Clinical Outcomes After Isolated Arthroscopic Single-Bundle Posterior Cruciate Ligament Reconstruction

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Purpose: The purpose of this study was to evaluate the clinical outcomes after arthroscopic single-bundle posterior cruciate ligament (PCL) reconstruction in patients with isolated grade III PCL injuries. **Type of Study:** Retrospective review. **Methods:** Twenty-one patients who underwent an isolated arthroscopic single-bundle PCL reconstruction for the treatment of a grade III PCL injury between 1989 and 1998 were included in the study. There were 15 male and 6 female patients with an average age of 38 years (range, 20 to 62 years). The length of follow-up was 5.9 years (range, 2.6 to 11 years), and the average time from injury to surgery was 4.5 years (median, 1.3 years; range, 2 weeks to 25 years). All patients completed a subjective evaluation and 14 patients returned for a physical examination and radiographs. One patient underwent an acute reconstruction (<3 weeks), 4 had a subacute (<3 months), and 16 underwent a chronic (>3 months) reconstruction. The anterolateral bundle of the PCL was reconstructed using an Achilles tendon allograft passed through femoral and tibial bone tunnels. **Results:** The overall average Activities of Daily Living Scale (ADLS), Sports Activities Scale (SAS), and SF-36 scores were 79.3, 71.6, and 98 points, respectively. There was a significant difference identified when the ADLS (91.3 *v* 75.6) and the SAS (90.4 *v* 65.8) scores of the subacute/acute group were compared with those of the chronic reconstruction group. Using the International Knee Documentation Committee (IKDC) subjective assessment, 57% of the patients had normal/near normal knee function, and 62% had a normal/near normal activity level. The average extension and flexion losses were 1° and 5°, respectively. Instrumented laxity examination revealed that 62% had less than a 3-mm and 31% had a 3- to 5-mm side-to-side difference in corrected posterior displacement. Radiographs at follow-up showed that 75% had normal/near normal findings according to IKDC guidelines. **Conclusions:** The clinical outcomes after arthroscopic single-bundle PCL reconstruction in this study produced a satisfactory return of function and improvement in symptoms. All patients in this study had improved laxity of at least 1 grade. When compared with chronic reconstructions, acute reconstructions had statistically significant better ADLS and SAS scores. **Level of Evidence:** IV, case series. **Key Words:** Posterior cruciate ligament—Reconstruction—Ligament.

The management of posterior cruciate ligament (PCL) injuries remains a challenging clinical problem. The PCL is the primary restraint to posterior tibial translation and a secondary restraint to external tibial rotation.[1-5] Isolated sectioning of the PCL results in increased posterior tibial translation, which is more pronounced at 90° of flexion and decreases near full extension.[1,6-7] Isolated and combined PCL injuries

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have also been shown to increase the contact forces in the medial and patellofemoral compartments of the knee, which may lead to increased wear and early chondrosis.[8] Although reports of several clinical studies recommend nonoperative treatment for isolated PCL injuries,[9-12] other reports have questioned the efficacy of this form of treatment.[13-15]

The single-bundle technique was developed to reconstruct the anterolateral PCL bundle because of its larger size and greater biomechanical properties when compared with the posteromedial bundle.[16-20] In addition, the anterolateral bundle of the PCL has the greatest tension at 90° of flexion, which is the most functional position to resist posterior tibial translation. Although several studies have attempted to determine the optimal isometric femoral tunnel position for reconstructing the anterolateral PCL bundle, no isometric point has been found.[21-31] Despite these and many other recent studies, no single PCL reconstruction technique has been widely accepted.

The primary purpose of this study was to retrospectively evaluate the clinical outcomes following isolated single-bundle PCL reconstruction. Secondarily, the results of the acute and chronic reconstructions were also compared. We hypothesized that the clinical outcomes after single-bundle PCL reconstruction would be satisfactory and that the acute reconstructions would have better results than the chronic reconstructions.

