Chapter 53

Overview and Indications for Articular Cartilage Restoration

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Introduction

The treatment of articular cartilage lesions in the knee remains a challenge. Studies have shown that up to 66% of knees have a chondral lesion at the time of arthroscopy, but many of these lesions are partial-thickness injuries, and they are generally asymptomatic. The natural history of these chondral lesions is largely unknown. Clinical experience suggests that, because of the poor vascular supply in articular cartilage and its limited capacity for repair, chondral lesions are likely to deteriorate with time and can progress to a symptomatic joint condition. Early intervention for symptomatic chondral defects often is recommended to restore force distribution and joint congruity and, most important, to reduce pain and improve function.

The goals of surgical intervention are to improve symptoms and restore joint function, thereby allowing patients to return to their desired activity level. To select the most appropriate surgery to meet these goals, each case should be considered on an individual basis through careful consideration of the patient's history, physical examination, copathologies, activity level, and expectations.

Preoperative Evaluation

History

The decision to treat a chondral lesion begins with a thorough discussion with the patient about the dysfunction in the affected knee. The clinical presentation of chondral defects is highly variable, from asymptomatic with minimal limitations to significant pain, swelling, and functional disability.

As in any evaluation, patients should be asked about the location and quality of the pain, as well as activities that provoke or improve symptoms. Reports of achy discomfort, effusions, mechanical symptoms, or pain with weight bearing suggest a symptomatic chondral defect. Pain with prolonged sitting, stair climbing, or kneeling suggests a cartilage defect on the patella or femoral trochlea. Discomfort that is localized to the medial or lateral joint line is more suggestive of a chondral lesion on the femoral condyle or tibial plateau. The patient's clinical response to previous nonsurgical interventions, including nonsteroidal anti-inflammatory drugs (NSAIDs), physical therapy, and intra-articular corticosteroid or visco-supplementation injections, should be assessed. Any previous surgery must be reviewed thoroughly, including surgical findings documented in surgical notes or intraoperative photographs. Noting the time from surgery and any symptomatic relief gained from the procedure helps determine the subsequent surgical procedures, which may differ from the index treatment. The choice of additional surgical intervention often can be affected significantly by the type of surgery that previously was done and the findings of that surgery.

Finally, a realistic and comprehensive understanding of the patient's desired activity level and expectations is critical to any decision to treat a symptomatic chondral defect.

Physical Examination

Physical examination should begin with an evaluation of the patient's gait.

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Figure 1 AP view of a left knee in a skeletally immature patient. Note the lucency in the bone on the lateral side of the medial condyle, which is consistent with an OCD lesion.

Information about limb-length discrepancy, alignment, varus or valgus thrust, and any associated muscular weaknesses or avoidance patterns (eg, Trendelenburg, foot drop, quadriceps avoidance) can be appreciated by watching the patient walk. General inspection of the affected limb should include evaluation of alignment and the location of any previous incisions. Any muscle atrophy or swelling should be assessed and compared with the unaffected extremity. Palpation of the knee can locate the specific area of pain and any associated warmth or effusion. The specific location of the pain may help to localize the area of the cartilage defect. For example, patients with classic osteochondritis dissecans (OCD) may experience tenderness on the anteromedial aspect of the knee. Patients with femoral condylar defects may experience tenderness over the defect on the medial or lateral side of the knee. This tenderness is best appreciated with the knee in flexion. In addition to chondral injury with joint line or condylar tenderness, the possibility of associated meniscal

Figure 2 Full-length weight-bearing AP radiograph of a patient with varus alignment of the knee. The red line extends from the center of the hip to the center of the ankle and is consistent with the weight-bearing axis of the knee joint. Normally, this line should pass near the center of the knee. In varus malalignment, the center passes thought the medial compartment. The yellow lines indicate the degree of correction required with a high tibial osteotomy to restore neutral alignment and protect the medial joint should cartilage restoration procedures be indicated.

pathology should be considered. Meniscal tenderness, however, typically is more posterior along the joint line than tenderness associated with cartilage defects. Range of motion should be assessed by extending and flexing the knee as far as possible. (Normal range of motion is 1° to 2° of extension and 125° to 135° of flexion.) Special tests can be used to evaluate for associated pathologies such as ligamentous insufficiency or concomitant meniscal deficiency. Evaluation and management of these associated pathologies is essential to restore normal joint kinematics and improve the likelihood of successful surgical intervention.

