Endoscopic Single-Bundle Posterior Cruciate Ligament Reconstruction: Results at Minimum 2-Year Follow-up

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Purpose: The goal of this study was to evaluate the clinical outcome of single-bundle posterior cruciate ligament (PCL) reconstruction with retention of the PCL remnant and hamstring tendon autograft with interference screw fixation in patients with isolated PCL laxity. **Type of Study:** Prospective case series with minimum 2-year follow-up evaluation. **Methods:** Thirty-one patients for whom conservative management had failed underwent surgery using a 4-strand hamstring tendon autograft with interference screw fixation. The median time from injury to reconstructive surgery was 9 months (range, 4 to 120 months). At a minimum of 2 years after surgery, patients were assessed with the International Knee Documentation Committee (IKDC) Knee Ligament evaluation, Lysholm knee score, and KT-1000 instrumented testing. **Results:** Before surgery, the median Lysholm knee score was 64 (95% confidence interval, 51 to 67). No patient rated knee function as normal, and all patients showed at least grade 2 posterior drawer laxity. At review, the median Lysholm knee score was 94 (95% confidence interval, 83 to 94), 56% rated the knee as normal and only one patient was found to exhibit grade 2 laxity on posterior drawer testing. Before injury, 94% of patients participated in moderate or strenuous activity. This figure fell to 26% after injury and had increased to 63% at review. **Conclusions:** Endoscopic reconstruction of PCL laxity using single-bundle 4-strand hamstring tendon autograft, without removal of the PCL stump, provides a significant reduction in knee symptoms and allows 63% of patients to return to moderate or strenuous activity. This is an effective procedure for symptomatic patients who have isolated PCL laxity and for whom conservative management has failed. **Key Words:** Posterior cruciate ligament—Reconstruction—Hamstring tendon graft—Clinical study.

The management of posterior cruciate ligament (PCL) rupture remains controversial. A consensus of opinion agrees that acute osseous avulsion injuries should be managed surgically.[1,2] However, the management of soft tissue disruption of the PCL is controversial. Researchers have previously strongly argued that conservative management with physiotherapy is sufficient.[3-6] However, more-detailed

long-term follow-up reviews have identified a significant level of persistent morbidity with pain on activity and symptomatic giving way in some patients.[7-11]

The advent of arthroscopic techniques has substantially reduced surgical morbidity from this procedure, permitting reconstruction as a single-day procedure and allowing for an earlier and more aggressive rehabilitation program. A variety of constructs may be used for reconstruction, including prosthetic material, allograft and autograft tissue.[12-14] Most authors agree that PCL disruption with greater than 10-mm maximal displacement (often found in association with PLC injury) should be managed with an initial period of physiotherapy, but that return to preinjury activity may be associated with chondral or meniscal injury. Therefore, delaying surgery shows no clear advantage because no reparative process is ongoing.[15]

Determining the true outcome of surgery for reconstruction of the PCL remains unclear. Those few series that do report outcome are weakened by the small numbers of patients, differing procedures performed within individual series, and retrospective nature of the analyses.[16-21] We have prospectively determined the outcome for arthroscopic reconstruction of the PCL by a single surgeon using a standard procedure.

METHODS

Thirty-one patients underwent arthroscopic reconstruction for chronic (>3 months) PCL laxity over a 30-month period from June 1994 to December 1996. All patients had presented to the senior author (L.A.P.) after a history of knee dysfunction secondary to a specific injury. A primary care physician had assessed all patients before consultation.

Indications for Surgery

All patients had undergone a supervised program of physiotherapy and quadriceps-strengthening exercises for at least 14 weeks with the goal of restoring range of movement. Despite conservative management, all patients complained of pain or instability preventing return to a desired level of functional activity, including sprinting, running downhill, and deceleration. Rupture of the PCL with at least grade 2 laxity on posterior drawer testing was shown on clinical examination before surgical intervention. Radiographic examination had excluded the presence of an avulsion fracture. The senior author performed all surgery.

