Two-Stage Revision Anterior Cruciate Ligament Reconstruction

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abstract

The number of primary anterior cruciate ligament (ACL) tears is rapidly increasing. In patients who wish to return to their preoperative level of function, specifically as it pertains to participation in sports, the gold standard of treatment following an ACL tear remains an anterior cruciate ligament (ACL) reconstruction. Despite a majority of good/excellent results following primary ACL reconstruction, there is a growing subset of patients with persistent or recurrent functional instability who require revision ACL reconstruction. Preoperative planning for revision ACL reconstruction requires a careful understanding of the root cause of ACL failure, including possible technical causes of primary ACL failure and the presence of combined knee pathology that was not addressed at the index ACL reconstruction. The decision to perform 2-stage revision ACL reconstruction is multifactorial and is reached by technical considerations that may make a 1-stage revision less optimal, including tunnel widening, arthrofibrosis, active infection, and others. Concomitant knee pathology such as meniscal deficiency, malalignment (including an increase in posterior tibial slope), chondral lesions, and other ligamentous laxity may also require a staged approach to treatment. This evidence-based review covers the indications for 2-stage revision ACL reconstruction, surgical techniques, evidence for and technique of bone grafting prior ACL tunnels, and outcomes of 2-stage revision stratified by initial cause of ACL reconstruction failure. With proper preoperative planning and an understanding of the cause of failure following the primary ACL reconstruction, revision ACL reconstruction can offer excellent outcomes in the motivated patient. [Orthopedics. 2016; 39(3):e456-e464.]

Anterior cruciate ligament (ACL) reconstruction is the gold standard treatment option for young, active patients with functional instability following an ACL tear. It is estimated that there are greater than 250,000 ACL tears annually in the United States, more than half of which will undergo reconstruction. This equates to an annual cost of approximately $1 billion for the health care industry. Despite good or excellent outcomes in the majority of patients, graft rupture rates after reconstruction range from 5% to 25%, with the highest rates found in young athletes involved in cutting or pivoting sports and lower rates found in those who are jumpers or who pursue straight line activities. In addition, a significant subset of patients have persistent or recurrent functional instability following ACL reconstruction that limits their ability to return to sport, even without overt graft failure.

With the increase in the number of primary ACL reconstructions, the need for revision ACL reconstructions is also increasing. Some authors estimate the revision ACL reconstruction burden to...
Successful revision surgery requires an understanding of the root cause of failure, careful preoperative planning, meticulous surgical execution, proper postoperative rehabilitation, and appropriate patient counseling. A relatively small but challenging subset of patients requires 2-stage revision ACL reconstruction. Recognition of patients who may benefit from this treatment strategy is critical. Major reasons to proceed with a 2-stage strategy include tunnel widening or other loss of bone stock, arthrofibrosis, active infection, concomitant meniscal deficiency, malalignment, and focal chondral lesions and/or other ligamentous laxity that may require a staged approach.10,11

This article will provide an evidence-based review of 2-stage revision ACL reconstruction. It will address the epidemiology of revision ACL reconstruction; root causes of primary ACL failure; evaluation and workup of a patient with a failed primary ACL reconstruction; determination of 1-stage vs 2-stage revision reconstruction; and technical aspects of 2-stage reconstruction, including evidence for and techniques of bone grafting ACL tunnels, outcomes of revision ACL reconstruction, and return-to-sport prognosis for these difficult cases.

Epidemiology of Revision Anterior Cruciate Ligament Reconstruction

In the United States, the incidence of ACL reconstruction has risen from 86,687 in 1994 to 129,836 in 2006, with 95% of these surgeries performed in an outpatient setting (compared with just 43% in 1994).12 The revision rate for primary ACL reconstruction varies from 1.5% to almost 10% depending on surgeon experience and patient age, among other factors.13-16 The revision rate often peaks between 1 to 2 years after the primary ACL reconstruction, likely secondary to return to sport,17 and the outcomes after revision surgery are generally inferior to those after primary ACL reconstruction.17,18 The rerupture rate after a revision ACL reconstruction is highly variable and has been reported to be between 3.5% to 33% in the hands of an experienced surgeon.9,17,18 Patients who received allograft tissue at the time of their revision surgery are at an even higher risk for failure.13,17,23 In addition to rerupture, patients with revision ACL reconstruction have inferior outcomes in functional scores, quality of life, strength, and other outcome measures compared with primary ACL reconstruction.12,17,18,24 This must be conveyed to the patient preoperatively to set realistic expectations for the postoperative course.

