Outcomes of Treatment of Acute Grade-III Isolated and Combined Posterolateral Knee Injuries

A Prospective Case Series and Surgical Technique

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Background: Few studies have reported the outcomes of surgical treatment of an acute grade-III posterolateral knee injury. Our purpose was to report the objective stability and subjective outcomes for a prospective series of patients with an acute grade-III posterolateral knee injury treated with anatomic repair and/or reconstruction of all injured structures.

Methods: A prospective study of all patients with a grade-III posterolateral knee injury treated with an anatomic repair and/or reconstruction within six weeks of injury was initiated in May 2005. International Knee Documentation Committee (IKDC) objective scores and bilateral varus stress radiographs were obtained at each visit, including preoperatively and at the final follow-up visit. In addition, all patients completed Cincinnati and IKDC subjective evaluations. All associated cruciate ligament tears were reconstructed concurrently.

Results: Twenty-nine patients (twenty-four men and five women with a mean age of twenty-seven years) (thirty knees) were enrolled in the study. Eight knees had an isolated posterolateral corner injury, ten also had an anterior cruciate ligament tear, four also had a posterior cruciate ligament tear, and eight also had tears of both cruciate ligaments. Four patients were lost to follow-up prior to two years, resulting in a final study cohort of twenty-five patients (twenty-six knees). All five IKDC objective subscores had improved significantly at the time of the final follow-up evaluation at an average of 2.4 years postoperatively. Varus stress radiographs demonstrated a significant improvement in the side-to-side difference in the lateral compartment gap, from 6.2 mm preoperatively to 0.1 mm at the time of the final follow-up. The mean Cincinnati and IKDC subjective outcomes scores improved from 21.9 to 81.4 points and from 29.1 to 81.5 points, respectively.

Conclusions: Treatment of grade-III posterolateral knee injuries with acute repair of avulsed structures, reconstruction of midsubstance tears, and concurrent reconstruction of any cruciate ligament tears resulted in significantly improved objective stability.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

Historically, it has been recommended that acute complete grade-III posterolateral corner injuries be treated surgically within the first few weeks following the injury (when possible) because of the difficulty that tissue retraction, adhesions, and scar-tissue entrapment of the common peroneal nerve[1-4] can pose during late repair.

There has been a paucity of reports on the surgical treatment and outcomes of acute posterolateral corner injuries, and

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A commentary by Christopher D. Harner, MD, is linked to the online version of this article at jbjs.org.

many of these reports were published more than a decade ago[1,2,5-9]. However, an increasing number of reports have indicated that primary repair of these structures is often insufficient to restore objective knee stability, and that reconstruction of acute midsubstance tears of the fibular collateral ligament (FCL), popliteus tendon, and popliteofibular ligament (PFL) may provide superior objective stability outcomes[1,8,10,11].

Our hypothesis was that reconstruction of midsubstance tears of the main posterolateral knee structures, along with a combination of acute repair of avulsions of these main structures and other associated posterolateral knee injuries, would result in improved objective stability. Our purpose was to describe our technique and to report the objective stability and subjective outcomes in these patients.

Materials and Methods

Subjects

All patients who presented to a single surgeon (R.F.L.) at a single site with a grade-III posterolateral corner injury between May 2005 and February 2008 were prospectively identified. The study was approved by our institutional review board, and informed patient consent for study inclusion was obtained. The inclusion criteria were combined varus and posterolateral rotatory instability in a patient who reported, or had findings of, functional instability and/or knee pain. For the purposes of our study, acute injuries were defined as injuries that were operatively treated within six weeks. Patients with an active infection or comorbidities that did not allow operative treatment within six weeks after the injury were excluded from the study.

Clinical and Radiographic Diagnosis

Patients were evaluated preoperatively for the presence of a qualitative increase in posterolateral instability, compared with the contralateral knee, of at least two grades according to the International Knee Documentation Committee (IKDC) objective knee scoring criteria[12] on one or more of the following knee stability examinations: lateral joint opening at 20° under varus stress, external rotation at 30° and at 90° (dial test), the posterolateral drawer test, and coupled posterolateral rotatory subluxation on the reverse pivot-shift test. Preoperative and postoperative bilateral varus stress radiographs[13] were obtained preoperatively and at the six-month and yearly follow-up visits, and posterior (kneeling) knee stress radiographs[14] were also obtained for patients with a concomitant posterior cruciate ligament tear. Magnetic resonance imaging scans were obtained for all patients.

Evaluation and Rating Scales

The IKDC objective knee examination form was completed preoperatively and at each follow-up evaluation. In addition, all patients completed a Cincinnati subjective scoring form[15] and an IKDC subjective questionnaire[12] preoperatively and at the six-month and yearly follow-up visits.

Surgical Treatment

Surgical Approach

The open surgical approach was performed prior to arthroscopy, in order to permit the identification of injured structures prior to extravasation of arthroscopic fluid into the injured tissues. A hockey-stick-shaped incision was made over the posterolateral aspect of the knee, centered approximately over the midportion of the iliotibial band[10,16-18].

Deep Dissection, Peroneal Nerve Neurolysis, and Posterolateral Corner Injury Identification

A posteriorly based tissue flap was developed, and neurolysis of the common peroneal nerve was performed beginning at the fascial band of the peroneus longus muscle and extending approximately 8 cm proximally. If the common biceps femoris tendon was avulsed from the fibular head, a tag suture was placed in the distal aspect of the avulsed tendon (Fig. 1).