Surgical Technique

The surgical technique used has been described previously.[22] The patient was positioned supine with a thigh bolster and a footrest to hold the knee at 80° of flexion. Intravenous antibiotics were administered before inflation of a high thigh tourniquet. A standard arthroscopic examination of the joint was performed using low anterolateral and high anteromedial portals. The anterolateral remnants of the PCL only were removed. Residual posteromedial tissue was left, and the procedure was directed toward reconstruction of the anterolateral bundle. The femoral tunnel was placed 8 to 10 mm from the anterior or distal medial femoral articular margin on a line continuous with the junction of the roof and medial wall of the intercondylar notch. The femoral tunnel was initially drilled with a 4.5-mm AO drill using the anterolateral portal.

Through a separate longitudinal proximal tibial in-cision, the semitendinosus and gracilis tendons were harvested and fashioned to form a 4-strand hamstring tendon graft with a minimum graft length of 13 cm. The tendons at the proximal and distal ends of the graft were sutured using a whipstitch. The central, intra-articular, 4 cm of the graft remained free of suture material. The diameter of the graft was ascertained using a sizer demarcated in 0.5-mm increments. A mark was made 30 mm from the free end of graft with a methylene blue pen, allowing for confirmation of complete docking of the graft into the femoral tunnel at final insertion. A 2.4-mm Beath pin was passed through the femoral tunnel, and over this a cannulated drill reamed the distal portion of the tunnel to a depth of 30 mm at the predetermined diameter of the hamstring graft.

A posteromedial portal was created under direct vision, and the most distal insertion of the PCL on the proximal tibia was elevated with a curette. A drill guide was inserted through the posteromedial portal and a tibial hole made using a 4.5-mm drill directed from anterior to posterior. A 2.4-mm (blunt leading end) Beath pin was then inserted through this hole and reamed according to graft diameter. A pullout suture was threaded in a retrograde fashion.[22] Using this, the 4-strand hamstring graft was pulled through the tibial hole and subsequently through the femoral hole. Proximal femoral fixation was obtained using a 7 × 25 mm round-head cannulated interference screw (RCI Smith & Nephew, Andover, MA) inserted over a Beath pin. The graft was then grasped and pulled tightly out of the anterior tibial hole, the knee taken through at least 10 range-of-motion cycles, and a 7 × 25 mm RCI screw inserted partially at 60° of knee flexion.

After the first threads of the screw caught, the knee was extended and the screw fully introduced and seated at the most posterior part of the tibial hole. In the event of a short graft ending inside the tibial tunnel, additional fixation was obtained using a post screw. If the graft was overlong or found to protrude out of the anterior tibial tunnel, supplementary fixation was obtained with the use of a staple. The patient was allowed to commence full weight bearing as tolerated without brace support after surgery. Intensive physiotherapy was begun on the day of surgery using closed-chain exercises focusing on quadriceps strengthening.

Review

Symptoms and signs of knee function were assessed to complete the International Knee Documentation

Committee (IKDC) grade.[23] The Lysholm knee score was completed by means of a self-questionnaire because this has been shown to give more reliable results.[24,25] Ligament testing was performed by means of Lachman test, posterior drawer, and reverse pivot shift.[26-28] A reverse pivot shift is defined as positive if a reduction sensation is appreciated when the flexed externally rotated knee is extended with a valgus stress.[27] Instrumented laxity testing was determined using a KT-1000 arthrometer (MedMetric, San Diego, CA). The quadriceps neutral angle was determined on the normal contralateral knee using the arthrometer and the PCL pro (MedMetric).[29] This is the knee flexion angle at which no tibial displacement occurs with contraction of the quadriceps musculature. The amount of anterior and posterior tibial translation with a 9.1 kg (20 lb) force was recorded at this angle for both knees. Side-to-side differences were used to determine the magnitude of pathologic ligamentous laxity.

Statistical Analysis

For the purposes of analysis, it was not assumed that data followed a normal distribution. Nonparametric methods of analyses were used for all computations; $P < .05$ was regarded as significant. A statistical analysis was performed using SPSS version 8 for Windows (Prentice Hall, Chicago, IL). For interval and ordinal data, comparisons between prereconstruction and postreconstruction results were made using Wilcoxon signed-rank test. For nominal data, comparisons were made using McNemar's test. Confidence intervals were determined using the method of ranks.[30]

RESULTS

The original study group comprised a total of 31 patients. Preoperative data were complete on all patients. During the review period, one patient experienced a traumatic graft rupture 24 months after surgery when tackled directly in a rugby game. One patient experienced a fatal pulmonary embolism 11 days after surgery. This left a total of 29 patients, of whom complete questionnaire data were available for 27 subjects (93%). Clinical examination, including instrumented testing, was performed on 24 patients (89%).

