Systematic Review

Humeral Head Reconstruction With Osteochondral Allograft Transplantation

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Purpose: To synthesize, in a systematic review, the available clinical evidence of osteochondral allograft transplants for large osteochondral defects of the humeral head. **Methods:** The Medline, Embase, and Cochrane databases were searched for studies reporting clinical or radiographic outcomes of osteochondral allograft transplantation for humeral head defects. Descriptive statistics were provided for all outcomes. After checking for data normality, we compared postoperative and preoperative values using the Student *t* test. **Results:** We included 12 studies (8 case reports and 4 case series) in this review. The study group consisted of 35 patients. The mean age was 35.4 ± 18.1 years; 77% of patients were male patients. Thirty-three patients had large Hill-Sachs lesions due to instability, 1 had an osteochondritis dissecans lesion, and 1 had an iatrogenic lesion after resection of synovial chondromatosis. The mean lesion size was 3 ± 1.4 cm (anteroposterior) by 2.25 ± 0.3 cm (medial-lateral), representing on average 40.5% ± 4.73% of the native articular surface. Of the 35 patients, 3 received a fresh graft, with all others receiving frozen grafts. Twenty-three femoral heads, 10 humeral heads, and 2 sets of osteochondral plugs were used. The mean length of follow-up was 57 months. Significant improvements were seen in forward flexion at 6 months (68° ± 18.1°, $P < .001$), forward flexion at 12 months (83.42° ± 18.3°, $P < .001$), and external rotation at 12 months (38.72° ± 18.8°, $P < .001$). American Shoulder and Elbow Surgeons scores improved by 14 points ($P = .02$). Radiographic studies at final follow-up showed allograft necrosis in 8.7% of cases, resorption in 36.2%, and glenohumeral arthritic changes in 35.7%. Complication rates were between 20% and 30%, and the reoperation rate was 26.67%. Although only 3 patients received fresh allografts, there were no reports of graft resorption, necrosis, or arthritic changes in these patients. **Conclusions:** Humeral head allograft—most commonly used in the setting of large Hill-Sachs lesions due to instability—has shown significant improvements in shoulder motion and American Shoulder and Elbow Surgeons scores as far as 1 year postoperatively. Return-to-work rates and satisfaction levels are high after the intervention. Complication and reoperation rates are substantial, although it is possible that use of fresh allograft tissue may result in less resorption and necrosis. **Level of Evidence:** Level V, systematic review of Level IV and V studies.

Traumatic glenohumeral instability is a common problem facing orthopaedic surgeons, with an annual rate of 11.2 per 100,000 patients.[1] Hill-Sachs lesions and reverse Hill-Sachs lesions are impaction injuries to the softer cancellous portions of the humeral head that may occur after traumatic anterior and posterior glenohumeral joint dislocations, respectively. These bony injuries are associated with a higher rate of recurrent shoulder instability, by creating an articular arc mismatch.[2] Large defects pose a significant challenge to the orthopaedic surgeon when attempting to restore normal glenohumeral biomechanics and prevent continued subluxation or dislocation events.[2,3] In the setting of humeral bone loss, nonoperative treatment for shoulder instability is generally reserved for patients with low functional demands, poor compliance with postoperative rehabilitation protocols, significant medical comorbidities that would preclude surgical intervention without unacceptably high risks, or anatomic factors including a small osseous defect size or non-engaging lesions.[4,5] Kaar et al.[6] quantified through cadaveric analysis that glenohumeral stability decreased in abduction and external rotation with defects of greater than five-eighths of the humeral head radius. Many surgical strategies have been used in recent years to address these large lesions, including humeral head augmentation, humeroplasty, disimpaction with elevation and bone

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grafting, and arthroplasty.[7] Remplissage has been proposed as well for smaller defects, with success in terms of redislocation and recurrent instability rates.[8]

Another recently implemented method to restore a spherical humeral head is osteochondral allograft transplantation. The use of osteochondral allografts has been proposed to address moderate to large humeral-sided defects (>40% of the articular surface). Size-matched fresh-frozen humeral or femoral head allograft plugs are press fit into the humeral defect and seated flush with the surrounding articular surface.[5] This allows reconstruction of the native articular contour, as well as filling of the subchondral bony defect with structural graft.[4,5] However, fresh-frozen grafts are essentially acellular because of the freeze-thaw process. Fixation devices may be used to secure the graft; however, it is unclear to what extent this is necessary.[9] In theory, the addition of a cartilaginous interface with restoration of normal anatomy for articulation with the glenoid may prevent future lesion engagement and subsequent instability. Because humeral head osteochondral allograft transplantation has only recently been introduced, the outcomes of the procedure are poorly understood.

