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Long-term Outcome of Endoscopic Anterior Cruciate Ligament Reconstruction With Patellar Tendon Autograft

Minimum 13-Year Review

Lucy J. Salmon,*† BAppSci(Physio), Vivianne J. Russell,† BSc(Biomed), Kathryn Refshauge,‡ PhD, Deiary Kader,† FRCS(Tr&Orth), Chris Connolly,† FRCS(Tr&Orth), James Linklater,§ FRANZCR, and Leo A. Pinczewski,† FRACS

From the †Australian Institute of Musculoskeletal Research, Sydney, Australia, the ‡University of Sydney, Sydney, Australia, and §Castlereagh Imaging, Sydney, Australia

Background: Short-term results of anterior cruciate ligament reconstruction are well reported; however, there are no studies evaluating endoscopic reconstruction of the anterior cruciate ligament with a minimum 10-year follow-up.

Hypothesis: Anterior cruciate ligament reconstruction with patellar tendon graft affords good subjective results and clinical laxity assessments but may be associated with development of osteoarthritis over the long term.

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

Methods: Endoscopic anterior cruciate ligament reconstruction was performed in 67 consecutive patients without significant articular surface damage. Patients were assessed at 5, 7, and 13 years after surgery with the International Knee Documentation Committee Knee Ligament Evaluation Form, Lysholm knee score, hop tests, kneeling pain, and radiographs.

Results: At 13-year review, self-reported assessments remained excellent; 96% of patients reported normal or nearly normal knee function. Grade 0 or 1 results were seen in more than 92% of patients on laxity testing. Patients who had undergone meniscectomy at the time of reconstruction had increased laxity between 7 and 13 years on instrumented testing ($P = .03$) and 6 times greater odds of anterior cruciate ligament graft rupture than if they had not undergone meniscectomy (95% confidence interval, 1-37). Degenerative changes on radiographs were found in 79% of patients at 13 years and were associated with meniscectomy ($P = .006$), loss of extension ($P = .05$), and greater laxity on Lachman test ($P = .04$).

Conclusions: Endoscopic anterior cruciate ligament reconstruction with patellar tendon autograft affords and maintains good self-reported assessments and clinical ligament evaluation up to 13 years. Radiographic degenerative changes were seen in three quarters of patients. Almost half developed loss of extension, suggesting onset of early osteoarthritis. Patients who had undergone meniscectomy at the time of reconstruction had increased clinical ligament laxity over time and greater odds of graft rupture, possibly reflecting the effect of prolonged increased strain on the graft. Continued follow-up is required to resolve concerns regarding integrity of the patellar tendon graft beyond 13 years, particularly in the absence of meniscal tissue.

Keywords: anterior cruciate ligament (ACL); long term; patellar tendon graft; interference screw fixation

Anterior cruciate ligament reconstruction is a very commonly performed procedure in modern orthopaedics. There have been significant advances during the past 2 decades in the techniques used to treat ACL deficiency. Surgical options have evolved from primary repair and augmented primary repair to reconstruction with biologic tissue grafts. Reconstruction using open and mini-arthrotomy techniques has further evolved to arthroscopically assisted and endoscopic procedures. These modern techniques have enabled the ACL to be reconstructed with less disruption of the extensor mechanism, less scarring, and reduced potential trauma to the articular surfaces.[11] Although the short-term results of these techniques are now well

*Address correspondence to Lucy J. Salmon, BAppSci(Physio), 286 Pacific Highway, Crows Nest, Sydney, NSW, Australia 2010 (e-mail: lsalmon@nsosmc.com.au).

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reported, to date there have been no studies evaluating endoscopic reconstruction of the ACL with at least 10 years of follow-up on all subjects.

Long-term results have been reported for ACL reconstruction with open or mini-arthrotomy techniques.[1,8,12,13,20,25,31] Although the results of contemporary endoscopic reconstruction have been reported to 8 years[8,14,15,30] (see Table 1), beyond this, published results are scarce. It has been suggested that damage to the knee joint after ACL reconstruction may only become apparent after 7 years from surgery.[31] Thus, we agree with others[10] that there is a clear need for studies evaluating minimum 10-year follow-up of contemporary ACL techniques with patellar tendon autograft. Furthermore, it has been shown that the clinical results of endoscopic ACL reconstruction may change over time up to 7 years,[28,29] but beyond this, the results are currently unknown. In this longitudinal series, we present the changes over time at 5, 7, and 13 years after ACL reconstruction.

This is the first longitudinal study to report the results of ACL reconstruction with patellar tendon autograft and single-incision endoscopic technique beyond 10 years. We assessed the long-term outcome and changes over time in a series of 67 patients with a minimum 13-year follow-up using validated outcome measures, including self-reported function, clinical ligament stability, and the development of degenerative change.

MATERIALS AND METHODS

Between March and November 1989, the senior author performed ACL reconstructions in 97 consecutive patients. 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 involving appropriate physical therapy. Patients with significant articular surface damage (10 patients) or concurrent medial collateral ligament repair at the time of reconstruction (15 patients) were excluded. Five other patients were excluded who had suffered a previous contralateral ACL rupture, leaving 67 patients in the study group.

The operative technique was standardized in all patients and has been previously described in detail.[26] First, an arthroscopic examination was performed using high anterolateral and low anteromedial portals. A central-third patellar tendon autograft was harvested via two 2-cm longitudinal incisions at the distal aspect of the patella and just medial to the tibial tubercle. The graft was fixed with a 25-mm long, 6.5-mm diameter AO fully threaded, noncannulated cancellous screw on both the tibial and the femoral sides via the low anteromedial portal. Patients used a continuous passive motion machine from 30° to 90° for 24 hours. They were then fitted with a range of motion hinged brace with 30° to 90° of motion permitted and remained nonweightbearing on crutches for a period of 4 weeks. Physical therapy was then commenced focusing on range of motion and strength. Patients were assessed by the surgeon at 10 days, 6 weeks, and 3, 6, and 12 months. Return to competitive sports involving pivoting, cutting, or sidestepping was prohibited until 9 months after surgery.

