Surgical Management of Knee Dislocations

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Background: The evaluation and management of knee dislocations remain variable and controversial. The purpose of this study was to describe our method of surgical treatment of knee dislocations with use of a standardized protocol and to report the clinical results.

Methods: Forty-seven consecutive patients presented with an occult (reduced) or grossly dislocated knee. Fourteen of these patients were not included in this series because of confounding variables: four had an open knee dislocation, five had vascular injury requiring repair, three were treated with external fixation, and two had associated injury. The remaining thirty-three patients underwent surgical treatment for the knee dislocation with our standard approach. Anatomical repair and/or replacement was performed with fresh-frozen allograft tissue. Thirty-one of the thirty-three patients returned for subjective and objective evaluation with use of four different knee rating scales at a minimum of twenty-four months after the operation.

Results: Nineteen of the thirty-one patients were treated acutely (less than three weeks after the injury) and twelve, chronically. The mean Lysholm score was 91 points for the acutely reconstructed knees and 80 points for the chronically reconstructed knees. The Knee Outcome Survey Activities of Daily Living scores averaged 91 points for the acutely reconstructed knees and 84 points for the chronically reconstructed knees. The Knee Outcome Survey Sports Activity scores averaged 89 points for the acutely reconstructed knees and 69 points for the chronically reconstructed knees. According to the Meyers ratings, twenty-three patients had an excellent or good score and eight had a fair or poor score. Sixteen of the nineteen acutely reconstructed knees and seven of the twelve chronically reconstructed knees were given an excellent or a good Meyers score. The average loss of extension was 1°, and the average loss of flexion was 12°. There was no difference in the range of motion between the acutely and chronically treated patients. Four acutely reconstructed knees required manipulation because of loss of flexion. Laxity tests demonstrated consistently improved stability in all patients, with more predictable results in the acutely treated patients.

Conclusions: Surgical treatment of the knee dislocations in our series provided satisfactory subjective and objective outcomes at two to six years postoperatively. The patients who were treated acutely had higher subjective scores and better objective restoration of knee stability than did patients treated three weeks or more after the injury. Nearly all patients were able to perform daily activities with few problems. However, the ability of patients to return to high-demand sports and strenuous manual labor was less predictable.

Level of Evidence: Therapeutic study, Level III-2 (retrospective cohort study). See Instructions to Authors for a complete description of levels of evidence.

Traumatic dislocation of the knee involves damage to multiple soft-tissue stabilizing structures. Although there have been reports of isolated injuries of the anterior or posterior cruciate ligament in the setting of a dislocation[1-3], most often both cruciate ligaments are completely disrupted. In addition to cruciate ligament injury, knee dislocation usually results in injury to either the medial or the lateral capsular structures, resulting in combined instability patterns. Articular and meniscal cartilage injuries, associated osseous fractwures, and injuries to the neurovascular structures often add more complexity to the evaluation and management of these dislocations. Historically, loss of motion, chronic instability, and poor functional results have been common outcomes for patients who sustain these complex injuries[4-8].

Strategies for the management of knee dislocation have been varied and controversial[9-11]. Because immobilization has generally resulted in poor outcomes[6,12], most experienced surgeons have preferred surgical treatment[5,7,8,13-18]. Surgical management remains controversial, especially with regard to timing, which structures to repair and/or reconstruct, and

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graft selection. Many experienced knee surgeons have advocated that all associated ligamentous, capsular, and meniscal injuries be treated with anatomical restoration (with repair and/or replacement)[11,15,16,18-22]. Their philosophy has been that addressing only a portion of the injury in these severely injured and unstable knees will lead to residual laxity[11,20-23]. Generally speaking, primary repair of the cruciate ligaments has fallen out of favor unless there is an osseous avulsion[11,20-22,24,25]. Anatomical replacement with allograft or autograft tissue is the technique preferred by most surgeons[11,20-22]. With respect to the timing of surgery, recommendations have ranged from immobilization followed by delayed surgery[20,24] to surgical treatment within three weeks after the injury[4,5,7,11,18,21,22]. Finally, recommendations for postoperative rehabilitation have ranged from an immediate range of motion[11,21,22,24,25] to immobilization for three to six weeks postoperatively[8,20].

The controversy over the management of these complex injuries is in large part due to inconsistent treatment protocols, small and poorly defined patient populations, and a variety of surgical techniques. The purpose of this study was to evaluate the clinical outcomes of surgical treatment of knee dislocation with use of a standard treatment protocol that included surgical treatment within three weeks when possible, addressing all injured ligaments, and an early protected postoperative range of motion. Our hypothesis was that good or excellent results can be achieved with use of this standardized surgical approach and postoperative protocol and that surgical treatment within the first three weeks leads to better clinical outcomes than does treatment after three weeks.

Materials and Methods

Patients

Forty-seven consecutive patients with either obvious or occult (reduced) traumatic knee dislocation were evaluated at the University of Pittsburgh Medical Center between 1990 and 1995. Obvious knee dislocations were those that required reduction. Occult knee dislocations spontaneously reduced and were defined by the presence of injuries to both cruciate ligaments, as previously described by Schenck[26] and Wascher et al.[27].

We retrospectively reviewed the records of all patients with a closed knee dislocation that had been treated with our standard protocol. Of the forty-seven patients with a dislocation, fourteen were excluded because of confounding variables that necessitated alteration of our standard protocol. These patients included four with open dislocation, five with vascular injury requiring emergent vascular surgery, three treated with external fixation, and two with associated injury (severe closed head injury and contralateral below-the-knee amputation) that affected their treatment. The remaining thirty-three patients underwent standard preoperative evaluation, surgical management, and postoperative rehabilitation.

Preoperative Evaluation

In addition to a detailed history and physical examination, the initial evaluation included standard radiographs and magnetic resonance imaging studies of all patients. We defined acute surgical treatment as that performed within the first three weeks after the injury and chronic treatment as that carried out any time thereafter[14]. Of the thirty-five patients who presented with an acute dislocation, thirty-two were evaluated with arteriograms, and six of those studies were positive. Five of the six patients underwent emergent vascular surgery and were not included in this study. The sixth patient had an intimal tear of the popliteal artery and was included in the study.

Patients with a chronic dislocation were referred to the senior author (C.D.H.). They were seen in the office, where the medical history was obtained and physical examination and imaging studies were performed. Patients with major arthritic changes noted on 45° posteroanterior flexion weight-bearing, lateral, or Merchant radiographs were excluded from the study. In addition, patients with a varus thrust on examination and/or malalignment on long-cassette radiographs were excluded, as they were managed differently.

Surgical Management

Surgical management was based on preoperative data, findings of the examination under anesthesia, and arthroscopic findings. After anesthesia was induced, the patient was positioned supine on the operating table, and an examination under anesthesia was performed with use of the contralateral knee as the control. A sandbag and lateral post were positioned to hold the knee and hip at 90° of flexion. This setup also enabled us to move the knee through a full range of motion throughout the examination and operation. A Foley catheter was inserted, and distal pulses were checked with Doppler ultrasound. A tourniquet on the proximal part of the thigh was utilized for all patients.

