Review Article

Functional Outcomes and Return to Sport After Cartilage Restoration of the Knee in High-level Athletes

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ABSTRACT

Articular cartilage injuries of the knee are being observed with increasing frequency in athletes and have proven to be difficult to treat given the limited regenerative ability of cartilage and the potential for progressive joint degeneration. A wide range of surgical treatments such as microfracture, autologous chondrocyte implantation, and osteochondral autograft and allograft have demonstrated promising results in these high-demand individuals. These procedures permit healing of cartilage defects while decreasing pain and restoring function with patient-reported outcomes demonstrating significant improvement at short-, mid-, and long-term follow-up. Most athletes are able to return to play after cartilage restoration of the knee, regardless of the surgical technique used. Although there is a large degree of heterogeneity across the literature and no consensus as to the optimal technique, osteochondral autograft transfer seems to offer the highest rate of return to sport and return to play at preinjury level. However, autologous chondrocyte implantation and osteochondral allograft transplantation are often used for larger defects or salvage after previous procedures, so results may be confounded. In addition, a multitude of factors including patient history, characteristics of the chondral lesion, and postoperative management may affect functional outcomes in athletes.

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Articular cartilage injuries of the knee are being observed with increasing frequency. A recent systematic review demonstrated that full-thickness chondral defects occur in 36% of athletes.[1] In addition, they have been identified in up to 50% of athletes undergoing anterior cruciate ligament (ACL) reconstruction.[2] They may result from an acute injury or repetitive microtrauma in athletes participating in high-impact sports. Although cartilage injuries may initially be treated conservatively, they often require surgical treatment in a higher demand cohort to restore function. Although the natural history of cartilage lesions is not fully

understood, their poor capacity to heal is well known, and there is potential for progressive joint degeneration if left untreated.[3]

Advances in cartilage restoration have led to the development of new techniques to optimize outcomes for the athletic cohort. Current cartilage procedures include chondroplasty, microfracture, osteochondral autograft transplantation (OAT), osteochondral allograft transplantation (OCA), and autologous chondrocyte implantation (ACI). We have included the pros and cons of each surgical technique (Table 1). A systematic approach is crucial in choosing the correct treatment to fit both the lesion and the athlete's needs. Critical factors to consider during preoperative planning include patient's age, activity level, lesion size, concomitant pathology, malalignment, and cost. Various algorithms have been proposed with lesion size generally being the primary decision point.

Although there is still debate regarding the optimal use of each technique, there is consensus that all can provide favorable results in clinical outcome scores.[4-7] In addition, there is evidence that return to high-level athletics is possible regardless of the technique used.[8-10] However, there is significant heterogeneity throughout the literature with little comparative information, so uncertainty remains about the superiority of any one technique. American Academy of Orthopaedic Surgeons clinical practice guidelines for the treatment of osteochondritis dissecans do not recommend for or against any specific cartilage repair technique with an inconclusive strength of recommendation, although no official guidelines exist for the treatment of cartilage injuries in athletes.[11] Our purpose is to provide a detailed review of outcomes and return to sport data after cartilage procedures in the athletic cohort.

Surgical Options and Outcomes

Chondroplasty

Historically, chondroplasty is one of the most commonly used techniques in treating chondral defects of the knee. It involves smoothing of the defect with no violation of the subchondral bone. Anderson et al[12] retrospectively examined 53 patients undergoing isolated chondroplasty and demonstrated significant improvement in nearly all patient-reported outcomes (PROs) at a mean follow-up of 31.5 months. However, on regression analysis, the authors found that International Cartilage Repair Society (ICRS) grade 3 and 4 lesions showed less improvement in outcomes, suggesting that more severe injuries were less effectively treated with chondroplasty.

Microfracture

Microfracture is widely used for treatment of cartilage injuries given its low cost and technical ease. It is performed by puncturing holes in the subchondral layer to allow for release of precursor cells that can reorganize to form fibrocartilage (Figure 1). The primary drawback is a lack of restoration of hyaline cartilage, which is the best-suited surface for handling typical joint forces.