Imaging Studies

Plain radiographs and MRI are the most useful investigations in the assessment of chondral lesions and associated pathologies. Plain radiographs, including bilateral weight-bearing AP, non–weight-bearing lateral, bilateral weight-bearing PA in 45° of flexion, and sunrise views, are obtained in all patients with a suspected cartilage lesion, because each projection provides specific information. The AP and notch views are useful in evaluating for the presence of joint space narrowing, osteophyte formation, and involvement of more than one compartment. Chondral defects can be seen on some views if the lesion is deep enough to compromise the underlying bone, such as an OCD lesion. The notch view may be particularly helpful in evaluating for a suspected OCD lesion because these lesions tend to be in the posterolateral aspect of the medial femoral condyle (**Figure 1**). The sunrise view is useful in evaluating the position of the patella within the trochlear groove (lateral tilt) as well as the integrity of the patellofemoral joint (joint space narrowing) in knees with suspected patellofemoral lesions that may require a tibial tubercle osteotomy. Finally, all views should be reviewed for an associated loose body in the knee joint.

Malalignment should be assessed radiographically with weight-bearing full-length AP radiographs (**Figure 2**). Failure to correct malalignment has been implicated in the failure of cartilage restoration procedures. Varus alignment causes the load-bearing axis to shift to the inside, causing increased load on the medial compart-

ment of the knee. For knees with medial compartment lesions, high tibial osteotomy should be considered to "off load" the medial knee after the cartilage restoration procedure. Alternatively, valgus alignment shifts the load bearing axis to the lateral knee. Valgus malalignment can be corrected to a neutral alignment with a distal femoral osteotomy. To analyze load distribution, a line is drawn from the center of the hip to the center of the ankle on the full-length weight-bearing radiographs (**Figure 2**). The point of intersection at the joint line is the weight-bearing axis of the extremity. In normally aligned limbs, the weight-bearing axis should pass approximately through the center of the knee joint. To determine the degree of correction necessary to achieve neutral alignment, a line is drawn from the center of the hip to the desired point of weight-bearing on the joint line. A second line is drawn from the center of the tibiotalar joint to the same point on the joint line. The angle subtended by these two lines is the required degree of correction to achieve neutral alignment (**Figure 2**).

MRI with or without contrast enhancement will provide additional information about the extent and position of articular cartilage disease. T1- and T2-weighted, 3D, and spoiled gradient-echo (SPGR) images have been reported to be very sensitive in detecting articular cartilage defects. A new technique, delayed gadolinium-enhanced **MRI** of cartilage (**dGEMRIC**), can evaluate the glycosaminoglycan (GAG) content within the cartilage, which may have implications for longitudinal evaluations of the injured cartilage. MRI also can evaluate the location, number, size, and depth of the defects and the condition of the subchondral bone and the surrounding and opposing surface cartilage (**Figure 3**). Associated pathologies of the meniscus, ligaments, and other anatomic structures can be analyzed to substantiate the physical examination and history.

Diagnostic Arthroscopy

Diagnostic arthroscopic examination can be used in selected patients to obtain additional information for the decision-making process, including a definitive diagnosis, the extent of associated pathologies, and the condition of the opposing cartilage surface. In some patients, arthroscopic lavage or débridement can be used as palliative treatment. If autologous chondrocyte implantation (ACI) is thought to be an appropriate treatment, a biopsy sample also can be taken at the time of arthroscopy. At the time of this writing, a biopsy sample can be cryopreserved for up to 2 years.

Patients with a history of previous surgical intervention may require a diagnostic arthroscopic examination if arthroscopic images are unavailable to assess the integrity of the cartilage lesion and supporting structures, or if enough time has passed since the surgery that the chondral defect may have changed or new injuries may have occurred. During arthroscopy, care should be taken to assess the location, depth, size, and degree of containment of the chondral defect to determine the appropriate treatment. The zone of damaged cartilage often extends well beyond the most visible aspects of the chondral defect, which must be considered in the context of surgical decision-making.

