Systematic Review

Return to Play After Osteochondral Autograft Transplantation of the Capitellum: A Systematic Review

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Purpose: To determine the rate of return to play and to identify lesion or osteochondral graft characteristics that may influence the return to competitive athletics after osteochondral autograft transplantation (OAT) for symptomatic osteochondritis dissecans (OCD) lesions. **Methods:** A systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. A duplicate search of PubMed, Embase, Scopus, Web of Science, and CENTRAL databases was performed, beginning from the database inception dates through July 2016, for all articles evaluating the return to play after OAT for OCD lesions of the capitellum. A methodological quality assessment was completed for all included studies. Patient demographics, osteochondral lesion and graft characteristics, the number of patients, and timing of return to competitive activity were collected and evaluated. Association between graft size/number, the time to osseous healing, and return to sport was evaluated. **Results:** Seven articles met the inclusion criteria. All included studies were case series of moderate quality with a mean Methodological Index for Non-Randomized Studies score of 12/16. Overall, 94% (119/126) of patients undergoing OAT for OCD lesions of the capitellum successfully returned to competitive sports. The mean reported time for unrestricted return to athletic competition after OAT was 5.6 months (range, 3-14 months). **Conclusions:** Current best evidence suggests that OAT is successful in treating advanced OCD lesions of the capitellum and returning athletes to high-level competition. Evidence supporting the association between the size and number of grafts used and the time to osseous healing and return to sport is currently limited. Our assessment of the time to return to athletic competition was limited because of variable surgical technique, postoperative rehabilitation protocols, and outcome assessment. **Level of Evidence:** Level IV, systematic review of Level IV studies.

Osteochondritis dissecans (OCD) of the capitellum is a painful condition that typically affects high-level adolescent athletes. The etiology of OCD is likely multifactorial and has not been fully elucidated. Repetitive radiocapitellar compression and subsequent microtrauma resulting from either a valgus or an axial load appears to be an essential component of the pathogenesis of capitellar OCD and is most commonly seen in highly competitive baseball players and gymnasts.[1-12] Baseball pitchers experience radiocapitellar compression during the early acceleration phase of the pitching motion, when a substantial valgus force is produced at the elbow.[13-15] Conversely, gymnasts often axially load the elbow while fully extended, which results in approximately 60% of the axial force being transmitted through the radiocapitellar articulation.[16]

Optimal surgical management of unstable capitellar OCD lesions remains controversial. Treatment modalities such as microfracture, debridement, and fragment excision are still largely considered to be the standard of care for this pathology. However, these approaches have been reported to have modest outcomes for advanced capitellar OCD lesions.[17-21] Over the past decade, encouraging data have been published on

From the Department of Orthopaedic Surgery (J.M.K., J.R.T., M.K., J.N.L., A.B.) and Taubman Health Sciences Library (W.A.T.), University of Michigan, Ann Arbor, Michigan, U.S.A.

The authors report the following potential conflicts of interest or sources of funding: J.R.T. received a $5,000 grant from the Orthopaedic Research Education Foundation, unrelated to this study. J.N.N. receives consultancy fees from Innomed for Instrument Design (no relevance to current study) and payment for development of educational presentations from AO Hand Faculty (no relevance to current study). A.B. receives consultancy fees from Arthrex and owns stock/stock options in A3 Surgical.

Received August 29, 2016; accepted January 25, 2017.

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0749-8063/16835/$36.00

http://dx.doi.org/10.1016/j.arthro.2017.01.046

patient-reported outcomes after osteochondral autograft transplantation (OAT) for capitellar OCD lesions in young athletes.[3,7,10,11,17,20,22-26] Despite this recent increase in published data, there is an overall paucity of information regarding the ability and optimal timing in which athletes return to competitive sports.

The purpose of this study was to determine the rate of return to play and to identify lesion or osteochondral graft characteristics that may influence the return to competitive athletics after OAT for symptomatic OCD lesions.

