Favorable short-term outcomes of micronized allogenic cartilage scaffold for glenoid cartilage defects associated with posterior glenohumeral instability

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Purpose: To determine clinical outcomes associated with micronized allogenic cartilage scaffold use for treatment of posterior glenoid cartilage defects at 2 years. **Study Design:** Case series. **Methods:** A retrospective analysis of prospectively collected data was performed on a consecutive series of patients who underwent arthroscopic treatment of a symptomatic posterior glenoid cartilage defect with micronized allogenic cartilage scaffold between January 2019 and December 2020. The primary outcome was subjective shoulder value (SSV) at latest follow-up. Secondary outcomes included visual analog scale (VAS), recurrence of instability, and range of motion (ROM). **Results:** Seven patients, including 4 in the setting of primary posterior instability and 3 in the setting of recurrent symptoms after arthroscopic posterior glenohumeral stabilization, were included in the analysis with a mean follow up of 2.6 years (range, 2-3.7 years). Statistically significant improvements were seen in SSV (median = 40, interquartile range [IQR] = 40-50 before surgery; vs median = 85, IQR = 67.5-87.5 after surgery; $P = .018$) and VAS (median = 4, IQR = 4-6.3 before surgery; vs median = 1, IQR = 0-1.5 after surgery; $P = .010$). No significant differences were seen in ROM. There were no cases of recurrent instability or reoperation. **Conclusions:** The use of micronized allogenic cartilage scaffold for glenoid cartilage defects is associated with clinical improvement at 2-year follow-up. This is the case when performed in conjunction with index posterior labral repair when there is a concomitant glenoid cartilage defect or when performed in the setting of persistent pain and mechanical symptoms after prior posterior labral repair. **Level of Evidence:** Level IV, therapeutic case series.

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Posterior glenohumeral instability is an increasingly recognized and treated entity in sports medicine and arthroscopic shoulder surgery.[1-5] Although anterior glenohumeral instability remains more common, recent reports have demonstrated an increasing proportion of posterior instability among all instability[6,7] than has been previously thought.[8-11] In addition to having a traumatic origin,[2,12,13] the pathology associated with posterior instability often involves microtrauma and edge-loading of the posterior glenoid rim and associated shear forces on the posterior glenoid cartilage.[14] Pain, rather than apprehension or instability, is typically the presenting symptom, and patients will often not have any history of dislocation or subluxation event.[3] Arthroscopic posterior stabilization has been shown to be largely successful with good clinical outcomes and low rates of recurrent instability and revision surgery.[8,15,16] However, activity-limiting shoulder pain after arthroscopic stabilization has been reported to be as high as 15.5% to 17.5%.[8,16] A possible explanation for this is an unrecognized or undertreated posterior

glenoid articular cartilage defect at the time of the index stabilization procedure. In one series, glenoid cartilage defects were seen in 16% of patients with posterior instability and were a significant risk factor for poor clinical outcomes.[17]

Treatment of glenoid articular cartilage defects can be challenging, especially in younger patients. Traditional treatment options include leaving the defect unaddressed, shifting the capsule to a stable glenoid rim, or microfracture. Although there is limited literature describing natural history of an untreated defect and capsular shift to cover the defect, theoretically they can result in progressive cartilage degeneration/osteoarthritis or overtightening, respectively. Microfracture has been the most widely adopted technique for small, isolated articular cartilage defects, particularly in weightbearing joints, with favorable short-term outcomes but less favorable long-term outcomes.[18-22] Despite favorable short-term outcomes,[23,24] microfracture in isolation has not been particularly successful in the shoulder. At an average 10-year follow up, Wang et al.[25] report a rate of progression to osteoarthritis of 21% and clinical failure of 33% to 42%.

One of the potential reasons for failure of microfracture is that it generates fibrocartilage, which is softer and does not withstand shear stresses as well as native hyaline cartilage.[26] Recently, there has been increasing interest in methods that recreate the composition or mechanical properties of hyaline cartilage in contained osteochondral defects. Such methods include osteochondral autograft transfer system, particulated juvenile articular cartilage (DeNovo NT; Zimmer Inc., Warsaw, IN), autologous cultured chondrocytes (Carticel; Genzyme Corp., Cambridge, MA), and micronized allogenic cartilage scaffold (BioCartilage; Arthrex, Naples, FL).