The grade of ligament injury was determined during the examination under anesthesia. These data were critical to surgical management. All grades were determined in comparison with that of the uninvolved knee. Grade-1+ laxity is a 3 to 5-mm side-to-side difference; grade-2+, 6 to 10-mm; and grade-3+, >10 mm. By definition, a partial ligament injury is categorized as grade 1+ or 2+ and a complete tear, as grade 3+. The anterior cruciate ligament was examined at 30° of flexion. The posterior cruciate ligament was examined at 90° of flexion with use of the medial tibial step-off as a guide. Varus laxity and valgus laxity were evaluated at 0° and 30° of flexion. Gross opening at 0° with varus or valgus stress is consistent with a complete collateral (grade-3+) ligament injury.

After sterile preparation and draping, proposed incisions were marked and the tourniquet was inflated. The cruciate ligaments were addressed first, with the goal of completing the majority of the cruciate ligament surgery within the first two hours so that the tourniquet could be released for the collateral ligament surgery. Gravity flow was used instead of an arthroscopic pump to minimize fluid extravasation into the leg. The thigh and calf were palpated prior to and throughout the procedure. If increased pressure was noted, the arthroscopic procedure was discontinued and the operation was completed with use of an open technique.

In our standard treatment protocol, avulsed ligaments

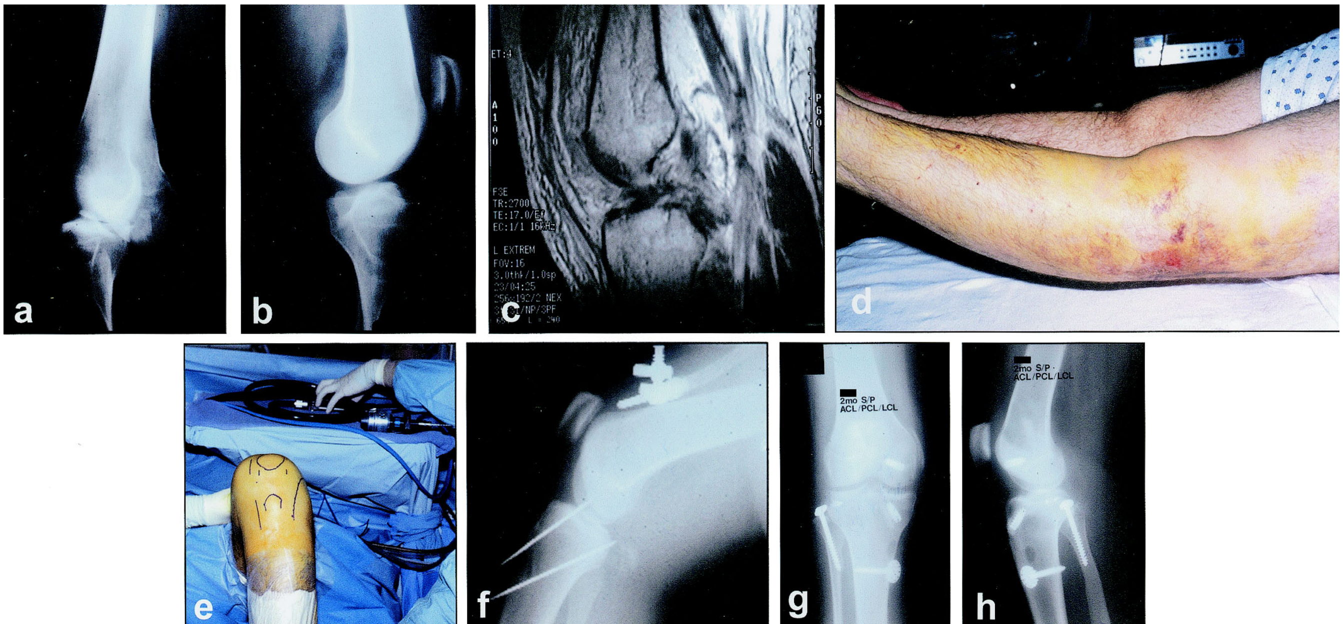

Fig. 1

Case 8 (see Appendix), an eighteen-year-old with injuries of the anterior cruciate ligament, posterior cruciate ligament, and posterolateral corner. *a:* Preoperative radiograph. *b:* Postreduction radiograph. *c:* Magnetic resonance image showing injuries of the anterior and posterior cruciate ligaments. *d:* Intraoperative examination. *e:* Intraoperative setup. *f:* Intraoperative radiograph showing the position of the Kirschner wires prior to drilling. *g* and *h:* Postoperative lateral (*g*) and anteroposterior (*h*) radiographs showing the fixation.

and tears of the medial collateral ligament were directly repaired, whereas complete tears of the cruciate and lateral collateral ligaments were reconstructed with fresh-frozen allograft tissue (LifeNet, Virginia Beach, Virginia). Remaining injuries to the posterolateral structures were addressed by direct repair and/or allograft replacement. Peripheral meniscal tears and capsular avulsions were directly repaired. Central or irreparable meniscal tears were débrided to a stable rim, with preservation of as much of the meniscus as possible.

Skin incisions were determined by the pattern of injury. Midline incisions were not used because of the potential for skin slough over the patella and the limited access that they provide to the collateral structures. In all knees, either a medial or a lateral curvilinear incision, as described by Hughston and Jacobson[28] and by Müller[13], was utilized for exposure of the collateral and capsular structures.

For combined (anterior and posterior) cruciate injuries with an associated posterolateral corner injury, we used a medially based incision for the cruciate replacement and a lateral curvilinear incision centered over the Gerdy tubercle and the lateral tibial condyle for the posterolateral corner (Fig. 1). The incisions were separated by at least a 10-cm skin bridge over the patella. For injuries of the anterior cruciate, posterior cruciate, and medial collateral ligaments, we began with arthroscopy-assisted preparation of the tunnels for the anterior and posterior cruciate ligaments. The medial collateral ligament was then repaired through a medial curvilinear incision (Fig. 2).