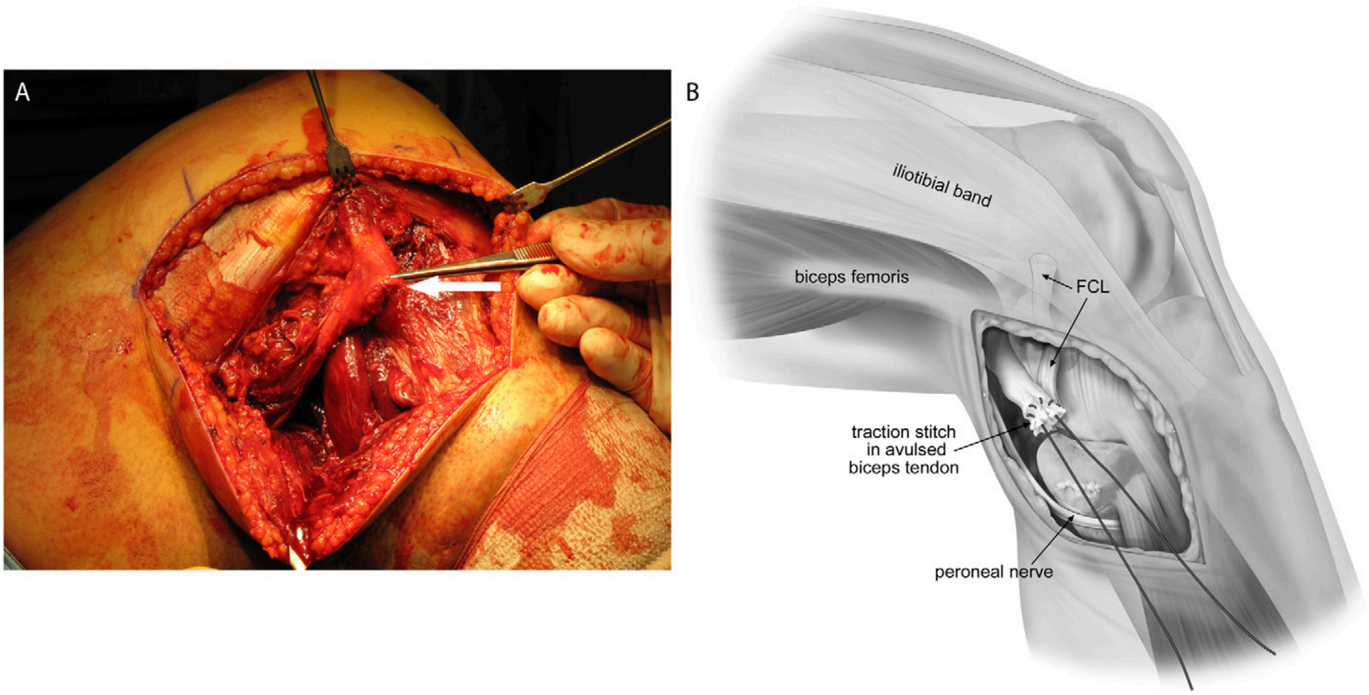

Fig. 1

A: Photograph of a right knee showing an avulsion of the biceps femoris tendon (arrow) from the fibular head. The peroneal nerve is visible in the posterolateral aspect of the incision. *B:* Illustration depicting a whipstitch placed into the distal end of the avulsed biceps femoris tendon prior to suture anchor repair. FCL = fibular collateral ligament.

Identification of the distal aspect of the FCL was performed via a 3-cm horizontal incision into the biceps femoris bursa[19]. A traction suture was then placed in the FCL within this bursa in order to assess for laxity (Fig. 2). A direct repair was considered if the FCL was avulsed from the fibula but could be anatomically reduced with the knee in full extension. A reconstruction was planned if a retracted tear of the FCL could not be reduced to the fibula with the knee in extension or if the FCL had undergone an intrasubstance stretch injury or a complete midsubstance tear. The integrity of the PFL was assessed next; the attachment of the PFL on the posteromedial downslope of the fibular styloid[20] was identified by either palpation or visualization after anterior retraction of the biceps femoris tendon.

Next, the superficial layer of the iliotibial band was split, beginning at a point proximal to the lateral epicondyle and extending distally to Gerdy's tubercle. Tension was applied to the previously placed FCL traction suture in an attempt to identify the proximal femoral attachment of the FCL. If the FCL was completely avulsed from the femur, the lateral epicondyle was located and the attachment site of the native FCL (located slightly proximal and posterior to the lateral epicondyle) was identified[20].

Next, a vertical incision was made through the lateral capsular ligament over the popliteus sulcus to identify the femoral attachment of the popliteus tendon[20]. If the popliteus tendon was avulsed but appeared to have only a minimal intrasubstance stretch injury or no obvious evidence of such an injury, a nonabsorbable suture was whipstitched into the end of the popliteus tendon (Fig. 3), and a recess procedure was performed later during the operation[4,21]. A reconstruction of the popliteus tendon[17,22] was planned if this tendon had a midsubstance tear, could not be reduced to its anatomic attachment with the knee in full extension, or had a substantial intrasubstance stretch injury or an avulsion at the musculotendinous junction.

Next, the tibial attachment of the middle third of the lateral capsular ligament was assessed, and any soft-tissue or osseous (Segond fracture) avulsion was identified[23,24]. If this attachment was torn, it was carefully dissected from the overlying layer of the iliotibial band to allow for direct repair (Fig. 4).

Arthroscopic Assessment and Treatment of Intra-Articular Structures

Arthroscopic assessment was performed after all posterolateral knee injuries were identified. Meniscal tears were repaired, or were resected if repair was not possible. Reconstruction of the anterior cruciate ligament (ACL) and/or the posterior cruciate ligament (PCL) was performed as necessary, and the graft was secured in the femoral tunnel. Fixation of the graft in the tibial tunnel was performed later in the operation.

Treatment of Posterolateral Corner Injuries

Once any intra-articular pathology was treated and any cruciate ligament graft was fixed in the femoral tunnel, repair and/or reconstruction of the posterolateral corner structures was performed. Treatment of grade-III posterolateral corner injuries was performed in a stepwise manner according to the region of injury. The main regions assessed, in the order of repair and/or reconstruction of the attached structures, were (1) the femur, (2) the lateral meniscus, (3) the tibia, and (4) the fibular head and styloid.

The initial assessment addressed whether a damaged posterolateral corner structure was avulsed from its attachment and could be repaired or was torn in the midsubstance and required a reconstruction (Fig. 5). The structures that could require a reconstruction were the FCL, the popliteus tendon, and the PFL. Direct repair of the FCL and/or the popliteus tendon was considered only when the structure was avulsed from the bone, had no obvious midsubstance stretch injury, and could be reduced back to its anatomic attachment with the knee in full extension. Direct repair of the PFL was considered if the popliteus tendon was intact and the PFL was avulsed directly from the fibular head and sufficient tissue was present to permit reapproximation by suturing.

A tear of either the FCL or the popliteus tendon that was located in the midsubstance or that could not be repaired for other reasons was treated with an anatomic reconstruction with use of an autogenous hamstring graft[22,25] unless both structures were torn. If both the FCL and the popliteus tendon were torn, an anatomic posterolateral reconstruction was performed with use of an Achilles tendon allograft[10,17].

