A commentary by James P. Stannard, MD, is available at www.jbjs.org/commentary and as supplemental material to the online version of this article.

Outcomes of an Anatomic Posterolateral Knee Reconstruction

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Background: Chronic posterolateral knee injuries often result in substantial patient morbidity and functional instability. The clinical stability and functional outcomes following anatomic reconstructions in patients with a chronic posterolateral knee injury have not been determined, to our knowledge.

Methods: A two-center outcomes study of sixty-four patients with grade-3 chronic posterolateral instability was performed. The patients were evaluated subjectively with the modified Cincinnati and International Knee Documentation Committee (IKDC) subjective scores and objectively with the IKDC objective score.

Results: Eighteen patients had an isolated posterolateral knee reconstruction, and forty-six patients underwent a single-stage multiple-ligament reconstruction that included reconstruction of one or both cruciate ligaments along with the posterolateral knee reconstruction. The average duration of follow-up was 4.3 years. The fifty-four patients who were available for follow-up had an average total Cincinnati score of 65.7 points. A significant improvement was found between the preoperative and postoperative IKDC objective scores for varus opening at 20°, external rotation at 30°, reverse pivot shift, and single-leg hop.

Conclusions: An anatomic posterolateral reconstruction resulted in improved clinical outcomes and objective stability for patients with a grade-3 posterolateral knee injury.

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

Primary repair of posterolateral knee injuries has been reported to yield good results if performed acutely within the first three weeks after the injury[1-4]. However, primary repair is not always performed or possible, given a delay in the diagnosis or treatment, and various reconstructions, tenodeses, osteotomies, and advancement procedures have been described for chronic posterolateral knee injuries. These include reconstruction of the fibular collateral ligament[5,6], fibular collateral ligament allograft reinforcement[3], femoral bone-block advancement[7,8], biceps femoris tenodesis[9-15], proximal tibial osteotomy[4,16,17], reconstruction of the popliteus tendon and popliteofibular ligament with use of a split patellar tendon graft[5], popliteus recess procedures[18], and use of a central slip iliotibial band or biceps femoris graft[5,13,19]. The goal of all of these reconstructions is to reproduce the function of the posterolateral knee structures. However, they do not anatomically reconstruct the main posterolateral structures, and we theorized that, in order to restore optimal stability, the procedure should be based on the normal anatomy.

To our knowledge, there have been no clinical outcome studies of an anatomic posterolateral knee reconstruction. In 2004, we described an anatomic posterolateral reconstruction

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technique[20] based on the quantitative attachment anatomy of the fibular collateral ligament, the popliteus tendon, and the popliteofibular ligament[21]. On the basis of an in vitro biomechanical study, we concluded that this anatomic reconstruction can restore static stability under varus and external rotation testing conditions[20].

In theory, an anatomic reconstruction of the primary static stabilizers of the posterolateral aspect of the knee should lead to improved knee stability and clinical outcomes, similar to the outcomes in patients who have undergone anatomic reconstruction of the anterior or posterior cruciate ligament. Therefore, our hypothesis was that an anatomic posterolateral knee reconstruction would improve overall patient function and restore static stability in varus and external rotation in knees with a chronic posterolateral injury. Our purpose was to report the subjective and objective outcomes in a series of knees treated with an anatomic posterolateral reconstruction technique.

Materials and Methods

Subjects

Patients with a chronic unilateral grade-3 (complete) posterolateral knee injury were included in this study. These patients were treated by three surgeons (R.F.L., S.J., and L.E.) at two sites, and this study was approved by the institutional review board at both sites. The inclusion criteria were combined varus and posterolateral rotatory instability in a patient who reported, or had findings of, functional instability, pain, a varus thrust gait, or a failed previous ligament reconstruction. In addition, the patient had to have normal or valgus alignment of the lower extremity or to have undergone a successful proximal tibial opening-wedge osteotomy to correct varus malalignment and continued to have symptoms of instability at a minimum of three months after the osteotomy site had healed[17]. Patients were excluded from the study if they had a history of substantial knee arthritis (with more than minimal joint-space narrowing and periarticular osteophyte formation), connective-tissue disease, tibial nerve injury, or ligament injuries of both lower extremities. The studies at the two centers were originally established independently with different patient scoring evaluations. In September 2005, representatives of the two sites met and decided to combine and standardize the follow-up evaluations. Modified Cincinnati and subjective International Knee Documentation Committee (IKDC) patient outcome questionnaires were subsequently administered to all patients at the time of follow-up. Subsequently, one investigator (R.F.L.) performed a final follow-up evaluation of all of the patients at the two sites.

