



Fresh Osteochondral Allograft Transplantation for Focal Chondral Defect of the Humerus Associated With Anchor Arthropathy and Failed SLAP Repair

Kevin C. Wang, B.S., Brian R. Waterman, M.D., Eric J. Cotter, B.S., Rachel M. Frank, M.D., and Brian J. Cole, M.D., M.B.A.

Abstract: Isolated, full-thickness articular cartilage lesions of the glenohumeral joint can cause pain, mechanical symptoms, and impaired function. Reports on operative management of these injuries with arthroscopic techniques, such as marrow stimulation, have shown improvement in patient symptoms. In cases where the subchondral bone is involved, osteochondral allograft (OCA) transplantation has shown positive results for contained, focal cartilage defects. The technique for OCA transplantation to treat Hill-Sachs lesions has been reported in detail, and there are multiple case series reporting on the outcomes of OCA used for this purpose. This Technical Note shows the application of OCA to treat a case of anchor arthropathy where a glenoid anchor placed during arthroscopic stabilization causes iatrogenic damage to the humeral head. This type of injury can result in cartilage lesions in uncommon locations, such as on the posterior humeral head. In this description, the technical pearls and pitfalls of managing difficult-to-access posterior humeral head lesions are presented along with the senior authors' general technique for OCA to treat focal lesions of the humeral head cartilage.

Focal articular cartilage defects of the glenohumeral joint can lead to significant pain, loss of range of motion, worsening function, and diminishing quality of

life in active patients.^{1,2} Given the inconsistent results with arthroscopic debridement and marrow stimulation for symptomatic chondral defects of the glenohumeral joint,^{2,3} osteochondral allograft (OCA) transplantation has emerged as a viable option for osteochondral reconstruction, particularly with subchondral involvement due to trauma and/or shoulder instability (i.e. Hill-Sachs lesions).⁴⁻⁶ Previously, OCA has shown excellent outcomes for treating articular lesions in the knee,⁷ and the initial results reported for defects of the glenohumeral joint have yielded promising results.^{1,8} Although the cause is not always clear in cases of avascular necrosis or chondrolysis, numerous cases of osteochondral defects associated with anchor arthropathy have been reported in the literature.^{9,10} These patients may often present after prior posterior stabilization or SLAP tear repair, with proud, malpositioned, or loose implants and/or excessive knot prominence contributing to broad-based posterior humeral head lesions and linear stripe wear. With a more posterior-based lesion, establishing exposure using open techniques such as OCA can be difficult, and alternate surgical approaches may be required.^{4,11} The authors present the case of a focal articular cartilage defect that occurred after an arthroscopic posterior shoulder stabilization surgery. Our technique for OCA transplantation for focal

From the Department of Orthopaedic Surgery, Rush University Medical Center, Chicago, Illinois, U.S.A.

The authors report the following potential conflicts of interest or sources of funding: B.R.W. is board member of Arthroscopy; and receives other support from American Journal of Orthopedics; Arthroscopy; Arthroscopy Association of North America; Elsevier Publishing; and Society of Military Orthopaedic Surgeons. B.J.C. receives consulting fee from Arthrex; is a board member of Arthroscopy; has grants/grants pending from Arthrex; and receives royalties from Arthrex. He reports personal other support from Aesculap/B.Braun; American Journal of Orthopedics; American Orthopaedic Society for Sports Medicine; American Shoulder and Elbow Surgeons; Arthroscopy Association of North America; Athletico; Carticept; Cytori; DJ Orthopaedics; Elsevier Publishing; International Cartilage Repair Society; Journal of Bone & Joint Surgery—American; Journal of Shoulder and Elbow Surgery; Journal of the American Academy of Orthopaedic Surgeons; Medipost; National Institutes of Health (NIAMS & NICHD); Ossur; Regentis; Saunders/Mosby-Elsevier; Smith & Nephew; Tornier; and Zimmer. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received March 30, 2017; accepted June 1, 2017.

