Comparison of Tibial Inlay Versus Transtibial Techniques for Isolated Posterior Cruciate Ligament Reconstruction: Minimum 2-Year Follow-up

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Purpose: Surgical treatment of isolated posterior cruciate ligament (PCL) injuries is controversial. The purpose of this retrospective study was to evaluate the surgical outcomes of PCL reconstruction. Two techniques were compared, the traditional endoscopic and the more recent tibial inlay, to determine if the inlay technique yielded more stable reconstructions. **Type of Study:** Retrospective study of surgical outcomes. **Methods:** Between 1980 and 1997, 29 patients underwent surgery for isolated PCL injuries at our institution. Two patients underwent primary repair, 4 underwent primary repair with semitendinosus-gracilis augmentation, and 1 had a tibial inlay with a double femoral tunnel, and these patients were excluded from this study. Two patients were lost to follow-up, leaving 20 patients who were evaluated at a mean follow-up of 5.7 years (range, 2 to 15 years). The average age at surgery was 29 years (range, 17 to 49 years). The primary indication for surgery was instability (95%). The surgical procedures included 13 traditional endoscopic transtibial PCL reconstructions (9 bone–patellar tendon–bone [BPTB] autograft, 2 BPTB allograft, and 2 allograft Achilles tendon) and 7 tibial inlay (all BPTB, 5 allograft and 2 autograft). Each patient was evaluated using the Tegner, Lysholm, and American Academy of Orthopaedic Surgeons (AAOS) knee-rating scales, physical examination, corrected KT-1000 arthrometry, functional testing, and radiographs. Statistical analysis was performed using the Fisher exact *t* test, Wilcoxon signed-ranks test, and Mann-Whitney test. **Results:** Overall, 90% pf patients were satisfied with their surgery. The postoperative posterior drawer test result improved in 4 of 7 (57%) in the inlay group, and in 5 of 13 (38%) in the endoscopic group. The mean corrected KT-1000 measurement was 5.7 mm overall, 5.5 mm (inlay) and 5.9 mm (endoscopic). The mean preoperative Tegner score was 6.86 (inlay) and 6.92 (endoscopic). The mean postoperative Tegner score was 6.00 for both groups. The mean Lysholm score was 76 (inlay) and 82 (endoscopic), and the AAOS knee score was 77 (inlay) and 90 (endoscopic). There was a trend toward increased radiographic progression of Fairbanks changes in the medial and patellofemoral compartments in the endoscopic group, but the numbers did not reach statistical significance ($P = .057$). **Conclusions:** When comparing the traditional endoscopic reconstructions with the tibial inlay technique, there were no significant differences in posterior drawer testing, KT-1000, functional testing, or Lysholm, Tegner, and AAOS knee scores at a minimum 2 year follow-up. **Clinical Relevance:** The results of this study indicate that neither method (transtibial or inlay) of PCL reconstruction consistently restores anteroposterior stability to its original state when using a single-bundle femoral attachment site. **Key Words:** Posterior cruciate ligament—Transtibial—Tibial Inlay—Single-bundle.

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The incidence rate of posterior cruciate ligament (PCL) tears ranges from 3% of acute knee injuries in the general population to 38% of acute knee injuries reported in emergency rooms.[1] Clancy and Sutherland[2] reported that 40% of PCL injuries are isolated to the ligament. The treatment of isolated PCL injuries still remains controversial in the field of sports medicine. Isolated PCL tears have traditionally been treated nonoperatively because most patients do well with conservative care.[3]

Despite encouraging results with the nonoperative management of isolated PCL tears, a certain percentage of patients will develop chronic, symptomatic posterior instability and may require surgical reconstruction. Numerous studies have shown that patients with isolated PCL tears treated nonoperatively can develop increased clinical instability and arthritic changes over time.[4-6] However, few studies have been published on the surgical treatment of isolated PCL injuries.