Repairs of the other torn structures were then performed systematically according to the region of injury, as described previously. An avulsion of the popliteus tendon from the femur was repaired with a recess procedure if there was no substantial stretch injury of the tendon and if the native length of the tendon could be restored with the knee in full extension (Fig. 3)[4,21]. First, an eyelet pin was centered directly over the attachment site of the popliteus tendon[20]. A small incision was made medially, and blunt dissection was performed under the vastus medialis obliquus muscle. The eyelet pin was then drilled anteromedially across the femur, and a 5-mm-diameter tunnel was reamed to a 1-cm depth. The whipstitched suture ends in the avulsed popliteus tendon were

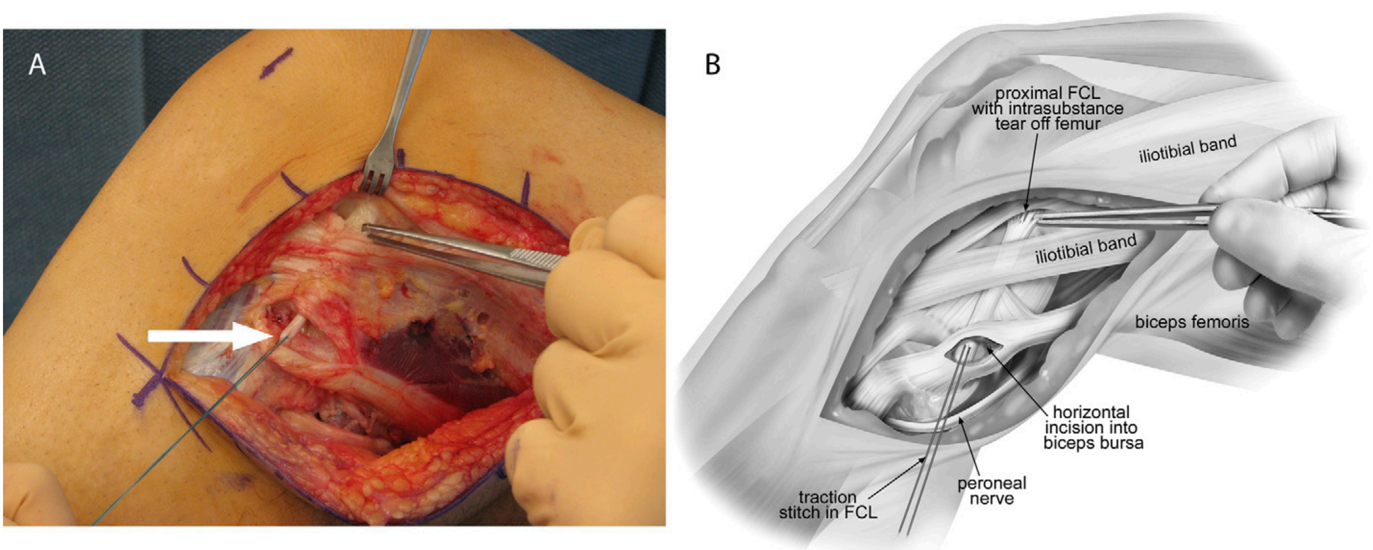

Fig. 2

A: Photograph of a left knee showing a proximal intrasubstance tear of the fibular collateral ligament (FCL) (in forceps) and a traction suture placed in the FCL (arrow) through an incision in the biceps bursa. *B:* Illustration depicting a proximal tear of the FCL and a traction suture placed in the distal aspect of the FCL.

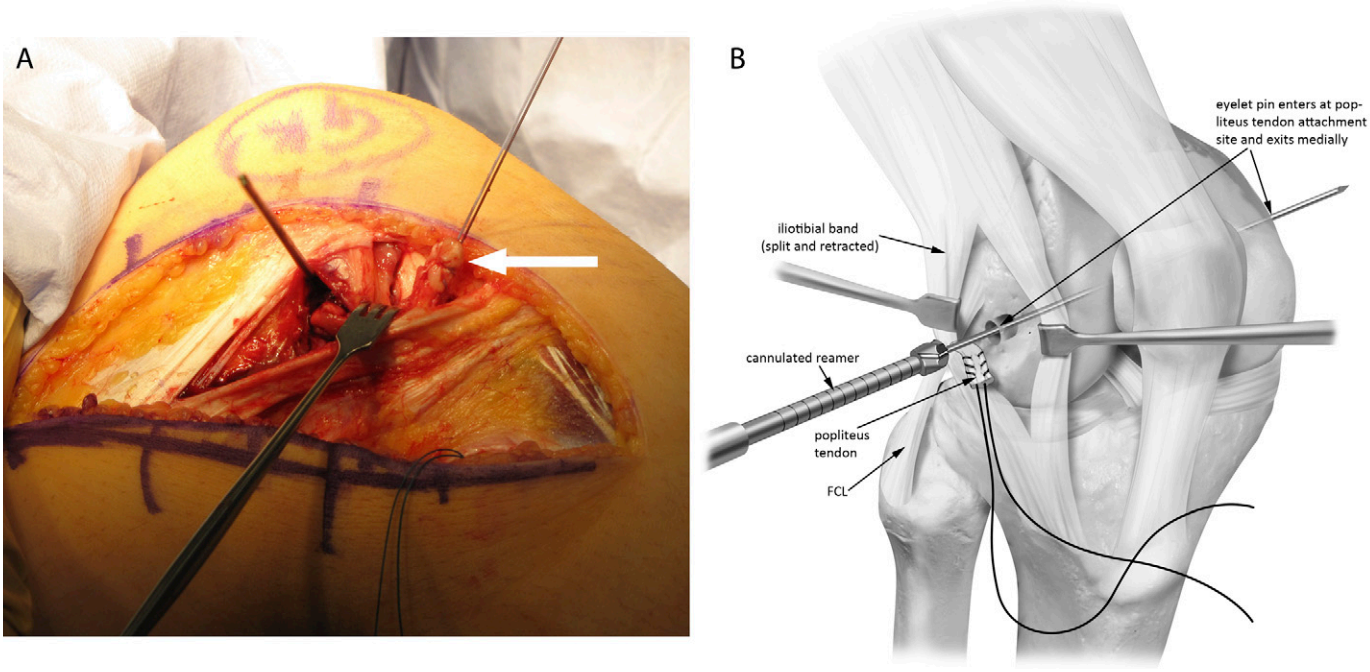

Fig. 3

A: Photograph of a right knee showing sutures placed in the femoral attachment of the avulsed popliteus tendon (arrow) in preparation for a recess procedure. *B:* Illustration depicting the popliteus recess procedure. The cannulated reamer is shown producing a recess for femoral fixation of the popliteus tendon. FCL = fibular collateral ligament.

placed into the eyelet pin and pulled out medially. The tendon was then pulled into the tunnel, and the sutures were tied over a button with the knee in full extension.

A tear of the popliteomeniscal fascicles or of the coronary ligament to the posterior horn of the lateral meniscus was repaired with use of mattress sutures under direct vision. An avulsion of the tibial attachment of the lateral capsular ligament[23,24] was repaired with use of suture anchors (Fig. 4).

