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Fifteen-Year Outcome of Endoscopic Anterior Cruciate Ligament Reconstruction With Patellar Tendon Autograft for "Isolated" Anterior Cruciate Ligament Tear

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Background: Few studies report the long-term results of anterior cruciate ligament rupture and single-incision endoscopic reconstructive surgery. Outcomes are often clouded by concomitant meniscal, chondral, or ligament injuries.

Purpose: To determine the 15-year outcomes of anterior cruciate ligament ruptures treated with endoscopic anterior cruciate ligament reconstruction using middle-third patellar tendon autograft.

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

Methods: Between January 1993 and April 1994, 333 consecutive patients underwent anterior cruciate ligament reconstruction. Patients with associated ligamentous injury requiring surgery, previous meniscectomy, or meniscal injury requiring more than one-third meniscectomy; chondral injury diagnosed at arthroscopy; and an abnormal contralateral knee were excluded. Ninety patients met the inclusion criteria. Outcomes included range of motion, Lachman and pivot-shift tests, instrumented ligament testing, single-legged hop test, Lysholm Knee Score, the International Knee Documentation Committee evaluation, and radiographic assessment.

Results: Thirty percent of patients had further anterior cruciate ligament injury. Twenty-four percent of patients (n = 22) sustained contralateral anterior cruciate ligament ruptures, and 8% (n = 7) ruptured the graft (P = .009). Graft rupture was associated with a graft inclination angle $<17°$ (P = .02). Contralateral anterior cruciate ligament rupture was associated with age <18 years at time of primary injury (P = .001). All patients had normal or nearly normal (International Knee Documentation Committee evaluation) Lachman and instrumented testing, and 91% had a negative pivot-shift result. Seventy percent of patients had kneeling pain. Median subjective International Knee Documentation Committee evaluation was 91 of 100. Fifty-one percent of patients had radiographic evidence of osteoarthritis (41% grade B; 10% grade C).

Conclusion: Good results are maintained at 15 years after surgery with respect to ligamentous stability, subjective outcomes, and range of motion. Kneeling pain remains a significant problem. Concern remains regarding the incidence of further anterior cruciate ligament injury and the increasing number of patients with radiographic and clinical signs of osteoarthritis despite surgical stabilization.

Keywords: knee; anterior cruciate ligament (ACL); reconstruction; long-term outcome

Anterior cruciate ligament rupture can be a devastating injury. Not only does it negatively affect quality of life, but it has also been shown to affect the long-term function of the knee.[7,38,39] Instability after ACL injury may lead to recurrent episodes of giving way, an increased risk of meniscal injury, and premature osteoarthritis (OA).[6,10,13,25,38,49]

Treatment options for ACL rupture include nonoperative, direct repair, and extra-articular and intra-articular procedures using open, arthroscopically assisted, or arthroscopic techniques.[5,11,13,16,25,28,34] With modern techniques, endoscopic ACL reconstruction is becoming the standard of care.[9] Controversy still remains regarding graft selection and graft fixation. Whichever procedure or technique is used, the goals remain the same—in the short term, secure,

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anatomical graft placement allowing immediate accelerated rehabilitation and a stable knee that permits return to sports; in the long term, prevention of further intra-articular injury and OA.[25]

There are few studies reporting the long-term results of ACL rupture and single-incision endoscopic reconstructive surgery.[23,28,46,48] In addition, assessment of outcome after ACL reconstruction may be affected by associated injuries to the menisci, chondral surfaces, and collateral ligaments.[6,12,27,36,50] These injuries may be sustained at the time of the initial injury or during subsequent episodes of instability. In an effort to determine the true outcome of ACL reconstruction, we have eliminated almost all of these confounding factors through careful patient selection. We have previously reported the outcomes of this cohort of patients at 2 and 5 years after surgery.[15,57] In addition, we have compared this group of patients to an essentially isolated ACL rupture group treated with endoscopic reconstruction using 4-strand hamstring tendon autograft at 2, 5, 7, and 10 years after surgery.[14,41,42,44] The purpose of this study is to determine the 15-year outcomes of this essentially isolated ACL rupture group treated with endoscopic reconstruction using middle-third patellar tendon autograft.

METHODS

Patient Selection

Between January 1993 and April 1994, 333 consecutive patients underwent ACL reconstruction at one institution. All patients had an ACL rupture diagnosed on clinical examination and confirmed at arthroscopy and wished to return to sports involving pivoting, cutting, or sidestepping, or they had repeated episodes of instability despite nonoperative treatment and appropriate rehabilitation. Exclusion criteria included any associated ligament injury requiring surgery, evidence of chondral damage or degeneration, previous meniscectomy or meniscal injury requiring more than one-third meniscectomy at the time of reconstruction, abnormal radiograph results, abnormal contralateral knee, patients seeking compensation for their injuries, and patients who did not wish to participate in a research study. Therefore, the study group consisted of 90 patients with an essentially isolated ACL injury.