Address correspondence to Brian J. Cole, M.D., M.B.A., Department of Orthopaedic Surgery, 1611 W Harrison Street, Suite 300, Chicago, IL 60612, U.S.A. E-mail: bcole@rushortho.com

*© 2017 by the Arthroscopy Association of North America
2212-6287/17446/\$36.00*

<http://dx.doi.org/10.1016/j.eats.2017.06.008>

articular cartilage defects of the glenohumeral joint is described with specific pearls for addressing lesions of the posterior humeral head.

Surgical Technique

Indication

Older, lower demand patients with glenohumeral defects may benefit from palliative treatment options (i.e. arthroscopic debridement and capsular release) or other adjunctive procedures (e.g. subacromial decompression, biceps tenodesis) to address additional pain generators, whereas younger patients may benefit from restorative options. Purely arthroscopic techniques, such as glenohumeral microfracture, can provide positive outcomes for patients with smaller, well-circumscribed defects, whereas OCA transplantation may be beneficial for patients with more widespread disease, subchondral bone involvement, or bipolar disease.^{1,2} In addition to the history and physical examination (Video 1), magnetic resonance imaging and diagnostic arthroscopy play a pivotal role in the diagnosis of focal cartilage defects of the glenohumeral by allowing defect localization, defect grading, and evaluation for concomitant pathologies (Video 1). The magnetic resonance imaging findings in this case depict a posteriorly based articular cartilage lesion (Fig 1A) with a notable proud anchor (Fig 1B). A diagnostic arthroscopy should be performed for initial defect staging. If images from a recent diagnostic arthroscopy are available, these can be used for staging purposes.

Patient Positioning

For isolated articular cartilage lesions of the anterior or central humeral head, adequate access can be achieved in the beach-chair position on a standard operating table with an articulating arm positioner. Alternatively, for posterior lesions of the humeral head with anchor arthropathy or anterior shoulder instability, it may be beneficial to place the patient in the supine or lateral decubitus position on a Jackson table for an appropriate surgical approach and access (Fig 2A). This positioning enables free manipulation of the glenohumeral joint to allow for adequate access to all portions of the humeral head, particularly the posterior region.

Surgical Approach

Standard anterior and posterior arthroscopic portals are established for initial diagnostic arthroscopy and planning of a surgical approach. In the case of anchor arthropathy, removal of the proud or migrated anchor is attempted during this phase of the procedure (Video 1). PEEK (polyether ether ketone) anchors may be fractured initially to dislodge them from the underlying bone (Video 1), whereas metal anchors are preferably removed en masse to decrease third body wear and