The study group comprised 20 women and 47 men. The median age was 27 years (95% confidence interval [CI], 25-28 years). There were 35 left knees and 32 right knees undergoing surgery. Reconstruction was performed within 3 weeks of injury in 25 patients, between 3 and 12 weeks from injury in 11 patients, and after more than 12 weeks from injury in 31 patients.

Meniscectomy at the time of reconstruction was performed in 25 patients (37%), 7 patients had a meniscal suture (10%), and 3 patients had undergone meniscal excision before ACL reconstruction (5%). The remaining 32 patients (48%) had intact menisci at the time of reconstruction. For the purposes of comparison, those patients who underwent previous or concurrent meniscectomy were grouped and compared with patients with intact menisci or meniscal suture.

Anterior cruciate ligament graft rupture occurred in 9 of the 67 patients (13%) during the 13-year follow-up period. All of these patients proceeded to revision surgery and therefore could not be included in this analysis. Of the remaining 58 patients with intact ACL grafts, 48 (83%) were reviewed at 5 years, 42 (72%) were reviewed at 7 years, and 49 (85%) were reviewed at 13 years. At 13 years, there were 6 patients who were unable to attend for review because of geographical limitations. These patients completed the subjective review only.

Assessment was performed by either a physical therapist or a clinical researcher with extensive experience in knee assessment. Assessment consisted of the International Knee Documentation Committee (IKDC) Knee Ligament Evaluation Form (2001),[2] which incorporates multiple subjective and objective criteria. Ligament stability was measured by the Lachman[22] and pivot-shift tests.[8] The Lachman was graded as 0 (<3 mm laxity), 1 (3-5 mm laxity), or 2 (>5 mm laxity) and the pivot-shift test as 0 (negative), 1 (glide), 2 (clunk), or 3 (gross). Instrumented knee testing was performed using the KT-1000 arthrometer (MEDmetric Corp, San Diego, Calif) using the manual maximum test. Patients rated pain intensity on a 0 to 10 scale when kneeling on a carpeted surface. The level of sporting activity was assessed according to the IKDC levels 1 through 4, which correspond respectively to strenuous (rugby, basketball), moderate (skiing, tennis, heavy manual labor), light (jogging), and sedentary activities. Patients completed the Lysholm knee score[21] to further document subjective symptoms. 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 highest obtainable score is 100.

Radiographic examination was performed using bilateral 30° posteroanterior weightbearing, AP, 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.[19] Radiographs were graded by 3 independent observers, 1 musculoskeletal radiologist

TABLE 1
Published Studies Examining the Long-term Results of ACL Reconstruction With Patellar Tendon Graft[a]

Study	No. of Patients	Months of Follow-up (range)	Operative Technique	Mean Lysholm Score	Grade 0-1 Lachman, %	Mean Instrumented Testing, mm	Instrumented Testing, % <3 mm	Abnormal Radiographs, %	ACL Graft Rupture, %	Contralateral ACL Rupture, %
Drogset and Grontvedt[8]	68	96	Arthroscopic with and without ligament augmentation device	84-87	84	NA	72	50	11	15
Bach et al[4]	97	79 (66-113)	Double-incision arthroscopic assisted	87	98	1	70	89	NA	NA
Ruiz et al[30]	30	84 (64-114)	Arthroscopic	87	88	NA	73	50	NA	NA
Jomha et al[15]	59	84	Arthroscopic	94	95	1.7	64	57	4	13
Wu et al[34]	63	120 (108-156)	Double incision and arthroscopic	88	97	2.3	NA	32[b]	5	NA
Jarvela et al[13]	100	84 (60-108)	Mini-arthrotomy	82	97	0.4	NA	47	3	NA
Myklebust et al[25]	79	94 (72-132)	Nonoperative, 22; bone–patellar tendon–bone, 47; other, 10	85	NA	3.3	NA	42	11	9
Jarvela et al[12]	91	84 (60-108)	Mini-arthrotomy	82	97	0.4	NA	46	4	10
Maletius and Messner[21]	56	240 (216-288)	Acute nonaugmented repair and others	90	63	NA	NA	87	13	NA
Mitsou and Vallianatos[22]	334	60-108	Mini-arthrotomy	NA	92	NA	78	NA	NA	NA
Shelbourne and Gray[31]	482	103 (60-180)	Arthrotomy	NA	NA	2.2	84	78	NA	NA
Aglietti et al[1]	67	84 (48-120)	Arthrotomy with lateral iliotibial band tenodesis	NA	93	NA	57	61	NA	NA

[a]NA, data not available.
[b]Radiographic results reported on 34 of 63 patients reviewed.

TABLE 2
Details of Patients Who Suffered an ACL Graft Rupture[a]

Gender	Side	Meniscectomy	Age at Index Surgery, y	Time to Graft Rupture, mo	Mechanism of Graft Rupture
F	L	Y	17	55	Touch football, sidestep
F	R	N	18	80	Basketball, jump
M	L	Y	22	84	Unknown
F	L	N	17	143	Soccer, tackle
M	R	N	24	108	Soccer, sidestep
M	L	Y	22	53	Rugby, tackle
M	L	Y	28	92	Netball, jump
M	R	Y	28	27	Hockey, sidestep
M	R	Y	20	54	Basketball, jump

[a]F, female; M, male; L, left; R, right; Y, yes; N, no.

and 2 orthopaedic fellows, to assess the reliability of the grading system. For the purposes of analysis and reporting, the musculoskeletal radiologist's results were used, as he was the most experienced of the observers.