The objective of this systematic review was to assess the clinical and radiographic outcomes after humeral head reconstruction with osteochondral allograft transplantation. Our hypothesis was that osteochondral allograft transplantation for traumatic defects of the humeral head in the setting of glenohumeral instability would improve range of motion (ROM) and functional outcome scores and would prevent recurrent instability episodes.

Methods

Study Design and Data Collection

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (www.prisma-statement.org) were used to design our systematic review of the literature. The Medline, Embase, and Cochrane databases were reviewed for all English-language studies published between inception of the databases and August 2014. Two key phrases were used to search each database: (1) “humerus allograft” and (2) “humeral allograft.” The inclusion criteria included (1) Level I through V studies, (2) studies reporting on the use of osteochondral allograft transfer for humeral head defects, and (3) studies reporting clinical or radiographic outcomes. The exclusion criteria included (1) studies that were not available in English, (2) unpublished studies, and (3) studies that used allograft tissue for purposes other than cartilage resurfacing of the humeral head. All abstracts were reviewed in duplicate by 2 of the authors (B.M.S., J.C.R.) and assessed based on the aforementioned criteria. The full text of eligible studies was then reviewed by the same authors before final inclusion. Data were extracted in duplicate from all studies using a standardized form created by the authors at the onset of the review. Inconsistencies between reviewers were resolved by joint review of the involved studies.

Data Synthesis and Statistical Analysis

Because of the availability of Level IV and V studies only, formal meta-analysis was not indicated. Therefore frequency-weighted means were calculated with standard deviations to summarize continuous variables from multiple studies. Weights were assigned based on the number of patients in each study. For continuous variables that were reported preoperatively and postoperatively, 2-tailed t test calculations were performed using the summary data in Tables 1 and 2. Statistical significance was set at $P < .05$. All analyses were performed with JMP software (SAS Institute, Cary, NC).

Sources of Funding

No internal or external funding sources were used in this investigation.

Results

Study and Patient Demographic Characteristics

Twelve studies, published between 1996 and 2013, met the inclusion criteria for this systematic review (Table 3).[7,10-20] Our search strategy is summarized in a PRISMA flowchart (Fig 1). Four of the studies were cases series, whereas 8 were single-case reports. A total of 35 patients were available for analysis. They were followed up for a mean of 57.02 ± 34.14 months (range, 8 to 122 months). The patients were predominantly male patients (77.14% ± 26.37%), and the dominant arm was typically affected (74.15% ± 27.99%). At baseline, the patients had poor ROM in all planes and low American Shoulder and Elbow Surgeons (ASES) scores (Table 1). In 33 of the 35 patients, osteochondral defects of the humeral head developed from traumatic instability; 1 patient had synovial chondromatosis with extensive humeral head erosion; and 1 patient had a diagnosis of osteochondritis dissecans. Of the patients with glenohumeral instability, 9 had anterior instability and 24 had posterior instability. The humeral head defects requiring allograft tissue were on average 3 ± 1.41 cm in anteroposterior diameter, 2.25 ± 0.35 cm in medial-lateral diameter, and 1.62 ± 0.54 cm deep. This represented 40.52% ± 4.73% of the native humeral head (Table 1).

