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Long-term outcomes after osteochondral allograft transplantation to the humeral head

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Background: Long-term outcomes of osteochondral allograft (OCA) transplantation to the humeral head have been sparsely reported in the literature.
Purpose: To evaluate outcomes and survivorship of OCA transplantation to the humeral head in patients with osteochondral defects at a minimum of 10 years of follow-up.
Methods: A registry of patients who underwent humeral head OCA transplantation between 2004 and 2012 was reviewed. Patients completed pre and postoperative surveys including the American Shoulder and Elbow Surgeons score, Simple Shoulder Test, Short Form 12, and the visual analog scale. Failure was defined by conversion to shoulder arthroplasty.
Results: Fifteen of 21 (71%) patients with a minimum of ten year of follow-up (mean: 14.2 ± 2.40) were identified. Mean patient age was 26.1 ± 8.8 years at the time of transplantation and eight (53%) patients were male. Surgery was performed on the dominant shoulder in 11 of the 15 (73%) cases. The use of local anesthetic delivered via an intra-articular pain pump was the most often reported underlying etiology of chondral injury (n = 9; 60%). Eight (53%) patients were treated with an allograft plug, while seven (47%) patients were treated with a mushroom cap allograft. At final follow-up, mean American Shoulder and Elbow Surgeons (49.9 to 81.1; $P = .048$) and Simple Shoulder Test (43.1 to 83.3; $P = .010$) significantly improved compared to baseline. Changes in mean SF-12 physical (41.4 to 48.1; $P = .354$), SF-12 mental (57.5 to 51.8; $P = .354$), and visual analog scale (4.0 to 2.8; $P = .618$) did not reach statistical significance. Eight (53%) patients required conversion to shoulder arthroplasty at an average of 4.8 ± 4.7 years (range: 0.6-13.2). Kaplan-Meier graft survival probabilities were 60% at 10 years and 41% at 15 years.
Conclusion: OCA transplantation to the humeral head can result in acceptable long-term function for patients with osteochondral defects. While patient-reported outcomes metrics were generally improved compared to baseline, OCA graft survival probabilities diminished with time. The findings from this study can be used to counsel future patients with significant glenohumeral cartilage injuries and set expectations about the potential for further surgery.
Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Allograft; osteochondral defect; humeral head; shoulder; glenohumeral joint

Investigation performed at Midwest Orthopaedics at Rush University Medical Center, Chicago, IL, USA.
The Institutional Review Board at Rush University Medical Center approved this study (ORA: 19112608-IRB01).

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The causes of glenohumeral cartilage injuries are wide-ranging and include primary degeneration, trauma, recurrent instability, osteonecrosis, inflammatory conditions, osteochondritis dissecans, idiopathic chondrolysis, and iatrogenic postsurgical chondrolysis.[14] Previous studies have reported that chondral injuries can be found in up to 17% of patients undergoing shoulder arthroscopy.[3,4,14] While these injuries are often clinically silent, symptomatic chondral lesions can be a significant source of shoulder pain and dysfunction.

The natural history of glenohumeral articular cartilage injuries is not well understood in comparison to similar lesions of the knee or hip. It is well known that because of its relative avascular nature, articular cartilage has a limited capacity for regeneration.[20] When conservative treatment of glenohumeral cartilage injuries fails to sufficiently manage symptoms or limit the progression to osteoarthritis, shoulder arthroplasty is an excellent treatment option but may be associated with activity limitations and lifting restrictions in younger, active patients.[1,16,17]

Osteochondral allograft (OCA) transplantation to the humeral head has emerged as an increasingly popular treatment option for focal chondral defects of the shoulder that is refractory to conservative treatment methods. First utilized for the treatment of focal chondral defects of the femoral condyle of the knee, multiple techniques and allograft types have since been described for OCA transplantation to the humeral head.[6,12-14,18,21] Case series have reported generally favorable outcomes following OCA transplantation to the humeral head; however, current literature is limited by small sample sizes, variable graft sources, and limited follow-up.[1,2,5,8,10,15]

To our knowledge, no previous study has investigated clinical outcomes and survivorship following OCA transplantation to the humeral using fresh humeral head allograft at a minimum 10-year clinical follow-up. This study aimed to evaluate long-term functional outcomes, patient satisfaction, and survivorship of humeral head OCA transplantation in patients with isolated focal chondral defects. It was hypothesized that patients who underwent OCA transplantation to the humeral head would demonstrate both significant improvements from baseline across multiple patient-reported outcome measures (PROMs) and a high rate of allograft survivorship at a minimum 10-year follow-up.

