

Cartilage repair of the knee

Overview

ETIOLOGY AND DIAGNOSIS

- Articular cartilage injuries in the knee result from age-related degenerative changes, previous trauma or injury, congenital osteochondral defects, inflammatory conditions, infection, and other causes [1].
- The chronicity, severity, and focal versus generalized nature of a patient's cartilage injury guides treatment [1].
- Physical examination along with radiographic or advanced imaging findings must be used concomitantly to determine the source of symptoms and appropriate surgical intervention when nonsurgical measures have failed [1].
- Nonsurgical measures for knee cartilage injury include activity modification, weight loss, nonsteroidal anti-inflammatory drugs (NSAIDs), corticosteroid injections, and physical therapy [1].
- MRI has been found to underestimate the size of articular cartilage defects in approximately 75% of cases [2].
- Articular cartilage injury usually occurs on the medial femoral condyle [2].
- Articular cartilage injury occurs as a result of rotational forces in direct trauma [2].
- Osteochondritis dissecans (OCD) involves subchondral bone and overlying cartilage separation [2].
- OCD in adults is usually symptomatic and leads to arthritis if left untreated [2].
- Poor prognostic factors for adult OCD include larger, more severe lesions; older age; discoid meniscus; and mechanical symptoms [2].

INDICATIONS AND CONTRAINDICATIONS

- Patients with symptoms and physical examination findings localized to the site of focal full-thickness cartilage loss in the knee are candidates for cartilage restoration procedures [4].
- Cartilage restoration procedures are not appropriate in the setting of multifocal cartilage loss, diffuse arthritis, or inflammatory arthropathy [4].
- Patients with unaddressed ligamentous instability, malalignment, or meniscal deficiency are not candidates for cartilage restoration procedures [4].

- Diffuse chondral damage is a relative contraindication to microfracture, chondrocyte implantation, and osteochondral transfer [2].
- Age, lesion size, patient's desired activity level, alignment, meniscal integrity, and ligamentous stability must all be taken into consideration in selection of the appropriate treatment option for discrete, isolated, full-thickness cartilage injuries [2].
- Concomitant osteotomies should be considered to correct malalignment in patients undergoing cartilage repair [2].
- Cartilage repair techniques are generally limited to the younger patient without global osteoarthritis of the knee [22].
- It is generally not recommended to perform isolated cartilage repair techniques in patients with complete joint space loss [22].
- Contraindications for cartilage repair include advanced arthritis, with elderly patients best treated with arthroplasty [22].
- Relative contraindications for cartilage repair include limb malalignment, ligamentous insufficiency, and meniscal damage unless they are concurrently treated [22].
- The lower limb should be well aligned for cartilage repair, and if not, realignment osteotomy should be performed to protect the cartilage repair site [22].

BONE MARROW STIMULATION TECHNIQUES

- Bone marrow stimulation techniques include abrasion chondroplasty and microfracture [4].
- Bone marrow stimulation techniques are single-stage arthroscopic surgeries that fill the defect with nonhyaline fibrocartilaginous tissue [4].
- Bone marrow stimulation techniques involve perforation of the subchondral bone after removal of the "tidemark" cartilage, with eventual clot formation and fibrocartilaginous repair tissue [2].
- The repair tissue from bone marrow stimulation techniques is composed of Type I collagen with inferior wear characteristics [2].
- Good clinical results in small defects (<2 to 3 cm²) are obtained in 60% to 80% of patients undergoing bone marrow stimulation techniques [2].
- Bone marrow stimulation techniques present the risk of osseous overgrowth that can result in increased joint contact pressures [4].
- Mesenchymal stem cell (MSC) concentration decreases with age, which may render bone marrow stimulation procedures less efficacious in older patients [4].
- Clinical deterioration has been shown across patients of all ages with long-term follow-up after knee microfracture [4].
- Abrasion arthroplasty involves using an arthroscopic shaver to débride cartilage defects and penetrate the subchondral bone plate to cause bleeding [10].
- The goal of abrasion arthroplasty is formation of a blood clot, which undergoes metaplasia to become fibrocartilage, a process estimated to take 8 weeks [10].

- Fibrocartilage is primarily composed of type I collagen as opposed to the type II collagen of normal hyaline cartilage [10].
- In microfracture, cartilage defects are débrided to a stable rim, and the resulting exposed subchondral bone is penetrated with a small drill or awl [10].
- Some studies have demonstrated by 2 years post-operatively that the fibrocartilage cap from subchondral drilling or microfracture is significantly degraded or no longer present [10].

OSTEOCHONDRAL AUTOGRAFT TRANSFER

- Osteochondral autograft transfer (OAT) utilizes osteochondral plugs from autograft sources to replace areas of articular cartilage ± subchondral bone loss [4].
- Autologous grafts for OAT are harvested from a non-weight-bearing area of the knee, commonly the superomedial/superolateral trochlea or intercondylar notch [4].
- OAT is a single-stage surgery that fills subchondral bone defects with hyaline cartilage [4].
- Mosaicplasty can be used to address medium-sized lesions (2–3 cm²) that include subchondral bone loss [2].
- Lateral trochlea and medial trochlea are acceptable harvest locations for mosaicplasty [2].
- Complications of mosaicplasty include donor site morbidity [2].
- OAT is best suited to lesions that are 1 to 2 cm in diameter because donor tissue volume is limited [22].
- Displaced osteochondral fragments can sometimes be replaced and secured with small recessed screws or absorbable pins [2].

OSTEOCHONDRAL ALLOGRAFT TRANSPLANTATION

- Osteochondral allograft transplant utilizes cadaveric donor plugs to replace areas of articular cartilage ± subchondral bone loss [4].
- Osteochondral allografts can be used for larger lesions (≥ 4 cm²), especially with bone loss [2].
- Main concerns with osteochondral allografts include the small risk of disease transmission and chondrocyte viability [2].
- Chondrocyte viability for osteochondral allografts has improved with graft preservation techniques [2].
- Osteochondral allografts are ideally used within 14 to 28 days of donor death [2].
- Osteochondral allografts allow for precise surface contour matching [4].
- Risk of immunological rejection is a disadvantage of osteochondral allograft transplantation [4].

AUTOLOGOUS CHONDROCYTE IMPLANTATION (ACI)

- Autologous chondrocyte implantation (ACI) is a two-stage process including biopsy of the patient's articular cartilage, followed by ex vivo expansion, with subsequent implantation into the defect [2].
- ACI allows for creation of type II collagen-rich hyaline-like cartilage, with minimal type I collagen or fibrocartilage present [2].
- ACI is indicated for medium-sized to larger chondral lesions without bony defects [2].

- ACI is indicated for active patients with a stable, well-aligned knee and a cartilage defect larger than 4 cm [22].
- Best results for ACI have occurred in isolated femoral condyle lesions [22].
- Complications related to ACI include chondrocyte overgrowth and periosteal flap hypertrophy, along with the morbidity of the second surgical procedure [2].
- ACI requires intact subchondral bone [4].
- ACI has demonstrated good clinical outcomes for treatment of large and even bipolar (abutting) lesions in the tibiofemoral and patellofemoral joints [4].
- Histology-proven hyaline cartilage fill has been demonstrated with ACI [4].
- Second-look arthroscopy has shown hyaline-like tissue repair in most patients undergoing ACI [22].
- The first-generation ACI technique (ACI-P) required harvesting of proximal tibia periosteum to be used as a patch to contain the chondrocyte suspension [68].
- The second-generation ACI technique (ACI-C) used a synthetic type I/III collagen membrane in exchange for periosteum [68].
- The current third-generation technique, matrix-induced autologous chondrocyte implantation (MACI), consists of expansion and direct in vitro seeding of the chondrocytes onto the type I/III collagen membrane [68].
- MACI allows for fixation of the implant to the subchondral bone with fibrin glue and an even distribution of chondrocytes on the membrane [68].
- For ACI, a full-thickness cartilage biopsy weighing 200 to 300 mg is taken from the superolateral intercondylar notch or the periphery of the trochlea [68].
- The ACI implant is typically ready for reimplantation after 4 to 6 weeks of in vitro chondrocyte expansion [68].
- The ACI process can be interrupted by a cryopreservation stage, allowing implantation to be delayed for up to 2 years [68].
- The second-stage ACI procedure commonly requires a medial or lateral parapatellar arthrotomy but can be performed arthroscopically in select cases [68].
- Postoperative rehabilitation for ACI starts with immediate motion using a continuous passive motion machine for 6 to 8 hours a day for the first 6 weeks [68].
- Patients undergoing ACI remain toe-touch weight bearing for 6 weeks and then progress toward weight bearing as tolerated for defects in the femoral condyles [68].
- Patellofemoral defects treated with ACI can weight bear as tolerated in full extension from the beginning [68].
- Running is not allowed for 9 to 12 months after ACI, and strenuous sports activity is restricted for 12 months [68].

