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Osteochondral Allograft Transplantation and Osteochondral Autograft Transfer

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Cartilage defects commonly occur in young, active patients and can be debilitating injuries with patients experiencing significant pain and swelling. Clinical diagnosis is made using a combination of patient history, physical exam, imaging, and diagnostic arthroscopy. In patients who have failed conservative measures such as physical therapy, tolerable lifestyle modification, and injection treatments, surgical options exist including microfracture, autologous chondrocyte implantation, osteochondral autograft transfer, or osteochondral allograft transplantation. In this article, we present the diagnosis, indications, surgical technique, and reported outcomes for the treatment of cartilage defects with both osteochondral autograft transfer and osteochondral allograft transplantation.
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Overview

The management of articular cartilage injuries in the active patient can present a challenging problem; however, with proper indications, patient selection, and technical expertise, these patients may have substantial increases in function and satisfaction and a high rate of return to activity. Patients should have specific intraarticular symptoms, be of a relatively normal body mass index (BMI) and have neutral alignment. Radiographic and arthroscopically confirmed pathology should align with the patient's symptoms and exam. The articular cartilage lesion size and location will influence the treatment strategy and concomitant pathology simultaneously addressed.

History, Exam, Imaging

Patients with cartilage defects typically present with a history of prior knee injury and or surgery. Localized knee pain and joint swelling are common symptoms which are often exacerbated by physical activity. Patients may report mechanical symptoms including catching, locking, and giving way.

On physical examination, patients typically have preserved range of motion and an effusion is often observed. The affected compartment is typically tender to palpation there may be catching or accreditation in the affected compartment. Quadriceps atrophy is typically seen secondary to the chronicity of the pathology. Loose bodies from chondral fragments are not uncommon and may be associated with locking or limited range of motion.

Current imaging practices include weight bearing radiographs. We obtain a weight bearing anteroposterior, lateral, and skiers or notch view of the knee (Fig. 1). A sunrise view is obtained to evaluate patellofemoral joint. We also obtain bilateral long leg alignment radiographs to evaluate the mechanical axis for any varus or valgus deformity that may be predispose the patient to chondral damage (Fig. 1).

Recent knee magnetic resonance imaging is imperative for preoperative planning. T2 weighted magnetic resonance imaging provides the best method of preoperatively estimating the defect size and evaluating the subchondral bone for edema or possible cysts which may require bone grafting (Fig. 2).

The authors prefer to treat the cartilage lesions in a staged fashion to accurately assess the degree of pathology and lesion dimensions after diagnostic arthroscopy and debridement (Fig. 3). Some patients improve following debridement and may become at least temporarily asymptomatic.[1] If an outside surgeon has recently performed a knee arthroscopy or previously treated the cartilage defect, the operative report, and intraoperative arthroscopic photographs should be obtained for preoperative planning.

