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SPECIAL FOCUS

Osteochondral Allografts for Large Defects in the Knee

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ABSTRACT

Localized osteochondral and chondral lesions of the knee are commonly encountered in orthopaedic practice. They may become symptomatic with patients experiencing pain, swelling, and mechanical symptoms. These lesions have limited ability to heal and may progress to osteoarthritis. This presents an especially difficult clinical problem in young, high-demand individuals. This has led surgeons to pursue biologic solutions for the restoration of damaged cartilage and underlying bone. We have investigated the use of prolonged fresh osteochondral allografts for the treatment of large defects of the knee. The surgical considerations and techniques are presented in this article.
Keywords: osteochondral allograft, knee, articular cartilage, transplantation

HISTORICAL PERSPECTIVE

Larger and deeper defects have limited ability to heal and may progress to osteoarthritis.[1–6] The ability to resurface these defects with mature hyaline articular cartilage and address the underlying bone deficit in a single procedure makes osteochondral allograft (OCA) transplantation an attractive option. The appropriate size and surface contour can be matched when the graft is obtained from an appropriately selected organ donor. The biology of articular cartilage makes it ideal for transplantation. It is both aneural and relatively avascular, receiving its nutrition by diffusion from synovial fluid. Furthermore, it is a relatively immuno-privileged tissue.[7] The chondrocytes are protected from the host immune surveillance by the surrounding matrix. Therefore, this allows mature living chondrocytes to survive for many years after transplantation without the need for tissue matching or immunosuppressive therapy.[8,9]

In the 1970s, musculoskeletal tumor surgeons began using frozen OCAs for reconstruction.[3,10] The freezing process decreased immunogenicity and prolonged storage times, but at the expense of chondrocyte viability. These are best considered biologic implants, rather than transplants, because the cells are not alive. Therefore, surgeons seeking to restore focal osteoarticular defects with living chondrocytes have sought to use fresh allografts.

Recent advances in allograft processing and storage have made fresh grafts more commercially available. Grafts are harvested and are kept refrigerated in dimethyl sulfoxide at 4°C. This allows for the storage of the grafts for up to 42 days, or so-called "prolonged fresh" grafts.[11,12] These grafts have been shown to have minimal immune response, preserved chondrocyte viability, and enhanced revascularization of the bone.[13,14]

The ability to prolong fresh grafts up to several weeks has several practical advantages. The safety of the grafts is enhanced by allowing time for complete bacteriologic and DNA polymerase chain reaction screening. This testing period may take up to 14 days, during which the patient and surgeon are able to schedule and plan for the surgery. The longer life of the graft affords more time to find an appropriate match and perform the transplant, thereby minimizing the number of donor grafts wasted due to expiration. This effectively increases the supply of grafts and makes them now more available to the general orthopedic community. These factors have spawned renewed interest in their use for the treatment of osteochondral defects in young, active patients.

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PREOPERATIVE EVALUATION

History

The diagnosis of a symptomatic osteochondral lesion in the knee may be suspected based on the patient's history. However, the presentation may vary based on the etiology of the lesion. Most commonly, these patients will have a history of an osteochondritis dissecans (OCD) lesion diagnosed in adolescence. Avascular necrosis may have an insidious onset of pain, which can often be linked to a history of known risk factors, such as steroid or alcohol use. Those with traumatic defects will often recall a specific inciting event or injury, whereas those with more degenerative lesions often will not.

It is important to note that not all osteochondral lesions require treatment. Incidental lesions are frequently found on radiographs or during knee arthroscopy for the treatment of other pathology. For all incidental lesions, it is preferable to follow patients nonoperatively and delay treatment until they develop signs and symptoms referable to the lesion. This often involves waiting up to 6 months after a meniscectomy, debridement, bone grafting, microfracture, or ligament reconstruction.

Typically, patients will complain of mechanical symptoms such as catching, locking, or giving way. They will often give a history of recurrent knee swelling after activity. They may complain of pain specific to the compartment involved, although the level of pain is often quite variable. For those with avascular necrosis, pain may be the presenting complaint. For those with OCD, pain may be relatively minor compared with their mechanical symptoms.