ALLOGRAFT CELL-BASED THERAPY

- Allograft cell-based therapies include particulated juvenile cartilage and acellular extracellular matrix (Biocartilage) [4].
- Allograft cell-based therapies allow for single-stage surgery and are technically easy [4].
- Particulated juvenile cartilage allograft remains investigational [2].
- Allograft cell-based therapies lack long-term outcome data [4].
- Surface allograft transplantation consists of particulated juvenile cartilage, osteochondral graft matrix, or cryopreserved chondral allograft [22].
- Surface allografts require normal or near-normal subchondral bone for implantation [22].
- Limited clinical data exist on surface allograft transplantation techniques [22].

OUTCOMES AND COMPARATIVE DATA

- Condylar lesions undergoing cartilage restoration techniques demonstrate superior outcomes compared with patellofemoral lesions [2].
- Improved clinical outcomes following microfracture, OAT, or ACI are seen in well-selected patients [2].
- Long-term results following microfracture are variable in high-demand patients [2].
- Current best available research suggests that for smaller lesions, microfracture, OAT, and ACI have similar recovery periods and functional results [2].
- Donor-site problems and creation of true articular cartilage at the recipient site are still challenges for cartilage restoration procedures [2].

ARTHROSCOPIC MANAGEMENT OF DEGENERATIVE ARTHRITIS

- Performing arthroscopy for the treatment of early-stage osteoarthritis of the knee may help delay the need for knee arthroplasty, but proper patient selection is imperative [10].
- Arthroscopic débridement allows assessment of the joint and affords the ability to débride the meniscus, loose articular cartilage, and synovium, as well as to remove any loose bodies [10].
- Arthroscopic indications for degenerative arthritis include mild to moderate arthritis with minimal malalignment and mechanical symptoms consistent with a loose body, meniscus tear, synovitis, or painful osteophytes [10].
- Arthroscopic procedures are contraindicated in the knee with advanced arthritis, especially when varus or valgus malalignment is present [10].
- Some studies have demonstrated improvement in short-term outcomes with arthroscopic treatment of degenerative arthritis, with most demonstrating equivalent outcomes to nonsurgical treatment at mid to long-term follow-up [10].
- Arthroscopic lavage and débridement of the arthritic knee is controversial but effective when properly indicated [10].

- Indications for arthroscopic lavage and débridement are limited to specific mechanical symptoms caused by loose bone, cartilage flaps or particles, meniscal tears, or synovial impingement [10].
- The irrigation during lavage dilutes the joint fluid, which reduces the concentration of degradative enzymes [10].
- Chondroplasty involves removing or stabilizing diseased cartilage using a shaver, laser, or radiofrequency probe [10].
- The potential for thermal damage when using a laser or radiofrequency probe has resulted in decreased use of these techniques [10].

OSTEOTOMY

- Osteotomy of the knee is effective in treating arthritis because of a varus or valgus malalignment and can delay the need for total knee arthroplasty (TKA) [56].
- Osteotomy of the knee is frequently combined with cartilage restoration procedures to provide a better mechanical environment for the biologic repair [56].
- Osteotomy of the knee is ideal for the young, active patient with isolated medial or lateral compartment disease because it realigns the limb and reduces stresses on the articular cartilage of the diseased compartment [56].
- Medial compartment arthritis in the varus malaligned limb is treated with a valgus-producing high tibial osteotomy [56].
- Lateral compartment arthritis in the valgus malaligned limb is usually treated with a varus-producing distal femoral osteotomy to avoid an oblique joint line [56].
- Slight overcorrection of the varus deformity to 8° to 10° of valgus has produced good results in high tibial osteotomy [56].
- The goal of distal femoral osteotomy is to correct the deformity to 0° (neutral) to 2° of valgus [56].
- Valgus-producing high tibial osteotomy has been successful in approximately 50% to 85% of patients at 10 years [56].
- Varus-producing distal femoral osteotomy has been successful in up to 87% of patients at 10 years [56].
- Contraindications for valgus-producing high tibial osteotomy include lateral compartment arthritis, patellofemoral arthritis, inability to accept cosmetic appearance of leg, greater than 15° flexion contracture, range of motion less than 90°, and loss of lateral meniscus [56].
- Contraindications for varus-producing distal femoral osteotomy include medial compartment arthritis, greater than 15° flexion contracture, range of motion less than 90°, loss of medial meniscus, and patellofemoral arthritis [56].
- An osteotomy of the distal femur or proximal tibia may be performed in isolation, or as a concomitant procedure, to correct malalignment, off-load a single compartment, or improve knee joint stability [62].
- Long-leg standing radiographs assist with determining the mechanical axis and thus the degree of corrective osteotomy [62].

- High tibial osteotomy may be used in conjunction with osteochondral resurfacing, meniscal repair, or knee instability procedures [62].
- Contraindications for high tibial osteotomy include severe osteoarthritis (stage III–IV), limited knee ROM (<120 degrees), soft tissue compromise, and age less than 65 years [62].
- Distal femoral varus osteotomy is a treatment option for symptomatic valgus malalignment, including isolated lateral compartment osteoarthritis in a young, active patient [62].
- Medial closing wedge distal femoral osteotomy is indicated when the angle of correction is more than 17.5 degrees or in cases of limb-length discrepancy [62].
- Limited long-term data exist for distal femoral varus osteotomy, with a reported 20% major complication rate and 64% 10-year survival rate [62].

MENISCAL CONSIDERATIONS

- Meniscal tear is the most common injury to the knee that necessitates surgery [5].
- The medial meniscus is torn approximately three times more often than the lateral meniscus [5].
- Lateral meniscus tears occur more commonly with acute ACL tears [5].
- There is an increased rate of osteoarthritis in knees after meniscal tears and meniscectomy, particularly on the lateral side [5].
- Meniscal root tears are functionally equivalent to a total meniscectomy [5].
- Medial root tears are associated with chondral injuries [5].
- Acute meniscal root tears should be repaired whenever possible [5].
- Partial meniscectomy increases peak stresses in the affected compartment [5].
- Success rate for meniscal repair is 90% when performed in conjunction with an ACL reconstruction, 60% when performed in a knee with an intact ACL, and 30% when performed in a knee with a deficient ACL [5].
- Meniscal transplantation is controversial and all nonoperative management modalities should be exhausted prior to consideration [18].
- Indications for meniscal transplantation include prior total or near-total meniscectomy (especially lateral), pain in the involved compartment, body mass index less than 30, patient younger than 50 years, addressable full-thickness chondral lesions, normal alignment, and ligament

Anatomy & Pathophysiology

ETIOLOGY AND EPIDEMIOLOGY

- Chondral or osteochondral lesions are identified in as high as 61% to 66% of patients undergoing knee arthroscopy [19].
- The overall prevalence of focal chondral defects of the knee in athletes is estimated to be 36% [19].

- Cartilage defects may be idiopathic, traumatic, associated with repetitive microtrauma, or a combination thereof [19].
- Acute anterior cruciate ligament tears and meniscal derangement are highly correlated with chondral defects [19].
- Chondral and osteochondral lesions are reported in upward of 90% of patients following patellar dislocation [19].
- A large percentage of cartilage defects are asymptomatic, making true incidence and prevalence difficult to determine [19].