Surgical Technique

The operative technique was standardized in all patients and has previously been described in detail.[57] The senior author performed all procedures. Examination under anesthesia confirmed anterolateral rotatory instability and positive Lachman testing results in all patients. With the patient under general anesthesia, a single dose of intravenous cephalosporin was administered. The limb was exsanguinated using an Esmarch bandage, and a high thigh tourniquet was used. Diagnostic arthroscopy was performed first, using high anterolateral and low anteromedial portals. Suturing of appropriate meniscal lesions was carried out using an inside-out technique. A central-third patellar tendon autograft was harvested through two 2-cm longitudinal incisions at the distal aspect of the patella and just medial to the tibial tubercle. The femoral tunnel was positioned 5 mm anterior to the posterior capsule insertion and was drilled through the low anteromedial portal with the knee in maximum flexion. The tibial tunnel was positioned on the line between the anterior tibial spine and the anterior horn of the lateral meniscus, immediately anterior to the posterior cruciate ligament. The graft was fixed on the femoral side with a 7×25 mm round-headed cannulated interference screw (Smith and Nephew Acufex, Mansfield, Massachusetts) through the low anteromedial portal and a 7×25 mm round-headed cannulated interference screw on the tibial side. Full hyperextension, and stable Lachman and anterior drawer tests were achieved in all patients.

Postoperative Protocol

Patients were admitted to the hospital for a median of 2 nights (range, 1-5 nights). Immediate weightbearing with the aid of crutches was encouraged. The median time of crutch use was 10 days (range, 2-21 days). An accelerated rehabilitation program commenced on postoperative day 1 to reduce pain and swelling with the goal of achieving full extension by 6 weeks. The rehabilitation program included closed-chain exercises with an emphasis on proprioceptive training. At 6 weeks, patients began jogging in straight lines. From 12 weeks, general strengthening exercises were continued with agility work and sporting activities encouraged. Return to competitive sport involving jumping, pivoting, or sidestepping was not permitted until 6 to 9 months after surgery.

Clinical Assessment

Assessments were performed by independent physical therapists or researchers with extensive experience in knee assessment. Clinical assessment included range of motion (ROM), ligament stability, instrumented knee testing using the KT-1000 arthrometer (MEDmetric Corp, San Diego, California) at manual maximum test, and the International Knee Documentation Committee (IKDC) Knee Ligament Evaluation Form.[4,8] Ligament stability was measured by the Lachman and pivot-shift tests.[32] The Lachman was graded as 0 (negative), 1 (1- to 5-mm laxity), 2 (6- to 10-mm laxity), or 3 (>10-mm laxity) and the pivot-shift test as 0 (negative), 1 (glide), 2 (clunk), or 3 (gross). Subjective assessment included the Lysholm knee score[4,8] and IKDC subjective knee function score. The single-legged hop test was used for functional assessment. Evaluation was conducted preoperatively, annually for 5 years, then at 7, 10, and 15 years after surgery.

Radiographic Assessment

Radiographic examination was performed using bilateral weightbearing 35° to 45° posteroanterior, anteroposterior,