Gobbi et al[13] examined 61 athletes with chondral lesions with an average size of 4.00 cm^2 treated with microfracture with an average follow-up of over 15 years. At 2 years, International Knee Documentation Committee (IKDC), Lysholm, and Tegner scores all significantly improved; however, these outcomes deteriorated at 5 years and final follow-up, a phenomenon that has been corroborated in the literature.[4,14]

A systematic review of 13 level I to IV studies described 821 athletes undergoing microfracture with mean follow-up of 42 months.[4] Good and excellent results were reported in 67% including significant improvements in multiple PROs. Notably, between 2 and 5 years, 5 studies reported a deterioration in activity scores. However, these decreased scores were still significantly higher than preoperative scores.

Osteochondral Autograft Transplantation

In OAT, the surgeon harvests one or more osteochondral plugs from a limited weight-bearing portion of the patient's knee and transplants them into the defect. In mosaicplasty, multiple smaller plugs are harvested and implanted in a mosaic pattern. These techniques are limited to smaller defects given the risk of donor site morbidity.

In a level I randomized controlled trial by Gudas et al,[15] 57 Lithuanian athletes underwent either OAT or microfracture for chondral defects of average size 2.8 cm^2. At mean follow-up of 3 years, OAT demonstrated significantly better HSS scores, a significantly greater percentage of good and excellent results, and less failures. In addition, on postoperative MRI and biopsies, the OAT group showed a significantly greater percentage of excellent and good repairs and higher ICRS scores, respectively.

A systematic review of 10 studies with 610 patients undergoing OAT demonstrated successful outcomes in 72% of patients with statistically significant increases in multiple PROs, including IKDC and Lysholm scores.[16] However, the mean failure rate was 28%, with a mean

Table 1. Pros and Cons for Each Surgical Technique for Cartilage Repair

Technique	Pros	Cons
Chondroplasty	• Technically simple • Inexpensive • Minimal postoperative rehabilitation	• May not be used for larger defect (>2 cm^2) • Cannot be used for osteochondral lesions
Microfracture	• Technically simple • Inexpensive • Minimal postoperative rehabilitation	• May not be used for larger defect (>2 cm^2) • Cannot be used for osteochondral lesions • Deterioration in outcomes after short-term follow-up
OAT	• Immediate bony and cartilaginous integrity • Better healing potential with autograft tissue • Inexpensive	• Donor site morbidity • May not be used for larger defect (>2 cm^2) • Extensive postoperative rehabilitation
OCA	• No donor site morbidity • May be used for larger defect (>2 cm^2) • Immediate bony and cartilaginous integrity • Good salvage option	• Expensive • Decreased healing potential with allograft tissue • Extensive postoperative rehabilitation
ACI	• May be used for larger defect (>2 cm^2) • Good salvage option	• Requires two stages • Expensive • Extensive postoperative rehabilitation

ACI = autologous chondrocyte implantation, OAT = osteochondral autograft transplantation, OCA = osteochondral allograft transplantation

revision surgery rate of 19%. In a multiple regression analysis, the rate of failure and revision surgery was positively correlated with increased age, previous operations, and larger defect size.

Osteochondral Allograft Transplantation

OCA is more suitable for larger lesions than OAT as the osteochondral plug can be harvested from a size-matched donor (Figure 2). Similar to OAT, the immediate implantation of viable bone and cartilage surfaces offers significant advantages over other techniques.

Familiari et al[6] performed a systematic review of over 1,000 patients undergoing OCA. Although there was a large amount of heterogeneity, the authors reported significant improvements in PROs across all studies at a mean follow-up of 8.7 years, including IKDC score, Knee Society Function score, and Lysholm score. Among the 12 studies that performed a Kaplan-Meier survival analysis, the mean 5-year survival rate was 86.7%, the mean 10-year survival rate was 78.7%, and the mean 20-year survival rate was 67.5%. Seven of the studies evaluated radiographic healing postoperatively on MRI and found that 83.1% of the grafts were healed or well incorporated in the surrounding bone.

