Chapter 27

Failed Cartilage Repair

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The management of traumatic and degenerative cartilage lesions is a known challenge given the limited vascularity and lack of pluripotent cells that contribute to the tissue's inherently poor regenerative capacity. Many surgical techniques have been described in an effort to palliate symptoms, promote substitute tissue growth, and/or restore normal hyaline cartilage. Surgical failure of these techniques, however, may occur when the patient experiences incomplete or recurrent symptoms, or an inability to return to his or her desired activity level. Unfortunately, when all techniques are considered in aggregate, there remains a clinical failure rate that approaches 25% in most series. Technical error, graft dislodgment, graft resorption, and the failure to recognize concomitant injury leading to premature graft destruction are common causes for surgical failure. Successful revision articular cartilage repair requires a thorough evaluation of comorbid conditions such as ligament instability, malalignment, and meniscal deficiency. These complications, left untreated, can have a detrimental effect on the cartilage repair procedure because of abnormal shear stress, increased contact pressure, and decreased contact area.

Clinical Evaluation

History

Articular cartilage injuries may be caused by a direct trauma associated with impact or an indirect injury usually involving a twisting or shearing movement associated with an axial load. Patients with a history of a previous cartilage repair procedure may not describe their additional symptoms as a new injury to the knee. However, a thorough discussion about the patient's additional symptoms such as mechanical clicking, locking, or instability may help discern whether an associated pathology may have contributed to cartilage failure.

Similar to patients with a primary focal cartilage defect, pain is most often the patient's chief complaint, which is aggravated by certain positions or activities. Pain at the ipsilateral joint line is often associated with a condylar injury and can be aggravated by weight-bearing activities. Joint line pain caused by meniscal deficiency may be difficult to discern from a focal cartilage defect. However, a previous history of meniscectomy may heighten the surgeon's awareness to the possibility of meniscal deficiency causing or contributing to continued symptoms. Patients presenting with pain in the anterior compartment of the knee may be suffering from a trochlear or patellar lesion, which can be aggravated by activities that increase patellofemoral contact pressure, such as stair climbing or squatting. In addition to pain, patients may also report activity-related effusions in the knee.

Prior attempts at treatment should be reviewed with the patient. If prior surgeries have been performed, the timing and type of surgery, type of rehabilitation that followed, and whether the patient experienced a period of symptomatic relief postoperatively should be thoroughly discussed preoperatively. In addition, nonsurgical management such as oral medications, injections, bracing, physical therapy, and lifestyle modification should also be discussed as an important part of the patient's prior treatment.

Physical Examination

The physical examination of a patient with a symptomatic cartilage lesion begins with observation of the patient's gait and body habitus. Gait evaluation may reveal any antalgia caused by pain or weakness, malalignment or a varus or valgus thrust associated with ligament insufficiency or clinical malalignment. The physician should also observe and measure any associated quadriceps atrophy and effusions, and determine the location of any previous surgical incisions.

Palpation of bony and soft tissue structures about the knee may provide some insight into the location of the patient's symptoms, associated conditions such as meniscal deficiency, or presence of a subtle effusion. Patients with chondral injuries of the condyle typically present with ipsilateral joint line tenderness. Meniscal injury or deficiency may also present similarly to condylar pain with joint line tenderness; however, the pain is usually appreciated more posteriorly. Patellofemoral lesions may have pain and crepitus in the anterior compartment. Patellar tilt and glide should be evaluated for tightness of the lateral retinaculum and potential patellar instability. Finally, range of motion should be assessed in both knees, noting limitation in range and/or flexion contractures.

Identification of associated pathology is critical to the successful outcome of revision and complex articular cartilage restoration. As noted, persistent instability, malalignment, or meniscal deficiency is often a cause of premature failure of articular cartilage repairs and poor outcomes. Stability of the anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL), as well as the lateral collateral ligament (LCL) and posterolateral complex, should be a routine part of any knee examination.