Physical Examination

The physical examination begins with inspection. An evaluation of the patient's gait may reveal an antalgic or stiff-knee gait. This also allows for an evaluation of the overall limb alignment. For example, large medial lesions will often result in an obvious varus malalignment. Quadriceps atrophy correlates with the duration and severity of symptoms. The presence of an effusion is of paramount importance in detecting intraarticular pathology. Occasionally, patients referred for treatment of a meniscal tear will present with a tense effusion. This degree of swelling should increase one's suspicion for an osteochondral lesion. Range of motion is usually preserved but may be limited in patients with a large effusion or loose bodies. Ranging the knee also allows for the assessment of the location of the lesion when catching, or crepitus in a specific range is identified. Patients with large condylar lesions will often have tenderness to palpation directly over the condyle with the knee placed in flexion. Up to one half of these patients may present with bilateral knee pathology, and it is therefore important to evaluate both knees.

TABLE 1. *Standard Radiographic Series*

- Standing anterior-posterior view with the knee in full extension
- Standing posterior-anterior view with the knee flexed 45 degrees (Tunnel or Notch view)
- Lateral view
- Patellar (Sunrise) view
- Bilateral long-leg alignment films

Imaging

A standardized series of radiographs is included in Table 1. Weight-bearing views are essential in determining the degree of joint space narrowing and arthrosis. In addition to the standing anterior-posterior view, a standing posterior-anterior tunnel view obtained in 45 degrees of flexion is helpful (Fig. 1). Occasionally, a large OCD lesion will only be detected on this view. Standing bilateral long-leg alignment views are also used to measure the mechanical axis through the knee. These will be used to ensure that the knee is corrected to a neutral position with a concomitant osteotomy if needed. These views should be obtained with a radiologic marker alongside the knee, which will be used to correct for magnification when ordering donor tissue of an appropriate size.

Magnetic resonance imaging (MRI) remains the gold standard for the evaluation of osteochondral lesions. The sagittal and coronal images can be used to assess the size, depth, and location of the lesion (Fig. 2). Chondral lesions will often have high signal on T2 images in the underlying subchondral bone marrow due to edema. It is important to differentiate this reactive edema from a true osseous defect, so as not to overestimate the extent of the lesion. The presence of high signal on T2 images behind an OCD lesion is highly suggestive of an unstable fragment. In general, a closed high-field magnet (Tesla of 1.5 or greater) with proton density fast-spin echo sequences often provides the greatest resolution of articular cartilage. MR arthrography is not widely used in the knee.

Patients often present with the arthroscopic photographs from their previous procedure. These can be very helpful and may obviate the need for a diagnostic arthroscopy. However, most patients will require a diagnostic arthroscopy to adequately assess the lesion and any concomitant pathology.

Indications and Contraindications

This procedure is indicated for patients with symptomatic, large osteochondral, or full-thickness chondral lesions. Some defects are not amenable to other resurfacing techniques due to their size, location, or depth. Smaller lesions may be amenable to autologous osteochondral

