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Osteochondral Allograft Transplantation

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Introduction

Patients with symptomatic chondral and osteochondral defects of the knee are commonly encountered in orthopedic practice. Left untreated, cartilage lesions may contribute to chronic joint irritation and inflammation resulting in early progression of osteoarthritis.[1] This increasingly common clinical problem has led surgeons and scientists to pursue and refine biologic solutions for joint restoration.[2] Fresh osteochondral allograft (OCA) transplantation is a technique that has been successfully used for primary treatment of a wide spectrum of articular injuries and joint diseases as well as for the salvage of failed cartilage repair. For the surgeon, use of fresh OCA provides an opportunity to achieve durable biological joint restoration. For the patient, this procedure provides predictable symptomatic relief and lasting functional improvement with the possibility of delaying or eliminating the need for arthroplasty.[3]

Indications

- Diagnosis
  - In general, conditions of the knee indicated for treatment with fresh OCA include large chondral and osteochondral lesions secondary to the following:
    - Osteochondritis dissecans (Figure 18-1)
    - Focal avascular necrosis
    - Other conditions involving cartilage disease or absence of subchondral (ie, fracture malunion)
    - Failed cartilage repair procedures (ie, microfracture, osteochondral autologous transfer, autologous chondrocyte implantation)
    - Degenerative knee conditions (select cases) in which arthroplasty is relatively contraindicated[4]

Sgaglione NA, Lubowitz JH, Provencher MT, eds. *The Knee: AANA Advanced Arthroscopic Surgical Techniques* (pp 243-255).

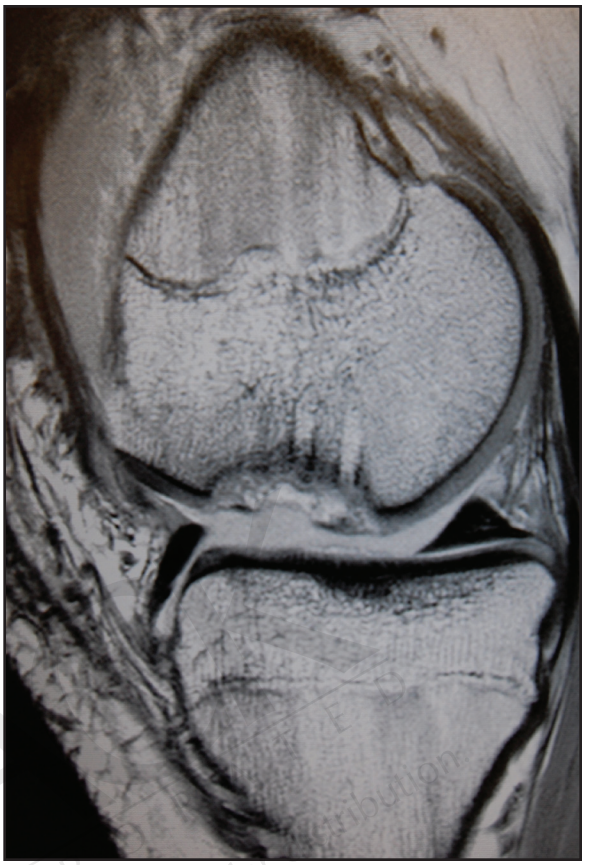

Figure 18-1. The most common indication for osteochondral allografting is osteochondritis dissecans with an unsalvageable fragment, as shown in this MRI.

- Lesion size and location
  - Primary management of chondral or osteochondral defects (≤ 2 cm^2)
  - Larger/deeper lesions of the femoral condyles (> 2 cm^2 to ≤ 10, 6 to 10 mm deep) for which other techniques may be less effective, contraindicated, and/or limited by availability of donor tissue
  - Tibial chondral defects
    - Entire tibial and meniscal surface may be transplanted
  - Bipolar (ie, "kissing") lesions of the femur and tibia
    - Relatively indicated when secondary changes occur on the nontraumatized side of the lesion
    - Less successful than treatment of unipolar cartilage defects
- Salvage
  - Management of clinical failure of primary OCA transplantation
  - Success rates comparable to primary allografting[5]

Relative Contraindications

- Age
  - No absolute age limitations
  - Inferior outcomes have been reported in older patients (ie, age > 40 years)[6]

- Comorbid conditions
  - Uncorrected joint malalignment and/or ligamentous instability
  - Meniscal insufficiency
  - Inflammatory arthropathy
  - Diffuse degenerative arthrosis
  - Morbid obesity, body mass index (BMI) > 30 kg/m^2