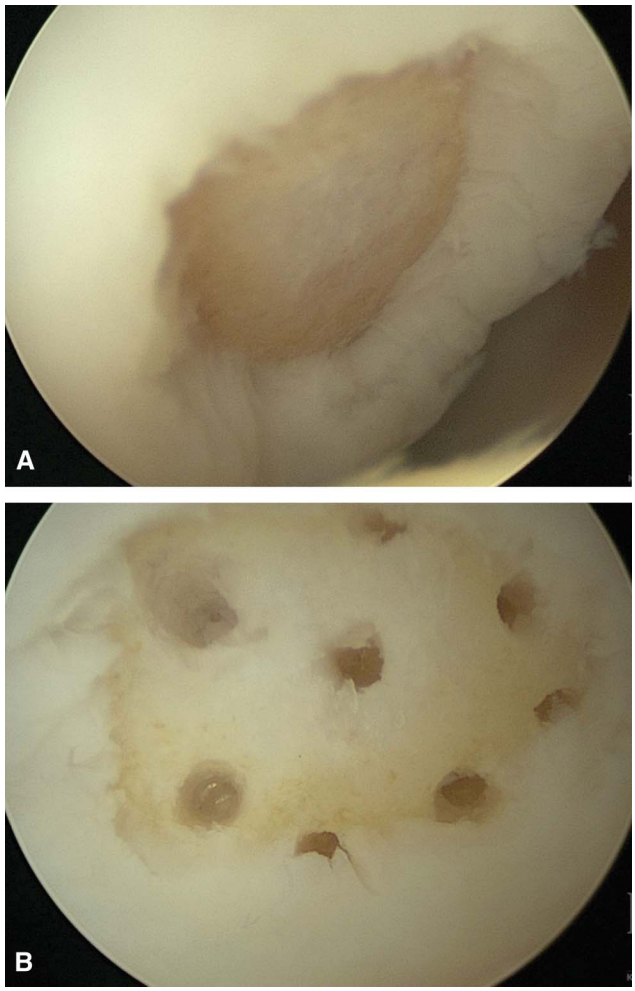
In another large case series, Nielsen et al[17] studied OCA in 149 knees in 142 high-level athletes and followed them for an average of 6 years. Seventy-one percent of patients reported excellent or very good knee function postoperatively, and 79% were able to return to a high level of activity according to the IKDC subjective evaluation form. In addition, 91% of patients stated that they were satisfied with the surgery. Despite these positive functional outcomes, 25.5% of knees underwent revision surgery, and 9.4% failed, requiring revision OCA or knee arthroplasty.

Autologous Chondrocyte Implantation

ACI is a two-stage procedure beginning with a cartilage harvest, followed by a 4- to 6-week period where harvested chondrocytes are cultured with growth factors and ultimately reimplanted into the defect in the second stage. There are multiple generations of ACI. Earlier techniques involved injection of the chondrocytes under an autologous periosteal patch or allograft collagen membrane. In third-generation matrix-induced ACI (MACI), direct implantation of cells onto a biomatrix is performed and then placed into the defect (Figure 3).

In a level I study by Ebert et al,[18] 63 patients underwent MACI for full-thickness chondral injuries. At 2- and 5-year follow-up, significant improvements were reported in all subscales of the Knee injury and Osteoarthritis Outcome Score (KOOS), Short Form-36, and Visual Analog Scale. Although most of these functional increases were made by the 2-year mark, the sport and recreation subscale of the KOOS significantly improved from 2 to 5 years, suggesting that athletes undergoing ACI may make gains after 2 years. In a postoperative questionnaire, 94% of the cohort was satisfied with their relief in knee pain, and 95% were satisfied with the improvement in their ability to

Figure 1



Microfracture. **A**, Femoral condyle chondral lesion after débridement to stable cartilage rim and removal of calcified cartilage layer to expose the subchondral plate. **B**, Microfracture holes made perpendicular to bone approximately 4 mm apart.

perform daily activities. Fifty-eight patients were evaluated with MRI postoperatively and demonstrated significant improvement in graft healing over time, but there were no correlations between any of the MRI variables and clinical outcome scores.

A level I study by Brittberg et al[7] compared MACI and microfracture in symptomatic cartilage defects greater than 3 cm^2 in 128 patients. The authors demonstrated significantly greater improvement in all KOOS subscales at 2 years in the MACI group. In addition, this greater improvement in the MACI group was sustained in the coprimary end points of KOOS Pain and Function at 5 years. However, MRI evaluation showed similar improvement in defect filling in both groups, suggesting that MRI is not a valid surrogate for clinical effect.