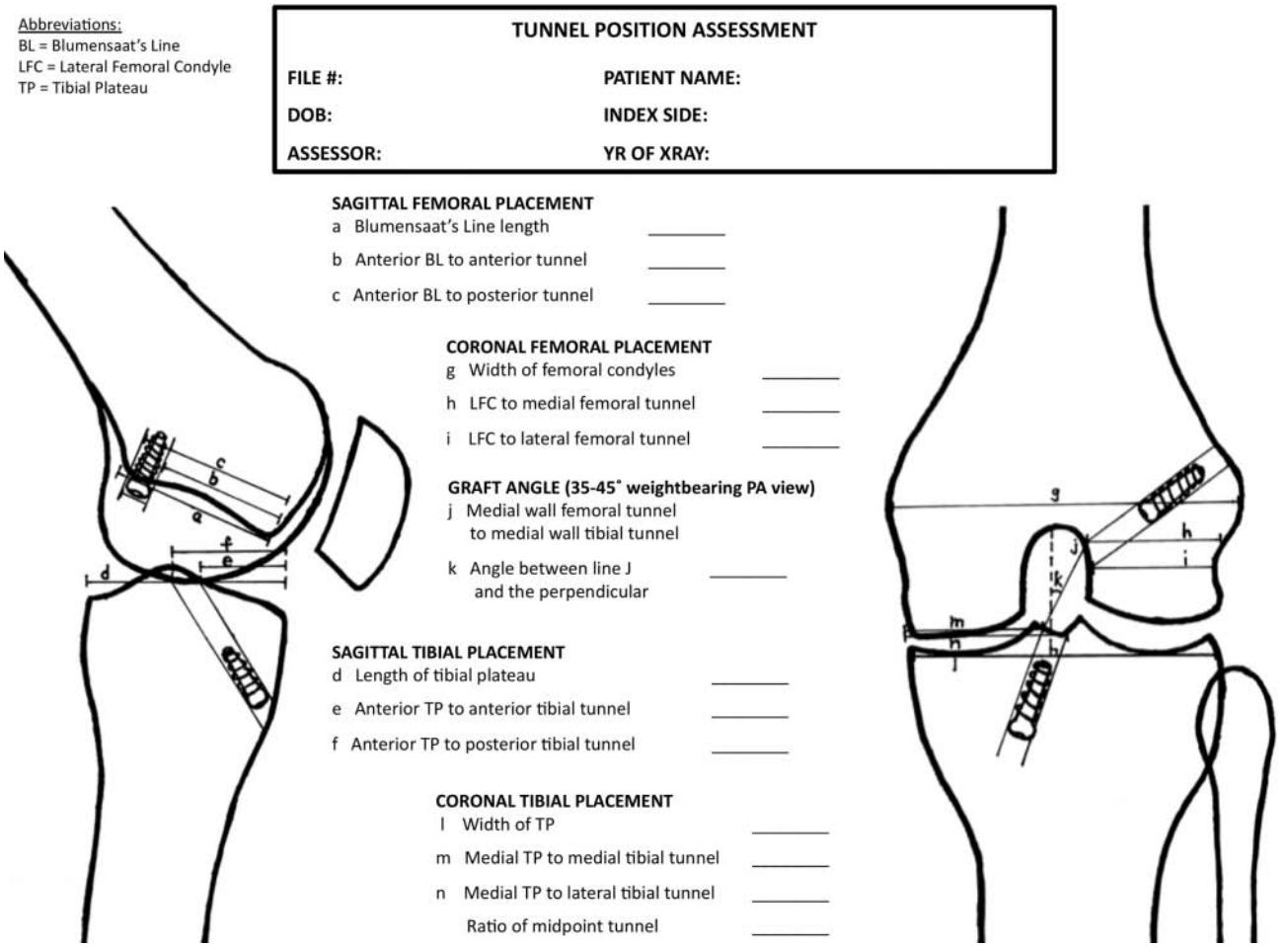

Figure 1. Anterior cruciate ligament tunnel position assessment form.

lateral, and patellar skyline views. Radiographs were classified according to the IKDC guidelines as follows: A, normal; B, minimal changes and barely detectable joint space narrowing; C, moderate changes and joint space narrowing of up to 50%; and D, severe changes and more than 50% joint space narrowing. This grading has been shown to be both reliable and reproducible with longitudinal data.[26] An experienced musculoskeletal radiologist graded all radiographs.

Tunnel position was assessed in the sagittal and coronal planes, and the graft inclination angle was measured using a method that has previously been described in detail[43] (Figure 1).

Statistical Analysis

All data were assumed to be nonparametric. The Wilcoxon signed ranked test was used to assess change over time. Comparisons between subgroups were performed with the Mann-Whitney *U* test. Logistic regression analysis was used to assess the relative contribution of selected variables on dichotomous outcomes. Statistical significance was set at $P = .05$. SPSS 11.0 for Windows (SPSS Science Inc, Chicago, Illinois) was used for all the above statistical analysis.

RESULTS

Study Group

Ninety patients met the inclusion criteria. There were 46 male (51%) and 44 female (49%) participants. The left side was involved in 35 patients (39%) and the right in 55 (61%). Mean age at the time of reconstruction was 25 years (range, 15-42 years). Reconstruction was performed within 3 weeks of injury in 3 patients (3%), between 3 and 12 weeks in 64 (71%), and after 12 weeks in 23 (26%). All patients had a preoperative Lachman test of grade 1 or 2, and 94% had a positive pivot-shift result; the remainder had locked knees, and a pivot-shift test could not be performed. Three patients (3%) with an acute injury had grade 2 laxity of the medial collateral ligament;

TABLE 1
State of the 90 Menisci at the Time of ACL Reconstruction

Meniscus	Medial	Lateral
Intact	73	56
Healed	6	7
Untreated[a]	6	19
Sutured[b]	5	2
Partly excised (1/3)	0	6

[a]Untreated were small tears that were stable to probing.
[b]Sutured were longitudinal red-on-red or red-on-white tears that required stabilization.

all were successfully treated by a preoperative hinged ROM brace with an extension block at 30° for 6 weeks.

Operative Findings

Seventy-seven patients (86%) had intact menisci at the time of ACL reconstruction. Seven (8%) required meniscal suture at the time of surgery, and 6 (7%) required excision of less than one third of the meniscus. The state of the menisci at the time of surgery in this group is shown in Table 1.