Clinical and Radiographic Diagnosis

The patients were evaluated preoperatively to determine whether there was an increase, as compared with the findings in the contralateral knee, of at least two grades, according to the IKDC objective knee scoring examination form, in one or more measures of posterolateral instability—i.e., whether there was increased varus opening at 30°, an increase in external rotation at 30° (as evaluated with the dial test), an increase on posterolateral drawer testing, and/or an increased amount of subluxation on the reverse pivot shift test.

Standing anteroposterior and lateral radiographs, a 45° patellar sunrise radiograph, and a single long leg standing anteroposterior alignment radiograph were made as part of the preoperative screening of all patients. The lower limb was noted as being in varus alignment if the weight-bearing axis (a line connecting the center of the femoral head and the center of the ankle mortise) passed medial to the tip of the medial tibial eminence[17]. In addition, all patients underwent magnetic resonance imaging with use of posterolateral knee imaging sequences[22] to assist with preoperative planning. Patients with genu varus alignment first underwent a biplanar proximal tibial opening-wedge osteotomy and were reassessed at a minimum of six months postoperatively for evidence of continued instability prior to a second-stage ligament reconstruction[17].

Evaluation and Rating Scales

All patients who underwent a posterolateral reconstruction for treatment of chronic posterolateral knee instability completed a modified Cincinnati subjective scoring form and an IKDC subjective questionnaire at the time of final follow-up. The IKDC objective knee examination form was completed preoperatively, by the treating surgeon at one site and on the basis of a retrospective chart review at the other site, and at the time of the follow-up examination at both sites.

Objective changes in knee stability were evaluated by comparing the preoperative and postoperative findings of the clinical examinations and assessments performed with the IKDC objective knee examination form. A grade (A for normal, B for nearly normal, C for abnormal, and D for severely abnormal) was given on the basis of the findings of the individual physical examination pertinent to posterolateral knee instability.

Surgical Technique

The posterolateral knee reconstruction procedure was performed without a tourniquet initially to save tourniquet time. After a lateral hockey-stick incision was used to gain access to the posterolateral knee structures[23], the attachment sites of the fibular collateral ligament on the lateral aspect of the fibular head and the popliteofibular ligament on the posteromedial aspect of the fibular styloid were identified. With the help of a cannulated cruciate-ligament-reconstruction-aiming device, a guide pin was drilled through the fibular collateral ligament attachment on the lateral aspect of the fibular head in a posteromedial direction toward the popliteofibular ligament attachment, and a 7-mm tunnel was then reamed over the guide pin.

Next, the posterior tibial popliteal sulcus[24], which marks the location of the musculotendinous junction of the popliteus muscle, was identified by palpation through the interval between the lateral head of the gastrocnemius and the soleus. A transtibial guide pin was then drilled from anterior, at the flat spot just distal and medial to the Gerdy tubercle[20,25], to posterior at this sulcus. Care was taken to protect the neurovascular bundle by using a large Chandler retractor (V. Mueller, Deerfield, Illinois). A 9-mm tunnel was then reamed over this guide pin, and the entry and exit sites were smoothed with a rasp.

The femoral attachments of the fibular collateral ligament and the popliteus tendon, the midpoints of which have been reported to be 18.5 mm apart[21], were next identified. Two eyelet-tipped guide pins were then drilled from lateral to anteromedial through the femur at these attachment sites. A 9-mm reamer was used to ream over these guide pins to a depth of 20 mm to prepare the femoral tunnels. The eyelet pins were then removed if there were any intra-articular pathological findings to be addressed.

At this point, any arthroscopic intra-articular or cruciate ligament reconstruction procedures were performed with or without a tourniquet as needed. Once the articular cartilage and meniscal abnormalities had been addressed, the cruciate ligament grafts were passed into and fixed into their respective femoral tunnels. The order for the final graft fixation was to secure the posterior cruciate ligament graft to the tibia first, then to secure the posterolateral grafts to the fibula and tibia, and finally to secure the anterior cruciate ligament graft to the tibia[26].