OSTEOCHONDRAL UNIT AND PATHOPHYSIOLOGY

- Articular cartilage and subchondral bone should be viewed as a closely related osteochondral unit [8].
- Defects that extend beyond the superficial chondral surface have the potential to affect the underlying subchondral bone [8].
- Any disturbance of the osteochondral unit can lead to altered biomechanics and abnormal joint contact pressures [8].
- Altered biomechanics and abnormal joint contact pressures lead to an inflammatory response [8].
- The inflammatory response may result in pain and dysfunction with the theoretical risk of widespread joint degeneration [8].
- Disruption of the osteochondral unit may result in increased joint contact forces to the surrounding chondral surfaces and subchondral bone [19].
- Mechanical wear and loose body formation may initiate an inflammatory response with release of cartilage-degrading enzymes [19].
- If left untreated, chondral defects can lead to osteoarthritis [19].
- Osteochondritis dissecans involves subchondral bone and overlying cartilage separation [2].
- Osteochondritis dissecans in adults is usually symptomatic and leads to arthritis if left untreated [2].
- Poor prognostic factors for osteochondritis dissecans include larger and more severe lesions, older age, discoid meniscus, and mechanical symptoms [2].
- Patients treated with cartilage repair demonstrated less progression of degenerative changes on MRI at 6-year follow-up than a control group treated nonsurgically with initial identical osteochondral defects [19].

BONY ANATOMY

- The medial femoral condyle is larger and projects farther posteriorly and distally than the lateral condyle [26].
- The lateral femoral condyle projects farther anteriorly and is wider in the medial-lateral direction than the medial femoral condyle [26].
- The sulcus terminalis is a small ridge on the lateral femoral condyle just distal to the intercondylar notch that separates the patellofemoral and tibiofemoral articular surfaces [26].

- The trochlear groove separates the femoral condyles anteriorly and constitutes the patellofemoral articulation [26].
- The tibial articular surface slopes 7° to 10° in the sagittal plane [26].
- The medial tibial plateau is larger than the lateral plateau and is concave in its frontal and sagittal planes [26].
- The lateral tibial plateau is smaller and more circular than the medial plateau, concave in the frontal plane and convex in the sagittal plane [26].
- The patella is the largest sesamoid bone in the body, averaging 2.5 cm in thickness [26].
- The patella has the thickest articular surface in the body, approximately 5 mm in the midportion and 2 mm on the sides [26].
- The posterior slope of the medial tibial plateau averages 10.7° and the lateral plateau averages 7.2° [30].
- The medial compartment has a large surface area containing a convex femoral condyle and concave tibial plateau [30].
- The lateral compartment has a smaller surface area containing a convex femoral condyle and convex lateral plateau in the sagittal plane [30].

MENISCI

- The menisci are C-shaped fibrocartilaginous disks that provide shock absorption, increase congruency between joint surfaces, enhance joint stability, and aid in distribution of synovial fluid [12].
- The medial meniscus is firmly attached to the joint capsule along its entire peripheral edge [12].
- The lateral meniscus is attached to the anterior and posterior capsule but has a region posterolaterally where it is not firmly attached [12].
- The medial meniscus has less mobility than the lateral meniscus and is more susceptible to tearing when trapped between the femoral condyle and tibial plateau [12].
- The lateral meniscus is larger than the medial meniscus and carries a greater share of the lateral compartment pressure [12].
- Menisci are crescent-shaped, fibrocartilaginous structures with a triangular cross section [30].
- Menisci consist of type I collagen fibers arranged obliquely, radially, and vertically [30].
- The vascular supply to the menisci is derived from the geniculate arteries, which penetrate into 20% to 30% of the peripheral medial meniscus and 10% to 25% of the peripheral lateral meniscus [30].
- Meniscal root tears completely disrupt the circumferential fibers of the meniscus [5].
- Biomechanically, meniscal root tears result in a loss of hoop stresses and an increase in contact forces [5].
- Lateral meniscal root tears are associated with ACL tears [5].
- Medial meniscal root tears are associated with chondral injuries [5].
- Tears in the peripheral third of the meniscus have the highest potential for healing due to vascular supply [5].

LIGAMENTS AND KINEMATICS

- The knee is a hinge joint that incorporates both gliding and rolling, which are essential to its kinematics [27].
- The “screw-home” mechanism involves the tibia externally rotating 5 degrees in the final 15 degrees of extension [27].
- The anterior cruciate ligament (ACL) is composed of 90% type I collagen and 10% type III collagen [26].
- The mean length of the ACL is 33 mm and the mean midsubstance width is 11 mm [26].
- The femoral attachment of the ACL is a semicircular area on the posteromedial aspect of the lateral femoral condyle [26].
- The tibial attachment of the ACL is a broad, irregular, oval-shaped area slightly medial and anterior to the midline between the tibial spinous processes [26].
- The posterior cruciate ligament (PCL) has a mean length of 38 mm and a mean width of 13 mm [30].
- The PCL has a broad, crescent-shaped femoral attachment on the anterolateral medial femoral condyle [30].
- The PCL tibial insertion is located 10 to 15 mm distal to the joint line of the knee [30].
- The middle geniculate artery supplies both the anterior and posterior cruciate ligaments [26].
- The greatest range of motion in the knee occurs in the sagittal plane, approximately 160° [39].
- Knee rotation ranges from 45° in external rotation to 30° in internal rotation [39].
- In the frontal plane, the range of motion in both abduction and adduction reaches a maximum of 10° [39].
- During walking, knee range of motion reaches approximately 70° in the sagittal plane, 15° in the frontal plane, and 10° in the transverse plane [39].
- Rupture of the cruciate ligaments or disruption of the tibiofemoral surface, including the menisci, causes a major change in the path of the instant center, leading to articular dysfunction [39].

IMAGING AND DIAGNOSTIC CONSIDERATIONS

- Plain radiographs are appropriate initial imaging studies for most knee conditions because they allow assessment of traumatic injury, arthritis, patellofemoral alignment, osteochondral injury, bone neoplasm, and surgical implants [6].
- Weight-bearing AP views in extension are used to assess cartilage loss from the distal femur and tibial plateau [6].
- Weight-bearing PA (Rosenberg) views in flexion are used to assess cartilage loss from the posterior femur and tibial plateau [6].
- Patellofemoral views are used to assess patellofemoral alignment, patellar and trochlear morphology, osteochondral injury, and patellofemoral arthritis [6].
- MRI may identify the degree of articular cartilage injury, including chondrosis and full-thickness cartilage loss [6].
- MRI may identify the presence of associated bone marrow edema and the location of cartilage injury [6].

- Physical examination along with radiographic or advanced imaging findings must be used concomitantly to determine the source of symptoms and appropriate surgical intervention [1].
- Assessment of the joint must combine physical examination with radiographic findings, including full-length alignment views, and MRI findings [3].

Classification

- Articular cartilage injuries within the knee can result from age-related degenerative changes [1].
- Articular cartilage injuries within the knee can result from previous trauma or injury [1].
- Articular cartilage injuries within the knee can result from congenital osteochondral defects [1].
- Articular cartilage injuries within the knee can result from inflammatory conditions [1].
- Articular cartilage injuries within the knee can result from infection [1].
- The chronicity of a patient's cartilage injury guides treatment [1].
- The severity of a patient's cartilage injury guides treatment [1].
- The focal versus generalized nature of a patient's cartilage injury guides treatment [1].
- Physical examination must be used concomitantly with radiographic or advanced imaging findings to determine the source of each patient's symptoms [1].
- Physical examination must be used concomitantly with radiographic or advanced imaging findings to determine appropriate surgical intervention when nonsurgical measures have failed [1].

Clinical Presentation

HISTORY AND PHYSICAL EXAMINATION

- A detailed history for knee pain must include onset, quality, duration, tempo, and location of symptoms, modifying factors, ability to bear weight, and history of trauma [59].
- Physical examination of the knee includes inspection, palpation, gait assessment, range of motion testing, stability testing, neurovascular assessment, hip examination, and special tests for specific pathologies [59].
- Inspection of the knee can reveal skin abnormalities, evidence of trauma, malalignment, and swelling [59].
- Palpation of the knee focuses on points of tenderness to identify focal pathologies such as joint line tenderness, patellar tendon tenderness, or pes anserine bursa tenderness [59].
- Palpation of peripatellar tissue can reveal the presence of effusion and/or synovitis [59].
- Knee alignment (varus, valgus, or neutral) should be assessed in both supine and standing positions, as weight-bearing may dynamically change alignment [59].
- Range of motion testing distinguishes between active and passive motion to differentiate pain-related, mechanical, or neuromuscular causes of blocks to motion [59].
- Hip range of motion should be examined to identify referred pain from intra-articular hip pathology [59].