Surgical Technique and Graft Fixation

In all but 1 study (with a single patient), a deltopectoral approach to the shoulder was used; a single patient underwent arthroscopic placement of humeral head allograft plugs.[10] A variety of graft types and fixation techniques were used. Of 12 studies, 5 used fresh-frozen femoral head allograft (Table 3). Three studies used fresh-frozen humeral head allograft. Two studies used

Table 1. Grouped Summary Data of Preoperative Patient Demographic Characteristics

	No. of Patients Available for Analysis	Mean	SD
% male	35	77.14	26.37
% dominant arm	18	74.15	27.99
FF preoperatively, °	25	47.00	18.37
Abd preoperatively, °	7	40.00	26.46
ER preoperatively, °	25	17.53	20.78
ASES score preoperatively	5	70.12	11.25
AP size, cm	2	3.00	1.41
ML size, cm	2	2.25	0.35
Depth, cm	2	1.62	0.54
% articular surface affected	29	40.52	4.73

Abd, abduction; AP, anteroposterior; ASES, American Shoulder and Elbow Surgeons; ER, external rotation; FF, forward flexion; ML, medial-lateral.

fresh humeral head allograft, and 2 studies used allograft osteoarticular plugs (Table 3). Fixation was achieved by press fitting (3 studies), partially threaded cancellous screws (5 studies), or headless compression screws (4 studies). Several concomitant procedures were performed to address coexisting glenohumeral pathology (Table 3).

Rehabilitation

A variety of postoperative protocols were recommended in the included studies. These are summarized in Figure 2. Temporary sling immobilization was used in 10 of 12 studies, ranging from 2 to 6 weeks, with 6 weeks being most common. Five of 12 studies reported immediate initiation of passive ROM, typically with limitations on external rotation to protect the subscapularis repair. The other groups waited 2 to 6 weeks to initiate passive ROM. Patients in half of the studies started a strengthening program at 4 to 6 weeks, whereas patients in the other half waited until 3 months after surgery.

Range of Motion

Preoperative ROM was typically poor in patients requiring a humeral head allograft and improved significantly between baseline and final follow-up (Table 2). Specifically, forward flexion improved by 68° ± 18.1° at 6 months ($P < .001$) and by 83.42° ± 18.3° at 12 months ($P < .001$) (Table 2). External rotation was not different at 6 months; however, a significant improvement (38.72° ± 18.8°, $P < .001$) was noted by 12 months. Internal rotation at 12 months was 68.43° ± 1.51°; however, none of the studies reported internal rotation at baseline for comparison.

Return to Work

Only 7 of 12 studies reported on return to work, but within these studies, 100% of patients were able to return to work. Data on work type in terms of specific postoperative activity levels were not available. Return to work occurred at a mean of 4.29 ± 0.76 months after surgery (Table 2).

Table 2. Grouped Summary Data of Postoperative Patient Outcomes

	No. of Patients Available for Analysis	Mean	SD	Comparison With Baseline	
				Mean Difference ± SD	*P* Value
Follow-up length, mo	35	57.02	34.14	NA	NA
Return to work, %	7	100.00	0.00	NA	NA
Time to return to work, mo	7	4.29	0.76	NA	NA
FF at 6 mo, °	2	115.00	7.07	68 ± 18.1	< .001*
ER at 6 mo, °	2	37.50	10.61	19.97 ± 20.47	.20
Final postoperative FF, °	12	130.42	18.14	83.42 ± 18.3	< .001*
Final postoperative Abd, °	7	123.71	20.41	83.71 ± 23.6	< .001*
Final postoperative ER, °	12	56.25	13.71	38.72 ± 18.8	< .001*
Final postoperative IR, °	7	68.43	1.51	NA	NA
% instability at final follow-up	32	3.13	3.84	NA	NA
% with pain	28	32.11	17.62	NA	NA
% satisfied	20	90.00	8.17	NA	NA
Constant score at final follow-up	23	78.15	10.26	NA	NA
ASES score at final follow-up	5	84.84	1.03	14.72 ± 8	.02*
Intraoperative complications, %	13	38.50	0.00	NA	NA
Postoperative complications, %	9	22.22	26.35	NA	NA
Infection, %	5	0.00	0.00	NA	NA
Revision surgery, %	15	26.67	22.09	NA	NA
Allograft necrosis, %	23	8.70	8.34	NA	NA
Allograft resorption, %	30	36.23	21.71	NA	NA
Arthritic changes, %	14	35.71	23.44	NA	NA

Abd, abduction; ASES, American Shoulder and Elbow Surgeons; ER, external rotation; FF, forward flexion; IR, internal reduction; NA, not applicable.

