

Injuries to the Posterior Cruciate Ligament and Posterolateral Instabilities of the Knee

Ching-Jen Wang, MD

Unlike anterior cruciate ligament (ACL) injury, disability from isolated posterior cruciate ligament (PCL) injury varies from no interference with life style to severe impairment of daily activities. Therefore, management of isolated PCL injuries remains controversial. High-energy vehicular accidents often cause more-serious PCL injuries, while less-severe injuries result from low-energy trauma including sports. The natural history and prognosis of PCL injury are correlated with the type and extent of instability and the development of degenerative changes in the knee. Indications for surgery include pain and instability of the knee.

Arthroscopic single-bundle PCL reconstruction improved the function and stability of the knee with 77.4% satisfactory results in medium-term follow-up. Complete restoration of ligament stability was achieved in only 52% of knees, while 1/3 of the knees showed mild and 9.7% showed moderate residual ligament laxity. The incidence of degenerative changes was 52%, and the rate was correlated with duration of injury and severity of ligament laxity. Therefore, the significance of PCL injury has been overly simplified, and the functional disability of knees with PCL injury underestimated. Early surgical reconstruction of knees with grade III PCL injury is recommended.

PCL injury is frequently associated with multiple ligamentous injuries. Combined PCL and posterolateral instabilities are serious knee injuries and frequently result in severe functional disability due to pain, instability, and degenerative changes in the knee. Unlike isolated PCL injury, there is a consensus of opinion that surgical reconstruction is indicated in knees with combined PCL and posterolateral instabilities. Commonly employed methods of reconstruction of the posterolateral corner include popliteus reconstruction, lateral collateral reconstruction or advancement, and a combination of the two. Combined arthroscopic PCL reconstruction and posterolateral reconstruction achieved 64% satisfactory (24% excellent and 40% good) and 36% unsatisfactory (24% fair and 12% poor) results over an average of 32 months of follow-up. Complete restoration of ligament stability was noted in only 44% of knees. The incidence of degenerative changes was 44%, and the rate was correlated with duration from injury to surgery and severity of ligament laxity. Despite the fact that currently employed surgical techniques only achieve modest success in restoration of ligament stability, early surgical reconstruction in knees with combined PCL and posterolateral instabilities achieved the best clinical results and a high rate of patient satisfaction. (*Chang Gung Med J* 2002;25:288-97)

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From the Department of Orthopedic Surgery, Chang Gung Memorial Hospital, Kaohsiung.

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Address for reprints: Dr. Ching-Jen Wang, Department of Orthopedic Surgery, Chang Gung Memorial Hospital, 123, Ta-Pei Road, Niasung, Kaohsiung 833, Taiwan, R.O.C. Tel.: 886-7-7335279; Fax: 886-7-7335515; E-mail: w281211@adm.cgmh.org.tw

The posterior cruciate ligament (PCL) is the strongest ligament in the knee. However, disability after PCL injury varies from no interference with lifestyle to severe impairment of daily activities.⁽¹⁻⁷⁾ Therefore, treatment of PCL injuries remains controversial. Unlike anterior cruciate ligament (ACL) injury, high-energy trauma accounts for the majority of PCL injuries.^(2,4-8) Therefore, injuries to the ACL are considered to be sports-related, while those to the PCL are trauma-related. A paradox exists because some authors in earlier reports regarded PCL injury as a benign condition and treated it non-operatively,⁽⁹⁻¹²⁾ yet others at a later time recommended surgical treatment.⁽¹³⁻²²⁾ Information from recent studies of natural history, functional anatomy, knee kinematics, and biomechanics has changed the concepts and altered the method of treatment of patients with PCL injury.

Contrary to isolated PCL injury, combined PCL and posterolateral injuries of the knee often cause severe functional disability, pain, instability, and deterioration of the articular cartilage of the knee. There is a consensus of opinion that surgical reconstruction is indicated.^(7,23-32) However, the currently employed surgical techniques can only achieve modest success in restoration of ligament stability. The purpose of this study was to review current concepts and management of knees with isolated PCL injury and combined PCL and posterolateral instabilities.

