Remnant Posterior Cruciate Ligament–Augmenting Stent Procedure for Injuries in the Acute or Subacute Stage

Young-Bok Jung, M.D., Ho-Joong Jung, M.D., Kwang-Sup Song, M.D., Jae Yoon Kim, M.D., Han Jun Lee, M.D., and Jae-Sung Lee, M.D.

Purpose: To evaluate the results of a remnant posterior cruciate ligament (PCL)–augmenting stent procedure for acute- or subacute-stage PCL injuries in terms of stability and clinical results. **Methods:** Between September 2003 and March 2006, 32 patients with a PCL tear underwent a reconstructive stent procedure with an autogenous hamstring tendon graft to augment the remains of the injured PCL. Of these patients, 20 who satisfied our inclusion criteria and could be followed up for a minimum duration of 24 months were enrolled in our study. The remnant PCL and synovium were preserved, and augmentation was performed by use of the transtibial technique. A femoral tunnel was created near the footprint of the anterolateral bundle. Stability was measured on posterior stress radiographs and by use of a maximum manual displacement test performed with a KT-1000 arthrometer (MEDmetric, San Diego, CA). The International Knee Documentation Committee (IKDC) and Orthopädische Arbeitsgruppe Knie scoring systems were used for clinical evaluation. **Results:** Stress radiographs showed that the mean side-to-side differences in displacement were reduced from 9.9 ± 4.0 mm preoperatively to 3.0 ± 2.6 mm at the last follow-up, whereas KT-1000 tests showed that these differences were reduced from 6.9 ± 2.1 mm preoperatively to 2.7 ± 1.5 mm. The final IKDC score was A in 7 patients (35%), B in 10 (50%), C in 2 (10%), and D in 1 (5%). The mean Orthopädische Arbeitsgruppe Knie score improved from 61.6 ± 13.1 to 88.2 ± 9.5. **Conclusions:** Of the patients, 90% showed satisfactory posterior stability and 85% had a normal or nearly normal rating based on the IKDC score at a mean of 3 years after the remnant PCL–augmenting stent procedure in the acute or subacute stage of PCL injuries. **Level of Evidence:** Level IV, therapeutic case series.

Some authors have reported that the posterior cruciate ligament (PCL) can heal spontaneously,[1-6] and many investigators have reported that conservative treatment of knees with an acute PCL injury yields favorable clinical results, despite residual posterior laxity.[7-10] The surgical indicator for an isolated PCL injury is generally a posterior displacement of greater than 10 mm,[11] but recent improvements in surgical techniques have increased the number of satisfactory clinical outcomes after surgical reconstruction with an 8- to 10-mm posterior displacement.[12] Moreover, if the PCL injury is combined with other ligament injuries, such as posterolateral corner injury or collateral ligament injury, operative treatment would be needed. Wang et al.[13] reported on the remnant-augmenting stent method for PCL injuries and suggested that the PCL can retain its normal tension only if the injured ligament is maintained anatomically and that the PCL remnant may be beneficial to ligament healing and postoperative rehabilitation. The purpose of this study was to evaluate the results of a

From the Department of Orthopaedic Surgery, Medical Center of Chung-Ang University (Y.-B.J., H.-J.J., K.-S.S., J.Y.K.) and Department of Orthopaedic Surgery, Yong-San Hospital, Chung-Ang University (H.J.L., J.-S.L.), Seoul, Republic of Korea.

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Address correspondence and reprint requests to Ho-Joong Jung, M.D., Department of Orthopaedic Surgery, Medical Center of Chung-Ang University. 224-1, Heukseok-dong, Dongjak-gu, Seoul, 156-755, Republic of Korea. E-mail: sunu@cau.ac.kr

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remnant PCL–augmenting stent procedure for acute- or subacute-stage PCL injuries in terms of stability and clinical results. We hypothesized that the stent procedure in the acute or subacute stage would significantly contribute to the posterior stability of the knee joint, improving clinical results.