Preoperative Factors Affecting Return to Play

Age

Throughout the literature, age is one of the strongest predictors of return to sport after cartilage repair regardless of technique used. However, the threshold for age that portends decreased return to athletics varies from 25 to 40 years across studies. In a level 1 study comparing OAT and microfracture, Gudas et al[16] demonstrated significantly improved ICRS and Tegner scores at 10-year follow-up in athletes younger than 25 years at the time of surgery in both groups. Similarly, Krych et al[19] demonstrated that athletes older than 25 years undergoing OCA were significant less likely to return to sport. There are many explanations for this disparity with some attributing it to the younger athlete's inherent ability to heal or rehabilitate more vigorously. However, confounding factors such as more failed surgeries in older patients and a natural decrease in sporting activity with age have been suggested.

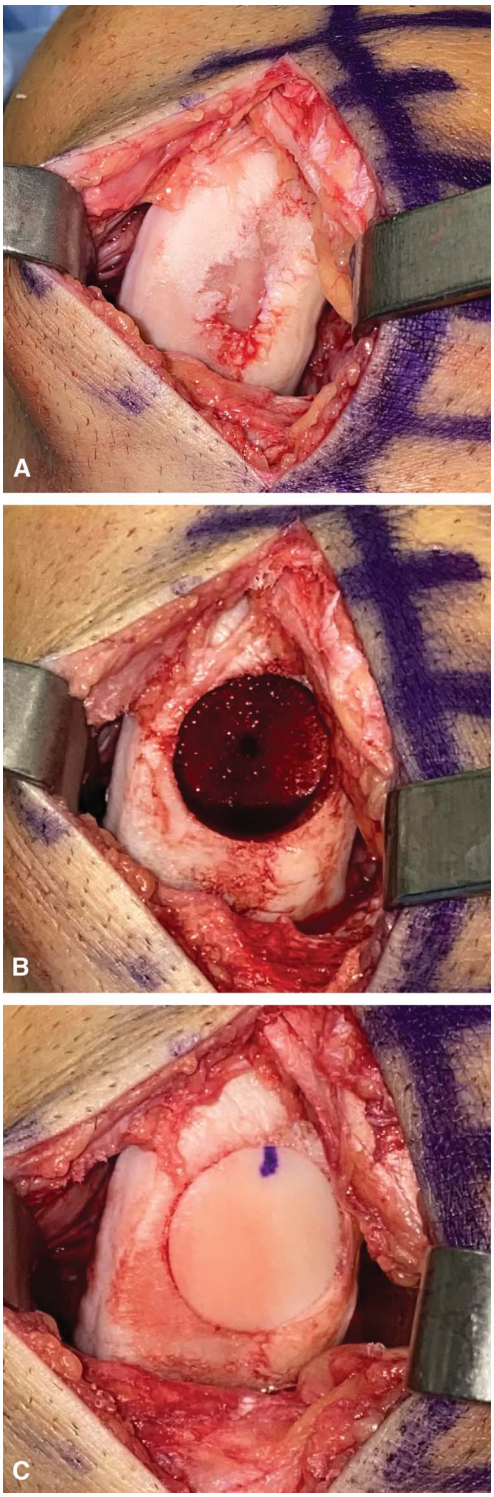
Level of Sports Participation

Higher level of competition has been suggested as a positive prognostic indicator for return to athletics after cartilage surgery. Greater access to elite rehabilitation, timely recognition and care of injury, and the motivation of compensation in professional sports may all contribute. Panics et al[20] evaluated a group of 61 Division I-III soccer players undergoing OAT and demonstrated a significantly greater return to soccer in the Division I players compared with the others (89% vs 62%). In another study, patients with regular or competitive sports participation (1 to 7 times per week) returned to activity at a higher rate and showed significantly better outcome scores than patients with minimal sports involvement (1 to 3 times per month) after ACI.[21] Similar findings of improved return to sport for athletes at a higher level of competition have been demonstrated for OCA and microfracture.[19,22]