- Basic varus and valgus stability testing is performed at 0° and 30° of flexion, with testing at 30° best isolating the MCL and LCL [59].
- The Lachman test involves flexing the knee to 30°, holding the femur firmly, and translating the tibia anteriorly to assess ACL competence [59].
- The posterior drawer test involves flexing the knee to 90° with the patient supine and translating the tibia posteriorly to assess PCL competence [59].
- The J-sign test involves bringing the knee from full extension into flexion to identify patellar maltracking via a visible J-shaped shift [59].
- The McMurray test for medial meniscus tears involves flexing the knee, externally rotating the tibia, extending the knee, and applying pressure to the medial joint line [59].
- The McMurray test for lateral meniscus tears involves flexing the knee, internally rotating the tibia, extending the knee, and applying pressure to the lateral joint line [59].
- The dial test for PLC deficiency involves externally rotating both tibiae with the patient prone and knee flexed to 30° [59].
- The dial test for PLC plus PCL deficiency involves externally rotating both tibiae with the patient prone and knee flexed to 90° [59].
- Patients with nonfocal cartilage loss typically present with complaints of knee swelling, locking, catching, or sudden giving way [21].
- Physical examination for patients with nonfocal cartilage loss often reveals an effusion, joint line tenderness, and positive meniscal signs including pain or palpable click with McMurray's test, pain with Thessaly's test or Apley's test, or pain while performing a deep squat [21].
- In the early phase of secondary osteonecrosis of the knee, the physical examination is unremarkable except for condylar tenderness with compression of condyles (positive "squeeze test") and the patient walks without a limp [23].
- In later phases of secondary osteonecrosis of the knee, pain becomes localized to the area affected by joint surface deformation, the knee has an effusion with synovial inflammation, and the patient limps [23].
- The archetypal presentation for secondary osteonecrosis of the knee is a middle-aged female on prednisone for long-standing SLE presenting with gradual onset of anterior and lateral knee pain with no history of trauma [23].
- Spontaneous osteonecrosis of the knee presents with sudden onset of medial knee pain, frequently with a limp, and acute pain lasting 6 to 8 weeks located over the femoral condyle [63].
- The archetypal presentation for spontaneous osteonecrosis of the knee is an overweight, elderly female with osteoporosis presenting with acute onset of medial knee pain and limp, reporting no prior history of knee injury [63].
- In nonarthritic knees, focal joint line tenderness, effusion, and positive meniscal signs on physical examination may indicate meniscal pathology as a symptomatic source worthy of surgical intervention [64].
- In the presence of osteoarthritis, mechanical symptoms such as locking or catching in combination with unstable meniscal tears on MRI warrant intervention [64].

IMAGING

- Weight-bearing AP (extension) radiographs are used to assess cartilage loss from the distal femur and tibial plateau [6].
- Weight-bearing PA (Rosenberg; flexion) radiographs are used to assess cartilage loss from the posterior femur and tibial plateau [6].
- The notch view is used to assess posterior femoral cartilage, notch width, and osteophytes [6].
- Radiographic findings for osteochondral defects include subchondral radiolucency, most commonly in the medial femoral condyle [6].
- MRI may identify the degree of articular cartilage injury (chondrosis, full-thickness cartilage loss), the presence of associated bone marrow edema, and the location (medial condyle, lateral condyle, trochlea, patella; anterior, posterior) [6].
- The crescent sign is a radiographic hallmark of secondary osteonecrosis of the knee that portends joint surface demise [23].
- Spontaneous osteonecrosis of the knee shows a sclerotic halo around a lucent area of collapse, in distinct contrast to the crescent sign pattern of secondary osteonecrosis [63].

EPIDEMIOLOGY AND NATURAL HISTORY

- Articular cartilage injuries within the knee can result from age-related degenerative changes, previous trauma or injury, congenital osteochondral defects, inflammatory conditions, infection, and other causes [1].
- Studies have demonstrated chondral or osteochondral lesions in as high as 61% to 66% of patients undergoing knee arthroscopy [19].
- The overall prevalence of focal chondral defects of the knee in athletes has been estimated to be 36% [19].
- Acute anterior cruciate ligament tears and meniscal derangement have been highly correlated with chondral defects [19].
- Chondral and osteochondral lesions have been reported in upward of 90% of patients following patellar dislocation [19].
- Poor prognostic factors for OCD include larger, more severe lesions, older age, discoid meniscus, and mechanical symptoms [2].
- Meniscal injury is identified on MRI in 31% of asymptomatic athletes and 91% of patients with knee osteoarthritis [64].

Investigations

CLINICAL ASSESSMENT

- Physical examination and radiographic or advanced imaging findings must be used concomitantly to determine the source of symptoms and appropriate surgical intervention [1].

- Assessment of the knee joint must combine physical examination with radiographic findings, including full-length alignment views, and MRI findings [3].
- The history of a knee injury is obtained by asking specific questions, and the physical examination begins with observation of the patient's gait [12].
- During physical examination, the uninjured knee is examined as a basis of comparison with the injured knee [12].
- Swelling or effusion is noted during examination, with small effusions causing obliteration of the recesses on the medial and lateral aspects of the patellar tendon [12].
- With larger effusions, diffuse swelling is present in the region of the suprapatellar pouch and a fluid wave can be palpated on the sides of the patella [12].
- Active and passive range of motion are tested carefully during the physical examination [12].
- The knee is palpated to define areas of localized tenderness [12].
- Joint lines are located at the level of the inferior pole of the patella when the knee is flexed to 90 degrees [12].
- Varus and valgus stability are determined by holding the patient's foot between the examiner's elbow and hip to free both hands for palpation [12].

PLAIN RADIOGRAPHY

- Plain radiographs are appropriate initial imaging studies for most knee conditions [6].
- Plain radiographs allow assessment of traumatic injury, arthritis, patellofemoral alignment, osteochondral injury, bone neoplasm, and surgical implants [6].
- Imaging studies should include at least two perpendicular views: AP and lateral [6].
- Non-weight-bearing radiographs may identify acute traumatic injury without the risk of fracture displacement [6].
- Radiography may identify subchondral sclerosis, joint space narrowing, subchondral cysts, osteophytes, and joint subluxation in osteoarthritis [6].
- Radiography may identify joint space loss and peripheral bone erosion in inflammatory arthropathy [6].
- Subchondral radiolucency is a radiographic finding for osteochondral defects, most common in the medial femoral condyle [6].
- Linear radiolucency or radiodensity is a radiographic finding for stress fractures, most common in the proximal medial tibia [6].
- Osteonecrosis presents as a mixed sclerotic pattern with a subchondral, epiphyseal, or metaphyseal location on radiography [6].
- Patellofemoral disease is identified by malalignment, osteophytes, cysts, and joint space loss on radiography [6].
- Radiographs are the standard for initial evaluation of knee arthritis [41].
- Images for arthritis evaluation should include weight-bearing AP and lateral views [41].