Functional anatomy

The PCL is an average 38 mm in length, and 13 mm in width, and the cross-sectional area decreases from the proximal end to the distal attachment.^(1,5,33) It attaches proximally to the inner wall of the medial femoral condyle, and distally at 10 mm below the articular surface slightly lateral to the center of the proximal tibia. It is morphologically divided into a larger anterolateral bundle that is tight in flexion and lax in extension, and a smaller posteromedial bundle that is tight in extension and lax in flexion. Approximately 70% of knees also show a menisocofemoral ligament of Humphrey anteriorly or a ligament of Wrisberg posteriorly that reinforces PCL stability. Based on the orientation of the fibers, the mechanical behavior during motion of the joint, and the osseous sites of insertion, 4 fiber regions were identified including the anterior, central, posterior longitudinal, and posterior oblique. Most of the PCL

substance is made up of the anterior and central fiber regions that behave non-isometrically. Only 15% of the posterior fibers show isometric behavior.^(1,2,5,33-35)

Important posterolateral structures include the lateral collateral ligament (LCL), the popliteofemoral ligament, the popliteofibular ligament, and the arcuate ligament complex. The popliteus tendon complex consists of a Y-shaped structure including the popliteofemoral ligament, popliteofibular ligament, and the posterior capsular component, and is the primary posterolateral stabilizer. The LCL primarily resists varus angulation. The arcuate complex along with the popliteus tendon complex reinforces posterolateral stability of the knee.^(25,26,28,30,31,36) While the PCL is the primary posterior stabilizer, injury to the PCL can also cause mild to moderate posterolateral instability of the knee.^(32,37) Knees with isolated PCL injury typically show increased posterior translation at 90° of knee flexion. Physical examination of knees with combined PCL and posterolateral instabilities shows increased posterior translation and increased posterolateral rotatory instability. Posterior translation is best demonstrated by posterior sagging, posterior drawer, reverse Lachman test, and active quadriceps test, while posterolateral rotatory instability is shown by coupled posterolateral drawer at 30° and 90° of knee flexion, increased external tibial rotation, and varus angulation test.

Biomechanics and kinematics

The PCL is the primary restraint against straight posterior translation of the tibia at all positions of the knee.^(5,10,26,30,31,36,38-40) It also plays an important role in posterolateral stability of the knee.^(32,41) Forces in the PCL increase as the distance between the attachment sites increases with flexion of the knee. The length pattern between insertion sites is very sensitive within the femoral attachment, but is much less sensitive to changes within the tibial attachment; the fixation site of the femoral graft is the primary determinant of changes in length of the graft during motion of the knee.^(2,14,26,34,36,38,40,42-44) Most of the ligament fibers including the anterior and central fibers were found to be highly non-isometric and to tighten with flexion of the knee. Only approximately 15% of the posterior fibers showed near-isometric behavior.⁽²⁾

Sectioning of the PCL resulted in increased medial compartment pressure, while sectioning of the PCL and posterolateral structures led to increased

patellofemoral pressure and quadriceps load.⁽⁴⁵⁾ Gollehon et al.⁽²⁶⁾ demonstrated that the PCL is the principal structure preventing posterior translation, and isolated sectioning of the PCL showed no effect on varus or external rotation. The LCL is the principal structure preventing varus angulation and rotation. Combined sectioning of the PCL and the LCL resulted in increased posterior translation and varus rotation. Grood et al.⁽²⁸⁾ showed that posterior translation after sectioning of the PCL was greatest at 90° of knee flexion, and least at 0° as a result of slackening in the posterior capsule. The magnitude of varus angulation and external tibial rotation after sectioning of posterolateral structures was most noticeable at 30° of knee flexion, and least at 90° of knee flexion. When both PCL and posterolateral structures were cut, increased posterior translation and external tibial rotation were equally noticeable both at 30° and 90° of knee flexion. Veltri et al.⁽³⁰⁾ further demonstrated that combined sectioning of the PCL and posterolateral ligaments resulted in increased primary posterior translation, primary varus and external rotation, and coupled external rotation at all angles of knee flexion. Examination of the knee at 30° and 90° of flexion can discriminate between combined PCL and posterolateral injuries and isolated posterolateral injury. Other studies showed that the PCL plays a major part in maintaining both posterior 1-plane stability and rotational stability of the knee.^(32,41)