*Statistical significance was reached ($P < .05$).

Table 3. Demographic Characteristics and Descriptions

Authors	Year of Publication	No. of Study Participants	Participant Group	Level of Evidence	Graft Type	Fixation Technique	Concomitant Procedures	Follow-up Period, mo	Outcomes
Gerber and Lambert[12]	1996	4	Case series with single treatment group	IV	Fresh-frozen femoral head (3), fresh femoral head (1)	Cancellous bone screws or press fit	—	68	Constant score, ROM, radiographs, complications
Johnson and Warner[13]	1997	1	Case report with single treatment group	V	Fresh-frozen humeral head	Press fit	—	36	Radiographs, complications
Yagishita and Thomas[20]	2002	1	Case report with single treatment group	V	Fresh-frozen femoral head	Press fit	Bankart repair, rotator cuff repair	24	ROM, radiographs, complications
Chapovsky and Kelly[10]	2005	1	Case report with single treatment group	V	Fresh-frozen allograft plugs	Press fit	Bankart repair	12	Radiographs, complications
McCarty and Cole[15]	2007	1	Case report with single treatment group	V	Fresh-frozen humeral head	Variable-pitch compression screws	Lateral meniscal allograft	24	ROM, SST score, ASES score, SF-12 score, VAS, radiographs, complications
DiPaola et al.[11]	2010	4	Case series with single treatment group	IV	Fresh-frozen femoral head or allograft plugs	Headless Acutrak* screws (femoral head) or press fit (allograft plugs)	—	27	ASES score, UCLA score, ROM, radiographs, revision surgery, complications
Diklic et al.[7]	2010	13	Case series with single treatment group	IV	Fresh-frozen femoral head	Partially threaded cancellous screws	—	54	Constant, ROM, complications, radiographs
Provencher et al.[18]	2010	1	Case report with single treatment group	V	Fresh humeral head	Plastic compression screw	Distal tibial allograft to glenoid, removal of hardware	16	ROM, radiographs, complications
Trajkovski et al.[19]	2011	1	Case report with single treatment group	V	Fresh-frozen allograft plugs	Partially threaded cancellous screws	Extensive synovectomy	30	ROM, TESS, MSTS-87 score, radiographs, complications
Patrizio and Sabetta[17]	2011	1	Case report with single treatment group	V	Fresh-frozen femoral head	Herbert screws	ORIF of lesser tuberosity and posterior glenoid	8	Radiographs, complications
Nathan and Parikh[16]	2012	1	Case report with single treatment group	V	Fresh humeral head	Partially threaded cancellous screws	—	30	Radiographs, complications
Martinez et al.[14]	2013	6	Case series with single treatment group	IV	Fresh-frozen humeral head	Herbert screws	Lateral capsulectomy	122	Constant score, ROM, radiographs, revision surgery, complications

ASES, American Shoulder and Elbow Surgeons; MSTS-87, Musculoskeletal Tumor Society—87; ORIF, open reduction—internal fixation; ROM, range of motion; SF-12, Short Form 12; SST, Simple Shoulder Test; TESS, Toronto Extremity Salvage Score; UCLA, University of California, Los Angeles; VAS, visual analog scale.

*Hillsboro, OR.