Further ACL Injury

Overall, 30% of patients sustained a subsequent ACL injury, either ACL graft rupture or contralateral ACL (CACL) injury, at 15 years. Seven patients (8%) ruptured the ACL graft at a median time of 63 months (range, 12-124 months) postoperatively. These patients subsequently underwent revision ACL reconstruction and were then excluded from the study. All graft ruptures occurred in males. The incidence of ACL graft rupture in males was 15% (7/48 patients) compared with 0% incidence in females (P = .007). Regression analysis showed that patients with a coronal graft inclination angle of <17° had a 10 times greater odds of ACL graft rupture (odds ratio [OR] 95% confidence interval [CI], 1.5-70.1; P = .02). Gender was not a significant predictor of ACL graft rupture (OR, 0.1; P = .81). Age younger than 18 years was also not a predictor of ACL graft rupture (OR, 1.4; P = .81)

Twenty-two patients (24%) had a CACL rupture at a median of 68 months postoperatively (range, 22-165 months). These patients were excluded from subsequent instrumented testing and single-legged hop test data. All CACL ruptures underwent ACL reconstruction. There was no significant difference (P = .71) in the incidence of CACL rupture between males (26%) and females (23%). There were significantly more CACL ruptures than graft ruptures over the 15-year follow-up period (P = .009) (Figure 2). Regression analysis showed that patients younger than 18 years had a 7 times greater odds of CACL rupture than did those older than 18 years (95% CI, 2.3-22.8; P = .001). Gender was not a predictor of CACL rupture

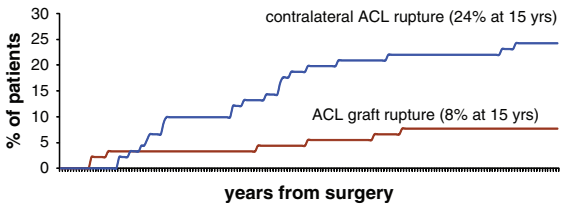

Figure 2. Graft versus contralateral ACL ruptures.

TABLE 2
Further Surgery

No. of Patients	Surgery	Months Postoperative
1	Arthroscopic debridement of cyclops lesion	6
1	Arthroscopic arthrolysis	3
1	Excision of patellar tendon cyst	24
1	Arthroscopic chondroplasty	21
1	Removal of tibial screw	87
4	Partial medial meniscectomy	18, 62, 69, 99
2	Partial lateral meniscectomy	14, 99
7	Revision ACL reconstruction[a]	12-124
22	Contralateral ACL reconstruction[a]	22-165

[a]Two patients sustained both ACL graft rupture and contralateral ACL rupture.

(OR, 1.1; 95% CI, 0.3-3.0; P = .92). Five patients (6%) sustained multiple (>2) further ACL injuries.

Complications

There was 1 superficial wound infection in the proximal wound of the graft harvest that was treated successfully with oral antibiotics. Two patients developed patellar tendinitis at 9 and 23 months postoperatively and were treated successfully with analgesia and physical therapy. Eleven patients had further surgery, as shown in Table 2. In total, there were 6 meniscectomies performed after ACL reconstruction over the 15-year period. All 6 meniscal tears occurred during sporting activities. One patient died of unrelated causes at 9 years postoperatively.

Follow-Up

Mean follow-up time was 184 months (range, 169-199 months). Patients who sustained rupture of the ACL graft were excluded from the study after rerupture, as was the patient who died. Reviews were performed on 72 of a possible 82 patients (88%) at 15 years. Fifty-eight patients returned for clinical assessment. The remaining 14 patients completed self-reported assessments but were unable to return for clinical assessment because of geographical reasons.

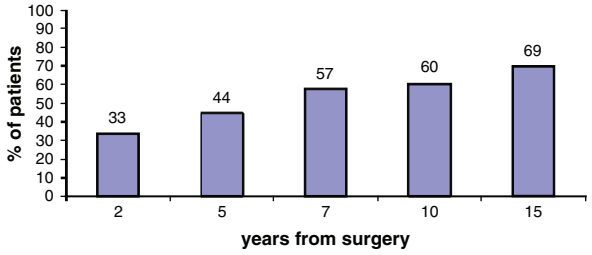

Figure 3. Percentage of patients with kneeling pain or difficulty at each review.

Self-reported Assessment

Lysholm Knee Score. The Lysholm knee score is designed to evaluate specific symptoms relating to knee function (limp, need for support, locking, instability, pain, swelling, and impairment of stair-climbing or squatting ability). The best score is 100.[4] Preoperative median Lysholm knee score was 64 (range, 6-97). At 15 years, the median Lysholm knee score was 95 (range, 39-100).

Subjective Knee Assessment (IKDC). Patients were asked to rate the function of their knees on a scale of 0 to 10, with 10 being normal, excellent function and 0 being the inability to perform any daily activities, prior to surgery and at 15 years after surgery. Median reported knee function before knee injury was 10 (range, 4-10). Median reported knee function at 15 years after surgery was 9.5 (range, 0-10). This difference was statistically significant (P = .001). Median subjective IKDC score at 15 years was 91 of a possible 100 (range, 34-100). Previous data were unavailable for this assessment as it was introduced at the 15-year review.