METHODS

Patient Selection and Evaluation

The remnant PCL–augmenting stent procedure for PCL reconstruction was considered to be needed for active athletic patients or manual labor workers with PCL injuries that were grade III or higher in severity or grade II combined with other ligament injuries. We also only used the stent technique after we confirmed, by preoperative magnetic resonance imaging or arthroscopic examination during the acute or subacute stage (<3 months), that the PCL showed partial continuity or its remains were sufficient for the stent procedure. Between September 2003 and March 2006, a total of 213 patients with PCL injuries were treated at our hospital. Of these patients, 47 underwent conservative treatment,[14] 79 underwent tensioning augmentation by use of the inlay method,[15] 34 underwent double-bundle reconstruction with the inlay method,[16] 21 underwent transtibial single-bundle reconstruction, and 32 underwent the remnant PCL–augmenting stent procedure. Of the 32 patients who underwent the stent procedure, 11 were excluded because they met 1 of the following exclusion criteria: (1) concomitant anterior cruciate ligament (ACL) reconstruction, (2) an associated fracture in the lower extremities of such magnitude that knee function could be affected, (3) chronic injury (>3 months), or (4) concomitant severe life-threatening medical disease. In addition, 1 patient was lost to follow-up, which left 20 patients who met the inclusion criteria and could be followed up for a minimum of 24 months. For all patients, the ipsilateral or contralateral autogenous hamstring tendon served as the graft for remnant PCL augmentation. If medial collateral ligament injury or posterolateral corner injury was present, contralateral hamstrings were used for the graft. The study was approved by the institutional review board of our hospital, and all patients provided informed consent.

There were 17 male and 3 female patients who were aged 34.9 years on average (range, 21 to 49 years). The mean duration of follow-up after surgery was 36.5 months (range, 24.9 to 52.2 months). The mechanism of injury was proximal pretibial trauma (11 patients), hyperextension injury (7 patients), or unexplained injury (2 patients). The mean duration from the time of injury to PCL surgery was 1.4 months (range, 9 to 81 days). At the time of surgery, physical examination with the patient under anesthesia showed grade III posterior instability (displacement of tibia posterior to condyle) in 10 patients and grade II posterior instability (tibia is flush with medial femoral condyle) in 10 patients. All grade II PCL injury cases had other injuries as well, namely, posterolateral rotatory instability (PLRI) (5 patients), medial collateral ligament injury (4 patients), and a partial ACL tear (1 patient). Among the 5 patients with PLRI, 1 patient showed marked improvement in stability after PCL reconstruction, whereas 4 patients underwent posterolateral corner reconstruction simultaneously during PCL reconstruction, by use of the modified fibular tunnel method,[17] with a tibialis posterior allograft, because rotatory instability persisted immediately after PCL reconstruction. All patients with medial collateral ligament injuries underwent nonoperative management. For patients with partial tears of the ACL (grade 1.5), conservative treatment was also applied, because instability was not so severe and synovial coverage was intact.

Surgical Technique

The patient is placed in the supine position, and general or spinal anesthesia is given. The end of the operating table is lowered so that the patient's knee can be flexed to 90°. The arthroscope is introduced through a high anterolateral arthroscopic portal, and the intra-articular structures are examined; meniscal surgery is performed when needed. For proper preparation of the tibial tunnel, a posteromedial portal is made. The posterior capsule is detached from its attachment, and frayed soft tissue is removed through the posteromedial or anteromedial portal by use of a shaver. A 4-cm oblique skin incision is made medial to the tibial tuberosity along the superior margin of the pes anserinus for graft harvesting and preparation of the transtibial tunnel. The graft tendon (semitendinosus and gracilis) is then harvested. While viewing through the posteromedial portal with the aid of a C-arm, the surgeon introduces the tip of the guide through the anteromedial portal and advances it to the back side of the PCL, positioning it 1 to 1.5 cm below the articular surface, just distal to the tibial PCL insertion, to avoid damage to remnant PCL attachment (Fig 1). The drill guide angle of the tibia is oriented at 55° to 60°, and the tunnel diameter is determined