Preoperative Duration of Symptoms

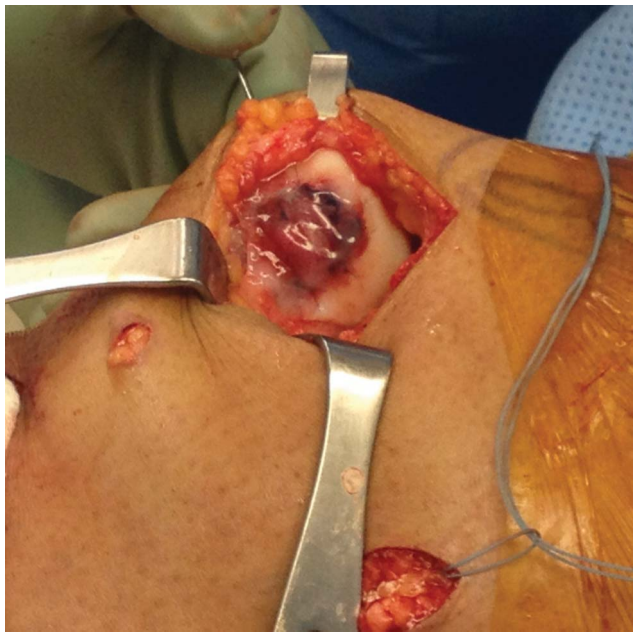
Improved clinical results have been described in athletes with a shorter duration of symptoms before surgery. This may be attributed to decreased healing potential of chronic lesions, development of degenerative joint disease, and greater deconditioning that accompanies a longer interval of symptoms. In a systematic review on ACI, DiBartola et al[23] found that preoperative duration of symptoms was the only factor that influenced clinical outcomes including return to athletics. In a prospective

Figure 2



Osteochondral allograft transplantation. **A**, Large medial femoral condyle chondral lesion. **B**, The lesion has been reamed to a base of bleeding subchondral bone. **C**, The allograft osteochondral plug has been transplanted into the patient's femoral condyle with an orientation mark at the 12-o'clock position.

Figure 3



Third-generation matrix-induced autologous chondrocyte implantation with a collagen membrane preimplanted with chondrocytes affixed to a patellar chondral lesion with fibrin glue.

case series of 32 athletes undergoing microfracture, 67% of players with symptoms for less than 12 months before treatment returned to sport, whereas only 14% of those with symptoms for greater than 12 months returned.[22] Similar effects have also been reported for OCA.[19]

Previous Surgeries

The athlete's number of previous cartilage surgeries has been suggested to influence return to sport. Patients with a history of failed surgeries may have compromised healing potential or may be physically or mentally unable to return to competition. Mithoefer et al[24] treated 20 athletes with ACI and showed a significant negative correlation between the number of previous cartilage surgeries and the ability to return to sport. In another study on microfracture, 86% of athletes without previous cartilage operations successfully returned to competition compared with 33% of those who had previous procedures.[22]

Intraoperative Factors Affecting Return to Play

Defect Size

Lesion size has been associated with rate of return to play. In a study by Gobbi et al,[13] a statistically significant

Table 2. Summary of Recent Studies Discussing Return to Sport in Athletes After Surgical Management of Articular Cartilage Lesions of the Knee

Study	No. of Athletes	Mean Defect Size, cm^2 (Range)	Mean Age, yr (Range)	Return to Sport	Level of Sport
Gobbi et al[13] (MFX)	61	4.0 (2-6)	31.4	60% at 24 mo f/u to preinjury level	Professional (48%), recreational (52%)
Schallmo et al[28] (MFX)	131	NA	28.2	79% by 9.8 mo	Professional
Panics et al[20] (OAT)	61	2.4 (1-5)	25.3 (16-41)	87% by 4.5 mo, 67% to preinjury level	Professional
Werner et al[29] (OAT)	20	1.34 (0.15-2.8)	21.1	100% by 2.8 mo	Professional/collegiate (50%), varsity high school (35%), regional/national level (15%)
Krych et al[19] (OCA)	43	7.25 (2.5-13.9)	33 (18-49)	88% at 30 mo f/u, 79% to preinjury level by 9.6 mo	Professional (2%), collegiate (23%), recreational (74%)
Nielsen et al[17] (OCA)	142	8.2	31.2	75%	Competitive
Kreuz et al[21] (ACI)	118	6.5 (3-16)	35 (18-50)	94% at 18 mo f/u, 100% at 36 mo f/u to preinjury level	Competitive (58%), recreational (42%)
Pestka et al[25] (ACI)	130	4.4 (1.5-9.0)	34.9 (18-55)	73%, 51% to preinjury level or better	NA
Gudas et al[16] (MFX vs OAT)	60	2.8	24.3 (15-40)	OAT: 90% at 6.7 mo to preinjury level; MFX: 52% at 6.9 mo to preinjury level	Competitive
Kon et al[14] (MFX vs ACI)	41	2	25 (16-37)	ACI: 86% at 12.5 mo, 67% to preinjury level; MFX: 80% at 8 mo, 75% to preinjury level	Professional, semiprofessional