Activity. At 15 years after surgery, regular participation was 44% (n = 32) in very strenuous activities such as soccer and basketball, 18% (n = 13) in strenuous activities such as skiing or tennis, 24% (n = 17) in moderate activities such as running or jogging, and 14% (n = 10) in light activities such as walking. Fifty-nine percent (20/34) of males and 32% (12/38) of females reported that they regularly participated in very strenuous activities like basketball or soccer (P = .012).

Symptoms with Activity. At 15 years after surgery, very strenuous or strenuous activities could be performed without pain in 68% (n = 49) of patients, without swelling in 74% (n = 53) of patients, and without giving way in 81% (n = 58) of patients.

Kneeling Pain. The proportion of patients with kneeling pain or difficulty is reported in Figure 3. There was a significant increase in the incidence of kneeling pain between 2 and 15 years (P = .001).

Clinical Assessment

Effusion. At 15 years after surgery, 81% (n = 47) had no effusion, and 19% (n = 11) had a mild effusion.

Range of Motion. With patients having CACL ruptures and revision ACL reconstructions excluded from this data set, 43 patients were reviewed at 15 years. At 15 years after surgery, 79% of patients (n = 34) had <3° extension loss, and 21% (n = 9) had between 3° and 5° loss of extension. No patients had >5° loss of flexion at 15 years (Figure 4). The percentage of patients with extension loss significantly increased between 2 and 5 years (P = .002), but there was no significant change between 5 and 15 years (P = .37).

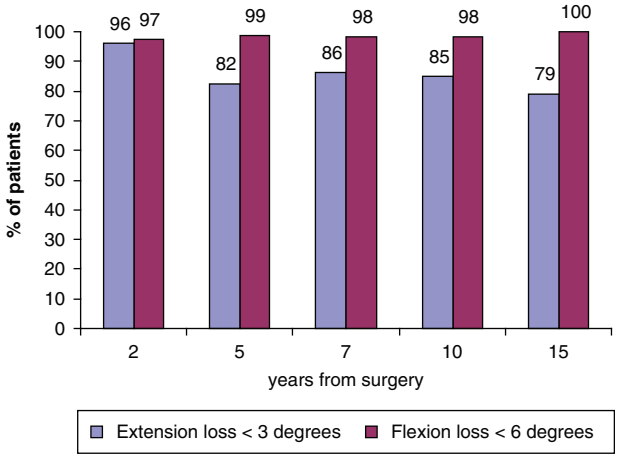

Figure 4. Range of motion: The percentage of patients with extension loss significantly increased between 2 and 5 years (P = .002), but there was no significant change between 5 and 15 years (P = .37). There was no significant change over time in flexion loss.

Single-Legged Hop Test. The single-legged hop test of knee function determines the percentage of the distance achieved by hopping on the involved limb compared with on the contralateral normal limb. With patients having CACL ruptures and revision ACL reconstructions excluded from this data set, 43 patients were reviewed at 15 years. Sixty-five percent of patients (n = 28) were able to hop >90% of the contralateral limb, and 35% (n = 15) were able to hop between 76% and 89% of the contralateral limb. There was a significant decrease in the proportion of patients able to hop >90% of the contralateral limb from 87% at 10 years to 65% at 15 years (P = .01).

Ligament Testing. Figure 5 demonstrates the percentage of patients with normal (0- to 2-mm laxity) or nearly normal Lachman test (3- to 5-mm laxity), pivot-shift test, and instrumented testing at 15 years. There were 7 grade 2 Lachman and pivot-shift tests found in the 7 patients who sustained an ACL graft rerupture. There was no significant difference between 2 and 15 years in the Lachman test (P = .13), pivot-shift test (P = .26), or instrumented testing (P = .28).

Overall IKDC Grading

Figure 6 shows the 15-year IKDC grade for the 3 subgroups of effusion, ROM, and ligament evaluation, as well as the overall IKDC grade. Overall IKDC score is a very conservative scale because the worst rating of any item in a given group determines the overall group rating.

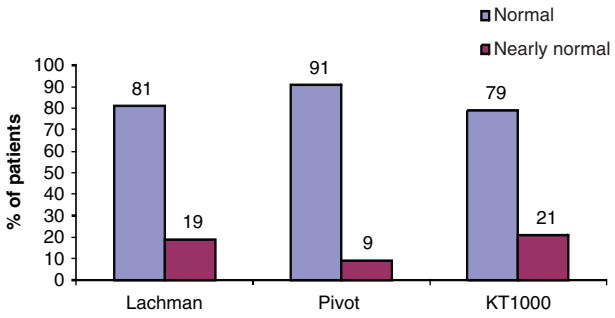

Figure 5. Percentage of patients with normal or nearly normal ligament examination at 15-year Lachman and pivot-shift testing.