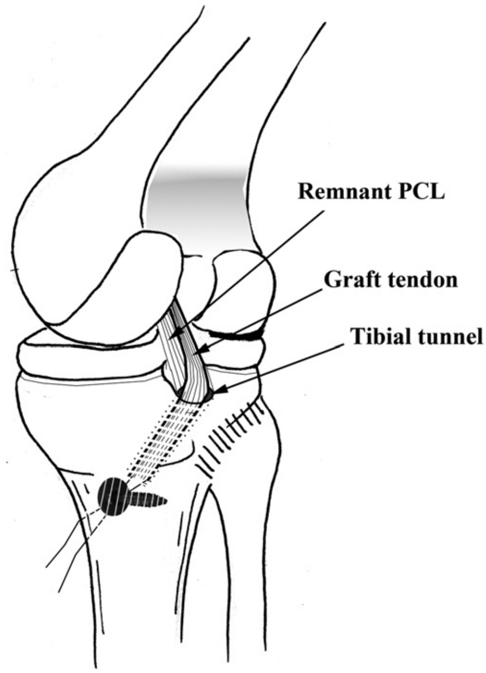

FIGURE 1. The tibial tunnel is created just distal to the tibial PCL insertion. The graft is first fixed with a 10-mm staple or post tie.

based on the graft diameter. A straight reamer is then used and should measure a half millimeter less than the diameter of the graft. In the last step of tibial tunnel preparation, a dilator (Linvatec, Largo, FL) is used to prevent neurovascular injury and the posterior wall of the tibia from breaking.

To prepare the femoral tunnel without removing the remains of the PCL, while viewing through the anteromedial portal, the surgeon places the tip of an ACL tibial guide (Acufex Microsurgical, Mansfield, MA) 5 to 6 mm proximal to the margin of the articular cartilage of the medial femoral condyle at the 12:30- to 1-o'clock position for a right knee and at the 11- to 11:30-o'clock position for a left knee (Fig 2). The distal femoral cortex is exposed medially through a 3- to 5-cm-long skin incision, and the vastus medialis is elevated subperiosteally. After placement of the guide pin, a tunnel is made through the medial femoral condyle by use of a cannulated drill. We start making a femoral tunnel with a 6-mm cannulated reamer and then sequentially dilate the femoral tunnel manually in 0.5-mm increments of dilator size according to the graft diameter to avoid damaging the remaining PCL. The tunnel edge is then chamfered with rasps. A 21-gauge wire loop is passed through the femoral tunnel, directed toward the medial side of the remnant PCL, and pulled through the tibial tunnel for graft passage.

The tendon graft traction sutures are passed with a wire loop from the outer tibial orifice into the tibial tunnel, and the graft is pulled up through the knee joint into the femoral tunnel. The graft tendon is fixed to the femoral tunnel, first with a biodegradable interference screw and then with a staple or post tie. After the tension and accurate positioning of the graft are assessed arthroscopically, the graft is cyclically loaded with 67 N of tension and fixed with a biodegradable interference screw to the tibial tunnel with the knee joint flexed at 70° to 90°. It is then fixed with a 10-mm staple or post tie (Fig 1). Finally, the knee joint is assessed once more to check that full extension and flexion can occur without any resistance.

For the first 2 or 3 weeks after surgery, a long leg splint is used to hold the knee in full extension. The splint has a posterior pad that prevents the tibia from posterior sagging (Fig 3). Straight-leg raising and quadriceps-setting exercises are started the day after surgery, and the patient is allowed partial weight bearing using crutches. Starting on the second postoperative day, the splint is removed once or twice a day, and the patient is encouraged to perform passive range-of-motion exercises at 30° to 90° of flexion; he or she

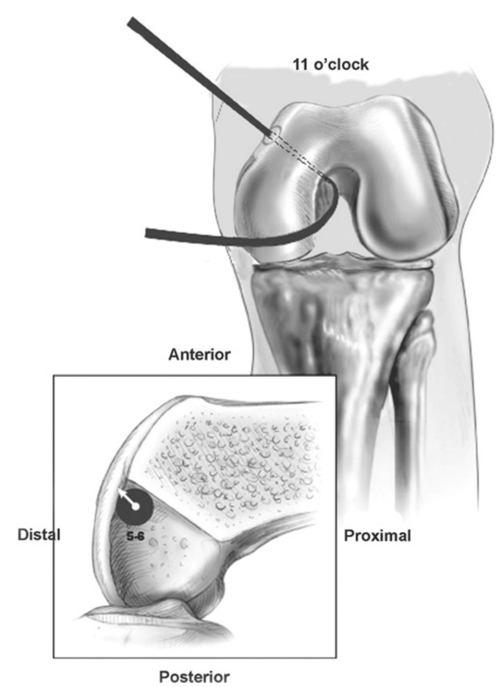

FIGURE 2. The center of the femoral tunnel is located 5 or 6 mm proximal to the margin of the articular cartilage at the 11- or 11:30-o'clock position (left knee).

