	Range	Standard Deviation
IKDC	71	23-97	22
KOOS pain	84	36-100	18
KOOS symptom	77	25-100	21
KOOS ADL	91	50-100	14
Tegner (before any surgery)	8.4	2-10	2.1
Tegner (before revision)	5.0	0-10	3.3
Tegner (most recent follow-up)	6.3	0-10	2.6
Lysholm	75	30-100	22
Noyes sports function	72	0-100	26
Noyes functional ADL	30	17-40	30
Modified Cincinnati	7.2	2-10	2.2
SF-12 mental	55	27-66	8
SF-12 physical	48	20-59	11
Visual analog scale	2.9	0-9	2.5

translations were significantly reduced ($P = .001$) compared with their preoperative status. The mean side-to-side difference was 1.9 mm (range, -1 to 8 mm; SD, 2.4). Twenty-seven patients (84%) had side-to-side differences ≤ 3 mm, 3 patients (9%) between 3 and 5 mm, and 2 patients (6%) ≥ 5 mm (Fig 5).

Rating Scales

For a complete list see Table 2. The postoperative IKDC mean score was 71 points (range, 23-97; SD, 22). The postrevision Modified Cincinnati mean score was 7.23 points (range, 2-10; SD, 2.2). The Noyes sports activity score before index ACL reconstruction had a mean of 87 points (range, 20-100; SD, 18). The mean Noyes sports activity score before revision was 55 points (range, 0-100; SD, 34). The mean current Noyes sports activity score was 70 points (range, 0-100; SD, 26). The SF-12 results revealed that the physical component mean score was 48 points (range, 20-59; SD, 11) and that the mental component mean score was 55 points (range, 27-66; SD, 8). A 10-point visual analog scale was used to assess the present level of pain with 0 equal to no pain and 10 equal to the worst pain imaginable. The average postoperative pain score was 2.9 points (range, 0-9; SD, 2.5).

Subjective Results

Twenty-eight of the 32 patients (87%) were completely or mostly satisfied with the surgical procedure. Fifty percent of the patients were completely satisfied with their result, 3 patients (9%) were somewhat satisfied, and 1 patient (3%) was dissatisfied. Nineteen percent of the patients reported pain with stair climb-

ing as moderate, severe, or extreme, and 47% reported difficulty kneeling (Fig 6).

Rate of Failure

Failure was defined as the presence of a pivot-shift and/or a KT-1000 manual maximum test result of greater than 5 mm of side-to-side difference. Eight patients had a grade 1 pivot-shift test result and 1 had a grade 2. Five patients had a KT-1000 greater than 3 mm and, in this subgroup, each had a grade 1 or higher pivot-shift. This resulted in 9 of 32 revision ACL reconstructions (28%) failing according to our clinical criteria. If, however, one defined an objective failure as a 2+ or 3+ pivot-shift and/or a manual maximum difference greater than 5 mm on KT-1000 testing, then our failure rate was 6%.

Complications

There were no infections, no additional surgeries for arthrofibrosis, and no removal of hardware performed. There was no evidence of graft rejection or clinical evidence of disease transmission (no blood testing was performed) at the time of follow-up. Two patients had a small effusion at the follow-up examination.

DISCUSSION

The success of revision ACL reconstruction has been not comparable to that of primary ACL reconstruction.^{8,22,23} Our results further support this finding. When compared with the results of primary ACL reconstruction by the senior author (B.R.B.)¹¹ using a similar technique and rehabilitation program, we found distinct differences. For primary reconstruction, the patients' rating of success was 92% mostly or completely satisfied, compared with 87% for the revision patients. The positive pivot-shift (grade 1 and higher) was present in 9% of patients in the primary

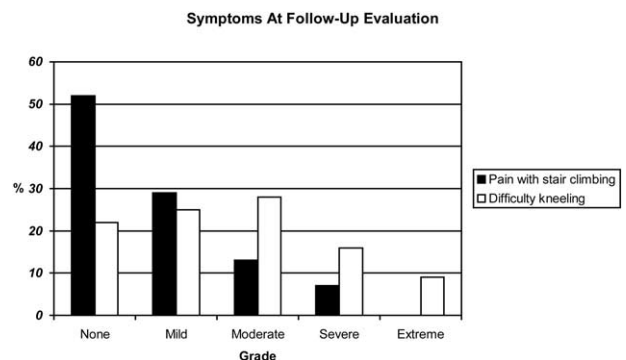


FIGURE 6. Anterior knee pain as defined by stair climbing symptoms or kneeling problems is stratified.

setting compared with 28% in our revision group. In the primary group, 74% had a normal Lachman test versus 56% in the revision group.

The less favorable results can be attributed to many factors including number of previous surgeries, meniscal damage, and chondral abnormalities to the knee. Seventy percent of our patients had articular cartilage damage at the time of surgery and 50% had previously had a meniscal procedure. Noyes and Barber-Westin^{8,24} observed that 56% of patients had abnormal articular cartilage at the time of revision. To further support the assertion that the higher failure rate was not due to the allograft, there is an ongoing study at the same institute with similar study design evaluating primary ACL reconstruction with a nonirradiated allograft patellar tendon. This study has found 57 of 60 patients with a negative pivot-shift result.²⁵

