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Rehabilitation and Return to Play Following Osteochondral Allograft Transplantation in the Knee

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Symptomatic articular cartilage lesions of the knee can be debilitating, particularly in athletic patient populations. For patients with focal articular chondral defects in the knee, fresh osteochondral allograft transplantation (OCA) has been shown to be an effective single-stage procedure, particularly for larger lesions (>2 cm^2) to restore the articular surface with hyaline cartilage. Indications for OCA continue to expand as a growing body of literature suggests good to excellent long-term clinical outcomes in appropriately selected patients as both a primary and salvage cartilage restoration procedure. In this review, a thorough summation of the most current literature regarding OCA in athletes, including associations between demographic and surgical variables and the ability to return to sport, and a detailed description of the senior author's rehabilitation protocol with sport-specific considerations will be presented.
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Introduction

Articular cartilage lesions of the knee are common, particularly in athletic patient populations. Several large arthroscopic studies of the knee have reported a prevalence of chondral injuries ranging from 60%-66%.[1-4] The most recent of these arthroscopic studies noted the patellar articular surface (36%) and medial femoral condyle (30%) to be the most common locations of articular defects.[4] Chondral or osteochondral lesions of the knee are difficult to treat as symptoms are often nonspecific or may not be present until significant damage has been sustained. Further, many lesions are discovered incidentally either on advanced imaging or during arthroscopy, but are asymptomatic.[5] Determining which lesions are symptomatic and require treatment vs which lesions can be treated with benign neglect can be extremely challenging. Atraumatic onset of pain and swelling with athletic activity is a common presentation, with only 50% of patients reporting a traumatic injury before the onset of symptoms.[6] These lesions can be debilitating, especially in active individuals who regularly place high stress loads across the knee joint, and may lead to an inability to perform activities of daily living or return to play (RTP).[7]

Osteochondral allograft transplantation (OCA) has been shown to be an effective cartilage restoration procedure as both a primary surgical option and as a salvage procedure for patients who have not responded to prior cartilage procedures (Figs. 1-3).[8-10] OCA restores the articular surface with hyaline cartilage, affording it biologic advantages over marrow stimulation techniques and has been shown to effectively treat lesions >2 cm^2 in a single-stage procedure.[11-13] The indications for OCA continue to expand as many have reported good clinical outcomes of OCA for a variety of etiologies such as osteochondritis dissecans,[14,15] previous failed marrow stimulation,[16] and traumatic injury[17,18]—with others reporting good clinical outcomes in different compartments of the knee (ie, patellofemoral, medial and lateral femoral condyles, and tibial plateau).[8,19-21] Notably, concomitant pathology such as

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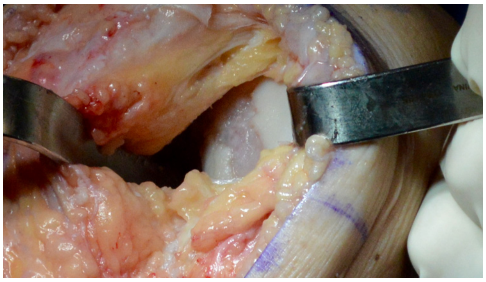

Figure 1 Intraoperative image of a right knee, focal medial femoral condyle $20 \times 20\ mm^2$ osteochondral defect in a 21-year-old woman former college basketball player. (Color version of the figure available online.)

meniscal deficiency, malalignment, and ligamentous injury should be addressed at the same time as OCA in appropriately indicated patients to protect the osteochondral allograft from early failure.[6,22,23] More recently, authors have begun to investigate the utility of OCA in treating isolated chondral defects in athletes to allow them to RTP.[24-27] The purpose of this article is to review the most recent literature regarding OCA in the treatment of chondral defects of the knee in athletes and the ability of these athletes to RTP. In addition, the preferred postoperative rehabilitation protocol for the senior author (B.J.C.) will be described including sport and athlete specific considerations.