Imaging

Standard radiographs for cartilage injury should include bilateral knees in at least three views: anteroposterior (AP) weight-bearing view; non–weight-bearing, 45-degree flexion lateral view; and axial (Merchant) view of the patellofemoral joint. Additional views include a 45-degree flexion posteroanterior (PA) view, which may be useful to identify subtle joint space narrowing. A full-length alignment view of the affected and unaffected limb may help evaluate the mechanical axis and associated varus or valgus malalignment (Fig. 27-1). A computed tomography (CT) scan may be useful to

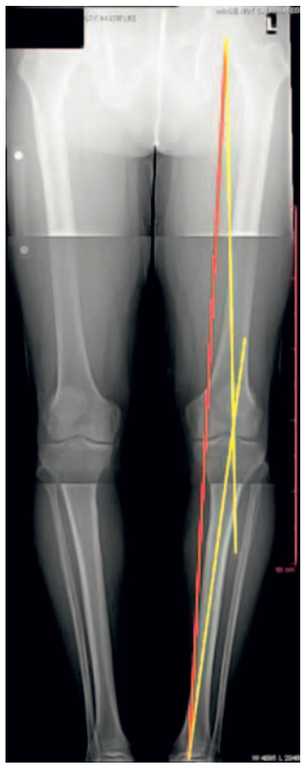

Figure 27-1. Standing long-leg alignment x-rays. The mechanical axis of the extremity is represented by the red line from the center of the femoral head to the center of the talus. This patient has an obvious varus deformity to the lower extremity. The desired correction for this patient is just beyond neutral. This angle is calculated by a line drawn from the center of the femoral head to the desired correction level at the joint line and a second line from the center of the talus to the same correction point at the joint line *(yellow).*

assess the patellofemoral joint and the associated tibial tubercle–trochlear groove (TT-TG) distance.[1,13] This measurement is particularly useful in patients with patellar instability when associated with chondrosis. Magnetic resonance imaging (MRI) scans are often used in the preoperative assessment of previously failed cartilage repair procedure. They provide a detailed assessment of lesion size, depth, quality of subchondral bone, and presence or absence of bony fractures. MRI may also confirm the presence of associated ligamentous, meniscal, or other soft tissue pathology.

Treatment

The appropriate treatment of a specific cartilage lesion is individualized to each patient and special considerations should be given to their postoperative goals and expectations. The overall goal of surgical intervention is to improve joint congruency, eliminate instability, and protect the repaired cartilage.

Nonoperative Treatment

Nonoperative therapies play a role for patients with previous cartilage repair surgery. Patients with unreasonable expectations or goals, failed multiple procedures, advanced physiologic age with low demand, or unwilling to have further surgery may be amenable to these conservative modalities. These therapies include oral medications, physical therapy, weight loss, and injections (cortisone and hyaluronic acid derivatives). Oral medications such as nonsteroidal anti-inflammatory drugs and oral chondroprotective agents (e.g., glucosamine, chondroitin sulfate) are commonly used in symptomatic patients. Although the precise mechanism of action of these medications has not been elucidated, it has been hypothesized that glucosamine stimulates chondrocytes and synoviocytes to increase production of extracellular matrix, whereas chondroitin manages to inhibit fibrin clot formation and degradative enzymes.[2]

Cortisone injections are commonly used in practice for short-term pain relief because of the anti-inflammatory action of the steroids. Similarly, intra-articular injections containing hyaluronic acid provides viscosupplementation, resulting in significant pain reduction and improved function.[5,7,12,14]

Operative Treatment

Surgical managements of articular cartilage lesions can be grouped into three categories:

1. Palliative procedures, which include arthroscopic débridement and lavage to provide symptomatic relief to patients with little potential for cartilage regeneration
2. Reparative procedures, which include marrow stimulation techniques that create a pluripotent fibrin clot, ultimately resulting in fibrocartilage replacement
3. Restorative procedures, which attempt to restore the natural hyaline surface of articular cartilage using cultured chondrocytes or an osteochondral graft

The appropriate treatment for any given cartilage lesion is patient- and defect-specific. Lesion-specific variables include lesion size, location, depth, geometry, and bone quality; patient-specific variables include the patient's physiologic age, activity level, goals and expectations, and previous surgeries. Consideration of these variables and the associated comorbid conditions allow the management of cartilage lesions to be considered as part of an algorithm from the least invasive to the most invasive intervention (Fig. 27-2). The overall goal is to restore the patient's function and ameliorate symptoms using the least invasive technique. In the setting of a revision procedure, the least invasive procedure can often be exhausted, with undesirable outcomes requiring the surgeon to consider more invasive techniques for cartilage restoration while also addressing the reasons for primary failure, as noted earlier.