- Images for arthritis evaluation should include a view of the weight-bearing knee flexed at 45-degree angle, imaged posterior to anterior [41].
- Images for arthritis evaluation should include a sunrise view (Merchant view) [41].
- Images for arthritis evaluation should include extension and flexion lateral views [41].
- A standing full-length AP radiograph from hip joint to ankle joint is used to evaluate limb alignment and knee deformity [41].
- The Kellgren-Lawrence (KL) rating grades the extent of osteoarthritis based on review of the AP knee radiograph [41].
- Primary features used for KL rating include osteophytes, joint space narrowing, subchondral sclerosis with or without subchondral cysts, and altered shape of periarticular bones [41].
- KL Grade 0 indicates normal knee features with no osteoarthritis [41].
- KL Grade 1 indicates osteoarthritis possibly present [41].
- KL Grade 2 indicates osteoarthritis present with minimal severity [41].
- KL Grade 3 indicates osteoarthritis present with moderate severity [41].
- KL Grade 4 indicates osteoarthritis present with severe severity [41].
- Knee arthroplasty is recommended when KL Grade 4 findings are present [41].
- Supine AP knee radiographs do not adequately estimate the joint space width needed to estimate the degree of osteoarthritis progression [43].
- Plain frontal radiographs of the knee may not accurately display the actual joint space due to different cartilage wear patterns, meniscal integrity, or variances in tibial slopes [43].
- A 45° standing flexion view was introduced by Rosenberg et al. to better evaluate joint space [43].
- A fixed flexion view (FFV) technique has been introduced with improved reproducibility and good evaluation of the joint space [43].
- In the FFV method, the X-ray irradiation angle is fixed in a 10° caudal direction and the limb position is fixed relative to the cassette [43].
- For a PA FFV, the foot is 10° externally rotated and toes and anterior thigh are in close contact to the radiograph cassette [43].
- The Lyon Schuss view (LSV) uses the same posture as the FFV but requires fluoroscopic adjustment of the irradiation angle relative to the medial tibial plateau [43].
- The LSV is more accurate for measuring actual joint space width but has higher radiation exposure dose and more complex positioning [43].
- Goniometer readings of long limb alignment or measured on an FFV correlate well with the angle measured on long limb radiographs [43].

MAGNETIC RESONANCE IMAGING (MRI)

- Advanced radiographic imaging studies may help assess overall limb alignment and further delineate intra-articular and extra-articular soft tissues [6].

- MRI may identify the presence of associated bone marrow edema in articular cartilage injury [6].
- MRI may identify the location of articular cartilage injury, including medial condyle, lateral condyle, trochlea, patella, anterior, and posterior regions [6].
- MRI is the most useful study for differentiating osteonecrosis from other conditions such as osteochondritis dissecans, transient osteoporosis, bone bruises, or occult fractures [45].
- Bone edema on MRI is a common feature of osteoarthritis, osteonecrosis, cartilage injury, and transient regional osteoporosis [45].
- Serpentine lesions within a well-demarcated border are a specific finding on MRI for osteonecrosis [45].
- MRI is grossly overused in the arthritic patient population [41].
- If the joint space is significantly narrowed on radiograph, MRI is not indicated [41].
- MRI is used when osteonecrosis is suspected [41].
- An injected contrast agent, intravenous or intra-articular, may help delineate specific tissues of interest on MRI [6].
- Increasing strength of the magnetic field, measured in Tesla units, increases the resolution of MRI images [6].
- MRI may identify the presence of edema, intra-articular fluid, disruption of ligament fibers, and atypical ligament contour to suggest cruciate ligament injury [6].
- Patterns of meniscal injury can be identified by location, pattern, and displacement on MRI [6].
- MRI may be used to assess the continuity of the quadriceps or patellar tendon [6].
- MRI may be used to assess the margin of resection for a neoplasm, identify vascular malformation, or define the location of nerves or vessels relative to popliteal cysts [6].
- Radiographic evaluations are essential when diagnosing an osteochondritis dissecans (OCD) lesion of the knee, but important aspects of OCD lesions may be better seen with MRI [17].
- Assessing the potential instability of an OCD lesion is key to early treatment [17].

COMPUTED TOMOGRAPHY (CT)

- CT is a three-dimensional study performed with ionizing radiation that provides enhanced bone detail [6].
- Imaging in the axial, sagittal, and coronal planes may help visualize fracture lines and displacement on CT [6].
- CT may help visualize osteolytic lesions around joint arthroplasty and cortical disruption in cases of infection or neoplasia [6].
- Three-dimensional reconstructions may help with preoperative planning for complex intra-articular fractures [6].
- Three-dimensional reconstructions may help with preoperative planning for multiplanar osteotomy for limb malalignment [6].
- Three-dimensional reconstructions may help with reconstitution of bone loss in joint arthroplasty [6].

- Axial plane imaging of the hip and knee can help assess the rotational alignment of components of a total knee arthroplasty in cases of patellar maltracking [6].
- Three-dimensional CT with remodeling is used for preoperative planning for reconstruction associated with dysplasia [41].
- Three-dimensional CT with remodeling is used for post-trauma planning [41].
- Three-dimensional CT with remodeling is used for complex total knee arthroplasty (TKA) planning [41].

NUCLEAR MEDICINE

- Nuclear medicine involves labeled radionuclide injection followed by delayed imaging of gamma radiation [6].
- Areas of increased radionuclide concentration appear bright or “hot” on nuclear medicine imaging [6].
- Nuclear medicine provides a nonspecific study that does not define the etiology of an abnormality but rather the presence of an abnormality that may correlate with a clinical concern [6].
- Increased radionuclide activity in bone may be a normal postoperative finding for up to 6 to 12 months after a fracture repair or arthroplasty [6].
- Technetium-99 (Tc-99) is a radionuclide that may help identify infection, neoplasia, occult fracture, bone healing, active phases of heterotopic ossification, implant loosening, or failure of osseointegration [6].
- Gallium-67 (Ga-67) is a radionuclide that may help differentiate between aseptic and septic prosthetic loosening [6].
- 24 to 72 hours are needed for a complete Gallium-67 study [6].

Treatment

NONSURGICAL MANAGEMENT

- An initial trial of nonsurgical management is usually warranted for articular cartilage injuries, consisting of rest, activity modification, anti-inflammatory medications, physical therapy, bracing treatment, or injections [8].
- Nonsurgical measures such as activity modification, weight loss, nonsteroidal anti-inflammatory drugs (NSAIDs), corticosteroid injections, and physical therapy are indicated when they have failed to resolve symptoms prior to surgical intervention [1].
- In the absence of mechanical symptoms, knee arthroscopy with débridement is not effective in managing osteoarthritis of the knee [53].
- Weight loss for patients with a body mass index above 25 kg/m² is effective in decreasing pain and minimizing the progression of symptomatic osteoarthritis of the knee [53].
- Intra-articular corticosteroid injections are effective for symptomatic management of osteoarthritis of the knee [53].

- Oral supplementation with glucosamine and/or chondroitin sulfate has no benefit for management of symptomatic osteoarthritis of the knee [53].
- For meniscal tears, in the absence of intermittent swelling, catching, and locking, tears—particularly degenerative tears—may be treated conservatively [5].
- Nonsurgical treatment for osteochondritis dissecans (OCD) in skeletally immature patients may have a better prognosis for healing [47].
- Activity restrictions that include a period of casting or the use of an unloading brace can improve healing rates for OCD [47].
- Healing rates greater than 50% to 60% have been reported for appropriately selected patients with OCD treated nonsurgically [47].
- Using the International Cartilage Repair Society classification, grade I-II OCD lesions were managed successfully 78% of the time with conservative management [50].
- The risk of failure in grade III-IV OCD lesions is high with conservative management [50].
- At least 33.5% of pediatric patients with knee OCD progressed to surgery [50].
- In patients with multifocal OCD lesions, 74% required surgery [50].
- Of patients treated nonsurgically for OCD, approximately 30% are likely to develop arthritis at 35 years after diagnosis [50].

ARTHROSCOPIC PROCEDURES

- Arthroscopic débridement may provide relief from mechanical symptoms in carefully selected osteoarthritis patients, but should not be offered as a first-line treatment in lieu of nonsurgical measures [3].
- Arthroscopic treatment is indicated for débridement, chondroplasty, loose body removal, microfracture, and partial meniscectomy [3].
- A landmark study by Moseley et al comparing arthroscopic débridement with sham surgery in patients with knee arthritis found no difference in postoperative pain or functional outcomes between groups [21].
- Studies assessing outcomes after partial meniscectomy versus physical therapy for patients with knee osteoarthritis and a meniscal tear have demonstrated no significant difference in outcomes between groups [21].
- Approximately 30% of patients randomized to the physical therapy group for knee osteoarthritis and meniscal tear crossed over to undergo surgery because of continued pain [21].
- Good outcomes were achieved in patients who crossed over from physical therapy to delayed meniscectomy [21].
- The literature lacks well-designed studies to evaluate the efficacy of arthroscopic procedures for degenerative arthritis, with most demonstrating equivalent outcomes to nonsurgical treatment at mid to long-term follow-up [10].
- Arthroscopic lavage and débridement of the arthritic knee is controversial but effective when properly indicated for specific mechanical symptoms caused by loose bone, cartilage flaps or particles, meniscal tears, or synovial impingement [10].