Mechanism of injury

Trauma produces for the majority of PCL and posterolateral injuries.⁽²³⁾ More-serious grade III PCL injuries and combined PCL and posterolateral instabilities are often caused by high-energy vehicular trauma, and are frequently associated with ipsilateral fracture of the femur and tibia.^(3,4,23) Fanelli et al.⁽⁴⁾ reported that PCL injury occurred in 38% of all acute trauma patients, and that 96.5% of PCL injuries occurred in combination with other ligament injuries. Low-energy trauma including sports injuries, however, caused less-serious PCL injuries, and patients generally do well with conservative treatment.^(9-11,16,18,46) The mechanism of injury is usually associated with contact involving a direct anterior force to the flexed knee (dashboard injury), or significant force on a hyper-extended knee. When a valgus or varus force is applied to an extended knee, such as in a football injury, combined ligament

injuries are more likely. The mechanism of combined PCL and posterolateral injuries consists of a rotational injury due to a blow to the anteromedial aspect of the flexed knee. Such force usually causes injury first to the arcuate ligament complex, then as the rotational force continues, the posterior cruciate ligament is injured.⁽²³⁾ Our observations from surgical findings suggest that the PCL might be injured first, followed by the posterolateral structures as the force continues.

Natural history and indications for surgery

The natural history of isolated PCL injury is not well known. Covey et al.⁽³⁴⁾ described 3 phases after PCL injury. The first phase is functional adaptation that ranges from 3 to 18 months. The second phase is functional tolerance that ranges from 15 to 20 years, and the third phase is osteoarthritic deterioration that usually occurs after 25 years. In addition, they regarded isolated PCL injury as a benign condition. Unlike ACL injury, disability after isolated PCL injury varies from no interference with lifestyle to severe impairment of daily activities. PCL injury is more frequently associated with pain than with instability. Dejour et al.⁽⁴⁷⁾ made a similar observation and recommended repair of acute PCL injury in young people. Torg et al.⁽⁸⁾ stated that the natural history and prognosis of PCL injury are correlated with the type and extent of instability, and that the functional outcome of PCL injury can be predicted on the basis of the type of instability. PCL injury with no associated ligament laxity will remain symptom free, while for PCL injury with combined instabilities, a less than desirable functional result will probably occur. Grade III PCL injuries often result from high-energy trauma including motor vehicle accidents, while low-energy injuries including sports may cause grade I or II PCL injuries. Patients with less-severe PCL injuries may do well with conservative treatment. However, patients with grade III PCL injuries are at risk of recurrent pain and instability, and development of degenerative changes in the knee. Indications for surgery in knees with isolated PCL injury include pain and instability (Fig. 1).

Combined PCL and posterolateral injuries frequently result in severe functional disability due to pain and instability of the knee, and ultimate deterioration of the articular cartilage.^(23,29,48) Patients complain of pain and giving way of the knee, and walk



Fig. 1 Reconstruction indicated for a complete PCL tear with pain and instability.



Fig. 2 Patient with combined PCL and posterolateral instabilities.

with a lateral thrust (Fig. 2). Physical examination revealed posterior sagging, posterior drawer test, reverse Lachman test, increased coupled posterolateral translation with the knee at 30° and 90° of flexion, varus angulation test, and increased external tibial rotation. There is a consensus of opinion that surgery is indicated in knees with combined PCL and

posterolateral injuries.^(1,15,17,23,24,46,49-52)

Non-operative treatment

The functional disability of isolated PCL injury ranges from no interference with lifestyle to severe impairment of daily activities, and knee function is correlated with the severity of ligament laxity. Many authors have reported satisfactory results of PCL injury treated conservatively.^(9-12,45) Most of their patients sustained a PCL injury from low-energy trauma including sports injuries. Cross et al.⁽¹⁶⁾ reported that 47 of 55 sports-related PCL injuries did well with conservative treatment, while only 5 of 61 trauma-related PCL injuries did as well, and recommended early repair of trauma-related PCL injuries. Keller et al.⁽¹⁸⁾ reported 90% of patients complaining of pain and 49% of patients failing to recover normal knee function 6 years after an isolated PCL injury. Clancy et al.⁽¹⁵⁾ showed destructive changes of the articular cartilage 2 years after PCL injury in 20% of patellofemoral joints and 70% of femorotibial joints, with a 48% incidence of degenerative changes in knees with chronic PCL injury, and thus recommended surgical reconstruction. Torg et al.⁽⁸⁾ noted a correlation in the prognosis of PCL injury with the type and severity of instability. Conservative treatments gave less than desirable functional results in knees with combined ligament injuries and severe ligament laxity. In general, knees with less than grade III isolated PCL injury from low-energy trauma can be treated conservatively, and satisfactory results can be anticipated. However, knees with grade III isolated PCL injury and combined PCL and posterolateral instabilities require surgical reconstruction.