An avulsion of the biceps femoris was repaired with use of suture anchors with the knee in full extension (Fig. 1). A proximal release of the long head of the biceps from adhesions to the lateral aspect of the thigh was performed bluntly

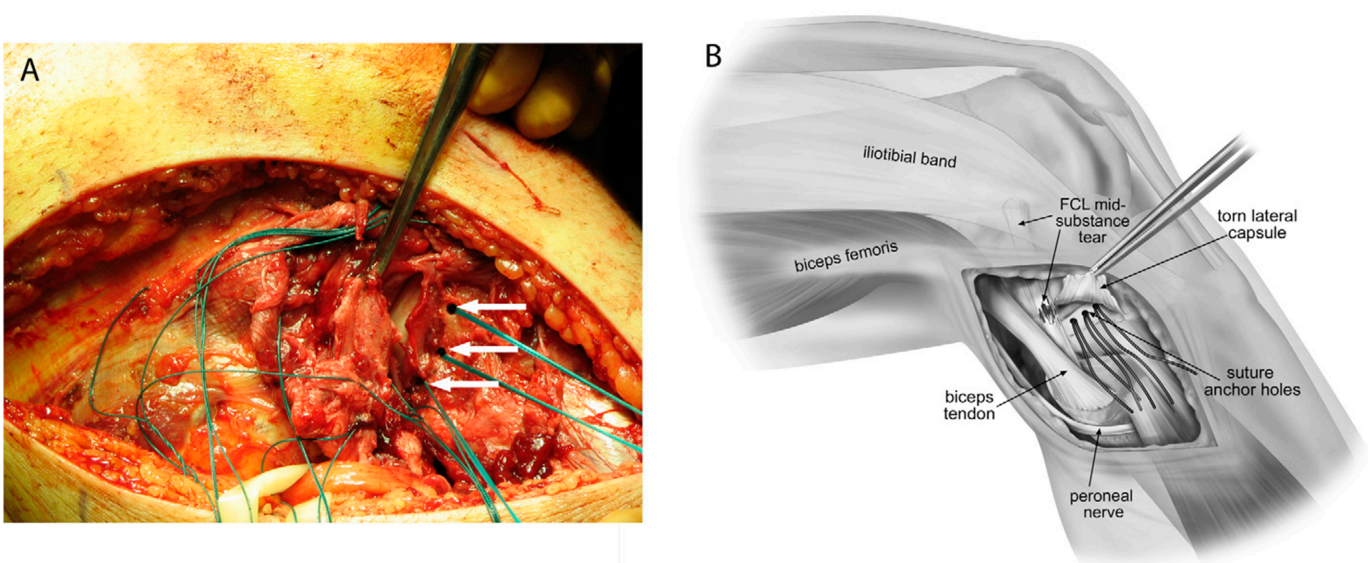

Fig. 4

A: Photograph of a right knee showing an avulsion of the lateral capsular ligament (in forceps) from the tibia and placement of suture anchors (arrows) for repair. *B:* Illustration depicting a torn lateral capsular ligament with suture anchor holes for repair; a midsubstance tear of the fibular collateral ligament (FCL) is also visible.

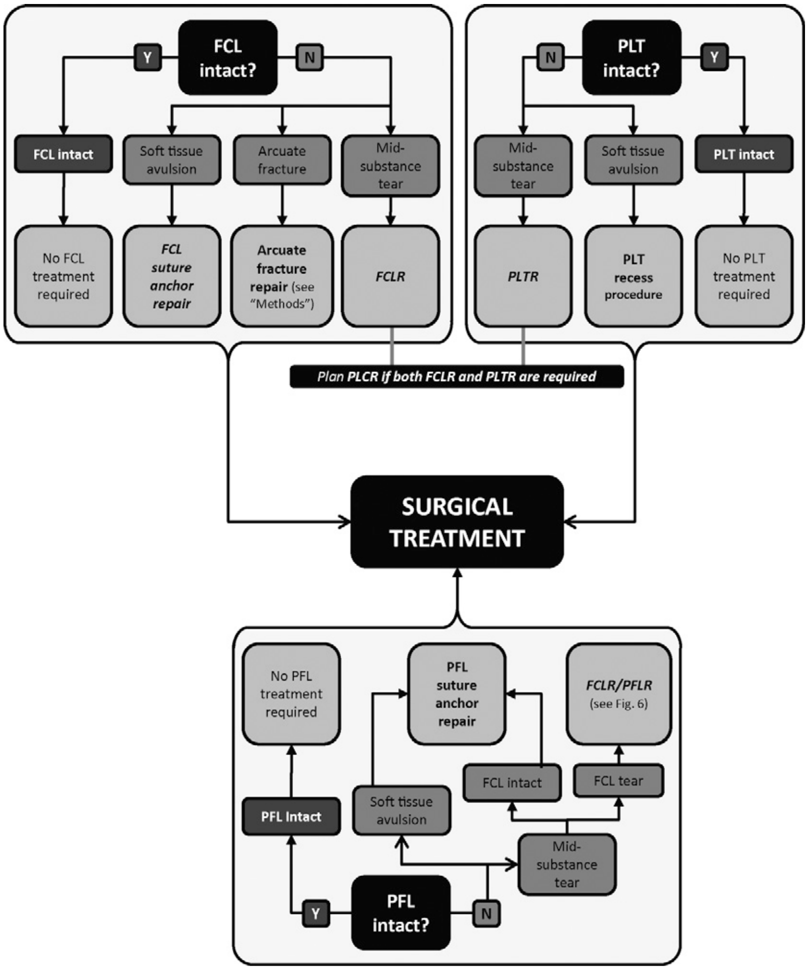

Fig. 5

Algorithm for repair versus reconstruction of posterolateral corner (PLC) structures. As indicated in the figure, a complete posterolateral corner repair is indicated when both the fibular collateral ligament (FCL) and the popliteus tendon are torn, regardless of the status of the popliteofibular ligament (PFL). FCLR = FCL reconstruction, PLT = popliteus tendon reconstruction, PLTR = PLT reconstruction, PFLR = PFL reconstruction, and PLCR = PLC (i.e., FCL, PLT, and PFL) reconstruction.

until the avulsed tendon could be reduced back to its anatomic attachment site with the knee in extension.

A tear of the PFL was repaired with use of a suture anchor if either the FCL or the popliteus tendon was still intact. If a concurrent reconstruction of the FCL and repair of the PFL could not be performed, a reconstruction of the PFL was performed. The portion of the FCL graft that passed out of the posteromedial aspect of the reconstruction tunnel in the fibular head was looped around the intact popliteus tendon at the musculotendinous junction, passed back laterally, and sutured onto itself to reconstruct the PFL (Fig. 6).

An avulsion (arcuate) fracture of the fibular head[16,26] was repaired primarily. A nonabsorbable number-5 cerclage suture was placed through the proximal fracture fragment and into the common biceps tendon. This suture was passed through drill holes in the lateral aspect of the fibula, 1 cm distal to the fracture edge, and the suture was tied with the knee in extension (Fig. 7).