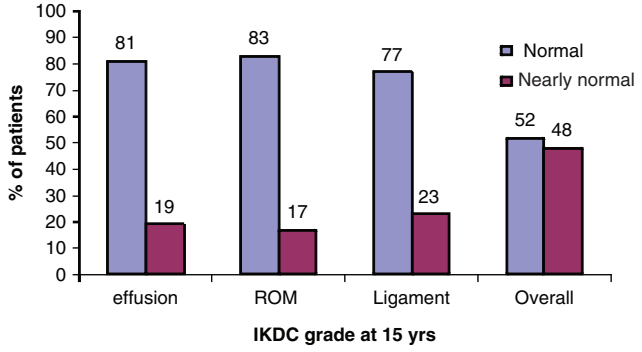

Figure 6. Fifteen-year International Knee Documentation Committee Knee Ligament Evaluation Form.

Therefore, only patients with an absolutely normal knee will be rated class A.[8]

Radiographic Assessment

Radiographs were reviewed in 59 patients. Any incomplete or inadequate radiographs were excluded. The compartment with the most degenerative changes determines the overall IKDC radiographic grade. Results are shown in Figure 7. Overall, 51% had evidence of OA at 15 years after surgery. Regression analysis showed that further surgery was the only predictor of OA (OR, 10.7; P = .03). Single-legged hop testing at 1 year, extension loss, and ACL laxity at 2 years were not statistically significant predictors of OA. At 15 years, the medial tibiofemoral joint showed no degenerative changes in 53% (n = 31), mild degenerative changes in 39% (n = 23), and moderate degenerative changes in 9% (n = 56). The lateral tibiofemoral joint showed no degenerative changes in 80% (n = 47), mild degenerative changes in 19% (n = 11), and moderate degenerative changes in 2% (n = 1). The patellofemoral joint showed no degenerative changes in 85% (n = 50), mild degenerative changes in 14% (n = 8), and moderate degenerative changes in 2% (n = 1).

Tunnel placement was assessed in 84 patients (93%). The femoral tunnel was located at a mean 85% (SD, 7%) posterior along Blumensaat's line, and the tibial tunnel was 40% (SD, 7%) posterior along the tibial plateau. In the coronal plane, the tibial tunnel was 45% (SD, 2%) along from the medial border of the tibial plateau. The mean coronal graft inclination was 19° (SD, 4°).

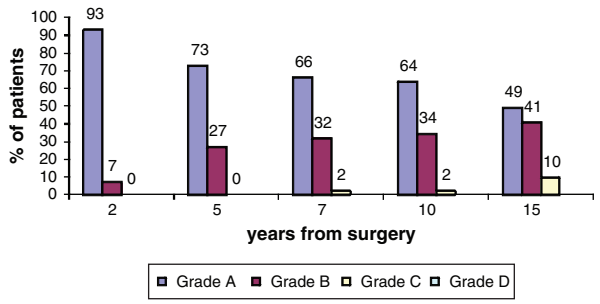

Figure 7. Overall International Knee Documentation Committee radiological grading.

The mean coronal graft inclination angle of patients who sustained an ACL graft rupture was 15.6° compared to 19.7° for those with intact ACL grafts at 15 years (P = .04). Regression analysis showed that coronal graft inclination angle of <17° was associated with a 10 times greater odds of ACL graft rupture (OR 95% CI, 1.5-70.1; P = .02). There were no other significant differences in the other measured tunnel placement parameters between patients with intact ACL grafts and those with ACL graft ruptures.

DISCUSSION

This study reports the 15-year outcomes of endoscopic ACL reconstruction using middle-third patellar tendon autograft. There are few studies reporting the long-term results of endoscopic ACL reconstruction.[23,28,46,48] When trying to establish the risk factors for meniscal injury and early arthritis, it is important to distinguish between the effects of recurrent instability due to ACL deficiency and the deterioration of the menisci and chondral surfaces injured at the time of ACL rupture.[6,12,27,36,50] Although we recognize that a truly "isolated" ACL rupture probably does not exist, we used very specific exclusion criteria in an attempt to produce a patient population with ACL rupture without major associated injuries, to more clearly determine the natural history of ACL reconstruction. On the basis of these strict inclusion criteria, the study population represented less than one third of the patients who underwent ACL reconstruction during the study period.