ACI = autologous chondrocyte implantation, f/u = follow-up, NA = not available, MFX = microfracture, OAT = osteochondral autograft transplantation, OCA = osteochondral allograft transplantation

negative correlation was seen between lesion size and Tegner score in athletes undergoing microfracture. Seventy-five percent of patients with smaller lesions (<4 cm^2) were able to return to preinjury activity level, whereas only 25% of those with larger lesions (>4 cm^2) were able to return. Likewise, in a study examining soccer players undergoing OAT, the average lesion size in athletes who returned to soccer was significantly smaller than in those who were unable to return (2.2 vs 3 cm^2).[20] In contrast, ACI and OCA have not demonstrated similar effects. Pestka et al[25] treated 130 patients with ACI and found no link between cartilage defect size and return to sport. In a series of 43 athletes treated with OCA, there was no difference in lesion size between those who returned to sport and those who did not.[19] It is possible that the results of these techniques are less affected by size because they are typically used for larger defects or that the restoration of hyaline cartilage makes the size of the defect less consequential.

Defect Location

Lesion location has been identified as a relevant factor in determining success after cartilage repair. In a study by Panics et al,[20] 61 professional soccer players were treated with mosaicplasty, and 79% of those with cartilage lesions on the femoral condyles returned to sport, whereas no patients with lesions on the trochlea, patella, or tibia returned. In contrast, a prospective study of 32 athletes undergoing microfracture showed similar percentages of good and excellent outcomes as well as rate of return to sport between athletes with lesions on the femoral condyles and trochlea.[22] Notably,

no lesions were present on the patella. Two studies on ACI demonstrated no statistically significant correlation between defect location and return to athletics.[25,26] These differences may be attributed to small sample size of noncondyle locations in most studies.

Postoperative Factors Affecting Return to Play

The effect of postoperative factors such as socioeconomic and psychological issues on return to play has been studied at length in the ACL literature, but not as extensively reviewed in cartilage surgery.[27] One study examining OCA transplantation in 142 athletes found that 75.2% returned to sport, whereas the 24.8% who did not return cited both knee-related and lifestyle factors as primary reasons.[17] Among these patients, 72% were confident that their knee could tolerate sport-related activity. Regarding reasons for not returning, 41% reported concerns over reinjury, 24% cited health concerns unrelated to their knee, 12% attributed it to less interest in their sport, and 12% cited family or career considerations. Given the paucity of data, future research should focus on elucidating the effects of these variables.

Return to Play

Regardless of the surgical technique used, most athletes are able to return to play after cartilage surgery. However, there exists a high degree of heterogeneity as well as a low level of evidence among many available studies. Some recent studies are summarized in Table 2.

Chondroplasty

Scillia et al[30] performed a study of 52 National Football League players who underwent chondroplasty at a single institution. Sixty-seven percent of players were able to return to football at an average of 8.2 months. Those who played greater than 11.6 games per season preinjury were 4.7 times more likely to return to play than those who played fewer games per season. All included players underwent additional procedures such as microfracture or loose body removal, so the effect of chondroplasty could not be isolated.

Microfracture

In a retrospective review examining athletes across 4 professional sports, 131 players underwent microfracture for symptomatic chondral defects of the knee.[28] One hundred three of 131 athletes (78.6%) successfully returned to play at an average of 293 days. Return to play rate was noted to be significantly higher for baseball players compared with all other sports (100.0% vs 75.0%) and lower for football players compared with all other sports (71.1% vs 89.0%). In addition, return time was significantly longer for football players compared with all other sports (327 vs 255 days). Baseball players returned to their preinjury level of play after one postoperative season of decreased statistics, whereas basketball players performed significantly worse for three seasons after surgery. The authors concluded that the variations in return to play and performance metrics were explained by the relative physical demands for each sport in terms of physiologic load placed on the knee.