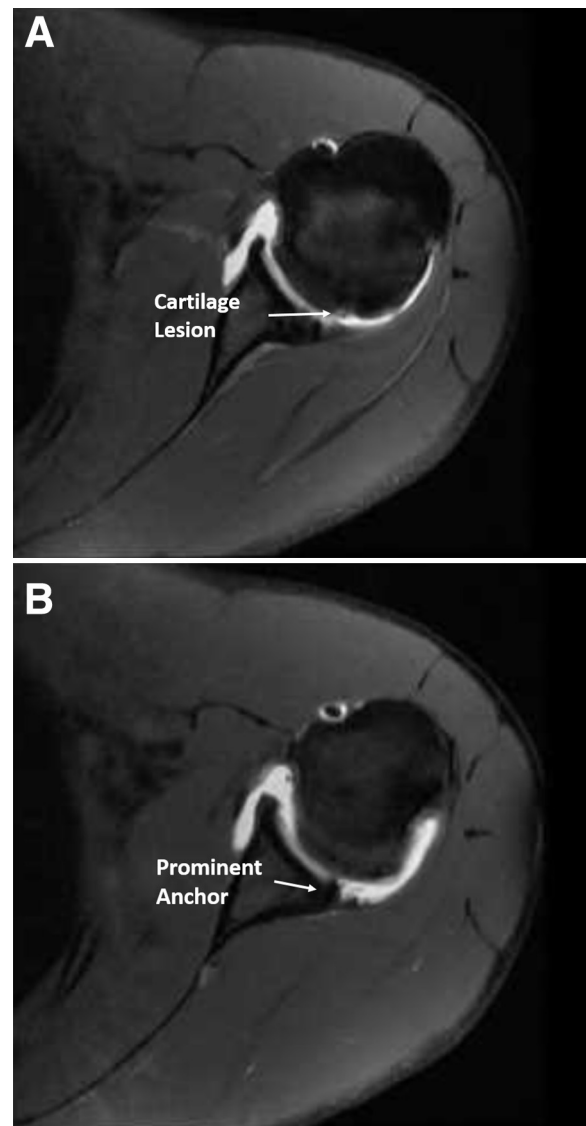


Fig 1. (A) Axial image of a T2-weighted magnetic resonance arthrogram of the left shoulder at the level of the mid-glenoid showing focal high-grade cartilage loss of the posterior inferior aspect of the humeral head with underlying subchondral edema. (B) Axial image of a T2-weighted magnetic resonance arthrogram at the level of the mid-glenoid showing a low-intensity implant of the left shoulder in the posterosuperior glenoid with intra-articular protrusion adjacent to the focal area of humeral chondral loss. This is consistent with a prominent, malpositioned PEEK (polyether ether ketone) suture anchor from prior superior labral repair.

facilitate advanced imaging without obscuring metal artifact. After diagnostic arthroscopy, a 4- to 6-cm deltopectoral incision is made after the patient is repositioned in a semi-beach-chair position. The cephalic vein is protected, and the interval between the subdeltoid and conjoint tendon is retracted. A proximally based partial subscapularis tenotomy is performed approximately 1 to 1.5 cm medial to the long head of the biceps tendon, depending on required exposure.