- Abrasion arthroplasty uses an arthroscopic shaver to débride cartilage defects and penetrate the subchondral bone plate to cause bleeding [10].
- The goal of abrasion arthroplasty is the formation of a blood clot, which undergoes metaplasia to become fibrocartilage, a process estimated to take 8 weeks [10].
- In subchondral drilling or microfracture, cartilage defects are débrided to a stable rim, and the resulting exposed subchondral bone is penetrated with a small drill or awl [10].
- Some studies have demonstrated by 2 years post-operatively that the fibrocartilage cap from marrow stimulation is significantly degraded or no longer present [10].

CARTILAGE RESTORATION: BONE MARROW STIMULATION

- Bone marrow stimulation techniques include abrasion chondroplasty and microfracture, which are single-stage arthroscopic surgeries [4].
- Bone marrow stimulation techniques fill the defect with nonhyaline fibrocartilaginous tissue [4].
- Bone marrow stimulation techniques are technically easy and cost-effective [4].
- Good clinical results in small defects (<2 to 3 cm²) are obtained in 60% to 80% of patients undergoing marrow-stimulating techniques [2].
- Débridement and chondroplasty are currently recommended for symptomatic articular cartilage lesions [2].
- Biologic adjuvants are safe supplements to marrow stimulation for treating cartilage defects in the adult knee [9].
- Individual trials report both equivalent and superior clinical outcomes for microfracture augmented with biologic adjuvants compared with microfracture alone, making definitive conclusions on efficacy difficult without higher quality evidence [9].

CARTILAGE RESTORATION: OSTEOCHONDRAL AUTOGRAFT

- Osteochondral autograft transfer (OAT) involves transferring osteochondral plugs from a non-weight-bearing area of the knee to replace areas of articular cartilage and subchondral bone loss [4].
- Common harvest locations for OAT include the superomedial/superolateral trochlea or intercondylar notch [4].
- Donor site morbidity is a disadvantage of osteochondral autograft transfer [4].
- A prospective study on OCD comparing microfracture with osteochondral autograft implantation found that patients in the osteochondral implantation group had better results at an average follow-up of 4.2 years [47].
- One study suggested that donor-site morbidity for osteochondral autografts may not be significant in young patients [47].
- Some adult studies have shown significant rates of symptoms at OAT harvest sites [47].

CARTILAGE RESTORATION: OSTEOCHONDRAL ALLOGRAFT

- Osteochondral allograft transplantation utilizes cadaveric donor plugs to replace areas of articular cartilage and subchondral bone loss [4].
- Chondrocyte viability in osteochondral allografts has improved with graft preservation techniques [2].
- Osteochondral allograft transplantation allows for precise surface contour matching [4].
- Risk of immunological rejection or disease transmission is a disadvantage of osteochondral allograft transplantation [4].

CARTILAGE RESTORATION: CELL-BASED THERAPIES

- Autologous chondrocyte implantation (ACI) is a two-stage process involving biopsy of the patient's articular cartilage, ex vivo expansion, and subsequent implantation into the defect [2].
- ACI allows for the creation of type II collagen-rich hyaline-like cartilage with minimal type I collagen or fibrocartilage [2].
- Complications related to ACI include chondrocyte overgrowth, periosteal flap hypertrophy, and the morbidity of the second surgical procedure [2].
- Matrix-induced ACI (MACI) involves autologous cultured chondrocytes on a porcine collagen membrane [4].
- Autologous cell-based therapies such as ACI and MACI have demonstrated good clinical outcomes for treatment of large and even bipolar lesions in the tibiofemoral and patellofemoral joints [4].
- Histology-proven hyaline cartilage fill has been demonstrated with autologous cell-based therapies [4].
- Autologous cell-based therapies require intact subchondral bone [4].
- Allograft cell-based therapies such as particulated juvenile cartilage or acellular extracellular matrix allow for single-stage surgery [4].
- Allograft cell-based therapies heal with hyaline-like cartilage [4].
- Diffuse chondral damage is a relative contraindication to cartilage restoration procedures including microfracture, chondrocyte implantation, and osteochondral transfer [2].
- Age, lesion size, patient's desired activity level, alignment, meniscal integrity, and ligamentous stability must be taken into consideration in selection of the appropriate cartilage treatment option [2].
- Variable long-term results following microfracture are seen in high-demand patients [2].
- In a 2010 study, 74% of patients reporting their status as better or the same as previous years at a mean follow-up of 12.8 years after ACI [11].
- In a 2010 study, 92% of patients were satisfied and would have the ACI procedure again [11].
- In a 2014 study following 210 patients for a mean of 12 years after ACI, survivorship was 71% at 10 years [11].
- In a 2014 study, 75% of patients reported improved function at 10 years after ACI [11].
- In a 2014 study, at least one graft failed in 53 of 210 patients (25%) after ACI [11].

- Concurrent osteotomy significantly increased graft survivorship after ACI (88% with osteotomy versus 66% without) [11].
- In a 20-year follow-up study of 23 patients who underwent first-generation ACI, the survival rate was 63% [11].
- In a 20-year follow-up study, 79% of patients maintained their native knee and were satisfied at final evaluation after ACI [11].
- In a study of 104 patients with chronic chondral and osteochondral defects treated with ACI, 27 patients (26%) experienced graft failure at a mean of 5.7 years [11].
- Of the 73 patients with surviving grafts in a study of chronic defects, 88% reported good to excellent results after ACI [11].
- A systematic review of 771 patients treated with ACI followed for an average of 11.4 years found successful outcomes in 82% of patients [11].
- A systematic review of 771 patients treated with ACI found a revision surgery rate of 37% [11].
- Increased patient age and lesion size greater than 4.5 cm² were determined to be risk factors for revision surgery and failure after ACI [11].
- In a large multicenter study of 110 patients treated with ACI for cartilage defects of the patella, 92% of patients stated they would undergo the procedure again [11].
- In a large multicenter study of 110 patients treated with ACI for cartilage defects of the patella, 86% rated their knees as good or excellent at final follow-up [11].
- In a study of 30 patients with isolated chondral lesions of the patella treated with ACI, knee function was rated as good to excellent in 25 (83%) at final follow-up [11].
- In a study of 30 patients with isolated chondral lesions of the patella treated with ACI, there were three failures that occurred at 6.25 years postoperatively [11].
- Prior marrow stimulation procedures such as microfracture may have a detrimental effect on outcomes following ACI [11].
- In a 2009 study, 26% of grafts in the prior marrow stimulation group failed compared with 8% in patients who did not have a prior marrow stimulation procedure after ACI [11].
- In a 2012 study, there were significantly more failures associated with ACI after microfracture (7 of 28) than with ACI as a first-line treatment (1 of 28) [11].
- Inferior clinical outcome was associated with ACI after microfracture [11].

MENISCAL TREATMENT

- Tears that are not amenable to repair are best treated with partial meniscectomy [5].
- Indications for meniscal repair include a tear between 1 and 4 cm, vertical tear, red-red tear, meniscal root tear, and patient younger than 40 years [5].
- Concomitant ACL reconstruction may extend the indications for meniscal repair because results are typically better [5].