The subjects included 25 men and 2 women. The median age at surgery was 27 years (range, 18 to 57 years). The mean time from injury to surgical recon-

struction was 24 months (range, 4 to 120 months). Sixteen patients underwent surgery between 4 and 12 months after injury and the remaining 11 patients underwent surgical reconstruction more than 12 months after PCL disruption. The median period from surgery to review was 40 months (range, 24 to 64 months).

Mechanism of Injury

Twenty-four patients were injured while participating in sports. Of these, 15 patients reported injury occurring from a direct tackle. Of the remaining, 4 patients fell onto the proximal tibia, 2 patients sustained a twisting injury, a bull kicked one patient, and 2 patients sustained a PCL rupture after forced hyperextension of the knee. The documented sport at the time of the injury was rugby for 12 patients, soccer for 4 patients, cycling for 2 patients, and snow skiing for 2 patients. Participation in hockey, baseball, rodeo, and water skiing accounted for 1 injury each. Three patients sustained a rupture of the PCL from a direct blow to the proximal tibia of a flexed knee in a motor vehicle accident.

Previous Surgery

Nine of the 27 patients reviewed had undergone previous surgery to the index limb. All previous surgery had been performed before the PCL injury. In 4 patients, a previous arthroscopic examination without removal of meniscal tissue had been performed. Four patients had undergone ipsilateral partial medial meniscectomy. One patient had sustained a closed fracture of the ipsilateral femur with minimal residual angular or torsional deformity.

Surgical Findings

At surgery, the site of rupture of the PCL was midsubstance in 19 patients, distal in 3 patients, and ill defined in 5 patients. A 4-strand hamstring graft was used in 24 patients and a 3-strand graft in 3 patients. Proximal femoral site fixation was performed in all patients using a standard 7×25 mm RCI screw (Smith & Nephew). Graft fixation at the tibial end was achieved using an RCI screw and staple fixation in 22 patients. In 5 patients, an RCI screw was combined with tying the leading graft sutures over a post screw at the tibial end.

Meniscal Injury and Treatment

At index arthroscopy, normal medial meniscal tissue was seen in 21 patients. Four patients showed

evidence of previous medial meniscectomy with stable remnant meniscal tissue. One patient had a displaced bucket handle tear, and one patient had a posterior horn avulsion tear, both of which required subtotal meniscectomy. Twenty patients were found to have no abnormality of the lateral meniscus at index arthroscopy. Three patients had stable tears, which were not treated surgically. Four patients required partial lateral meniscectomy.

Collateral Ligament Injury

Three patients were found to have a medial collateral ligament injury at presentation (grade II or III). One patient was treated successfully with conservative management. Two patients required open reconstruction despite prior conservative treatment in a brace for significant grade II collateral ligament instability at the time of PCL reconstruction. No patient had significant lateral collateral ligament laxity or evidence of significant ($>1+$) posterolateral corner instability.

Lysholm Knee Score

The Lysholm knee score is designed to evaluate specific symptoms relating to knee function (limp, support, locking, instability, pain, swelling, stair-climbing, squatting). The highest obtainable score is 100. The preoperative median Lysholm knee score was 64 (95% confidence interval, 51-66). At review, the median score was 94 (95% confidence interval, 84-94) ($P < .01$). Table 1 outlines the percentage change for absence of key components of the Lysholm knee score before and after surgical reconstruction. This shows that significant improvements were recorded for the absence of subjective instability ($P < .01$), pain ($P < .01$), stairs performance ($P < .01$), and squatting ($P < .01$).

TABLE 1. *Percentage of Patients With Absence of Key Symptoms From the Lysholm Knee Score*

Assessment Category	Preoperative		Review	
	No of Patients	%	No of Patients	%
No instability	2	7	22	82
No pain	1	3	9	33
No problems with stairs	5	16	24	89
No problems with squatting	3	10	12	44

NOTE. Significant difference between preoperative and review assessment $P < .01$ in all categories.