Operative treatment

Arthroscopic PCL reconstruction has evolved as the method of choice for the management of knees with PCL injury. Although satisfactory results of double-bundle PCL reconstruction were recently reported,⁽²²⁾ the choice between single- and double-bundle PCL reconstruction remains unsettled, and additional information is needed. For single-bundle PCL reconstruction, there is a disparity of opinions on the best knee position and the ideal graft tension. Some authors have suggested isometric placement of the PCL graft,⁽⁵³⁾ while others have recommended non-isometric reconstruction.^(13,14,43,52) Burns et al.⁽¹⁴⁾ suggested the use of single-bundle PCL reconstruc-

tion with the graft tensioned at 90° of knee flexion. Bomberg et al.⁽¹³⁾ recommended that the PCL graft should be slightly tighter at knee flexion, while Warren et al.⁽⁵²⁾ showed that the best position of the knee for PCL graft tension is full extension. Galloway et al.⁽⁴³⁾ suggested that non-isometric reconstruction of the PCL, in which the graft was secured at 30° of knee flexion, produced the most physiologic pattern of femorotibial stability and kinematics. The ideal graft tension is unknown. Burns et al.⁽¹⁴⁾ recommended 156 N of force applied to the anterior tibial surface in PCL reconstruction. Wascher et al.,⁽⁵⁴⁾ however, showed that 10 to 50 N of force as external tibial torque increased the PCL tension, but the tension decreased when the knee was in external or internal rotation. The results of our study in cadaveric knees showed that the PCL graft is best tensioned with 15 lbs (68 N) at 20°-30° of knee flexion. Ohkoshi et al.⁽²⁰⁾ recommended an anterolateral approach for the tibial tunnel to minimize graft angulation by avoiding the "killer turn" that potentially causes graft impingement after PCL reconstruction.

The graft may be autogenous or allogenic. Autogenous grafts include patellar bone-tendon-bone, quadriceps-bone, and combined semitendinous and gracilis. Allografts include the Achilles tendon, the patellar bone-tendon-bone, and quadriceps-bone unit. There are advantages and disadvantages to both auto- and allografts. However, clinical results showed no significant difference between the two.⁽⁵⁵⁾ Methods of graft fixation vary considerably. The most-commonly used methods of fixation include interference screw fixation and screw-post fixation. The advantages and disadvantages of these types of fixation are being studied. The results of our study showed no significant difference in the average load of graft failure between interference screw fixation and screw-post fixation; however, the modes of graft failure differ. Failure sites consisted of 75% at the bone-tendon interface and 25% within the ligament. Modes of failure included bone plug pullout in interference fixation, and suture breakage and fracture of the bone plug in screw-post fixation.

In knees with combined PCL and posterolateral instabilities, concomitant arthroscopic PCL reconstruction and reconstruction of the posterolateral structures are recommended. Associated intra-articular pathologies such as meniscus tearing or chon-

dral lesions can also be treated arthroscopically. The magnitude and complexity of posterolateral reconstruction are dictated by the type and severity of ligament laxities. Lateral collateral ligament reconstruction or advancement is indicated in knees with a positive varus angulation test at extension. Popliteus tendon reconstruction is performed in knees with increased coupled posterolateral instability and increased external tibial rotation. Often, combined popliteus reconstruction and LCL advancement are necessary to reconstruct knees with complex posterolateral instabilities. Currently employed surgical reconstruction for posterolateral structures includes 2 strips of iliotibial bands to reconstruct the popliteofemoral and popliteofibular ligaments (Fig. 3); lateral collateral ligament advancement or tenodesis (Fig. 4); and combined popliteus reconstruction and LCL advancement (Fig. 5). Other methods of reconstruction including allografts have also been reported.⁽⁵⁵⁾

In acute settings of knees with combined PCL and MCL (medial collateral ligament) injuries, immobilization for 2 to 4 weeks to heal the MCL, and late PCL reconstruction are recommended. When the PCL, ACL, and MCL are all injured, recommendations include non-operative treatment for the MCL, semi-acute reconstruction of the PCL, and late ACL reconstruction. In knees with combined PCL and LCL injuries, semi-acute repair of the LCL