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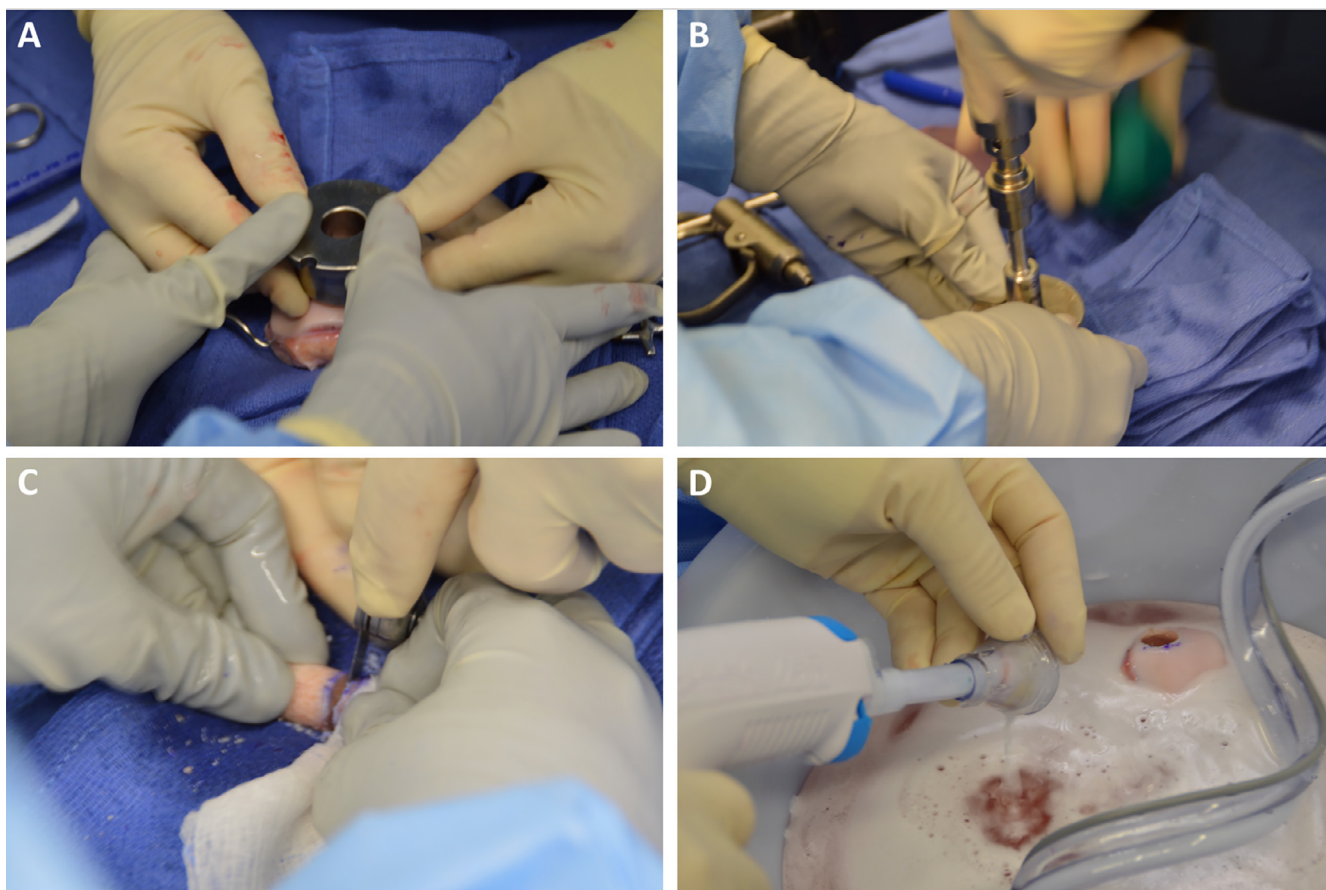
Figure 1 Preoperative radiographs. (A) Representative standing weight-bearing radiograph to evaluate sagittal alignment demonstrating varus deformity predisposing the patient to medial compartment osteochondral pathology. (B) Representative anteroposterior standing radiograph of bilateral knees showing a potential osteochondral lesion of the right medial femoral condyle. (C) Lateral radiograph of the right knee.
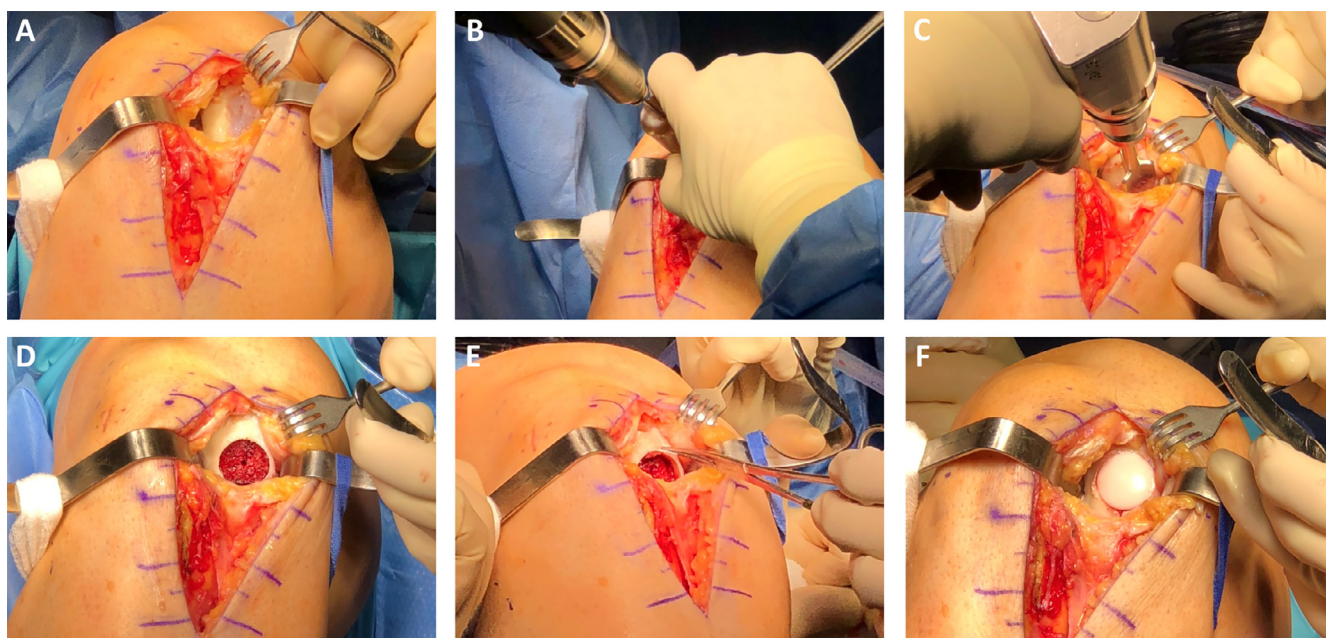