Decision-Making Principles

The appropriate management of articular cartilage lesions in the knee should focus on patient-specific and lesion-specific variables, which individualizes treatment and avoids "linear thinking." Several potential causes of knee pain exist and many chondral

Figure 3 T1-weighted coronal MRI of a chondral defect of the medial femoral condyle. The size, depth, and location of the chondral lesion can be evaluated more accurately with MRI than with radiographs. Additional information may be gained about any associated pathology (ligamentous or meniscal deficiency) and the quality of the bone underlying the chondral lesion. This lesion is well-contained and solitary, with associated bony edema under the lesion.

defects are well tolerated and not associated with any symptoms. Thus, careful consideration of alternative sources of knee pain is important.

Patient-Specific Factors

A patient's chronologic age often is cited as a relative indication or contraindication to nonarthroplasty solutions for cartilage injury. It is the patient's physiologic age, however, that is more appropriate for determining eligibility. Physiologic age correlates with the patient's activity level and physical demands more closely than does chronologic age and better determines the appropriate treatment of a specific cartilage lesion. Active, high-demand patients may require more aggressive intervention, such as an osteochondral autograft or allograft or ACI, earlier in the treatment algorithm than less active patients. The primary relevance of chronologic age is that the older the patient is at the time of presentation, the longer they

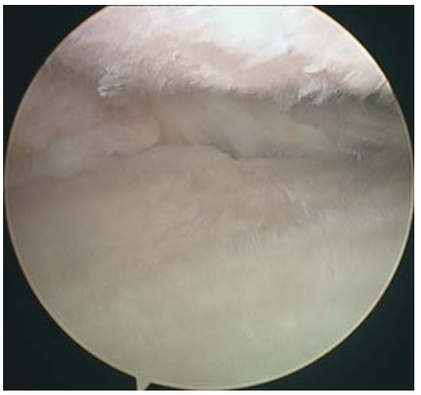

Figure 4 Arthroscopic view obtained during a diagnostic arthroscopic examination of a patient with medial joint pain shows evidence of significant meniscal deficiency in addition to chondral disease. This patient underwent an osteochondral allograft and concomitant meniscal transplant.

have been living with asymptomatic disease and the greater the likelihood that biologic restoration will not be feasible.

The patient's history and symptoms also are important preoperative considerations. The location of the pain may help determine whether a cartilage lesion is clinically significant. For example, a patient with anterior knee pain and a cartilage lesion on the medial femoral condyle that is evident on MRI should be evaluated for a patellofemoral etiology to explain the symptoms. Weight-bearing pain along the joint line may be more indicative of a symptomatic cartilage lesion on the weight-bearing portion of the femoral condyle or tibial plateau rather than a patellofemoral lesion. Patients with cartilage lesions typically describe activity-related effusions in the joint. Finally, any previous treatments and their results should be noted.

Perhaps the most important factors in preoperative decision-making are the patient's goals for, concerns about, and expectations of surgical intervention. Clarifying these issues during the preoperative discussion is critical to achieving a successful outcome from the patient's perspective. Specific issues to be discussed include the patient's desired activity level, results of previous surgical procedures, and the predicted marginal improvements expected from additional procedures. Patients often express concerns about the continued progression of the cartilage lesion if surgical treatment is delayed and whether or not it is safe to remain active despite symptoms. Given the current knowledge from existing literature, we educate patients with asymptomatic defects about symptoms that may develop and, as such, often delay treatments in some settings until proper indications exist.

Lesion-Specific Factors

The appropriate intervention for a specific cartilage lesion also is guided by specific characteristics of the defect such as size, location, number, and bone quality. Large lesions (more than 2 to 3 cm^2), for example, are better treated with osteochondral allograft or ACI, whereas small lesions typically are best treated with marrow-stimulation techniques or osteochondral autograft transplantation (OAT). Lesion location must be evaluated as well. Patellofemoral lesions, for example, may be difficult to treat with allograft or autograft procedures because of the contour of the patella and trochlea. The bone quality under the lesion and condition of the opposing cartilage surface may guide treatment options and help predict the outcome. Defects with bone loss may require bone grafting procedures or necessitate an allograft or autograft procedure. In addition, defects for which MRI indicates significant subchondral edema may require solutions that involve the subchondral bone (ie, osteochondral allograft) rather than surface treatment (ie, ACI).