Methods

This study was conducted according to the methods of the Cochrane Handbook[27] and is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[28]

Identification of Studies

A systematic literature search was conducted in PubMed, Embase, Scopus, Web of Science, and CENTRAL databases beginning from the database inception dates through July 14, 2016. A medical informationist experienced in the conduct of systematic reviews assisted in developing and performing the search. The search strategy combined the following terms: OAT, OATs, "osteochondral autograft transplantation," "osteochondral plug," "ostochondral autograft," or mosaicplasty; "osteochondritis dissecans," "osteochondral lesions," "osteochondral lesion" or OCD; and elbow or capitellum (Appendix 1). Medical subject headings (MeSH) and Emtree headings and subheadings were used in various combinations in Ovid and supplemented with free text to increase sensitivity. A manual search of related references and cited articles was performed to identify any additional relevant studies for inclusion. Two reviewers (J.M.K. and J.R.T.) who were well versed with the subject matter and methodologic process independently screened the titles and abstracts of all studies for eligibility using piloted screening forms. Duplicate articles were manually excluded. Both reviewers reviewed the full text of all potentially eligible studies identified by title and abstract screening to determine final eligibility. All discrepancies were resolved by consensus decision.

Assessment of Study Eligibility

Inclusion criteria consisted of the following: patients must have undergone OAT for an unstable OCD capitellar lesion, defined either radiographically by magnetic resonance imaging or intraoperatively, or after failing 6 months of nonoperative treatment; a minimum of 6 months of postoperative follow-up; patients must have participated in competitive athletics as identified by the study; a minimum of 10 eligible patients; additional hardware for graft stabilization used in no more than 10% of the study population; reported a time frame for return to competitive athletic activity; and Level IV evidence or higher.

Articles were excluded from this review if the study was Level V evidence; had <10 eligible patients; did not report time to return to sport; used additional internal fixation in >10% of study population; published only an abstract; or was a review article, surgical technique guide, imaging study, medical conference abstract, cadaveric study, or biomechanical study.

Data Extraction and Assessment of Risk of Bias

Data were extracted independently and in duplicate by both reviewers (J.M.K. and J.R.T.) using a piloted electronic data extraction form. Extracted data included the following: year and journal of publication, number of patients, gender of patients, age at time of surgery, size of osteochondral lesion or articular defect, donor plug site, whether the dominant extremity was affected, the time of follow-up, size and total number of osteochondral plugs used, preoperative sport, postoperative sport, time from surgery to beginning rehabilitation, time to return to competitive activity, and the number of patients that returned to competitive activity. Two reviewers (J.M.K. and J.R.T.) performed an independent assessment of the methodological quality of the included studies using the Methodological Index for Non-Randomized Studies[29] tool for all nonrandomized studies and the Cochrane risk of bias tool[27] for all randomized controlled trials. Furthermore, we analyzed the grade of evidence in each article included in the final analysis according to the criteria established by Wright et al.[30]

Data Analysis

Descriptive statistics were calculated to reflect the frequency of outcome measures. The κ (kappa) statistic was used to examine interobserver agreement for study eligibility. On the basis of the guidelines of Landis and Koch,[31] a κ of 0 to 0.2 represents slight agreement, 0.21 to 0.40 fair agreement, 0.41 to 0.60 moderate agreement, and 0.61 to 0.80 substantial agreement. A value above 0.80 is considered almost perfect agreement. Interobserver agreement for methodologic quality assessment was calculated using the intraclass correlation coefficient. Both the κ and intraclass correlation coefficient were calculated using SPSS statistical analysis software (IBM, Armonk, NY).

Results

Study Identification

The literature search generated 216 relevant citations. After duplicate removal and application of eligibility criteria, 88 articles underwent title and abstract screening by 2 independent reviewers (J.M.K. and J.R.T.) with methodologic and content expertise.