Figure 2 Preoperative magnetic resonance imaging right knee. T2 weighted sagittal (A) and coronal (B) MRI images depicting a focal chondral defect of the posterior lateral femoral condyle with subchondral edema. (C) T2 weighted axial MRI image depicting a focal chondral defect of the medial patellar facet.
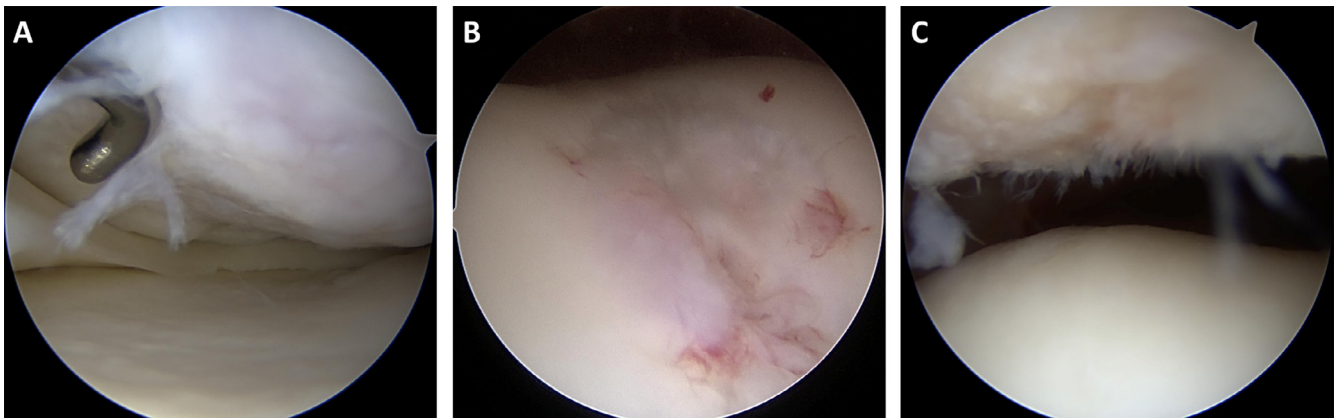
Figure 3 Intraoperative Findings. (A) Arthroscopic images of ICRS Grade III/IV focal chondral defects of the right (A) lateral femoral condyle, (B) central trochlea, and C) patella.

Osteochondral Autograft

Indications

The initial treatment strategy for chondral defects includes rest, oral nonsteroidal anti-inflammatory drugs, and injection with cortisone and/or hyaluronic acid. Physical therapy prior to surgical intervention may also be considered. For patients with refractory symptoms, osteochondral autograft transfer (OAT) may be considered for those patients with higher demands and an articular cartilage lesion less than 2-3 cm^2. Patients should have neutral alignment and a relatively normal BMI.

Surgical Technique

The patient should be positioned supine for knee arthroscopy. A standard leg holder may be used with the foot of the bed dropped to allow greater flexibility in accessing the lesions on the posterior femoral condyle. A tourniquet is used to improve visualization. Diagnostic arthroscopy is performed through standard anterolateral and anteromedial portals. Trajectories for plug harvest can be confirmed arthroscopically with spinal needle localization to plan for the most efficient harvest and placement incisions. The senior author (B.J.C.) prefers to harvest through a small incision and implant arthroscopically.