A proposed advantage of micronized allogenic cartilage scaffold is that it results in well-distributed cartilage regeneration (as opposed to having mixed areas of hyaline cartilage and fibrocartilage in other techniques).[27] In a primate model, micronized cartilage matrix implanted into osteochondral defects resulted in hyaline-like cartilage on histology at 9 weeks.[28] Several case reports have described the use of micronized allogenic cartilage scaffold in lesions of the talus or knee with excellent results.[29-31] The purpose of this study was to determine 2-year clinical outcomes associated with micronized allogenic cartilage scaffold use for treatment of posterior glenoid cartilage defects. We hypothesize that micronized allogenic cartilage scaffold will be associated with an improvement in clinical outcome measures in the treatment of posterior glenoid cartilage defects.

Methods

Patient Selection

A consecutive series of patients treated with micronized allogenic cartilage scaffold during a 2-year period from January 2019 through December 2020 was identified. Inclusion criteria were defined as patients age 18 to 50 years with a posterior glenoid articular cartilage defect (with or without posterior labral tear) treated with micronized allogenic cartilage scaffold (BioCartilage) within the past 2 years. Exclusion criteria were age <18 or >50 years, follow-up less than 2 years, and preoperative radiographic evidence of glenohumeral osteoarthritis. Clinical data were collected and analyzed retrospectively. Informed consent for study participation was obtained via the Military Orthopaedics Tracking Injuries and Outcomes Network (MOTION) with Institutional Review Board approval.

Surgical Technique

Patient Positioning and Portal Placement

Patients were positioned in the lateral decubitus position with a bean bag high in the axilla and a 3-point shoulder traction device (Fig 1A). This ensures that the glenoid acts as a flat work surface parallel to the floor to facilitate graft application. An anterior superior portal was made first without direct visualization which allows for exact placement of the posterior portal to allow for a more perpendicular trajectory for instrumentation of the glenoid. A cannula at least 8 mm in diameter was placed in this portal for passing the arthroscopic sponges and graft applicator. An additional low anterior portal is used for passing instruments and suture management (Fig 1B). Additionally, a percutaneous 5 o'clock portal was often used to place the inferior anchors for the labral repair.

Glenoid Defect Preparation

Glenoid defects were considered amenable to cartilage grafting with micronized allogenic cartilage scaffold if the lesion was isolated with minimum 5 mm × 5 mm diameter (Fig 2A). At this point, 30 to 60 mL of the patient's blood is drawn for platelet rich plasma preparation and preparation of an autogenic fibrin clot. An arthroscopic shaver and curette are used to debride the chondral defect down to a base of subchondral bone with stable vertical cartilaginous borders (Fig 2B).

The labral repair was then completed which allows for full containment of the cartilage defect (Fig 2C). The anchor selection and suture pattern are not specific to the use of micronized cartilage allograft. In cases with prior posterior labral repair, examination findings under anesthesia were not consistent with recurrent instability, and the integrity of the labral repair was

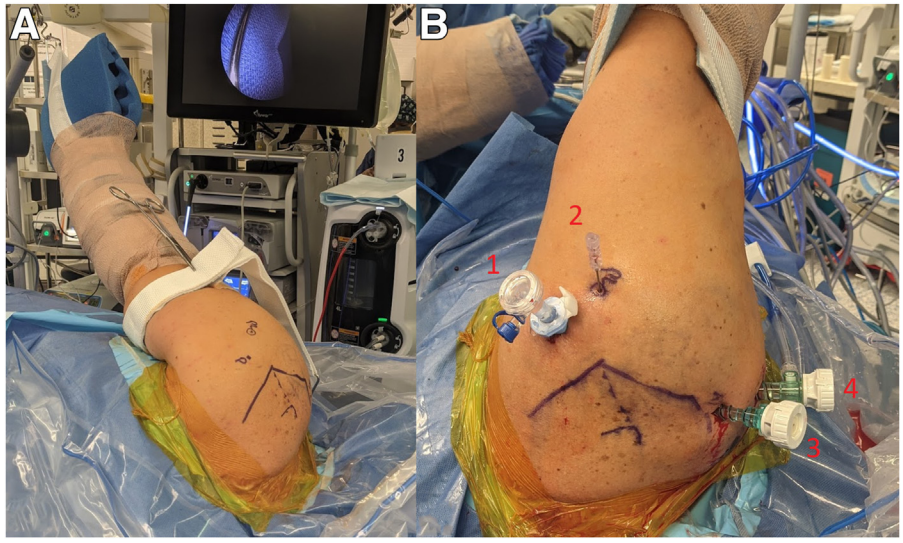

Fig 1. Patient positioning and cannula placement for glenoid micronized allogenic cartilage scaffold. **(A)** Patient in lateral decubitus position with STaR arm traction sleeve on left arm (Arthrex, Naples, FL). **(B)** Typical cannula placement: 1 = posterior portal; 2 = posterolateral portal; 3 = anterior superior portal; 4 = low anterior portal.

assessed during surgery and found to be intact and were therefore not revised.