The primary goal of surgical reconstruction of the PCL is to restore its normal anatomy. The PCL consists of 2 bundles: the larger, stiffer, and longer anterolateral bundle, which tightens in flexion, and the smaller, weaker, and shorter posteromedial bundle, which is taut in extension.[7] Traditionally, the aim of arthroscopic transtibial techniques has been to reconstruct the stronger anterolateral bundle. Unfortunately, as the graft exits the tibial tunnel it must make an acute bend around the proximal posterior tibia, termed the "killer turn," and stresses on the graft caused by this bend can lead to attenuation and late graft failure.[8] The tibial inlay technique was developed to reduce the acute bending of the graft as it exits the tibial tunnel.[9]

The purpose of the present study was to evaluate the surgical outcomes of PCL reconstructions for isolated PCL injuries. Two single-bundle reconstruction techniques were compared, the traditional endoscopic and the tibial inlay techniques, to determine if the inlay technique yielded more stable reconstructions.

METHODS

From January 1980 to March 1997, 29 patients underwent surgery for an isolated PCL injury. Two patients underwent primary repair, 4 underwent primary repair with semitendinosus-gracilis augmentation, 1 patient underwent tibial inlay with a double femoral tunnel, and 2 patients were lost to follow-up, leaving 20 patients available for this retrospective study. Inclusion criteria consisted of an isolated PCL tear with no other ligamentous injury detected by physical examination and confirmed by magnetic resonance imaging. Patients had to have a minimum 2-year follow-up after a PCL reconstruction with either a transtibial technique with a single femoral tunnel (group I) or a tibial inlay procedure with a single femoral tunnel (group II). There were 3 surgeons involved in the series and the technique of transtibial versus inlay was based on surgeon preference. Institutional review board approval for this study and informed consent of all patients to participate were obtained.

There were 13 patients in group I and 7 patients in group II. Patient age at the time of surgery for group I averaged 29 years (range, 17 to 49 years) and for group II, 31 years (range, 23 to 39 years) (Table 1). We believe that the traditional grading system for the posterior drawer of 1+, 2+, and 3+ is inherently ambiguous because it relies on the subjective estimation by the examiner of the number of millimeters of posterior displacement of the tibia on the femur.[10] Often, published reports will quote posterior drawer results as 1+, 2+, or 3+ and interchange these with grade 1, 2, 3, or grade 4 injuries to the PCL, without indicating where the tibia is in relation to the femur. Noyes et al.[11] have abandoned this grading system altogether. In their chapter on PCL injuries, they state that ". . . PCL tears are divided into 2 groups based on the millimeters of increased posterior tibial displacement, indicating either undamaged ($<$10 mm) or insufficient ($>$10 mm) secondary restraints. This division is somewhat arbitrary because it is difficult, without using stress radiography under defined loading conditions, to determine the exact increase in posterior tibial translation with PCL ruptures."[11]

We, therefore, have devised a more simplified grading system for the posterior drawer test. The system does not seek to determine if an injury is partial or complete. Rather, it assesses the competence of whatever ligament, or ligament remnant is present. The grading system is: normal, indicating no loss of tibial offset; grade A, slight loss of tibial offset when applying a posterior force to the tibia at 90°; grade B, the tibia is flush with the femur; and grade C, the tibia is able to be displaced behind the femur (Fig 1). In our opinion, this grading system has been more reproducible in our clinic because it relies on displacement of the tibia relative to basic landmarks, rather than displacement based on number of millimeters.

Surgeons have debated and will continue to debate the degree of injury to the PCL in the B or C category. This is complicated by the presence of partial injuries and the fact that PCL injuries will often heal in an

Table 1. *Preoperative Data*

Patient	Age	Sex	Mechanism of Injury	Posterior Drawer	Radiographic Changes	Tegner Score	Cartilage Grade: MC	Cartilage Grade: PF
Tibial tunnel (group I)								
1	17	M	Football	C	0	9	NL	NL
2	23	M	MVA	B	0	9	NL	NL
3	23	F	MVA	B	0	4	NL	I
4	24	M	Football	C	1	10	III MFC,TP	II
5	49	F	Roller-Skating	C	1	5	NL	NL
6	37	F	Skiing	B	0	7	NL	NL
7	27	M	Skiing	C	0	9	NL	NL
8	37	M	Skiing	C	0	7	NL	NL
9	34	M	Fall	C	1	NA	IV MFC,TP	NL
10	38	M	Ice Boating	C	1	5	NL	NL
11	26	M	Football	B	1	6	NL	NL
12	20	M	Football	C	0	7	NL	III
13	18	M	Fall	B	0	NA	NL	NL
Mean	29				0	7		
Tibial inlay (group II)								
1	24	M	MVA	C	0	8	NL	NL
2	23	M	Basketball	C	0	8	NL	NL
3	37	M	Fall	B	0	7	NL	NL
4	39	M	Martial Arts	B	0	10	NL	NL
5	31	F	MVA	C	0	6	NL	NL
6	34	M	MVA	C	1	5	III MFC,TP	III
7	28	F	MVA	B	0	4	NL	NL
Mean	31				0	7		
P value	.44					.96		