Pertinent Physical Findings

- Historical points
  - Focus on the location, duration, and onset of knee symptoms, including the following predictors of significant intra-articular pathology:
    - Knee swelling
    - Mechanical symptoms
    - Joint instability
  - Review all prior conservative and/or surgical treatments.
  - Screen for risk factors of osteonecrosis and any contraindications to OCA transplantation.
  - Patient age, sex, BMI, activity level, and expectations should influence patient selection.
- Physical examination findings
- Evaluation of the entire affected extremity is required, with attention to the following:
  - Limb malalignment and/or rotational deformity, diffuse hyperlaxity, and/or ipsilateral hip/ankle disorders
  - A focused examination of the knee joint should assess the following:
    - Joint alignment, range of motion (ROM), ligamentous stability, and function during gait.
    - Presence of swelling/effusion, muscular atrophy, and tenderness to palpation at the site of the lesion
      - Best test: Correlation of chondral lesion locations with the patient's symptomatic complaints or site of tenderness is the best test to predict the outcome of osteochondral allografting
    - A dynamic strength assessment, particularly of the quadriceps[7]

Pertinent Imaging

- X-rays
  - Standing anteroposterior view with the knee in full extension (weightbearing) to assess anterior joint space narrowing and to allow tissue banks to size-match allografts
    - Use a marker to correct for magnification[8]
      - Femoral lesions: Width of the affected condyle is measured, with an acceptable match considered as allograft condyle within ±2 mm[9]
      - Tibial lesions: Width of the affected tibial plateau is measured from the medial to lateral cortex just distal to the articular surface.

- Standing posteroanterior view with the knee flexed 45 degrees (weightbearing) to assess posterior joint space narrowing
- Lateral view to assess patellofemoral relationship (ie, alta or baja)
- Patellar view to assess the presence of trochlear or patellar dysplasia, patellar tilt, and/or maltracking
- Standing bilateral long-leg alignment view to measure the mechanical axis through the knee

- Magnetic resonance imaging (MRI)
  - To assess cartilage integrity and bone quality of/adjacent to articular lesion as well as concomitant ligamentous and/or meniscal pathology.
  - The true size of the articular lesion may be underestimated.[10]
- Conventional computed tomography (CT)
  - To quantify the extent of bone involvement, bone quality, and/or evaluate patellofemoral relationship (ie, tibial tubercle to trochlear groove distance)
- Single-photon emission CT)
  - A hybrid imaging technique that combines bone scintigraphy with high-resolution CT images is useful in patients for whom MRI is contraindicated and/or when image quality is impaired by retained metallic implants.[11]
- Arthroscopic images
  - Photographic images recorded during previous surgical procedures provide insight into defect dimensions, degree of containment, and associated pathology.
  - They may obviate the need for another diagnostic knee arthroscopy.

Equipment

The equipment required depends on the surface to be grafted and the surgical technique used. For most contained defects of the femoral condyles, a press-fit technique can be performed using commercially available systems (Arthrex) that simplifies site preparation, donor harvesting, and graft insertion (Figure 18-2).[12] However, if the size or location of the lesion does not permit use of a dowel-type press-fit system, the surgeon should be prepared to perform the shell graft technique. Because shell grafts require measured resection and sculpting of bone and cartilage, additional surgical equipment on hand should include calipers, depth-gauge, high-speed burr, reciprocating and oscillating saws, bone files, and/or rasps. In addition, use of fluoroscopy is critical for the treatment of certain large knee defects (ie, tibial plateau) and may enhance accuracy when treating other anatomic locations as well. For either technique, the allograft is opened and inspected prior to surgical incision to ensure it is acceptable for implantation. Although most grafts can be press-fit without fixation, multiple options for graft fixation should be available, including bioabsorbable pins and/or low-profile interfragmentary screws 3 mm in diameter or less.

Positioning and Portals

The patient is positioned supine with a proximal thigh tourniquet. A leg or foot holder helps to position and maintain the knee in flexion between 70 and 110 degrees (Figure 18-3). Prophylactic antibiotics are administered at the induction of anesthesia. The operative extremity is prepared and draped to permit an anterior approach to the knee. Old incision sites are marked. If an