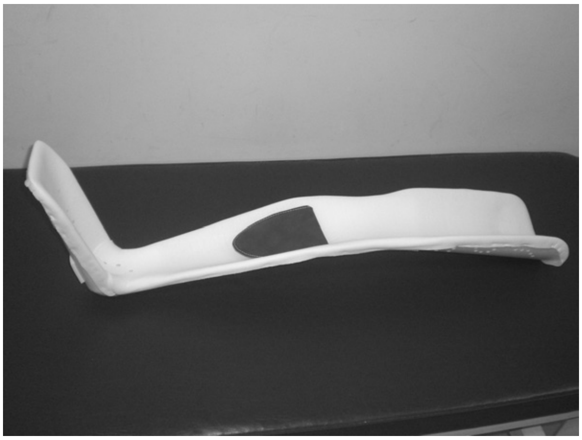

FIGURE 3. A long leg splint with a tibial supporter in full extension prevents posterior sagging and is used for 2 or 3 weeks postoperatively.

uses both hands to support the proximal part of the tibia or performs these exercises in the prone position with an assistant to prevent tibial sagging. The range of flexion is allowed to reach 90° by the sixth postoperative week and reaches 140° by week 12. Full weight bearing is started by the sixth week. Modification of the weight-bearing protocol was not needed even in cases with combined PLRI, because in all such cases in our series PLRI was less than grade II (≥10° increase in the posterolateral drawer test compared with the contralateral knee with minimal varus instability). At 3 to 6 weeks after surgery, a PCL brace with a tibial supporter is applied. At 3 to 6 months postoperatively, a progressive program of running is initiated if the knee is asymptomatic with this activity. By 8 to 10 months, sports activities such as soccer can be resumed if the rehabilitation has progressed satisfactorily.

Patient Assessment

Serial postoperative evaluations were performed 6 weeks and 3, 6, and 12 months after the operation and every 12 months thereafter. To evaluate the stability of the knee, a posterior stress radiograph (push view) obtained by use of a Telos stress device (Austin & Associates, Fallston, MD) and a maximum manual displacement test[18] by use of a KT-1000 arthrometer (MEDmetric, San Diego, CA) (instrumented drawer testing) were used both preoperatively and after the third postoperative month. The posterior stress radiograph was obtained at 150 N with the knee flexed at 90°. The difference between the involved limb and the contralateral limb was recorded. The maximum manual displacement test with the KT-1000 arthrometer was performed by pushing the tibia posteriorly before performing a maximum manual anterior drawer test with the knee flexed at 70°. To evaluate the functional results, the knee scoring systems of Orthopädische Arbeitsgruppe Knie (OAK)[19] and the International Knee Documentation Committee (IKDC)[20] were used. The parametric paired *t* test and the nonparametric Wilcoxon signed rank test were used to determine the significance of differences between the preoperative and follow-up evaluations in terms of the mean side-to-side differences (as shown on the push radiographs and by the maximum manual displacement test) and the mean OAK scores. $P < .01$ was considered significant (power, 0.8; $\alpha = .01$). We performed an a priori power analysis by use of G-power 3.0 (Kiel University, Germany).

RESULTS

Stability

In the 20 patients the mean side-to-side difference in posterior translation, as measured by posterior stress radiography, was 10.4 ± 2.1 mm preoperatively and 3.0 ± 2.6 mm at the last follow-up. At the last evaluation, 9 patients (45%) exhibited displacement of less than 3 mm, 9 (45%) had between 3 and 5 mm of displacement, and 2 (10%) showed displacement exceeding 5 mm. The difference between the last follow-up evaluation value and the value before reconstruction was significant ($P < .001$) (Table 1). The

TABLE 1. *Results of Stent Procedure in Terms of Stability*

	Preoperative (N = 20)	Last Follow-up (N = 20)	*P* Value
Stress view			
(mean ± SD)*	9.9 ± 4.0	3.0 ± 2.6	< .001
<3 mm	0	9 (45%)	
3-5 mm	2 (10%)	9 (45%)	
>5 mm	18 (90%)	2 (10%)	
KT-1000 (mean ± SD)†	6.9 ± 2.1	2.7 ± 1.5	< .001
<3 mm	0	10 (50%)	
3-5 mm	0	8 (40%)	
>5 mm	20 (100%)	2 (10%)	

NOTE. Data are presented as No. of cases (%) unless otherwise indicated.