Abbreviations: PF, patellofemoral; NL, normal; MVA, motor vehicle accident; MFC, medial femoral condyle; TP tibial plateau.

elongated, nonfunctional position. Thus, grading as to the degree of injury is somewhat arbitrary and a system that simply states the position of the tibia on the femur will be easier to use and eliminate biases in reporting results.

All patients were evaluated postoperatively using the Tegner, Lysholm, and the American Academy of Orthopaedic Surgeons knee rating scale. Each subject underwent an objective evaluation postoperatively, which included a physical examination by the lead author, a corrected KT-1000 measurement (side-to-side difference) using the technique described by Daniel et al.[12] (all performed by the same physical therapist), functional testing consisting of the single-leg hop test, and radiographs of both knees consisting of standing anteroposterior, posteroanterior at 40° of flexion, lateral at 90° of flexion, and Merchant views. The radiographs were compared with ipsilateral preoperative radiographs. Articular degeneration was graded on a 0 to 3 scale.[4,6] Grade 0 corresponded to a normal appearing radiograph. Grade 1 corresponded to evidence of mild degeneration, slightly decreased joint space, mild osteophytes, and subchondral sclerosis. Grade 2 corresponded to degenerative changes such as moderate joint space narrowing and subchondral sclerosis without articular bony contact. Grade 3 corresponded with radiographs that showed bone-on-bone articular contact.

SURGICAL TECHNIQUE

Group I: Arthroscopic Transtibial Technique

Thirteen patients underwent the traditional endoscopic transtibial reconstruction with a single femoral tunnel. The surgical technique has been described in detail elsewhere[1,13] (Fig 2). The graft choices for group I included autologous bone–patellar tendon–bone (BPTB) in 9 patients, allograft BPTB in 2, and allograft Achilles tendon in 2. The sizes of the graft varied based on the use of autograft versus allograft. The autografts were harvested with 11-mm bone plugs and tendons, whereas the allografts had 11-mm bone plugs with slightly larger tendons ranging between 12 and 14 mm.

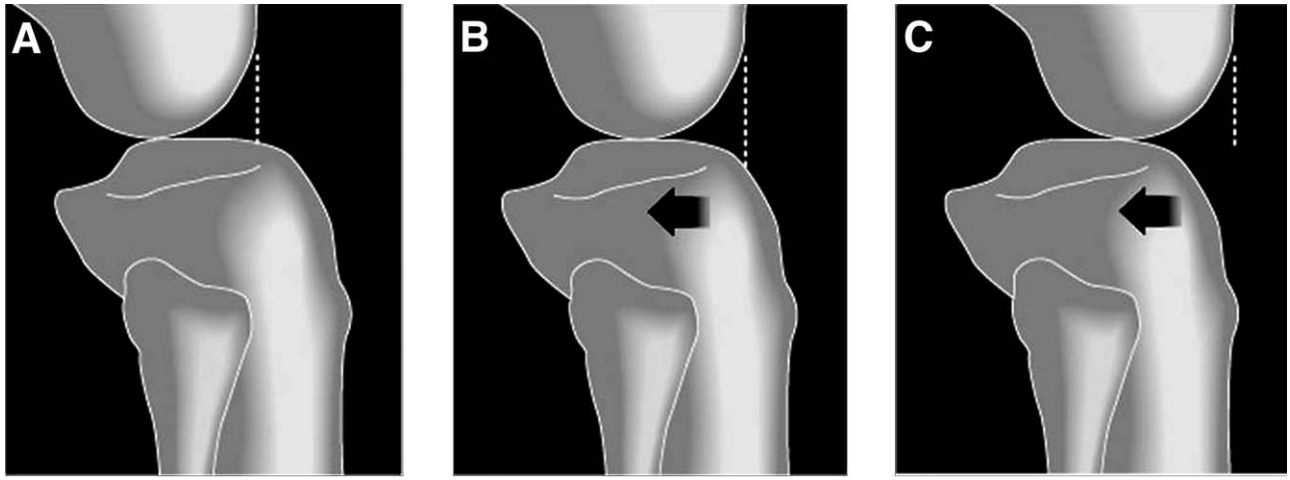

FIGURE 1. Posterior drawer grading system. Normal (not shown); (A) grade A, slight loss of tibial offset with a posterior force applied to the tibia at 90 degrees of flexion; (B) grade B, tibia flush with femur; and (C) grade C, tibia displaced posterior to femur.