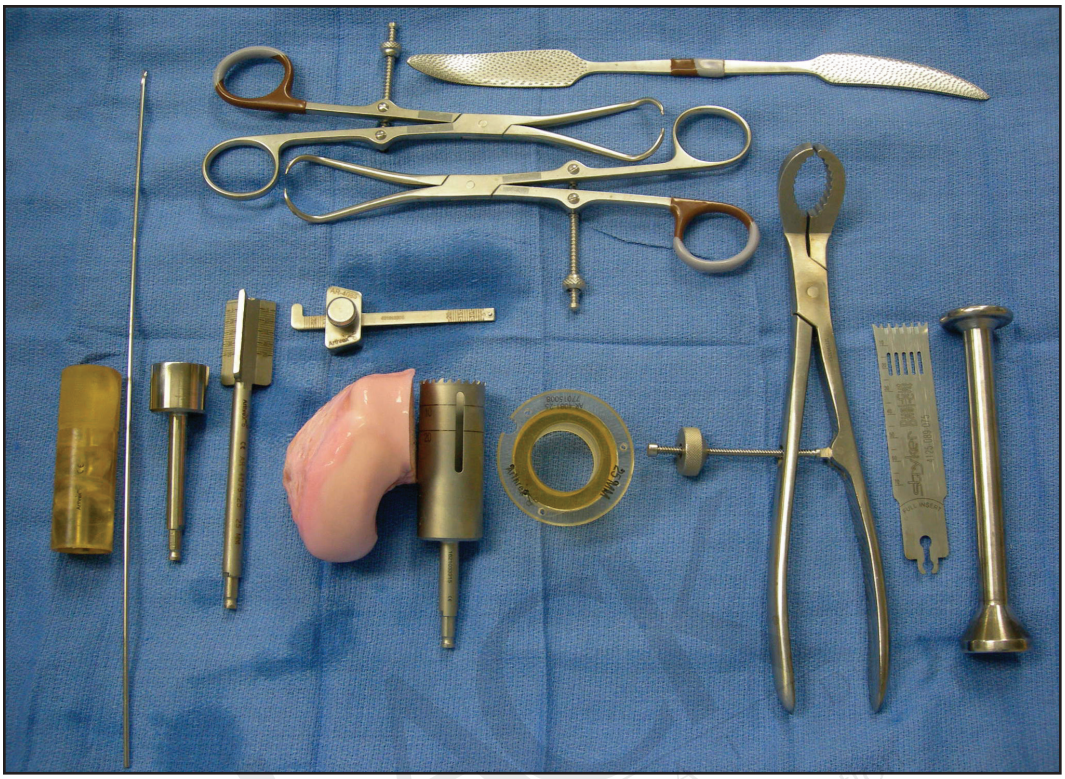

Figure 18-2. Typical instruments used to prepare and insert a plug-type allograft.

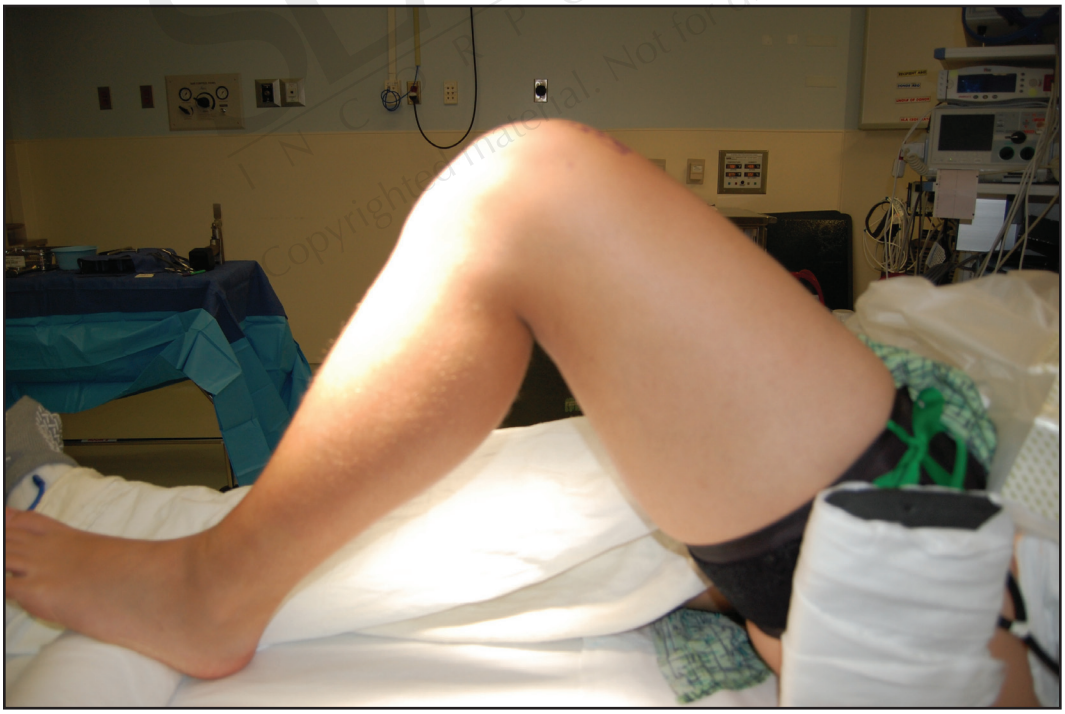

Figure 18-3. Stable limb positioning that allows for various degrees of knee flexion facilitates exposure of the lesion.

osteotomy is planned, it may be advantageous to have access to the ipsilateral anterior superior iliac spine as a source of autograft bone and as a reference to evaluate alignment. A diagnostic arthroscopy may be performed before the OCA transplantation to confirm lesion size and/or to treat coexisting pathology.