RTP After OCA

Until recently, the literature evaluating the efficacy of OCA in returning athletes to play has been limited. In a study of 43 patients who regularly participated in athletics before OCA for isolated chondral or osteochondral lesions in the knee, Krych et al[26] identified potential risk factors for not returning to play. The preoperative level of athletic participation in this cohort was recreational in 74%, collegiate in 23%, and professional in 2%. Notably, the authors excluded patients who underwent concomitant meniscal allograft transplantation and malalignment corrective osteotomy. Overall, 70% of the athletes were male, the mean age 33 years, and 58% had prior ipsilateral knee surgery, with 23% having failed prior cartilage procedures. The authors reported significant improvements in activities of daily living scores, International Knee Documentation Committee (IKDC) scores, and Marx Activity Rating Scale from baseline to the time of final follow-up at a mean 2.5 years. The RTP rate was 88% (38 of 43 athletes); however, return to previous level of sport was 79% (34 of 43 athletes). In the 34 athletes who returned to their preoperative level of sport, it took on average 9.6 months to do so (range: 7-13 months). Krych and colleagues identified several risk factors associated with inferior rates of RTP. Specifically, athlete age ≥25 at time of surgery and preoperative duration of symptoms greater than 12 months were associated with significantly increased odds of failure to return to full athletic activity. Participating in athletic activities at least 4 days a week, having multifocal cartilage injury, receiving multiple OCA plugs, having previous surgery specifically cartilage procedure, lesion area, and concomitant procedures were not found to be associated with decreased rates of RTP.[26]

Figure 2 Intraoperative image of a right knee, medial femoral condyle defect $20 \times 20\ mm^2$ now reamed to a depth of approximately 6-8 mm. (Color version of the figure available online.)

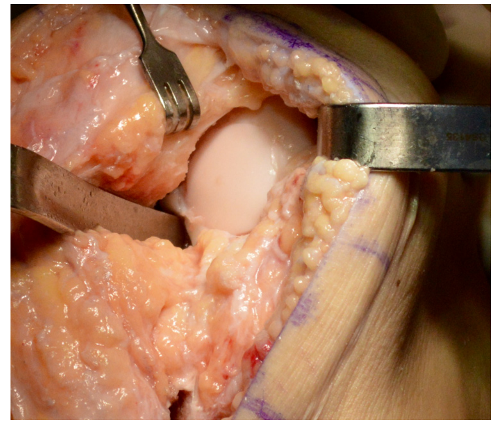

Figure 3 Intraoperative image of a $20 \times 20\ mm^2$ osteochondral allograft plug impacted flush to the surrounding cartilage on the medial femoral condyle in the right knee. (Color version of the figure available online.)

More recently, Nielsen et al[24] reported on RTP after OCA in the largest cohort. Sport was cited as a primary cause of injury in 67.2% of patients. Preoperatively, patients were asked to categorize themselves as highly competitive athletes (45%) or well-trained and frequently sporting (55%). Further classification by level of sport (college, professional, and recreational) was not provided. Notably, activities such as walking, using a stationary bicycle or elliptical machine, weightlifting, and yoga were not considered sports or recreational activities for the purposes of their investigation. The authors reported that 75.2% (112/149 knees) RTP or recreational activity after OCA and 91% of athletes were extremely satisfied or satisfied with their clinical outcome at time of final follow-up. Patients who did not RTP cited both lifestyle characteristics and knee-related problems including pain, concern about reinjury, among others, as determining factors. Patient age, body mass index, and preinjury activity level were not found to be significantly different between those that returned to activity and those who did not. A total of 25% of patients underwent additional surgery with 9.4% failing to revision OCA or arthroplasty. Graft survivorship in this active cohort was 91% and 89% at 5 and 10 years, respectively.

The results from these studies show that OCA is an efficacious, durable treatment option for patients with an active lifestyle, including lower level athletics. Careful patient selection is important as multifocal cartilage disease with concomitant pathology such as malalignment or meniscal deficiency represent an overall more complex knee pathology, which may have an effect on ability to RTP. There is conflicting evidence on the association of demographic variables such as patient age on RTP, thus more work is needed going forward to better elucidate what variables, if any, affect athletes' ability to RTP. Hardly any clinical data exists evaluating OCA in high-level athletes, including collegiate and professionals, thus no conclusions may be drawn on the viability of OCA in higher intensity athletes.