Group II: Tibial Inlay Technique

Because of concerns about late laxity associated with endoscopic transtibial PCL reconstruction, 1 of the authors began using the tibial inlay technique in 1992[9,14] (Figs 3 and 4). The graft choices for group II included autologous BPTB in 2 patients and allograft BPTB in 5 patients. We fashioned the bone block for the inlay in a rectangular fashion with the dimensions 15-mm wide, 25-mm long, and 5-mm thick for the allografts and the same for the autografts. The tendon for the autograft was harvested at 11 mm, whereas with the allografts, the tendon was between 12 and 14 mm wide. The femoral bone plugs were 11 mm for both autografts and allografts. Femoral fixation was consistent for both the transtibial and inlay groups, with primary interference screw fixation backed up with either a ligament button, a screw and washer, or a staple.

Postoperative Management

The operative knee was braced in extension for 4 to 6 weeks. The patient was allowed toe-touch weight-bearing for the first 4 weeks, then progressed to partial weight-bearing for 2 weeks, and then full weight bearing was permitted thereafter. In the early postoperative period, passive range of motion to 90°, isometric quadriceps strengthening and straight-leg raises were allowed. The patient was allowed to return to full activities 9 to 12 months postoperatively.

Statistical Analysis

Statistical analysis was performed using Fisher exact *t* test, Wilcoxon signed-rank test, and Mann-Whitney *U* test.

RESULTS

A summary of the results is presented in Table 2. There were no statistically significant differences between the 2 groups with regard to age, sex, reason for surgery, timing from injury to operation, duration of follow-up, or preoperative posterior drawer. The mean duration of follow-up for group I was 6.3 years (range, 2.4 to 15 years) and for group II was 4.7 years (range, 2 to 7 years) ($P = .383$). All patients in both groups had surgery for chronic PCL deficiency, which was defined as more than 12 weeks from the time of injury to surgery. All patients had either a grade B or C posterior drawer test result preoperatively, and no other surgically correctable ligamentous laxity as determined by examination under anesthesia and preoperative magnetic resonance imaging. The primary indication for surgery was functional instability in 12 of 13 patients (92%) in group I and in 7 of 7 patients (100%) in group II. The other patient in group I had chronic pain. Instability in all cases was defined as either partial or complete giving way episodes with desired activities of daily living, despite having undergone a complete physical therapy and strengthening program for a minimum of 6 weeks.