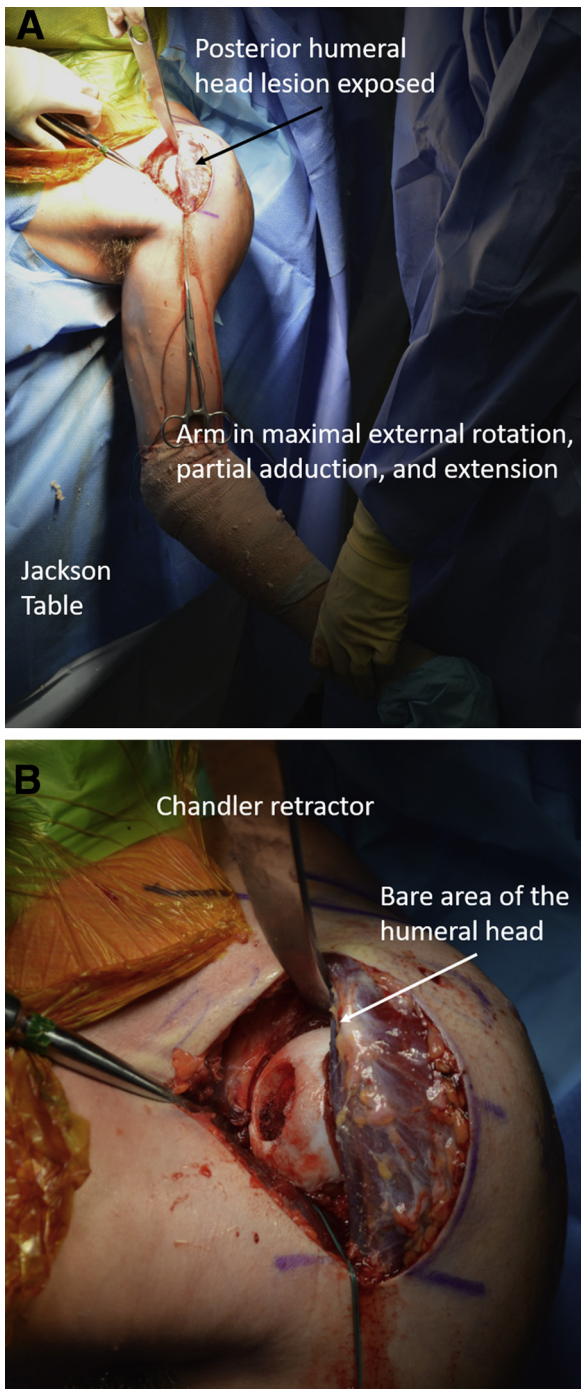


Fig 2. (A) Lazy beach-chair positioning on a Jackson table allows for access to posterior lesions of the humeral head. In this figure, this positioning is demonstrated for a posterior humeral head lesion of the left shoulder. After tenotomy of the superior half of the subscapularis tendon, the arm is abducted, extended, and externally rotated to dislocate the humeral head. In this case, patient positioning and exposure for a posterior lesion of the left humeral head are depicted. (B) A retractor is used to lift and expose the posterior humeral head. The retractor is placed on the bare area of the humeral head to avoid iatrogenic cartilage injury; in this case, a Chandler retractor is used as a lever to dislocate the humeral

After partial subscapularis release, the perforating vessels of the anterior humeral circumflex artery and vein are ligated as needed and the proximal humerus is delivered through maximal external rotation, partial adduction, and extension to allow adequate visualization of and unfettered access to the posterior humeral head (Video 1) (Fig 2A).

To expose posterior lesions, a Chandler retractor may be additionally used to lever the humeral head anteriorly, while exercising caution to avoid iatrogenic damage to the adjacent intact cartilage on the posterior-inferior humeral head (Fig 2B). After adequate exposure is achieved, the remainder of the procedure is similar for posterior and anterior/central lesions. The lesion is sized using cannulated, cylindrical sizing guides (Fig 3A). A guide pin is then placed at the center of the lesion and sufficiently seated through the sizing template to avoid toggle and ensure appropriate orientation. Care must be taken to position the sizing template and guide pin perpendicular to the surface of the humeral head. After sizing, the surface of the humeral head is scored with a coring drill (Arthrex, Naples, FL) to ensure clean edges. The lesion is then reamed to a maximum bone depth of 6 to 8 mm, depending on the size, depth, and radius of curvature of the recipient lesion. During reaming, irrigation fluid is used to prevent thermal necrosis to the surrounding bone and cartilage. The freshly reamed lesion is cleaned with pulse lavage to remove any chondral or soft-tissue debris, and the depth is measured at the 3-, 6-, 9-, and 12-o'clock positions (Video 1). The fresh (15-28 days) humeral head allograft (JRF Ortho, Centennial, CO) is opened and placed in room temperature saline, and the corresponding area on the allograft is matched with a graft template (Arthrex). Subchondral bone reamings are maintained as needed to ensure appropriate depth and articular congruity on implantation.

When an assistant stabilizes the graft, the donor plug is harvested using a coring reamer with constant irrigation (Fig 4A). The plug is marked at the 12-o'clock position and measured to match the recipient site. A sagittal saw and rasp are used to prepare the donor plug to the appropriate depth. The prepared plug is copiously treated with pulsatile lavage with 50,000 units of Bacitracin dissolved in 3 L of normal saline for 5 to 7 minutes to remove any remaining marrow elements (Video 1). The donor plug is then press-fit into place and gently impacted with an oversized tamp to ensure congruity with the surrounding articular

head and facilitate appropriate exposure of the lesion site. In this photograph, the articular cartilage defect has already been reamed in preparation for the OCA.