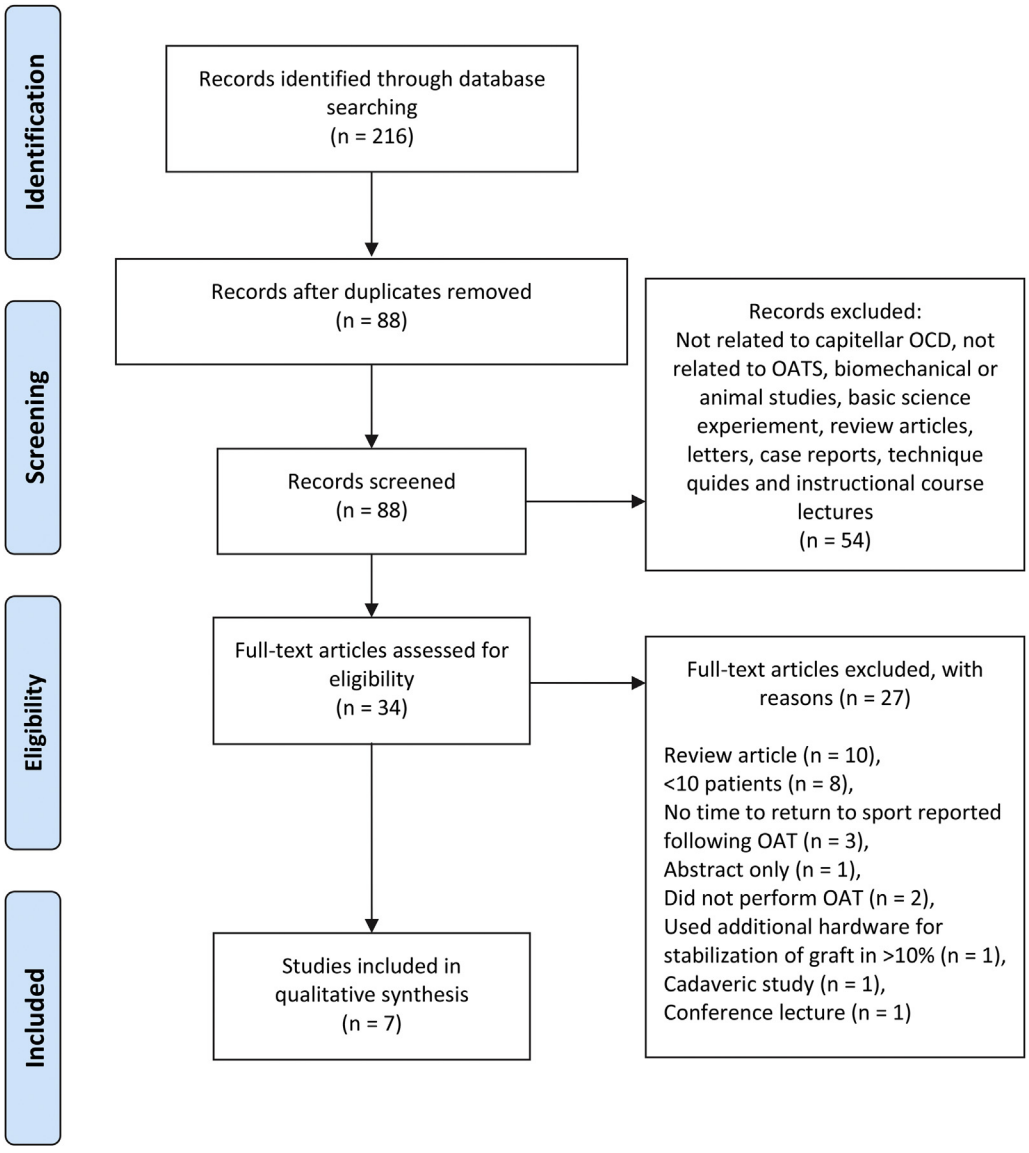

Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram for systematic review of osteochondral autograft transplantation of the capitellum. (OAT, osteochondral autograft transplantation; OCD, osteochondritis dissecans.)

Thirty-four articles underwent full-text review, ultimately producing 7 articles that met the inclusion criteria of this report (Fig 1).[3,10,11,23,25,26,32] The κ value for overall agreement between reviewers (J.M.K. and J.R.T.) for the final eligibility decision was 0.86 (95% confidence interval, 0.67-1.00), indicating almost perfect agreement.

Study Characteristics

One hundred twenty-seven patients (126 male, 1 female) were involved across all studies included for final review. The mean follow-up for the group was 30.2 months (range, 6-87 months), and the mean age at the time of surgery was 14.3 years (range, 13.6-16 years) (Table 1).