Materials and methods

Patient selection

Local institutional review board approval was obtained before the initiation of this study. A retrospective review of a prospectively maintained registry of consecutive patients was performed to identify patients who underwent fresh humeral head OCA transplantation by two fellowship-trained orthopedic surgeons at a single institution between July 2004 and April 2012. All patients who were aged 18 years or older at the time of 10-year postoperative follow-up were included. Follow-up was defined as an in-person or telemedicine clinic visit, completion of validated PROM surveys, or failed transplantation treatment at any postoperative time point.

Surgical technique

The preferred technique of the senior author for OCA transplantation to the humeral head has been described previously.[9,11,14,21] All patients were positioned in the beach chair position. Diagnostic arthroscopy was performed in all patients prior to OCA transplantation by utilizing standard anterior and posterior arthroscopic portals to evaluate the glenohumeral cartilage and to assess for additional shoulder pathology. Following diagnostic evaluation, humeral head OCA transplantation was performed in an open fashion.

Contained defects less than or equal to 30 mm in diameter were treated with implantation of an allograft plug (Fig. 1). Contained lesions were sized with a cannulated, cylindrical sizing guide and the humeral head surface was cored using a drill (Arthrex, Naples, FL, USA) to a depth of 6 to 8 mm. A sized-matched cylindrical plug was then cut from a fresh humeral head allograft (JRF Ortho, Centennial, CO, USA) to a depth that matches the cored recipient site on the humerus. Before implantation, the allograft plug and recipient site were flushed with normal saline pulse lavage to remove marrow elements and debris. The plug was then press-fit into the cored humeral site and impacted with a tamp to ensure flush congruency with the articular humeral surface. Uncontained lesions or lesions larger than 30 mm in diameter were treated with a stemmed mushroom cap allograft that reconstructed the entire humeral head chondral surface. The entire humeral head was osteotomized at the humeral head-neck junction and a 15 mm reamer was used to create a recipient socket for the cap allograft stem. Supplemental allograft fixation was achieved as needed using either bioabsorbable compression screws (Bio-Compression; Arthrex Inc., Naples, FL, USA) or metallic, headless compression screws (Acutrak 2 Standard; Acumed, Hillsboro, OR, USA).

Concomitant procedures were performed as needed and at the discretion of the surgeon. Such additional procedures included capsular release, distal clavicle excision, and acromioclavicular joint reconstruction. In a subset of patients with bipolar disease of the humeral head and glenoid surfaces, either microfracture of the glenoid or biologic interposition arthroplasty with lateral meniscal allograft (LMAT) was concomitantly performed at the time of OCA transplantation. The technique for LMAT interposition has been described previously.[11] First concentric reaming of the glenoid is carefully performed to create a punctate surface for allograft adhesion and to correct any apparent glenoid version without damaging the labrum. The glenoid surface is then covered using an appropriately sized, fresh lateral meniscal allograft (JRF Ortho, Centennial, CO, USA) that is sewn together at the anterior and posterior horns with 2-0 nonabsorbable suture. The LMAT was then appropriately fixated with the anterior horns facing anteriorly within the glenoid using six to ten suture anchors.