Palliative Procedures

Arthroscopic débridement and lavage are usually performed as a first-line treatment and considered for patients suffering from an acute injury causing pain and incongruency caused by a dislodged piece of cartilage (<2 cm^2). Simple irrigation to remove debris, inflammatory cytokines, and proteases may help alleviate the patient's symptoms. In a revision setting, an arthroscopic débridement may temporarily alleviate the patient's symptoms and may also be used as a diagnostic tool to assess cartilage abnormalities and concomitant pathology. This may be especially true in the setting of previous autologous chondrocyte implantation (ACI) with resultant graft

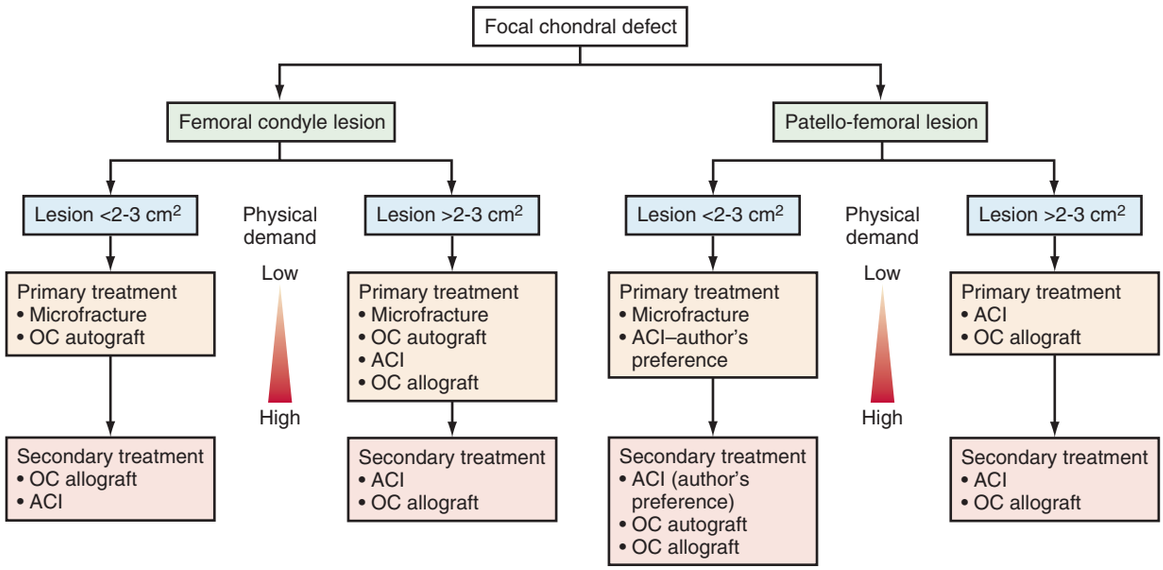

Figure 27-2. Algorithm used to guide decision making for primary and revision articular cartilage repair.

hypertrophy,[4] graft resorption with loose bodies, or advanced joint degeneration.

Reparative Procedure

Small to medium-sized (2 to 3 cm^2), full-thickness chondral defects can be managed using marrow stimulation techniques, such as microfracture, subchondral drilling and abrasion arthroplasty. Microfracture involves the use of a surgical awl on the subchondral bone to allow migration of marrow elements (mesenchymal cells). This migration results in the formation of a surgically induced fibrin clot at the defect site and the production of fibrocartilage. The newly formed repair tissue possesses a preponderance of types I and II collagen,[11] rendering it biologically and mechanically inferior to hyaline cartilage. This is especially helpful when prior procedures have been only partially successful in creating a complete defect repair (Fig. 27-3).

Restorative Procedures

Larger lesions and/or previously failed reparative procedures are often managed with restorative procedures. Restorative procedures include autologous chondrocyte implantation (ACI), osteoarticular autograft transplantation (OAT), and osteochondral allograft (OA) transplantation.