After viewing the medial and lateral compartments to look for meniscal and articular cartilage lesions, we began the cruciate ligament surgery by identifying the tibial attachment of the anterior and posterior cruciate ligaments arthroscopically. The details of anterior and posterior cruciate ligament replacement have been described in previous reports[29-32]. The femoral tunnel for the posterior cruciate ligament was placed to reproduce the anterolateral component of the native ligament[32,33]. The tibial tunnel for the posterior cruciate ligament was approximated with a Kirschner wire with use of an arthroscopic posterior cruciate ligament guide (Linvatec, Largo, Florida). An anterior cruciate ligament tibial tunnel guide (Linvatec) was used to place a Kirschner wire through the central portion of the anterior cruciate ligament footprint, with the wire exiting 2 to 3 cm proximal to the posterior cruciate ligament guide wire on the medial tibial cortex. Intraoperative radiographs were made to check the positions of the guide wires prior to drilling (Fig. 1, *f*). The tibial tunnel for the posterior cruciate ligament was drilled 10 to 11 mm under direct arthroscopic control. The tibial tunnel for the anterior cruciate ligament was then drilled 10 to 11 mm. The femoral tunnel for the posterior cruciate ligament was drilled with an outside-in technique, through a 3-cm medial parapatellar incision[32]. The femoral tunnel for the anterior cruciate ligament was drilled with use of an endoscopic technique[30]. On a separate table, fresh-frozen irradiated allografts were prepared after thawing for twenty minutes. A 10 to 11-mm Achilles tendon graft was prepared for the posterior cruciate ligament, and a 10 to 11-mm patellar tendon graft was prepared for the anterior cruciate ligament. The Achilles tendon (i.e., the posterior cruciate replacement) was passed from the femur to the tibia, and the calcaneal bone plug was secured in the femoral tunnel with use of a 7 or 9-mm interference screw (Linvatec) at the femur. The patellar tendon graft (the anterior cruciate replacement) was passed from the tibia to the femur and secured on the femoral side with a 7 × 25-mm interference screw. The tibial sides of both grafts were left free, and the collateral ligaments were then addressed. At this point, the tourniquet was deflated, the peripheral pulses were checked by palpation or Doppler ultrasound, and the collateral ligament surgery was performed.

Injuries of the Anterior and Posterior Cruciate Ligaments and Posterolateral Corner (Nine Knees)

For combined injuries of the anterior and posterior cruciate ligaments and posterolateral corner, a 12 to 18-cm lateral curvilinear incision was centered over the lateral epicondyle (Fig. 1, *e*)[13,28]. The course of the peroneal nerve around the fibular neck was identified, but the nerve was not dissected unless peroneal nerve injury had been documented preoperatively. When such an injury had been documented, the extent of the damage was noted, and we released the nerve as it passed around the fibular neck in three patients.

Each of the structures of the posterolateral corner was then systematically evaluated. Lateral repairs and replacements were performed with the knee in 30° of flexion. Peripheral tears of the lateral meniscus were repaired with use of nonabsorbable sutures, and capsular avulsions were repaired with suture anchors. Osseous avulsion of the lateral collateral ligament or the popliteus was directly repaired. More commonly, the injury of the lateral collateral ligament was a midsubstance lesion requiring replacement, which was done with an Achilles tendon allograft. A 7 to 8-mm bone plug was placed into the fibular head and was secured with a metal interference screw. The allograft was secured to the lateral femoral epicondyle with suture anchors, and the native lateral collateral ligament was then repaired to the graft.

If there was increased posterolateral rotation on examination with the patient under anesthesia, then the popliteus and its various attachments were addressed. Great care was taken to identify the location of the injury (femur, midsubstance, or tibia). If a femoral avulsion of the popliteus tendon was noted, direct repair was performed. If a midsubstance injury had occurred, reconstruction was performed with a hamstring tendon autograft in conjunction with a primary repair. The reconstruction is designed to reproduce the popliteal fibular ligament[34]. A 6 to 7-mm tunnel was created in the proximal part of the fibula. The hamstring graft was doubled over and taken through the

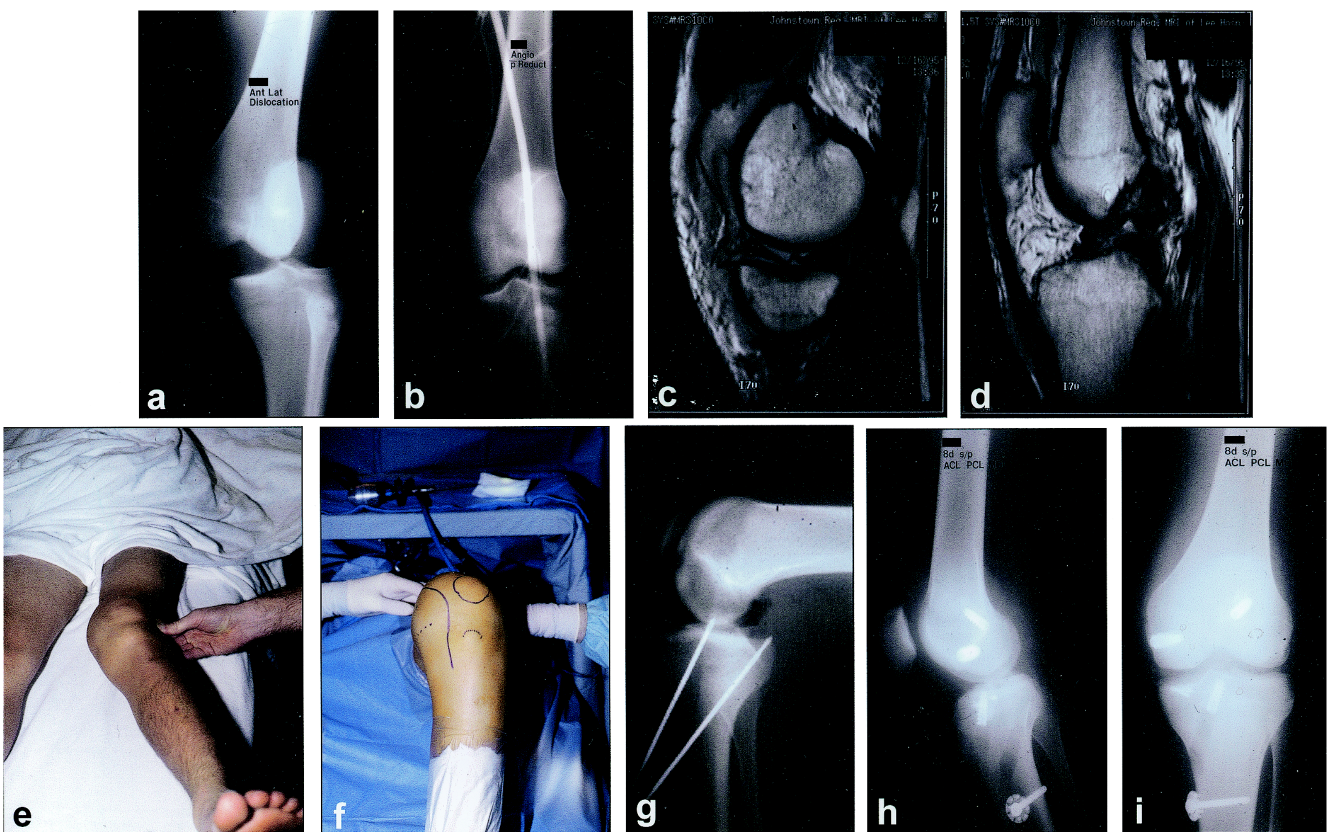

Fig. 2

Case 5 (see Appendix), a twenty-two-year-old with injuries of the anterior cruciate, posterior cruciate, and medial collateral ligaments. *a:* Preoperative radiograph. *b:* Postreduction radiograph with arteriogram. *c:* Magnetic resonance image showing the injury of the medial collateral ligament. *d:* Magnetic resonance image showing the injuries of the anterior and posterior cruciate ligaments. *e:* Intraoperative examination. *f:* Intraoperative setup. *g:* Intraoperative radiograph showing the position of the Kirschner wires prior to drilling. *h* and *i:* Postoperative lateral (*h*) and anteroposterior (*i*) radiographs showing the fixation.