Statistical Analysis

The Wilcoxon signed ranked test was used to assess change over time. Comparisons between subgroups were performed with the Mann-Whitney *U* test. Linear regression analysis was performed to assess the relative contribution of selected variables on linear outcomes. Multiple regression analysis was used to assess the relative contribution of selected variables on dichotomous outcomes. Statistical significance was set at .05. SPSS 11.0 for Windows (SPSS Science Inc, Chicago, Ill) was used for all the above statistical analysis. The interrater reliability of the 13-year radiographic examination was assessed using a weighted kappa test using MedCalc for Windows, version 8.0.0.

RESULTS

Complications and Further Surgery

There were 9 patients who suffered an ACL graft rupture during the 13-year assessment period (Table 2). Multiple regression analysis was performed to assess the relationship between ACL graft rupture and age, gender, and meniscectomy at index reconstruction. Age younger than 21 years increased the odds of a graft rupture by a factor of 10 (adjusted odds ratio, 10; 95% CI, 2-62; $P = .02$). Graft rupture occurred in 4 of the 13 patients (31%) younger than 21 years and 5 of the 62 patients (8%) 21 years or older. Meniscal excision also increased the odds of an ACL graft rupture by a factor of 6 (adjusted odds ratio, 6; 95% CI, 1-37; $P = .05$). Anterior cruciate ligament graft rupture occurred in 21% of those patients who had a meniscal excision and 8% of those who did not. There was no relationship between ACL graft rupture and gender (adjusted odds ratio, 1.4; 95% CI, 0.3-7.1; $P = .72$).

There were 15 patients who suffered a contralateral ACL rupture during the study period (Table 3). The incidence of contralateral ACL rupture was not significantly different from the risk of ACL graft rupture ($P = .11$). There was no significant difference between the timing of ACL graft rupture or contralateral ACL rupture ($P = .38$). One patient suffered both a contralateral ACL rupture and ACL graft rupture. Multiple regression analysis revealed no significant relationship between contralateral ACL rupture and age (adjusted odds ratio, 1.0; 95% CI, 1.0-1.1; $P = .74$) or gender (adjusted odds ratio, 0.9; 95% CI, 0.3-2.9; $P = .92$). The details of further complications and surgery are shown in Table 4.

Self-Reported Data

Self-reported assessment included the Lysholm knee score and the IKDC categories of perceived knee function, symptoms with activity, current activity level, and graft harvest site symptoms.

Lysholm Knee Score. The mean Lysholm knee score was 94 (95% CI, 91-97) at 5 years, 94 (95% CI, 92-96) at 7 years, and 89 (95% CI, 83-94) at 13 years. No significant change was found between 5 and 7 years ($P = .70$), but there was a significant decrease between 7 and 13 years ($P = .05$).

IKDC Subjective Knee Function. At 13 years, 47 of 49 patients rated their knee function as normal or nearly normal. Two patients (4%) regarded their knee function as abnormal (Figure 1).

Symptoms With Activity. At 13 years, moderate to strenuous activities could be performed without pain in 92% of patients, without swelling in 96% of patients, and without giving way in 96% of patients. There was no significant change between 5 and 7 years for the variable of pain, swelling, or giving way with activity. The percentage of patients reporting pain or giving way with moderate to strenuous activity did not significantly change between 7 and 13 years; however, the percentage of patients reporting

TABLE 3
Details of Patients Who Suffered a Contralateral ACL Injury[a]

Sex	Side	Age at Surgery, y	Time to Contralateral ACL Rupture, mo	Mechanism of Contralateral ACL Rupture
M	R	16	83	Rugby, twist
F	L	32	144	Basketball, sidestep
F	L	37	11	Grid iron, sidestep
M	R	18	42	Rugby, jump
F	R	44	135	Skiing, twist
F	L	23	46	Basketball, jump
M	R	26	138	Soccer, jump
M	L	17	40	Rugby, sidestep
M	R	29	32	Cricket, hyperextension
M	L	27	84	Cricket, twist
M	R	30	12	Rugby, tackle
M	L	27	56	Martial arts, jump
F	L	23	7	Basketball, jump
M	L	22	120	Work, fall
M	R	34	48	Squash, sidestep

[a]F, female; M, male; L, left; R, right.

TABLE 4
Details of Postoperative Complications

Complication	n	Mean Months From Surgery	Range
Contralateral ACL rupture	15	67	7-135
ACL graft rupture	9	77	27-143
Removal of screws	6	59	1-151
Medial meniscectomy	4	45	16-60
Contralateral medial meniscectomy	4	66	7-156
Lateral meniscectomy	2	79	4-153
Stiffness requiring manipulation under anesthesia	2	4	3-4
Arthroscopic debridement	1	58	
Arthroscopic chondroplasty	1	44	

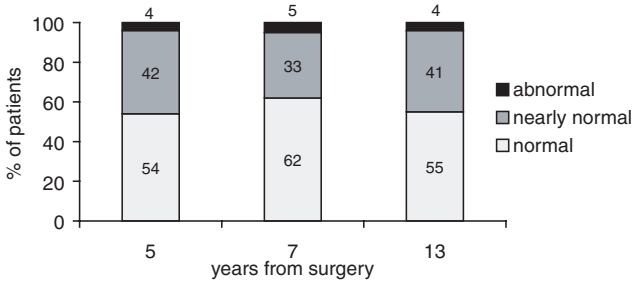

Figure 1. Self-reported knee function at each time point. No significant change over time was seen.

swelling increased significantly from 12% at 7 years to 37% at 13 years ($P = .03$).

Two patients reported symptoms of giving way with moderate activity. On examination of these 2 patients, both had grade 1 Lachman tests, grade 0 pivot-shift tests, and 2 cm of thigh atrophy relative to the contralateral knee.