ACI is a two-stage procedure, with the first involving an arthroscopic biopsy of normal articular cartilage from a non–weight-bearing area. The biopsy tissue is used for in vitro dedifferentiation and culture of chondrocytes. The second step involves the implantation of the cultured cells with the off-label use of a synthetic collagen membrane patch to hold the cells in place.[4] The senior author soaks the membrane with a vial of cells prior to suturing rather than using saline. These cultured dedifferentiated cells produce a hyaline-like cartilage with superior biomechanical properties when compared with fibrocartilage. ACI is indicated for large defects measuring 2 to 10 cm^2, with limited bone loss, and may be used as a revision procedure for a previous palliative or reparative procedure. However, some concerns regarding the use of ACI as a revision procedure following microfracture have recently been raised, especially when the subchondral bone is highly involved, as seen by MRI.[9]

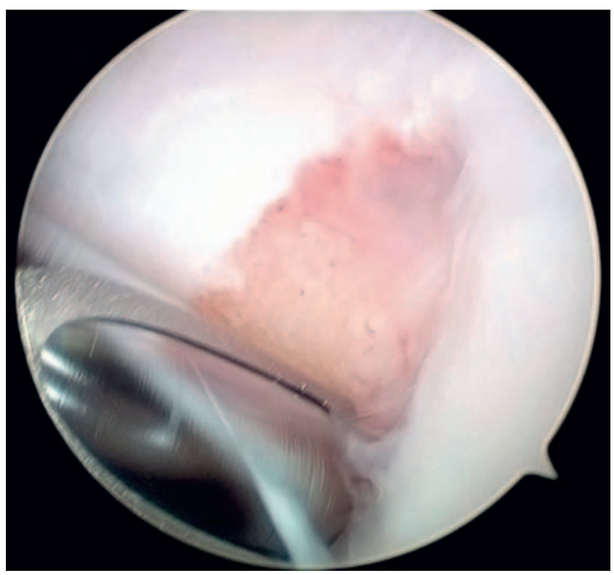

Figure 27-3. Second-look arthroscopy of a trochlear defect previously treated by ACI, with partial delamination of the repair site being prepared for microfracture.

Lesions that present with subchondral bone loss are more commonly treated using osteochondral grafting. The source of the cylindric plug can be from the host (autograft) or from a cadaveric donor (allograft).

OAT is advantageous by virtue of using the patient's own tissue, eliminating immunologic concerns. Harvested tissue from non–weight-bearing regions are transplanted to the areas of defect, resulting in the replacement of the damaged articular cartilage. The OAT procedure is indicated for

symptomatic patients presenting with full-thickness defects and can be used as first-line treatment for a high-demand patient or as a revision to a previously performed microfracture or even ACI, assuming that the defect is small enough. This technique is indicated for smaller defects (<2 cm^2) because of limited supply of donor tissue as well as donor site morbidity.

Larger defects require the use of an OA graft in many cases. An OA graft involves transplantation of cadaveric mature hyaline cartilage with living chondrocytes and subchondral bone matrix to enhance osteointegration. In general, an OA graft is used as a secondary revision procedure and is considered the last biologic procedure before a total knee replacement.

Revision Procedures

Patients in the setting of revision articular cartilage surgery who have previously undergone and failed a simpler palliative or reparative procedure require the operating surgeon to consider more aggressive management techniques to achieve the goals.

As noted, a firm understanding of the reason(s) for failure is crucial before a revision procedure is performed to ensure prevention of further complications. Often, a comorbid condition, such as malalignment, instability, or meniscal deficiency, can lead to a premature degradation of the surgically induced replacement tissue. A diagnostic arthroscopy is often required to evaluate the extent of these comorbid conditions as well as to determine the integrity of the cartilage lesion and subchondral bone. In addition, not uncommonly, cartilage deterioration might have continued locally, adjacent to the initially treated cartilage defect, or might have developed in new locations or on opposing surfaces.