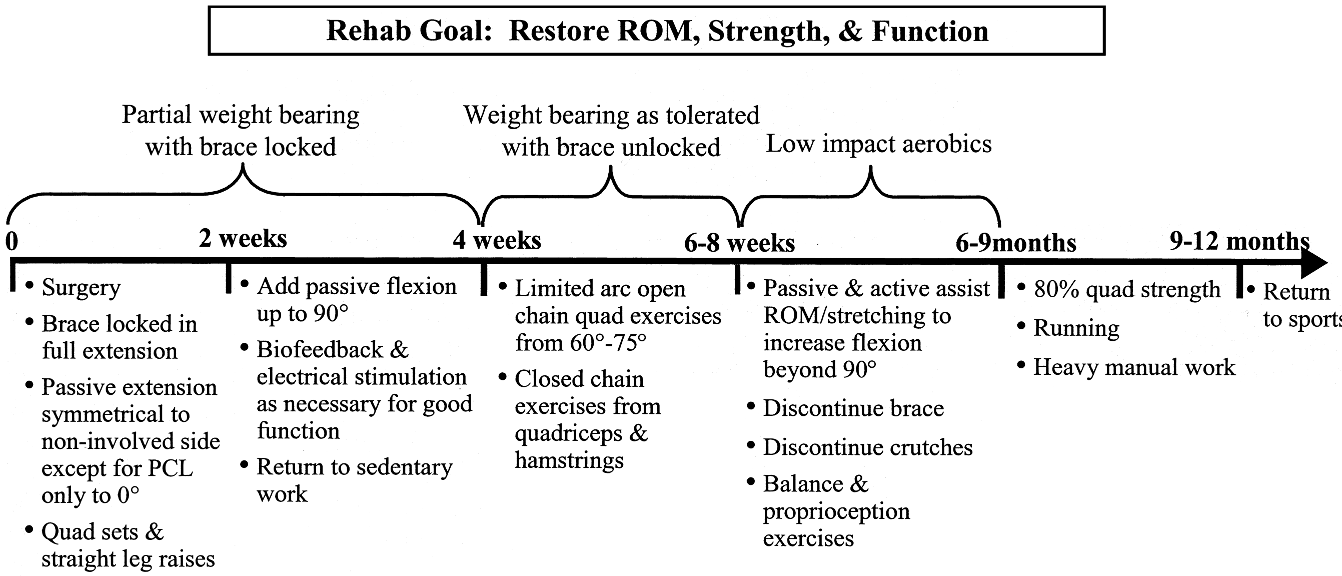

Fig. 3

Algorithm showing the rehabilitation regimen after multiple ligament reconstruction. ROM = range of motion, and PCL = posterior cruciate ligament.

fibular head tunnel. The graft was then passed underneath the lateral collateral ligament and was placed into a closed-end tunnel (7 mm in diameter) at the femoral attachment of the popliteus tendon. The femoral attachment was then tied over a plastic button on the medial femoral cortex. The final fixation of the lateral structures was performed with the knee flexed to 30°. The popliteofibular ligament was secured with a bioabsorbable screw in the fibular head. If the surgery addressed both the lateral collateral ligament and the popliteofibular ligament, the lateral collateral ligament was reconstructed and was secured into a tunnel in the proximal part of the fibula as described above. The popliteofibular graft was secured proximally, as described; passed deep to the lateral collateral ligament graft; and brought from posterior to anterior through a soft-tissue tunnel created at the biceps tendon insertion.

During this stage of the surgery, a bolster of sterile towels or drapes was placed behind the tibia to maintain reduction. After the replacement or repair of the collateral ligaments was completed, the knee was flexed to 90° and the medial tibial step-off was palpated to reproduce the anatomy of the uninvolved knee (usually 1 cm). The graft used for replacement of the posterior cruciate ligament was tensioned and was fixed to the tibia with a soft-tissue washer and screw (Linvatec). The knee was brought into full extension, and the tibial side of the anterior cruciate ligament graft was secured with a 7 × 25-mm interference screw (Linvatec) (Fig. 1, *g*). Finally, the incisions were irrigated and hemostasis was obtained. A drain was not utilized. The knee was braced in full extension to minimize posteriorly directed forces on the tibia from gravity and the hamstring muscles.

Injuries of the Anterior Cruciate, Posterior Cruciate, and Medial Collateral Ligaments (Fifteen Knees)

For combined injuries of the anterior cruciate, posterior cruciate, and medial collateral ligaments in which the medial collateral ligament injury was grade 3+ with valgus stress in full extension, combined cruciate ligament surgery with repair of the medial collateral ligament was performed. If the knee did not exhibit a grade-3+ injury of the medial collateral ligament in full extension, we did not repair the medial side and addressed only the cruciate ligaments. (Four grade-2+ injuries of the medial collateral ligament were not repaired.) After arthroscopic evaluation, tunnels were placed for the cruciate ligaments prior to the medial-side repair. For repairs of the medial collateral ligament, a single medial curvilinear incision was made beginning at the level of the vastus medialis and was continued over the medial femoral epicondyle to the anteromedial aspect of the tibia (Fig. 2, *f*). This allowed exposure of the medial collateral ligament and medial joint line. Repair was performed with a series of nonabsorbable sutures and suture anchors. Avulsions of the medial collateral ligament were reattached with suture anchors, whereas midsubstance tears were primarily repaired with nonabsorbable sutures. Access to the intercondylar notch was easily obtained through the same incision. The anterior and posterior cruciate ligaments were assessed and were replaced with use of arthroscopically assisted techniques without fluid. In the three chronically injured knees with an injury of the medial collateral ligament, the area of the injury (tibia, midsubstance, or femur) was identified, and repair or reconstruction was focused in this area. The magnetic resonance imaging and arthroscopic examination were extremely helpful in identifying the location of the injury of the medial collateral ligament. If the meniscus separated from the femur, we identified a femoral-side injury, and if it separated from the tibia, we diagnosed a tibial-side injury. If reconstruction was needed in addition to the repair, a semitendinosus autograft or an Achilles tendon allograft was placed anatomically in the femoral and tibial attachments. The repair or replacement was performed with the knee in 30° of flexion. The knee was flexed and extended during the operation to ensure that the repair or replacement did not overconstrain knee motion, which would lead to either stiffness or, eventually, to residual laxity. The cruciate ligaments were then fixed on the tibial side, and the knee was braced in full extension.

In general, the patients were observed overnight in the hospital and discharged home on the following day. Prophylaxis against deep venous thrombosis was given to high-risk patients.