Self-reported Activity Level. Activity level was graded according to the IKDC questionnaire, with level 1 being strenuous activity; 2, moderate activity; 3, light activity; and 4, sedentary activity. This assessment was introduced after the 5-year assessment period; therefore, the results are available for the 7- and 13-year reviews only. Before injury, all patients participated in level 1 or 2 activities. Continued participation in level 1 or 2 activities was present in 56% of patients at 7 years and 47% at 13 years. The change between 7 and 13 years was not significant ($P = .32$).

Harvest Site Problems. Patients were asked to note tenderness, irritation, or numbness at the autograft harvest site and grade as A (none), B (mild), C (moderate), or D (severe). This assessment was introduced after the 5-year assessment period; therefore, the results are available for the 7- and 13-year reviews only. At 7 years, 57% were graded A, 35% were graded B, and 8% were graded C. At 13 years, 58% were graded A, 35% were graded B, and 7% were graded C. No patient at either time period rated knee discomfort as grade D. There was no significant change between 7 and 13 years ($P = .78$).

Ligament Testing

Ligament laxity was assessed with the Lachman, pivot-shift, and KT-1000 arthrometer instrumented tests.

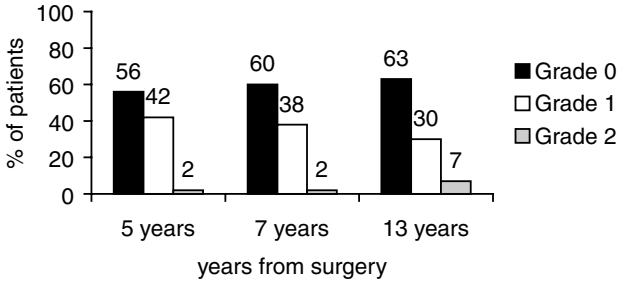

Figure 2. Lachman test results at each review point. No significant change over time was seen.

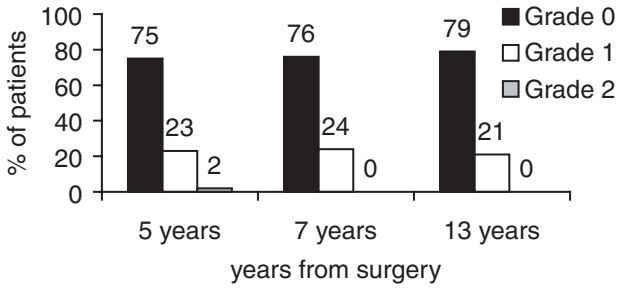

Figure 3. Pivot-shift test results at each review period. No significant change over time was seen.

Lachman Tests. At 13 years, 27 patients (63%) had a grade 0 Lachman test result, 13 patients (30%) had a grade 1 test result, and 3 patients (7%) had a grade 2 test result. The results at 5, 7, and 13 years are shown in Figure 2.

No significant change was found over time (5 vs 7 years, $P = .71$; 7 vs 13 years, $P = .25$). Normal Lachman testing was associated with a normal meniscus at the time of index surgery ($P = .001$). There was also weak association between normal Lachman and self-reported knee function ($P = .09$), but this finding did not reach significance. There was no relationship between Lachman test result and gender ($P = .32$) or age ($P = .22$).

Pivot-Shift Test. On pivot-shift testing at 13 years, 34 patients (79%) had a grade 0 test result, 9 patients (21%) had a grade 1 test result, and no patients had a grade 2 test result (Figure 3). No significant change was found over time (5 vs 7 years, $P = .99$; 7 vs 13 years, $P = .26$).

Normal pivot-shift test results were associated with normal menisci at the time of index surgery ($P = .001$). Pivot-shift test results were not associated with age ($P = .98$), self-reported knee function ($P = .20$), or gender ($P = .48$).

Instrumented Testing. Instrumented testing with the KT-1000 arthrometer was performed on 35 patients at 13 years and 33 at 7 years. The 14 patients not assessed with the KT-1000 arthrometer had suffered a contralateral ACL injury during the follow-up period and were therefore excluded from this analysis, which assumes a normal contralateral knee. There was no significant change between 7 and 13 years on percentage of patients with <3 mm on manual maximum testing ($P = .16$, Mann-Whitney) (Figure 4). The mean manual maximum was 2.0 mm at 13 years and 1.9 mm at 7 years (Figure 5). There was no significant change over time ($P = .31$).

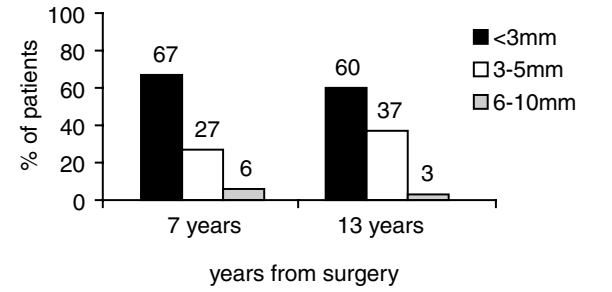

Figure 4. Percentage of patients with <3 mm of manual maximum side-to-side difference on KT-1000 arthrometer testing over time. No significant change over time was seen.

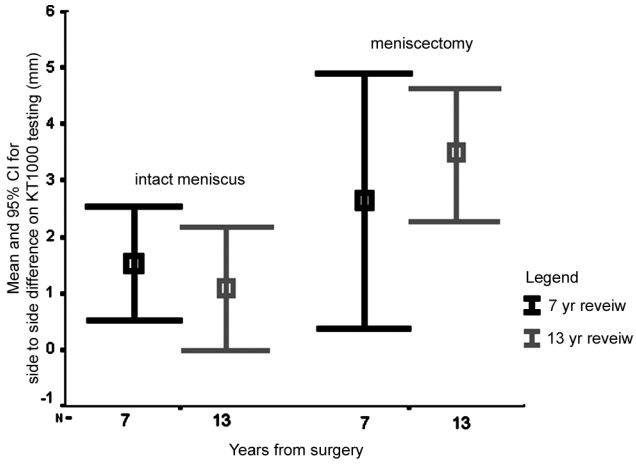

Figure 5. Mean and 95% confidence interval (CI) for KT-1000 arthrometer testing in patients with meniscectomy and without meniscectomy at 7- and 13-year review. No significant change over time in patients with an intact meniscus at the time of reconstruction ($P = .87$) was seen. Patients who underwent a meniscectomy at the time of reconstruction had a significant increase in manual maximum test between 7 and 13 years ($P = .03$).