Cartilage or Meniscus Deficiency with Malalignment

A focal cartilage defect in association with meniscal deficiency and/or with varus or valgus alignment can be managed simultaneously or in stages. Focal cartilage defects previously treated with a reparative technique can be followed by a restorative technique, such as with ACI, OAT, or OA grafting, depending on the location of defect. In the presence of varus or valgus alignment, a high tibial osteotomy (Fig. 27-4) or a distal femoral osteotomy (Fig. 27-5) can be performed simultaneously with the revision articular cartilage procedure, especially in young and active patients. Older, less active patients with lower physical demands may benefit from a staged procedure. An osteotomy is performed first in an effort to offload the symptomatic compartment, followed by a period of observation. If patients present with satisfactory symptomatic relief, an additional restorative cartilage procedure may not be warranted. In the case of cartilage preservation, an osteotomy should be performed to correct the mechanical axis to neutral; however, in the setting of pain and arthrosis, the osteotomy should be corrected slightly beyond neutral. Patellofemoral lesions are most often treated with a distal realignment procedure of the tibial tubercle to decrease the contact pressure of the patellofemoral joint with the cartilage procedure. The degree of anteriorization versus medialization can be titrated based on the patient's history of instability, maltracking (TT-TG distance), or arthrosis (Fig. 27-6).

Figure 27-4. A high tibial osteotomy has been performed to correct the mechanical axis in this patient with medial knee pain and varus deformity.

Cartilage or Meniscus Deficiency with Ligament Deficiency

Cartilage lesions or meniscal deficiency with instability caused by ACL deficiency (Fig. 27-7) can be managed with an ACL reconstruction and a concomitant cartilage restoration or meniscal transplantation procedure, with an overall goal of restoring joint kinematics. Previously failed ACL reconstruction with bony tunnel expansion is often managed with a staged bone-grafting procedure. After successful grafting, an ACL reconstruction can follow simultaneously with the appropriate cartilage restorative procedure. Allografts are most commonly used for the ACL reconstruction in this setting.

Cartilage or Meniscus Deficiency With Malalignment and Ligament Deficiency

The most difficult clinical challenge is the patient who presents with focal cartilage lesions, compartment malalignment, and instability caused by ligament deficiency. Joint restorative efforts in such patients often require multiple procedures; with an ideal sequence of procedure considered on a case by case basis after thorough assessment of the patient's symptoms and postoperative goals and expectations. Patients with pain as their primary symptom may be managed with a corrective osteotomy to unload the affected compartment. However, if instability is described as the chief complaint, a ligament reconstruction should be considered as first-line surgery. In rare cases, patients present with both pain and instability, and these should be managed in a staged

Figure 27-5. Distal femoral osteotomy in this patient with obvious lateral compartment arthrosis and valgus malalignment is performed in an effort to offload the affected lateral compartment and relieve the patient's symptoms.

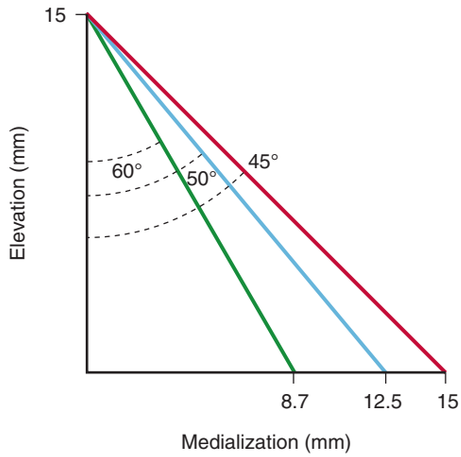

Figure 27-6. The amount of medialization may be adjusted by the angle of the osteotomy and degree of elevation. For a standard elevation of approximately 15 mm, the degree of medialization increases from 8.7 mm for a 60-degree cut relative to the anterior tibia to 15 mm for a 45-degree cut, as shown here. The amount of medialization may be titrated based on factors such as the patient's history of instability versus arthrosis.