To the current authors’ knowledge, there is no report on the total number of 1-stage vs 2-stage revision ACL reconstructions. However, there are significantly more reports on the outcomes of 1-stage revision ACL reconstruction than 2-stage approaches.

Root Causes of Primary Anterior Cruciate Ligament Failure

Failure of primary ACL reconstruction is often multifactorial. Graft failure can be divided into traumatic and atraumatic. Traumatic etiologies account for approximately 25% of graft failures.25 Patients who sustain a traumatic failure often return to high levels of activity prior to achieving appropriate neuromuscular control.13 In general, this cohort reports progressing well in the postoperative rehabilitation period prior to a recurrent traumatic pivoting event. Radiographs often show properly aligned tunnels (Figure 1).

Atraumatic causes of graft failure, encompassing 75% of failures, occur when the patient notes a feeling of recurrent instability in the knee without a history of a new traumatic event.25 Although there are many potential causes of atraumatic failure, technical errors, specifically tunnel malposition, are cited as the most common cause of atraumatic graft failure after ACL reconstruction.25 Although a
A second cause of atraumatic graft failure is failure of the graft to incorporate and undergo proper ligamentization.\textsuperscript{14,28} This can occur due to poor initial graft choice, lack of vascularity, the patient’s immunologic response, aggressive rehabilitation, or impingement.\textsuperscript{21,28} Insufficient fixation of the graft can also lead to failure. The stability of the graft at time zero is completely dependent on the fixation method, and if the fixation achieved at the time of surgery is inadequate, the graft may fail.

Loss of motion in either knee flexion or extension can compromise a patient’s outcome after ACL reconstruction and lead to atraumatic failure.\textsuperscript{13} A loss of only 5° of extension or 15° of flexion can compromise a patient’s ability to function properly and necessitate a revision procedure.\textsuperscript{29} This slight loss of extension can cause the patient to walk with a bent-knee gait, resulting in quadriceps fatigue, dysfunction, and weakness as well as anterior knee pain.\textsuperscript{14} Loss of motion can be secondary to technical errors in graft/tunnel placement, improper rehabilitation in the postoperative setting, arthrofibrosis, infection, or pain syndromes that result in a patient’s refusal to move the knee.\textsuperscript{11,23,30} Notch or posterior cruciate ligament impingement of the graft from nonanatomic position or from scar adjacent to the notch (ie, cyclops lesion) can cause loss of motion and/or lead to a graft failure over time (Figure 4).\textsuperscript{30,31} Patients who experience a loss of motion following ACL reconstruction are at a higher risk of developing arthritis.\textsuperscript{32}

Meniscal deficiency can also be a significant cause of a primary ACL failure given the multifaceted role the meniscus plays in knee stability, as well as lubrication and proprioception.\textsuperscript{27} It is well established that the medial meniscus uses the breakstop mechanism and acts as an important secondary stabilizer to anterior tibial translation.\textsuperscript{33,34} In the medial meniscus–deficient state, the ACL graft experiences significantly more stress and is therefore more likely to fail.\textsuperscript{13,33} There is also growing evidence to suggest that the lateral meniscus may play a stabilizing role in tibial internal rotation and in helping to modulate the pivot shift.\textsuperscript{35}

Malalignment is also an important factor regarding ACL failure. Extremes of coronal malalignment (ie, varus, valgus) may lead to failure through excessive graft forces or by accentuating laxity in extraarticular secondary stabilizing ligaments (ie, medial collateral ligament, postero-lateral corner). In addition, recent studies have shown that increased posterior tibial slope is also a risk factor for failure of ACL reconstruction.\textsuperscript{36,37} In patients with increased tibial slope, there is increased anterior translational force that can increase strain.\textsuperscript{38,39} Recognizing and addressing these risk factors for ACL failure is critical to successful revision ACL surgery.