Normal instrumented test results were associated with a normal meniscus at the time of index surgery ($P = .002$) and younger age ($P = .05$). Instrumented test results were not associated with self-reported knee function ($P = .20$) or gender ($P = .33$).

For those patients with an intact meniscus at the time of reconstruction, there was no significant change in manual maximum test result between 7 and 13 years ($P = .87$). For patients who underwent a meniscectomy at the time of reconstruction, there was a significant increase in manual maximum test result between 7 and 13 years ($P = .03$).

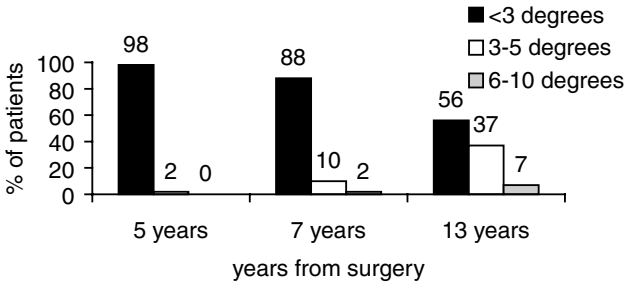

Figure 6. Percentage of patients with loss of extension at each review. The percentage of patients with an extension loss increased between both 5 and 7 years (P = .06) and 7 and 13 years (P = .02).

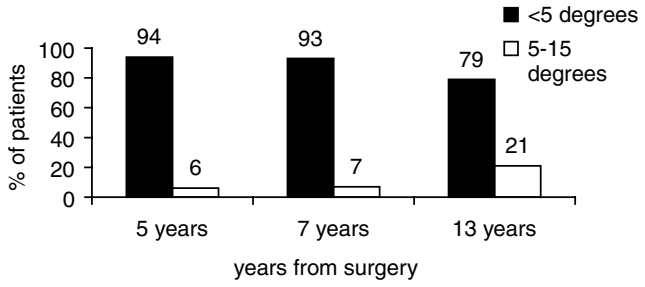

Figure 7. Percentage of patients with loss of flexion range over time. No significant change over time was seen.

Range of Movement

The median range of motion for the index limb was 0° of extension (95% CI, –1.5 to 0.4) to 130° of flexion (95% CI, 130 to 133). The difference in knee extension between the reconstructed and the contralateral limb is shown in Figure 6.

The percentage of patients with extension loss increased from 2% at 5 years to 12% at 7 years, and further to 44% at 13 years (5 vs 7 years, P = .06; 7 vs 13 years, P = .02). On regression analysis, extension loss was associated with an abnormal result on radiographic examination at 13 years (P = .05). The variables of age (P = .52), meniscectomy (P = .11), and Lachman test result at 13 years (P = .71) were not significantly related to extension loss at 13 years.

When compared with the contralateral limb, 34 of 43 patients had less than 5° of flexion loss, and 9 of 43 patients displayed between 5° and 15° of flexion loss. There was no significant change over time in the amount of flexion loss (Figure 7).

Overall IKDC Grade

Of the 43 patients with full IKDC assessment at 13 years, 32 patients had a normal or nearly normal overall IKDC grade and 11 patients an abnormal or severely abnormal grade (Figure 8). The change over time was not significant between 5 and 7 years (P = .06) or between 7 and 13 years (P = .37), but a significant deterioration occurred between 5 and 13 years (P = .01).

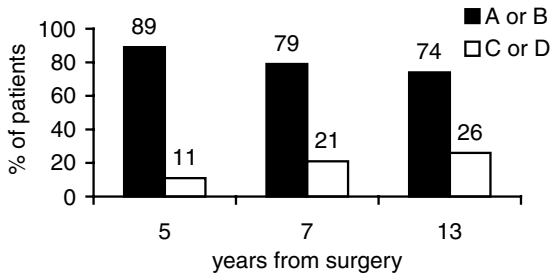

Figure 8. Overall International Knee Documentation Committee (IKDC) grade at each review. No significant change between 5 and 7 years (P = .06) or between 7 and 13 years (P = .37) was seen, but a significant deterioration occurred in overall IKDC between 5 and 13 years (P = .01).

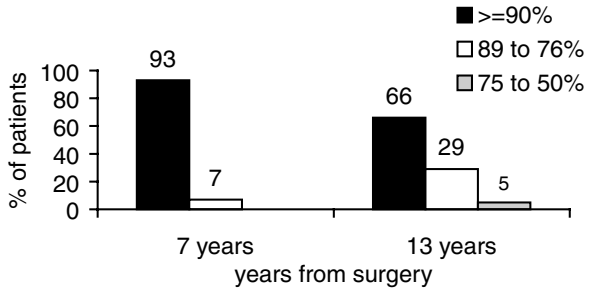

Figure 9. Performance of the single-legged hop for distance test. There was a significant deterioration in the performance of the hop test between 7 and 13 years (P = .01).

Functional Testing

Single-Legged Hop Test. The patient was asked to perform a single-legged hop for distance on the index and normal side. Three trials for each leg were recorded and averaged. A ratio of the index to normal knee was calculated. The results are shown in Figure 9. Two patients at 13 years and 1 patient at 7 years did not complete this test because of ankle injury or pregnancy. There was a significant deterioration in the performance of the hop test between 7 and 13 years (P = .01).

Kneeling Pain. Kneeling pain was assessed by asking the patient to kneel on a carpeted surface for approximately 1 minute and to note the presence of pain. Intensity was graded from 0 to 10, with 0 being no pain and 10 being severe pain. This assessment was introduced after the 5-year assessment period; therefore, the results are available for the 7- and 13-year reviews only.