After the contained defect is established, the graft recipient site is microfractured with an awl or motorized pick device with holes evenly placed about every 4 mm in the defect (Figs 2D and 2E). Arthroscopic fluid is removed with suction from the joint and the recipient site is thoroughly dried with arthroscopic sponge and suction via a Frazier tip (Fig 2F).

Graft Mixing and Application

A micronized cartilage allograft mixture is prepared using 1 mL of platelet rich plasma (PRP) from the previously drawn blood sample with 1 mL of allograft material. Additional PRP can be added to the graft material if it proves to be too viscus to extravasate from the syringe (Fig 3A). Rehydrating the graft with PRP is favored over whole blood because of the ability of PRP to potentiate cartilage repair and induce chemotaxis of mesenchymal stem cells.[32]

The micronized allograft and PRP mixture are then injected into the microfractured defect and spread evenly using the applicator syringe. The prepared defect is filled to a level just slightly recessed relative to the native cartilage surface (Fig 3B). An 18-gauge spinal needle on a syringe was used for precise removal of excess graft (Fig 3C). Finally, a thin layer of autogenetic fibrin is applied with an 18-gauge needle to seal the edges of the graft and improve mechanical strength[33] (Fig 3D). All instruments are removed from the joint, and the fibrin clot is allowed to set for 5 minutes.

Postoperative Rehabilitation

After treatment of glenoid chondral defects with this cartilage allograft technique, the patients are placed in a shoulder immobilizer and begin a standard labral repair protocol. They remain in a sling for 6 weeks. During this period, they are allowed to come out of the sling for hygiene, supported pendulums exercises, and elbow range of motion.

Outcome measurements

A retrospective review of prospectively collected data was performed. Preoperative characteristics including chief complaint (pain, instability, mechanical symptoms, or a combination), physical examination findings (Kim test, Jerk test, load and shift, sulcus) and magnetic resonance imaging (MRI) characteristics (glenoid version, glenoid bone loss, glenoid morphology, and concurrent intra-articular pathology) were evaluated and any association with the primary or secondary outcomes was determined. The primary outcome measure was the subjective shoulder value (SSV), which has been validated as a reliable outcome measure in shoulder surgery.[34] Secondary outcomes included pain as reported on the visual analog scale (VAS); recurrence of instability defined as continued or new onset of subjective or objective findings associated with posterior instability (i.e., new complaints of pain or subluxation/dislocation, positive Kim/Jerk/load shift test results); resolution or persistence of mechanical symptoms; range of motion (forward elevation, abduction, internal and external rotation); and operative time.

Statistics

The mean, standard error, median and interquartile range were calculated for continuous variables. For categorical variables, frequencies and proportions were calculated; 95% confidence interval (CI) was also