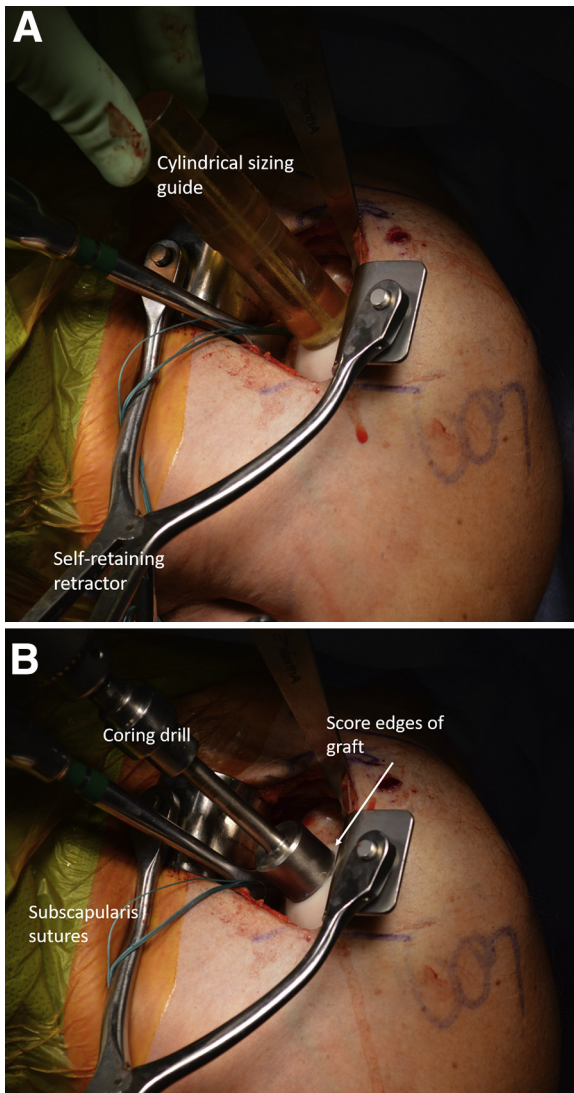


Fig 3. In this figure, the patient is positioned in the lazy beach chair position. The left shoulder is depicted. (A) Measuring the defect using a cannulated cylindrical sizing guide (labeled). The guide pin is placed at the center of the lesion with the sizing guide in place to ensure appropriate placement. Images from the original case for this step of the procedure were unavailable; this image depicts defect sizing for a patient with an isolated articular cartilage lesion of the central humeral head of the left shoulder. A self-retaining retractor can be useful in exposing the defect. (B) A coring drill (labeled) is used to score the articular cartilage before reaming. This ensures a clean edge by preventing shearing of the articular cartilage during reaming. Care must be taken to avoid damage to the sutures securing the subscapularis during coring and reaming.

surface (Fig 4B). If the plug is too proud, consider removing it with either a freer elevator (or centrally placed threaded guide pin), and adjusting it to the appropriate depth with a rasp or light impaction (Video 1). Closure is performed in layers using 3 No. 2 high tensile nonabsorbable sutures for tendon-to-tendon subscapularis reapproximation and a limited

lateral closure of the rotator interval to ensure that the subscapularis is effectively returned to its anatomic cephalad position. The deltopectoral interval is reapproximated with the preservation of the cephalic vein in situ, and the superficial fascia and skin are closed in a standard fashion. Finally, a sterile dressing is applied, and the arm is placed in an abduction sling in internal rotation. Table 1 describes technical tips for this procedure.