METHODS

Twenty-five patients underwent isolated arthroscopic single-bundle PCL reconstruction for the treatment of a grade III PCL injury between 1989 and 1998 at our institution. All patients selected for surgery were felt to represent isolated PCL injuries. A grade III PCL was defined according to the International Knee Documentation Committee (IKDC) score of greater than 10 mm of posterior tibial translation compared with the contralateral knee at 90° of flexion, which corresponds clinically to the anteromedial tibial plateau passing posterior to the medial femoral condyle during a posterior drawer examination.[21] Twenty-one of these patients were available for follow-up and were included in the study. All of the patients completed subjective questionnaires and 14 of these patients returned for a physical and radiographic examination. There were 15 male and 6 female patients with a mean age of 38 years (range, 20 to 62 years). The mean length of follow-up was 5.9 years (range, 2.6 to 11 years). The average time from injury to surgery was 4.5 years (median, 1.3 years; range, 2 weeks to 25 years). One patient underwent an acute reconstruction (<3 weeks), 4 had a subacute (<3 months) and 16 a chronic (>3 months) reconstruction.

Surgical technique

The patients included in this study underwent a single-bundle PCL reconstruction. An Achilles tendon allograft was used to reconstruct the anterolateral bundle of the PCL. An examination under anesthesia was performed to confirm a grade III PCL injury without evidence of posterolateral or posteromedial insufficiency.

Arthroscopy was then performed and any associated meniscal pathology was addressed. The damaged PCL was debrided, leaving a remnant of the tibial and femoral attachments, and preserving the meniscofemoral ligaments whenever possible. An accessory posteromedial arthroscopic portal and a 70° arthroscope were also used for improved visualization.[32]

With the knee in 90° of flexion, a PCL drill-guide (Linvatec, Largo, FL) was used to place a transtibial guide pin from the anteromedial tibia through the center of the tibial footprint, which is usually located 1 cm below the joint line, just lateral to the center of the lateral tibial tubercle. A lateral radiograph was then made to verify the appropriate pin placement (Fig 1). The tibial tunnel was carefully drilled to an 11-mm diameter and then compressed with an 11-mm dilator. A guide pin was then placed in the anatomic femoral footprint of the anterolateral bundle through the anterolateral portal at the 1 o'clock position in a right knee, 6 mm off of the articular margin (Fig 2). The femoral tunnel was then drilled to an 11-mm diameter

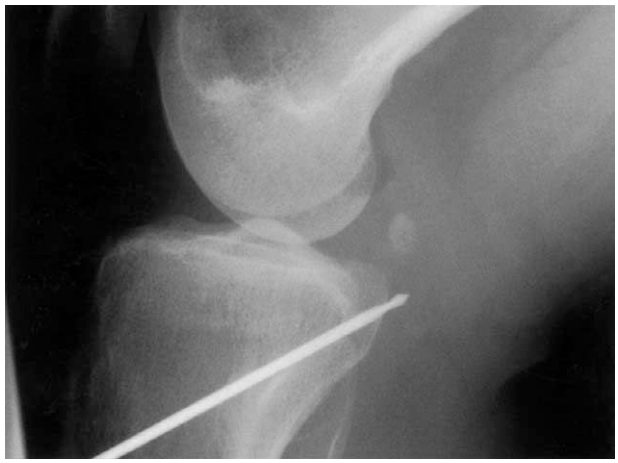

FIGURE 1. Intraoperative lateral radiograph showing appropriate guide pin placement for the PCL tibial tunnel.