Grafts were prepared from an allogenic Achilles tendon, which was split lengthwise, and two 9 by 20-mm bone plugs were prepared for the femoral tunnels. The tendons were then tubularized and sized to fit through the fibular and tibial tunnels.

The passing sutures in the bone plugs for the posterolateral reconstruction grafts were placed into the eyelet pins, and the bone plugs were pulled into the femoral tunnels. The bone plugs were anchored in the superior aspect of the femoral tunnels with use of 7-mm cannulated interference screws. The graft anchored in the popliteal sulcus was used to reconstruct the static function of the popliteus tendon. It was passed distally through the popliteal hiatus. The second graft, anchored proximally and posterior to the lateral femoral epicondyle, was used to reconstruct both the fibular collateral ligament and the popliteofibular ligament. It was passed medial (deep) to the superficial layer of the iliotibial band and the anterior arm of the long head of the biceps femoris, following the normal path of the fibular collateral ligament. The graft was then passed through the fibular tunnel in a posteromedial direction. The posterolateral graft passing through the fibular tunnel was anchored with a 7-mm cannulated interference screw with the knee in 30° of flexion, the tibia in neutral rotation, and a slight valgus force applied to reduce any potential lateral compartment gapping. The remaining portion of the graft, which was now medial to the fibula, was used to reconstruct the popliteofibular ligament. Both the popliteofibular ligament graft and the popliteus tendon graft were then passed from posterior to anterior through the tibial tunnel and were tightened by applying an anterior traction force with the knee flexed to 60° and the tibia in neutral rotation. The grafts were fixed in the tibial tunnel with a 9-mm cannulated interference screw (Fig. 1).

Postoperative Rehabilitation

Patients were non-weight-bearing for the first six weeks postoperatively. For the first two postoperative weeks, they performed quadriceps sets and straight leg raises while wearing a knee immobilizer, and they performed range-of-motion exercises without the immobilizer four times a day. The goal was to achieve at least 90° of knee flexion by the end of the second week. The patients continued to perform the quadriceps sets and straight leg raises during the third through sixth weeks. If they could perform the straight leg raises without an extension lag, they were allowed to do them without a knee immobilizer. The range of motion of the operatively treated knee was increased as tolerated, with the goal of achieving full extension and flexion by the end of the sixth week. During this phase of the rehabilitation, basic lower-extremity and core-strengthening exercises were performed without weight-bearing. Caution was taken to avoid exercises that could compromise graft integrity, including those that could increase knee forces in varus, hyperextension, or tibial external rotation.

The patients began bearing weight at seven weeks and were weaned off crutches once they could walk without a limp or other subtle gait abnormalities or compensation patterns. They were allowed to use a stationary bicycle once 105° to 110° of knee flexion had been achieved, with the idea of initially increasing knee motion with low-resistance exercises rather than trying to gain strength. In addition, no active, isolated hamstring exercises were allowed for the first four months postoperatively. The patients also began limited-resistance weight-training, starting with one-quarter of their body weight and progressing to one-half of their body weight as tolerated, but they were instructed not to exceed 70° of flexion while performing leg presses or mini-squat exercises. Other weight-bearing exercises to restore joint proprioception and balance were initiated at this point in the rehabilitation.

It was anticipated that the patients should have achieved a full range of motion and a normal gait pattern by the thirteenth to sixteenth week. From four to six months postoperatively, the patients worked on increasing endurance, strength, and proprioception, with an emphasis on low-impact exercises (cycling, swimming, walking, or using elliptical machines) until four months postoperatively. They were also allowed to begin step-up exercises on blocks of increasing heights. After this time, the patients continued their endurance and strength programs. Once cleared by the surgeon, starting at seven months postoperatively when an isolated posterolateral knee reconstruction had been done and at nine months when a combined reconstruction had been performed, and after an evaluation of their strength and stability and their recovery from any other surgical procedures done in combination with the index procedure and any other associated knee and lower-extremity comorbidities, they could return to full competitive and pivot activities. Patients with mild osteoarthritis, a history