Step-by-Step Description of the Procedure

Management of Concomitant Pathology

For cartilage defects of the knee, if malalignment is present, realignment osteotomy is required to decrease the load on the graft. In general, opening wedge high tibial osteotomy is used to correct varus malalignment, and opening wedge lateral distal femoral osteotomy is used to correct valgus deformity.[13] For the patellofemoral joint, optimization of patellofemoral biomechanics may result in better outcomes, although this has not been proven in the context of osteochondral allografting. Therefore, in the setting of a patellofemoral lesion, tibial tubercle anteriorization or anteromedialization may be performed to transfer load and/or correct maltracking.[14] Management of ligament and meniscal deficiency is critical to normalization of compartment contact stresses and shear forces. Ligament reconstruction and/or meniscal allograft transplantation may be performed concomitantly with osteochondral transplantation to optimize graft survival and improve clinical outcome.[15]

Surgical Exposure

A standard midline incision is made. Depending on lesion location, a medial or lateral arthrotomy may be used. Once the joint capsule has been incised and the retractors have been placed, the knee is brought into the degree of flexion that presents the lesion into the arthrotomy site. In some cases, when the lesion is posterior, detachment and reflection of the meniscus may aid exposure. Angled retractors are placed medially and laterally to expose the condyle. A carefully placed retractor into the notch is useful to aid in patellar retraction (Figure 18-4). Extension of the deep incision proximally and distally aids in patellar mobilization.

Lesion Inspection and Preparation

The articular lesion is inspected to define the margins. Surrounding damaged cartilage and bone is debrided to facilitate accurate sizing of the lesion. The lesion is assessed to determine the allograft shape that will best match the defect. The 2 techniques for OCA preparation include the press-fit circular plug technique and the shell graft technique. Whenever possible, the press-fit technique is preferred based on the relative ease in achieving a precise graft fit and the low likelihood for need of supplemental internal fixation. If the lesion is not amenable to a press-fit OCA, a shell graft may be used.

Dowel or Plug Technique (See Video)

The size of the OCA is estimated using the commercially available cannulated, cylindrical sizing guides. Each guide is positioned to encompass the defect and thereby determine the optimal plug diameter. The guide must sit flush with the surrounding normal cartilage to properly restore the geometry of the articular surface. If the lesion is between 2 sizes, begin with the smaller size. Once a size has been determined, ensure that the available graft can accommodate the harvesting of this size graft as anatomic differences can occur that may change the surgical plan (ie, the surgeon may choose to place two 20-mm grafts rather than one 30-mm graft if the allograft condyle

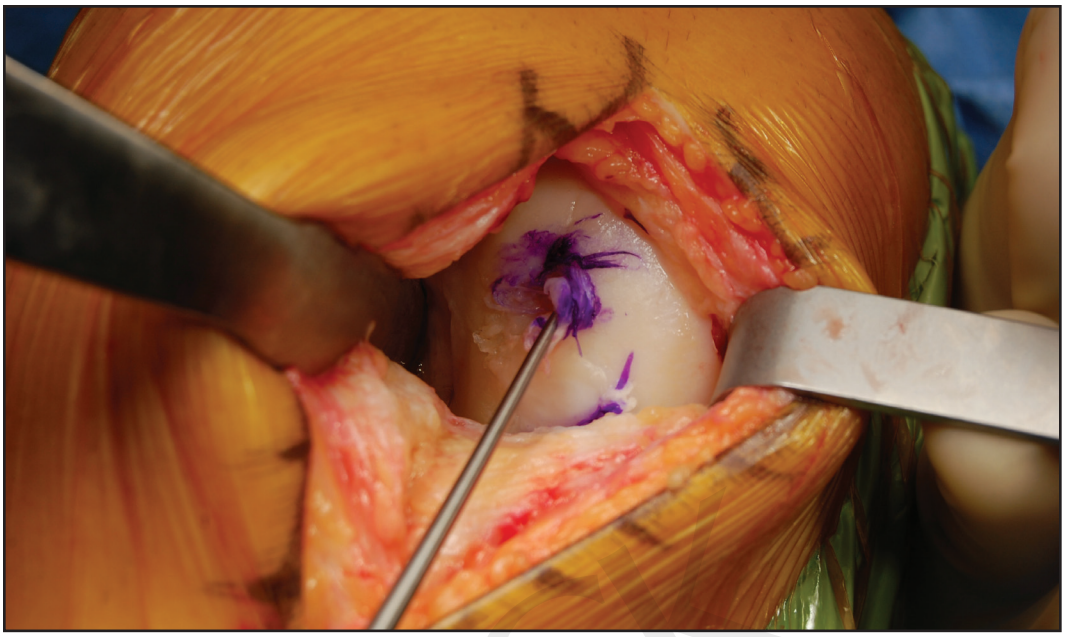

Figure 18-4. Exposure of the lesion with small arthrotomy and retractor placement. This patient has a failed microfracture of the medial femoral condyle.