**EVALUATION AND WORKUP OF A PATIENT WITH A FAILED ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION**

Evaluation of the patient begins with a thorough history, making sure to clarify the inciting event that caused the initial ACL tear, as well as the clinical course following primary ACL reconstruction. The timing and symptoms associated with
failure of the primary ACL reconstruction should be elucidated to determine the type and cause of failure. Failures within 6 months are more likely to be caused by technical errors or early return to sport prior to regaining appropriate neuromuscular control. Insidious onset of recurrent knee laxity may be due to technical errors or failure of graft incorporation. Lack of motion in the early postoperative period may be representative of arthrofibrosis. Patients with fevers, chills, inability to bear weight, or significant painful motion should be evaluated closely to rule out infection. Failures after 1 to 2 years are typically traumatic and often occur in the setting of a previously well-functioning knee. Atraumatic late failures may be secondary to concomitant knee pathology, including meniscal deficiency, malalignment, chondral lesions, or other missed ligamentous injury.

Every effort should be made to obtain previous operative reports. Technical issues such as tunnel size, technique of drilling, graft choice, fixation, and any concomitant procedures should be taken into consideration. This will aid in determining causes of failure and planning a revision ACL reconstruction.

**Physical Examination**

As with any other knee examination, the physical examination should start with inspection, palpation, passive ROM, active ROM, strength testing of the entire leg, and special tests. Prone heel height should be measured by comparison with the uninjured side. A loss of 1 cm of heel height equates to roughly 1° loss of extension. Loss of extension compared with the contralateral side can lead to a bent-knee gait pattern with anterior knee pain and quadriceps muscle weakness. This is often more problematic than loss of flexion. The ACL can be evaluated using the anterior drawer, Lachman, and pivot shift tests. The Lachman test is the most sensitive test in evaluating the ACL, whereas the pivot shift test, particularly when performed under anesthesia, is the most specific. The posterior cruciate ligament can be evaluated with the posterior drawer and sag sign, and posteromedial and posterolateral corner pathology can be determined by varus/valgus and rotational stress testing in both supine and prone position. Failure to recognize and address deficiencies in the knee secondary stabilizers at the time of revision ACL reconstruction increases the risk of recurrent ACL reconstruction failure.

**Imaging Studies**

Imaging studies for the patient presenting with a clinical failed ACL reconstruction begin with radiographs, including anteroposterior (AP), Rosenberg (45° flexion posteroanterior), lateral, Merchant, and, in select cases, full-length mechanical axis views. These should be used to determine the position of any hardware and previous femoral and tibial tunnels, the presence of joint-space narrowing, overall limb alignment, and any concomitant pathology (ie, Segond fracture, Pellegrini-Stieda lesion). Tunnel position should be critically assessed on true AP and lateral views, and tunnel widening should be ruled out, typically best seen using the AP view for the femoral tunnel and lateral view for the tibial tunnel.

Once radiographs have been completed, advanced imaging may be warranted. This includes magnetic resonance imaging (MRI), as well as computed tomography (CT) if there is concern for tunnel widening. If there is a traumatic injury, MRI may demonstrate the characteristic pattern of bone edema in the posterior aspect of the lateral tibial plateau and anterolateral femoral condyle. Magnetic resonance imaging can also allow assessment of tunnel position and estimation of the cross-sectional area of the tunnels to look for femoral and tibial tunnel widening.

The current gold standard for evaluating tunnel widening is CT because studies have shown that CT outperforms MRI and radiographs in both inter- and intraobserver reliability for evaluating tunnel widening. The authors favor a selective approach to ordering CT scans to evaluate tunnel position and widening. The decision to order a CT scan in addition to the radiographs and MRI is based on the quality of the MRI and the surgeon’s comfort with using MRI to evaluate tunnel position and widening. Assessment of tunnel position and widening is crucial because this can help dictate whether the patient will undergo a 1- or 2-stage revision ACL reconstruction. Radiographs (Figures 5A-B), as

![Figure 5: Anteroposterior (A) and lateral (B) radiographs of a knee demonstrating widening of the tibial tunnel in the setting of a failed anterior cruciate ligament reconstruction. Sagittal magnetic resonance imaging demonstrating widening of the tibial tunnel in the setting of a failed anterior cruciate ligament reconstruction (C).](image-url)
Bone grafting can also be used with aperture or suspensory fixation. If there is minimal widening, an intraoperative decision can be made regarding a 1- vs 2-stage revision. In this case of borderline widening (ie, 3-5 mm), 2 interference screws can be stacked to provide adequate aperture fixation, tunnel trajectory can be altered by different femoral drilling techniques (eg, anteromedial portal, outside-in), or a larger graft such as a quadriceps autograft may be used with aperture or suspensory fixation to fill the void of the widened tunnel.13,50,51