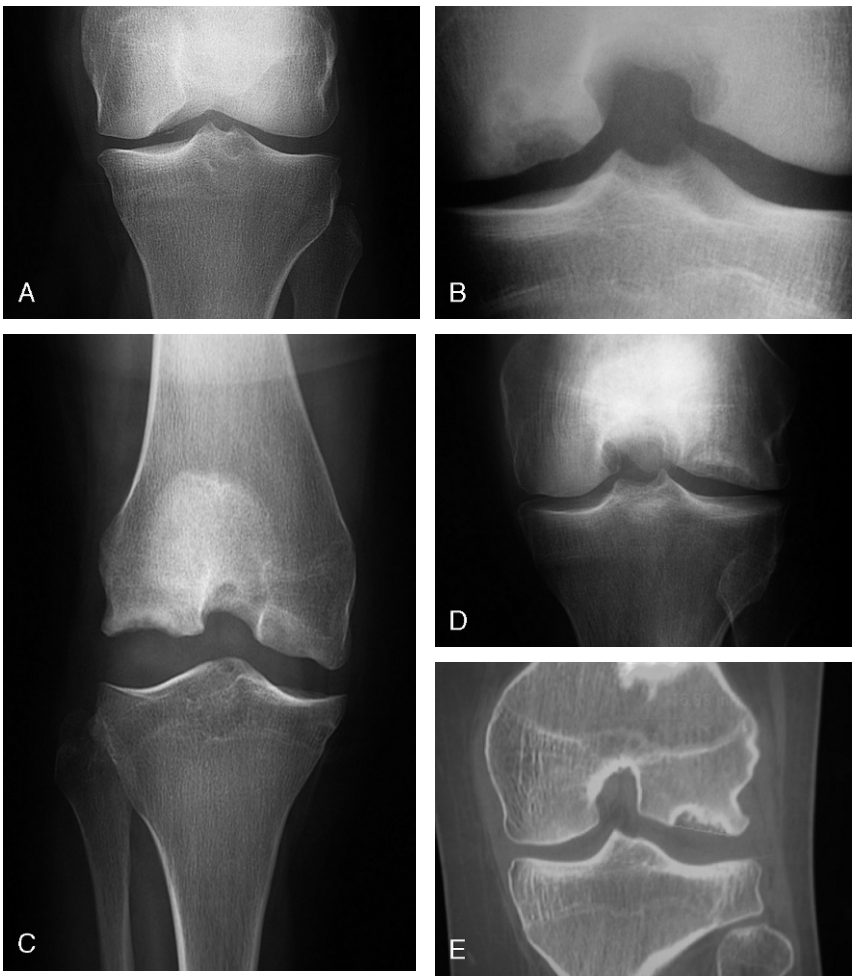

FIGURE 1. **(A)** Anterior-posterior radiograph of OCD lesion on the lateral aspect of the medial femoral condyle. **(B)** The notch view more clearly demonstrates the size of the lesion. **(C)** Radiograph demonstrating severe deformity of the condyles in a young patient before undergoing OCA transplantation to both condyles. **(D)** Standard radiographic notch view shows a large OCD lesion of the lateral femoral condyle. **(E)** A CT scan demonstrates the extent of bone loss in this LFC defect.

plug transfer. However, the amount of available autologous tissue and the associated donor site morbidity may be prohibitive for lesions larger than 2 to 3 cm^2. Microfracture or autologous chondrocyte implantation is useful for superficial defects. When the defect extends through the subchondral bone or involves a structural or uncontained segment, osteochondral allografting may be preferred as a single-stage treatment. In fact, most patients

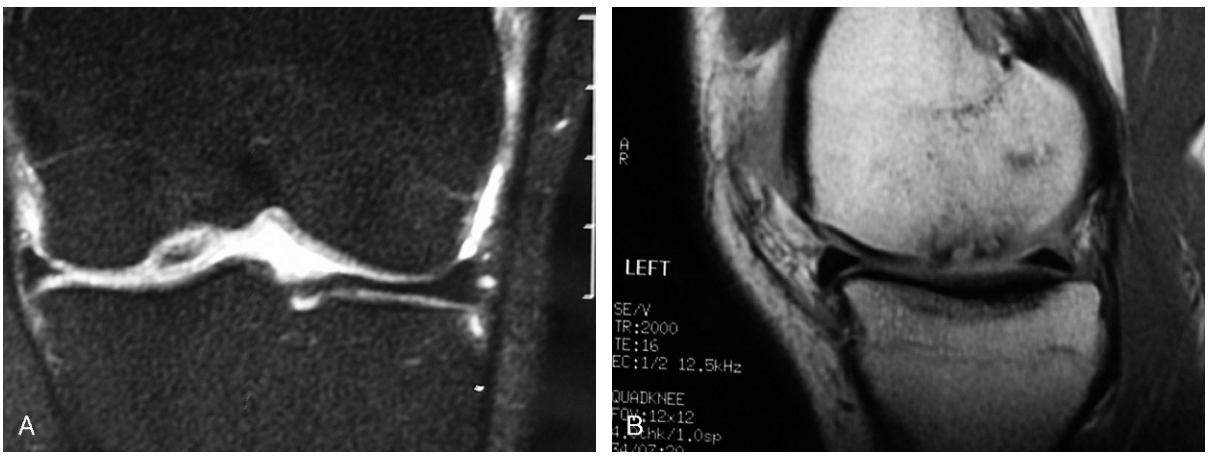

FIGURE 2. **(A)** MRI of an OCD lesion on the medial femoral condyle—coronal view. **(B)** MRI of an OCD lesion on the medial femoral condyle—sagittal view.

undergoing OCA transplantation have failed other techniques. In general, OCA transplantation is an excellent option for focal defects larger than 2 to 3 cm^2 with underlying bony deficiency or as salvage for other failed resurfacing technique.