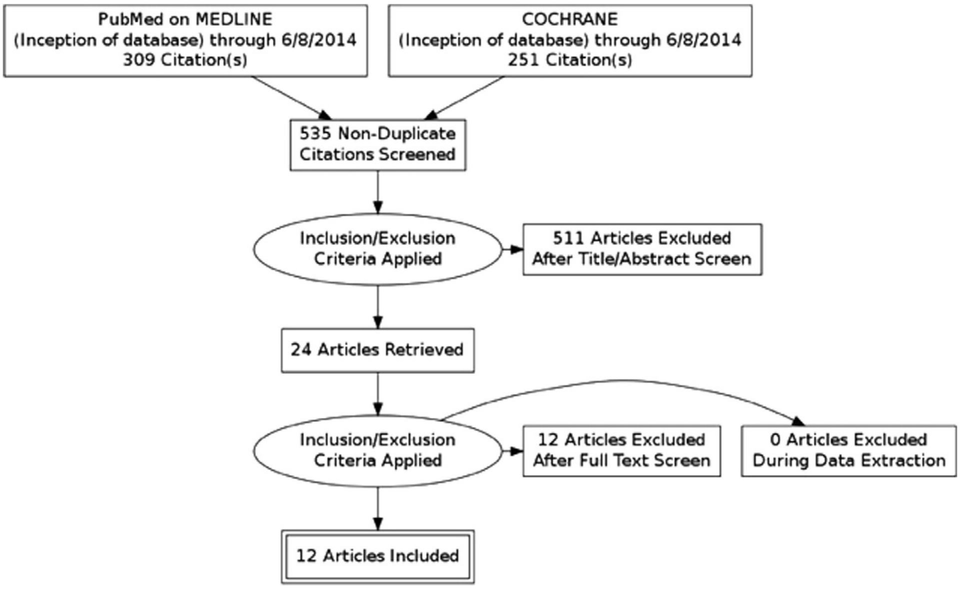

Fig 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart diagramming search process to determine articles for inclusion.

Functional Outcomes

Multiple functional outcome measures were reported in the available studies, including the Constant score; ASES score; Simple Shoulder Test score; Toronto Extremity Salvage Score; Musculoskeletal Tumor Society—87 score; University of California, Los Angeles score; and Short Form 12 score. Only the Constant and ASES scores were reported in more than 1 study and could be quantitatively synthesized. The mean postoperative Constant score was 78.15 ± 10.26 (Table 2). Preoperative Constant scores were not reported for comparison. The mean postoperative ASES score was 84.84 ± 1.03, which was a 14.72 ± 8 increase from preoperative values ($P = .02$). Several nonvalidated outcome scores were also reported. Of the patients, 90% ± 8.17% were subjectively satisfied with their outcome. Only 3.13% ± 3.84% had recurrent instability. However, 32.11% ± 17.62% of patients had residual pain at final clinical follow-up.

Radiographic Outcomes

Radiographic studies at final follow-up (57.02 ± 34.14 months) showed allograft necrosis in 8.7% ± 8.4% of cases, allograft resorption in 36.23% ± 21.71% of cases, and glenohumeral arthritic changes in 35.71% ± 23.44% of cases. These results are stratified by graft type in Table 4.

Complications

Complication rates were not explicitly reported in all studies. One study reported 5 intraoperative complications, which represented 38.5% of the study's cohort.[7] These included 2 cases of posterior capsular avulsion requiring intraoperative suture anchor fixation and 3 cases of damage to the long head of the biceps requiring biceps tenodesis.[7] Although the other studies did not report any intraoperative complications, their absence was not explicitly communicated.

Another study reported 2 postoperative complications in 4 patients.[11] Complex regional pain syndrome developed in 1 patient, and the other patient required reoperation for removal of prominent hardware (partially threaded cancellous screws).[11] Five other studies commented on the absence of postoperative complications. Therefore the weighted mean incidence of postoperative complications was 22.22% ± 26.35%. There were no reports of postoperative infection, whether early or late, in any study.

A single study reported long-term failure due to the development of glenohumeral osteoarthritis.[14] Three of six patients in that study required conversion to a total shoulder arthroplasty at 8 years (2 patients) and 10 years (1 patient) after surgery. Of note, this was the only study with a clinical follow-up period of more than 5 years.

Discussion

The principal findings of this study were that humeral head reconstruction with an osteochondral allograft can improve shoulder ROM, improve functional outcome scores, and result in a low subsequent dislocation rate. However, the risks of the procedure include a 20% to 30% complication rate and a 26% reoperation rate. In addition, when patients were followed up for 5 years or more, 50% required conversion to a total shoulder arthroplasty.