Determinants of 1-Stage Versus 2-Stage Anterior Cruciate Ligament Reconstruction

Patients who have properly positioned tunnels, good bone stock, and hardware that can be removed or will not interfere with graft fixation should be considered for a 1-stage revision ACL reconstruction. If the original tunnels are far enough off from the ideal position (ie, vertical graft) that the tunnel and fixation will not interfere with anatomic tunnel placement, a 1-stage revision can also be performed while leaving the existing hardware in place. If the original tunnels are in the proper position but there is a significant amount of widening present either before or after removal of the hardware, these patients may be better served by a 2-staged approach.13,51,52 An absolute threshold for how much tunnel widening and bone loss is acceptable to undergo a single stage with intraoperative bone grafting prior to drilling has not been established. Based on the available evidence, the current authors recommend a 2-stage procedure, with bone grafting at the first stage when there is more than 10 to 15 mm of tunnel widening.13,50,51 If there is minimal widening, an intraoperative decision can be made regarding a 1- vs 2-stage revision. In this case of borderline widening (ie, 3-5 mm), 2 interference screws can be stacked to provide adequate aperture fixation, tunnel trajectory can be altered by different femoral drilling techniques (eg, anteromedial portal, outside-in), or a larger graft such as a quadriceps autograft may be used with aperture or suspensory fixation to fill the void of the widened tunnel.53

Meniscal status, alignment, other ligament status, and presence of high-grade chondral lesions affect decision making for a 1- vs 2-stage revision ACL reconstruction. In an otherwise well-aligned knee where the meniscal, chondral, and other ligament status is clearly defined preoperatively, 1-stage ACL reconstruction may be performed alongside other ligament stabilization, meniscal allograft transplantation, and/or cartilage restoration. If the meniscal, chondral, or other ligament status is unclear or unknown, consideration should be made for a staging diagnostic arthroscopy and planned 2-stage revision approach. Similarly, if the knee is malaligned and the meniscal/chondral/ligamentous status is well known, a 1-stage approach, realignment osteotomy, revision ACL reconstruction, and other concomitant intra-articular procedures, can be considered.

In the malaligned knee, if it is unclear whether there is ACL tunnel widening, meniscal deficiency, other ligament injury, and/or high-grade cartilage lesion, a 2-stage approach should be considered. During the first stage, arthroscopy should be performed with intra-articular synovectomy/lysis of adhesions, evaluation of ACL tunnels with removal of hardware and possible bone grafting, evaluation of ligament and meniscal status, and determination of size and location of cartilage lesions. Following arthroscopy, extra-articular procedures such as realignment osteotomy plus possible other ligament stabilization (eg, posteromedial/posterolateral corner reconstruction) should be performed during the first stage. Once the bone heals and the patient regains full ROM, the second stage should be performed, including revision ACL reconstruction and addressing other intra-articular pathology with meniscal allograft transplantation and/or cartilage procedure as indicated.

Other indications for 2-stage revision ACL reconstruction include arthrofibrosis or active infection. In the setting of arthrofibrosis, the remnant ACL should be evaluated and debrided in its entirety provided it is not synthetic. If it is synthetic, it should be removed whole to avoid creating an inflammatory response, although some authors still remove this graft with a shaver.54 Excessive debridement of the fat pad is avoided to minimize the risk of postoperative hemaarthrosis and further development of arthrofibrosis. The patient may also need manipulation under anesthesia at the time of the first stage, and performing a revision ACL reconstruction at the same time is not recommended.20,51 Bone grafting can also be done during the arthrofibrosis procedure. The patient should be started in an aggressive rehabilitation program to attempt to regain as much ROM as possible prior to revision ACL reconstruction. If a patient has an active infection with failed ACL reconstruction, new hardware should not be implanted, and revision ACL reconstruction would involve 2 stages, with initial washout, debridement, synovectomy, and antibiotics to fully eradicate the infection followed by the second stage of revision ACL reconstruction once the infection has been eradicated.