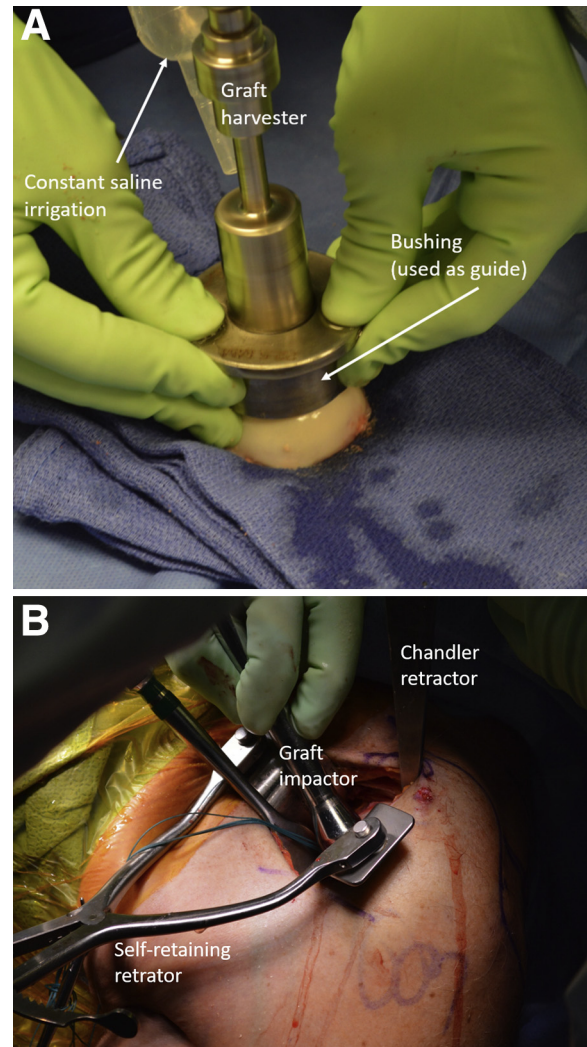


Fig 4. (A) Preparing the humeral head allograft. The graft is warmed in room temperature saline before implantation. Saline irrigation is used during harvesting to prevent heat necrosis. During harvest, a bushing is used to stabilize the graft and serve as a guide during harvesting. This should be sized to fit the coring drill used to harvest the graft. An assistant is necessary to stabilize the bushing during harvest, and an additional assistant can be helpful to irrigate the graft during harvesting. (B) After measurement, the donor plug is press-fit into the freshly reamed defect. The head of the graft impactor should be larger than the graft itself. This prevents overimpaction of the graft. The plug is gently impacted to ensure a flush fit.

Table 1. Pearls and Pitfalls of the Described Osteochondral Allograft Transplantation of the Humeral Head With a Specific Focus on Lesions of the Posterior Humeral Head

Step	Pearls	Pitfalls
Surgical planning	<ul style="list-style-type: none"> • Perform a staging arthroscopy to confirm lesion size, surgical approach for access, and the absence of advanced bipolar disease or osteoarthritis • Perform a deltopectoral exposure that will easily permit conversion to shoulder arthroplasty in the future 	<ul style="list-style-type: none"> • Failure to address coexisting pathology or sources of third body wear (e.g. loose body in the axillary pouch)
Patient positioning	<ul style="list-style-type: none"> • Ensure adequate lateral patient positioning in a lazy beach-chair position to permit adequate manipulation of the shoulder 	<ul style="list-style-type: none"> • Limited draping of the surgical field • Inadequate access for an adjunctive posterior approach
Hardware removal	<ul style="list-style-type: none"> • Prominent hardware resulting from failed SLAP repair or prior labral stabilization may be removed with a large arthroscopic grasper • A small circular burr may be used to contour the prominent portion even with subchondral bone if the hardware is rigidly fixed or encased in an articular position 	<ul style="list-style-type: none"> • Inadequate instruments available for loose body or hardware removal
Surgical Exposure	<ul style="list-style-type: none"> • Perform a titrated tenotomy of the superior half of the subscapularis to expose the humeral head • Place a blunt Chandler retractor on the nonarticular bare area of the posterior humeral head to anteriorly translate the humerus 	<ul style="list-style-type: none"> • Avoid sharp, juxta-articular retractor placement that may damage the adjacent healthy humeral head or glenoid cartilage
Lesion Preparation	<ul style="list-style-type: none"> • For most central or posteriorly based humeral lesions, maximal external rotation ($>60^\circ$), full adduction, and partial extension (approximately 20°) will allow perpendicular access for scoring and reaming of the recipient site • Score the peripheral cartilage before reaming to prevent iatrogenic damage at the lesion periphery 	<ul style="list-style-type: none"> • Avoid prolonged positioning in this at-risk position, as this can contribute to peripheral nerve or brachial plexus injury • Prevent thermal necrosis with constant cold saline irrigation during reaming • Avoid excessively deep reaming of the underlying subchondral bone to limit the surface area for the graft-host bone interface
Graft Harvest	<ul style="list-style-type: none"> • Ensure the precise depth of the donor plug at the 3-, 6-, 9-, and 12-o'clock position with care to match the approximate radius of curvature and perpendicularity • Perform copious lavage of the donor graft with antibiotic saline pulse lavage to minimize the risk of disease transmission and immunogenicity 	<ul style="list-style-type: none"> • Errant placement of the bushing or inadvertent oblique graft harvest contributing to residual mismatch after final osteochondral graft impaction
Graft Placement	<ul style="list-style-type: none"> • "Shoehorn" graft into place with a Freer elevator and gentle, circumferential impactions using an oversized tamp 	<ul style="list-style-type: none"> • Avoid aggressive impaction or excessive seating of the osteochondral allograft to limit the effect on donor chondrocyte viability
Closure	<ul style="list-style-type: none"> • Ensure watertight closure of the subscapularis tenotomy to limit surgical site morbidity 	<ul style="list-style-type: none"> • Subscapularis reapproximation in external rotation without manual posterior humeral head translation