A small superolateral incision is made and 2 retractors are used to expose the superolateral trochlea. The lateral trochlea offers the advantages of low contact forces, a convex curvature to match recipient sites, and relatively easy access through limited incisions. Additional sources of osteochondral donor plugs include the superomedial trochlea and superolateral notch. The contralateral knee could also be considered but is generally avoided.

Once the lesion has been assessed with diagnostic arthroscopy and concomitant pathology addressed, the osteochondral autograft plug can be harvested. We prefer to use the OATS transport system (Arthrex Inc., Naples, FL). A superolateral incision is used to expose the lateral trochlea. An assembled tube extractor is selected based on the lesion size. The harvester is placed perpendicular to the articular surface and mallet used to advance it to a depth of 10-15 mm. The harvester is rotated 90° clockwise and the plug extracted. The plug is removed and inspected. The plug depth is measured to match the recipient site and placed into the recipient site. The graft may be implanted in an open or arthroscopic fashion, but accurate placement without graft prominence is imperative. The surgical incisions are then closed in a layered fashion.

Osteochondral Allograft

Indications

Osteochondral allograft transplantation (OCA) in the knee may be used to treat a variety of disorders including osteochondral defects, malignant disease, or abnormal development.[2-5] OCA was traditionally used to treat chondral defects arising from osteochondritis dissecans or other traumatic cartilage defects after unsuccessful treatment with techniques such as microfracture, mosaicplasty, and autologous chondrocyte implantation (ACI). Cartilage lesions which have not demonstrated success with these techniques in the past are now increasingly being treated with primary OCA. Candidates for OCA have full thickness chondral or osteochondral defects. Larger lesions that are not full-thickness may also be considered due to the size that precludes other cartilage repair or restoration techniques. Focal unipolar defects larger than 2-3 cm^2 are ideal candidates for OCA.

Modifiable comorbidities and concomitant pathologies should be addressed prior to or during OCA including correction of limb malalignment, ligament deficiency, and meniscal deficiency. Bipolar disease is a relative contraindication due to inferior outcomes, although the techniques are evolving. The need for multiple osteochondral allografts for multifocal chondral disease is not contraindicated.[3] Ideally, the patient's body mass index should be less than 30 kg/m^2.

Surgical Technique

The patient is placed supine on a standard operating table with a tourniquet placed on the most proximal thigh. The foot of the bed can be lowered when treating femoral condyle lesions to allow better exposure of the posterior condyles.

The leg is exsanguinated and tourniquet inflated to allow increased visualization. We prefer to first perform a diagnostic arthroscopy to address any additional or interval pathology prior to the allograft transplant.

A medial or lateral parapatellar arthrotomy incision is used to expose the defect on the respective femoral condyle (Fig. 4A). The exposure may be enhanced with retractors placed in the medial or lateral gutter and in the femoral notch. For patellofemoral lesions, a medial parapatellar arthrotomy is utilized. The patella can be everted to expose the articular surface or retracted to expose the femoral trochlea. A cannulated sizing cylinder (Arthrex Inc., Naples, FL) is used to assess defect size (Fig. 4B). The cylinder is centered on the cartilage defect and a guide pin is drilled perpendicularly to the lesion (Fig. 4B). The sizing cylinder is removed and a cannulated reamer is passed over the guide pin and reamed to a depth of 6-8 mm (Fig. 4C, D). The reamer may damage the soft tissue or patellar cartilage if not properly protected and should be monitored during drilling. After reaming, the 12 o'clock position is marked on the recipient site. A no. 15 scalpel is used to sharply debride the recipient site to clean edges as needed. A ruler is used to measure the depth of the recipient site at 12-, 3-, 6-, and 9-o'clock positions in order to accurately prepare the donor osteochondral plug (Fig. 4E). A Kirshner wire or small drill can be used to create vascular channels in the base of the recipient site. The recipient site is then thoroughly irrigated with antibiotic infused saline to remove any osseous or chondral fragments.

The osteochondral allograft plug is fashioned from a femoral hemicondyle allograft. The hemicondyle is trimmed with a powersaw as needed to securely fit it into the allograft workstation. An appropriate radius of curvature is identified on the graft to match that of the donor site. A diameter-specific bushing is centered over the planned harvest site and held securely in place (Fig. 5A). The guide must remain locked in position to avoid compromise of the graft harvest. A circular reamer is then placed into the guide and the cylindrical allograft dowel is reamed with cold irrigation to avoid thermal necrosis (Fig. 5B). After the graft is removed, the 12-o'clock position is confirmed, and the base of the graft is trimmed to the recipient depth measurements using an ACL saw (Fig. 5C). Prior to implantation, the graft is irrigated with pulsatile lavage to removal any remaining marrow components (Fig. 5D).