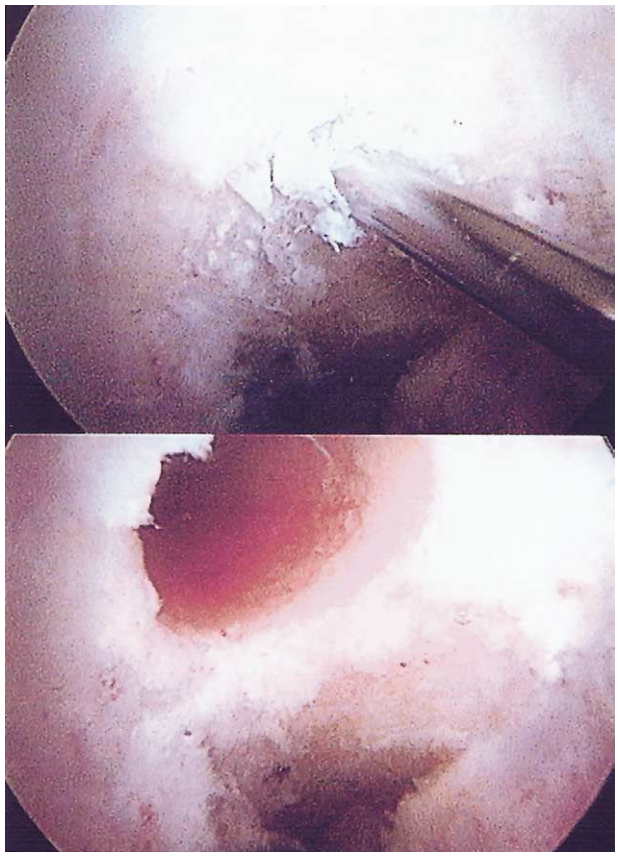

Figure 2. The top image shows the guide pin in the footprint of the anterolateral bundle of the PCL. The bottom image shows the 11-mm anterolateral femoral tunnel for the PCL graft.

and a depth of 30 mm. The edges of the femoral and tibial tunnels were smoothed with a rasp to prevent graft abrasion.

The Achilles tendon allograft with attached bone plug (11 × 25 mm) was prepared to fit an 11-mm tunnel and sutured with No. 5 braided nonabsorbable suture (Fig 3). An 18-gauge wire loop was threaded up the tibial tunnel from outside-in, and then grasped from inside-out through the femoral tunnel. This wire loop was then used to pull the Achilles graft from outside the femoral tunnel, which was then passed intra-articularly into the knee joint and then into the tibial tunnel. The bone plug was fixed in the femoral tunnel with a metal interference screw placed from outside-in. The graft was then tensioned while the knee was brought through several flexion-extension cycles. The knee was then flexed to 90°, and an anterior drawer was applied to the tibia. With tension applied to the graft, a screw and soft tissue washer were used fix the Achilles tendon allograft to the anteromedial tibia (Fig 4).

Figure 3. The Achilles tendon allograft is fashioned to fit the 11-mm tunnels and secured with No. 5, braided, nonabsorbable suture on both ends.

The knee was then examined. If any residual laxity persisted, the tibial fixation was repeated until stability was obtained. An intact vascular examination was always confirmed. The knee was braced in full extension with passive flexion allowed to 90° for 4 weeks. Gradual progressive motion and resistive exercises were then started.

Follow-up evaluation

All of the patients completed subjective questionnaires including specific and general measures of health status. The specific measures of health status included the Knee Outcome Survey[33] and the subjective assessment of the IKDC Knee Ligament Standard Evaluation Form. The SF-36[34,35] was used as a measure of general health status.

The Knee Outcome Survey[33] is a knee specific measure of symptoms and functional limitations that has been developed for individuals with a variety of knee problems including meniscal injuries. The Knee Outcome Survey consists of 2 separate scales, the Activities of Daily Living (ADLS) and the Sports Activity Scale (SAS). The ADLS includes symptom-

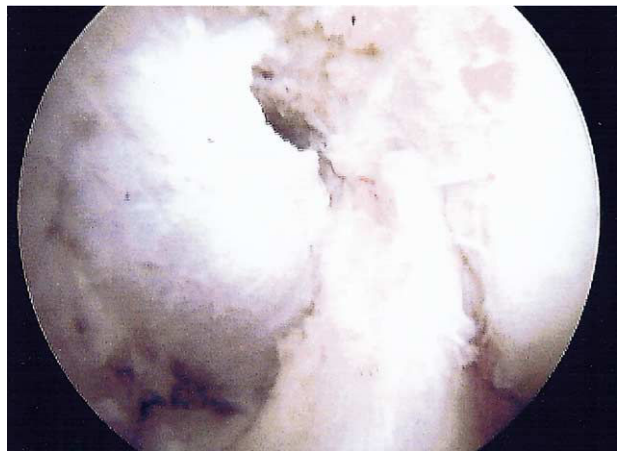

Figure 4. Arthroscopic view of the single-bundle PCL reconstruction with the knee in 70° of flexion.

atic and functional limitations experienced during activities of daily living and the SAS consists of symptomatic and functional limitations experienced during sports activities. Each scale is scored from 0 to 100 with 100 representing higher levels of function and the absence of symptoms.