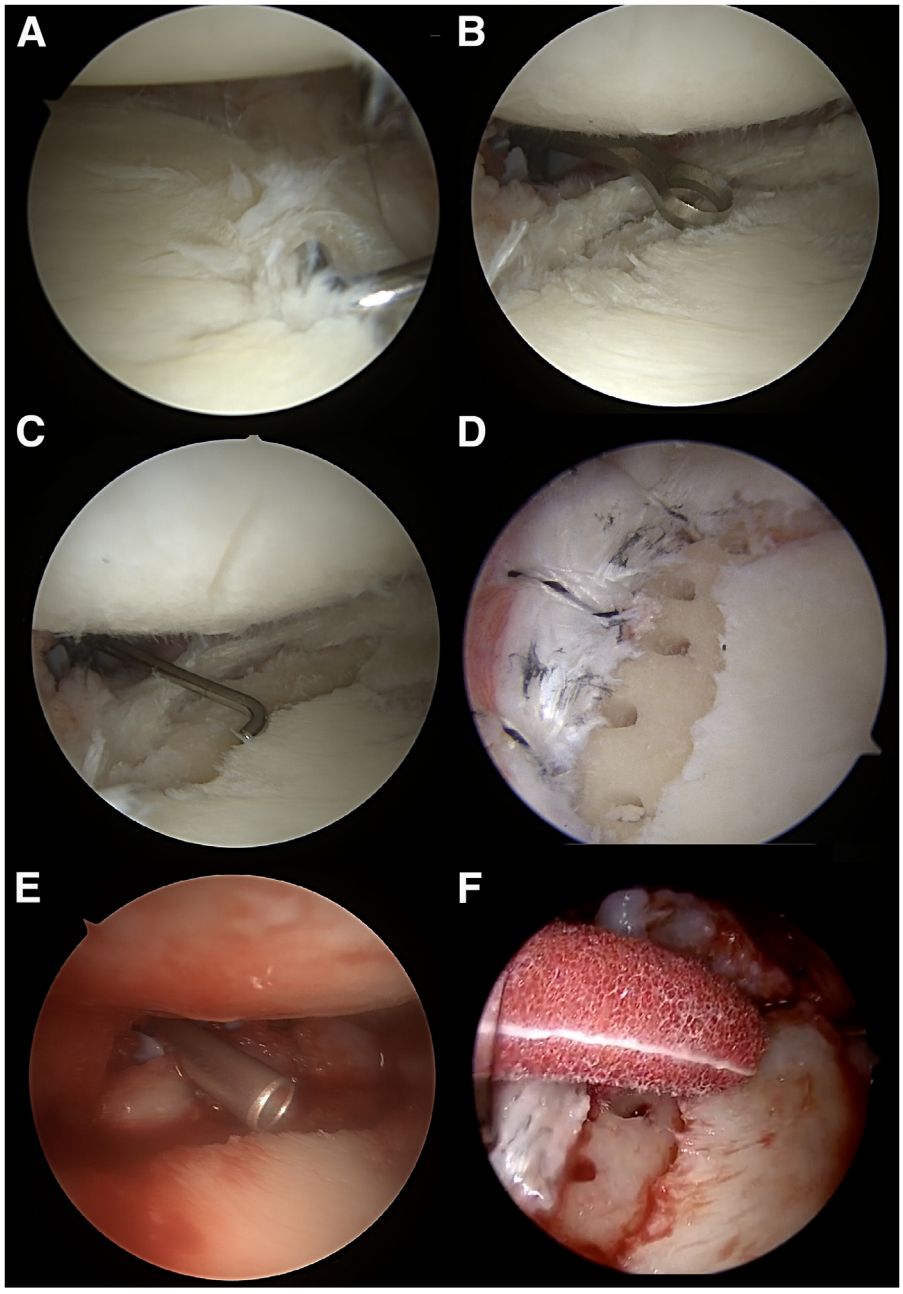

Fig 2. Glenoid defect preparation for micronized allogenic cartilage scaffold. All arthroscopic images are taken in the lateral decubitus position viewing from anterior and instrumenting from posterior in a left shoulder. **(A)** Glenoid cartilage defect identified and measured with the tip of a probe. **(B)** Cartilage debrided with ring curette. **(C)** Stable vertical edge of cartilage established. **(D)** Posterior labrum repaired to glenoid rim with suture anchors and microfracture performed with awl or motorized pick device. **(E)** Arthroscopic fluid stopped, allowing extravasation of fat and blood from microfracture sites being suctioned with Frazier tip. **(F)** Glenoid surface is dried with arthroscopic sponge.

calculated, where appropriate. Ordinal data were compared with a χ^2 test or Fisher exact test, and nominal data were compared with a *t* test or Mann-Whitney test, as appropriate. Calculations were performed with OpenEpi[35] and R (v4.0.2, Vienna, Austria) in RStudio (v1.3; RStudio, Inc., Boston, MA).