Rehabilitation

A previously described postoperative program for knees with multiple ligament injuries was utilized (Fig. 3)[35]. To protect the healing structures, the limb was placed in a postoperative brace that was locked in full extension for the first four weeks. Immediately after surgery, emphasis was placed on restoring full passive extension symmetrical to that of the uninvolved knee and restoring quadriceps function so that the patient could perform a straight-leg raise without a quadriceps lag. The exception to this was that passive knee extension was restricted to zero and hyperextension was avoided for those who had had a repair or replacement of the posterolateral corner. Exercises immediately after surgery included passive knee extension and isometric quadriceps exercises with the knee in full extension. Electrical stimulation that was sufficient to produce a strong quadriceps contraction and/or electromyographic biofeedback was used as necessary to enhance quadriceps function.

Passive flexion exercises, with use of an anteriorly directed force on the proximal part of the tibia, were initiated two weeks after surgery. Active contraction of the hamstrings to flex the knee was avoided for the first six weeks, and motion during this period was limited to 90° of flexion. After six weeks, passive and active-assisted range-of-motion and/or stretching exercises were initiated to increase knee flexion. Use of the rehabilitation brace was discontinued after six weeks if 90° to 100° of knee flexion had been achieved. Knee flexion symmetrical to that of the uninvolved knee was expected within twelve weeks. If the patient had <90° of flexion after eight to twelve weeks, manipulation was performed with the patient under anesthesia.

Quadriceps exercises were progressed to include limited-arc open-chain knee-extension exercises in the midrange from 75° to 60° of flexion, which corresponds to the quadriceps-neutral angle[36], as tolerated after four weeks. Open-chain hamstring exercises were avoided for at least three months. Closed-chain exercises were initiated four to six weeks after surgery. Exercises that impart a valgus stress on the knee (i.e., hip adduction exercises) were avoided for patients who had had a repair or replacement of the medial collateral ligament, and exercises that impart a varus stress on the knee (i.e., hip abduction exercises) were avoided for those who had had a repair or replacement of the lateral collateral ligament or posterolateral corner.

Immediately after surgery, the patient was limited to partial weight-bearing with the brace locked in full extension. After four to six weeks, the brace was unlocked for controlled gait training, and the patient progressed to weight-bearing as tolerated. Use of crutches was discontinued six to eight weeks after surgery, when the patient had minimal swelling in the knee, full active and passive knee extension, and 100° of knee flexion and was able to walk without a bent-knee gait. Once the patient was fully weight-bearing, balance and proprioception exercises were initiated, beginning with standing on the involved limb on a stable surface with the eyes open. Balance and proprioception exercises were gradually progressed to include the use of unstable surfaces such as foam mats and uniaxial and multiaxial balance boards. Patients who performed sedentary work usually returned to work within two weeks, but those who performed strenuous manual work did not return to work until six to nine months. Individuals were allowed to return to low-impact aerobic activities, such as walking, swimming, and bicycling, eight to twelve weeks after surgery. They were allowed to run at six months provided that they had at least 80% quadriceps strength compared with that of the uninvolved knee. Return to sports activities requiring sudden changes in direction and pivoting was delayed for nine to twelve months.

Follow-up Evaluation

Thirty-one of the thirty-three patients were evaluated more than two years following surgery (see Appendix). Clinical evaluation included completion of a series of self-administered questionnaires that allowed calculation of the Lysholm, Meyers, and Knee Outcome Survey scores. Meyers functional scores have been reported specifically for patients with knee dislocation and have been utilized in studies by several authors[4,7,18,22,27]. The ratings were determined as proposed by Meyers and Harvey[18] and Meyers et al.[4]. An excellent rating indicates symptom-free return to work or to the preinjury level of activity with a stable knee. A good rating indicates slight pain and instability that does not preclude the patient's return to the preinjury occupation or activity level. A fair rating indicates difficulty with stairs or running causing the patient to avoid those activities. A poor rating indicates marked limitation of activities of daily living or an inability to work because of marked pain or instability.

The Knee Outcome Survey was developed at the University of Pittsburgh as a patient-reported measure of symptoms and functional limitations for patients with a variety of knee disorders, including ligamentous and meniscal injuries[37]. The Knee Outcome Survey consists of two scales: the Activities of Daily Living Scale and the Sports Activity Scale. The Activities of Daily Living Scale measures symptoms and functional limitations during activities of daily living. The score ranges from 0 to 100 points, with 100 points indicating an absence of symptoms and functional limitations during activities of daily living. The Activities of Daily Living Scale has been shown to be a reliable, valid, and responsive measure of symptoms and functional limitations during activities of daily living in individuals with a variety of knee injuries[37]. The Sports Activity

Scale measures symptoms and functional limitations experienced during sports activities. The Sports Activity Scale score ranges from 0 to 100 points, with 100 points representing the absence of symptoms and functional limitations during sports activities[38]. The scores on the Sports Activity Scale in our study are noteworthy since the majority of our patients sustained the dislocation during sports activity.

All patients underwent a physical examination that included evaluation of the range of motion and stability. The range of motion of both knees was measured with use of a standard goniometric technique, and the loss of flexion and extension relative to the uninvolved side was calculated. Stability was determined manually and with the KT-1000 arthrometer (MEDmetric, San Diego, California). The examination with the KT-1000 arthrometer was performed with the knee at the quadriceps-neutral angle to determine corrected anterior and posterior translation[36,39]. A thorough manual examination of the ligaments was performed by one of the authors, and the results were graded according to the guidelines of the International Knee Documentation Committee (IKDC)[40]. When the Lachman and anterior and posterior drawer tests were performed, care was taken to ensure a normal tibiofemoral step-off prior to application of stress to the tibia. Varus and valgus stability were determined at 30° of knee flexion. The final overall IKDC rating was calculated according to the guidelines described by Hefti et al.[40]. The overall final IKDC rating is based on group ratings for function, symptoms, range of motion, and laxity. Each group rating is based on the two or more items that are rated as normal, nearly normal, abnormal, or severely abnormal. The worst rating for any item within a group determines the group rating, and the worst group rating determines the overall final rating. Thus, the worst rating for any particular item determines the overall final rating.

Data Analysis

Descriptive statistics, including means and standard deviations for continuous variables and frequency counts for nominal and ordinal level variables, were calculated. Independent t tests were performed for continuous variables and chi-square tests were performed for nominal and ordinal level variables to determine the significance of differences between patients treated with acute replacement (less than three weeks after the injury) and those treated with chronic replacement (more than three weeks after the injury).

Results

Thirty-one of thirty-three patients were available for evaluation at a mean of forty-four months (range, two to six years) following surgery (see Appendix). The mean age of these patients at the time of surgery was 28.4 years (range, sixteen to fifty-one years). Seventeen patients were injured during sports activity; four, in an automobile accident; four, in a motorcycle accident; four, in a work-related accident; and two, in a fall. Nineteen patients underwent surgery less than three weeks (average, twelve days; range, five to twenty-one days) after the injury. Twelve patients underwent surgery more than three weeks (average, 6.5 months; range, five weeks to twenty-two months) after the injury.