The SF-36[34,35] is a general health-status measure that is applicable to diverse populations of individuals with a variety of conditions. The SF-36 consists of 8 scales including physical function, role limitations due to physical problems, bodily pain, general health, vitality, social functioning, role limitations due to emotional problems, and mental health. The 8 scale scores can be combined into physical and mental components. The SF-36 has been used to measure general health status for a variety of orthopaedic conditions, including anterior cruciate ligament reconstruction and meniscus transplantation.[36,37]

The follow-up examination was performed by an independent physical therapist and physician. The examination included an assessment of swelling, crepitus, range of motion, stability, and functional strength. Crepitus of the patellofemoral, medial, and lateral compartments, and swelling were graded by palpation as present or absent. Range of motion was measured with a goniometer and the side-to-side differences for extension and flexion were calculated.

The examination for laxity included the Lachman, pivot-shift, anterior drawer, and posterior drawer tests, and tests for anterolateral and posterolateral rotatory and varus/valgus laxity. Laxity was graded relative to the contralateral side according to IKDC guidelines as normal (<2 mm side-to-side difference), nearly normal (3 to 5 mm side-to-side difference), abnormal (6 to 10 mm side-to-side difference), or severely abnormal (>10 mm side-to-side difference). A corrected KT-1000 arthrometer (MEDmetric, San Diego, CA) measurement (using the quadriceps active test at the neutral angle) was also performed to assess posterior laxity of the injured compared with the uninjured knee.[38]

Functional testing was also performed, including the single-leg hop and vertical-jump tests. Both lower extremities were tested and the results were reported as a percentage of the noninvolved side.

Radiographs were obtained on the return visit and were compared with those obtained preoperatively. These included posteroanterior 45° flexion weight-bearing, lateral, Merchant, and long cassette views. The medial and lateral joint spaces of both knees were measured on posteroanterior 45° flexion weight-bearing views using a digital micrometer rounded off to the nearest millimeter. In addition, both preoperative and follow-up radiographs were staged according to IKDC radiographic criteria. In addition to the IKDC ligament examination and radiographic findings, IKDC scores were generated for all other categories including subjective assessment, symptoms, range of motion, and an overall evaluation.

Data analysis

Descriptive statistics, including frequencies and mean values, were calculated for all variables. The independent t test for the continuous outcome measures and the χ-square tests for frequency outcome measures were used to compare the outcomes of the acute/subacute (<3 months) with those of the chronic (>3 months) reconstructions. A dependent t test was used to evaluate changes in the joint space from before surgery to follow-up. Significance was set at $P < .05$.

RESULTS

Subjective results

IKDC Subjective Assessment

The IKDC subjective evaluation was based on patient-reported self-assessments of their knee function and activity level (Table 1). In terms of knee function, 57% of patients stated that they were normal or nearly normal, whereas 43% were abnormal or severely abnormal. In terms of activity level, 62% of patients described a normal or nearly normal level of activity and 38% who reported abnormal or severely abnormal activity level.

In the acute/subacute group, all patients reported normal or nearly normal knee function. In the chronic reconstruction group, 43.7% of patients reported normal or nearly normal knee function versus 56.3% who reported abnormal or severely abnormal function ($P = .17$).

All patients in the acute/subacute group reported a normal or nearly normal activity level. Fifty percent of patients in the chronic group stated that they had a normal or nearly normal activity level; 50% of patients reported that they were abnormal or severely abnormal ($P = .20$).