At 7 years, 19% reported kneeling pain with a median intensity of 3 (range, 1-6). At the 13-year review, 45% reported the presence of kneeling pain with a median intensity of 3 (range, 1-8). There was a significant increase in the percentage of patients reporting kneeling pain between 7 and 13 years (P = .01, Mann-Whitney).

Radiographic Assessment

Radiographs were performed on 52 patients at 5 years, 44 patients at 7 years, and 43 patients at 13 years. There

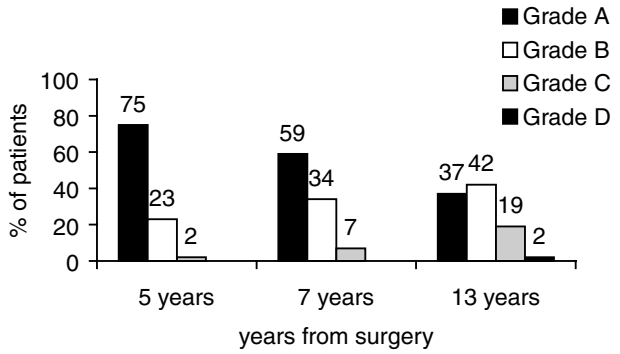

Figure 10. Radiographic International Knee Documentation Committee grade. There was a significant increase in the proportion of patients with an abnormal radiograph result between 5 and 7 years ($P = .003$) and between 7 and 13 years ($P = .01$).

TABLE 5
Predictors of Poor Radiographic Grade at 13 Years

Variable	*P*
Medial meniscectomy at index surgery	.006[a]
Greater Lachman test at 13 years	.04[a]
Greater extension loss at 13 years	.05[a]
Lateral meniscectomy at index surgery	.26
Age	.28
Gender	.32

[a]Denotes statistically significant relationship between variable and radiographic outcome.

were 6 patients reviewed at 13 years without radiographs, owing to pregnancy in 2 patients and to the review being conducted at a peripheral clinic without radiographic facilities in 4 patients.

IKDC Radiographic Grade. The results of the IKDC radiographic assessment are shown in Figure 10. There was a significant increase in the proportion of patients with an abnormal radiograph result between 5 and 7 years ($P = .003$) and between 7 and 13 years ($P = .01$).

Regression analysis was performed to assess the relative contributions on the outcome of radiographic examination of age, gender, Lachman test result at 13 years, loss of extension range of motion at 13 years, and lateral or medial meniscectomy performed at index surgery. The results are shown in Table 5. Poorer radiographic grade was associated with medial meniscectomy at index surgery ($P = .006$), greater laxity on Lachman test ($P = .04$), and loss of extension ($P = .05$).

In the medial tibiofemoral joint at 13 years, 18 patients (42%) had no degenerative change, 17 patients (40%) had mild degenerative change, and 8 patients (18%) had moderate to severe degenerative change. In the lateral tibiofemoral joint at 13 years, 30 patients (70%) had no degenerative change, 11 patients (26%) had mild degenerative change, and 2 patients (5%) had moderate degenerative change.

TABLE 6
Interrater Weighted Kappa Statistics for the International Knee Documentation Committee Radiographic Grading System

	Observer 1	Observer 2
Medial tibiofemoral joint		
Observer 2	0.67	
Observer 3	0.42	0.63
Lateral tibiofemoral joint		
Observer 2	0.83	
Observer 3	0.52	0.58
Patellofemoral joint		
Observer 2	0.41	
Observer 3	0.45	0.77
Overall grade		
Observer 2	0.67	
Observer 3	0.39	0.65

In the patellofemoral joint at 13 years, 32 patients (74%) had no degenerative change, and 11 patients (26%) had mild degenerative change.

Interrater Reliability of Radiographic Grading

All radiographs were assessed by 3 independent observers: 1 musculoskeletal radiologist and 2 orthopaedic fellows. The results reported above represent those of the musculoskeletal radiologist as the most experienced of the observers. Interrater reliability of the 13-year radiographs was assessed using the weighted kappa statistic, and the results are shown in Table 6. Landis and Koch[17] suggested that the value of this coefficient may be interpreted as follows: ≤0.2, slight agreement; 0.21 to 0.4, fair agreement; 0.41 to 0.6, moderate agreement; 0.61 to 0.8, substantial agreement; and 0.81 to 1.0, almost perfect agreement. Observer 1 (musculoskeletal radiologist) and observer 2 (orthopaedic fellow 1) had substantial to almost perfect agreement on the overall grade and on the medial and lateral tibiofemoral joint grades. Observer 1 (musculoskeletal radiologist) and observer 3 (orthopaedic fellow 2) had only fair to moderate agreement on all grades.

Blackburne-Peel Ratio. The Blackburne-Peel ratio assesses patellar height. The normal ratio is defined as 0.8, and greater than 1.0 is considered patella alta.[7] At 5 years, the mean Blackburne-Peel ratio was 0.75 (95% CI, 0.71-0.80), 0.74 (95% CI, 0.70-0.78) at 7 years, and 0.70 (95% CI, 0.66-0.75) at 13 years (Figure 11). There was no significant change between 5 and 7 years ($P = .96$). There was a significant decrease in patellar height between 7 and 13 years ($P = .04$). Regression analysis revealed no relationship between patellar height at 13 years and the variables of age ($P = .57$), meniscectomy at the time of reconstruction ($P = .67$), gender