Injury patterns were variable and were determined by magnetic resonance imaging, examination with the patient under anesthesia, and arthroscopy. Fifteen of the nineteen patients with an acute injury underwent replacement of both the anterior and the posterior cruciate ligament with fresh-frozen allografts. One patient had a grade-2+ injury of the anterior cruciate ligament that was not reconstructed, and two patients (Cases 10 and 18; see Appendix) had a grade-2+ injury of the posterior cruciate ligament that was not reconstructed. The other cruciate ligament was replaced in all three patients. One patient had a peel-off injury of the posterior cruciate ligament that was repaired primarily as well an injury of the anterior cruciate ligament that was reconstructed with an allograft.

Of the nineteen patients who underwent acute treatment, ten had combined injuries of the anterior cruciate, posterior cruciate, and medial collateral ligaments with no lateral injury. Eight of those ten patients had repair of a grade-3+ injury of the medial collateral ligament, and two did not undergo repair of a grade-2+ injury. Seven of the nineteen patients had injuries of the anterior cruciate ligament, posterior cruciate ligament, and posterolateral corner. Five of the seven underwent allograft reconstruction of the lateral collateral ligament with repair of posterolateral corner structures. One patient had repair of an avulsion injury that included the lateral collateral ligament and the biceps femoris insertion onto the fibular head. One patient had an intact lateral collateral ligament and posterolateral corner, but the anterolateral capsule and iliotibial band were avulsed and were repaired. The remaining two acutely treated patients had sustained a low-velocity knee dislocation. One of these patients had grade-3+ injuries of the anterior and posterior cruciate ligaments but only grade-1+ injuries of the medial collateral and lateral collateral ligaments. The other patient sustained grade-3+ injuries of the anterior and posterior cruciate ligaments and the medial collateral ligament with a grade-1+ injury of the posterolateral corner that did not require surgical treatment.

The laxity patterns in the patients undergoing delayed surgery were determined with intraoperative physical examination at the time of ligament replacement. Eleven of the twelve patients with a chronic injury underwent fresh-frozen allograft replacement of the anterior and posterior cruciate ligaments. One seventeen-year-old patient underwent a primary repair of an avulsion injury of the anterior cruciate ligament and an allograft replacement of the posterior cruciate ligament one month after injury. Five patients who underwent chronic treatment had injuries of the anterior cruciate, posterior cruciate, and medial collateral ligaments. Three of the five patients had grade-3+ laxity of the medial collateral ligament requiring repair. Two of the five had grade-2+ laxity of the medial collateral ligament, and the anterior and posterior cruciate ligaments were replaced without repair of the medial collateral ligament. Two patients who underwent chronic treatment had grade-3+ injuries of the anterior and posterior cruciate ligament and laxity of the posterolateral corner. The lateral collateral ligament was reconstructed with fresh-frozen allograft in each of these patients. Five chronically treated patients had isolated laxity of the anterior and posterior cruciate ligaments without substantial varus or valgus laxity; no medial or lateral surgery was performed in these patients.

Four patients had an injury of the common peroneal nerve. Three of these injuries were transient, and one was permanent. One of the patients with transient symptoms had paresthesias over the dorsum of the foot without motor weakness on examination. The subjective paresthesias decreased over the ten days prior to surgery. Since the symptoms were decreasing and the patient only had minor varus laxity on examination under anesthesia, a lateral approach was not thought to be necessary and the nerve was not explored. In the other three patients, the nerve was identified and released as it passed the fibula. Two patients with transient symptoms had decreased sensation over the dorsum of the foot with weak ankle and toe dorsiflexion. Intraoperatively, both patients were noted to have focal hemorrhage and swelling of the nerve. Gradual return to full motor and sensory function occurred over approximately two months postoperatively. The only patient who had a complete nerve deficit had had a complete motor and sensory deficit at the time of presentation (Case 11; see Appendix). This patient had an osseous avulsion of both the lateral collateral ligament and the biceps femoris from the fibular head. The nerve was in continuity, although gross swelling and hemorrhage were present over several centimeters surrounding the proximal part of the fibula. The patient never regained function and underwent a tendon transfer approximately nine months following knee surgery.

Clinical Results

Clinical results were determined with an extensive questionnaire and physical examination (see Appendix). The mean Lysholm score (and standard deviation) was 87 ± 12.7 points (range, 50 to 100 points) for the series as a whole, 91 ± 7.0 points (range, 72 to 100 points) for the nineteen patients who underwent acute surgery, and 80 ± 16.9 points (range, 50 to 100 points) for the twelve patients who underwent surgery more than three weeks after injury. This difference between the acute and chronic groups approached significance (two-tailed significance, $p = 0.07$, assuming unequal variances).

The average Knee Outcome Survey Activities of Daily Living score for all patients was 89 points (range, 64 to 99 points) in the series as a whole. The score averaged 91 ± 6.4 points (range, 73 to 99 points) for the acutely treated patients and 84 ± 11.8 points (range, 64 to 99 points) for the patients who underwent chronic treatment. This difference approached significance (two-tailed significance, $p = 0.07$, assuming unequal variances). The average score on the Sports Activities Scale was 82 points (range, 0 to 100 points) in the entire series. The patients in the acute group had an average score of 89 ± 10.3 points (range, 60 to 100 points), and those in the chronic group had an average score of 69 ± 27.9 points (range, 0 to 100 points). This difference was significant (two tailed significance, $p = 0.04$, assuming unequal variances).

There were ten excellent, thirteen good, five fair, and three poor results according to the Meyers functional rating. Of the nineteen patients in the acute group, sixteen received an excellent or good rating and three received a fair rating. Of the twelve patients in the chronic group, seven received an excellent or good rating, two received a fair rating, and three received a poor rating. The difference in the Meyers ratings between the acute and chronic groups approached significance ($p = 0.14$).

All patients underwent a follow-up physical examination to determine the range of motion and ligamentous stability (see Appendix). The total arc of motion was similar between those who had undergone acute treatment (mean, 128° ± 10°; range, 115° to 145°) and those who had undergone chronic treatment (mean, 129° ± 15°; range, 104° to 144°). Flexion loss was calculated by subtracting the flexion of the involved knee from that of the uninvolved knee, whereas extension loss was the difference from anatomic zero as dictated by the 1993 IKDC guidelines[40]. The average extension loss was 1° ± 2° (range, 0° to 5°). The thirteen patients with a slight flexion contracture had an average loss of extension of 3°, and only one patient had a flexion contracture of >5°. This patient had a 9° flexion contracture for the injured knee; however, the patient also had an idiopathic 10° flexion contracture of the contralateral, "normal" knee. Flexion loss was more pronounced, with an average loss of 12° ± 9° (range, 0° to 33°). Fourteen patients lost between 5° and 15° of flexion, five patients lost between 16° and 25° of flexion, and three patients lost >25° of flexion. The patients in the acute group had an average loss of 13° ± 8° (range, 0° to 33°), and the patients in the chronic group had an average loss of 10° ± 9° (range, 0° to 32°). The difference in the range of motion between the patients who underwent acute treatment and those who underwent chronic reconstruction was not significant.