The benefits of ACL reconstruction are well established in the short term and midterm both clinically and subjectively.[22,27,31,36,39,41,53] The menisco-protective role of ACL reconstruction in restoring stability to the knee[10,48] was confirmed with only 6 meniscectomies performed in the 15 years after reconstruction. Ligamentous examination, in this group of patients with less than one-third meniscectomy and essentially isolated ACL injury, remained stable with no statistically significant differences over time,

showing that the graft does not elongate and that the meniscus is an important secondary knee stabilizer.[25,48,59] We had previously reported, at 5 years after surgery, a worrisome increase in fixed flexion deformity in this same group of 90 patients.[15] We have found that the extent of fixed flexion deformity did not increase with time, as all patients had <5° loss of ROM at 15 years. These results are consistent with the recent literature.[28,31]

Previous studies have determined that OA after ACL reconstruction increases with the presence of other intra-articular injuries including meniscal tears and chondral injuries.[6,12,13,19,27,34] We have shown that OA may develop in patients with no other intra-articular injuries. In this group of patients with essentially isolated ACL rupture 15 years after endoscopic reconstruction, 51% had radiographic evidence of OA. We found that radiographic evidence of OA was present in 27% of patients at the 5-year follow-up mark.[15] Over the subsequent 10 years, OA did progress in these patients, with 41% of patients showing grade B changes (small osteophytes, slight sclerosis or flattening of the femoral condyle, minimal joint space narrowing) that likely represent posttraumatic changes and 10% showing grade C changes (up to 50% joint space narrowing), which are almost certainly those developing posttraumatic OA from the ACL injury (Figure 7). Petersson et al[40] have shown that the incidence of radiographic OA in those with knee pain lasting more than 3 months is approximately 5% in those aged between 35 and 54 years. Regression analysis showed that further surgery was the only predictor for the development of OA in our series of patients. Gillquist and Messner[19] stated that about 70% of ACL-deficient knees will have radiological signs of arthrosis at 10 to 20 years after injury. We have shown that the incidence of radiographic OA is lower in patients treated with ACL reconstruction compared with previous reports of patients with nonoperative treatment of ACL deficiency.

It is concerning that 30% of patients sustained a subsequent ACL injury at 15 years (8% ACL graft rupture; 24% CACL rupture). Others have shown that ACL injury may be decreased with the implementation of a specific motor-retraining rehabilitation program.[37] If 1 in 3 patients will suffer a further ACL injury after reconstruction, the addition of these programs to the rehabilitation of ACL-reconstructed patients to reduce this risk is a worthwhile consideration. We have now integrated this into our rehabilitation protocol.

There was a 7 times greater odds of CACL rupture in patients younger than 18 years. This supports the findings of Shelbourne et al[51] who recently showed an increased risk of subsequent ACL injury to be significantly higher in patients younger than 18 years at 5 years after patellar tendon ACL reconstruction. This may be related to increased exposure to high-risk activities in younger subjects.

There were significantly more patients sustaining a native CACL rupture than an ACL graft rupture in this study (24% vs 8%). There are several possible reasons for this. First, the patient protects the reconstructed knee, placing the CACL at risk of rupture. Second, the CACL may be more susceptible to rupture because of genetic and/or biomechanical predisposition. Third, the reconstructed knee is more resilient than is the native ACL.

Our finding that 24% of patients had a CACL rupture at 15-year follow-up may seem higher than previously reported figures in the literature. However, these results have to be carefully examined. Wright et al and the MOON study group[58] reported a 3% incidence of both CACL and graft rupture at 2-year follow-up. When we critically analyze our results, at 2 years after surgery, our incidence of CACL and graft rupture is 2.2% and 3.3%, respectively, which is consistent with the rates reported by Wright et al. A closer examination of our patients sustaining CACL injuries during the 15-year follow-up period shows 2 peaks of CACL rupture. The first peak is between 22 and 39 months in which 9 patients had CACL ruptures, and the second peak is between 75 and 90 months in which 6 patients had CACL ruptures (Figure 2). Previous studies have reported that the risk factors for CACL rupture include returning to high-level activity, especially those requiring pivoting or jumping.[47,56] In the current study, 44% of our patients were participating in these "very strenuous" activities, even at 15 years after surgery. Furthermore, we have previously found that individuals who are young at the time of ACL reconstruction have a greater risk of a CACL injury during follow-up. Younger patients are more likely to return to a high level of activity than are older individuals with a first-time ACL injury, and they are expected to have a higher level of activity for a longer period of time. Also, a patient with a ruptured ACL is likely to have a higher risk of intrinsic factors making them more susceptible to further ACL injury.[42]

There was a 10 times greater odds of ACL graft rupture in patients with a graft inclination angle <17°. This suggests that vertical graft placement is an independent predictor of ACL graft rupture. Previous studies have shown that vertical graft placement is associated with persistent anterolateral rotational instability.[2,18,43] This has been shown to lead to lower patient satisfaction with lower Lysholm scores.[30] It may in fact lead to a pivoting mechanism of injury at a lower threshold than would be required for an anatomically positioned graft, resulting in subsequent graft rupture. Despite all patellar tendon graft ruptures occurring in males, gender was not found to be an independent predictor of graft rupture with multivariate regression analysis. This may be due to the overall number of patients suffering a graft rupture being small.