Once each posterolateral corner graft was secured in its femoral tunnel and passed into its fibular or tibial tunnel, the distal fixation of any grafts required for reconstruction of the ACL and/or the PCL was performed according to previously described techniques[10,27]. The PCL graft was secured first in order to restore the central pivot of the knee, then the posterolateral corner grafts were secured, and finally the ACL graft was secured[10,27].

All structures were repaired in such a way that the knee could be immobilized postoperatively in extension without obvious tension on the repair. During repair of injured structures, careful attention was paid to tissue tension and surgical release of retracted torn tissues to ensure that all structures could be anatomically repaired with the knee in full extension. Prior to skin closure, the patient's range-of-motion "safe zone" (subjectively assessed allowable tissue tension) was determined intraoperatively. The minimal goal for range of motion on postoperative day one was 0° to 90°, but further safe early motion that would not tear the repaired structures was sometimes possible.

Postoperative Rehabilitation

The patient was not permitted to bear weight on the limb for six weeks postoperatively. The knee was kept in extension in an immobilizer except when the patient was performing passive and passive-assisted range-of-motion exercises within the "safe zone" four times daily. The allowable flexion was increased at two weeks postoperatively. Partial weight-bearing was permitted at six weeks postoperatively and was increased as tolerated. Patients were also prescribed exercises on a stationary bicycle set at low resistance and leg presses at one-quarter body weight to a maximum of 70° of knee flexion at six weeks postoperatively.

It was anticipated that a full range of motion and a normal gait pattern should be achieved by three to four months postoperatively. Light jogging and

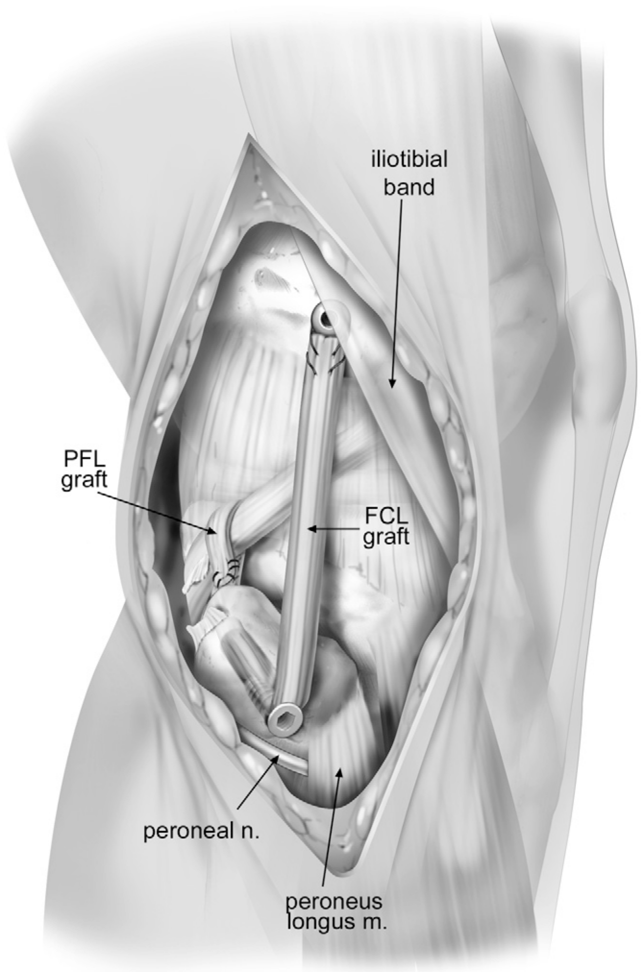

Fig. 6

Illustration of a right knee depicting a reconstruction of the popliteofibular ligament (PFL) with a concurrent fibular collateral ligament (FCL) reconstruction. The medial portion of the FCL graft was passed around the musculotendinous junction of the popliteus muscle, then passed back and sutured to itself, to reconstruct the PFL.

light side-to-side agility exercises were allowed at four months if the patient demonstrated adequate lower-extremity balance and strength and if the physical examination demonstrated adequate healing. A more detailed description of the treatment of various associated injuries and of the rehabilitation protocols is beyond the scope of the current study.

Data Analysis

The data obtained at the final follow-up (at a minimum of two years postoperatively) were compared with the preoperative data with use of a nonparametric Wilcoxon signed-rank test. A parametric paired t test was also used to compare normally distributed preoperative and postoperative data. The means of independent subgroups (e.g., the cohort with an isolated posterolateral corner injury and the cohort with a combined injury) were compared with use of a nonparametric rank-sum test. A conventional two-sample t test was also performed to compare normally distributed samples. A p value of <0.05 was considered significant.

Source of Funding

No external funding source was utilized.

Results

Patient Demographics

Twenty-nine patients (twenty-four men and five women; thirty knees) with an acute grade-III posterolateral corner injury were enrolled between May 2005 and February 2008. The mean age was twenty-seven years (range, sixteen to sixty-three years). The mean interval between the injury and surgery was seventeen days (range, three to forty-two days). The mean duration of follow-up was 2.4 years (range, two to 3.9 years).

Mechanism of Injury

Seven of the injuries were high-velocity and twenty-three were low-velocity; twenty were contact injuries and ten were noncontact. Nineteen of the injuries occurred during sporting activities. The injury involved an anteromedial and/or varus contact injury in eight knees, a contact injury with an unknown mechanism in seven, twisting in four, a motor-vehicle accident in four, hyperextension without contact in three, hyperextension with contact in two, and a fall in two knees.

Associated Comorbidities

In addition to the posterolateral corner injury, ten of the thirty knees had an ACL tear, four had a PCL tear, eight had both an ACL tear and a PCL tear, and eight knees had no concomitant injury of the cruciate ligaments. Eleven of the twenty-nine patients had neurapraxia of the common peroneal nerve, including a complete palsy in four patients, a partial sensory and motor palsy in four, a partial motor palsy in three, and a partial sensory palsy in two patients. Two of the patients with a complete palsy were treated with a tendon transfer, one had a partial recovery, and the fourth patient was using an ankle-foot orthosis and planned to undergo a tendon transfer.

IKDC Objective Scores and Knee Motion

Twenty-five patients (twenty-six knees) had at least two years of follow-up and formed the final patient cohort (Table I and Appendix). Five IKDC objective subscores were used to evaluate posterolateral corner stability and function preoperatively and at the final follow-up evaluation: lateral joint opening at 20° of knee extension, external rotation at 30°, external rotation at 90°, the reverse pivot-shift test, and the one-leg hop (Fig. 8). All five of these IKDC objective subscores had improved significantly at the time of the final follow-up ($p < 0.0001$) (Table II).