There are few contraindications for OCA transplantation. Patients with advanced or diffuse degenerative changes as seen on weight-bearing radiographs may be best served with knee arthroplasty. Bipolar lesions represent a relative contraindication and have less predictable outcomes. If present, both lesions should be addressed. Often the larger, deeper defect is allografted, and the more superficial kissing lesion is amenable to microfracture. Osteochondral allograft transplantation is contraindicated in patients with uncorrectable malalignment, ligamentous instability, or meniscal insufficiency. These comorbidities must be addressed before or during the transplantation to provide an optimal environment for the graft.

PREOPERATIVE PLANNING

As discussed above, a prior diagnostic arthroscopy can be helpful in determining the size and location of the defect and in identifying any other pathology that may require treatment. The required allograft tissues that are size and side matched can then be ordered. If needed, meniscal or ligament allografts are frozen and therefore can be reserved for the patient while awaiting availability of a fresh osteochondral graft. The tissue bank will provide notification when a potential graft has been harvested. It then takes approximately 7 to 14 days for the completion of all serologic and bacteriologic testing. This provides sufficient time to contact the patient and schedule the surgery. We prefer to implant the graft before 21 days after donor harvest due to concerns for decreasing cell viability beyond that time point.[15] Measurement of the limb alignment is made on the long-leg films (Fig. 3). If needed, high tibial or distal femoral osteotomies are used to correct malalignment. The degree of correction should be calculated to bring the mechanical axis to neutral, but not overcorrection as in salvage.

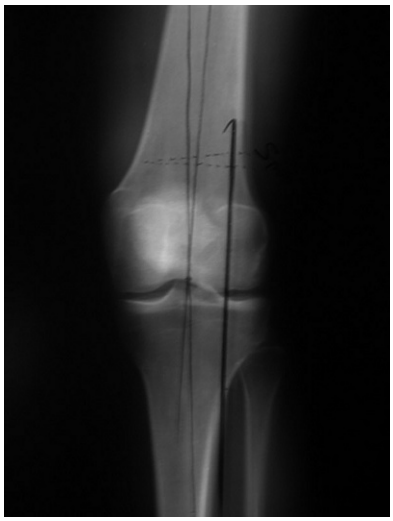

FIGURE 3. Long-leg alignment films are used to determine if an osteotomy is required to achieve neutral limb alignment.

TABLE 2. *Order of Concurrent Procedures*

1. Exam under anesthesia
2. Arthroscopy
a. Diagnostic arthroscopy
b. Debridement/Microfracture of any associated lesions
c. Ligament reconstruction and fixation
d. Meniscus transplantation
3. Arthrotomy
a. Osteochondral allograft transplantation
4. Osteotomy
5. Wound closure

It is not uncommon for a knee to require multiple procedures at the time of OCA transplantation. Therefore, the surgeon must select the optimal order for the steps involved in these concurrent procedures. An algorithm is presented in Table 2. In general, arthroscopic procedures should be performed before making the arthrotomy. This would include a diagnostic arthroscopy if it has not been previously performed by the treating surgeon. Other arthroscopic procedures such as meniscal transplantation and microfracture are best performed at this stage. If a ligament reconstruction is to be performed, drilling the tunnels, graft passage, and fixation can be performed before allograft transplantation. If an osteotomy is required, it may be best to perform this procedure at the end of the case to avoid undue stress at the osteotomy site.

SURGICAL TECHNIQUE

Positioning

This procedure is performed on an outpatient basis and can be done under general or regional anesthesia. Before induction, the surgeon must assess the allograft tissue to ensure that it is of the appropriate size and side matched. The patient is then placed supine on a standard operating room table. A well-padded proximal thigh tourniquet is placed on the patient and is inflated before the arthrotomy. A foot holder device is especially useful to maintain high degrees of flexion needed for accessing more posterior lesions.