Study Quality

No randomized controlled trials or Level I evidence was included. All 7 studies included were case series, Level IV evidence. The mean Methodological Index for Non-Randomized Studies was judged to be 12/16 (Table 1). Agreement between reviewers (J.M.K. and J.R.T.) in the assessment of study quality was good (intraclass correlation coefficient, 0.70; 95% confidence interval, 0.67-0.94).

Characterization of Lesion and Graft

The mean plug size among all included patients was 7.7 mm (range, 2.7-10 mm), and the mean number of plugs used was 2.1 (range, 1-6) (Table 2). Shimada et al.[10] reported in their 2012 study on the use of

cylindrical costal osteochondral autograft that, based on the anatomy of the donor site in their patient population (Japanese males), a single graft was used in each case, which was approximately 15 mm on average. The remaining studies used a femoral condyle autograft as the donor site of a single plug or mosaic of plugs sized to fill the defect.

Return to Play, Initiation of Rehabilitation, and Sport of Choice

Overall, 94% (119/126) of patients successfully returned to competitive sports after autologous osteochondral grafting of an OCD lesion of the capitellum. All of the studies included in this review defined return to athletic competition as return to the same competitive sport at the same or higher preinjury level. Four of the studies reported 100% return to play (Table 2).[10,24,26,32] Of note, 1 patient in Shimada and colleagues' 2012 study[10] was excluded from our analysis as this patient was not recognized by the authors as an athlete but rather a middle-aged patient who became symptomatic because of a loose body from an old OCD lesion.[10] Maruyama et al.[26] looked at 33 adolescent baseball players and reported that 94% (31/34 patients) returned to play. Of the 2 patients who did not return to baseball after OAT, one had an excellent outcome but decided to participate in competitive archery at a high level and the other patient retired from baseball after high school. The authors did not comment on whether these decisions were related to the presence of elbow symptoms. Iwasaki et al.[3] reported 89.5% (17/19) of baseball players in their study returned to play, with one patient deciding to play rugby and another opting for soccer despite both reporting "acceptable" results after surgery. The authors did not comment further on factors that influenced the decision to no longer play baseball (Table 3).

Two of the included studies listed a specific time for unrestricted return to athletic competition after OAT, with the mean number of months for this group reported to be 5.6 months (range, 3-14 months). Maruyama et al.[26] reported a time of 6.9 months, whereas Lyons et al.[25] reported a mean time of 4.4 months to return to sport. The remaining 5 studies did not report an absolute number of months or weeks required for the athletes to return to their previously obtained level of sport. Rather, these studies either reported a range of time or provided a time frame during which restrictions for their patients were released. Iwasaki et al.[3,32] reported in 2 separate studies a range of 8 to 12 months for return to play; however, it should be noted that this time frame was predetermined by surgeon protocol and is more accurately described as time until the patient was "allowed" to return to play. In 2005, Shimada et al.[23] reported a range of 6 to 9 months when athletes were able to return to playing

Table 1. Characteristics of Studies Reporting Return to Competitive Sports After Osteochondral Autograft Transplantation for Osteochondritis Dissecans of the Capitellum

Study	Location	No. of Included Patients	Mean Age (Time of Surgery)	Mean Follow-Up/Range of Follow-Up	Sport	Methodologic Quality: Mean MINORS Score	Level of Evidence
Lyons et al. 2015[25]	United States	11 (10 male/1 female)	14.5 yr	22.7 mo/6-49 mo	Baseball: 7 Basketball: 1 Football: 1 Football and Basketball: 1 Lacrosse: 1 Gymnast: 1	12.5/16	IV
Maruyama et al. 2014[26]	Japan	33 (33 male)	13.6 yr	28.4 mo/12-76 mo	Baseball: 33	12/16	IV
Shimada et al. 2012[10]	Japan	25 (25 male)	16 yr	36 mo (24-51 mo)	Baseball: 10 Unspecified: 15 Nonathlete: 1 (excluded)	13/16	IV
Iwasaki et al. 2009[3]	Japan	19 (19 male)	14.2 yr	45 mo/24-87 mo	Baseball: 17	11.5/16	IV
Iwasaki et al. 2009[32]	Japan	10 (10 male)	13.7 yr	12 mo	Baseball: 10	13.5/16	IV
Yamamoto et al. 2006[11]	Japan	18 (18 male)	13.6 yr	3.5 yr (24-63 mo)	Baseball: 18	12.5/16	IV
Shimada et al. 2005[23]	Japan	10 (10 male)	14.3 yr	25.5 mo (18-45 mo)	Baseball: 9 Judo: 1	10/16	IV

MINORS, Methodological Index for Non-Randomized Studies.