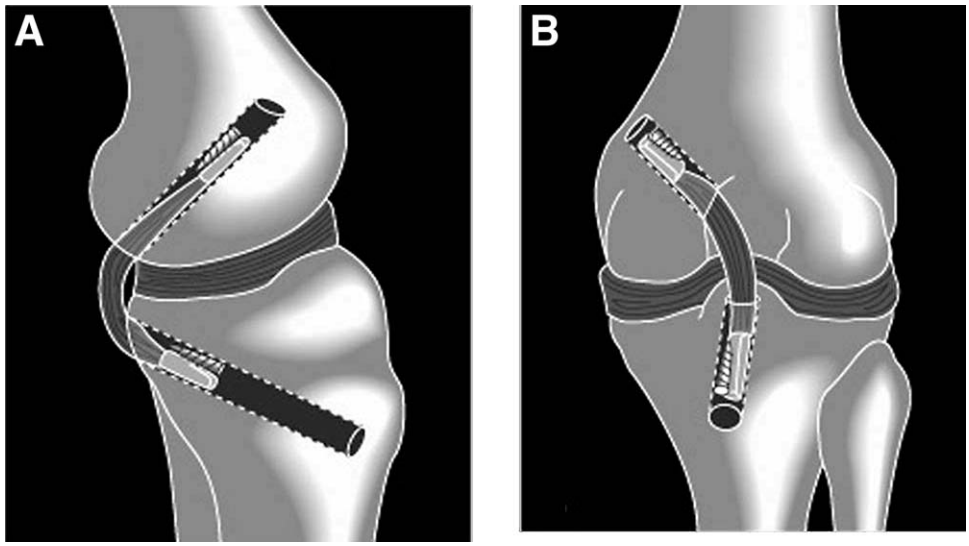

FIGURE 2. Traditional endoscopic transtibial reconstruction with a single femoral tunnel. (A) Laterval view. (B) Posterior view.

Associated Arthroscopic Findings and Procedures

Group I: There was 1 patient (patient 4, see Table 1) who had a medial meniscal tear and required a concomitant partial medial meniscectomy, removal of multiple loose bodies, and debridement of grade III chondromalacia of the medial femoral condyle and medial tibial plateau. Another patient (patient 9, Table 1) had grade IV changes on both the medial femoral condyle and medial tibial plateau at the time of reconstruction and subsequently went on to require a total knee replacement at 5 years, 9 months postoperatively. Two other patients had grade I and grade III chondromalacia of the patella respectively.

Group II: Only 1 patient (patient 6, Table 1) had associated grade III changes of the medial femoral condyle, medial tibial plateau, and patella.

Subjective Results

In group I, 92% (12 of 13) of patients were satisfied with their results and would have the surgery again, 7 of 13 (54%) reported no instability episodes postoperatively, 5 of 13 (38%) reported rare episodes, and 1 of 13 (8%) reported occasional episodes of instability. The 1 dissatisfied patient had grade IV changes in his medial and patellofemoral compartments at the time of PCL reconstruction, and later developed worsening knee pain at 69 months postoperatively, and went on to require a total knee arthroplasty. In retrospect, this patient was a poor candidate for a PCL reconstruction. In group II, 86% (6 of 7) of the patients were satisfied with their surgery, 3 of 7 (43%) denied any instability, 2 of 7 (29%) reported rare episodes, 1 of 7 (14%) reported occasional episodes of instability, and 1 of 7 (14%) complained of frequent giving way episodes. The 1 dissatisfied patient continued to complain of patellofemoral pain in addition to the recurrent instability. There were no significant differences between the 2 groups with respect to preoperative and postoperative Tegner scores, and postoperative Lysholm or AAOS scores (Table 2).

Objective Results

There were no significant differences between the groups in the corrected KT-1000 measurements, preoperative or postoperative posterior drawer testing, postoperative range of motion, or single-leg hop test. The radiographic progression of Fairbanks changes in the patellofemoral and medial compartments trended toward significance ($P = .057$), with the arthroscopic transtibial group showing a greater progression than the inlay group. This difference may be attributed to the longer follow-up in the transtibial group (mean, 6.3 years) compared with the inlay group (mean, 4.7 years) (Table 2).

In the tibial tunnel group, 5 of 13 (38%) patients improved with respect to their posterior drawer grade. Two patients went from a grade C to a grade A, 1 patient improved from a grade B to a grade A, and 2 patients improved from a grade C to a grade B.

In the tibial inlay group, 4 of 7 (57%) patients had improved posterior drawer examinations postoperatively. Two patients improved from a grade C to a