On examination of the knee, all patients had a firm end point during the Lachman test. Fifteen patients had a negative result of the Lachman test (0 to 2 mm of increased anterior tibial translation), and sixteen had 1+ laxity (3 to 5 mm of increased anterior tibial translation). All patients also had a firm end point on the posterior drawer test. Twenty-two patients had 1+ laxity (3 to 5 mm of increased posterior tibial translation), and nine patients had 2+ laxity (6 to 10 mm of increased posterior tibial translation). No patient had a grade-3+ posterior drawer. Only three of the patients in the acute group had 2+ laxity on posterior drawer testing, whereas six in the chronic group had 2+ laxity. This difference was significant (two-sided $p = 0.04$).

Varus stress testing at 30° revealed 1+ laxity (3 to 5 mm of increased laxity compared with that of the uninvolved knee) in nine patients and 2+ laxity (6 to 10 mm of increased laxity) in two patients. All other patients had <3 mm of increased laxity. Varus laxity was 2+ in two patients who had undergone replacement of the lateral collateral ligament.

Valgus stress testing at 30° revealed 1+ laxity (3 to 5-mm increase compared with that of the uninvolved knee) in five patients and 2+ laxity (6 to 10-mm increase) in four patients.

All other patients had <3 mm of increased laxity compared with that of the uninvolved knee. Only one acutely treated patient had 2+ laxity. At the time of examination under anesthesia, this patient had had only mild valgus instability and the medial collateral ligament was treated nonoperatively. The other three patients with 2+ valgus laxity at the time follow-up had been treated chronically. Two of these three had undergone repair of the medial collateral ligament because of grade-3+ laxity; one was treated five weeks after the injury and the other was treated seven months after the injury. The remaining patient with chronic 2+ valgus laxity had not had a repair of the medial collateral ligament.

KT-1000 data were obtained for twenty-five of the thirty-one patients and demonstrated a mean corrected side-to-side difference in anterior translation of 0.1 mm (range, −4 to 2.5 mm) and a mean corrected side-to-side difference in posterior translation of 2.6 mm (range, −1 to 7 mm). The mean corrected side-to-side difference in anterior tibial translation was <3 mm for fourteen of the twenty-five patients and was >5 mm for three. The remaining eight patients had 3 to 5 mm of increased anterior tibial translation compared with that on the uninvolved side. The mean corrected side-to-side difference in posterior tibial translation was <3 mm for fifteen of the twenty-five patients and was >5 mm for three. The remaining seven patients had a 3 to 5 mm of increased corrected posterior tibial translation compared with that on the uninvolved side.

The final overall IKDC rating was nearly normal for eleven knees, abnormal for twelve, and severely abnormal for eight. No knee received a normal overall IKDC rating. Ten of the eleven knees that received a nearly normal overall IKDC score had been treated acutely. Only one nearly normal knee had been treated chronically. Equal numbers of severely abnormal knees were found in the acute and chronic groups, but the percentages of the total were 21% and 33%, respectively. Of the knees with a severely abnormal overall IKDC rating, five received this rating because of activity-related symptoms and three received it because of flexion loss.

Complications included postoperative stiffness in four patients (Cases 4, 7, 13, and 14; see Appendix), all of whom had undergone acute reconstruction. All four knees were treated with manipulation with the patient under anesthesia. Three of the four knees were manipulated because of loss of flexion, and one (Case 14) underwent arthroscopic lysis of adhesions at the time of manipulation because of loss of extension. Of these four patients, one (Case 14) had a contralateral grade-I open tibial fracture with a compartment syndrome that required acute release at the time of presentation. As a result, this patient did not receive adequate physical therapy after the initial reconstruction. The time from the initial surgery to the manipulation for these four patients was nine, eleven, nine, and thirty weeks (mean, 14.8 weeks). Manipulation increased the total arc of motion by an average of 51° (range, 25° to 90°) at the time of manipulation and by an average of 55° (range, 28° to 106°) at the time of final follow-up. Two patients had residual flexion contractures of 5° and 9°, and all patients had flexion of ≥115°.

Discussion

Our goal in this study was to review the results of our protocol for surgical and postoperative management of knee dislocations. We found that allograft reconstruction provides a good functional result in the majority of patients. Subjective functional results were acceptable for patients who underwent the ligament surgery within the first three weeks after the injury. The scores on all three rating scales used in the evaluation showed this trend. Most patients had only slight symptoms and functional limitations during activities of daily living. Many patients were able to return to sports activities, although many had subjective symptoms and functional limitations. Patients who underwent surgery within the first three weeks after injury tended to have higher subjective scores. However, only the difference in the score on the Sports Activity Scale of the Knee Outcome Survey reached significance ($p = 0.04$).

Objectively, both the acutely and the chronically treated patients obtained a good range of motion. On examination, most knees were stable. Residual laxity of the posterior cruciate ligament was more common in the chronically treated patients. In addition, residual valgus laxity was more prevalent in the patients who underwent delayed repair of the medial collateral ligament. These findings are consistent with those of other studies on the surgical treatment of dislocated knees[12,22]. Clinically, however, the majority of patients did not report instability unless they attempted strenuous manual labor or sports activities requiring aggressive changes in direction or pivoting. In summary, our standard management for knee dislocation seems to provide good structural and functional results for the majority of patients.

Shelbourne et al. reported their experience with the management of low-velocity knee dislocations in a series of twenty-one patients who had been treated with several different nonoperative and operative approaches[24]. They recommended replacement of the posterior cruciate ligament with a patellar tendon autograft along with repair of the medial collateral ligament and lateral structures, whereas tears of the anterior cruciate ligament were not treated. In addition, they recommended delaying ligament replacement when the medial structures were involved (and the lateral side was normal) until the patient obtained >90° of flexion, nearly full extension, and good strength. They reported satisfactory results in nine patients treated in this manner and believed that the arthrofibrosis potentially associated with concurrent replacement of the anterior cruciate ligament or acute repair of the medial collateral ligament could be avoided. Across all treatment groups, the patients had an average extension loss of 3° and flexion loss of 15°. This range of motion was comparable with that in our series. Only 19% of the patients were able to return to their preoperative level of athletic competition.

Yeh et al.[25] also reported on isolated replacement of the posterior cruciate ligament after knee dislocation. Repairs of the collateral ligaments, capsule, and meniscus were performed "as necessary." All replacements were performed within twenty-five days after the injury. Yeh et al. reported good subjective and functional results, with a mean Lysholm score of 84 points and mean flexion of 129.6°. However, three of their twenty-three patients required arthroscopic lysis of adhesions.