TABLE 2. *Distribution for Subjective Knee Function Before and After Reconstruction*

Assessment Category	Preoperative		Review	
	No of Patients	%	No of Patients	%
Normal [A]	0	0	15	55
Nearly normal [B]	7	23	10	37
Abnormal [C]	23	74	1	4
Severely abnormal [D]	1	3	1	4

NOTE. Significant difference between preoperative and review assessment $P < .01$ in all categories.

IKDC Evaluation

The IKDC assessment combines symptoms and signs. Patients were graded as normal (A), nearly normal (B), abnormal (C), or severely abnormal (D). The final evaluation of A, B, C, or D is determined by the worst score in the principal categories: subjective assessment, symptoms, range of motion, and ligament examination.

Subjective Knee Function

Each patient was asked to grade the knee in 1 of 4 categories: normal (A), nearly normal (B), abnormal (C), or severely abnormal (D). Table 2 gives the breakdown of the percentages for each of these subgroups both before surgery and at review. Before surgery, 24 patients (77%) reported knee function as either abnormal or severely abnormal, and no patient reported knee function as normal. At review, only 2 patients reported knee function as abnormal ($P < .01$). A 22-year-old woman reported her knee function as severely abnormal. She complained of constant knee pain and occasional instability. On examination she displayed no quadriceps atrophy and full extension, but she lacked the terminal 10° of flexion. Ligament examination revealed a glide on pivot shift test, a grade 2 Lachman test, and grade 1 posterior sag test, both with a solid endpoint. Despite these symptoms, this patient was able to participate in competitive hockey twice weekly.

Symptoms

Patients were questioned about the presence of pain, swelling, or giving way with participation at the highest level of activity achievable. At review, we noted a significant increase in the percentage of patients able to participate at moderate or strenuous activity in the

absence of pain ($P < .01$), swelling ($P < .01$), or giving way ($P < .01$) (Table 3).

Range of Motion

Before surgery, 6 patients (19%) had a flexion deficit of greater than 5° compared with the contralateral side. At review, 5 patients (21%) had such a deficit. Before surgery, 1 patient (3%) had an extension deficit of greater than 5°. At review, no patient had such a deficit.

Ligament Testing

Before surgery, posterior drawer testing at 90° of knee flexion revealed that 18 patients (58%) exhibited grade 2 laxity, and 13 patients (42%) had grade 3 laxity. At review, 1 patient (4%) showed a grade 2 posterior drawer, 11 patients (46%) showed grade 1, and 12 patients (50%) had grade 0 laxity ($P < .01$).

The reverse pivot shift examination was not documented in 5 patients preoperatively. Of the remaining 22 patients, preoperative examination for a reverse pivot shift test found 15 patients (56%) with a grade 0 result and 7 patients (26%) with a grade I or II result. At review, 21 patients (88%) had a grade 0 reverse pivot shift and 3 patients (12%) had a persistently positive grade 1 result ($P = .08$).

Instrumented Testing

Instrumented testing was not performed in patients before surgery. Instrumented testing presumes the presence of an intact contralateral knee. Because one patient had sustained an anterior cruciate ligament (ACL) rupture on the opposite knee between PCL reconstruction and review, 23 patients were available for instrumented testing at review. The median side-to-side difference in total anterior and posterior trans-

TABLE 3. *Percentage of Patients Able to Participate in Moderate or Strenuous Activities in the Absence of Key Mechanical Symptoms*

Symptom	Preoperative		Review	
	No of Patients	%	No of Patients	%
No pain	5	16	21	78
No swelling	12	39	24	89
No partial giving way	8	26	24	89
No full giving way	10	32	25	93

NOTE. Significant difference between preoperative and review assessment $P < .01$ in all categories.

TABLE 4. *Distribution of Overall IKDC Assessment*

IKDC Grade	Preoperative		Review	
	No of Patients	%	No of Patients	%
Normal [A]	0	0	4	17
Nearly normal [B]	0	0	12	50
Abnormal [C]	9	29	7	29
Severely abnormal [D]	22	71	1	4

NOTE. Significant difference between preoperative and review assessment $P < .01$ in all categories.

lation recorded with 9.1 kg of force was 1.0 mm (range, −2 to 3 mm). The side-to-side difference in total anterior and posterior translation was less than or equal to 2 mm in 17 patients (74%) and between 3 and 4 mm in the remaining 6 patients (26%).