Immediately prior to graft implantation, the recipient site is dilated using a calibrated dilator to approximately 0.5 mm greater diameter. The 12 o'clock positions are aligned, and the graft is press-fit into the recipient site. An oversized tamp is used with very gentle impaction to fully seat the graft (Fig. 4F). Large grafts that may not be fully secured can be anchored using headless bioabsorbable or compression screws as needed. The arthrotomy is then closed using interrupted #1 or #2 suture. The subcutaneous tissue is then closed in the standard fashion. The knee is placed in a hinged brace locked in extension.

Outcomes
Autograft
OAT has been shown to be a successful, durable treatment option for focal chondral defects, yet there are limitations to its utility due to defect size and donor site morbidity. Hangody et al. reported 10-year outcomes after OAT with 92%, 87%, and 79% success rates in the femoral condyle, tibial plateau, and patella, respectively.[6] Pareek et al. performed a systematic review of 10 studies reporting long-term outcomes after OAT with a total of 610 patients at mean

Figure 4 Osteochondral allograft transplantation of the femoral condyle surgical technique. (A) The patient is placed on the operating table in the supine position with the right knee prepped and draped in a sterile fashion. A parapatellar arthrotomy is performed to expose the chondral defect of the affected condyle. (B) A cylindrical sizing guide is used to measure the chondral defect and appropriately place a guide pin in the center of the defect. (C) A cannulated bone reamer is placed over the guide pin and the chondral defect is reamed to a depth of appropriately 6-8 mm. (D) The recipient site is then irrigated and prepared by removing any loose fragments. (E) The depth of the recipient site is measured at the 12, 3, 6, and 9 o'clock positions to accurately prepare the donor allograft. (F) The allograft plug is press fit into the recipient site to restore the articular surface.
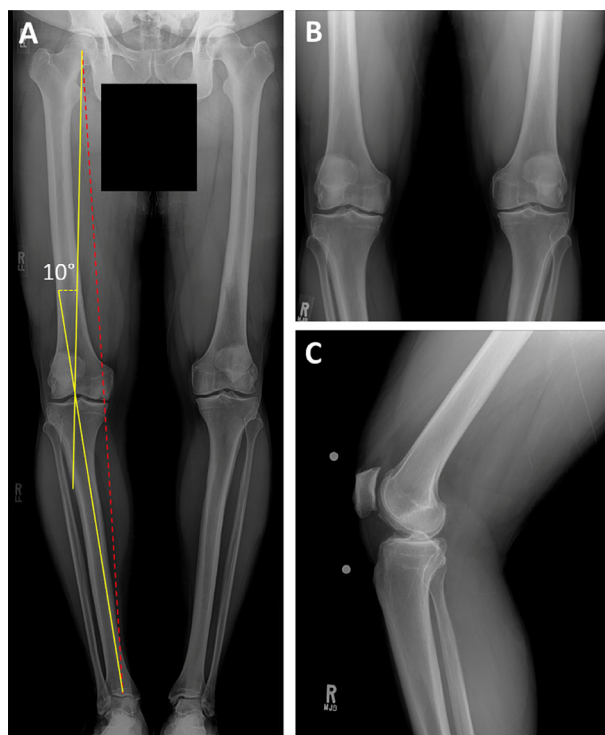
Figure 5 Osteochondral Allograft Preparation. (A) The intact allograft is placed on the sterile back table. A brushing is placed over the desired allograft donor site and (B) used as a guide to cut an allograft dowel using a circular donor harvester. (C) The desired depth, measured from the recipient site, is marked on the allograft dowel and an ACL saw is used to cut at the appropriate level. (D) The allograft plug is irrigated with antibiotic infuse saline via pulse lavage to remove any remaining DNA fragments from the allograft prior to implantation.