Exposure

An anterior skin incision is made from the proximal pole of the patella to the level of the joint surface. Although a midline incision is used most commonly, it can be moved medially or laterally toward the involved compartment. Once the capsule is exposed, a limited peripatellar arthrotomy is made over the involved compartment. This is

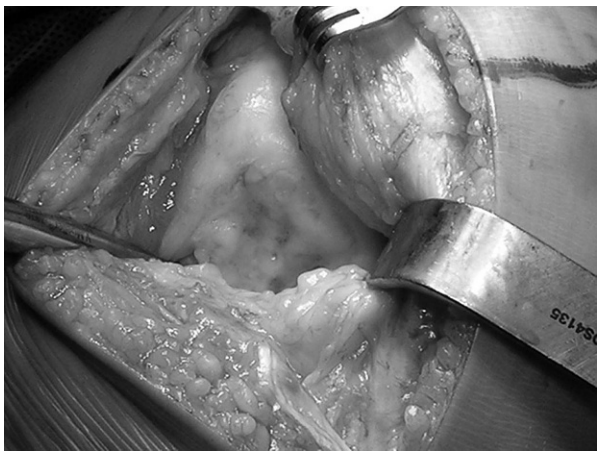

FIGURE 4. Exposure of lesion on lateral femoral condyle using a limited arthrotomy.

made laterally for lateral defects and medially for medial or bicondylar defects. The incision can be extended proximally using a sub-vastus or mid-vastus approach as needed for greater exposure. The patella is retracted by placing a z- or bent Hohman retractor in the notch. It can be helpful to release the fat pad and dissect the capsule off of the anterior horn of the meniscus to improve exposure. The knee can be flexed, extended, or rotated to place the defect in the center of the incision (Fig. 4). Once the defect has been confirmed, the allograft can be opened and placed on the back table allowing it to gradually rewarm at room temperature. We prefer to place the graft in cool saline with antibiotics (approximately 22°C) before placing in room temperature water because of concerns regarding the effects of rapid rewarming.[15]

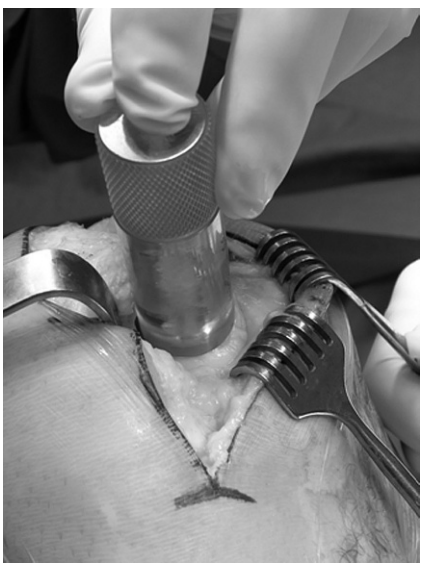

FIGURE 5. Sizing guide placed over defect. This will be used to determine the size of the allograft as it is harvested.

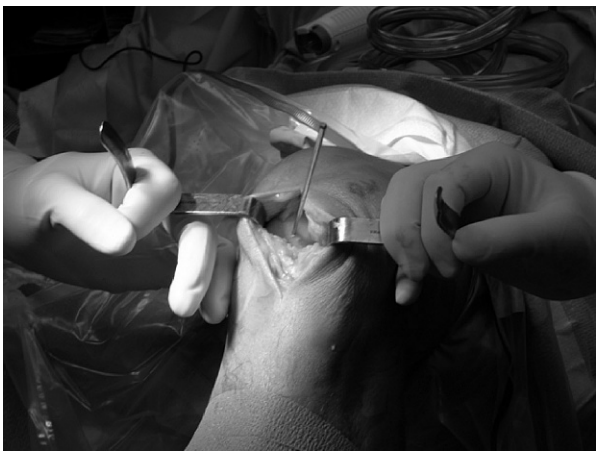

FIGURE 6. Guide pin driven into defect site to ensure perpendicular placement of the reamer.