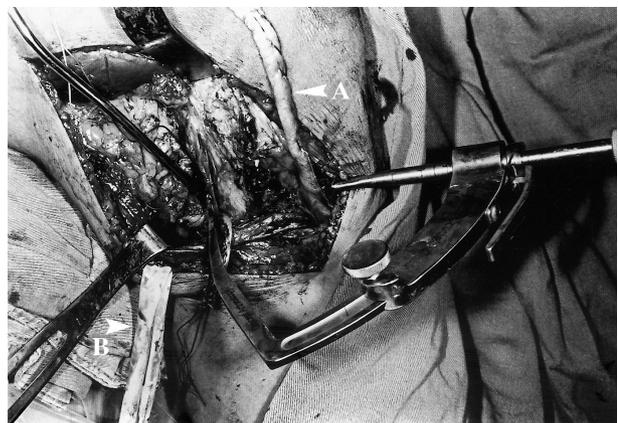


Fig. 3 The popliteofemoral and popliteofibular ligaments. A: Using the central 1/3 of the ITB bend to reconstruct the popliteofemoral ligament. B: Using the posterior 1/2 of the biceps femoris tendon to reconstruct the popliteofibular ligament.

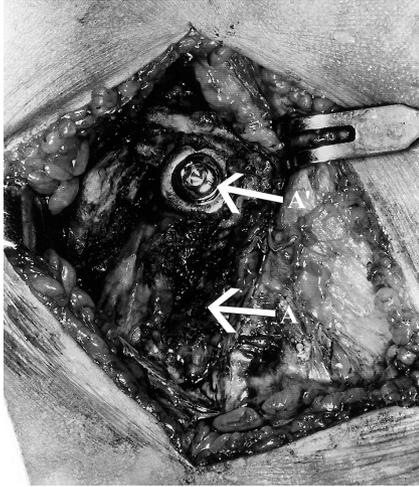


Fig. 4 Lateral collateral ligament advancement or tenodesis. The LCL is advanced from its original insertion A to the new location A'.

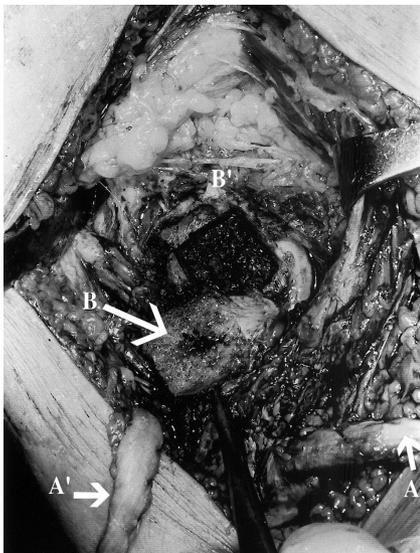


Fig. 5 Combined popliteus reconstruction and LCL advancement. A: Popliteus reconstruction using the ITB (A) and biceps femoris (A'). B: LCL advancement from its original insertion B to the new location B'.

and PCL reconstruction are suggested. When the PCL, ACL, and LCL are all injured, acute repair of the LCL, and semi-acute PCL and ACL reconstructions are recommended. In knees with acute dislocation, efforts should be made to avoid arthrofibrosis

after bi-cruciate reconstruction.

Knees with combined ligament instability and angular deformity due to degenerative changes are best treated with staged procedures. An open-wedge high tibial osteotomy should be performed first, with ligament reconstruction as a concomitant or separate procedure.

Postoperatively, the knee should be immobilized in extension with a knee brace for isolated PCL reconstruction. More-rigid immobilization including a cast splint or a full cast is recommended for knees with combined surgical reconstructions. A functional knee brace can be used after 6-8 weeks. The rehabilitation program should progress cautiously. Patients should remain on crutches with partial weight bearing on the affected leg for approximately 4-6 weeks, and full weight bearing is permitted after 3 months. Quadriceps strengthening exercises are encouraged; however, active hamstring exercises are usually withheld for 6 weeks. Patients are not permitted to return to strenuous activities including sports for 12 months.

Clinical results

Many studies on clinical results of PCL reconstruction show good early functional results, but the posterior laxity of the knee was not completely eliminated.^(17,19,22,49,50,52,56) Clancy et al.⁽¹⁵⁾ reported good to excellent results in 10 of 10 acute cases and 11 of 13 reconstructions for chronic PCL instability with single-bundle patellar bone-tendon-bone grafts. Richter et al.⁽²¹⁾ showed that primary repair of PCL injury provided good results in 2/3 of patients after 8 years. Kim et al.⁽¹⁹⁾ reported satisfactory results in 37 arthroscopic PCL reconstructions with 1 incision and attributed the good results to minimal surgical trauma to the extensor mechanism, especially the vastus medialis obliquus muscle and medial scar. Ohkoshi et al.⁽²⁰⁾ reported achieving normal or nearly normal knees in 20 of 21 cases using a modified endoscopic PCL reconstruction with an anterolateral approach that minimized graft angulation and avoided the "killer turn" posteriorly. However, Lipscomb⁽⁴⁶⁾ did not recommend PCL reconstruction using the semi-tendinous and gracilis because of inconsistencies in limiting the posterior instability postoperatively. Our experience with 31 knees in 30 patients undergoing arthroscopic single-bundle PCL reconstruction with 40 (24-108) months follow-up showed 77.4% satis-