Results

Baseline Characteristics

A total of 28 patients were treated operatively for posterior instability during the study period. Seven patients met inclusion and exclusion criteria and were included in the analysis. Four of these patients (14%) had an associated glenoid cartilage defect. Additionally, 3 patients presented in the setting of continued symptoms after previous arthroscopic posterior stabilization and underwent micronized allogenic cartilage scaffold without revision of the prior posterior labral repair (2 patients also had concurrent biceps tenodesis). The mean time from index surgery to revision was 11.2 months (range, 5.8-16.8 months). All patients were male with a mean age of 38.1 ± 4.7 years at time of surgery (Table 1). The chief complaint was pain in 6 of

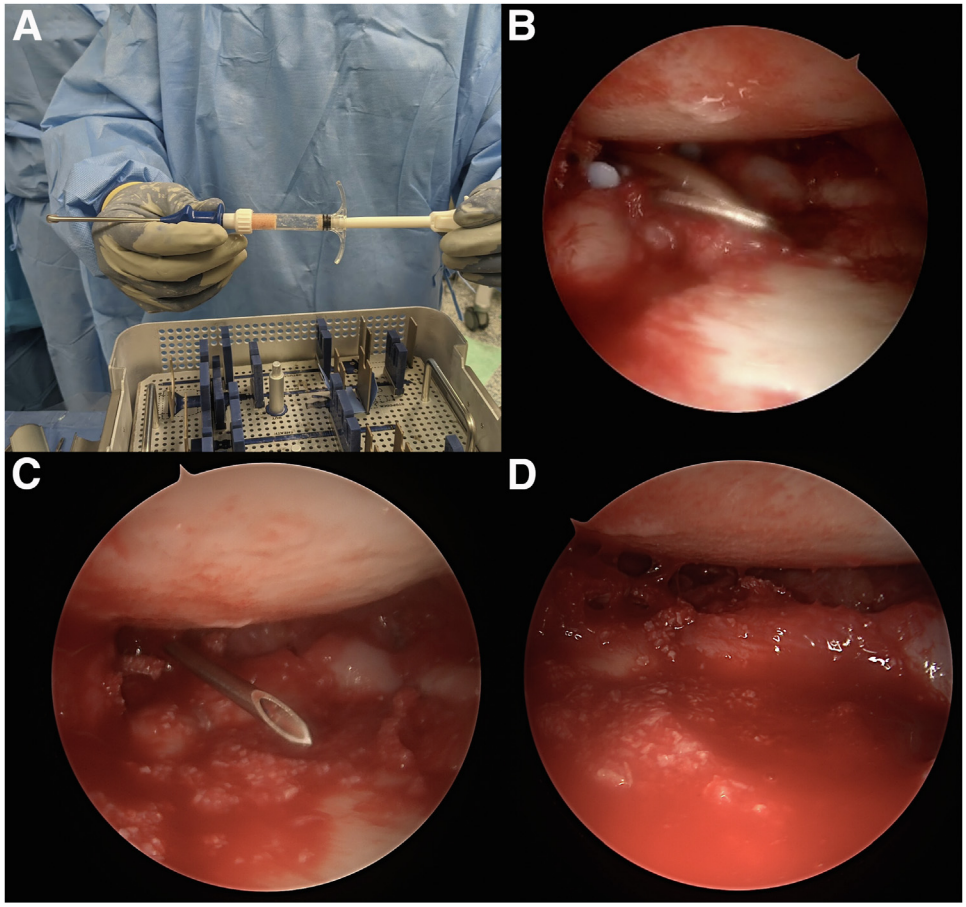

Fig 3. Micronized allogenic cartilage scaffold application. Arthroscopic images taken viewing from anterior superior portal and instrumenting from posterior portal in a left shoulder, lateral decubitus position. **(A)** Graft in applicator (BioCartilage; Arthrex, Naples, FL). **(B)** Applicator used to spread graft evenly over the posterior glenoid cartilage defect viewed from anteriorly and instrumenting from posterior. **(C)** Autogenous fibrin applied to seal edges of the defect. **(D)** Final construct.

7 patients, and mechanical symptoms without pain was the chief complaint in 1 patient. Of the patients with the primary complaint of pain, 3 patients reported instability, and 3 patients reported mechanical symptoms. Although the main physical examination finding for index cases was a positive Kim test result (4 of 4 patients), all 3 of the revision cases had a negative Kim test result but had crepitus with external rotation on physical examination. On preoperative MRI, the mean glenoid version was 9.0 ± 0.7 (95% CI = 7.6-10.5) degrees of retroversion. There was minimal glenoid bone loss (1.0% ± 0.6%, 95% CI = −0.2 to 2.3) and minimal other intra-articular pathology (mild to moderate biceps tendinosis in 2 patients). Subchondral cysts