We found a small subset of 5 patients who sustained multiple (>2) further ACL injuries to either the ACL-reconstructed or the contralateral knee during the 15-year follow-up period. All injuries occurred while playing sport. This subset of patients is obviously predisposed to ACL injury. Further study is warranted on a larger group of patients with multiple ACL injuries to identify specific characteristics that would allow counseling of these patients regarding participation in high-risk sports.

It has been shown previously that successful results 7 years after surgery are strongly associated with the radiological position of the tunnels.[43] We found that assessment of sagittal tunnel placement on the lateral radiograph and

graft inclination angle measured on the 35° to 45° weight-bearing posteroanterior radiograph were more reliable than were measurements of coronal tunnel placement on the anteroposterior radiograph. The intended tunnel position is determined arthroscopically from intraoperative landmarks. The information that can be obtained from an anteroposterior and lateral radiograph of the knee taken postoperatively allows the surgeon to correlate perceived intraoperative tunnel placement to an objective measure and to be able to learn the subtle variations in intraoperative anatomy between patients. We recommend the use of routine postoperative radiographs with measurement of sagittal tunnel placement and graft inclination. These measurements allow objective assessment of tunnel and graft placement, which are necessary to compare studies reporting the outcome of ACL reconstruction.

Donor site morbidity is one of the major concerns with patellar tendon autograft for ACL reconstruction.[3,5,24,27,28,35,45,52] Concerns include pain with kneeling, anterior knee pain, tendinitis, and patellar fracture.[3,5,29,45,55] Kneeling pain seems to be the most consistent difference between patellar tendon and hamstring tendon autograft.[1,17,20,33,44,54] It has been suggested that injury or neuroma of the infrapatellar branch of the saphenous nerve is the cause of this pain.[24] We used a 2-incision approach for patellar tendon harvest, which has previously been shown to decrease kneeling pain.[24] From the 2-year to the final 15-year follow-up, there was a consistent increase in patient-reported pain with kneeling on a hard surface. One would expect a continued decrease in pain with an injury or neuroma to the infrapatellar branch of the saphenous nerve over time rather than an increase in pain. This finding suggests that there may be progressive deterioration causing this increasing pain. However, our results show that patellofemoral OA changes were moderate in 2% (n = 1), mild in 14% (n = 8), and not present in 85% (n = 50); therefore, it is unlikely that progressive patellofemoral degeneration can account for this finding. Further research and follow-up are required to explain and determine whether this finding continues to progress over time.

The strengths of this study include the 15-year outcomes of endoscopic ACL reconstruction in a homogeneous group of patients with isolated ACL ruptures. Follow-up was available in 88% of patients. A single, experienced knee surgeon performed all surgeries, ensuring that the techniques and decision making were standardized. Trained, independent assessors examined all patients in follow-up. The same experienced musculoskeletal radiologist performed the reviews at all follow-up time points ensuring good interrater reliability.

Weaknesses of this study are related to the relatively small sample size. However, the study was designed with strict inclusion and exclusion criteria to study a very specific group of patients with essentially isolated ACL rupture and their outcomes after endoscopic ACL reconstruction. We included 6 patients who underwent less than one-third lateral meniscectomy and 7 patients who underwent meniscal repair in our study group. We acknowledge that excluding these patients would create a much purer group for analysis; however, there are several issues with doing this. First, despite our best attempts to eliminate most confounding factors to study an isolated ACL injury group, we recognize that no ACL injury is truly isolated. The mechanism of the injury itself does not make isolated ACL injury possible. Second, this study was designed 15 years ago with the inclusion/exclusion criteria determined at that time. The purpose of this current study is to report the 15-year outcomes of this group. By altering our study group now it would alter the sample size and power and potentially introduce more type I error. Higuchi et al[21] previously showed that patients with less than one-half meniscectomy had improved long-term functional outcomes compared with those with more than one-half meniscectomy. In addition, patients did better after lateral meniscectomy compared with medial meniscectomy, with more patients progressing to OA after medial meniscectomy. Therefore, the effect of a less than one-third lateral meniscectomy on long-term functional and radiographic outcome is most likely minimal. Of the 7 patients with meniscal repairs, only 1 patient who had medial meniscal repair required later meniscectomy, indicating that the other 6 patients had successful meniscal repair and were able to save their menisci.

This study reports the long-term outcome of patients with ACL rupture undergoing endoscopic reconstruction using middle-third patellar tendon autograft. We have shown that good results are maintained with respect to ligamentous stability, subjective outcomes, and ROM 15 years after endoscopic ACL reconstruction using middle-third patellar tendon in patients with essentially isolated ACL injury. Kneeling pain remains a significant problem. Concern remains regarding the 30% rate of further ACL injury (8% graft rupture; 24% CACL rupture) and the increasing number of patients with radiographic and clinical signs of OA despite surgical stabilization. Further investigation is planned to assess differences in outcomes in this group of patients with isolated ACL rupture compared with those undergoing endoscopic reconstruction using 4-strand hamstrings autograft.

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