There have been few clinical studies evaluating revision ACL surgery. Noyes and Barber-Westin⁸ evaluated 66 of their revision allograft ACL cases. They used a combination of irradiated ($n = 40$) and nonirradiated ($n = 26$) allografts. Additionally, 32 patients (48%) had a ligament-augmentation device implanted. Nine patients (14%) also had an extra-articular iliotibial-band procedure. This resulted in a heterogeneous group of revision ACL reconstructions. There were 57 patients (88%) with a postoperative pivot-shift result of grade 0 or 1 (this was not stratified into grade 0 [negative] and grade 1), 5 (8%) with a grade 2, and 3 (5%) with a grade 3. Noyes and Barber-Westin's definition of failure was based on KT-1000 test results. A failure had greater than 5.5 mm of difference between the involved and uninvolved knee, or had less than 50% improvement, or less than 3 mm side-to-side improvement from the preoperative level. Their failure rate was reported to be 33%. When evaluating their study more closely and evaluating a subgroup that most closely represented our population in which they did not have a ligament-augmentation device, advance of the posterolateral complex, meniscal allograft, or extra-articular iliotibial-band procedure ($n = 16$), 8 patients had a grade 0 pivot-shift and 8 patients had a grade 1, 2, or 3 pivot-shift. Of note, for their entire series, Noyes and Barber-Westin reported a 0/1+ pivot-shift incidence after revision of 87%, which was identical to our findings.

Noyes and Barber-Westin²⁴ also reported on 54 patients who had a revision ACL reconstruction with a patellar tendon autograft. The failure rate, which was determined in a fashion similar to their revision allograft report, was 24%. Of these 13 patients, 6 had a reharvested patellar tendon autograft.

The Pittsburgh series of Johnson et al.²² used irradiated fresh-frozen allografts. Nine of 25 patients (36%)

had a KT-1000 maximum manual side-to-side difference of greater than 5.5 mm. Eighty percent had a grade 0 or 1 Lachman result and 20% had a grade 2 Lachman result; 76% of patients were satisfied with their result.

Uribe et al.²³ reported on 54 patients who underwent a revision ACL reconstruction with a variety of grafts including ipsilateral patellar tendon autograft, contralateral patellar tendon autograft, allograft patellar tendon, and hamstring autograft. All of their patients had an improvement in their objective stability. However, only 54% of patients returned to their pre-ACL-injury activity level.

When we assessed our failure rate, it was 28% (9 of 32 patients). This failure rate is based on stringent criteria defined as the presence of a positive pivot-shift (grades 1, 2 or 3), and/or a KT-1000 result of greater than 5 mm of side-to-side difference. If we considered failure as those patients with greater than 5 mm of side-to-side difference with maximum manual KT-1000 testing and those with grade 2 or higher pivot-shift, our failure rate would be 2 of 32 (6%). In all of the published articles on revision ACL reconstruction, the criteria for failure, if defined, are variable.

The potential weaknesses of this study are that it is retrospective and nonrandomized. We did not have prospective data for the various scoring scales. Graft selection and the effects of rapid rehabilitation were not randomized (selection bias). Although we did not have a control group, we have several retrospective studies of patellar tendon autograft cohorts from our institution that provided a historical benchmark.^{10-12,26} The use of the patellar tendon allograft may reflect a surgeon's bias in terms of graft selection. Several questions arise from this study that remain unanswered. Could our results have been improved with the use of a different graft source (e.g., contralateral patellar tendon, ipsilateral hamstring, ipsilateral quadriceps tendon, or allograft Achilles tendon)? If we had used a more conservative rehabilitation protocol, selectively used meniscal allografts, performed staged bone grafting of tunnels, or used additional graft fixation augmentation (i.e., screw and post), would this have eliminated a few of the graft attenuations? Because our data are similar to the few reported studies, perhaps we cannot approach the stabilization success of index reconstructions, which have stability failure rates in the 8% to 20% range. Of interest is the observation that 87% of our patients were subjectively satisfied, 87% had a 0/1+ pivot-shift and 84% had a KT-1000 side-to-side difference of ≤ 3 mm.

Conversely, the study has many strengths. A single graft source (nonirradiated patellar tendon allograft) was used for a single specific index graft source failure (patellar tendon autograft). Grafts were used from one tissue

bank. Meniscal allograft surgery, posterolateral reconstructions, high tibial osteotomies, and contralateral ACL deficiency or reconstruction patients were eliminated by exclusionary criteria. Multiple validated outcome scores were used including the IKDC, KOOS, and SF-12. Postoperative KT-1000 testing and functional testing were performed by one experienced individual to prevent detection bias. The study was conducted at a center where numerous ACL clinical studies have been performed.^{10-12,26,27} An independent patient evaluation was performed, although one might argue that a sports medicine fellow may introduce a component of performance bias. The surgeries were conducted by 2 experienced knee ligament surgeons who have performed over 2,000 primary ACL reconstructions, thus reflecting considerable clinical experience.

This study contributes to the current body of literature on revision ACL surgery. These challenging cases present a variety of difficult technical decisions. Preoperatively, one must exclude associated pathologies and mechanical malalignments, and determine whether a meniscal allograft or substitute is warranted. Preoperative imaging may determine whether single or staged tunnel grafting is necessary, whether bone appears osteopenic, whether hardware must be removed or can be bypassed, and generally whether bone tunnels are placed anatomically or nonanatomically, whether they are overlapped or not overlapped, and whether they are expanded or not expanded. These technical factors, our observed results, the high incidence of chondral abnormalities and previous meniscal surgery, as well as the observation that only 50% of our patients were completely satisfied (37% mostly satisfied) underscores, in our opinion, that these procedures should be viewed as salvage procedures. We believe it is critical to carefully apprise patients of these issues before embarking on a revision procedure so that the patient does not have unrealistic expectations.

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