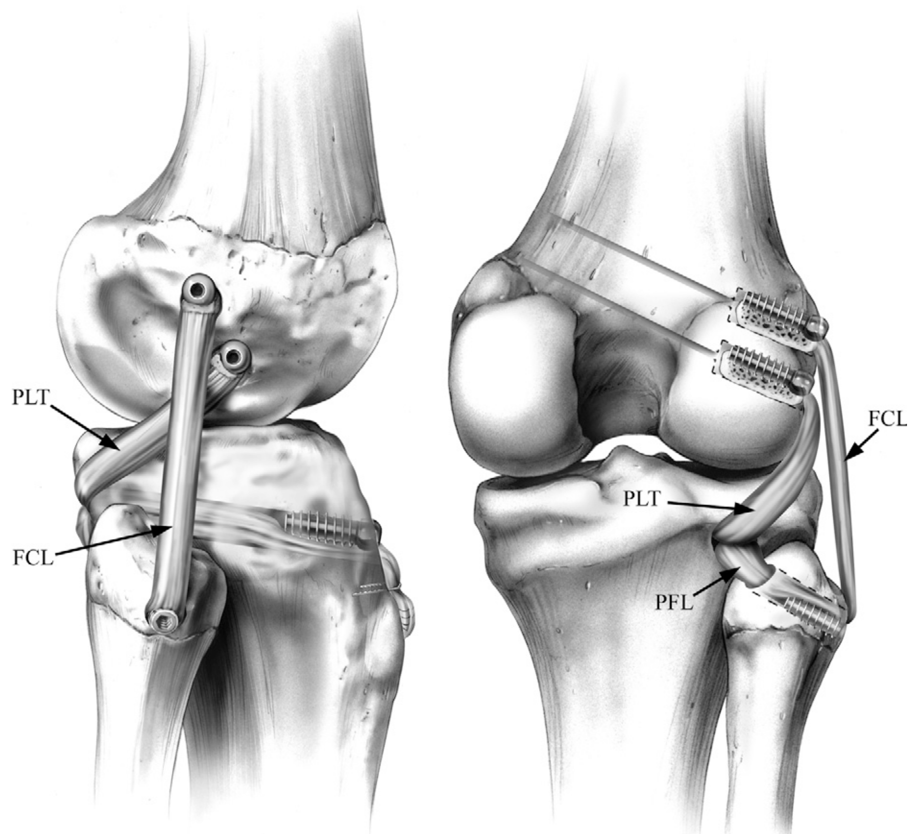

Fig. 1

Lateral (left image) and posteroanterior (right image) views of the graft and tunnel locations for the anatomic posterolateral knee reconstruction. FCL = fibular collateral ligament, PLT = popliteus tendon, and PFL = popliteofibular ligament. (Reprinted, with permission, from: LaPrade RF, Johansen S, Wentorf FA, Engebretsen L, Esterberg JL, Tso A. An analysis of an anatomical posterolateral knee reconstruction: an in vitro biomechanical study and development of a surgical technique. Am J Sports Med. 2004;32:1405-14. Figs. 3a and 3b.)

of a substantial partial meniscectomy, or residual instability from any of the reconstructions were encouraged to cross train with walking, cycling, or swimming and to avoid high-impact activities in the future.

Data Analysis

Means and frequencies were calculated for the demographic data and the results of the subjective questionnaire analysis. The chi-square test was used to compare the preoperative and postoperative IKDC objective scores.

Source of Funding

Funding for the cost of the postoperative follow-up examinations of the Oslo patients was provided by the Orthopaedic Center at the University of Oslo School of Medicine.

Results

Patient Demographics

From May 2000 to September 2005, sixty-four patients underwent a posterolateral knee reconstruction for the treatment of chronic posterolateral knee instability and pain. The average age of the patients at the time of this surgery was thirty-two years (range, eighteen to fifty-eight years). There were forty-four male and twenty female patients. The time interval between the initial injury and the posterolateral knee reconstruction was 4.4 years (range, two months to twelve years). Fifty-four (84%) of the patients were available for follow-up at an average of 4.3 years (range, two to 7.2 years) postoperatively.

Fifteen patients had undergone a first-stage proximal tibial opening-wedge osteotomy because of genu varus alignment prior to the posterolateral knee reconstruction. Eighteen patients had an isolated posterolateral reconstruction, twenty-two had a concurrent reconstruction of the anterior cruciate ligament, fourteen had a concurrent reconstruction of the posterior cruciate ligament, nine had concurrent reconstructions of the anterior and posterior cruciate ligaments, and one had concurrent reconstructions of the anterior cruciate ligament, medial collateral ligament, and posterior cruciate ligament.