Hill-Sachs lesions have provided appreciable difficulties for orthopaedic surgeons over the past several decades. Their role in recurrent instability and dislocation of the glenohumeral joint is proposed to be a result of a shortened rotational arc length of the humeral head on the glenoid.[21] The Hill-Sachs defect can engage

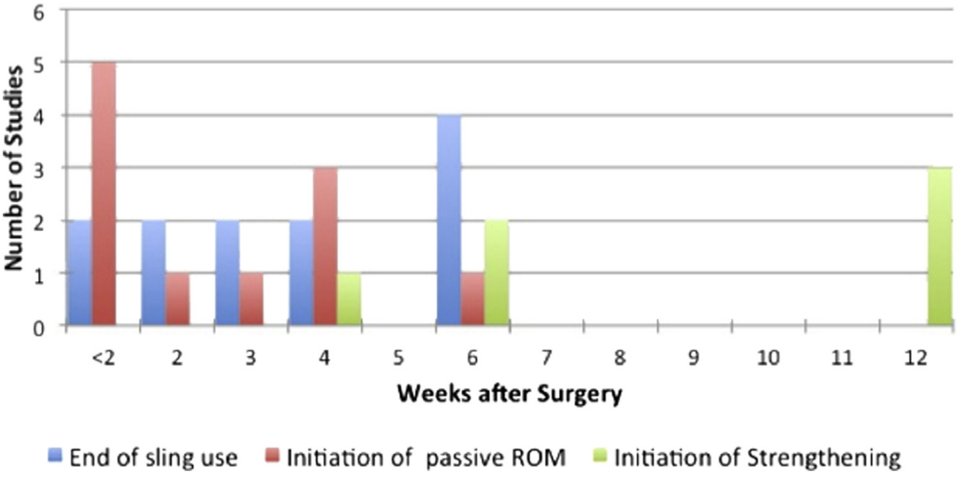

Fig 2. Summary of rehabilitation protocols.

with the glenoid and pivot on the glenoid rim, causing stress on the capsulolabral structures, subluxation of the glenohumeral joint, and repeated dislocations.[21]

Osteochondral allograft reconstruction of articular defects in the knee has been reported to distribute load across the joint surface, restoring normal contact pressures.[22,23] The intent is similar in these patients because the problem is both engagement of the lesion, causing recurrent dislocations, and this functioning as a large cartilage defect. Therefore, similar to using a distal tibial allograft in large glenoid defects,[24] humeral head allografts for large symptomatic humeral defects should be considered. Although the rate of humeral head allograft transplantation is thought to be on the rise, the literature is currently devoid of any high-level reports on its safety and efficacy.

Osteochondral allograft transplantation in the knee has been reported to have graft survival rates ranging from 84.5% to 100% at 5 years, 71% to 89% at 10 years, 74% to 76% at up to 15 years, and 66% at up to 20 years.[25] However, none of these reports have contained Level I evidence. In the ankle, reports of allograft reconstruction of the talus have shown significant collapse or resorption with joint space narrowing in up to 60% to 80% of patients.[26,27] Other studies have shown low rates of failure as defined by the need for conversion to arthrodesis or arthroplasty.[26] However, although the glenohumeral joint is non—weight bearing relative to the knee and ankle, it undergoes some level of load bearing. This difference in mechanics changes the proposed goal of the procedure, with humeral head grafting aiming to improve joint congruity as its primary benefit.

Notable from this study is the high rate of complications with the procedure. The highest incidences of complications were intraoperative and minor; however, the complications included damage to the long head of the biceps tendon requiring tenodesis and posterior capsular avulsion requiring suture anchor fixation. Postoperative complications also occurred in the minority of patients and occurred with repeat surgical intervention in a few patients for complaints such as prominent hardware. Ultimately, however, complication rates were not explicitly reported in all studies, which limits our understanding of the true incidence of morbidity.

The high allograft resorption rate (36%) is another notable finding from this study. None of the included studies provided a rationale for resorption of allograft at the humerus. This may result from the use of acellular tissue that has been frozen, just as improved results have been shown in the knee with fresh osteochondral allografts compared with frozen grafts. Data obtained through this study would seem to suggest this same finding, although the number of fresh allografts used was small (n = 2) in comparison with frozen allografts (n = 33) and thus a statistical comparison was not feasible. A femoral head graft source also trended toward less radiographic necrosis and allograft resorption than did those with a humeral head graft source, although the small numbers and heterogeneity of procedures again preclude direct statistical comparison.