Table 2. Characteristics of Capitellar Osteochondritis Dissecans Lesion, Osteochondral Autograft Plug, and Return to Sport Rate

Study	Mean Size of Lesion or Articular Defect	Donor Plug Site	Dominant Extremity Affected	Mean Size of Osteochondral Plug/Range (Diameter)	Mean/Range of Osteochondral Plugs Used	Time to Osseous Union	Time From Procedure to Beginning Rehabilitation	Mean Time to Return to Competitive Level	Number of Patients Who Returned to Sport
Lyons et al. 2015[25]	All >1 cm^2	Femoral condyle	—	6.8 mm (4-10 mm)	1.8 (1-4)	3 mo	3 mo	4.4 mo (3-7 mo)	11 (100%)
Maruyama et al. 2014[26]	16 × 14 mm	Femoral condyle	33 (100%)	7 mm (5-9 mm)	1.8 (1-3)	3.8 mo	3 mo	6.9 months (6-14 mo)	31/33 (94%)
Shimada et al. 2012[10]	16 × 16 mm	5th and 6th Rib	—	15 mm	1	3 mo	3 mo, no restrictions at 6 mo, pitchers unrestricted at 12 mo	6 mo Pitchers: full activity by 9-12 mo	25 (100%), 1 nonathlete (excluded)
Iwasaki et al. 2009[3]	147 mm^2	Femoral condyle	19 (100%)	3.5 mm (2.7-6.0 mm)	3.3 (2-6)	—	Strength: 3 mo Throwing: 6 mo	8-12 mo	17/19 (89.5%)
Iwasaki et al. 2009[32]	128 mm^2	Femoral condyle	10 (100%)	3.5 mm (2.7-4.5 mm)	4.0 (2-5)	3 mo: 0/10 6 mo: 4/10 12 mo: 10/10	Strength: 3 mo Throwing: 6 mo	8-12 mo	10/10 (100%)
Yamamoto et al. 2006[11]	—	Femoral condyle	18 (100%)	6.3 mm (5-9 mm)	1.5 (1-3)	3 mo	Gentle throwing at 3 mo, full throwing at 6 mo	Grade 3 lesions 7/9 < 1 yr Grade 4 lesions 8/9 < 2 yr	15/18 (83%)
Shimada et al. 2005[23]	15.6 mm × 14.4 mm	Femoral condyle	—	7.5 mm (5-8 mm)	1.4 (2-5)	3 mo	—	6-9 mo	10/10 (100%)

Table 3. Characteristics of Patients Who Did Not Return to Competitive Sports After Osteochondral Autograft Transplantation

Study	Patients	Previous Sport	New Sport/Activity	Reasons Given
Maruyama et al. 2014[26]	2/33	Baseball	Competitive archery, retired from baseball	Did not note whether elbow symptoms were cause for switch
Iwasaki et al. 2009[3]	2/19	Baseball	Rugby, soccer	No explicit reason despite "acceptable" results
Yamamoto et al. 2006[11]	3/18	Baseball	Retired, softball, skiing	The patient who retired did so for academic reasons. The patient who participated in skiing did so because of elbow pain.

baseball. In their 2012 study, Shimada and colleagues[10] chose to analyze baseball pitchers separately, reporting a range of 9 to 12 months before return to full pitching activities. All of their other athletes returned to competition by a mean time of 6 months. Finally, Yamamoto et al.[11] separated their results by magnetic resonance imaging grade of the OCD lesion and reported results in a binary fashion, with 7/9 patients with grade 3 lesions returning to play within 1 year and 8/9 patients with grade 4 lesions returning to play within 2 years.