Rehabilitation

Patients should remain in a sling for 4 weeks postoperatively to protect the superior subscapularis repair but are allowed to come out of the sling immediately for hygiene. Exercise and sleeping without the sling are generally allowed after 2 weeks. The first 6 weeks include passive- and active-assisted range of motion with goals of 90° of forward flexion, 40° of external rotation at the side, and 75° of abduction without rotation. To allow adequate healing of the subscapularis, no active internal rotation is permitted, and external rotation is determined by an intraoperative assessment of passive external rotation to avoid undue tension on the subscapularis. Beginning at 6 weeks, gentle internal rotation strengthening, resisted external rotation, forward flexion, and abduction are recommended. At 12 weeks, resisted internal rotation and extension exercises are initiated with eccentric motions and advanced strengthening exercises as tolerated.

After 6 months, patients can return to full activities as tolerated ([Video 1](#)).

Discussion

OCA transplantation of the humeral head has previously been described for the treatment of Hills-Sachs lesions associated with glenohumeral instability.^{4-6,11} Promising results have also been reported using this technique for humeral head articular cartilage defects.^{1,8} Although arthroscopic management techniques have shown some success with small glenohumeral defects, larger defects and those with subchondral bone involvement may benefit from OCA transplantation.¹⁻³ Anchor arthropathy, which can be induced by anchors used in stabilization procedures, is a special case in which focal osteochondral defects can occur on the humeral head. A previous case report has noted favorable outcomes after humeral head OCA treatment and biologic

Table 2. Advantages and Disadvantages of Osteochondral Allograft Transplantation of the Humeral Head Using the Described Technique

Advantages	Disadvantages
No hardware is used	Subscapularis is violated requiring prolonged postoperative precautions
Entire osteochondral unit is addressed	Limited-open approach leads to surgical-site morbidity
Able to access all portions of the humeral head	Prolonged (>6-month) period of activity restriction to ensure adequate graft incorporation and soft tissue reconstitution
Restoration of the cartilage with a single intact layer of the hyaline cartilage	Restricted supply of size-matched fresh cadaveric donor grafts

resurfacing of the glenoid in the case of metal anchor arthropathy,⁹ and anchor removal and debridement alone have shown poor outcomes.¹⁰ OCA treatment has the potential to provide effective symptomatic relief and prevent ongoing cartilage damage in patients with anchor arthropathy.

The advantages of the currently described technique are listed in Table 2 and include lack of hardware and the ability to comprehensively address the osteochondral unit. However, this technique is limited by the violation of the subscapularis, surgical-site morbidity associated with an open approach (e.g. scarring, blood loss), and a prolonged (i.e. >6-month) period of activity restriction. In addition, all OCA techniques are limited by the restricted supply of size-matched fresh donor grafts. Recent investigations have attempted to improve graft supply through radius of curvature matching with alternative osteoarticular graft sources, such as the proximal and distal femur or the talus.^{12,13} By broadening matching criteria, these radius of curvature matching investigations have the potential to reduce graft wait times and optimize available graft utilization.⁵ Future advances for all OCA techniques include the use of CO₂ lavage, which has been shown to improve the clearance of bone marrow elements from donor grafts.¹⁴ This has the potential to decrease immunogenicity of the donor grafts and improve graft incorporation. Another adjunct treatment that has been explored is the addition of bone marrow aspirate concentrate, which contains mesenchymal stem cells and has shown the potential to enhance graft incorporation in basic science studies.¹⁵ However, research remains to be conducted on the impact of bone marrow aspirate concentrate on clinical outcomes after OCA.