Associated Comorbidities

Six patients had a complete peroneal motor nerve injury with an associated foot drop as a result of the original injury. Five patients had had a previous popliteal artery bypass procedure. Two patients had had a previous posterolateral knee repair that had failed, and five had had a previous nonanatomic posterolateral reconstruction that had failed. Nine patients had had a previous isolated reconstruction of the anterior cruciate ligament that had failed, and two had had a previous isolated reconstruction of the posterior cruciate ligament that had failed.

Patient Outcome Scores

The total modified Cincinnati score averaged 65.7 points (range, 20 to 100 points) at the time of follow-up; the Cincinnati symptom subscore averaged 32 points (range, 8 to 50 points), and the Cincinnati function subscore averaged 34 points (range, 12 to 50 points). The IKDC subjective score averaged 62.6 points (range, 20 to 100 points) at the time of follow-up. With the numbers studied, there was no significant difference between the patients who had had an isolated posterolateral knee reconstruction and those treated with multiple ligament reconstructions with regard to the overall modified Cincinnati score (61.4 compared with 68.1 points), the symptom subscore (29.3 compared with 33.4 points), the function subscore (32.1 compared with 35.2 points), or the IKDC subjective score (66.7 compared with 60.6 points). There was also no significant difference between the patients who had not had an osteotomy prior to the posterolateral knee reconstruction and those who had required an osteotomy with regard to the overall modified Cincinnati score (66.5 compared with 62.6 points), the symptom subscore (33.1 compared with 27.6 points), the function subscore (33.9 compared with 35.0 points), or the IKDC subjective score (61.2 compared with 66.9 points).

IKDC Objective Scores and Knee Motion

Figure 2 demonstrates the preoperative and postoperative IKDC objective scores for passive extension, passive flexion, varus opening at 20°, external rotation at 30°, reverse pivot shift, and single-leg hop. The average preoperative knee motion was from –1.3° (mild hyperextension) to 132.5° of flexion. The average postoperative knee motion was from –2.0° to 132.7° of flexion. Chi-square analysis demonstrated a significant postoperative improvement in the scores for varus opening at 20°, external rotation at 30°, reverse pivot shift, and single-leg hop (all $p < 0.001$).

Complications

There was one postoperative infection at two months requiring removal of the grafts and a revision posterolateral knee reconstruction. One patient had a transient common peroneal nerve neurapraxia postoperatively, which resolved by four weeks postoperatively. Three patients had recurrent postero-