Subjective Patient Outcome Scores

The mean Cincinnati total score improved from 21.9 points (range, 6 to 52 points) preoperatively to 81.4 points (range, 28 to 100 points) at the time of the final follow-up ($p < 0.0001$). The mean symptom subscore improved from 5.9 points (range, 0 to 26 points) to 40.5 points (range, 10 to 50 points) ($p < 0.0001$), and the mean function subscore improved from 16 points (range, 6 to 34 points) to 40.9 points (range, 18 to 50 points) ($p < 0.0001$). The mean IKDC subjective score improved from 29.1 points (range, 10 to 66 points) preoperatively to 81.5 points (range, 40 to 100 points) at the time of the final follow-up ($p < 0.0001$).

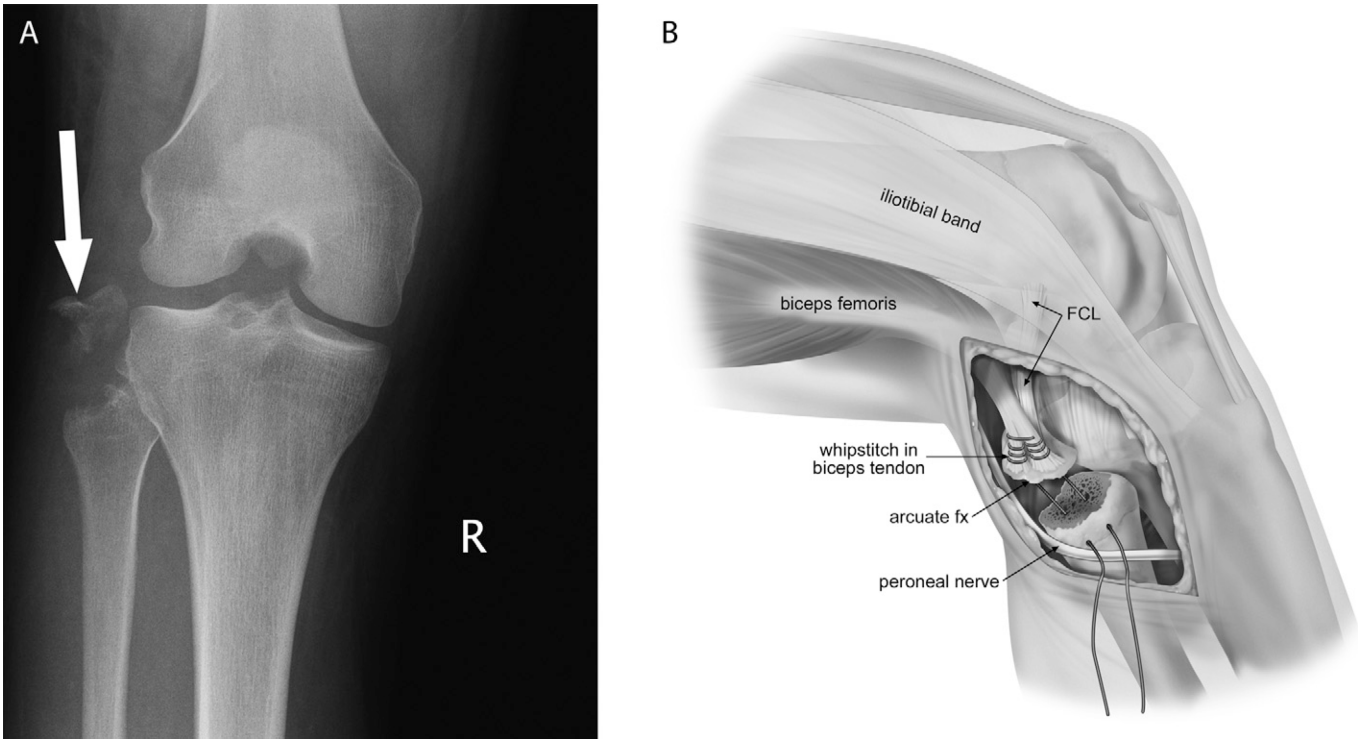

Fig. 7

A: Anteroposterior radiograph of a right knee showing an avulsion fracture of the fibular head (arrow). *B:* Illustration depicting repair of an arcuate fracture with a whipstitch in the distal aspect of the biceps femoris tendon and suture anchor holes through the fibula. FCL = fibular collateral ligament.

Isolated Compared with Combined Injuries

Seven patients (seven knees) had an isolated posterolateral corner injury. The posterolateral corner injuries in the remaining nineteen knees were combined with injury of the ACL, the PCL, or both. Four of the five IKDC objective stability subscores (lateral joint opening at 20°, external rotation at 30° and at 90°, and the reverse pivot-shift test) did not differ significantly between the cohort with an isolated posterolateral corner injury and the cohort with a combined injury at the time of the final follow-up ($p = 0.60$). All patients received a grade of A (normal) on these four maneuvers at the time of the final follow-up except for the one patient with a major complication (Fig. 8). However, the cohort with a combined posterolateral corner injury performed significantly more poorly than the cohort with an isolated injury on the one-leg hop at the time of the final follow-up ($p < 0.03$). The Cincinnati and IKDC subjective subscores at the time of the final follow-up did not differ significantly ($p = 0.24$ and $p = 0.15$, respectively) between the cohort with an isolated posterolateral corner injury and the cohort with a combined injury (Table III).

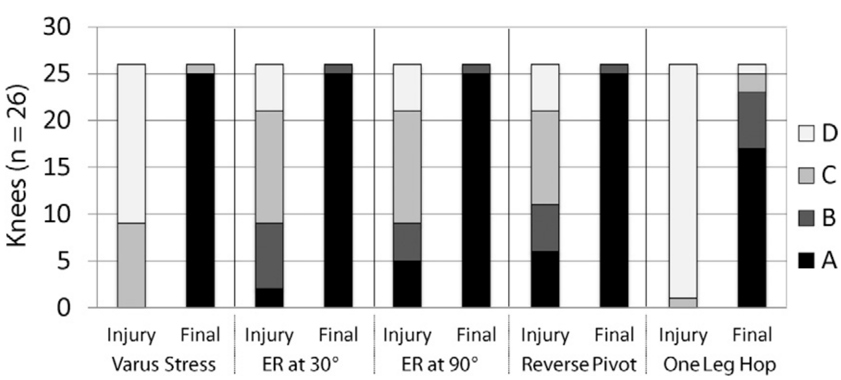

Fig. 8

International Knee Documentation Committee (IKDC) objective posterolateral stability and one-leg-hop scores at the initial preoperative evaluation and at the final follow-up evaluation after surgical treatment of an acute grade-III posterolateral knee injury. "A" = normal, "B" = nearly normal, "C" = abnormal, and "D" = severely abnormal. ER = external rotation, and varus stress = lateral joint opening at 20°.