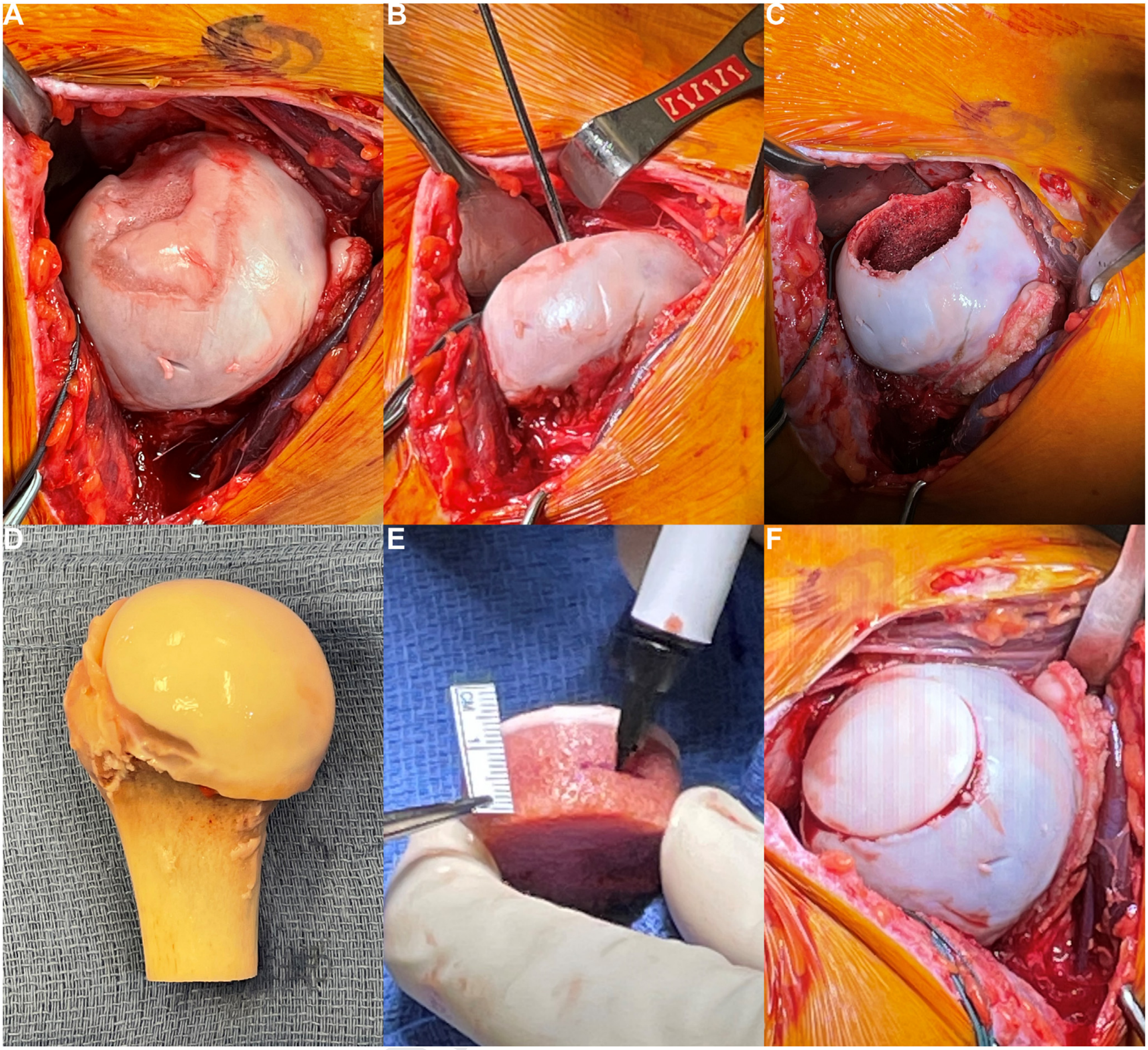

Figure 1 Osteochondral allograft transplantation to the humeral head using an allograft plug. (**A**) Prior to transplantation, the articular surface of the humeral head is visualized and measured for appropriate allograft sizing. (**B**, **C**) A guide pin is inserted into the *Center* of the chondral lesion to allow for precise core reaming. (**D**, **E**) A fresh humeral head allograft plug is cut to the same depth as the recipient core. (**F**) Final visualization of the press-fit allograft plug prior to closure.

Rehabilitation protocol

Following the procedure, patients remained in a sling for four weeks. During the first six weeks following surgery, patients progressed through passive and active-assisted range of motion to 90° of forward flexion, 40° of external rotation with the arm at the side, and 75° of abduction without rotation. Internal rotation was not permitted to protect the subscapularis. From six to 12 weeks postoperative, patients began mild internal rotation strengthening as well as resisted external rotation, forward flexion, and abduction exercises. At 12 weeks, patients began resisted internal rotation and extension exercises and strength training was advanced as tolerated. Patients were allowed to return to full activity beginning at six months postoperative.

Clinical assessment

The medical records of all patients included in the prospectively maintained database were queried to collect relevant preoperative, intraoperative, and postoperative details. Preoperative clinical documentation was reviewed for patient age, sex, medical comorbidities, injury laterality, hand dominance, presenting symptoms, and previous surgical intervention. Operative notes were reviewed for details such as chondral injury dimensions, location, and concomitant procedures.

All patients included in the study completed American Shoulder and Elbow Surgeons (ASES), Short Form 12 (SF-12) physical and mental, Simple Shoulder Test (SST), and visual analog scale (VAS) assessments before OCA transplantation and at interval time points following the index procedure. Patient satisfaction was also assessed by asking patients to define their overall outcome using one of the following responses: extremely satisfied, moderately satisfied, somewhat satisfied, or not satisfied at all. Treatment failure was defined by conversion to shoulder arthroplasty.