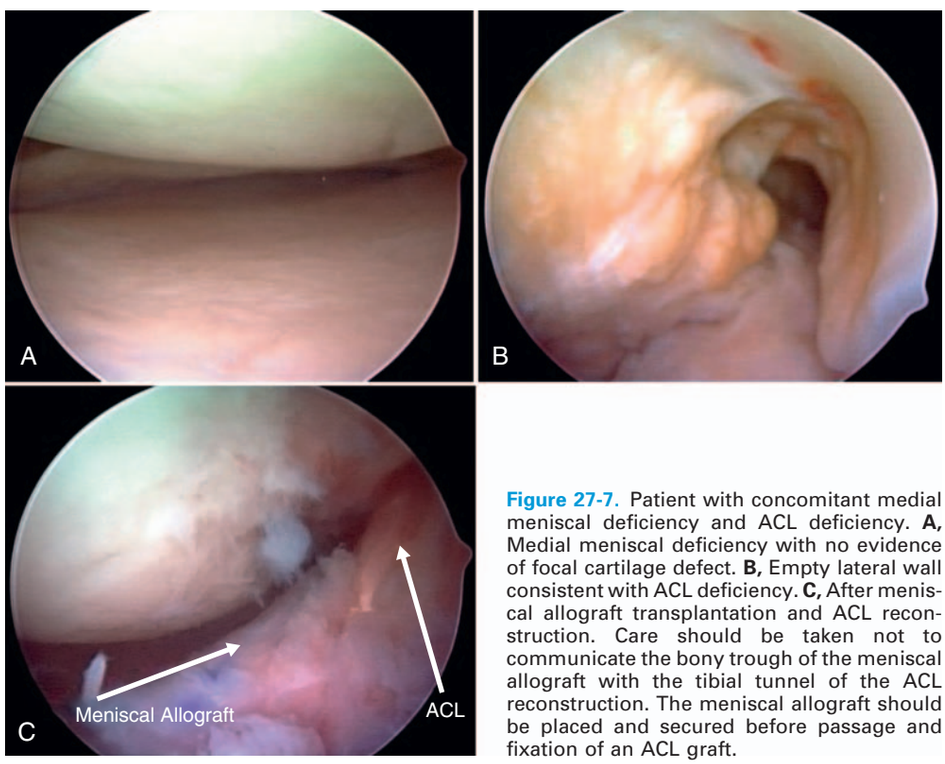

Figure 27-7. Patient with concomitant medial meniscal deficiency and ACL deficiency. **A,** Medial meniscal deficiency with no evidence of focal cartilage defect. **B,** Empty lateral wall consistent with ACL deficiency. **C,** After meniscal allograft transplantation and ACL reconstruction. Care should be taken not to communicate the bony trough of the meniscal allograft with the tibial tunnel of the ACL reconstruction. The meniscal allograft should be placed and secured before passage and fixation of an ACL graft.

algorithm, with ACL reconstruction first followed by restoration of alignment and cartilage resurfacing.

Additional Situations

Patients with a known ACL deficiency and malalignment may be managed with an ACL reconstruction alone, osteotomy alone, or as a combined procedure. The decision is again guided by the patient's symptoms, goals, and expectations. If a high tibial osteotomy is to be performed in isolation, the surgeon may consider a biplanar osteotomy whereby the varus alignment is addressed with an opening wedge medially; however, the ACL deficiency may be managed by simultaneously decreasing the tibial slope with the osteotomy cut. Alternatively, patients who are PCL-deficient with concomitant malalignment may have their tibial slope increased with an anterior-based opening wedge osteotomy to aid in reduced posterior tibial translation.

Finally, perhaps the most common scenario is the patient with a known focal cartilage defect and a history of previous meniscectomy who now has persistent joint line pain. As discussed earlier, it can often be difficult to discern whether the source of pain is the cartilage lesion or the loss of meniscal tissue. These patients are then managed with a concomitant meniscal transplantation and cartilage restorative procedure. They have generally been treated with a previous primary cartilage procedure, such as marrow stimulation or débridement, and are often revised with an osteochondral allograft in addition to the meniscal transplantation as a salvage procedure (Fig. 27-8).