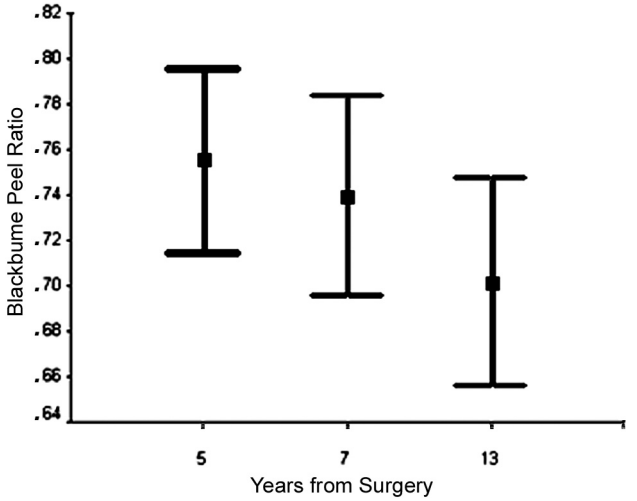

Figure 11. Mean and 95% confidence interval for the Blackburne-Peel ratio at each review point. No significant change between 5 and 7 years ($P = .96$) was seen. There was a significant decrease in patellar height between 7 and 13 years ($P = .04$).

($P = .61$), overall radiographic grade ($P = .85$), or patellofemoral joint radiographic grade ($P = .38$).

DISCUSSION

The results of endoscopic ACL reconstruction over the long term are, to date, poorly represented in the literature, and no studies report a minimum 10-year follow-up. We presented the 13-year results of endoscopic ACL reconstruction with patellar tendon autograft in a series of 67 patients. Good results were maintained for 13 years for self-reported assessments and clinical ligament evaluation despite evidence of degenerative changes on radiographs in three quarters of patients and almost half having early loss of extension, suggesting the onset of early osteoarthritis. Patients who had undergone meniscectomy at the time of reconstruction had increasing laxity with time and greater odds of graft rupture, possibly reflecting the effect of prolonged increased strain on the ACL graft that occurs in the absence of meniscal tissue.

Self-reported Assessment

Thirteen years after ACL reconstruction, the results of self-reported assessments remained excellent, with 96% of patients reporting normal or nearly normal knee function. Even if those patients who suffered a graft rupture during the 13-year follow-up period are included as "abnormal," this figure remains high at 82%. Similarly, at 13 years, good or excellent Lysholm knee scores were achieved in 80% of patients, with a mean score of 89. Others[‖] have reported similar subjective scores in long-term studies up to 8 years, and it is reassuring to note that these results are maintained to 13 years.

Ligament Stability and Repeat ACL Injury

Good clinical ligament stability was maintained up to 13 years in more than 93% of patients with intact ACL grafts. If patients who had a graft rupture during the study period are included and assumed to have at least grade 2 laxity, the percentage of patients with good clinical ligament stability at 13 years is 78%. Clinical ligament stability was associated with an intact meniscus at the time of surgery on Lachman ($P = .001$), pivot-shift ($P = .001$), and instrumented test results ($P = .002$) at 13 years. Similar findings have been seen by others[16,31]; however, Wu et al[34] recently reported no relationship between meniscectomy and laxity in their review of 63 patients 9 to 13 years after ACL reconstruction.

We found that patients who had undergone meniscectomy developed increasing laxity on instrumented testing between 7 and 13 years. Furthermore, the odds of ACL graft rupture in those patients who had undergone a meniscectomy were increased by a factor of 6. It appears that the absence of the meniscus after ACL reconstruction leads to the development of greater laxity over time and to higher odds of ACL graft rupture. This hypothesis is supported by a recent cadaveric study in which the absence of the medial meniscus resulted in 33% to 50% higher in situ forces on the ACL graft in a loaded position, thereby increasing the strain on the ACL graft.[27] In addition, others[5,6] have demonstrated that increased anterior laxity adversely affects the structural properties of the patellar tendon graft in a canine model. These findings, apparent at 13 years, were not seen at the 7-year review. The prolonged increased strain on the ACL graft in the absence of the meniscal tissue may result in elongation that does not become apparent until after 7 years. To our knowledge, this is the first study that has identified this trend, highlighting the importance of not only long-term follow-up but also the value of longitudinal data to assess change over time.

Younger age was also associated with greater laxity on instrumented testing ($P = .05$) at 13 years. Furthermore, the odds of ACL graft rupture were increased by a factor of 10 in those younger than 21 years ($P = .02$). These findings may reflect the higher activity level younger patients are likely to participate in, thereby placing their reconstructed knees under greater and more frequent stress.

During the 13-year review period, a total of 23 patients (34%) suffered an ACL injury subsequent to the reconstruction. Nine patients (12%) suffered an ACL graft rupture, and 15 patients (22%) suffered a contralateral ACL rupture. Similar ACL injury rates have been reported by other authors.[8,21,25] In the normal athletic population, the incidence of ACL injury is reported to be between 1.5% and 1.7% per year.[18,33] Although it is reassuring that the incidence of injury to the ACL graft and the contralateral ACL was similar, the total proportion of patients suffering a subsequent ACL injury (34%) after reconstruction is a cause for concern and may be greater than that seen in the normal population. It has been shown that ACL injury may be decreased

[‖]References 4, 8, 12, 13, 15, 21, 22, 25, 30, 31, 34.

with the implementation of specific motor-retraining programs.[24] If 1 in 3 patients will suffer a repeat ACL injury after reconstruction, the addition of these programs to the rehabilitation of ACL-reconstructed patients to reduce this risk may be of value and is worthy of further study.

Degenerative Changes

Early clinical signs of degenerative changes include loss of motion, swelling with activity, and changes on radiographs. In this study, there was a significant increase in percentage of patients with these findings between 7 and 13 years. By 13-year review, 37% of patients reported swelling after moderate activity, and extension loss was seen in 44% of patients. Furthermore, extension loss was associated with abnormal results on radiographic examination, which suggests that the observed loss of motion was related to the development of early degenerative change.