Surgical Considerations During 2-Stage Reconstruction

Tunnel Bone Grafting

To perform tunnel bone grafting, first remove any hardware that could interfere with future tunnel placement and check each tunnel to ensure there are no cortical breaches. Most screws can be removed with a 3.5-mm screwdriver, but operative reports should be obtained to determine the specific type of screw used in prior procedures so the appropriate equipment can be in the operating room. Screw removal can be difficult, and all soft tissue and bone over the screw heads should be removed to allow the screwdriver to seat properly on the screw to prevent stripping. A nitinol pin is placed in the screw to facilitate screwdriver seating. Screws that are stripped often need to be removed with broken screw–removal kits. Bioabsorbable screws are typically not resorbed.
at the time of revision ACL reconstruction and should be removed with care if present because they can break during removal. Because metal cross-links can be extremely difficult to remove, the authors recommend overdrilling these and removing the entire wedge of bone. Although this creates a somewhat larger defect, the authors’ experience is that this is typically the most effective way to address this situation. The defect will be filled with graft later in the procedure.

Once the hardware has been removed, debride the widened tunnels of any soft tissue and sclerotic bone using a shaver, burr, drill, rasp, and curette. The surgeon should attempt to preserve as much native bone as possible. Bone graft is then impacted into each tunnel. For allograft, a single bone dowel is used that is approximately 1 mm larger than the diameter of the tunnel and placed using a bone tamp for a press-fit technique, ensuring the entire tunnel is filled. The sterilization technique, risks, and cost information for these dowels has been previously described (Figure 6).

Another option for bone grafting the femoral tunnel is to use morselized bone graft, delivered via an enlarged anteromedial arthroscopic portal directly into the bone defect. The authors have found that a 3-mL syringe with the tip cut off or a shoulder arthroscopy cannula can facilitate delivery of graft to the defect while reducing extravasation into the rest of the joint. The tibial tunnel should be packed from outside the joint, with care taken to avoid breaching the joint with the bone graft. The joint is then checked thoroughly to ensure there are no free pieces of graft loose within the knee.

Following bone grafting, the patient should be followed clinically with repeat radiographs and CT approximately 3 to 4 months after the first stage to ensure the bone tunnels have fully consolidated. If the tunnels have not completely incorporated, the patient may need to wait an additional 2 to 3 months before definitive revision ACL reconstruction may be safely performed.

**Revision Anterior Cruciate Ligament Graft Choice**

The ideal graft choice for all revision ACL reconstruction procedures has yet to be elucidated and will often depend on graft used during the primary ACL reconstruction. Studies have shown both significantly lower rerupture rates as well as significantly better outcomes in several validated knee outcome measures in patients undergoing revision ACL reconstruction with autograft compared with allograft. The risk of graft rerupture following revision ACL reconstruction in patients receiving autograft is 2.78 times less likely than in those receiving allograft. For these reasons, the authors prefer using autograft for revision ACL reconstruction when possible. If the index procedure was an allograft or hamstring autograft, consideration is made for revision with ipsilateral bone-tendon-bone autograft. When bone-tendon-bone autograft is not available or when technical considerations may make large-diameter soft tissue graft more desirable,
consideration is made for quadriceps tendon autograft. This viable graft choice has demonstrated good outcomes, with a reported return-to-sport rate of greater than 90% following revision ACL reconstruction with quadriceps tendon autograft. For the quadriceps autograft, this can be taken with or without bone block, depending on surgeon preference and the need to fill any residual bone voids at the tunnel aperture. In some cases, graft preparation for 2-stage revision ACL reconstruction should be delayed until the bone graft tunnels have been assessed, to allow variation in bone plug size if needed. Rarely, the authors consider contralateral bone-tendon-bone autograft, ipsilateral or contralateral hamstring autograft, or allograft as a graft choice in certain situations (eg, ACL revision).

Miscellaneous Technical Pearls

Surgeons need to be prepared with multiple strategies for tunnel preparation and graft fixation in the revision setting. Surgeons should have a low threshold for supplemental fixation on the femoral and especially the tibial side due to weak bone from bone-grafted tunnels or enlarged tunnels. In addition, consideration should be made for alternative femoral and tibial drilling techniques, including outside-in or anteromedial portal techniques, to vary the trajectory of the tunnel from a previously drilled tunnel as necessary. Familiarity with and use of all-inside femoral and tibial sockets with cortical suspensory fixation may be necessary when aperture fixation is not possible or desirable. Finally, in revision ACL surgery, arthroscopic landmarks are often difficult to identify; therefore, intraoperative fluoroscopy can be used to assist in identifying tunnel position before drilling.