Preferred Treatment

Revision procedures isolated to the femoral condyle, with no additional copathology (e.g., malalignment, instability, meniscal deficiency), are generally treated with an OA graft after a failed marrow stimulation technique or débridement. Alternatively, a failed microfracture procedure for smaller lesions can be managed with an OAT procedure. Cartilage lesions on the patella or trochlea are treated with ACI and a simultaneous anteromedialization of the tibial tubercle after a failed primary treatment. In the presence of a concomitant pathology, surgical procedures are addressed in a staged

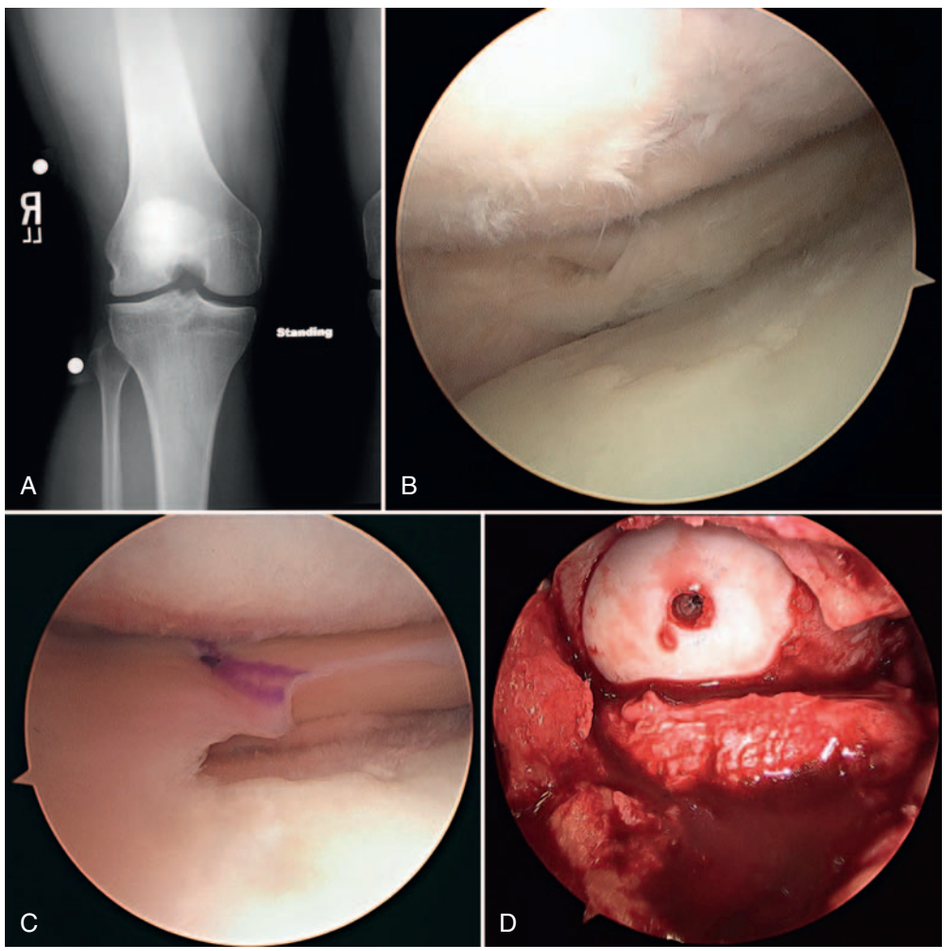

Figure 27-8. Patient with a combined meniscal deficiency and focal cartilage defect on the lateral side. **A,** Preoperative standing radiograph showing minimal evidence of joint space narrowing. **B,** Arthroscopic image of lateral compartment showing evidence of loss of meniscal tissue of the lateral compartment and a focal cartilage defect of the lateral femoral condyle. **C,** Arthroscopic image after placement of lateral meniscal allograft. **D,** Osteochondral allograft placed through a lateral parapatellar arthrotomy to restore articular cartilage architecture and surface congruence.

fashion or in combination with a revision cartilage procedure, as outlined earlier. Failed ACI of the patellofemoral (PF) joint are also revised with an OA graft.