In a level III study of 41 professional basketball players, microfracture was performed for femoral condylar, trochlear, and patellar cartilage injuries.[31] A control group of players was selected by matching demographic and performance metrics to the study cohort. Eighty-three percent of the cohort successfully returned to basketball at an average of 9.2 months. Postoperative performance was significantly worse relative to both preinjury performance and the control group in terms of points per game, steals per game, and player efficiency rating.

Namdari et al[32] performed a level III study of professional basketball players and demonstrated that 58% of athletes returned to play for greater than 1 season at an average of 6.3 months postoperatively, whereas one-third of the cohort never returned. When compared with a matched control, these players also experienced a significant decline in points and rebounds per game and were more than 8 times less likely to remain in the league after return.

Osteochondral Autograft Transplantation

Werner et al[29] evaluated return to sport in 20 competitive athletes after OAT with an accelerated rehabilitation protocol. Exclusion criteria included concomitant surgical procedures and chondral injuries in parts of the knee other than the medial and lateral femoral condyles. All patients successfully returned to sport at an average of 82.9 days and reported that they were able to keep up with most or all of their sport's physical demands. The rate of return to sport and time to return were both significantly better than previously reported for OAT in the literature. However, it is important to note that this study had a small sample size and may not be reproducible.

In a level I study examining OAT for femoral condyle articular cartilage defects, the return to sport rate was

93% for 28 athletes.[33] Return to preinjury level occurred at a mean of 6.5 months after surgery. Of the two patients who did not return, only one reported that it was due to knee complications.

In another study, Marcacci et al[34] prospectively evaluated 30 athletes after OAT. Forty-three percent of patients were previously operated, and 63.3% underwent concomitant procedures at the time of surgery. At 2-year follow-up, 73.3% of patients returned to sport at the same level, 13.3% at a lower level, and 13.3% not at all. At 7-year follow-up, 23.3% of patients still played at the same level, 46.7% at a lower level, and 30% not at all. Although the rate of return to preinjury level of play at short-term follow-up is in line with previous studies, the deterioration at 7 years may be attributed to natural decline in activity over time.

Osteochondral Allograft Transplantation

Nielsen et al[17] examined 142 athletes undergoing OCA transplantation and reported that 75.2% of athletes returned to play at a minimum of 1-year follow-up. Most patients who did not return stated that they were confident that their knee could tolerate playing, suggesting that psychosocial factors may have contributed to their lack of return.

In another case series, Krych et al[19] performed OCA transplantation on 43 athletes with chondral lesions averaging 7.25 ± 2.36 cm^2. In this study, the return to sport rate was 88%, and 79% of the athletes returned to play at their preinjury level. In those who returned to play at the same level, time to return was 9.6 ± 3.0 months. Multivariable regression analysis demonstrated that age greater than 25 years and preoperative duration of symptoms greater than 1 year were significant risk factors for not returning to preinjury level of sport.

McCarthy et al[35] studied OCA transplantation in 13 high-level high school, college, and professional athletes. All athletes had undergone previous cartilage-related surgeries to their knees. Seventy-seven percent of athletes returned to sport after surgery at a mean of 7.9 ± 3.5 months. Half of these athletes returned to play at the same level, whereas half returned at a lower level. Those who returned to a lower level cited graduation from school or another unrelated knee injury as the reason.

Autologous Chondrocyte Implantation

In a level II study, Kon et al[14] prospectively treated 41 semiprofessional soccer players with ACI versus microfracture for femoral articular cartilage defects. Of the 21 patients who underwent ACI, 86% returned to play soccer at a competitive level, although only 67% returned to their preinjury level. These athletes returned to training with the team at an average of 10.2 months and game play at 12.5 months and played at the same level for 3.0 ± 2.9 years after recovery.