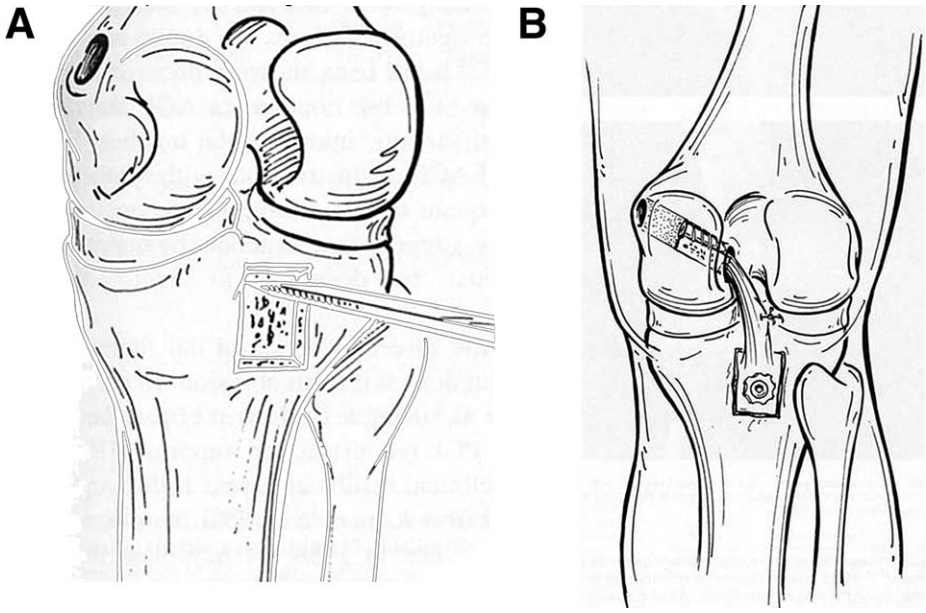

FIGURE 3. Tibial inlay technique. (A) An osseous window is created in the posterior tibial cortex. (B) The graft is inlayed into the window and secured with a screw and washer. Reprinted from Berg.[9]

grade A, 1 patient went from a grade B to a grade A, and 1 patient improved from a grade C to a grade B. There was also 1 patient in this group who went from a grade B posterior drawer preoperatively to a grade C postoperatively and this patient complained of continued instability (Table 3).

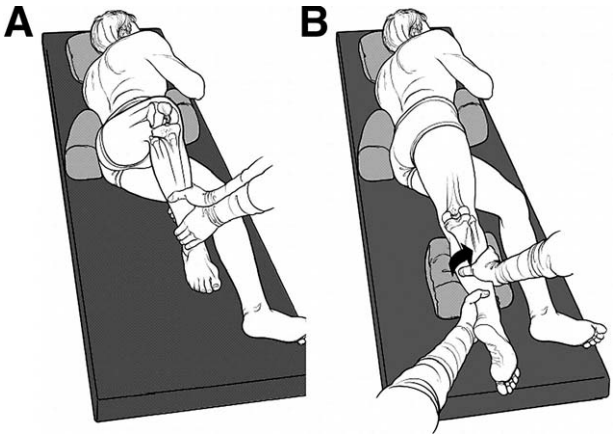

FIGURE 4. Patient positioning for tibial inlay technique. (A) Patient is placed in lateral decubitus position. The hip is abducted, externally rotated, and flexed to 90° for arthroscopy. (B) The posteromedial approach is facilitated by planning the table, adducting, and internally rotating the leg.

DISCUSSION

In 1995, Berg[9] reported on PCL reconstruction using a new inlay technique. He proposed that transtibial reconstruction was technically difficult, leading to ineffective in situ graft tensioning, and possibly allowing for late failure caused by abrasive wear of the graft at the margin of the tibial tunnel. He claimed that his inlay technique created a more anatomic PCL insertion, allowing easier and more effective graft tensioning. In his limited series of 4 patients treated with the inlay technique, there was an average improvement on KT-1000 arthrometry of 4 mm, no radiographic changes at 2-year follow-up, and significant subjective improvement in all patients.

Bergfeld et al.[15] went on to compare this new inlay technique with the standard transtibial technique in a cadaver model. They found that the inlay technique allowed for better graft tensioning with a significant reduction in anterior-posterior laxity when compared with the transtibial tunnel technique. After cycling the knee 72 times, they found evidence of mechanical degradation of the graft in the tibial tunnel group, but not in the inlay group.

Several studies have evaluated surgical reconstruction for PCL deficiency.[5,9,16-19] These studies, however, included both acute and chronic injuries.[5,16,18] Several of the studies included patients with concom-