- Augmentation techniques such as fibrin clot, platelet-rich plasma clot, vascular access channels, and synovial rasping may extend the indications for meniscal repair [5].
- The gold standard for meniscal repair remains the inside-out technique with vertical mattress sutures [5].
- In several studies, 80% to 90% success rates with meniscal repairs have been reported [5].
- Success rate for meniscal repair is 90% when performed in conjunction with an ACL reconstruction [5].
- Success rate for meniscal repair is 60% when performed in a knee with an intact ACL [5].
- Success rate for meniscal repair is 30% when performed in a knee with a deficient ACL [5].
- Rehabilitation following meniscus repair should involve avoidance of knee flexion beyond 90 degrees [5].
- Meniscal allograft transplantation is indicated for prior total or near-total meniscectomy, pain in the involved compartment, body mass index less than 30, patient younger than 50 years, addressable full-thickness chondral lesions, normal alignment, and ligamentous stability [18].
- Ligamentous deficiency and limb malalignment must be addressed to improve success rates of meniscal transplantation [18].
- Contraindications for meniscal transplantation include diffuse grades III and IV chondral changes, kissing lesions, advanced patient age, inflammatory arthritis, synovial disease, and uncorrected mechanical axis that lies in the affected compartment [18].
- Graft size accurate to within 5% of the native meniscus is crucial to success of meniscal transplantation [18].
- Undersized meniscal grafts result in poor congruity and increased load transmission [18].
- Oversized meniscal grafts result in meniscal extrusion and impaired ability to transmit compressive loads [18].
- Pain relief is the most consistent benefit of meniscal transplantation [18].
- The chondroprotective effect of meniscal transplantation has yet to be demonstrated clinically [18].
- Meniscal allograft tissue often remains hypocellular or acellular, particularly at the core [18].
- Collagen meniscal implantation has yielded promising initial results for irreparable medial meniscal tears with new meniscus-like matrix formation compared with partial meniscectomy [18].
- Long-term results for collagen meniscal implantation, especially from independent sources, have not been reported [18].

OSTEOCHONDritis DISSECANS (OCD) MANAGEMENT

- Surgical intervention should be considered for patients having unstable OCD lesions of the knee and/or OCD lesions that do not heal with nonsurgical treatment [17].

Complications

BONE MARROW STIMULATION TECHNIQUES

- Bone marrow stimulation techniques carry a risk of osseous overgrowth that can result in increased joint contact pressures [4].
- Mesenchymal stem cell concentration decreases with age, which may render bone marrow stimulation procedures less efficacious in older patients [4].
- Outcomes for bone marrow stimulation techniques are worse with larger cartilage defects or in patients with high body mass indexes [4].

OSTEOCHONDRAL AUTOGRAFT TRANSFER (OAT)

- Donor site morbidity is a complication of osteochondral autograft transfer [2].
- Donor site morbidity is a listed disadvantage of whole tissue transplantation including osteochondral autografts [4].

OSTEOCHONDRAL ALLOGRAFT TRANSPLANTATION

- Osteochondral allograft transplantation carries a risk of immunological rejection or disease transmission [4].
- The main concerns for osteochondral allografts include the small risk of disease transmission and chondrocyte viability [2].

AUTOLOGOUS CHONDROCYTE IMPLANTATION (ACI)

- Complications related to ACI include chondrocyte overgrowth and periosteal flap hypertrophy [2].
- The morbidity of the second surgical procedure is a complication associated with ACI [2].
- In a study of over 300 consecutive patients, 26% of grafts in the prior marrow stimulation group failed compared with 8% in patients who did not have a prior marrow stimulation procedure [11].
- A study comparing 28 patients treated with ACI after failed microfracture to 28 patients treated with ACI as first-line treatment found significantly more failures associated with ACI after microfracture (7 of 28) than with ACI as a first-line treatment (1 of 28) [11].
- Increased patient age and lesion size greater than 4.5 cm² are risk factors for revision surgery and failure following ACI [11].
- In a long-term study of 210 patients followed for a mean of 12 years, at least one graft failed in 53 of 210 patients (25%) [11].
- In a study of 104 patients with chronic chondral and osteochondral defects followed for an average of 10.4 years, 27 patients (26%) experienced graft failure at a mean of 5.7 years [11].

ARTHROSCOPIC DEBRIDEMENT

- Arthroscopic debridement for osteoarthritis does not significantly alter the natural progression of osteoarthritis [24].
- Approximately 20% of patients undergoing arthroscopic debridement for osteoarthritis had total knee arthroplasty within 3 years of the surgery [24].
- Patients older than age 70 years were almost five times more likely to have total knee arthroplasty within 1 year after debridement than were patients younger than 60 years [24].
- Abrasion chondroplasty is contraindicated in patients with inflammatory arthritis, significant knee stiffness, deformity, or instability [24].
- Abrasion chondroplasty is contraindicated in patients who are unwilling or unable to comply with 2 months of non-weight bearing after surgery [24].

GENERAL KNEE ARTHROSCOPY

- Overall complication rates for knee arthroscopy are generally cited as less than 1% in recent reports [25].
- Infection is the most common complication overall in knee arthroscopy [25].
- Saphenous and peroneal nerve injuries are reported with arthroscopic repairs, though frequency has decreased dramatically with all-inside techniques [25].
- The incidence of arthrofibrosis associated with anterior cruciate ligament reconstruction is increased when meniscal repair is performed [25].
- The incidence of infection associated with anterior cruciate ligament reconstructions is slightly increased when the reconstruction is performed in conjunction with meniscal repair [25].
- Deep vein thrombosis (DVT) is a concern with long, complicated procedures, particularly in patients who are overweight, have a history of DVT, are taking birth control pills, or have been inactive as a result of injury [25].
- Complex regional pain syndrome is a poorly understood condition that possibly could be decreased by better patient selection and decreased operating time [25].

Recovery

- Since the first description of autologous chondrocyte implantation (ACI) in 1994, numerous short-term to immediate-term studies have demonstrated favorable outcomes [11].
- A 2010 study following patients for a mean of 12.8 years found that 74% of patients reported their status as better or the same as the previous years [11].
- In the 2010 study with a mean follow-up of 12.8 years, 92% of patients were satisfied and would have the procedure again [11].
- A 2014 study followed up 210 patients for a mean of 12 years with an average defect size of 8.4 cm² [11].
- At 10 years in the 2014 study of 210 patients, graft survivorship was 71% [11].

- At 10 years in the 2014 study of 210 patients, 75% of patients reported improved function [11].
- In the 2014 study of 210 patients, at least one graft failed in 53 patients (25%) [11].
- In a subgroup analysis of the 2014 study, concurrent osteotomy significantly increased graft survivorship to 88% compared with 66% without osteotomy [11].
- A 20-year follow-up study of 23 patients who underwent first-generation ACI reported a survival rate of 63% [11].
- In the 20-year follow-up study of 23 patients, 79% of patients maintained their native knee and were satisfied at final evaluation [11].
- The patient cohort in the 20-year follow-up study had a mean of 2.1 lesions per knee and a large mean surface area of 11.8 cm² [11].
- A study of ACI for chronic chondral and osteochondral defects included 104 patients with a mean age of 30.2 years followed for an average of 10.4 years [11].
- Patients in the study of 104 patients had a mean duration of symptoms of 7.8 years and underwent an average of 1.3 cartilage procedures before ACI [11].
- In the study of 104 patients, 27 patients (26%) experienced graft failure at a mean of 5.7 years [11].
- Of the 73 patients with surviving grafts in the study of 104 patients, 88% reported good to excellent results [11].
- A recent systematic review included nine studies consisting of 771 patients treated with ACI followed for an average of 11.4 years [11].
- In the systematic review of 771 patients, the mean age was 33.4 years and the mean defect size was 5.9 cm² [11].
- In the systematic review of 771 patients, Tegner, Lysholm, and IKDC scores improved from preoperative to final follow-up with a favorable score change of 1.1, 24.9, and 16.5 points, respectively [11].
- In the systematic review of 771 patients, successful outcomes were reached in 82% of patients [11].
- In the systematic review of 771 patients, the revision surgery rate was 37% [11].
- Increased patient age and lesion size greater than 4.5 cm² were determined to be risk factors for revision surgery and failure in the systematic review of 771 patients [11].
- A large multicenter study treated 110 patients with ACI for cartilage defects of the patella and followed them up for at least 4 years [11].
- In the multicenter study of 110 patellar ACI patients, IKDC scores improved from 40 to 69 [11].
- In the multicenter study of 110 patellar ACI patients, modified Cincinnati scores improved from 3.2 to 6.2 [11].
- In the multicenter study of 110 patellar ACI patients, WOMAC scores improved from 50.4 to 28.6 [11].
- In the multicenter study of 110 patellar ACI patients, 92% of patients stated they would undergo the procedure again [11].
- In the multicenter study of 110 patellar ACI patients, 86% rated their knees as good or excellent at final follow-up [11].