Defect Preparation

Once the defect has been identified, the surrounding damaged cartilage and bone is debrided. This allows for more accurate sizing of the lesion. For most contained defects, a press-fit technique can be performed using a commercial system (Arthrex, Naples, FL). A cannulated, cylindrical sizing guide is positioned such that it completely encompasses the defect (Fig. 5). This determines the optimal plug diameter. It must sit flush with the surrounding normal cartilage to properly restore the geometry of the articular surface. A guide pin is driven into the base of the defect, thereby setting the center and perpendicular axis (Fig. 6). The sizing tube is then removed and taken to the back table where it is positioned on the donor graft to ensure that the size and location can be properly matched. A cannulated counter bore reamer is advanced over the guide pin to a depth of 6 to 8 mm (Fig. 7). Multiple perforations are made in the base of the defect using a k-wire to allow for

FIGURE 7. Counter-bore reamer advanced down to 6 to 8 mm into the defect site.

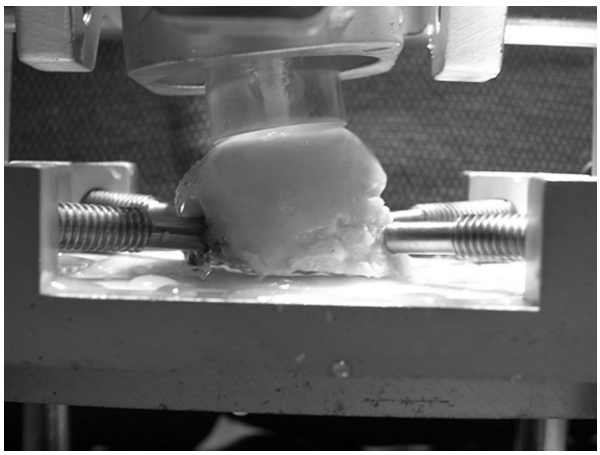

FIGURE 8. Sizing the allograft while it is fixed in the allograft harvester.

vascular inflow. A skin marker is used to mark the 12 o'clock position for reference. A 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.

For uncontained or large structural lesions, a free-hand technique is used. A skin marker is used to outline a geometrical shape that encompasses the defect. A 15-blade knife is used to incise the remaining cartilage, which is then removed using sharp curettes. A high-speed burr is used to remove the underlying bone. Cold irrigation is used during reaming or burring to prevent thermal injury to the surrounding normal tissues.

Graft Preparation

Graft preparation is performed on the back table. For the press-fit technique, it is helpful to use a graft workstation. The donor graft is positioned in the workstation and a bushing of the chosen diameter is placed in the platform. The sizing tube is again used to confirm that the selected angle will match the contour of the defect (Fig. 8). The 12 o'clock position is marked. A donor harvester is passed through the housing and advanced through the entire depth of the donor graft. The plug is then extracted from the harvester. The chosen depths are then marked for each of the 4 quadrants. An allograft forceps is used to hold the plug, whereas a sagittal saw is used to trim the excess bone. For the free-hand technique, the donor graft is fashioned using a sagittal saw. It is advisable to make these cuts slightly wider than measured to allow for trial fittings. Once the graft has been prepared, pulsatile lavage is used to remove any remaining marrow elements, which are felt to be the most immunogenic part of the graft.

Insertion and Fixation

By aligning the 12 o'clock markings, the graft is pressed into place by hand (Fig. 9). If it does not pass easily, the dilator can be used to provide an additional 0.5 mm of dilation. Occasionally, on oversized tamp is used to ensure that the graft is flush with the surrounding articular surface. This step should be minimized to preserve maximal chondrocyte viability. For the press-fit technique, additional fixation is usually not necessary. For the larger structural grafts, fixation can be achieved using compression screws or bioabsorbable polydioxanone pins (Johnson and Johnson Professional, Raynham, MA).

■ POSTOPERATIVE CONSIDERATIONS

Analgesia

These procedures are performed in an outpatient setting. For cases involving multiple procedures, a postoperative femoral nerve block can be used to assist with immediate postoperative analgesia. A compressive, cryotherapy