We previously would have assumed that the advent of minimally invasive techniques such as the arthroscope used to reconstruct the ACL may result in less trauma to the joint when compared with open techniques and thereby decrease the risk of developing degenerative changes later in life. Radiographic examination was performed on 43 of the 49 patients reviewed at 13 years after surgery. The proportion of patients with an abnormal radiograph result increased significantly from 25% at 5 years to 41% at 7 years and further increased to 79% at 13 years. Others have reported similar incidences of degenerative changes seen on radiographs at 7 years.[8,12,13,15,30] We have shown that after 7 years, there is a continued deterioration. These findings are comparable with the results of Shelbourne and Gray[31] 5 to 15 years after open ACL reconstruction and Maletius and Messner[21] 18 to 24 years after acute nonaugmented repair of the ACL. Thus, it seems that over the long term, endoscopic ACL reconstruction with patellar tendon graft is associated with the development of significant degenerative change, which has not been alleviated by the advent of endoscopic techniques.

As expected, we found that meniscectomy was associated with the development of degenerative change on radiographic examination ($P = .006$). If a meniscectomy was performed at the time of reconstruction, abnormal radiograph results were present in 87% of patients, versus 50% of those with an intact meniscus. These findings are comparable with the results of Shelbourne and Gray[31] 5 to 15 years after open ACL reconstruction as well as others.[8,34] Meniscectomy at the time of reconstruction was performed far more commonly in those patients with chronic ACL injuries (72%) than in those reconstructed within the subacute period (29%). Like other authors,[12,14] we support the importance of reconstructing the ACL in the period before secondary injuries occur as a result of an unstable knee to minimize the risk of subsequent meniscal injury and early degenerative change.

There was also an association between degenerative change seen on radiographs and increased laxity on Lachman testing ($P = .04$). Abnormal results on radiographic examination were present in 50% of patients with a grade 0 Lachman test result, 75% of those with a grade 1 result, and 100% of patients with a grade 2 result. The increase in degenerative change accompanying increased laxity of the knee may reflect the altered contact stresses affecting the tibiofemoral joint. To minimize degeneration, we must not only resolve pathologic laxity but also restore joint laxity that is as normal as possible.

It should be noted that the clinical features of degenerative change such as loss of extension and radiographic findings were not associated with poor subjective results. Other authors have reported similar findings.[25] In addition, although there was a significant deterioration in objective findings of degenerative change and performance on functional tests such as the hop test, the self-reported results remained essentially unchanged. So, although evidence of degeneration was present clinically, this has not yet been manifested in patients' self-reported results. This finding highlights the importance of continued follow-up to even longer time periods to assess when these conditions will affect symptoms.

Interrater Reliability of the IKDC Grading System for Radiographs

We assessed interrater reliability of the radiographic grading system suggested by the IKDC between 3 independent assessors: 1 musculoskeletal radiologist and 2 orthopaedic fellows. Although there was substantial to almost perfect agreement between the radiologist and one orthopaedic fellow, the other orthopaedic fellow showed only fair to moderate agreement with the radiologist. It has been shown that assessment tools, such as the IKDC system for grading knee radiographs, that incorporate both osteophytes and joint space narrowing offer the most precise estimation of the association of risk factors with disease worsening.[19] However, any assessment tool is more likely to be reliable when performed by a more experienced examiner. Our findings highlight the importance of using a skilled and experienced examiner when grading radiographs. Further studies examining the reliability and validity of the IKDC system of grading radiographs are warranted.

Patellar Shortening

We found a significant decrease in patellar height between 7 and 13 years as measured with the Blackburne-Peel ratio. Similar findings of patellar shortening after ACL reconstruction with patellar tendon graft have been reported by other authors.[13,23] However, we found no significant relationship between patellar shortening and any self-reported or objective measures including degenerative change seen on radiographs. The clinical significance of this finding thus remains unclear.

Graft Site Morbidity

It is known that use of the patellar tendon graft is frequently associated with high rates of graft site morbidity.[3,9,10,12,28] In this study, at 13-year review, 42% of patients reported symptoms related to the patellar tendon on IKDC assessment, and kneeling pain was present in 45%. Similar findings have been reported by others.[12] However, despite these symptoms, the patients' overall self-reported functional

scores were high, as previously discussed. Shelbourne and Trumper[32] suggested that the incidence of anterior knee pain may be decreased with modern accelerated rehabilitation programs. The patients in this study were braced and remained nonweightbearing for 4 weeks after surgery. We now use an accelerated rehabilitation program with immediate weightbearing as tolerated and aggressive early strengthening and range of motion program. Although it is plausible that these factors may decrease patellar tendon graft morbidity over the long term, this result has yet to be shown.

Advances that occur with all surgical techniques mean that long-term results will inevitably be out of date with current techniques. Although the patients in this study represent the longest review of arthroscopic reconstruction with patellar tendon autograft currently available, significant advances have subsequently been made in both intraoperative and postoperative management. The introduction of accelerated rehabilitation programs, lack of postoperative bracing, outpatient procedures, and improved fixation techniques may afford more favorable results. In addition, the use of alternative graft constructs such as the 4-strand hamstring tendon graft may significantly change the long-term outcome. Indeed, it has been shown that the use of the hamstring tendon graft may significantly reduce the prevalence of degenerative changes at 7 years when compared with the patellar tendon graft.[29] Continued long-term assessment of current surgical techniques is essential.

CONCLUSION

Endoscopic ACL reconstruction with patellar tendon graft and interference screw fixation affords excellent subjective results and good clinical ligament stability that persist over the long term. By 13 years after surgery, clinical signs of degenerative change were present in 3 of 4 patients but were not reflected in the self-reported assessments. If concurrent meniscectomy was performed, there was a higher incidence of degenerative change, greater laxity developing over time, and greater odds of ACL graft rupture. Continued follow-up is required to document the development of degenerative changes and to resolve concerns regarding the long-term integrity of the patellar tendon graft beyond 13 years, particularly in those patients who have had meniscal excision.

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