Additional Considerations

Additional copathologies, such as malalignment and ligamentous or meniscal deficiency, should be evaluated and considered in treatment decisions because they can affect the outcome of the cartilage procedure. Varus or valgus malalignment should be corrected with a high tibial osteotomy or distal femoral osteotomy, respectively, either before or at the time of the cartilage procedure. Similarly, deficient anterior or posterior cruciate ligaments should be reconstructed either before or at the time of the cartilage procedure because ligamentous laxity can increase the shear stress across the affected cartilage surface. Finally, careful examination and discussion with the patient about previous procedures, including meniscectomy, may necessitate further investigation. When the cartilage lesion is in the same compartment as the deficient meniscal tissue, it may be difficult to discern which pathology is contributing to the symptoms. In such a situation, diagnostic arthroscopy performed to evaluate the integrity of the meniscus can be a critical component in preoperative planning (**Figure 4**). Significant meniscal deficiency may warrant concomitant meniscal transplantation.

The final factor to consider when planning cartilage restoration procedures is the potential for future procedures. The treatment chosen should not rule out options for future treatment if the proposed procedure fails to relieve the symptoms. With this principle in mind, the least destructive and least invasive treatment necessary to alleviate the patient's symptoms and restore joint function should be done first. More extensive treatments should be reserved as potential "salvage" operations if symptoms persist.

Treatment

Indications

Indications for the surgical treatment of cartilage lesions include a symptomatic lesion that affects the patient's ability to participate in activities at his