Statistical analysis

Means and frequencies of all compiled preoperative, intraoperative, and postoperative data were compiled. Both paired and unpaired *t* tests and chi-square analysis were utilized to assess for differences in preoperative and postoperative clinical characteristics of the patient cohort. Kaplan-Meier estimation and Cox proportional hazards regression were performed to analyze survivorship and factors predictive of conversion to arthroplasty, respectively. Statistical significance for all comparisons was defined as $P < .05$. Statistical analysis was performed using SPSS (version 28.0; IBM Corp., Armonk, NY, USA).

Results

Patient demographics

Fifteen of 21 (71%) eligible patients with a minimum of ten years of follow-up (mean: 14.2 ± 2.40) were included in the analysis. All patient demographics are outlined in Table I. Mean patient age was 26.1 ± 8.8 years (range: 15.7-48.1) at the time of transplantation. Eight (53%) of the 15 patients were male. Surgery was performed on the dominant shoulder in 11 of the 15 (73%) cases. There was no reported history of diabetes mellitus. One patient had an active worker's compensation claim at the time of transplantation.

Glenohumeral chondrolysis resulting from the use of a postoperative intra-articular infusion of local anesthetic via a pain pump was the most often reported underlying etiology of chondral injury (n = 9, 60%), followed by arthropathy resulting from recurrent glenohumeral instability (n = 5, 33%), and reverse Hill-Sachs lesions following traumatic shoulder dislocation (n = 1, 7%). Before OCA transplantation, all patients had undergone previous surgery on the same shoulder, with a mean of 2.4 ± 1.1 (range: 1-5) prior surgeries on the ipsilateral shoulder. The most common primary surgery was Bankart repair (n = 5, 33%) followed by labral repair (n = 4, 27%); radiofrequency thermal capsulorrhaphy (n = 2, 13%); and open shoulder stabilization, arthroscopic labral débridement, capsular plication, and subacromial decompression with biceps tenodesis (all n = 1, 7%).

Intraoperative details

Intraoperative details are further outlined in Table I. The average chondral lesion size measured 24 ± 6 mm in diameter. Eight (53%) patients were treated with an allograft plug, while seven (47%) were treated with a mushroom cap allograft with an average stem diameter of 18 ± 2 mm. Six of the 15 (40%) grafts required screw fixation; the remaining nine grafts (60%) were adequately secured with direct press-fit and light tamping. Nine of the 15 (60%) patients underwent at least 1 concomitant procedure at the time of OCA transplantation. Six patients (40%) were treated with isolated LMAT interposition arthroplasty, two (14%) patients were treated with microfracture of the glenoid and LMAT interposition arthroplasty, and 1 (7%) was treated with isolated microfracture of the glenoid (Table I).

Treatment failure and survivorship analysis

Eight (53%) patients failed treatment and required conversion to shoulder arthroplasty at an average of 4.8 ± 4.7 years (range: 0.6-13.2) following transplantation. Of the eight failures, five patients with a history of pain pump chondrolysis failed at 3.8 ± 4.7 years (range: 0.8-13.2) following transplantation, while the remaining three, all of whom had developed chondral injury due to recurrent glenohumeral instability, failed at a mean of 6.5 ± 4.2 years (range: 0.6-10.0) posttransplant. Three of the patients that failed treatment were treated with mushroom cap allografts while the remaining five were treated with allograft plugs that were an average of 28 ± 4 mm (range: 20-30) in diameter. In two of the three patients treated with mushroom cap allografts, failure was caused by the collapse of the graft. The third patient treated with a mushroom allograft, as well as all five patients treated with a plug allograft, were converted to arthroplasty due to persistent pain and limited function. Five patients that failed treatment were also treated with a concomitant procedure at the time of transplantation. Four patients underwent concomitant LMAT interposition, while 1 patient was treated with concomitant glenoid microfracture.

Overall survival probabilities of OCA transplantation to the humeral head were 60% and 41% at 10 and 15 years, respectively (Fig. 2*A*). Median survivorship was estimated to be 9.7 years (95% confidence interval [(CI]: 6.5-12.9). When sorted by etiology, the median estimated survivorship time was found to be 8.2 years (95% CI: 4.2-12.2) in patients with a history of pain pump chondrolysis and 7.6 years (95% CI: 2.8-12.7) in patients with chondral injury resulting from recurrent instability (Fig. 2*B*). No significant difference in survivorship was apparent when comparing survivorship of pain pump chondrolysis ($P = .806$) or recurrent instability ($P = .207$) patients to

Table I Patient characteristics and intraoperative details of patients who met inclusion criteria and 10-year minimum follow-up.