10.2-year follow-up and found 72% overall survival and a 19% reoperation rate.[7] Overall, patients experienced significant symptomatic improvement by International Knee Documentation Committee and Lysholm scores.[7] Additionally, OAT has been found to have superior outcomes and return to activity rates when compared to microfracture.[8-10] Horas et al. performed a prospective trial reporting increased symptomatic improvement after OAT compared to ACI.[11] However, Lynch et al. performed a systematic review of 9 studies and did not find a significant difference in clinical outcomes when comparing OAT and ACI.[12]

Despite the successful long-term outcomes overall, correct patient selection is important as multiple factors have been associated with inferior outcomes. Jakob et al. reported an overall 92% success rate at mean 37-month follow-up, however both lesion size and number of plugs used were associated with inferior outcomes.[13] Specifically, patients treated with mosaicplasty requiring 8-12 plugs more commonly experienced donor site morbidity.[13] Similarly, Pareek et al. reported that increased age, defect size, and prior surgery were correlated with failure.[7] Additionally, Gudas et al. found patients with defects with a size less than 2 cm^2 had significantly higher return to sport rates than those with larger defects further supporting its use primarily for smaller lesions.[14]

Allograft

OCA in the knee demonstrates successful short-term, mid-term, and long-term clinical outcomes; however, the results vary depending on the severity of chondral disease, defect location, and patient demographics.[15,16] OCA is most commonly used to treat chondral lesions of the femoral condyles, but can be successfully employed in the patellofemoral joint.[15,17,18] Frank et al. reported a series of 180 patients treated with OCA at 5-year follow-up.[15] While the reoperation rate was high (32%), they found an 87% survival rate with significant symptomatic improvement by Lysholm, International Knee Documentation Committee, Knee Injury and Osteoarthritis Outcome Score, and Short form-12 physical component scores.[15] Similarly, a systematic review of OCA long-term outcomes analyzed a total of 251 patients from five studies and found a 75% survival rate at mean 12.3-year follow-up and significant symptomatic improvement measure by Knee Society Function Score, Knee Society Knee Score, and Lysholm score.[16]

Although the procedure is largely successful, multiple patient-specific factors have been identified that can impact the outcome of the procedure. Frank et al. found that increased body mass index (BMI), worker's compensation status, and increased number of prior knee procedures were associated with reoperation while only increased BMI and number of prior ipsilateral knee procedures were associated with failure.[15] The effect of BMI on OCA survival is unclear and demonstrates mixed results at short to intermediate term follow-up.[19,20] In other studies, age over 50 years old, symptom duration greater than 1 year have also been identified to be associated with inferior outcomes.[21-23]

The location of the chondral defect, extent of chondral disease, and concomitant pathology may also affect the outcome of OCA. The defect size was traditionally thought to negatively affect outcomes, but a recent analysis of OCA size, whether absolute or relative to the femoral condyle width, did not impact the patient reported outcomes at a mean of 6.0 years.[24] Patellofemoral OCA has been associated with less clinical improvement and higher rates of reoperation than femoral condyle lesions.[16] Specifically, Gracitelli et al. found isolated patellar OCA to have a 60.7% reoperation rate and a 28.6% failure rate at mean 9.7-year follow-up.[17] Interestingly, trochlear OCA has been shown to provide excellent clinical improvement and durability with 91.7% 10-year survival.[18] The extent of chondral disease can also affect the outcomes of OCA. Specifically, bipolar or reciprocal chondral defects (femoral condyle and tibial plateau or patella and trochlea) treated with OCA have been found to have significantly higher failure and reoperation rates than unipolar defects and should be utilized only in the correct patient.[25]

Rehabilitation Protocol

The patient is placed into a hinged knee brace locked in extension immediately postoperatively. The patient is heel-touch weight bearing for the first 6 weeks (Phase I), although early advances in weight bearing may be appropriate for

some patients. The brace is removed for range of motion only and remains locked in extension for ambulation until 2 weeks postoperatively when it can be discontinued. Phase I physical therapy goals include range of motion, quadriceps strengthening through straight leg raise, and core strengthening. At 6 weeks, patients are advanced to full weight bearing. Phase II (6-8 weeks) therapy goals focus on advancing Phase I exercises. By Phase III (8-12 weeks) physical therapy goals include gait training, closed-chain quadriceps strengthening, and beginning balance training. Phase IV (3-6 months) consists of advancing core strengthening and starting nonimpact conditioning. Once the graft is incorporated and adequate body control is established the patient is released to sport (typically 6-8 months depending on graft and healing).

Conclusion

OAT and OCA both provide patients with excellent clinical outcomes. Proper patient selection, careful evaluation, and graft selections are all critical factors to consider in order to maximize the patient's chances of a successful outcome.

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