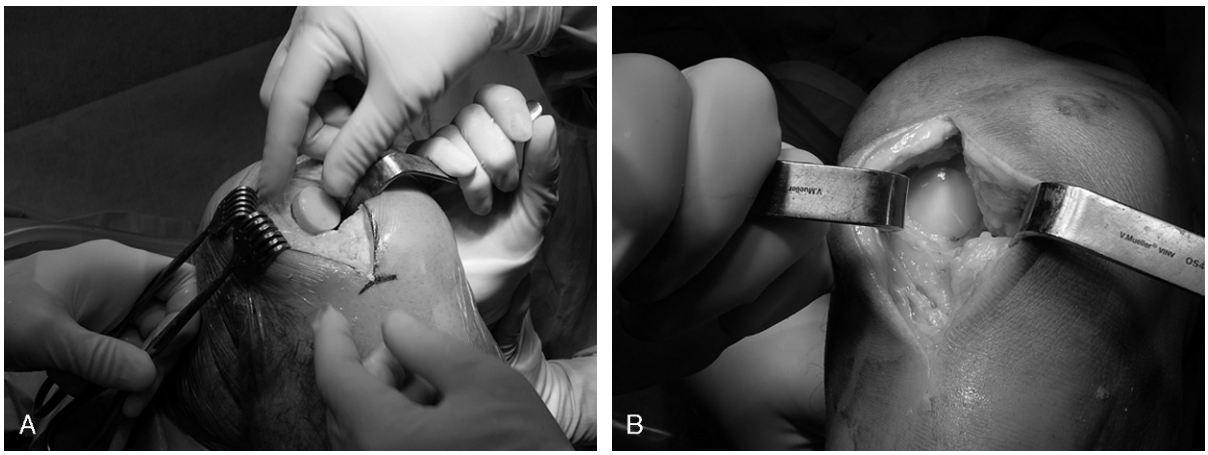

FIGURE 9. **(A)** Press-fitting the allograft into the recipient hole by hand. Occasionally, an oversize tamp will be used to ensure that the articular surfaces of the graft and native cartilage are even. **(B)** Final view of the allograft before closure. The graft has been press-fit into the recipient hole, and no further fixation is necessary.

TABLE 3. *Postoperative Rehabilitation Protocol*

Timing	Activity
0–6 wk	• CPM • Quad sets, straight leg raises, patellar mobilization • TTWB (alternatively, WBAT)
4–8 wk	• CPM • Stationary bicycle • Discontinue brace • Progress to full WB
4–6 mo	• Strengthening • Return to light recreational sports
12 mo	• Return to high-impact sports, if desired

CPM indicates continuous passive motion; TTWB, toe-touch weight-bearing; WBAT, weight-bearing as tolerated; WB, weight-bearing.

device (Game Ready, Inc., Berkeley, CA) is helpful to control pain and swelling. Nonsteroidal medications are generally not used during the period of graft integration.

Rehabilitation

Motion is essential to any chondral resurfacing procedure. Although a brace is used for protection during ambulation, patients are generally allowed unrestricted motion unless a concurrent procedure would dictate otherwise. Continuous passive motion (CPM) is started the day of surgery. Patients are encouraged to use the CPM for 6 to 8 hours per day for the first 6 weeks to prevent adhesions and to accelerate the healing process and to promote graft nutrition. Patients begin supervised physical therapy after the first postoperative visit. A therapy protocol is included in Table 3.

Traditionally, these patients have been placed on restricted weight-bearing with the use of crutches. This involves 6 weeks of toe- or heel-touch weight-bearing before they are gradually progressed to full weight-bearing. More recently, we have begun studying the use of immediate weight-bearing as tolerated for patients with stable grafts. Once quadriceps function has returned, the brace is discontinued and closed chain strengthening is begun. By 3 months, patients are expected to have full motion and near-normal quadriceps strength. Patients may begin light recreational activities by 4 to 6 months. Higher impact activities are not recommended during the first year.

Complications

Complications may arise due to the arthrotomy or the donor graft. Stiffness is a concern in the immediate postoperative period. The use of the limited arthrotomy and emphasis one arly motion minimize this risk. Infection and disease transmission are concerns with any allograft tissue. There is only one documented case of HIV transmission from an OCA back in 1988.[16] With present tissue banking regulations and the use of DNA polymerase chain reaction testing, there have been no known cases of HIV or Hepatitis C transmission that form an OCA. Occasionally, certain individuals may experience recurrent sterile effusions that are thought to be related to a host immune response. These typically resolve without requiring the removal of the graft. Graft nonunion or fragmentation and collapse is uncommon but may occur from months to years after the procedure. Periodic radiographic screening is recommended.