Symptoms

Patients' symptoms were graded according to the highest level of activity (strenuous, moderate, light, or sedentary) that the patient could perform without significant pain, swelling, or instability (Table 1). Based

TABLE 1. *IKDC Scores*

IKDC Categories	Normal	Nearly Normal	Abnormal	Severely Abnormal
Knee function	43% (9)	14% (3)	33% (7)	10% (2)
Acute/subacute	80% (4)	20% (1)	0% (0)	0% (0)
Chronic	31% (5)	12.5% (2)	44% (7)	12.5% (2)
Activity level	43% (9)	19% (4)	28% (6)	10% (2)
Acute/subacute	80% (4)	20% (1)	0% (0)	0% (0)
Chronic	31% (5)	19% (3)	37.5% (6)	12.5% (2)
Range of motion	64% (9)	29% (4)	7% (1)	0% (0)
Posterior drawer	0% (0)	50% (7)	50% (7)	0% (0)
Acute/subacute	0% (0)	75% (3)	25% (1)	0% (0)
Chronic	0% (0)	40% (4)	60% (6)	0% (0)
Reverse pivot-shift	86% (12)	7% (1)	0% (0)	7% (1)
External rotation 30°	86% (12)	7% (1)	7% (1)	0% (0)
External rotation 90°	86% (12)	0% (0)	14% (2)	0% (0)
Radiographic examination	25% (3)	50% (6)	17% (2)	8% (1)

on the IKDC assessment of symptoms, 15 patients did not have pain during ADL, 14 did not have swelling, and 4 patients had episodes of instability during ADL.

Fewer patients were asymptomatic during moderate and strenuous sports activities. Eleven patients could participate in moderate or strenuous sports without pain, 10 could participate without swelling, and 11 patients could participate in these activities without instability.

Knee Outcome Survey

The average ADLS score of the Knee Outcome Survey was 79 points (range, 43-100), and the average SAS score was 72 points (range, 10-100) (Fig 5). The average ADLS and SAS scores of the patients who underwent an acute/subacute reconstruction were 91 and 90, respectively. The average ADLS and SAS scores of the chronic reconstructions were 76 and 66, respectively. The differences in the scores of the acute/subacute and chronic groups were found to be statistically significant ($P = .009$ for ADLS and $P = .004$ for SAS).

SF-36 Scores

The scores of the 8 categories of the SF-36 suggest that the patients were functioning physically, mentally, and socially at average levels when compared with the standard population (Table 2, Fig 5). The physical and mental components summary scores represent a single combined score of the 8 categories of the SF-36. In the United States population, the physical and mental scores each have a mean of 50 and standard deviation of 10. The average physical component score overall was 47 points (range, 29-62), and the average mental component score was 51 points (range, 20-60). These scores indicate that physical function was slightly below and mental function was slightly above the US population norms.

The average physical component score of the acute/subacute group (53 points) was significantly higher than that of the chronic reconstructions (45 points) ($P = .036$). The average mental component scores of the acute/subacute versus the chronic reconstructions were 52 and 51, respectively ($P = .92$).

Overall Self-Rating

When patients were asked if they would undergo the procedure again given similar circumstances, 20 of 21 patients replied "yes."

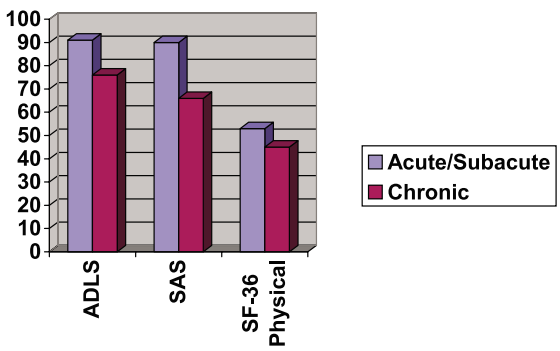

FIGURE 5. Subjective results of acute/subacute and chronic reconstructions. The scores for the acute/subacute groups are significantly higher than those of the chronic group for the ADLS, SAS, and SF-36 Physical Component Summary ($P < .05$).