Overall IKDC

Table 4 gives the breakdown for the percentage of patients in each of the 4 groups, A, B, C, and D, before surgery and at review. At review, 68% of patients had either a normal or nearly normal knee, a significant improvement from the preoperative assessment. Further details of the patient who received an IKDC grade of D are given in the subjective knee function category.

Kneeling Pain

Kneeling pain on a standard carpet surface was recorded for site and severity using an analogue score from 0 (no pain) to 10 (most severe pain). The presence of kneeling pain was not documented before surgery. At review, 21 patients reported no significant kneeling pain. However, the remaining 6 described discomfort localized to the anterior aspect of the knee with kneeling.

Activity Level

As shown in Fig 1, before injury, 29 patients (94%) participated regularly in moderate or strenuous activities. Before reconstruction, only 8 (26%) continued to perform at this level. At review, 17 patients (63%) were participating at this level of activity on a regular basis.

Influence of Timing of Surgery on Outcome

We examined the influence of the time between injury and surgical reconstruction on outcome. At
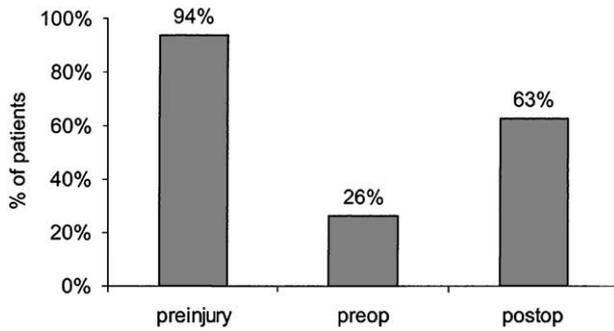
FIGURE 1. Patients participating in moderate to strenuous activities.

review, no correlation was found between time from surgery and the variables of subjective knee function ($P = .59$), posterior drawer testing ($P = .99$), overall IKDC grade ($P = .84$), Lysholm knee score ($P = .71$), or laxity on instrumented testing ($P = .51$).

Complications

One patient required a manipulation of the knee under general anesthesia 7 months after surgery for loss of knee flexion. One patient developed a deep venous thrombosis after surgery. This was managed successfully with thrombolytic medication. A 39-year old, nonsmoker with no previous risk factors sustained a fatal pulmonary embolus despite having a normal surgical and early postoperative course. Two patients required removal of a tibial RCI screw or tibial staple at 7 and 19 months after surgery for the presence of a ganglion mass. These resolved after surgical removal. One patient suffered a PCL graft rupture at 24 months after reconstruction during a football tackle. He subsequently underwent revision reconstruction. One patient suffered a contralateral ACL rupture at 12 months after surgery. He subsequently underwent endoscopic ACL reconstruction.

DISCUSSION

Isolated rupture of the PCL represents a small but distinct subgroup of traumatic injuries to the knee. PCL injuries are reported to account for between 3% and 37% of all knee ligament injuries.[31] The majority of PCL injuries may be treated with conservative means. However, some active patients will continue to exhibit symptoms such as an inability to run or pain with exercise and stairs. The results of this study suggest that arthroscopic reconstruction of the PCL significantly improves both the subjective and objec-

tive results for PCL-deficient patients for whom conservative management has failed.

Epidemiologic studies have identified sporting injuries and motor vehicle accidents as the 2 principal causes of PCL rupture.[32] In this study, sporting injury, with a direct tackle, accounted for the majority of injuries. A dashboard injury with posterior displacement of the tibia on the femur in a flexed knee was the second most common mechanism of trauma. A number of much less common mechanisms of injury have been described. These include extreme varus or valgus stress, forced hyperextension, and disruption in combination with other ligament injuries.[33]

The majority of PCL ruptures may be managed quite successfully with supervised conservative measures.[3-6] In this series, the total of 31 patients who underwent surgical intervention represent less than 50% of the total number seen by the principal investigator during the same study period. An aggressive quadriceps program should be directed at counteracting the tendency to posterior subluxation of the tibia and resultant episodes of instability. However, a minority of patients will continue to experience disabling symptoms despite such therapy.