Table 4. Radiographic Outcomes Stratified by Graft Type

		Radiographic Necrosis, % of Patients		Allograft Resorption, % of Patients		Arthritic Changes, % of Patients	
	n	Mean	SD	Mean	SD	Mean	SD
Graft preparation							
Fresh	2	0.00	0.00	0.00	0.00	0.00	0.00
Frozen	33	9.52	16.52	38.82	39.37	41.67	37.27
Graft source							
Humeral head	10	10.53	19.70	46.79	40.50	50.00	NA
Femoral head	23	0.00	0.00	19.80	25.56	33.33	40.82
Cylindrical allograft plugs	2	NA	NA	0.00	NA	0.00	NA

NA, not applicable.

Currently, there is not enough evidence to correlate the radiographic outcome of the procedure with patients' symptomatic improvement.

Limitations

The primary limitation to this study is its small overall cohort size, which is inherent to any systematic review of a topic with relatively low numbers of published studies. The included studies were of low quality, with 8 of the 12 included studies being case reports, and among the remaining 4 case series, the greatest patient cohort size was only 13 patients. These studies, of course, did not compare the index procedure with any control group or other surgical intervention.

There was appreciable heterogeneity in terms of patient etiology of humeral head defects, graft types and fixation means, rehabilitation methods, and reporting of complications. Thus the results of this report must be reviewed cautiously regarding generalizability of the procedure's efficacy without higher-level research being performed on the topic because any one of these variables may differentially affect the results of the procedure. Further research is required on the use of osteochondral allograft transplantation for humeral head defects, including well-designed controlled trials or prospective cohort studies, to allow further evaluation of the procedure in terms of clinical and radiographic efficacy, morbidity, and complication rates, particularly in comparison with the other anatomic-restoration procedures for defects of the humeral head, to determine superiority of any particular intervention.

Conclusions

Humeral head allograft—most commonly used in the setting of large Hill-Sachs lesions due to instability—has shown significant improvements in shoulder motion and ASES scores as far as 1 year postoperatively. Return-to-work rates and satisfaction levels are high after the intervention. Complication and reoperation rates are substantial, although it is possible that use of fresh allograft tissue may result in less resorption and necrosis.