TABLE I Surgical Treatment of the Three Main Posterolateral Stabilizers and of Concomitant Cruciate Ligament Tears*

	Reconstructed PLC Structures			Repaired PLC Structures				Reconstructed Cruciate Ligaments	
Patient	Complete PLC	FCL	FCL-PFL	PLT Recess	FCL	PFL	PLT	ACL	PCL
1	X							X	X
2					X		X	X	
3				X	X			X	
4			X					X	
5		X						X	
6		X		X				X	
7			X	X					
8	X								X
9			X						
10		X		X				X	
11	X							X	
12	X							X	
13		X				X			X
14	X							X	X
15	X							X	X
16		X				X			
17		X						X	
18	X							X	
19		X						X	
20		X				X			
21		X							
22		X				X			
23	X							X	X
24L	X							X	X
24R		X							
25	X								X

*PLC = posterolateral corner; FCL = fibular collateral ligament; PLT = popliteus tendon; PFL = popliteofibular ligament; complete PLC = FCL, PLT, and PFL reconstruction; FCL-PFL = combined FCL and PFL reconstruction; ACL = anterior cruciate ligament; and PCL = posterior cruciate ligament.

Complete Posterolateral Corner Reconstruction Compared with Repair or Repair and Reconstruction

Ten patients (ten knees) were treated with an anatomic posterolateral corner reconstruction[10,17]. The remaining sixteen knees (the "hybrid" treatment group) were treated with posterolateral corner repair or repair and reconstruction (Tables I and III). Analysis of IKDC objective stability subscores including lateral joint opening at 20°, external rotation at 30° and at 90°, and the reverse pivot-shift test revealed no significant difference between the two cohorts at the time of the final follow-up ($p = 0.24$). All but one of the patients received a grade of A (normal) on these four maneuvers at the time of the final follow-up (Fig. 8, Table II). However, the posterolateral corner reconstruction cohort performed significantly more poorly on the one-leg hop than the hybrid cohort at the time of the final follow-up ($p < 0.05$). The cohort treated with a posterolateral corner reconstruction had significantly lower preoperative Cincinnati total ($p < 0.004$) and IKDC subjective scores ($p < 0.002$) than the hybrid cohort did.

Stress Radiographs

Preoperative varus stress radiographs revealed a side-to-side difference in lateral compartment gapping of 6.2 mm (range, 3 to 13 mm), which improved significantly to 0.1 mm (range, –1.5 to 5 mm) at the time of the final follow-up ($p < 0.0001$) (Fig. 9). The mean side-to-side difference in posterior knee translation on kneeling stress radiographs also improved significantly in the eight patients with a PCL tear, from 14.9 mm (range, 12 to 22 mm) preoperatively to 1.2 mm (range, 0 to 4 mm) at an average of 2.5 years of follow-up ($p < 0.01$).

TABLE II IKDC Objective Scores at Injury and at the Final Follow-up Evaluation

	Grade* (no. of knees)			
	A	B	C	D
Lateral joint opening at 20°				
Preoperative	0	0	9	17
Final follow-up	25	0	1	0
External rotation at 30°				
Preoperative	2	7	12	5
Final follow-up	25	1	0	0
External rotation at 90°				
Preoperative	5	4	12	5
Final follow-up	25	1	0	0
Reverse pivot-shift test				
Preoperative	6	5	10	5
Final follow-up	25	1	0	0
One-leg hop				
Preoperative	0	0	1	25
Final follow-up	17	6	2	1

*"A" = normal, "B" = nearly normal, "C" = abnormal, and "D" = severely abnormal.

Complications

One patient had a major complication, which involved failure of an anatomic posterolateral reconstruction three months postoperatively. This patient had initially been treated with acute anatomic posterolateral corner reconstruction, acute repair of a lateral capsular tear and an arcuate fracture, and concurrent ACL reconstruction with use of an autogenous patellar tendon. The patient underwent a proximal tibial opening-wedge biplanar osteotomy six months after his original surgery to correct his alignment. A staged revision posterolateral corner

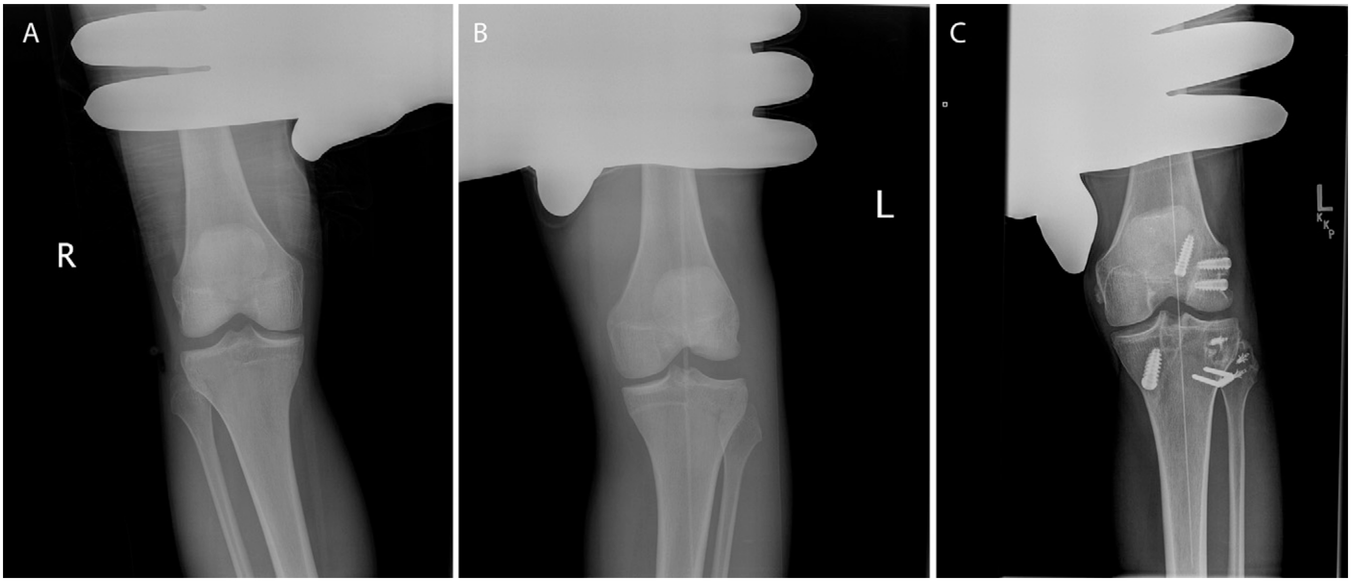

Fig. 9

Anteroposterior varus stress radiographs (at 20° of knee flexion) of a patient with an injury to the posterolateral corner of the left knee. *A* and *B:* Preoperative radiographs of the right and left knees showing a side-to-side difference of 7 mm. *C:* Radiograph of the left knee at the final follow-up evaluation. Following reconstruction of the posterolateral corner and the anterior cruciate ligament and repair of the lateral meniscus and the lateral capsular ligament, the side-to-side difference was –1 mm.