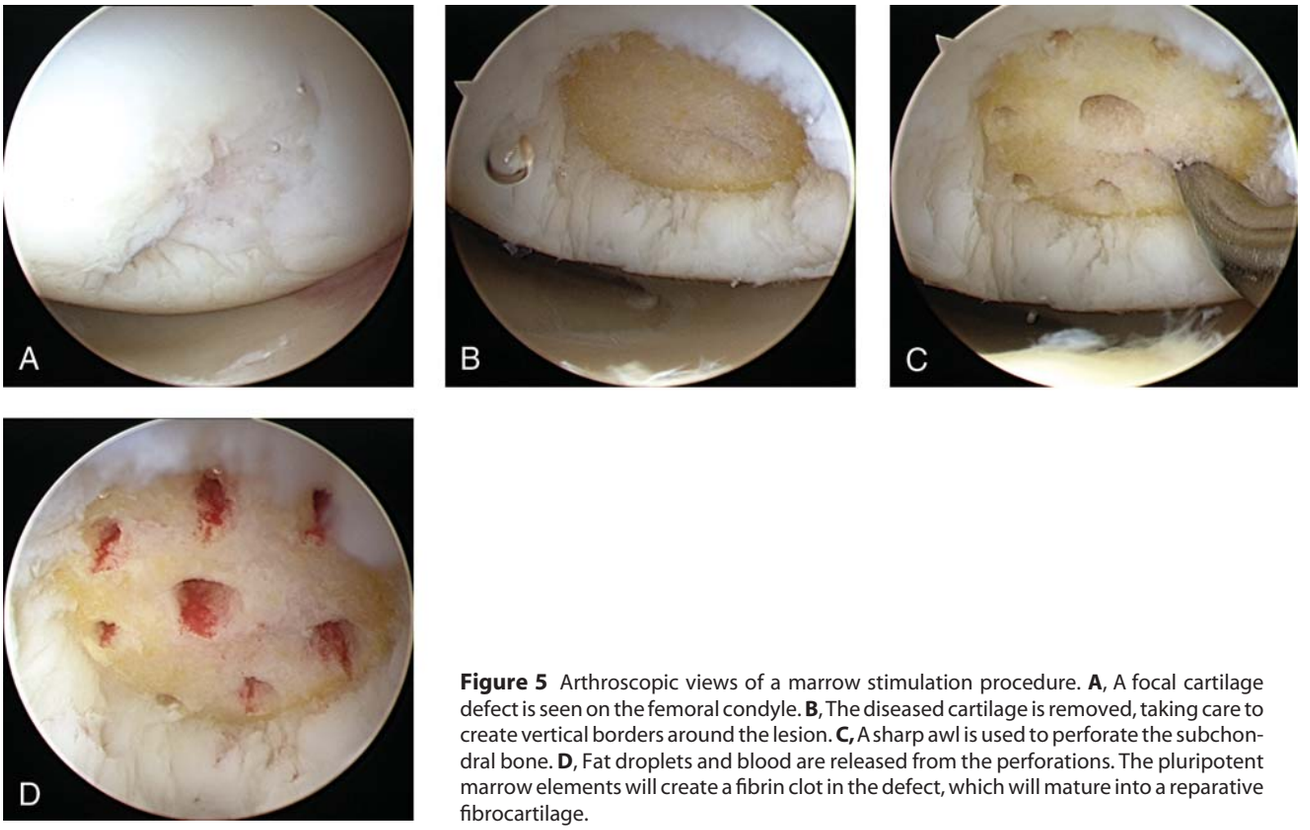

Figure 5 Arthroscopic views of a marrow stimulation procedure. **A**, A focal cartilage defect is seen on the femoral condyle. **B**, The diseased cartilage is removed, taking care to create vertical borders around the lesion. **C,** A sharp awl is used to perforate the subchondral bone. **D**, Fat droplets and blood are released from the perforations. The pluripotent marrow elements will create a fibrin clot in the defect, which will mature into a reparative fibrocartilage.

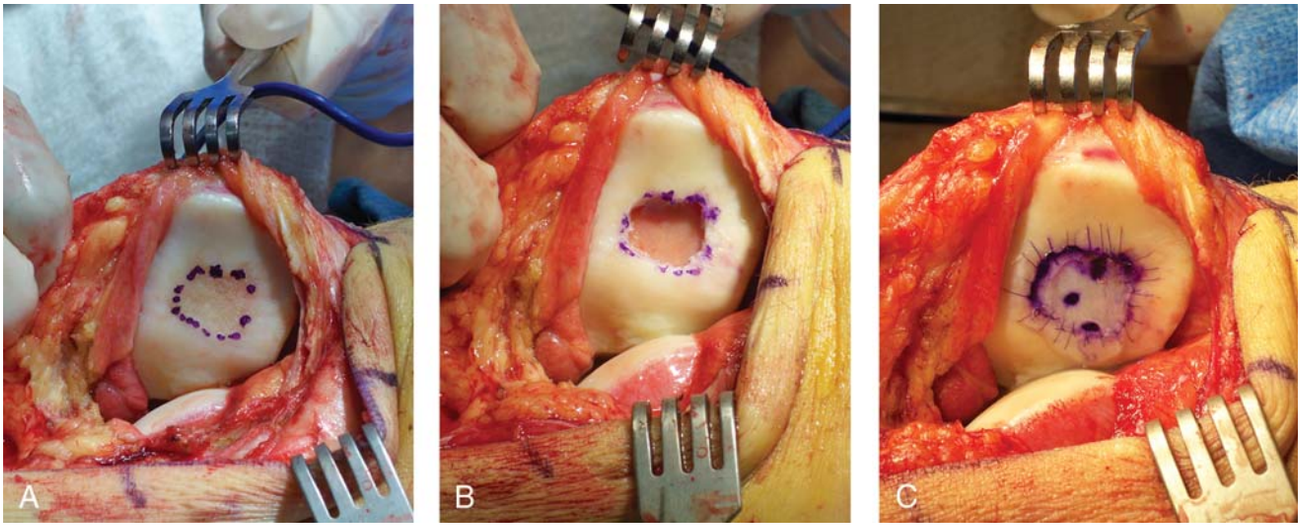

Figure 6 Intraoperative photographs of an autologous chondrocyte implantation procedure. **A**, The chondral lesion on the patella is marked by the purple dashed line. **B**, The diseased cartilage has been removed with sharp ring curets. **C**, A patch has been sewn in position over the defect, sealed with fibrin glue, and filled with cultured chondrocytes.