*Posterior stress radiographs by use of Telos stress device (Austin & Associates, Inc., USA).

†Manual maximum displacement test with knee flexed at 70° by use of KT-1000 arthrometer (MEDmetric) (instrumented drawer testing).

mean side-to-side difference as measured by the maximum manual test with the KT-1000 arthrometer was 8.2 ± 1.5 mm preoperatively and 2.7 ± 1.5 mm at the last follow-up evaluation. At the last evaluation, 10 patients (50%) exhibited less than 3 mm of displacement, 8 (40%) had between 3 and 5 mm of displacement, and 2 (10%) had more than 5 mm of displacement. The difference between the value after the last follow-up relative to the value before reconstruction was significant ($P < .001$) (Table 1).

Clinical Results

The mean OAK score was 61.6 ± 13.1 preoperatively and 88.2 ± 9.5 postoperatively. At the last evaluation, the results were classified as excellent in 11 patients (55%), good in 6 (30%), fair in 2 (10%), and poor in 1 (5%). Thus 85% of the patients had a good or excellent rating at the last evaluation (Table 2). The difference between the OAK scores before reconstruction and at last follow-up was significant ($P < .001$). When the IKDC evaluation form was used, 7 patients (35%) had a rating of A (normal) at the last evaluation, 10 (50%) had a rating of B (nearly normal), 2 (10%) had a rating of C (abnormal), and 1 (5%) had a rating of D (poor). Hence 85% of the patients had a rating of A or B at the last evaluation. The mean value of the IKDC subjective score was 85.4 ± 10.2 (Table 2). No significant differences in OAK or IKDC score at latest follow-up were evident when the patients were subdivided according to the graft-harvesting site or whether they also had other combined injuries. However, the statistical power of these data is too weak to provide clinical significance.

Table 2. *Clinical Results of Stent Procedure*

	Preoperative (N = 20)	Last Follow-up (N = 20)	P Value
OAK (mean ± SD)	61.6 ± 13.1	88.2 ± 9.5	< .001
Excellent	0	11 (55%)	
Good	2 (10%)	6 (30%)	
Fair	5 (25%)	2 (10%)	
Poor	13 (65%)	1 (5%)	
Subjective IKDC (mean ± SD)	45.8 ± 15.6	85.4 ± 10.2	< .001
Objective IKDC			< .001
A	0	7 (35%)	
B	1 (5%)	10 (50%)	
C	2 (10%)	2 (10%)	
D	17 (85%)	1 (5%)	

NOTE. Data are presented as No. of cases (%) unless otherwise indicated.

Complications

In 1 of the early cases in the series, posterior instability that exceeded 10 mm compared with the contralateral side recurred 8 months after the operation. PCL revision by a double-bundle reconstruction with an Achilles allograft was performed. None of the cases exhibited limitation of knee motion or any other complications after surgery or in the follow-up period.

DISCUSSION

In 1 of the early cases in our series, posterior instability recurred at 8 months after the operation, and revision by a double-bundle reconstruction was performed. Arthroscopic examination during the revision surgery showed that the initial tibial tunnel was located in the center of the original PCL fiber. We think that this might be a major cause of failure because the remnant PCL fiber can be too severely damaged during tunnel preparation. So, the tunnel positioning and preparation method is critical to avoid this complication.