Shapiro and Freedman[22] reported satisfactory functional results in six of seven patients evaluated at an average of four years following treatment of a knee dislocation with allograft replacement of the anterior and posterior cruciate ligaments. Other injured structures were treated with primary repair, and the operations were performed at an average of ten days after the injury. The mean flexion was 118°, and three patients had a flexion contracture of ≤5°. The mean Lysholm score was 75 points, and there were three excellent results, three good results, and one fair result according to the Meyers rating. Four of the seven patients required manipulation under anesthesia and/or arthroscopic lysis of adhesions because of arthrofibrosis.

Fanelli et al.[20] reported successful cruciate ligament replacement with either patellar tendon autografts or fresh-frozen allografts in twenty patients who had sustained a knee dislocation. Ten patients underwent the surgery acutely, and ten patients underwent delayed replacement. In contrast to our findings, they did not note differences between the acutely and chronically treated groups with the ligament-rating scales that they used. These authors therefore recommended that replacement for the treatment of injuries of the anterior cruciate ligament, posterior cruciate ligament, and posterolateral corner be delayed for at least two to three weeks and replacement for the treatment of injuries of the anterior cruciate, posterior cruciate, and medial collateral ligaments be delayed for six weeks to allow healing in a brace. The postoperative Lysholm scores averaged 91.3 points in their series.

Noyes and Barber-Westin[21] reviewed the results in eleven patients who had undergone mostly allograft replacement of the cruciate ligaments, lateral collateral ligament, and posterolateral corner structures. Seven patients were treated acutely and four patients were treated chronically. Notably, the patients who had undergone delayed reconstruction had lower overall ratings and more subjective difficulties with sports activities than did the patients treated acutely.

Wascher et al.[11] reported on thirteen patients who had undergone allograft replacement of the anterior and posterior cruciate ligaments. Nine patients had an acute injury, and four had a chronic injury. Wascher et al. also noted better results after early reconstructions than after late reconstructions. Mild residual laxity of the posterior cruciate ligament was common, as it was in our series. The Meyers score was excellent or good for eleven of their patients, the Lysholm scores averaged 88 points, and the IKDC overall rating was nearly normal for six knees, abnormal for five knees, and grossly abnormal for one knee. IKDC scores were not available for one patient. Two patients required postoperative manipulation and arthroscopic lysis of adhesions because of arthrofibrosis.

Our results are comparable with those in other series of patients who had undergone allograft reconstruction of the cruciate ligaments following knee dislocation[11,41-43]. On the basis of these results, we advocate early combined replacement of both cruciate ligaments and repair or replacement for complete collateral or capsular injuries. A review of the literature revealed that several surgeons have advocated delayed intervention in patients who have a complete injury of the medial collateral ligament[20,24]. We performed early primary repair of medial collateral ligaments with complete injuries. The timing of surgery, and specifically acute reconstruction of the anterior cruciate and medial collateral ligaments in the setting of knee dislocation, did not seem to increase the rate of arthrofibrosis in our series.

We favor the use of allograft rather than autograft for patients with a knee dislocation to avoid the additional surgical morbidity and increased surgical time associated with harvesting of the graft. In our series of thirty-one patients who had a total of sixty allograft cruciate reconstructions, there was only one graft failure that required a reoperation (Case 16; see Appendix).

The relationship between range-of-motion measurements and laxity and the resulting functional limitations and disability is not a direct one[44]. From the patients' perspective, functional limitations and disability are of utmost importance. Thus, we believe that the primary outcome measure for clinical research, including this study, should be the patients' perception of their functional limitations and disability. Measures such as range of motion and laxity should be considered to be secondary outcome measures. As a result, we chose to use several measures that focus on the patients' perception of their function and disability, including the Lysholm Knee Scale, the Meyers rating scale, and the Activities of Daily Living and Sports Activities Scales of the Knee Outcome Survey. The average Lysholm score for our patients, 87 points, was comparable with that in other reports[11,20,22,25], despite a large percentage of chronically treated patients in our series. The Meyers ratings for our patients were similar to those reported by others as well[11,22]. Seventy-four percent received an excellent or good rating, which implies that the majority of our patients were able to return to work or to their previous level of activity with no or minimal pain and instability. As indicated by the Knee Outcome Survey, the patients had fewer symptoms and functional limitations during activities of daily living than they did during sports.

On the basis of the results of this study, we have made several changes in our surgical management of these complex injuries. We no longer use a tourniquet because the combined tourniquet time exceeded two hours in twenty-six of the thirty-one patients. We have found that arthroscopic visibility and identification of collateral and capsular structures can be achieved without use of a tourniquet. Also, we no longer use an arthroscopic leg-holder because we found it to be too confining for assessment of range of motion and stability.

On the basis of our arthroscopic findings of various patterns of posterior cruciate ligament injury, we have been more selective about preserving the remaining components (anterolateral, posteromedial, or meniscofemoral) if they are intact[32]. In this series of patients, if the posterior cruciate ligament was replaced, we removed all remaining components with an anterolateral single-bundle procedure. We now identify and preserve any intact components and replace only what is torn. We are most likely to do this in knees with an acute dislocation, in which the meniscofemoral ligaments are usually intact and the posteromedial component is occasionally still present.

Finally, since 2000, we have been performing double-bundle posterior cruciate ligament replacement with use of an Achilles tendon allograft for the anterolateral bundle and a semitendinosus autograft for the posteromedial bundle in knees with a chronically deficient anterior cruciate ligament, posterior cruciate ligament, and posterolateral corner. This change was based on the results of our biomechanical studies and this retrospective review[45,46].

The overall IKDC rating for each knee was determined according to guidelines described by Hefti et al.[40]. According to the IKDC knee-ligament-rating scale, no knee was normal, eleven were nearly normal, twelve were abnormal, and eight were severely abnormal. Many times, the overall IKDC score did not provide an accurate representation of the patients' perception of the outcome, as evidenced by the fact that some patients with an abnormal or severely abnormal overall IKDC rating had high Lysholm, Knee Outcome Survey, and Meyers scores. Additional evidence of the validity of the IKDC guidelines for patients with multiple ligament injuries of the knee is necessary.

This study demonstrated that anatomic allograft reconstruction to treat all associated knee injuries yields good functional results in patients with a knee dislocation. However, our study was limited by the number of patients and the heterogeneity of injuries, which is inherent to a series of patients with knee dislocation.

In summary, replacement or repair to treat multiple ligament injuries following traumatic knee dislocation provided satisfactory subjective functional results, range of motion, and stability in the majority of the patients in this series. Patients who underwent surgery within the first three weeks after injury tended to have better subjective functional ratings and better restoration of ligamentous stability. Although the majority of patients had little difficulty with activities of daily living, the ability of patients to return to high-demand sports and strenuous manual labor is less predictable. Patients treated for chronic instability after knee dislocation may have more functional limitations than those who are treated acutely. It is important to discuss these issues with patients preoperatively so that their expectations are realistic.

Appendix

eA Tables showing data on all patients and the results of the follow-up evaluation are available with the electronic versions of this article, on our web site at www.jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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