Rehabilitation

Rehabilitation protocols vary according to the procedure(s) performed. In general, patients are place in a hinged knee brace postoperatively and advised to use a continuous passive motion machine for 4 to 6 weeks for up to 6 hours/day. Patients who have a revision procedure on the femoral condyle or required an osteotomy with their revision procedure are protected with partial weight bearing and often use a postoperative hinged unloader brace (TROM Adjuster, DonJoy, Carlsbad, Calif). Rehabilitation of a revision procedure performed on the PF compartment allows for weight bearing as tolerated, with a knee brace locked in extension, as long as the tibial tuberosity is not performed at the time, which would also require a period of protected weight bearing. The goals of early rehabilitation are increased range of motion, patellar mobilization, quadriceps sets, isometrics, and proximal core strengthening. Six to 12 weeks postoperatively, patients begin to focus on a functional strengthening program. At about 3 months postoperatively, patients are advanced to muscular endurance with progressive running activities, advanced closed-chain strengthening, and plyometrics.

Conclusions

The variable algorithm and concomitant procedures often performed in revision cartilage restoration result in less predictable patient outcomes when compared with primary procedures. Minas and colleagues,[9] in a cohort study, evaluated outcomes of 321 patients (325 joints) who underwent an ACI. Of the 325 joints, 214 joints had no prior treatment affecting the subchondral bone whereas 111 joints had undergone a marrow stimulation procedure penetrating subchondral bone. Of the 214 joints with no prior treatment, 17 joints (8%) failed their restorative procedures. Revision procedures on the remaining 111 joints reported failure of 29 joints (26%), a rate three times that of the nontreated defects. Another group, in a prospective multicenter cohort study, evaluated 154 patients undergoing ACI as a revision after a failed previous marrow stimulation or débridement. Zaslav and associates[15] reported a success rate of 76% in these patients, with no statistical difference in outcome between patient groups at an average postoperative time of 48 months. There was a high reoperation rate noted at 49%; of this, 40% was related to the ACI procedure, including graft hypertrophy caused by periosteal patch use. Graft hypertrophy is believed to be less of an issue with the use of newer synthetic patches.[4]

Osteochondral allografting performed as a revision because of a failed primary or revision procedure has been described. McCulloch and coworkers[8] evaluated outcomes of 25 patients who underwent fresh OA of the femoral condyle. Of these patients, 25 had undergone at least one previous surgical treatment, including débridement and lavage, microfracture, or ACI. Thirteen patients underwent a concomitant procedure for malalignment (osteotomy), instability (ligament reconstruction), or meniscal transplantation. Patients overall reported an 84% satisfaction with their surgical procedure, with no significant outcome difference between an isolated and combination OA grafting procedure. A similarly study conducted by LaPrade and associates[6] evaluated a group of 23 patients, of whom 20 had undergone a prior surgery and reported significant improvement in the International Knee Documentation Committee (IKDC) and Cincinnati outcomes.

Rue and coworkers,[10] in a prospective study, evaluated a group of 30 patients who underwent 31 combined meniscal transplantation and cartilage restoration procedures. Of these 31 procedures, 16 were an ACI and 15 were an OA graft; the patients were followed up for a minimum of 2 years. Of these, 28 patients reported an overall satisfaction of 76%, and 48% scored as normal or near-normal for functional outcome using IKDC at 2 years of follow-up. On rare occasions, a patient will present with articular lesions, meniscal deficiency, and malalignment. Gomoll and colleagues[3] evaluated 7 patients at an average of 2 years. They reported that 6 of 7 patients were able to return to their previous level of activity and demonstrated statistically significant improvement in outcome measures, with the exception of knee injury and osteoarthritis outcome score (KOOS) for pain ($P = .053$), KOOS symptoms ($P = .225$), and Short Form Health Survey SF-12 score ($P = .462$).

Revision articular restoration procedures remain a challenge for the operating surgeon. The goals of these procedures are to preserve joint function, improve congruity, and alleviate symptoms, thereby allowing patients to return to their desired level of activity. Treatment is guided by a thorough history and examination, discussion of the desired postoperative expectations, and consideration of the reason(s) for the failure of the primary cartilage procedure to avoid recurrence. Previous literature reports serve as a guide for expected outcomes; however, extreme caution should be taken when counseling this patient group because there are many confounding variables that may positively or negatively affect outcomes following revision procedures.

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