Table 2. *Postoperative Data*

Patient	Follow-up (mo)	Posterior Drawer	Corrected KT-1000	Radiographic changes	Tegner Score	Lysholm Score	AAOS Score
Tibial tunnel (group I)							
1	29	C	10	1	9	95	98
2	90	B	8.5	0	7	79	82
3	181	B	2.5	2	4	87	84
4	48	C	9.5	2	6	51	73
5	84	A	2.5	2	5	76	92
6	89	B	2	0	7	66	92
7	67	A	2.5	1	9	100	98
8	30	B	4	1	5	89	91
9	69	B	NA	2	NA	NA	NA
10	110	C	10.5	2	5	82	94
11	114	B	3.5	2	6	85	92
12	29	C	10	0	5	86	92
13	37	A	5	0	NA	NA	NA
Mean	75		5.9	1.15	6	81	90
Tibial inlay (group II)							
1	48	A	4.5	0	8	85	91
2	52	A	5	0	8	59	45
3	76	A	1	1	5	87	93
4	58	B	10	0	10	74	84
5	24	C	7.5	0	5	100	96
6	55	B	4.5	1	4	83	89
7	85	C	6	0	2	42	40
Mean	57		5.5	0.28	6	76	77
P value	.39	.48	.97	.06	.96	.54	.23

itant ligamentous injuries, intra-articular pathology, or patients who had undergone previous surgery for their PCL injuries.[5,9,16-18] None of these studies addressed the surgical treatment of isolated chronic PCL deficiency. In our study, only patients with chronic, isolated PCL injuries were included. Furthermore, all patients had undergone a trial of nonoperative treatment and failed because of chronic symptomatic instability or pain.

This study reviewed the outcome of PCL reconstruction in a select group of patients who presented with isolated chronic PCL deficiency. Furthermore, 2 surgical techniques (transtibial single femoral tunnel and inlay single femoral tunnel) and their clinical outcomes were evaluated. When comparing these 2 surgical techniques, we found no significant difference with regard to improved laxity on posterior drawer examination or on postoperative corrected KT-1000 testing (5.9 mm side-to-side *v* 5.5 mm). Many authors have noted that the functional results of PCL reconstruction are often better when compared with the objective findings of residual laxity.[16,18] Our study offers similar results, with subjective scores better than the objective measurements of laxity. Shelbourne et al.[3] found no correlation between radiographic changes and PCL laxity when examining 133 patients treated nonoperatively for isolated PCL injury. Our study offers results similar to others, with no correlation between laxity and radiographic changes.

Most studies comparing PCL reconstruction techniques are burdened by multiple confounding variables in their patient population. Our study looks only at chronic reconstruction of isolated PCL injuries. We compare only single-bundle reconstructions using the standard transtibial technique and the more recent tibial inlay technique.

Injury to the PCL is not common, and isolated PCL injury is even less common. Although the groups in our study are similar, the numbers are small and so conclusions may be limited. Our data did not show a significant difference between the 2 groups tested. However, although no difference was observed, we cannot conclude, based on our small numbers, that no difference exists. In addition, the graft type varied between autograft and allograft, although there was a mix of both in each group. We did not obtain preoperative KT-1000 measurements and so the postoperative KT values can only be evaluated based on the values from the contralateral uninjured knees. No randomization process was used because there were 3

TABLE 3. *Preoperative and Postoperative Drawer Changes*

	Preoperative	Postoperative	Improved	Grade Change
Tibial Tunnel Group				
1	C	C		
2	B	B		
3	B	B		
4	C	C		
5	C	A	Y	2
6	B	B		
7	C	A	Y	2
8	C	B	Y	1
9	C	B	Y	1
10	C	C		
11	B	B		
12	C	C		
13	B	A	Y	1
% Improved			38%	
Tibial Inlay Group				
1	C	A	Y	2
2	C	A	Y	2
3	B	A	Y	1
4	B	B		
5	C	C		
6	C	B	Y	1
7	B	C		
% Improved			57%	

treating surgeons and the surgical technique was based on their preferences. Other weaknesses include a difference in the length of follow-up between the groups and the fact that the study was retrospective. The majority of the transtibial reconstructions were performed at the beginning of this series so there are 2 distinctly different time frames being evaluated. In addition, because we began performing the transtibial reconstructions first, there was no way to avoid the disparity in follow-up. However, our minimum follow-up is 2 years in both groups.

CONCLUSIONS

Comparison of traditional endoscopic PCL reconstructions to tibial inlay reconstructions, in our small study group, yielded no significant differences in posterior drawer testing, KT-1000, functional testing, and Lysholm, Tegner, and AAOS knee scores at a minimum 2-year follow-up. The results of this study may indicate that neither method (transtibial or inlay) of PCL reconstruction consistently restores anteroposterior stability to its original state when using a single-bundle femoral attachment site.

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