A number of studies have examined the effect of conservative treatment on PCL injuries. Most recently, Shelbourne et al.[6] studied 133 patients with isolated PCL injuries treated with an unsupervised rehabilitation program and found that 42% consistently rated the knee as good or excellent. Shino et al.[3] studied 15 patients with PCL injuries and reported that 53% had an overall IKDC of A or B and 73% were participating in moderate to strenuous activities.

Boynton and Tietjens[7] reported poorer results in a series of 30 patients, of whom 81% reported at least occasional pain and 56% at least occasional swelling. Keller et al.[11] reported that 90% of 40 PCL-deficient subjects complained of knee pain with activity despite excellent muscular knee strength. Both Boynton and Tietjens[7] and Keller et al.[11] report a significant deterioration in both subjective symptoms and radiographic examination over time. Reports have been conflicting regarding the influence of the degree of laxity on subjective results.[6,7,11] To date, no comparative studies have been performed between conservative and surgical treatment of the PCL injury.

A limited amount of literature is currently available examining the effectiveness of surgical treatment of PCL injuries.[16-21] Unfortunately, a lack of standardization for surgical technique, type of injury, and surgeon limits these studies. These factors make comparing the results with those of this study or the results

of conservative treatment difficult. Additionally, most studies involve open surgical techniques for reconstructing the PCL. Previously, the perceived morbidity from open surgical reconstructive procedures was considered to outweigh any potential benefits of surgery. However, arthroscopic techniques have considerably reduced such surgical risk and offer the patient surgery as a single-day procedure with the opportunity to participate in an early rehabilitation program.

We believe that surgical reconstruction has an important role in a carefully selected group of patients who have shown knee pain secondary to PCL disruption despite a supervised program of appropriate physiotherapy. In this study, all patients had not obtained satisfactory outcomes preoperatively despite a supervised rehabilitation program of at least 14 weeks. All patients complained of pain or instability preventing running activities, and all had greater than grade 1 laxity on posterior drawer testing.

The principal indication for surgical reconstruction is the abolition of pain. This pain is experienced at the anterior aspect of the knee and may result from increased contact force at the patellofemoral articulation from loss of the quadriceps lever arm. On IKDC testing at review, 78% of patients reported being able to participate in moderate to strenuous activity without pain. However, the Lysholm knee score revealed that a significant minority of our patients continued to experience inconstant and slight discomfort during heavy exertion.

Surgeons must consider the severity of symptoms and level of activity of the patient during patient selection. Naturally, the more active patient appears more likely to require surgical reconstruction with the express goal of return to a high level of sports. In our study group, 94% of the group participated in moderate or strenuous activity before injury. This figure had fallen to 26% before reconstruction. Identifying an increase in this figure to 63% at 2-year review is encouraging.

The IKDC rating system and Lysholm knee score have been used extensively to analyze the outcome from reconstruction of the ACL, and both represent reliable methods of knee functional assessment.[25] PCL disruption is not frequently associated with significant loss of motion, and ligament testing is designed for assessing anterior translation. Therefore, subjective knee function and symptoms with activity should represent the most discriminatory variables for the outcome from PCL reconstruction. Indeed, before surgery, only 23% of patients believed that the knee function was normal or nearly normal. This figure

improved to 93% at review ($P < .01$). If the patient who experienced a graft rupture is included and assumed to report knee function as abnormal, this percentage remains high at 89%. A significant reduction in the percentage of patients experiencing pain, swelling, or giving way with activity was also recorded. The median Lysholm knee score improved from 64 before surgery to 94 at review. Significant improvements were found at review for the variables of knee locking, instability, pain, swelling, and squatting.

The role of instrumented testing in the assessment of knee function after PCL injury remains the subject of debate. Recently, a more standardized method of assessment has been proposed and validated.[29] We have used this technique to identify side-to-side differences in posterior displacement of the tibia on the femur. We were reassured to find that 17 patients (74%) were found to exhibit a displacement of 2 mm or less compared with the contralateral knee. No patient exhibited more than 3 mm side-to-side difference in laxity.