Rehabilitation protocols were not uniform across studies. Of the 6 studies that included information on time to initiation of rehabilitation,[3,10,25,26,32] 3 reported allowing "full" or "unrestricted" throwing at 6 months postoperatively (Table 2).[3,11,32] Shimada et al.[10] reported lifting restrictions at 6 months but again reported baseball pitchers separately, with restrictions being lifted at 12 months for this unique patient population. The authors' earlier study[23] did not comment on this time interval.

Discussion

The ability for young athletes to return to the same or higher level of sport after OAT of the capitellum appears to be remarkably good. This systematic review found that 94% (119/126) of patients were able to return to a competitive level of sports. Four of the 7 studies reported a 100% return to sport rate,[10,23,25,32] whereas the other 3 reported rates ranging from 83% to 94%.[3,11,26] Unrestricted return to athletic competition was possible by approximately 6 months (range, 3-14 months) in most patients. Overall, this study demonstrates that surgeons and patients can anticipate a high likelihood of returning to competitive athletics after OAT for OCD of the capitellum.

Osteochondral lesions of the capitellum are an infrequent but potentially debilitating cause of elbow pain in the young athlete. The management of these lesions is largely determined by their stability. Takahara and colleagues[17] defined stable lesions as those that have the ability to heal completely after a period of rest. These lesions typically occur in individuals with an open physis, normal elbow range of motion, and minimal radiographic changes. Several authors have demonstrated excellent outcomes when stable OCD lesions are managed nonoperatively with elbow rest and activity modification.[6,17,33]

Optimal intervention for unstable lesions remains to be determined. Unstable lesions tend to occur in individuals with a closed physis, decreased elbow range of motion of greater than 20°, or radiographic evidence of fragmentation.[17] Patients with unstable OCD lesions have suboptimal results when managed nonoperatively.[6,17] More conservative operative techniques such as fragment removal have produced poor long-term outcomes, with high rates of persistent pain, mechanical symptoms, and osteoarthritis.[18,19,21] Furthermore, Takahara and colleagues[21] reported that none of their patients were able to return to a similar level of athletic competition after fragment removal alone. One of the key advantages to OAT is the ability to use a patient's own subchondral bone and articular cartilage to provide mechanical support and an articular surface to the defect. Conversely, other techniques like microfracture rely on the production of fibrocartilage, which is not only mechanically inferior but may fail to re-establish subchondral bone stock and a congruent articular surface.[11,12,34]

The goals of osteochondral reconstruction in the young athlete are to allow patients to return to a high level of athletic competition unhindered by pain or mechanical symptoms and to help prevent the development of osteoarthritis. The indications for OAT for OCD of the capitellum are still being defined as more literature is becoming available. On the basis of the limited data available, OAT has been successful in restoring elbow function, alleviating pain, and returning athletes to a high level of competition. Patients and parents inevitably inquire about the likelihood and timing of returning to athletic competition. Clinical data regarding these important questions were previously limited to smaller case series scattered over a decade. Furthermore, it is difficult to interpret the available data because much of it is highly heterogeneous. There is no standard of practice regarding various aspects of the procedure and rehabilitation process.

Shimada and colleagues[10] represented the only study included in this analysis that used costal osteochondral grafts. Among the reasons cited by the authors influencing graft selection, costal cartilage contains hyaline cartilage and the osteochondral junction of the ribs has

biomechanical properties similar to those of the subchondral bone of synovial joints.[10] Furthermore, Shimada et al.[10] were able to use 1 large osteochondral graft for reconstruction, which otherwise would have required multiple osteochondral plugs, and therefore may potentially limit donor-site morbidity. The authors reported excellent results, with 100% return to sports in the second largest series included in this review. No patients in their series reported any donor-site pain after the first few postoperative days. Similar results using costal osteochondral grafts have been reported elsewhere in the literature.[20]

It is difficult to make a clinically astute assessment regarding the time to return to play on the basis of the findings of this study. Only Lyons et al.[25] and Maruyama et al.[26] provided a specific time for unrestricted return to athletic competition after OAT, which averaged 5.6 months (range, 3-14 months). The other authors included in this review had specific restrictions in their postoperative rehabilitation protocol, which limited individual assessment. However, with the exception of the highly advanced lesions reported in the subgroup by Yamamoto et al.,[11] all patients included in this review who returned to sport did so within the range established by Lyons et al.[25] and Maruyama et al.[26]