Special Population—Active Duty Military

The utility of OCA for treatment of articular cartilage defects in active duty military service members, who certainly have significant high-level activity demands, has been evaluated.[27,28] In 2011, Scully et al[28] evaluated 18 patients (17 males) with average 26.7 years at a mean 3.4-year follow-up following OCA. The authors found that one soldier returned to his previous combat arms position while 6 others remained in active duty roles but with restrictions prohibiting running and athletic activities. The remaining 9 patients underwent the medical evaluation board process for inability to remain on active duty.[28] More recently, Shaha et al[27] reported on 38 cases of OCA in treatment of large chondral defects (mean = 487 mm^2) in activity duty service members. Only 28.9% (11/38) returned to full duty with an additional 28.9% (11/38) returning to limited activity with permanent duty modifications. The remaining 42.1% (16/38) were unable to return to military service due to their surgical knee. The authors demonstrated that branch of service was a significant predictor of inferior outcomes with Marine Corps and Navy service members more likely to return to full duty and a military occupational specialty position was found to be predictive of inferior outcomes.[27] These results are in stark contrast to the high rates of return to sport and activity demonstrated in civilian populations. A possible explanation is the rigorous occupational physical demands of being a military service member especially as it relates to those with combat positions. As these cohorts are relatively small, additional investigations of larger cohorts with long-term follow-up will help evaluate demographic and surgical variables associated with inferior or superior outcomes.

Comparison of Cartilage Restoration Techniques in RTP

There are numerous cartilage reparative and restorative surgical options for treatment of articular cartilage defects in the knee. In a systematic review in 2009 of 20 studies including 1363 patients, Mithoefer et al[29] evaluated the efficacy of microfracture, autologous chondrocyte implantation (ACI), osteochondral autograft transplantation (OATS), and OCA (1 study only) for treatment of chondral or osteochondral defects in athletes' knees. Approximately 50% of patients underwent concomitant procedures, with patients who had OATS undergoing a concomitant procedure in 60% of cases. The authors noted an overall RTP rate of 73%, with microfracture having the lowest RTP rate at 66%, followed by 67% for ACI, and 91% for OATS. There was such limited information on RTP within the one OCA study that no significant conclusions could be drawn. Similarly, in 2013 Chalmers et al[30] compared activity-based outcomes after microfracture, ACI, and OATS in a systematic review of 20 studies, 5 of which reported specifically on RTP, including 1375 patients. In total, 23% of patients were professional or amateur competitive athletes and 81% of the treated defects were on the femoral condyles. RTP was shown to be quickest in patients who underwent microfracture (6.5-8 months) compared to ACI (12.5 months); however, clinical outcomes scores including IKDC and Tegner deteriorated after 2 years in microfracture patients whereas ACI scores remained stable. OATS was also shown to have a significantly greater return to competitive athletics when compared to microfracture.[30]

More recently, Krych et al[25] conducted a systematic review and meta-analysis of 44 studies (18 Level I/II, 26 Level III/IV) including 2549 patients (average age 35 years) regarding RTP rates after articular cartilage surgery. Their analysis included 3 publications involving OCA; however, 2 of those publications reported only on activity related functional outcomes (Tegner score) in nonathlete specific cohorts, thus limiting the data interpretation and analysis.[20,31] At an average follow-up of 47 months, the authors reported a 76% overall RTP rate with OATS having the highest RTP rate (93%) followed by OCA (88%), ACI (82%), and microfracture (58%). In addition, OATS demonstrated the fastest RTP at a mean 5.2 months compared to 9.1 months for microfracture, 9.6 months for OCA, and 11.8 months for ACI. Age, lesion size, and preoperative Tegner activity score were not shown to be predictive of RTP.

To date, most RTP literature for cartilage injuries in the knee has been reported for microfracture. Although these early results suggest that techniques including OCA restore the chondral surface with a more natural hyaline-like tissue often have more sustainable improvements in symptoms, more work needs to be done to define an evidence-based therapeutic approach to athletes with focal cartilage defects of the knee. OCA has typically been indicated for larger ($>2\ cm^2$) lesions in patients who have failed prior surgical management. With recent data demonstrating quality clinical outcomes in athletic populations as both a primary and salvage procedure, the indications for OCA may continue to expand for athletes. Although OCA is limited by the availability of donor tissue, it has numerous advantages including being a single-staged procedure, no harvest site morbidity compared to OATS, and restores the chondral surface with hyaline tissue compared to the predominantly fibrocartilage fill elicited by marrow stimulation.