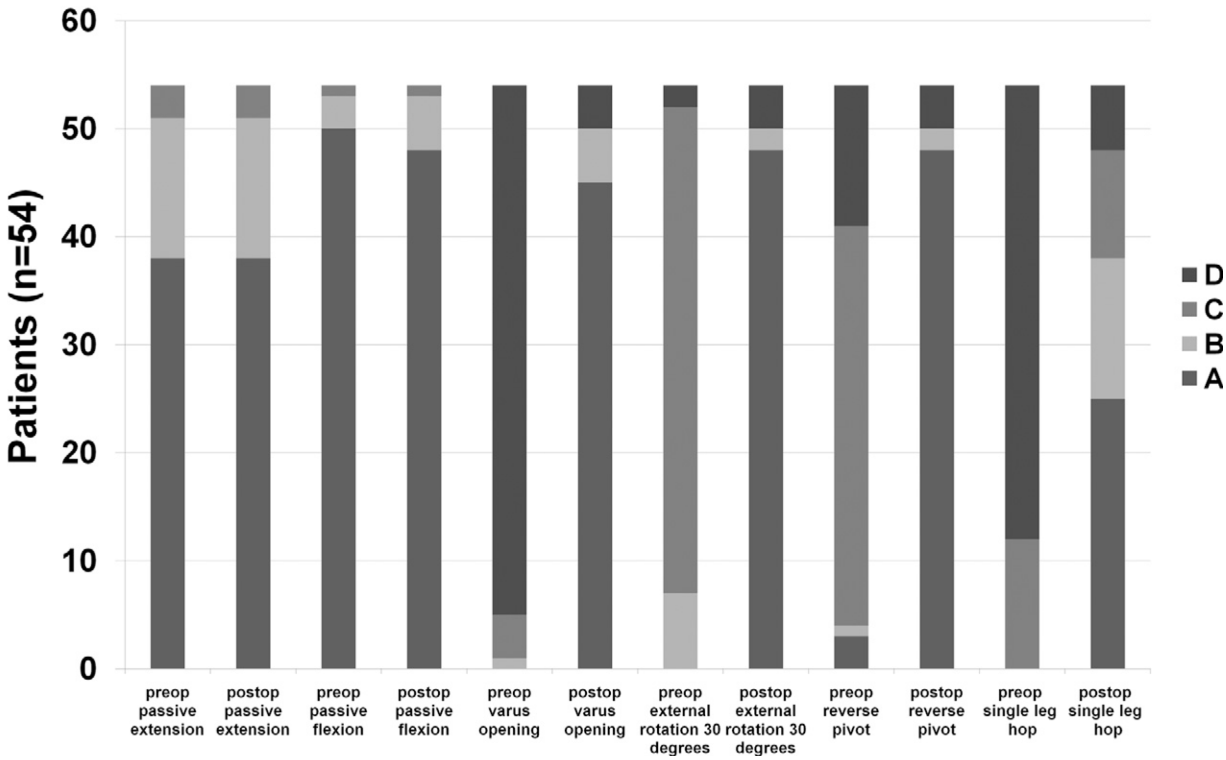

Fig. 2

IKDC objective knee motion, posterolateral stability, and single-leg-hop scores before and after the anatomic posterolateral knee reconstruction. A = normal, B = nearly normal, C = abnormal, and D = severely abnormal.

lateral knee instability that required a revision posterolateral knee reconstruction. Four patients underwent removal of symptomatic hardware (one prominent femoral interference screw and three proximal tibial interference screws).

Discussion

We found that an anatomic posterolateral knee reconstruction can result in significant improvement in the posterolateral knee stability of patients with this complex instability pattern. This technique was based on quantitative anatomy[21] and was previously shown to restore normal varus and rotational stability in in vitro biomechanical studies[20]. The results presented here are based on three surgeons' practices. The same three surgeons who performed the quantitative anatomic and biomechanical studies of the procedure[20,21] also carried out the posterolateral reconstructions in the present series[20,21].

It is now fairly clear that, in order to restore varus stability and limit coupled posterolateral translation in patients with chronic posterolateral knee instability, it is important to reconstruct the fibular collateral ligament, the popliteus tendon, and the popliteofibular ligament[27-29] as well as any injured cruciate ligaments simultaneously[30-33]. Most previous reports on posterolateral knee reconstructions were primarily descriptions of the techniques and provided few patient outcomes[34-40]. Our anatomic posterolateral knee reconstruction technique restored the native function of these three important knee stabilizers in the majority of patients with these chronic injuries. In fact, we found no difference in outcomes between patients who had required and those who had not required a first-stage proximal tibial opening-wedge osteotomy or between patients with an isolated injury and those with combined posterolateral knee injuries.

We acknowledge that this study has some weaknesses. One such weakness is that the majority of our patients had concurrent cruciate ligament reconstruction in combination with the posterolateral corner reconstructions rather than an isolated posterolateral reconstruction. However, in spite of the increased complexity of their operative treatment and postoperative rehabilitation, these patients still had an increase in their overall function and knee stability. Another weakness was that separate studies were independently established at the two sites, so we do not have both preoperative and postoperative patient subjective outcome scores. At the time of establishment of both studies, there were no validated patient outcome scores and the IKDC patient-reported subjective outcome score was not in widespread use. Another possible bias in this report is that only one surgical technique, rather than a randomized double-blind treatment protocol, was performed. However, in light of our previous anatomic[21] and biomechanical testing[20] of this technique, we believe that a randomized clinical study comparing this method with a nonanatomic technique was not indicated.

The posterolateral knee reconstruction technique presented here significantly improved objective stability in patients with a chronic posterolateral knee injury. We recommend that an anatomic posterolateral knee reconstruction be performed in patients with this difficult injury pattern to best improve functional and clinical outcomes. Although the four-year clinical results are very promising, long-term follow-up is necessary to confirm these intermediate-term findings. ■

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