PCL disruption allows for increased shear force transmission across the tibiofemoral interface and may predispose the joint to chondral or meniscal injury. Experimental studies of PCL rupture have shown increased patellofemoral contact forces and a reduced lever arm of the quadriceps mechanism.[34,35] Although researchers accept that chronic ACL rupture increases the risk of premature degenerative change in the knee, no such consensus of opinion exists for PCL disruption. Indeed, the most appropriate timing of surgical intervention remains uncertain. Earlier intervention may limit episodes of instability and reduce the risk of irreversible meniscal or chondral damage. Other authors[7,11] have found a high level of radiographic arthritic change in untreated ruptures. This change appeared to correlate with the length of time from injury. We have not specifically examined for temporal evidence of such change; however, planned medium-term review at 5 years with radiographic analysis may identify it.

We believe that this study is unique for a number of reasons. All surgery was performed by a single surgeon, with prospective evaluation of the outcome of intervention. However, limitations of the work must be acknowledged. No control group was studied. The graft used was always a hamstring composite, but 2 types of accessory distal fixations at the tibial side were used. We believe that the nature of PCL reconstruction and its anatomic configuration ensured that the fixation modalities used were required to ensure secure graft placement. The study group comprised

low-velocity sporting injuries with minimal collateral or posterolateral corner laxity. This study group remains the subject of ongoing review and we anticipated analyzing medium-term results.

In conclusion, the PCL remnant is retained in this reconstructive procedure, thus augmenting the PCL structure with an anterolateral 4-strand hamstring tendon autograft. In this select group of patients, for whom conservative management failed, short-term review of arthroscopic reconstruction of the PCL has been shown to produce a reliable surgical outcome. Clear indications must exist for surgical intervention. Surgical reconstruction allows for return to a high level of sporting activity in the absence of key symptoms of pain, swelling, or giving way, with the majority of patients rating their knee as normal or nearly normal.