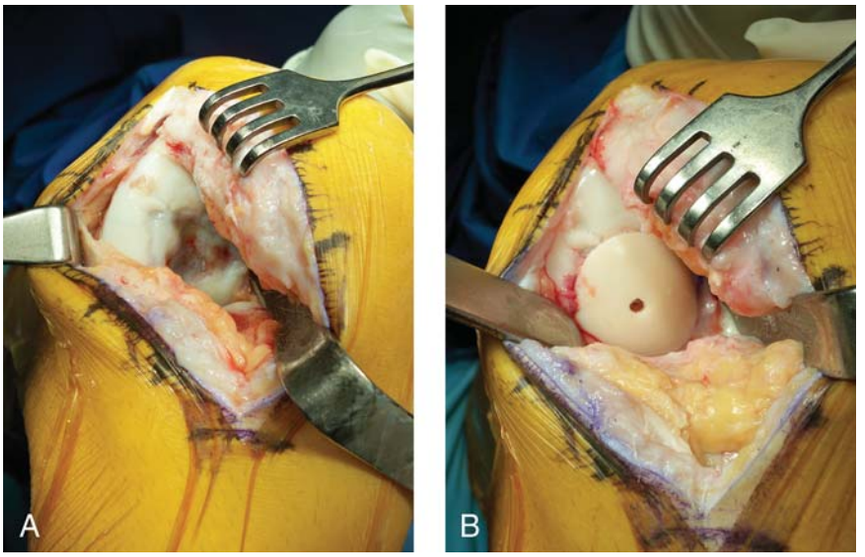

Figure 7 Intraoperative photographs of an osteochondral allograft procedure. **A**, A large osteochondral defect is seen in the lateral femoral condyle. **B,** After preparation of the defect, the osteochondral allograft was placed in the defect site. It is shown in position.

or her desired level and that has failed to improve with nonsurgical measures (activity modification, NSAIDs, injections). A successful outcome is more likely when the lesion seen on radiographs, MRI, or arthroscopy correlates with the patient's symptoms.

Contraindications

Relative contraindications to surgical treatment of cartilage lesions include copathology or comorbidity that could preclude an outcome that meets the patient's expectations. A body mass index (BMI) greater than 30 may be associated with less clinical improvement because of the higher contact forces in patients with a high BMI. Any malalignment or ligamentous or meniscal deficiency should be corrected either before or at the time of the cartilage procedure. Finally, relatively poor outcomes may be seen in bipolar lesions or cartilage injuries on opposing surfaces, such as the femoral condyle and tibial plateau.

Treatment Algorithm

The treatment options for articular cartilage lesions can be divided into palliative, reparative, and restorative procedures. Palliative procedures, including débridement and lavage, are done primarily for symptomatic relief and have little potential for cartilage regeneration. Reparative techniques, including marrow stimulation or microfracture, perforate the subchondral plate of the chondral defect to promote formation of a fibrin clot and migration of stem cells to the area (**Figure 5**). These pluripotent stem cells then create a reparative fibrocartilage tissue. Finally, restorative procedures such as osteochondral grafting and ACI (**Figure 6**) use osteochondral autografts or allografts (**Figure 7**) or cultured chondrocytes to replace or restore the native hyaline articular cartilage surface.

Our treatment algorithm for reparative and restorative procedures is shown in **Figure 8**. A systematic approach to choosing the best treatment for articular lesions should include a thorough evaluation of the patient- and lesion-specific variables in an effort to determine the least invasive and most effective treatment that will alleviate these patients' symptoms, meet their expectations, and allow them to return to their desired level of activity.