	No (%) or mean ± SD
Patients	15
Sex	
Male	8 (53%)
Female	7 (47%)
Age at surgery	26.1 ± 8.8 y
Elapsed time since OCA transplantation	14.2 ± 2.4 y
Laterality	
Right	11 (73%)
Left	4 (29%)
Dominant arm	11 (73%)
Etiology	
Pain pump chondrolysis	9 (60%)
Postoperative arthropathy	§ (33%)
Reverse Hill-Sachs lesion	1 (7%)
Previous operations	2.4 ± 1.1
Average chondral lesion size	24 ± 6 mm
Graft type	
Plug	8 (53%)
Mushroom	7 (47%)
Fixation	
Press-fit with tamping	9 (60%)
Screw fixation	6 (40%)
Concomitant procedures	
Isolated LMAT interposition	6 (40%)
LMAT interposition & glenoid microfracture	2 (22%)
Isolated glenoid microfracture	1 (11%)

LMAT, lateral meniscal allograft transplant; *OCA*, osteochondral allograft; *mm*, millimeter; *No*, number; *SD*, standard deviation.

overall survivorship. Estimations of survivorship could not be calculated for patients who required transplantation because of a large reverse Hill-Sachs lesion because no treatment failures were observed. Previous SLAP repair (P = .036) was the only preoperative or intraoperative variable associated with treatment failure, following cox proportional hazards regression. Conversely, no association was identified between failure and sex, arm dominance, injury etiology, concomitant procedures, lesion size, allograft type (plug versus mushroom cap), allograft fixation technique, or preoperative PROMs.

Patient-reported outcomes metrics and satisfaction

Among the patients who were not converted to shoulder arthroplasty, mean increases in ASES, SST, SF-12 Physical, and VAS pain indices were appreciated at the minimum 10-year follow-up; however, only ASES (49.9 to 81.1; P = .048) and SST (43.1 to 83.3; P = .010) scores reached statistical significance. Changes in SF-12 Physical (41.4 to 48.1; P = .354), SF-12 Mental (57.5 to 51.8; P = .354), and VAS (4.0 to 2.8; P = .618) did not reach statistical significance (Fig. 3). After stratifying PRO scores by patient variables, those with pain pump chondrolysis as the etiology of chondral disease (P = .049) and patients who underwent previous Bankart repair (P = .049) were associated with significantly worse VAS pain scores. No other preoperative or intraoperative variable was associated with a significant improvement or reduction in PROMs.

All 15 patients included in the analysis also completed a simple questionnaire about their level of satisfaction regarding OCA transplantation. All eight patients who failed treatment and required conversion to TSA reported no level of satisfaction with the procedure. Of the remaining seven patients, four reported being extremely satisfied, 1 reported being moderately satisfied, and two reported being somewhat satisfied.

Discussion

This study showed that OCA transplantation to the humeral head can result in acceptable long-term function for patients with osteochondral defects. Patient-reported outcomes were generally improved compared to baseline; however, OCA graft survival probabilities diminished with time. The results from this investigation support OCA transplantation as an effective intervention for the treatment of significant glenohumeral cartilage injuries, particularly in patients who because of age or desired activity level may not be immediate candidates for shoulder arthroplasty.

Only two other studies have investigated outcomes and survivorship of humeral head OCA transplantation with a mean follow-up beyond five years. Martinez et al. reported a 50% failure rate in six patients who underwent humeral head OCA transplantation following traumatic posterior dislocation of the humeral head at a mean of 122 months (range: 96-144) follow-up.[8] Among the three failures, two patients demonstrated graft collapse by four years, and both required shoulder arthroplasty eight years posttransplant, while the third patient underwent shoulder arthroplasty at 10 years secondary to progressive pain, stiffness, and arthrosis.[8] In our study, seven patients were treated with mushroom cap allografts, and two of the three failures were secondary to graft collapse.