- A study of 30 patients with isolated chondral lesions of the patella treated with ACI followed them for a mean of 7.3 years [11].
- In the study of 30 patellar ACI patients, 19 of the 30 patients underwent concomitant tibial tubercle osteotomy [11].
- In the study of 30 patellar ACI patients, the average patient age at time of surgery was 32 years and the average defect size was 4.7 cm² [11].
- In the study of 30 patellar ACI patients, all functional scores improved significantly at 24 months [11].
- At final follow-up in the study of 30 patellar ACI patients, knee function was rated as good to excellent in 25 patients (83%) [11].
- At final follow-up in the study of 30 patellar ACI patients, knee function was rated as fair in 4 patients (13%) [11].
- At final follow-up in the study of 30 patellar ACI patients, knee function was rated as poor in 1 patient (3%) [11].
- In the study of 30 patellar ACI patients, there were three failures that occurred at 6.25 years postoperatively [11].
- In the study of 30 patellar ACI patients, all three failures were in workers compensation patients who were older (average age 42 years) at the time of surgery [11].
- A 2009 study reviewed over 300 consecutive patients treated with ACI and grouped them based on whether they had previously undergone a marrow stimulation procedure [11].
- In the 2009 study of over 300 patients, 26% of grafts in the prior marrow stimulation group failed compared with 8% in patients who did not have a prior marrow stimulation procedure [11].
- A 2012 study compared 28 patients treated with ACI after microfracture had failed with 28 patients treated with ACI as a first-line treatment [11].
- In the 2012 study, there were significantly more failures associated with ACI after microfracture (7 of 28) than with ACI as a first-line treatment (1 of 28) [11].
- Inferior clinical outcome was associated with ACI after microfracture in the 2012 study [11].

References

[1] Orthopaedic Knowledge Update 13 Ebook Without Multimedia. Knee Arthroscopy and Preservation, Knee Reconstruction > Introduction.

[2] Miller S Review Of Orthopaedics. SECTION 16 PATELLAR TRACKING IN TOTAL KNEE ARTHROPLASTY > OSTEOCHONDRAL LESIONS > 1. Osteochondritis dissecans (OCD).

[3] Orthopaedic Knowledge Update 13 Ebook Without Multimedia. Knee Arthroscopy and Preservation, Knee Reconstruction > Summary.

[4] Orthopaedic Knowledge Update 13 Ebook Without Multimedia. Knee Arthroscopy and Preservation, Knee Reconstruction > Knee Preservation > Cartilage Restoration Procedures.

- [5] Miller S Review Of Orthopaedics. SECTION 16 PATELLAR TRACKING IN TOTAL KNEE ARTHROPLASTY > MENISCAL INJURIES.
- [6] Aaos Comprehensive Orthopaedic Review 3. Radiographic Evaluation and Surgical Anatomy of the Knee > I. Radiographic Evaluation.
- [8] Orthopaedic Knowledge Update Sports Medicine 6. Articular Cartilage of the Knee > Introduction.
- [9] Orthopaedic Knowledge Update Sports Medicine 6. Articular Cartilage of the Knee > Annotated References.
- [10] Aaos Comprehensive Orthopaedic Review 3. Nonarthroplasty Surgical Treatment of the Knee > I. Arthroscopic Management of the Arthritic Knee.
- [11] Orthopaedic Knowledge Update Sports Medicine 6. Articular Cartilage of the Knee > Outcomes > Autologous Chondrocyte Implantation.
- [12] A Lange Medical Book Current Diagnosis Treatment In Orthopedics Fifth Edition. **3Sports Medicine > Image KNEE INJURIES.**
- [17] Orthopaedic Knowledge Update. Osteochondritis Dissecans of the Knee and Elbow* > Summary.
- [18] Miller S Review Of Orthopaedics. SECTION 16 PATELLAR TRACKING IN TOTAL KNEE ARTHROPLASTY > 4. Meniscal transplantation.
- [19] Orthopaedic Knowledge Update Sports Medicine 6. Articular Cartilage of the Knee > Epidemiology/ Natural History.
- [21] Orthopaedic Knowledge Update 13 Ebook Without Multimedia. Knee Arthroscopy and Preservation, Knee Reconstruction > Knee Arthroscopy.
- [22] Aaos Comprehensive Orthopaedic Review 3. Nonarthroplasty Surgical Treatment of the Knee > III. Cartilage Reporative/Restorative Procedures.
- [23] Miller S Review Of Orthopaedics. SECTION 16 PATELLAR TRACKING IN TOTAL KNEE ARTHROPLASTY > SECONDARY OSTEONECROSIS KNEE.
- [24] Campbell S Operative Orthopaedics 4 Volume Set. SOFT-TISSUE PROCEDURES AND OSTEOTOMIES ABOUT THE KNEE > SURGICAL PROCEDURES > DEBRIDEMENT.
- [25] Campbell S Operative Orthopaedics 4 Volume Set. ANTERIOR CRUCIATE AND ANTEROLATERAL LIGAMENT RECONSTRUCTION (BOX 51.8) > COMPLICATIONS ASSOCIATED WITH KNEE ARTHROSCOPY.
- [26] Aaos Comprehensive Orthopaedic Review 3. Anatomy and Biomechanics of the Knee > I. Anatomy.
- [27] Miller S Review Of Orthopaedics. SECTION 16 PATELLAR TRACKING IN TOTAL KNEE ARTHROPLASTY > SECTION 1 KNEE > ANATOMY (FIG. 4.1).
- [30] Aaos Comprehensive Orthopaedic Review 3. Radiographic Evaluation and Surgical Anatomy of the Knee > II. Surgical Anatomy of the Knee.

- [39] Aaos Comprehensive Orthopaedic Review 3. Biomechanics and Wear in Joint Arthroplasty > III. The Knee Joint.
- [41] Miller S Review Of Orthopaedics. SECTION 16 PATELLAR TRACKING IN TOTAL KNEE ARTHROPLASTY > SECTION 11 KNEE ARTHRITIS ASSESSMENT.
- [43] Orthopaedic Knowledge Update 13 Ebook Without Multimedia. Knee Anatomy > Imaging (Radiograph, MRI, CT Scan, Dynamic Versus Static) > Radiograph.
- [45] Aaos Comprehensive Orthopaedic Review 3. General Evaluation of the Knee Patient > III. Osteonecrosis.
- [47] Orthopaedic Knowledge Update Sports Medicine 6. Osteochondritis Dissecans > OCD of the Knee > Management.
- [50] Orthopaedic Knowledge Update. Osteochondritis Dissecans of the Knee and Elbow* > OCD of the Knee > Management.
- [53] Orthopaedic Knowledge Update Sports Medicine 6. Nonarthroplasty Management of Osteoarthritis of the Knee > Summary.
- [56] Aaos Comprehensive Orthopaedic Review 3. Nonarthroplasty Surgical Treatment of the Knee > II. Osteotomy.
- [59] Orthopaedic Knowledge Update 13 Ebook Without Multimedia. Knee Anatomy > History and Physical Examination.
- [62] Miller S Review Of Orthopaedics. SECTION 16 PATELLAR TRACKING IN TOTAL KNEE ARTHROPLASTY > OSTEOCHONDRAL LESIONS > 3. Osteonecrosis.
- [63] Miller S Review Of Orthopaedics. SECTION 16 PATELLAR TRACKING IN TOTAL KNEE ARTHROPLASTY > SPONTANEOUS OSTONECROSIS KNEE.
- [64] Orthopaedic Knowledge Update 13 Ebook Without Multimedia. Knee Arthroscopy and Preservation, Knee Reconstruction > Knee Preservation > Meniscal Preservation.
- [68] Orthopaedic Knowledge Update Sports Medicine 6. Articular Cartilage of the Knee > Surgical Treatment Options > Autologous Chondrocyte Implantation.