is too narrow to harvest a 30-mm diameter graft). Recipient site preparation begins with placement of a guide wire through the cylindrical sizing guide into the center of the lesion, perpendicular to the articular surface. The cartilage surface is scored, and a cannulated counter bore reamer is used to remove the articular cartilage and 3 to 4 mm of subchondral bone. In deeper lesions, the pathologic bone is removed until there is healthy, bleeding bone. Generally, for treatment of chondral defects, depth does not exceed 6 to 8 mm (Figure 18-5). For treatment of osteochondral lesions, depth may reach up to 10 mm. The authors rarely find it necessary or appropriate to ream more than 8 mm total depth. The reamings are collected and may be used to graft osseous defects (cysts) or to optimize the position of the graft. At this point, the guide pin can be removed. If necessary, multiple perforations can be made in the base of the defect using a K-wire to promote vascular inflow. A skin marker is used to mark the 12 o'clock position for reference, and depth measurements are made and recorded in the 4 quadrants of the recipient site. A ruler or depth gauge is used to measure and record the socket depth at the 3, 6, 9, and 12 o'clock positions. The recipient socket is now complete and ready for the press-fit OCA.

The corresponding anatomic location of the recipient site is identified on the donor allograft. The allograft is then secured to the allograft workstation platform or held with clamps and positioned such that the appropriate diameter bushing may be positioned perpendicular to the articular surface, matching the orientation used to create the recipient site. The cylindrical sizing tube is used to confirm that the selected angle will match the contour of the defect, and the 12 o'clock position is marked with a surgical marker. The appropriate size-coring reamer is passed through the bushing and advanced through the entire depth. Once harvested from the donor condyle, the graft is removed as a long cylindrical plug. An oscillating saw can be used to release the graft from the donor condyle. The depths for the 4 quadrants of the recipient site are transferred to the graft, and the allograft plug thickness is customized using a microsagittal saw to trim excess bone to the thickness matching the recipient site. Just before insertion, it is beneficial to bevel the edges of the osseous portion with a small rongeur or rasp to facilitate the initial press-fit into the recipient socket. The donor graft should be irrigated copiously with a pulsatile lavage to remove blood and marrow cells to decrease the risk of a host immune response.[16] The donor graft is positioned by

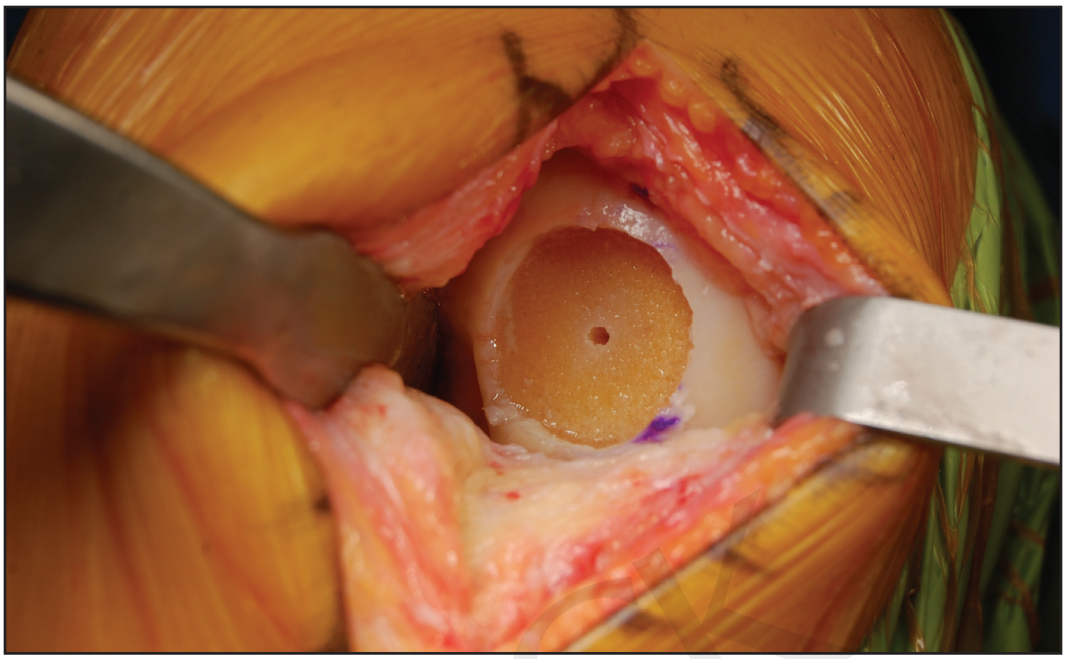

Figure 18-5. Preparation of the defect site is complete. Note the relatively shallow depth of the site.