So far, many data have been reported on transtibial PCL reconstruction,[21-26] and with advances in knowledge and surgical technique, better results have been reported recently. Ahn et al.[21] reported a remnant-preserving PCL reconstruction method in chronic PCL injuries (>8 months), and Zhao et al.[23] performed sandwich-style reconstruction using 8 strands of hamstring tendon with preservation of the remnant PCL fiber in chronic injuries (>6 months). The results of both studies showed excellent stability (≤5 mm in 97% to 100%) and clinical results (IKDC rating of A or B in 97% to 100%). We also prefer remnant-preserving PCL reconstruction in the chronic stage and have reported good results.[15,17] However, there is no report describing the results of remnant-preserving PCL reconstruction in the acute or subacute stage, even though operative management is sometimes needed even in the subacute stage because of combined injuries or for some other reason. So, we started using this operation as a part of our PCL treatment algorithm. If the PCL injury at the acute or subacute stage was grade II or less in severity and other ligament injuries (e.g., medial collateral ligament injury or PLRI) were absent, we chose to initiate active conservative treatment using an anti-sagging cylinder cast[14] and to re-evaluate the stability and function of the injured knee at the end of conservative treatment. However, for grade II injuries combined with other ligament injuries or for grade III injuries, we considered operative treatment even in the subacute stage, according to activity level and patient demand. In this situation we also considered the status of the remnant PCL tissue when selecting a surgical option for reconstruction. If there is no remnant tissue, we prefer a double-bundle reconstruction (although we seldom encountered such situations within 3 months of the injury). If there is partial continuity or the remnant tissue is sufficient for the stent procedure, we choose the remnant PCL–augmenting stent procedure for PCL reconstruction. Apart from the known theoretic benefit of remnant preserving, there are several potential benefits and a rationale for choosing the stent procedure for this stage. The first reason relates to the timing of the surgery. We only performed this stent procedure within 3 months after trauma. This may prevent the acquisition of subtle additional injuries due to secondary posterior capsuloligamentous restraint.[26] The second reason is the spontaneous healing potential of the PCL. Many authors have reported that the PCL can heal spontaneously,[2-6] and Jung et al.[27] suggested that this healing has a positive effect on stability, although this possibility requires proof that would be provided by more cases of second-look arthroscopy. Because we only subjected cases with remnant PCL tissue to the stent procedure, it is likely that these cases had optimal PCL healing. The third reason is that the stent procedure is simpler to perform than the remnant tissue tensioning and anterolateral bundle reconstruction using the modified inlay method that we use to treat chronic-stage patients.[15,17] Finally, with early surgical treatment, the morbidity period can be shortened and patients can return to their previous activities more quickly.

We expected better results in terms of stability and functional scores, considering the aforementioned potential benefit; however, our results were just comparable to the results of PCL reconstruction by use of the transtibial method.[21-26] In particular, in terms of clinical results, 85% of our patients had satisfactory IKDC and OAK scores at the last follow-up evaluation. Our clinical results are poorer than those of surgery performed in the chronic stage reported previously,[21-23,28] despite comparable stability. The possible reasons for this are as follows: First, although there is some consensus about how to evaluate clinical results, at this time, methods to quantify the functional results of the PCL-reconstructed knee including proprioception are imperfect and evolving, and this evaluation procedure may still not be sufficiently objective to allow comparisons to be made between studies.[29-33] Second, some of the subacute cases we treated with the stent procedure also had combined injuries that may have reduced the clinical results. Iwata et al.[34-36] recently suggested that instability in the near-extended knee position may cause major clinical disability. This, together with the fact that most surgeons (including us) reconstruct the anterolateral bundle for PCL injuries, may explain why we and other authors have found that the clinical results do not match the improvement in stability in the flexed position that is achieved by reconstructing the anterolateral bundle.[9,10,37,38] Consequently, we are currently focusing more on the status of the posteromedial bundle to obtain stability in the near-extended position. However, more biomechanical and clinical studies are needed to test whether this change in focus is valid.

Our study has some limitations, including a relatively short-term follow-up period, a small and heterogeneous sample group, and the absence of a control group who had chronic PCL injuries or underwent conservative treatment. In addition, we did not evaluate proprioception. On the other hand, this study is unique in that all operations were performed by a single surgeon using a standardized surgical technique within 3 months of acquiring the injury. Moreover, we used multiple knee scores as well as stress radiographs to evaluate our method.

Although our series could not show definitely better clinical results as compared with previous reports, we sometimes have to perform surgery in the subacute stage for PCL injuries for various reasons, and we obtained comparable stability using a simpler method than the remnant tissue–tensioning method in the chronic stage. Moreover, considering the aforementioned potential benefit, the stent procedure might be useful in the acute or subacute stage of PCL injuries. Although these short-term results are encouraging, long-term studies and evolving the new functional system, which can reflect proprioception, are needed to prove the potential benefit of this surgical method.

CONCLUSIONS

Of the patients, 90% showed satisfactory posterior stability and 85% had a normal or nearly normal rating based on the IKDC score at a mean of 3 years after the remnant PCL–augmenting stent procedure in the acute or subacute stage of PCL injuries.

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