Gerber and colleagues published outcomes of 22 shoulders treated with articular cartilage transplantation due to large reverse Hill-Sachs lesions at a mean follow-up of 128 months (range: 60-294).[5] Seventeen shoulders were treated with fresh-frozen humeral head allograft, while the remaining five shoulders were treated with structural autografts of the iliac crest. Three (13%) shoulders, all treated with allograft transplantation, failed treatment. Among the remaining 19 cases, 15 patients reported no subjective pain symptoms, and mean Constant-Murley scores increased from 37 to 77 points (no P value reported). However, seven of the 14 patients who were treated with allografts that did

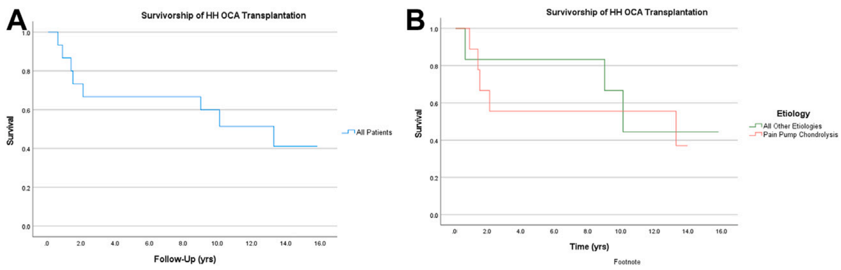

Figure 2 (**A**) Overall Kaplan-Meier survivorship estimation and (**B**) Kaplan-Meier survivorship stratified by etiology of chondral injury.

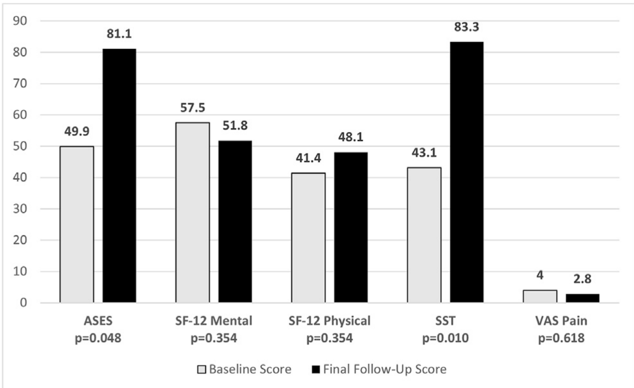

Figure 3 Patient-reported outcome metrics at baseline and most recent follow-up.

not fail treatment developed radiographic evidence of osteoarthritis, compared to none of the five autograft patients. Long-term failure rates within this cohort were improved compared to ours, even after accounting for the differences in transplant source. However, comparison of other clinical outcomes is difficult because different outcome measures were assessed.

Nine patients in this study underwent OCA transplantation secondary to prior use of a postoperative intra-articular local anesthetic infusion via a pain pump. All nine patients were treated using bupivacaine; however, lidocaine and ropivacaine have also been cited as offending chondral agents in the literature.[7] As such, the use of pain pump infusions for postoperative pain management has largely been phased out of clinical practice. In this cohort, seven patients with pain pump chondrolysis had widespread bipolar disease, six of which were treated with either LMAT interposition arthroplasty or LMAT interposition with microfracture of the glenoid. The remaining patient was treated with isolated microfracture of the glenoid. When considering previous studies that reported high failure rates following interposition arthroplasty, it was expected that patients who underwent concomitant LMAT interposition would fare similarly.[19] However, treatment failure was observed in only three of the six patients with history of pain-pump chondrolysis who underwent concomitant LMAT interposition. The 50% failure rate was slightly lower than the failure rate of the overall cohort (53%), and as such, regression analysis did not find LMAT interposition arthroplasty to be predictive of treatment failure. Similarly, patients with a history of pain pump chondrolysis were found to have longer median allograft survivorship (8.2 years; 95% CI: 4.2-12.2) than patients with recurrent instability (7.6 years; 95% CI: 2.8-12.7).

This study is not without limitations. This study was conducted as a retrospective case series of a prospectively maintained database, without a control group on a relatively small number of patients. The purely retrospective nature of this analysis limited our ability to collect additional patient-reported or imaging follow-up. Because of the overall small cohort size, logistic regression could not be reliably performed to analyze variables predictive of improved PROMs, and thus our analysis was limited. Furthermore, this was a single-center study, which limits the generalizability of our findings.

Conclusion

OCA transplantation to the humeral head can result in acceptable long-term function for patients with osteochondral defects. While patient-reported outcomes were generally improved compared to baseline, OCA graft survival probabilities diminished with time. Nonetheless, OCA transplantation remains a viable joint-preserving alternative in young active patients who wish to maintain an active lifestyle and delay the need for shoulder arthroplasty. Further investigation should be dictated toward comparing outcomes of OCA transplantation in patients with chondral injury of the shoulder relative to other joint-preserving and reconstructive treatment approaches.

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