Maruyama and colleagues[26] posited that the size and number of grafts used may influence healing rates, and therefore the ability and timing to return to sport. In their study, they suggested that using fewer large grafts may allow for earlier osseous union and return to play.[26] All but 1 of the studies included in this review commented on the time to radiographic osseous union. Iwasaki and colleagues[3] simply noted that radiographs obtained at the time of follow-up demonstrated union; however, the authors did not specify when union was first achieved. Radiographic osseous union was achieved by approximately 3 months after surgery in 5 of the 6 remaining studies.[10,11,23,25,26] In these studies, the mean size of the osteochondral grafts used measured 7.1 mm (range 4-15 mm), and, on average, 1.25 grafts were used per case. Conversely, Iwasaki and colleagues[32] used a higher number (mean of 4 graphs/case) of smaller grafts (mean 3.5 mm, range, 2.7-4.5 mm) in their series. They monitored for graft union with magnetic resonance images obtained at 3, 6, and 12 months after surgery. The authors observed 0/10, 4/10, and 10/10 patients with radiographic union at these respective times, as evidenced by a persistent fluid signal surrounding the graphs on T2-weighted images. Our interpretation of the association between graft size/number and the time to osseous union and whether this impacts the timing of return to sport cannot be concluded from this investigation. Future research may elucidate whether the use of fewer large grafts is beneficial in enhancing the time to osseous union and return to sport.

There are several strengths to this study. An exhaustive systematic review was performed to evaluate the ability to return to competitive athletics after OAT for capitellar OCD lesions, which demonstrated a high likelihood of return to play. The strengths of this study include broad search terms and duplicate assessment of study eligibility, as well as methodologic quality assessment of included studies. The agreement between reviewers regarding study eligibility and methodologic assessment was high.

Limitations

The main limitations of the applicability of this review relate to the sizes and study designs of the included studies. All studies were of Level IV methodologic quality, with small sample sizes. Included studies had variable operative technique and nonstandardized postoperative rehabilitation protocols. Furthermore, most athletes included were baseball players, which limits the generalizability of these results to athletes such as gymnasts who experience more direct axial loading of the elbow. The predominance of baseball players included in this study is likely in part due to the regional bias of the studies included in this review. All but 1 study was performed in Japan, where baseball is one of if not the most popular national sport. Given the significant heterogeneity of these studies, it is difficult to draw conclusions from the available data. For instance, surgeons differed significantly regarding their operative technique, particularly regarding the location of the donor graft, number and size of the grafts used, percentage of defect that was reconstructed, management of the lateral collateral ligament, and surgical approach used. Furthermore, most authors had predetermined the time periods for rehabilitation and return to competition. Given the high risk of bias across all studies included in this review, confidence in the finding of successful return to sport after OAT was given a GRADE[35,36] (Grades of Recommendation, Assessment, Development and Evaluation) score of "very low." This suggests that a significant risk of bias exists with the overall available body of evidence, and the true effect estimate may differ from the findings of this review.

Conclusions

Current best evidence suggests that OAT is successful in treating advanced OCD lesions of the capitellum and returning athletes to high-level competition. Evidence supporting the association between the size and number of grafts used and the time to osseous healing and return to sport is currently limited. Our assessment of the time to return to athletic competition was limited because of variable surgical technique, postoperative rehabilitation protocols, and outcome assessment.

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Appendix: PubMed Search Strategy

("osteochondral autograft transplantation" OR OAT [tiab] OR OATs[tiab] OR "Autologous osteochondral transplantation" OR OCT[tiab] OR Transplantation, Autologous[mesh] OR Cartilage/transplantation[mesh] OR "Osteochondral plug" OR "osteochondral autograft" OR mosaicplasty) AND ("osteochondritis dissecans" OR Osteochondritis Dissecans[mesh] OR "osteochondral lesions" OR "osteochondral lesion" OR OCD[tiab]) AND (Elbow OR capitellum OR "Elbow Joint"[Mesh] OR "Elbow"[Mesh])