The clinical outcomes of OCA for the humeral head have been reported in multiple studies. A systematic review identified that previous investigations used primarily fresh-frozen OCA for the humeral head, which have been suggested to result in worse outcomes because of chondrocyte death.^{8,16} In the only case series to date of fresh OCA for osteochondral defects, patients shown significantly improved American Shoulder and Elbow Surgeons and simple shoulder test scores with 80% graft survival at a 67-month mean follow-up (Video 1).¹

References

- Riff AJ, Yanke AB, Shin JJ, Romeo AA, Cole BJ. Midterm results of osteochondral allograft transplantation to the humeral head. *J Shoulder Elbow Surg* 2017;26:e207-e215.
- Frank RM, Van Thiel GS, Slabaugh MA, Romeo AA, Cole BJ, Verma NN. Clinical outcomes after microfracture of the glenohumeral joint. *Am J Sports Med* 2010;38:772-781.
- Van Thiel GS, Sheehan S, Frank RM, et al. Retrospective analysis of arthroscopic management of glenohumeral degenerative disease. *Arthroscopy* 2010;26:1451-1455.
- 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.
- Provencher MT, Sanchez G, Schantz K, et al. Anatomic humeral head reconstruction with fresh osteochondral talus allograft for recurrent glenohumeral instability with reverse Hill-Sachs lesion. *Arthrosc Tech* 2017;6:e255-e261.
- Black LO, Ko J-WK, Quilici SM, Crawford DC. Fresh osteochondral allograft to the humeral head for treatment of an engaging reverse Hill-Sachs lesion: Technical case report and literature review. *Orthop J Sports Med* 2016;4:2325967116670376.
- Frank RM, Lee S, Levy D, et al. Osteochondral allograft transplantation of the knee: Analysis of failures at 5 years. *Am J Sports Med* 2017;45:864-874.
- Saltzman BM, Riboh JC, Cole BJ, Yanke AB. Humeral head reconstruction with osteochondral allograft transplantation. *Arthroscopy* 2015;31:1827-1834.
- 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.
- Athwal GS, Shridharani SM, O'driscoll SW. Osteolysis and arthropathy of the shoulder after use of bioabsorbable knotless suture anchors. *J Bone Jt Surg* 2006;88:1840-1845.
- Chapovsky F, Kelly JD. Osteochondral allograft transplantation for treatment of glenohumeral instability. *Arthroscopy* 2005;21:1007.e1-1007.e4.
- Bernstein DT, O'Neill CA, Kim RS, et al. Osteochondral allograft donor-host matching by the femoral condyle radius of curvature. *Am J Sports Med* 2017;45:403-409.
- Chan CM, LeVasseur MR, Lerner AL, Maloney MD, Voloshin I. Computer modeling analysis of the talar dome

- as a graft for the humeral head. *Arthroscopy* 2016;32:1671-1675.
14. Meyer MA, McCarthy MA, Gitelis ME, et al. Effectiveness of lavage techniques in removing immunogenic elements from osteochondral allografts [published online December 9, 2016]. *Cartilage*. doi:10.1177/1947603516681132.
 15. Krych AJ, Nawabi DH, Farshad-Amacker NA, et al. Bone marrow concentrate improves early cartilage phase maturation of a scaffold plug in the knee: A comparative magnetic resonance imaging analysis to platelet-rich plasma and control. *Am J Sports Med* 2016;44:91-98.
 16. Pallante AL, Görtz S, Chen AC, et al. Treatment of articular cartilage defects in the goat with frozen versus fresh osteochondral allografts: Effects on cartilage stiffness, zonal composition, and structure at six months. *J Bone Jt Surg Am* 2012;94:1984-1995.