TABLE III Comparison of Mean Subjective Subscores at the Final Follow-up Evaluation for All Patients and Selected Subgroups*

	Cincinnati Score			IKDC Score
	Symptoms	Function	Total	Subjective
All patients	40.5	40.9	81.4	81.5
Isolated vs. combined injuries				
Isolated PLC injury	44.3	45.4	89.7	89.5
Combined PLC and cruciate ligament injury	39.1	39.3	78.3	78.5
Complete PLC reconstruction vs. hybrid				
Complete PLC reconstruction	35.4	33.7	69.1	68.8
Hybrid PLC repair and reconstruction	43.6	45.4	89.1	89.4

*IKDC = International Knee Documentation Committee, and PLC = posterolateral corner.

reconstruction was performed eight months later, which healed uneventfully.

Two patients had minor complications, which involved postoperative arthrofibrosis that resulted in a range of knee motion of 18° to 55° in one patient and 0° to 85° in the second patient. Both patients underwent arthroscopic debridement, and the patient with the extension deficit also underwent an arthroscopic posterior capsular release[28]. The resulting range of knee motion was –3° to 135° in the first patient and –5° to 135° in the second.

Discussion

We found that acute treatment of grade-III posterolateral knee injuries with surgical repair of avulsions of the FCL, popliteus tendon, and/or PFL (when the structure could be anatomically reduced to its attachment site with the knee in full extension) and reconstruction of the remaining injuries (including midsubstance injuries) to these main posterolateral corner structures resulted in a restoration of objective knee stability. In addition, the mean subjective knee scores were greater than those previously reported for anatomic posterolateral corner reconstruction in patients with a chronic posterolateral knee injury (Cincinnati subjective score, 65.7 points; IKDC subjective score, 62.6 points)[10]. All patients with a cruciate ligament tear or tears underwent concurrent cruciate ligament reconstruction, and the cohort with an isolated posterolateral corner injury did not differ significantly from the cohort with combined posterolateral corner and cruciate ligament injury with respect to the IKDC objective posterolateral stability subscores or the subjective outcomes. Thus, we confirmed our hypothesis that a combination of acute repair of avulsed posterolateral knee structures and reconstruction of midsubstance tears of the main posterolateral corner structures would result in significantly improved objective knee stability in patients with a grade-III posterolateral corner injury.

Early reports regarding acute repair of posterolateral corner injuries reported that 88% to 100% of the outcomes were good or fair[2,5,29]. Therefore, it had historically been recommended that repair of the posterolateral corner structures be performed acutely in order to improve patient outcomes. However, all patients in these three previously reported series were treated with casting postoperatively, and validated outcomes scores involving knee function were not reported.

Recent studies have reported failure rates of 37% to 40% for primary repairs of the main posterolateral corner structures, whereas successful outcomes were reported in 94% of patients following acute reconstruction[1,8]. However, the timing of cruciate ligament reconstruction differed between the repair and reconstruction cohorts in these studies. Reconstruction of most concomitant cruciate ligament tears was performed in a staged fashion after primary repair of the posterolateral corner structures in the repair cohort, but at the same time as reconstruction in the reconstruction cohort. It is therefore difficult to determine whether the greater number of failures in the cohort treated with primary posterolateral corner repair resulted from the decision to repair rather than reconstruct the posterolateral corner injury, from performance of staged cruciate ligament reconstruction at a later time, or from both of these differences.

Recent advances in understanding the relevant anatomy and clinically relevant biomechanics have led to the development of anatomically based posterolateral corner reconstruction techniques to treat both acute irreparable midsubstance tears and chronic injuries[17,22,25]. In addition, biomechanical validation of posterolateral corner reconstruction techniques and the use of suture anchors to obtain stronger repairs of avulsed posterolateral corner structures have resulted in an evolution in the postoperative rehabilitation regimen, which has progressed from a six to eight-week period of casting[2,5,29] to early postoperative knee motion in order to decrease the risk of arthrofibrosis and muscle atrophy[30]. We believe that our results, as well as those of others who have reported the outcomes of treatment of both acute[1,8,9] and chronic[10,11] grade-III injuries to posterolateral corner structures, support the reconstruction of concomitant midsubstance tears and substantial intrasubstance stretch injuries of the FCL or the popliteus tendon in order to improve patient outcomes.

Although recent articles have reported a high failure rate for acute posterolateral corner repairs[1,8], we believe that there is a role for repair rather than reconstruction of an avulsion (either soft-tissue or osseous) of the FCL or the popliteus tendon, and our subjective and objective patient outcomes support this. It is also important to note that the recent studies[1,8] that indicated high failure rates performed a staged reconstruction of most concurrent cruciate ligament tears after the initial repair of the posterolateral corner structures, whereas a concurrent cruciate ligament reconstruction was performed in all patients with such a concomitant injury in our study. Biomechanical studies have demonstrated the important interactions between the posterolateral structures and the cruciate ligaments[31-33], and one previous study indicated that ACL deficiency resulted in a five-fold increase in the force on the posterolateral corner structures[34]. We recommend a careful assessment to verify that the posterolateral structures can be repaired with the knee in full extension, and we recommend intraoperative confirmation that the fixation is adequate to allow early knee motion without concerns regarding failure of the repair.

Our study has limitations. As with any study of posterolateral knee injuries[16,35], the majority of the injuries were not isolated posterolateral corner injuries. However, there was no clinical or objective evidence of failure of any of the concurrent cruciate ligament reconstructions at the time of the final follow-up. It must also be noted that neither preinjury activity scores nor preinjury subjective scores were available. In addition, only one surgical algorithm was used, and comparisons with different reconstruction techniques or with direct repair only were not performed. However, repair of midsubstance cruciate ligament tears has been shown to result in poorer objective stability than reconstruction[36], and a similar situation is expected to exist with isolated midsubstance tears of the FCL or the popliteus tendon. We advocate that reconstruction be performed to treat midsubstance tears of these two structures[1,8,11], or that an anatomic posterolateral reconstruction be performed if both structures are torn and not repairable[10,17].

In conclusion, surgical treatment of grade-III posterolateral corner injuries by repair of avulsions of the main posterolateral corner structures combined with reconstruction of midsubstance tears of these structures resulted in significantly improved objective stability. We recommend that concomitant cruciate ligament tears be reconstructed concurrently with treatment of the posterolateral corner injury. Furthermore, we recommend that all repaired structures be secured with the knee in full extension and that early knee motion be initiated immediately postoperatively within an intraoperatively determined "safe zone" (normally at least 0° to 90°). Adherence to these guidelines significantly improved objective stability for patients with acute grade-III posterolateral corner injuries with or without concomitant knee injuries.

Appendix

eA A table summarizing the knee injuries in each patient is available with the online version of this article as a data supplement at jbjs.org. ■

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