References

1. Simonet WT, Melton LJ III, Cofield RH, Ilstrup DM. Incidence of anterior shoulder dislocation in Olmset County, Minnesota. *Clin Orthop Relat Res* 1984:186-191.
2. Burkhart SS, De Beer JF. Traumatic glenohumeral bone defects and their relationship to failure of arthroscopic Bankart repairs: Significance of the inverted-pear glenoid and the humeral engaging Hill-Sachs lesion. *Arthroscopy* 2000;16:677-694.
3. Boileau P, Villalba M, Hery JY, Balg F, Ahrens P, Neyton L. Risk factors for recurrence of shoulder instability after arthroscopic Bankart repair. *J Bone Joint Surg Am* 2006;88:1755-1763.
4. Mascarenhas R, Rusen J, Saltzman BM, et al. Management of humeral and glenoid bone loss in recurrent glenohumeral instability. *Adv Orthop* 2014;2014:640952.
5. Snir N, Wolfson TS, Hamula MJ, Gyftopoulos S, Meislin RJ. Arthroscopic anatomic humeral head reconstruction with osteochondral allograft transplantation for large Hill-Sachs lesions. *Arthrosc Tech* 2013;2:e289-e293.
6. Kaar SG, Fening SD, Jones MH, Colbrunn RW, Miniaci A. Effect of humeral head defect size on glenohumeral stability: A cadaveric study of simulated Hill-Sachs defects. *Am J Sports Med* 2010;38:594-599.
7. Diklic ID, Ganic ZD, Blagojevic ZD, Nho SJ, Romeo AA. Treatment of locked chronic posterior dislocation of the shoulder by reconstruction of the defect in the humeral head with an allograft. *J Bone Joint Surg Br* 2010;92:71-76.
8. Rashid MS, Crichton J, Butt U, Akimau PI, Charalambous CP. Arthroscopic "remplissage" for shoulder instability: A systematic review. *Knee Surg Sports Traumatol Arthrosc* in press, available online 6 February, 2014. doi:10.1007/s00167-014-2881-0.
9. Sahajpal DT, Zuckerman JD. Chronic glenohumeral dislocation. *J Am Acad Orthop Surg* 2008;16:385-398.
10. Chapovsky F, Kelly JD. Osteochondral allograft transplantation for treatment of glenohumeral instability. *Arthroscopy* 2005;21:1007.
11. DiPaola MJ, Jazrawi LM, Rokito AS, et al. Management of humeral and glenoid bone loss—Associated with glenohumeral instability. *Bull NYU Hosp Jt Dis* 2010;68:245-250.
12. Gerber C, Lambert SM. Allograft reconstruction of segmental defects of the humeral head for the treatment of chronic locked posterior dislocation of the shoulder. *J Bone Joint Surg Am* 1996;78:375-381.
13. Johnson DL, Warner JP. Osteochondritis dissecans of the humeral head: Treatment with a matched osteochondral allograft. *J Shoulder Elbow Surg* 1997;6:160-163.
14. Martinez AA, Navarro E, Iglesias D, Domingo J, Calvo A, Carbonel I. Long-term follow-up of allograft reconstruction of segmental defects of the humeral head associated with posterior dislocation of the shoulder. *Injury* 2013;44:488-491.
15. McCarty LP III, Cole BJ. Reconstruction of the glenohumeral joint using a lateral meniscal allograft to the glenoid and osteoarticular humeral head allograft after bipolar chondrolysis. *J Shoulder Elbow Surg* 2007;16:e20-e24.
16. Nathan ST, Parikh SN. Osteoarticular allograft reconstruction for Hill-Sachs lesion in an adolescent. *Orthopedics* 2012;35:e744-e747.
17. Patrizio L, Sabetta E. Acute posterior shoulder dislocation with reverse Hill-Sachs lesion of the epiphyseal humeral head. *ISRN Surg* 2011;2011:851051.
18. Provencher MT, LeClere LE, Ghodadra N, Solomon DJ. Postsurgical glenohumeral anchor arthropathy treated with a fresh distal tibia allograft to the glenoid and a fresh allograft to the humeral head. *J Shoulder Elbow Surg* 2010;19:e6-e11.
19. Trajkovski T, Mayne IP, Deheshi BM, Ferguson PC. Synovial chondromatosis of the shoulder: Open synovectomy and insertion of osteoarticular allograft with internal fixation to repair intraoperative glenohumeral joint instability. *Am J Orthop (Belle Mead NJ)* 2011;40:E154-E158.

20. Yagishita K, Thomas BJ. Use of allograft for large Hill-Sachs lesion associated with anterior glenohumeral dislocation: A case report. *Injury* 2002;33:791-794.
21. Kropf EJ, Sekiya JK. Osteoarticular allograft transplantation for large humeral head defects in glenohumeral instability. *Arthroscopy* 2007;23:322-326.
22. Mankin HJ, Doppelt S, Tomford W. Clinical experience with allograft implantation: The first ten years. *Clin Orthop Relat Res* 1983:69-86.
23. McDermott AB, Langer F, Pritzker JKP, Gross AE. Fresh small-fragment osteochondral allografts: Long-term follow-up study on first 100 cases. *Clin Orthop Relat Res* 1965:96-102.
24. Provencher MT, Ghodadra N, LeClere L, Solomon DJ, Romeo AA. Anatomic osteochondral glenoid reconstruction for recurrent glenohumeral instability with glenoid deficiency using a distal tibia allograft. *Arthroscopy* 2009;25: 446-452.
25. Sherman SL, Garrity J, Bauer K, Cook J, Stannard J, Bugbee W. Fresh osteochondral allograft transplantation for the knee: Current concepts. *J Am Acad Orthop Surg* 2014;22:121-133.
26. El-Rashidy H, Villacis D, Omar I, Kelikian AS. Fresh osteochondral allograft for the treatment of cartilage defects of the talus: A retrospective review. *J Bone Joint Surg Am* 2011;93:1634-1640.
27. Raikin SM. Fresh osteochondral allografts for large volume cystic osteochondral defects of the talus. *J Bone Joint Surg Am* 2009;91:2818-2826.