Surgical Rehabilitation Protocol

The senior author (B.J.C.) utilizes a 5-phase progressive rehabilitation protocol for OCA of the knee (Table). The rehabilitation approach to each patient may need to be modified to accommodate unique patient-specific variables and surgical factors, particularly in the setting of concomitant procedures such as high tibial or distal femoral osteotomy, meniscus allograft transplantation, or ligament reconstruction. Each phase has targeted goals designed to systematically advance weight-bearing loads, increases in range of motion, and sport-specific activities. Athletes in particular can be challenging to treat as many often push the limits of their rehabilitation in an attempt to RTP earlier than recommended medically. Good communication between the treating physician and physical therapy team is essential to ensure appropriate progression through rehabilitation protocol, early protection of the osteochondral allograft to allow osseous integration, and ultimately, safe RTP. In general, the authors recommend return to sports at 6-8 months following the OCA procedure. Of note, the authors do not recommend the use of routine postoperative imaging studies to guide treatment decision-making.

Phase I (0-6 Weeks)

The goal of this phase is to allow incorporation of the transplanted graft and begin early ROM exercises to reduce the risk of contracture and intraarticular scarring. To minimize stress on the healing osteochondral graft, weight bearing is limited to heel touch to minimize the risk of graft dislodgement. For the first two weeks (or until quadriceps control is gained as demonstrated by a lack of quad lag during straight leg raise), an extension brace is utilized to lock the knee in full extension except during strengthening exercises or use of continuous passive motion (CPM). CPM is utilized approximately 6 hours per day beginning at the 0°-40° range and advancing 5°-10° per day as tolerated. The goal for CPM is to gain 100° of motion by week 6. During the first 2 weeks postoperatively, quadriceps sets, straight leg raises, calf pumps, and passive leg hangs to 90° are performed at home for strengthening to minimize muscle atrophy during this period. From 2-6 weeks postoperatively, passive ROM (PROM) and active ROM exercises are initiated as tolerated. Strengthening and mobilization are key during this phase, including gluteal sets, hamstring stretches, and core strengthening. Manual patellar and tibiofibular joint mobilization are utilized to minimize scar tissue formation.

Phase II (6-8 Weeks)

At this stage, therapy goals center on progressing toward full weight bearing and ROM. Weight bearing is initiated with 25% of total body weight and advanced 25% weekly until full weight bearing is achieved. ROM is gradually increased daily with CPM and PROM exercises to a goal of 130° of flexion. Exercise goals are focused on improving strength, flexibility, and neuromuscular control, and cardiovascular training is initiated. Until full weight bearing is achieved, training is limited to stationary bike and continuation of exercises from Phase I with weight-bearing precautions. Manual therapy, including scar and patellar mobilizations, is continued to minimize scar formation.

Table Rehabilitation Protocol for Isolated Osteochondral Allograft Transplantation of a Femoral Condyle

Phase	Weight Bearing	Brace	Range of Motion	Exercises
Phase I (0-6 weeks)	Heel touch	0-2 week: locked in full extension at all times	0-6 weeks: use CPM for 6 h/day, beginning at 0-40°	0-2 weeks: Quad sets, SLR, calf pumps, passive leg hangs to 90° at home
		Off for CPM and exercise only Discontinue after 2 weeks	Advance 5°-10° daily as tolerated	2-6 weeks: PROM/AAROM to tolerance, patella and tibiofibular joint mobs, quad, hamstring, and glut sets, SLR, side-lying hip and core
Phase II (6-8 weeks)	Advance 25% weekly until full	None	Full	Advance Phase I exercises
Phase III (8-12 weeks)	Full	None	Full	Gait training, begin closed chain activities: wall sits, shuttle, mini-squats, toe raises. Begin unilateral stance activities, balance training
Phase IV (12 weeks-6 months)	Full	None	Full	Advance Phase III exercises; maximize core/glutes, pelvic stability work, eccentric hamstrings. May advance to elliptical, bike, and pool as tolerated
Phase V (6-12 months)	Full	None	Full	Advance functional activity. Return to sport-specific activity and impact when cleared by MD after 8 months

SLR, single-leg raise; AAROM, active-assisted range of motion; Quad, quadriceps; MD, medical doctor.