REFERENCES

1. Deehan DJ, Pinczewski LA. Arthroscopic reattachment of an avulsion fracture of the tibial insertion of the posterior cruciate ligament: A novel technique. *Arthroscopy* 2001;17:422-425.
2. Torisu T. Avulsion fracture of the tibial attachment of the posterior cruciate ligament: Indications and results of delayed repairs. *Clin Orthop Rel Res* 1979;143:107-114.
3. Shino K, Horibe S, Nakata K, et al. Conservative treatment of isolated injuries to the posterior cruciate ligament in athletes. *J Bone Joint Surg Br* 1995;77:895-900.
4. Fowler PJ, Messieh SS. Isolated posterior cruciate ligament injuries in athletes. *Am J Sports Med* 1987;15:553-557.
5. Parolie JM, Bergfeld JA. Long-term results of non-operative treatment of isolated posterior cruciate ligament injuries in the athlete. *Am J Sports Med* 1986;14:35-38.
6. Shelbourne KD, Davis TJ, Patel DV. The natural history of acute, isolated, non-operatively treated posterior cruciate ligament injuries. *Am J Sports Med* 1999;27:276-283.
7. Boynton MD, Tietjens BR. Long-term followup of the untreated isolated posterior cruciate ligament-deficient knee. *Am J Sports Med* 1996;24:306-310.
8. Cross M, Powell J. Long-term follow-up of posterior cruciate ligament rupture: A study of 116 cases. *Am J Sports Med* 1984;12:292-297.
9. Dandy D, Pusey R. The long-term results of unrepaired tears of the posterior cruciate ligament. *J Bone Joint Surg Br* 1982; 64:92-94.
10. Dejour H, Walch G, Peyrot J, Eberhard P. The natural history of rupture of the posterior cruciate ligament. *Orthop Trans* 1987;11:146.
11. Keller PM, Shelbourne KD, McCarroll JR, Rettig AC. Non-operatively treated isolated posterior cruciate ligament injuries. *AM J Sports Med* 1993;21:132-136.
12. Covey DC, Sapega AA. Current concepts review: Injuries to the posterior cruciate ligament. *J Bone Joint Surg Am* 1993; 75:1376-1386.
13. Clancy W, Pandya R. Posterior cruciate ligament reconstruction with patellar tendon autograft. *Clin Sports Med* 1994;13: 561-570.
14. Rosenberg T, Paulos L, Abbott P. Arthroscopic cruciate repair and reconstruction: An overview and description of technique. In: Feagin, J, ed. *The crucial ligaments: Diagnosis and treat-*
ment of ligamentous injuries about the knee. New York: Churchill Livingstone, 1988;409-423.
15. Strobel M. Posterior cruciate ligament. In: Strobel M, ed. *Manual of arthroscopic surgery.* Heidelberg: Springer-Verlag; 2002.
16. Kim S, Kim H, Kim H. Arthroscopic posterior cruciate ligament reconstruction using a one-incision technique. *Clin Orthop* 1999;359:156-166.
17. Mariani P, Adriani E, Santori N, Maresca G. Arthroscopic posterior cruciate ligament reconstruction with bone-patellar-bone tendon graft. *Knee Surg Sports Traumatol Arthrosc* 1997; 5:239-244.
18. Noyes F, Barber-Westin S. Posterior cruciate ligament allograft reconstruction with and without a ligament augmentation device. *Arthroscopy* 1994;10:371-382.
19. Richter M, Kiefer H, Hehl G, Kinzl L. Primary repair for posterior cruciate ligament injuries: An eight-year followup of fifty-three patients. *Am J Sports Med* 1996;24:298-305.
20. Fanelli GC, Giannotti BF, Edson CJ. Arthroscopically assisted combined posterior cruciate ligament/posterior lateral complex reconstruction. *Arthroscopy* 1996;12:521-530.
21. Insalata J, Harner C. Treatment of acute and chronic posterior cruciate ligament deficiency. *Am J Knee Surg* 1996;9:185-193.
22. Pinczewski L, Thuresson P, Otto D, Nyquist F. Arthroscopic posterior cruciate ligament reconstruction using four-strand hamstring tendon graft and interference screws. *Arthroscopy* 1997;13:661-665.
23. Anderson AF. Rating Scales. In: Fu FH, Harner CD, Vince KG, eds. *Knee Surgery.* Baltimore: Williams & Wilkins, 1994; 275-296.
24. Hoher J, Bach T, Munster A, et al. Does the mode of data collection change results in a subjective knee score? Self-administration versus interview. *Am J Sports Med* 1997;25: 642-647.
25. Tegner YJL. Rating systems in the evaluation of knee ligament injuries. *Clin Orthop* 1985;198:43-49.
26. Galway R, Beaupre A, MacIntosh D. Pivot shift: a clinical sign of symptomatic anterior cruciate ligament insufficiency. *J Bone Joint Surg Br* 1972;71:763-764.
27. Jakob R, Hassler H, Staeubli H. Observations of rotary instability of the lateral compartment of the knee: Experimental studies on the functional anatomy and pathomechanism of the true and reversed pivot shift sign. *Acta Orthop Scand* 1981; 52S:1-32 (suppl).
28. Torg J, Conrad W, Kalen V. Clinical diagnosis of anterior cruciate ligament instability in the athlete. *Am J Sports Med* 1976;4:84-93.
29. Huber FE, Irrgang JJ, Harner C, Lephart S. Intratester and intertester reliability of the KT-100 arthrometer in the assessment of posterior laxity of the knee. *Am J Sports Med* 1997; 25:479-485.
30. Altman D. *Practical Statistics for Medical Research.* London: Chapman and Hall, 1991.
31. Harner CD, Hoher J. Evaluation and treatment of posterior cruciate ligament injuries. *Am J Sports Med* 1998;26:471-482.
32. Johnson C, Bach B. Current concepts review: Posterior cruciate ligament. *Am J Knee Surg* 1990;3:143-153.
33. Fanelli G, Giannotti B, Edson C. Current concepts review: The PCL arthroscopic evaluation and treatment. *Arthroscopy* 1994; 10:673-688.
34. Hagena F, Plitz W, Muhlberger G, Carl C. Retropatellar forces after rupture of the PCL and patello-tibial transfixation: An in vitro study. *Knee Surg Sports Traumatol Arthrosc* 1994;2:31-37.
35. Tibone J, Aantich T, Perry J, Moynes D. Functional analyses of untreated and reconstructed posterior cruciate ligament injuries. *Am J Sports Med* 1988;16:217-223.