Surgical Outcomes of 2-Stage Anterior Cruciate Ligament Reconstruction

It is an accepted fact that outcomes from revision ACL reconstruction are inferior to those from primary ACL reconstruction. Carson et al reported 43 patients who underwent a 1-stage revision ACL reconstruction, 93% of whom had a concomitant procedure at the time of revision ACL reconstruction. They found that at 2 years postoperatively, 86% had a negative pivot shift and a grade 0 or 1 Lachman, 63% had good or excellent results on the Hospital for Special Surgery (HSS) knee rating system, and 74% returned to athletic activity at the preoperative level or with some limitations. Diamantopoulos et al reviewed 107 revision ACLRs, 6 of which were 2-stage procedures. At 73 months, a significant improvement in Lysholm (88.5±12.4 vs 51.5±24.9; \( P<.001 \)) and Tegner scores (6.3±1.8 vs 2.8±1.8; \( P<.001 \)) was seen, but most patients did not achieve their preinjury activity level. The authors did not stratify their results by whether the patient underwent a 1- or 2-stage procedure.

There are fewer studies reporting the outcomes of 2-stage revision ACL reconstruction alone. Franceschi et al evaluated 30 patients who underwent 2-stage revision ACL reconstruction after a traumatic rupture of their ACL. All patients in the study underwent hardware removal and filling of the tunnels (which measured, on average, 10.4 mm in diameter and 26.4 mm in length) with autograft harvested from the tibial metaphysis. The second stage of the revision ACL reconstruction was performed a minimum of 3 months later, after obtaining CT demonstrating adequate fill of the tunnels using hamstring autograft through a transtibial drilling technique. At 5 years postoperatively, 86.7% of patients had full extension, 90% had less than a 5° difference in flexion compared with the contralateral knee, 66.7% returned to preinjury sport activity level, and there was a significant improvement in Lysholm score when comparing pre- and postoperative values.

Thomas et al reported the results of 49 consecutive 2-stage revision ACL reconstructions in which the hardware was removed and the tibial tunnel grafted during the first stage, followed by an ACL reconstruction using various grafts and fixation methods for the second stage. This group was then compared with a group of patients who underwent a primary ACL reconstruction. The 2-stage group contained significantly more patients with meniscal and chondral pathology compared with the primary ACL reconstruction group. At a mean follow-up of 6 years, there was an improvement in International Knee Documentation Committee scores for both groups, with higher scores seen in the primary ACL reconstruction group. However, the objective laxity measurements of the graft were not significantly different between groups. The authors had a subset of 8 patients who received 1-stage revision ACL reconstruction, but data from these patients were not included in this study.

**Return to Activity After 2-Stage Revision Anterior Cruciate Ligament Reconstruction**

Several studies have confirmed the success of returning athletes, both recreational and elite, to sport after primary ACL reconstruction. However, revision ACL reconstruction is a different scenario for the patient and physician. The patient must understand going in to the procedure that revision ACL reconstruction is a salvage operation, with the goal of obtaining a functional stable knee for activities of daily living. The return-to-sport rate is lower than in primary ACL reconstruction, with studies citing a 62% to 74% rate of return to sport in revision ACL reconstruction, with high school and college athletes achieving a higher return-to-sport rate (74%) than recreational athletes (62%). Patients must understand their time to return to sport may be longer after revision ACL reconstruction and will depend on their ability to regain symmetric strength compared with the contralateral leg and to complete a series of sport-specific tests. The physician must ensure...
the patient has a proper understanding of this to avoid a feeling of failure if return to sport is not obtained, despite obtaining a stable knee and improved quality of life.

**CONCLUSION**

Failure of primary ACL reconstruction presents a unique set of challenges, including technical considerations and concomitant knee pathology that must be addressed at the time of revision surgery. Two-stage revision ACL reconstruction should be considered in cases of ACL tunnel widening, arthrofibrosis, or infection, or in cases with concomitant knee malalignment, meniscal deficiency, chondral lesions, and/or other ligament instability.

Two-stage revision ACL reconstruction carries a more guarded prognosis than primary ACL reconstruction. However, careful preoperative planning, meticulous surgical technique, patient-specific postoperative rehabilitation, and realistic patient expectations may increase the chance of a good result in this challenging patient population.

**References**


31. Chen JL, Allen CR, Stephens TE, et al. Differences in mechanisms of failure, intraop-