Table 2. *SF-36 Results*

SF-36	Average Score Overall	Average Score Acute/Subacute	Average Score Chronic	*P* Value
Physical component	47	53	45	.036
Mental component	51	52	51	.92

Objective results

Fourteen of the 21 patients had a complete physical and radiographic examination. Five of the patients in the acute/subacute group and 9 of the patients in the chronic group had the examination and radiographs at follow-up. The results of the objective parameters are as follows.

Range of Motion

The average loss of flexion compared with the noninvolved knee was 5° ± 5° (range, −1° to 18°). The average loss of extension compared with the noninvolved knee was 1° ± 3° (range, 6° more extension to 5° loss of extension on the involved side).

The side-to-side difference of flexion and extension were combined according to IKDC guidelines to create an IKDC group rating (Table 1). The IKDC group rating for range of motion was normal or nearly normal for 93% of patients, with 7% having an abnormal score.

Stability Testing

IKDC Ligament Examination (Table 1): No patient had a normal posterior drawer test. Fifty percent had a nearly normal posterior drawer and 50% had an abnormal posterior drawer. Total posteroanterior translation was normal or nearly normal in 86% of patients; 14% of patients had an abnormal or severely abnormal examination with posteroanterior translation. Ninety-three percent of patients had a normal or nearly normal reverse pivot-shift test versus 7% with a severely abnormal pivot-shift. Twelve patients had less than a 5° side-to-side difference in external rotation at 30° and 90° of knee flexion. One patient had a nearly normal examination result in external rotation at 30° and 1 patient had an abnormal result at 30°. Two patients had an abnormal result in external rotation at 90°. All patients had normal or near normal findings with the remaining ligament testing, including the Lachman test, anterior drawer, and pivot-shift test.

The posterior drawer examination was normal or nearly normal in 75% of the acute/subacute patients versus 40% in the chronic group. The posterior drawer examination was abnormal or severely abnormal in 25% of the acute/subacute group versus 60% in the chronic group ($P = .24$).

KT-1000 Arthrometer Testing (Table 3): The average corrected posterior drawer using the KT-1000 on the involved knee was 4.5 mm (range, 2 to 10 mm). When this value was compared with the uninvolved knee, the average side-to-side difference was 1.96 mm (range, −1 to 6 mm). Overall, the corrected KT-1000 posterior laxity measurement showed that 62% of the tested patients had less than a 3-mm side-to-side difference, 31% had a 3- to 5-mm side-to-side difference in corrected posterior displacement, and 8% had a 6- to 10-mm side-to-side difference.

The average corrected posterior drawer in the acute/subacute group was 4.3 mm versus 4.6 mm in the chronic group ($P = .81$). The average side-to-side corrected posterior drawer difference was 1.3 mm in the acute/subacute group and 2.3 mm in the chronic reconstruction group ($P = .45$).

Functional Testing

The single-leg hop and vertical jump tests were performed to assess functional strength. Expressed as a percentage of the noninvolved leg, the single-leg hop and vertical jump averaged 90% ± 16% (range, 54% to 104%) and 91% ± 13% (range 67% to 111%), respectively.

Radiographic Evaluation

Radiographs obtained at follow-up of the involved knee were normal in 25% of the patients, nearly normal in 50%, abnormal in 17%, and severely abnormal in 8% of the patients according to IKDC guidelines.

DISCUSSION

The management of PCL injuries remains a challenging clinical problem. Numerous studies have de-

Table 3. *Corrected KT-1000 Posterior Displacement*

KT-1000	Mean Overall	Mean Acute/Subacute	Mean Chronic
Corrected posterior drawer	4.5 mm	4.3 mm	4.6 mm
Side-to-side difference	1.96 mm	1.25 mm	2.28 mm

scribed the anatomy and the biomechanical properties of the PCL.[39-42] Studies have also provided a scientific rationale for PCL reconstruction (single- *v* double-bundle), graft selection, tunnel placement, and fixation.[43-61] However, no single PCL reconstruction technique has emerged as the one that is consistently accepted by all orthopaedic surgeons.