aligning the markings and is pressed into place by hand. The authors prefer to use passive knee ROM to initially seat the graft, and then gentle tamping can be performed to fully seat the graft, but excessive impact loading with a mallet during allograft insertion may damage the extracellular matrix and/or result in chondrocyte death. If the graft does not fit, dilating the recipient site with a slightly oversized tamp or reinserting the guide wire and reaming deeper may be considered or the graft can be further trimmed or beveled. The final resting position of the graft should be flush relative to the surrounding articular surface, although the authors accept step-offs of less than 1 mm (Figure 18-6).[17] If the graft is unstable or has an exposed edge, absorbable pins or biocompression screws are used. For large femoral defects, more than 1 press-fit OCA plug may be required. The "snowman technique" facilitates coverage of a greater condylar area using a second press-fit plug (Figure 18-7). In this technique, the first graft is secured with a small K-wire or, if necessary, definitively fixed with biocompression screws to prevent dislodgement during preparation of the second overlapping site. Care is taken to minimize space between multiple grafts as this may lead to formation of biomechanically inferior fibrocartilage and/or lack of articular congruity (ie, cobble stoning) which may alter biomechanics and negatively affect clinical outcome.

Shell Technique

For uncontained or asymmetric lesions or for lesions in locations that are difficult to access on the femur, a free-hand technique is required to match donor tissue to the recipient defect. A skin marker is used to outline the shape of the defect, and a 15-blade scalpel is used to incise the remaining cartilage, which is then removed using sharp curettes. A high-speed burr is then used to remove the underlying pathologic bone to expose healthy bleeding bone. Creation of a simple recipient site geometry (ie, rectangle or trapezoid) simplifies subsequent freehand sizing of the OCA. After the recipient site is prepared, the donor graft is roughly fashioned with a microsagittal saw. It is best to make the initial cuts slightly wider than measured to oversize the donor graft. A series of trial fittings and repeated measurement guide sculpting of the donor tissue to achieve a precise fit.

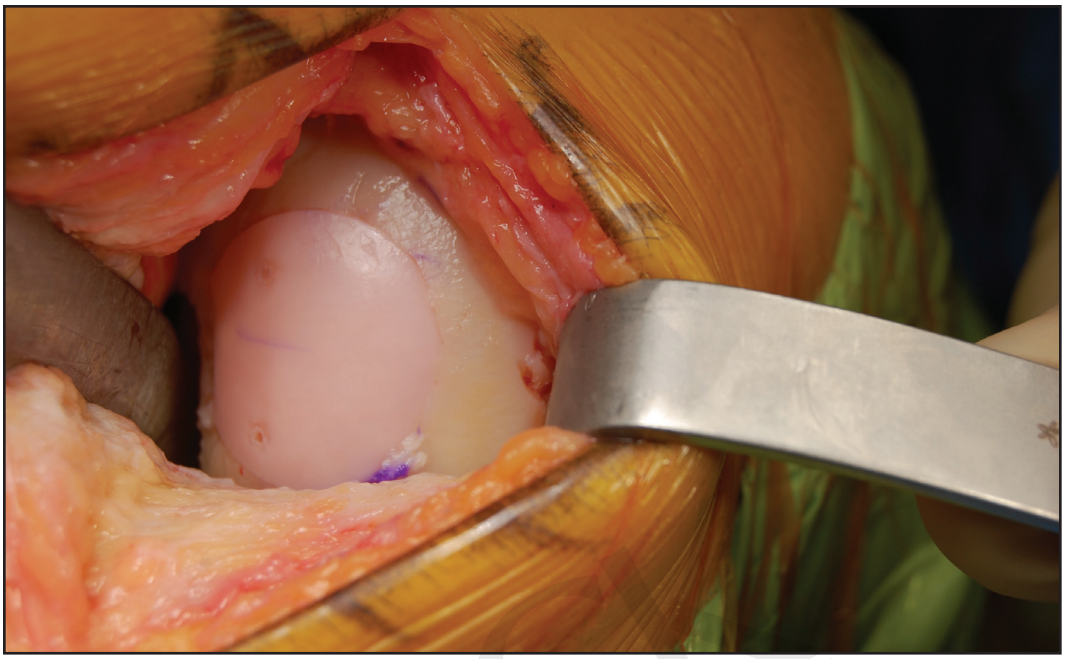

Figure 18-6. The graft has been inserted in appropriate orientation, and a flush press-fit has been obtained.