Phase III (8-12 Weeks)

At this juncture, the focus of rehabilitation is on restoring strength, flexibility, and neuromuscular control. Patients should progress to full and pain-free active and PROM during this phase. Gait training is initiated with weight bearing as tolerated to improve neuromuscular control and proprioception, and closed chain strengthening exercises, including wall sits, shuttle leg press, quarter-squats, and toe raises, are utilized to restore strength in the operative leg. To isolate the operative leg and restore strength, balance, and proprioception, unilateral stance exercises are initiated.

Phase IV (12 Weeks-6 Months)

By this stage, full, pain-free ROM and normal gait with full weight bearing should be achieved. Normal activities of daily living should be performed regularly during this phase as tolerated. Neuromuscular dynamic stability exercises should focus primarily on single-leg exercises. Balancing on wobble boards and BOSU Balance Trainer (BOSU, Ashland, OH) and comparing to the contralateral lower extremity for symmetry helps to gauge progress. Advanced strengthening exercises may be initiated as tolerated. These exercises include high step-ups progressing as high as waist height, backward stationary lunges, single-leg heel raises, and 2-leg press. Patients should achieve quadriceps and hamstring strength within 10% of contralateral, healthy leg before progressing to the next stage. This includes symmetric external weight load when performing movements such as single-leg lunges with weights. Patients may advance to single-leg curls and extensions between 14 and 16 weeks. Joint locking should be avoided. Full advancement to high intensity running is not recommended for condylar OCA until 8 months. For patellofemoral OCA, patients may begin running approximately 6 months postoperative.

Phase V (6-12 Months)

The goals of Phase V are to regain the high levels of proprioception, strength, neuromuscular control, and flexibility necessary to perform high-demand athletic activities. Sport-specific activities are emphasized, and baseline testing, specifically evaluating the strength of the lower extremities, is conducted to determine apparent deficits and assess for risk factors for injury. Early functional goals include proprioception training with single-leg and nonimpact drills, sport-specific coordination drills, and strengthening. After these are achieved, athletes may progress to more explosive, high-demand activities such as plyometrics and change of direction exercises dictated by monthly re-evaluation of all baseline variables assessed during baseline testing. This testing can be used to establish new monthly training goals for athletes centered on sport-specific demands. Patients who have undergone uncomplicated, isolated OCA to a femoral condyle, patella, or trochlea are typically cleared to RTP after the 6-8-month time point. General criteria for RTP include the achievement of full active ROM without apprehension and the surgical lower extremity should be within approximately 10% of contralateral lower extremity on isokinetic testing. The senior author does not routinely recommend any specific functional sports assessment or specific RTP tests when deciding if an athlete is ready to RTP although others may find functional sports assessments useful for this purpose.

Special Considerations: Concomitant Procedures

With concomitant procedures, the rehabilitation process becomes a more prolonged process. In the case of combined OCA and MAT, weight-bearing does not begin until 6 weeks postoperatively, and a brace is utilized to lock the knee in full extension until 2 weeks postoperatively and restrict ROM between 0° and 90° until 8 weeks. The restriction in weight bearing is designed to allow adequate healing of transplanted meniscal tissue, and ROM limitations are intended to protect the posterior horn of the new meniscus. Progression in activity level and final maximum medical improvement in these cases is generally limited by the meniscus. In cases with concomitant osteotomy, weight bearing and ROM restrictions are similar to those for combined OCA and MAT (nonweight bearing with ROM constrained by bracing until 6 weeks). In these cases, final maximum medical improvement is often closer to what can be expected after isolated OCA.

Sport-Specific Rehabilitation Recommendations

During the sport-specific rehabilitation phase, specific principles should be adhered to in an effort to minimize the risk for reinjury, including compensatory injuries, and prevent setbacks. In designing training programs, the principles of progression, individualization, and specificity should be employed in early phases. As athletes become more comfortable with their postoperative knee, increased variation and individualization (based on monthly and iterative functional assessments) are applied to rehabilitation programs.

Conclusion

OCA is an effective single-staged cartilage restoration procedure that has been shown to have good utility and high rates of RTP for the treatment of focal articular cartilage defect in the knee of physically active patients. In the few reported studies, authors have shown conflicting results on patient and surgical variables that may be associated with inferior or superior clinical outcomes and RTP rates. In addition, the body of literature is significantly smaller than other articular cartilage procedures, especially microfracture, making comparisons to other techniques challenging. More work needs to be done to further elucidate which athletes may derive the most benefit from OCA and what patient and surgery specific variables may influence outcomes.

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