■ RESULTS

Several studies have reported the outcome of fresh OCA transplantation in the knee.[17–23] Since 1972, Allen Gross has been a pioneer in the use of OCA transplantation for traumatic defects of the knee. Although

TABLE 4. *Results of Osteochondral Allografting*

Author	Patient no.	Mean age	Location	Mean FU	Results
Meyers et al[23]	39	38	F, T, P	3.6 y	78% success 22% failure
Garrett[20]	17	20	F	3.5 y	94% success
Ghazavi et al[21]	123	35	F, T, P	7.5 y	85% success
Chu et al[19]	55	35	F, T, P	75 mo	76% good/excellent 16% failure
Bugbee[24]	122	34	F	5 and 10 y	91% success at 5 y 75% success at 10 y 5% failure
Aubin et al[17]	60	27	F	10 y	84% good/excellent 20% failure
Sasha et al[25]	65	N/A	T	12 y	Kaplan-Meier survival rate: 5 y—95% 10 y—80% 15 y—65% 20 y—46%

F indicates femur; T, tibia; P, patella.

many of these were larger, uncontained structural grafts, his Toronto group still reported excellent results with 85% survivorship of the grafts at follow-up of 7.5 and 10 years.[17,21,22] These grafts were stored for a maximum of 72 hours. Two studies looked specifically at its use for the treatment of OCD of the femoral condyles. Garrett[20] reported a successful outcome in 16 out of 17 patients who were asymptomatic at 2- to 9-year follow-up. Bugbee et al[18] reported 79% good or excellent results for a larger series of 69 patients at an average follow-up of 5 years when the grafts were implanted within 5 days of procurement. Meyers et al and Chu et al both reported on the use of fresh OCA for lesions due to multiple different diagnoses. In addition to OCD and traumatic defects, they also included degenerative and osteonecrotic lesions. They reported 77% and 84% good or excellent results, respectively.[19,23] The results are summarized in Table 4.

We recently completed a prospective study of 25 consecutive patients who underwent "prolonged fresh" OCA transplantation for defects on the femoral condyles with a minimum follow-up of 2 years. All procedures were performed by the senior author (B.J.C.). They included degenerative, traumatic, osteonecrotic, and OCDs lesions. The average size of the primary lesion was 5.24 cm^2. Ninety-six percent had undergone a previous surgery to treat the lesion, and the average number of previous procedures was 2.28. In contrast to the studies mentioned above, our "prolonged fresh" grafts were implanted at an average of 24 days after procurement. The average length of follow-up was 35 months. Statistically significant improvements were seen for Lysholm (39–67), IKDC (29–58), all 5 components of the KOOS scores (Pain, 43–73; Symptom, 46–64; Activities of Daily Living, 56–83; Sports, 18–46; Quality of Life, 22–50), and the SF-12 physical component score (36–40). Overall, patients reported an 84% satisfaction with their results and felt that the knee functioned at 79% of their unaffected knee. Radiographically, 88% were incorporated into host bone (Fig. 10), and there was one case of graft fragmentation. It is encouraging that these results of prolonged fresh grafts are similar to the other published reports of OCA transplantation performed within 1 week.

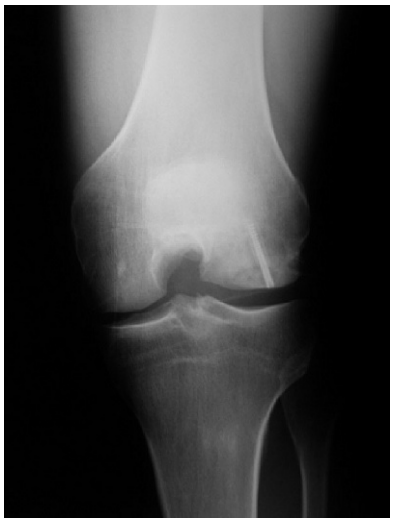

FIGURE 10. A radiograph taken at a 2-year follow-up visit demonstrates a well-integrated lateral femoral condyle allograft.

FUTURE OF THE TECHNIQUE

In summary, fresh OCA transplantation is a safe and effective procedure for the treatment of osteochondral defects of the femoral condyles. It decreases pain and improves function in young, high-demand patients in whom knee arthroplasty is a poor option. The effects of the duration of prolonged storage of these grafts on clinical outcome remain to be determined. Studies are presently underway to further assess the long-term viability of the cartilage, the influence of impaction at insertion, and the role of postoperative protected weight-bearing.

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