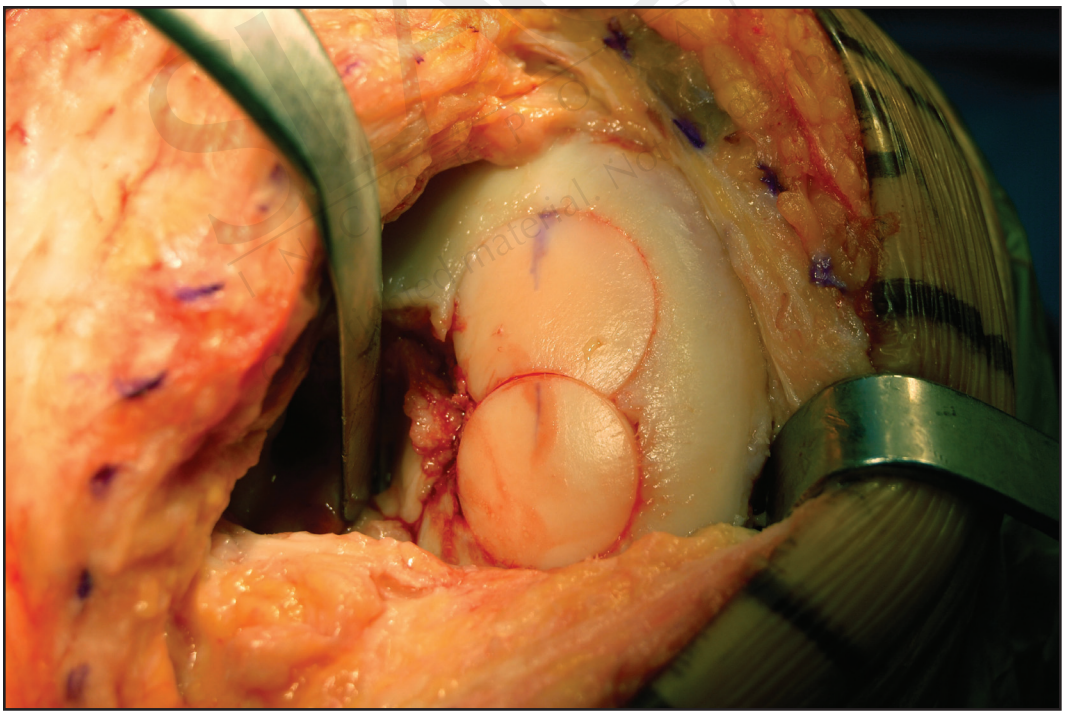

Figure 18-7. In this patient, 2 overlapping grafts have been used in the "snowman" configuration.

For the patella, although smaller lesions may be successfully managed with press-fit circular grafts, larger lesions are managed with a technique similar to that used in total knee arthroplasty. Patellar thickness is measured with calipers and resection of the articular surface is performed, maintaining at least 12 mm of residual bone. The donor graft is then resected in a similar fashion. The allograft is then lavaged and seated in the appropriate position. The graft is then secured with interfragmentary screw fixation from the anterior surface of the patella into the subchondral bone beneath the median ridge of the graft. Afterward, an assessment of patellar tracking will determine the need for any additional soft tissue or bony realignment procedures.

Large post-traumatic tibial plateau lesions are managed with a technique similar to that used in unicompartmental knee arthroplasty. Under fluoroscopic guidance, en bloc resection of the meniscotibial unit with an "L-cut" is performed. Two freehand cuts are made to resect a minimal amount of subchondral bone. K-wires or arthroplasty jigs may be used to assist the surgeon with these cuts. Measurements of the length and width of the resected surface and the joint space gap allow estimation of the required allograft dimensions. Next, the donor graft is secured in the graft holder, and the desired dimensions are marked. Ideally, tibial plateau grafts are 8 to 12 mm thick, which is typical for restoring plateau height after fracture malunion. A reciprocating saw is used to make the vertical cut, and an oscillating saw is used to make the horizontal cut referencing off the marks placed on the graft margins. Once sculpted to the optimal size and shape, the graft is lavaged and carefully inserted in the anatomic position adjacent to the femoral condyle. The knee is taken through a ROM, and the graft is inspected visually and under fluoroscopy to assess graft position and restoration of the joint line and tibial slope. Revisions are made as necessary to optimize graft fit and position as well as overall joint alignment and mechanics. The graft is then fixed with 2 interfragmentary screws placed from the submeniscal articular margin at the midcoronal and anterior positions. After fixation of the bone, the meniscus is repaired in the standard fashion.