factory results, and 87% of patients were satisfied with the surgical results. However, complete restoration of posterior laxity was observed in only 52% of knees, while approximately 1/3 of knees showed mild (0-5 mm), and 9.7% showed moderate (5-10 mm) posterior laxity postoperatively. It appeared that mild to moderate posterior laxities caused no significant functional impairment of the knee in the medium-term results.

The incidences of degenerative changes after PCL injury in the literature range from 48% to 90%, and were proportional to the interval from injury to surgery and the severity of ligament laxity.^(15,47,50) The incidence of degenerative changes in our series was 52%, and the rate was correlated with duration of injury, severity of ligament laxity, and length of follow-up. Preliminary results of double-bundle PCL reconstruction seemed appealing, and the conclusions are pending. The results of our study led us to believe that the significance of PCL injury has been overly simplified, and that early surgical reconstruction in knees with grade III PCL injury is recommended.

Results of combined PCL reconstruction and reconstruction of posterolateral structures vary considerably. Hughston et al.⁽⁴⁹⁾ reported 85% good, 14% fair, and 1% poor results after reconstruction by advancing the arcuate ligament complex anteriorly and distally in 96 knees in 95 patients with 2-13 years of follow-up. Noyes et al.^(55,57) reported 64% fully functional, 27% partially functional, and 9% failed results in 23 knees undergoing combined cruciate reconstruction and proximal advancement of the lateral collateral ligament and the posterolateral complex with 23-92 months of follow-up, and 76% good results in the reconstruction of the lateral collateral ligament with allograft tissue. Our experience in 25 patients undergoing combined arthroscopic PCL reconstruction and reconstruction of the posterolateral complex showed 64% satisfactory results and 36% unsatisfactory results with an average 32 (24-50) months of follow-up. Complete restoration of ligament laxity was observed in only 44% of knees, while 36% of knees showed mild (0-5 mm) and 20% showed moderate (5-10 mm) ligament laxity. The incidence of degenerative changes was 44%, and rates were higher in knees with more-serious ligament laxity, surgery performed longer than 1 year

previous, and knees with longer follow-up. It is our opinion that treatment of knees with combined PCL and posterolateral instabilities remains an unresolved orthopedic problem. Currently employed surgical techniques can achieve only modest success in restoration of ligament stability. Further improvements in surgical techniques including dynamic reconstruction of the popliteus tendon complex are deemed necessary, and early surgical reconstruction is recommended.

In conclusion, unlike ACL injuries, disability due to isolated PCL injury varies from no interference with life style to severe functional impairment of daily activities. Therefore, treatment of isolated PCL injury remains controversial. High-energy vehicular accidents are likely to cause more-serious grade III PCL injuries, while less-serious PCL injuries result from low-energy trauma including sports. The prognosis and natural history of PCL injuries are correlated with the severity and type of instability of the knees. Most knees with less than grade III PCL injury can be treated conservatively. Indications for surgery include pain and instability directly related to grade III PCL injury. Arthroscopic PCL reconstruction can significantly improve the function and stability of the knee. However, approximately 1/3 of knees showed mild to moderate residual ligament laxity. The incidence of degenerative changes with chronic PCL injury was approximately 52%, and the rate was correlated with the duration of injury and the severity of ligament laxity. Therefore, the significance of PCL injury has been overly simplified, and the severity underestimated.

Combined PCL and posterolateral instabilities are serious injuries and often result in severe functional disability and a high incidence of degenerative changes in the knee. There is a consensus of opinion that surgical reconstruction is indicated. Early arthroscopic PCL reconstruction and concomitant reconstruction of the posterolateral structures can significantly improve the functional stability of the knee. However, the currently employed surgical techniques can only achieve modest success in restoration of ligament stability. Therefore, combined PCL and posterolateral instabilities are an unsolved orthopedic problem, and additional improvements are needed.

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