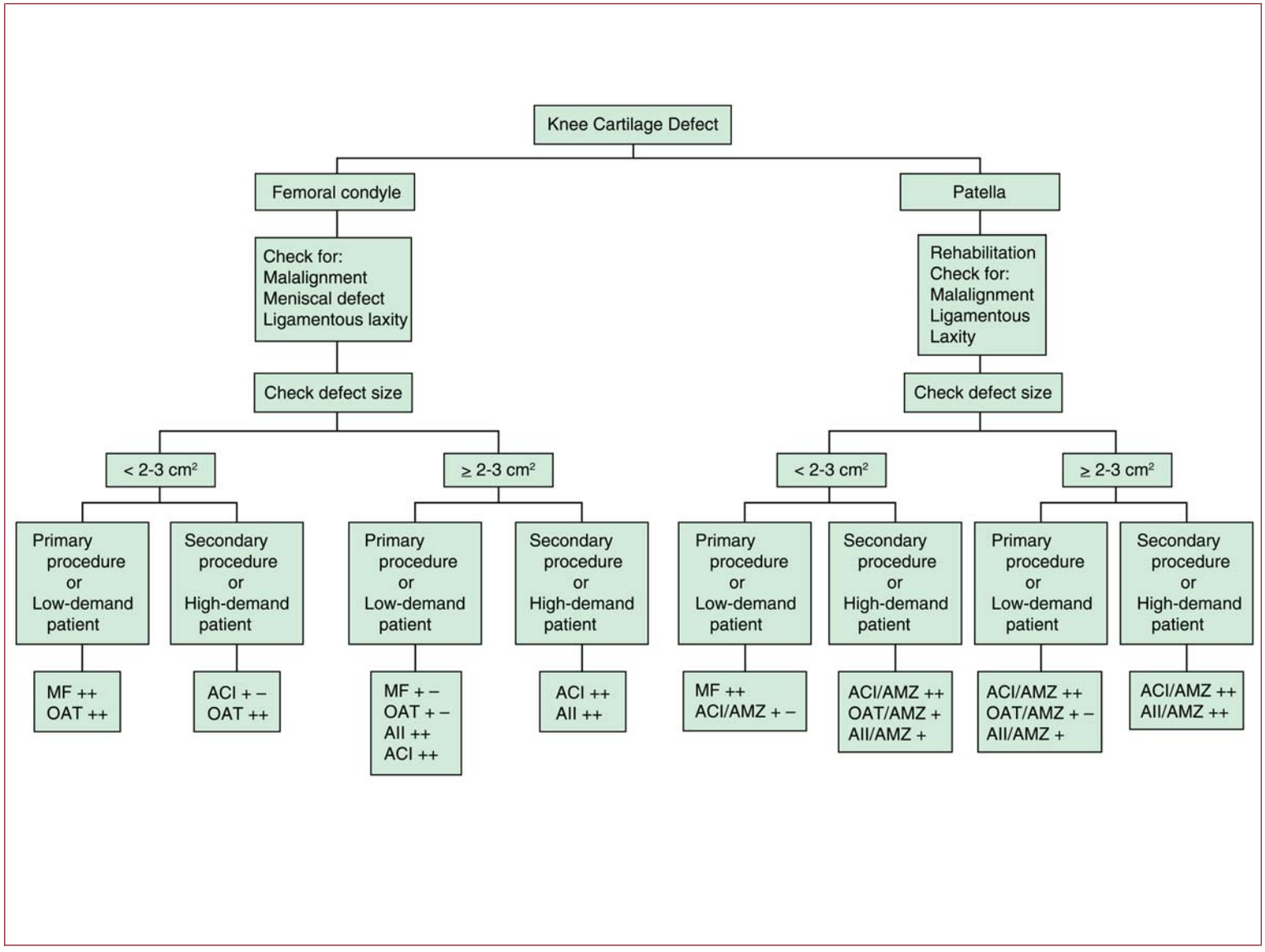

Figure 8 Treatment algorithm for cartilage injury. The decision points of the algorithm include the articular surface involved, concomitant pathology, lesion size, previous treatments, and the activity demand of the patient. Each arm of the algorithm concludes with competing procedures that have relative consideration. ++ = strong consideration, + = moderately strong consideration, + = less strong consideration, ACI = autologous chondrocyte implantation, OAT = osteochondral autograft transplantation; AMZ = anteromedialization of the tibial tubercle. (Reproduced with permission from Lewis PB, Nho SJ, Colton AE, and Cole BJ: Overview and First-Line Treatment. Surgical Management of Articular Cartilage Defects in the Knee 2009;42:1-16.)

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