Postoperative Protocol

Phase I: 0 to 4 Weeks

In the first phase of rehabilitation, patient goals are to control pain and swelling, restore muscle control, improve knee ROM, and protect the allograft. Patients are allowed unrestricted early nonweightbearing motion unless a concurrent procedure dictates otherwise. Weightbearing status varies based on lesion location, but the general goal is to avoid placing stress on the transplanted area. Patients with tibial or femoral grafts are restricted to toe-touch weightbearing for 6 weeks. Patients with patellofemoral grafts are permitted weightbearing as tolerated in extension but are limited to between 30 and 45 degrees of active flexion. In addition to passive- and active-assisted knee ROM, exercises include stretching and isometric strengthening of the quadriceps, hamstrings, and gluteus muscles. Although knee braces are not required, they may be useful for patients with patellofemoral grafts by limiting knee flexion to less than 45 degrees.[18] For patients with bipolar knee lesions, an unloader brace may be useful as they progress to full weightbearing.

Phase II: 4 to 12 Weeks

In the second phase, patient goals are to regain full ROM, a normalized gait, and the ability to perform functional activities of daily life. Stretching and isometric strengthening exercises are continued as weightbearing is progressed. Typically, once the patient has adequate quadriceps control and can perform a straight leg raise without an extension lag, initiation of a stationary cycle is appropriate. Gait training and closed chain exercises are introduced. For focal lesion treated with a single plug graft, full weightbearing is generally allowed by 6 to 8 weeks. Patients with large or complex grafts are restricted to partial weightbearing for 8 to 12 weeks.

Phase III: 12 to 18 Weeks

The final phase of rehabilitation varies based on the goals and expectations of the patient. For the patient with a goal of performing activities of daily living, a transition is made to a maintenance home exercise program. Recreational sports are not reintroduced until joint rehabilitation is complete and radiographic healing has been demonstrated, which generally occurs no earlier than 4 to 6 months postoperatively. In athletes, this phase focuses on advanced strengthening, core stabilization, proprioception, and gradual return to sport-specific training. At a minimum, athletes should demonstrate full knee ROM, no effusion, joint stability, excellent dynamic strength, and have clinical and radiographic evidence of complete graft incorporation before returning to the highest level of activity. Ideally, high-loading activities should be avoided until at least 6 to 12 months postoperatively.[19]

Potential Complications

Early Complications

Use of a limited arthrotomy and emphasis on early motion is advised to avoid arthrofibrosis. Superficial and deep surgical site infections may occur and must be distinguished based on laboratory markers, physical examination, and joint aspiration. The risk of surgical site infection is low as long as the graft is processed and handled properly and graft lavage and appropriate perioperative antibiotics are used. Allograft-related complications, such as disease transmission, infection, and immunogenic reaction, are rare but may arise.[20-23] Occasionally, patients may develop recurrent sterile effusions related to overuse or an immune-mediated synovitis. These symptoms typically resolve with symptomatic management (ie, aspiration, rest, ice, compression) without requiring graft removal. Graft failure with fragmentation and collapse may occur. Delayed or nonunion of the allograft is extremely rare but may occur with use of larger allografts or in patients with compromised subchondral bone.[24]

Late Complications

Late graft failure may be characterized by fracture of the graft, incomplete remodeling of the graft-bone interface, and/or resorption of allograft tissue. Graft fragmentation and collapse may result from incomplete healing with host bone due to limited revascularization.[25] Progression of the underlying disease process (ie, additional chondral lesions, osteoarthritis, avascular necrosis) may result in recurrent or persistent symptoms independent of graft status.

Top Technical Pearls for the Procedure

1. Prior to surgical incision, ensure the OCA is for the correct patient, the correct knee, and the correct anatomic location. Inspect the allograft tissue to confirm adequacy of the size-match and overall quality.
2. When using the press-fit technique, during preparation of the recipient site, ensure the cylinder-sizing guide is placed perpendicular to the joint surface to ensure a uniform socket for the donor plug.
3. During preparation of the recipient site articular surface, limit the depth of the recipient socket (eg, 5 to 8 mm) to reduce the amount of allograft bone that must ultimately heal/incorporate. Save subchondral bone from reaming to fill defects or adjust height of the OCA.
4. Pulse lavage of the OCA prior to insertion will decrease marrow elements and immunogenicity of allograft bone.
5. After implantation, if the OCA is not secure, fix with a bioabsorbable compression screw that is advanced to a level just below the articular surface and just beneath the subchondral plate.

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