There are very few clinical studies reporting the outcomes of isolated single-bundle PCL reconstructions, likely because of the relatively low incidence of this injury pattern and the high association with multiligament injuries. Mariani et al.[62] retrospectively reviewed 24 patients following arthroscopic single-bundle PCL reconstruction with a patellar tendon autograft. They found that, with a minimum follow-up of 2 years, only 25% of patients were normal and that 21% of patients were abnormal or severely abnormal according to IKDC criteria. Chen et al.[63] compared quadriceps tendon versus hamstring autograft for performing an isolated single-bundle PCL reconstruction with an average follow-up of 2 years. They found no differences between the 2 grafts and that 31% of patients were normal, 57% were nearly normal, and 12% were abnormal according to IKDC posterior drawer testing.

The clinical outcomes in this study after arthroscopic single-bundle PCL reconstruction produced a satisfactory return of function and improvement in symptoms and were in line with the 2 previous reports in the literature. Minimal symptoms were encountered in our patients during ADL. However, when activities were increased, symptoms increased.

Objectively, all patients had improved laxity of at least 1 grade with posterior drawer testing, with 50% of these patients improving 2 grades. The average corrected posterior drawer using the KT-1000 to compare side-to-side differences was 1.96 mm. Overall, the corrected KT-1000 posterior laxity measurement revealed that 62% of patients had less than a 3 mm and 31% had a 3 to 5 mm side-to-side difference in corrected posterior displacement. Range of motion was excellent at latest follow-up, with all but 1 patient having normal or nearly normal ratings according to IKDC criteria. The average vertical jump was 91% and single-leg hop was 90% of the uninvolved leg. Evaluation of radiographs at follow-up showed that 75% of the patients had normal or near normal findings according to IKDC guidelines.

Acute/subacute reconstructions had significantly better ADLS, SAS, and SF-36 (physical component) scores when compared with the chronic reconstructions. The differences seen between the 2 groups may be attributable to a number of factors. Chronic PCL deficiency may result in increased contact pressures in the patellofemoral and medial compartments of the knee that lead to compartmental pain and eventual arthrosis, which may be difficult to reverse despite surgical stabilization. In addition, chronic PCL injuries usually develop some degree of posterior tibial sag that may resist surgical correction. This does not occur in acute/subacute reconstructions.

While stability improved after surgery and persisted at latest follow-up, residual laxity was still present. Only moderate subjective results were obtained following single-bundle PCL reconstruction in this study. These results were not as good as those seen in previous studies from our institution of other knee surgeries, including anterior cruciate ligament reconstructions and meniscal allograft transplantations.

There are several possible reasons for the moderate results in this study. Isolated grade III PCL injuries are rare and are often associated with posterolateral corner injuries. Failure to address these posterolateral injuries at the time of the PCL reconstruction may have contributed to our results.[64,65] Also, recent studies have determined that a more "anatomic" double-bundle construct is necessary to restore in situ forces and kinematics of the native PCL.[42-47] It is possible that this double-bundle PCL reconstruction may have improved our results.

Some have suggested that the "killer turn" in the transtibial tunnel technique leads to graft wear and potential elongation as the ligament exits the intra-articular tibial tunnel. While some biomechanical studies have corroborated this belief, Noyes et al.[66] presented a study at the Annual Meeting of the American Academy of Orthopaedic Surgeons in 2003 that compared the tibial inlay to the transtibial technique. Thirty PCL reconstructions were included in the study, with 17 inlays and 13 transtibial tunnels. No statistical difference was found between the 2 techniques in posterior displacement at a mean follow-up of 42 months (range, 24 to 72 months).

Other weaknesses of our study include its retrospective design, small sample size, lack of control groups, and the loss of some patients to follow-up, which may have affected our results. Future directions include the functional analysis of PCL-deficient patients, a comparison of nonoperatively treated versus surgically reconstructed PCL-injured knees, and an assessment of clinical outcomes following double-bundle PCL reconstructions.

CONCLUSIONS

The clinical outcomes after arthroscopic single-bundle PCL reconstruction produced a satisfactory return of function and improvement in symptoms. All patients had improved laxity of at least 1 grade. Based on our data, acute/subacute reconstructions had statistically significant better subjective outcomes than did chronic reconstructions. Other differences may exist, but our sample size was not sufficient to detect them.

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