Pestka et al[25] performed a retrospective review of 130 patients participating in 32 different sports and recreational activities treated with ACI with an average follow-up of 5.3 years. Postoperatively, 40.0% of patients returned to activity at their preinjury level, whereas 48.9% of patients reduced their level of sports intensity and 10.8% increased their sports intensity. Overall, there were significant decreases in median frequency and duration of sports activity per week when comparing the year before surgery with postoperative status. In addition, the authors noted trends of increased participation in endurance and low-impact sports (eg, golf and gymnastics) and decreased participation in start-stop sports (eg, soccer and basketball) among the cohort postoperatively.

In another study of 44 athletes undergoing ACI, 54.3% of patients returned to their preinjury level of sport, 20% increased their level, and 25.7% decreased their level at 5-year follow-up.[36]

Comparing Return to Play

Despite overall satisfactory return to sport rates after cartilage repair, there does seem to be differences in results depending on the surgical technique used. In a recent systematic review of 44 studies by Krych et al,[8] the overall rate of return to sports was 76% and was greatest after OAT (93%), followed by OCA (88%), ACI (82%), and microfracture (58%). In terms of time to return to play, OAT was on average the fastest (5.2 months), followed by microfracture (9.1 months), OCA (9.6 months), and ACI (11.8 months). In another meta-analysis by Hurley et al,[9] OAT was also found to have the highest rate of return to sport (88.2%), although OCA was found to have the lowest rate (77.1%). Rate of return to preinjury level of play was highest for OAT (79.3%) and lowest for ACI (57.3%). Timing of return to play in this study was similar to the previous review with OAT producing shortest time to return (4.9 months) and ACI producing longest time to return (11.6 months).

Return to Play Guidelines

There is significant heterogeneity in return to play guidelines after cartilage restoration of the athlete's knee.

Although many different criteria are used throughout the literature, most are time based. According to a recent systematic review, there was significant variation among postoperative weight-bearing and return to play protocols used across the studies included.[9] One-quarter of the studies prevented return within 1 year, whereas about two-thirds of the studies permitted return within 6 months.

Although time-based criteria may be simple and easy to follow, they do not meet the individualized needs of each athlete. Objective and subjective patient measures such as pain, swelling, range of motion, and strength should be taken into consideration when considering return to sport. Return to play guidelines have been more extensively explored in the ACL literature. In one functional testing algorithm for return to play after ACL reconstruction, the authors integrated objective and subjective patient factors, a battery of functional tests, and psychological evaluation to determine whether it was appropriate for an athlete to return.[37]

Imaging-based criteria have been offered as a means of evaluating tissue healing at the site of chondral repair and whether it is sufficient to allow for physiologic athletic loads. Advances in morphological and biochemical MRI have provided greater ability to visualize and evaluate the quality of cartilage repair tissue and may be useful in surgical follow-up and clearance for return to sport.[38] However, multiple studies have questioned the prognostic value of MRI.[7,18]

Completion of a comprehensive postoperative rehabilitation regimen with the help of a multidisciplinary team is also crucial for safe and timely return to sport. An individualized approach should be used for each athlete taking into consideration the characteristics of the injury, the repair technique used, the athlete's symptoms and psychological status, and sport-specific demands. A stepwise program that relies on completion of well-defined checkpoints rather than fixed time points offers the most effective way for high-level athletes to return to sport.[39]

Summary

Articular cartilage lesions represent a growing issue in high-level athletes, causing significant debilitation that threatens the ability to participate in sport. Patient-reported outcomes have been satisfactory across all cartilage repair techniques at short and long-term follow-up. There is significant heterogeneity and a paucity of level I data in the literature in regard to return to athletics. However, recent data have confirmed that most athletes are able to return to play postoperatively regardless of the surgical technique used. According to two recent meta-analyses, OAT provides the highest rate of return to sport as well as shortest time to return, although its use is limited to smaller defects.[8,9] Further prospective, comparative studies are needed to establish superiority of any one technique. Multiple patient and lesion factors have been implicated in influencing return to play, and greater understanding of these variables will aid in patient counseling and predicting outcomes. Return to play criteria are primarily time based at this point and warrant further research to determine whether imaging-based criteria and functional testing can be of use.

References

References 7, 15, 16, 18, and 33 are level I studies. References 2, 14, 21, and 34 are level II studies. References 31 and 32 are level III studies. References 1, 3-6, 8-10, 12, 13, 17, 19, 20, 22-30, and 35-39 are level IV studies.

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