Table 1. Patient Data

					MRI				VAS		SSV		Final
Age (yr)	Sex	Index Vs Revision	Chief complaint	Kim test	Glenoid bone loss (% area)	Glenoid version	Defect size (cm × cm)	Operative time (min)	Pre	Post	Pre	Post	follow-up (yr)
29	M	Index	Pain, mechanical symptoms	+	0	7.4°	2.0 × 2.0	89	4	0	40	95	2.1
40	M	Index	Pain, instability	+	4.1	9.0°	0.5 × 1.5	139	8	1	35	90	2.0
41	M	Index	Pain, instability	+	0	8.4°	2.0 × 1.5	132	4	3	40	50	2.4
37	M	Index	Pain, instability	+	0	11.6°	0.7 × 1.5	141	4	0	40	60	2.0
35	M	Revision	Pain, mechanical symptoms	−	0	7.0°	1.5 × 1.0	124	5	0	50	85	3.6
45	M	Revision	Pain, mechanical symptoms	−	3.2	12.3°	1.2 × 1.0	68	3	2	70	75	3.7
40	M	Revision	Mechanical symptoms	−	0	7.6°	1.0 × 1.5	105	7.5	1	50	85	2.2

M, male; MRI, magnetic resonance imaging; Post, postoperative; Pre, preoperative; SSV, subjective shoulder value; VAS, Visual Analog Scale.

Table 2. Subjective Outcomes

		SSV, median (IQR)			VAS, median (IQR)		
	Patients (n)	Pre	Post	*P* Value	Pre	Post	*P* Value
Index	4	40 (38.8-40)	75 (57.5-91.3)	.09	4 (4-5)	0.5 (0-1.5)	.09
Revision	3	50 (50-60)	85 (80-85)	.16	5 (4-6.3)	1 (0.5-1.5)	.16
Total	7	40 (40-50)	85 (67.5-87.5)	**.018**	4 (4-6.3)	1 (0-1.5)	**.010**

IQR, interquartile range; Post, postoperative; Pre, preoperative; SSV, subjective shoulder value; VAS, visual analog scale,
All comparisons between index and revision did not reach statistical significance.

were seen in 6 of 7 patients with a mean area of 8.9 ± 2.2mm^2 (95% CI = 4.5-13.2) on axial cuts. Intraoperative defect area was 1.5 ± 0.4 cm^2 (95% CI = 0.8-2.2), with no significant difference between index or revision cases.

Outcomes

All patients had SSV, VAS, and ROM reported before and after surgery (Table 2). Mean follow-up was 2.6 years, ranging from 2 to 3.7 years. No patients experienced recurrence or new-onset instability after surgery, and no patients required revision surgery. One patient developed adhesive capsulitis treated with physical therapy. There was a statistically significant improvement in SSV (mean = 46.4 ± 4.1, 95% CI = 38.3-54.5, median = 40, interquartile range [IQR] = 40-50; vs mean = 77.1 ± 5.8, 95% CI = 65.8-88.5, median = 85, IQR = 67.5-87.5; P = .018) and VAS (mean = 5.1 ± 0.7, 95% CI = 3.8-6.4, median = 4, IQR = 4-6.3; vs mean = 1.0 ± 0.4, 95% CI = 0.2-1.8, median = 1, IQR = 0-1.5; P = .01). Comparison between index and revision procedures for postoperative VAS and SSV demonstrated no significant differences. No significant differences in range of motion before and after surgery were seen. Two patients underwent postoperative MRI more than 6 months after surgery, and the integrity of the micronized allogenic cartilage graft was demonstrated (Fig 4). Baseline variables including index versus revision surgery, chief complaint (pain vs instability vs mechanical symptoms), physical exam findings (+ vs − Kim/Jerk/sulcus), MRI findings (glenoid version >10° vs <10°, bone loss vs no bone loss) did not have a significant effect on primary or secondary outcomes on subgroup analysis.

Discussion

The most important finding of this study is that treatment of glenoid cartilage defects associated with posterior glenohumeral instability with micronized allogenic cartilage scaffold results in favorable outcomes at 2 years. Posterior glenohumeral instability continues to be an incompletely understood and increasingly recognized shoulder pathology. Although there are reports of revision surgery rates of 1.5% to 6%,[8,15,16,36,37] it is uncertain what role cartilage lesions have in failed labral repair. Glenoid cartilage lesions can be found incidentally in 6% to 17% of arthroscopic procedures[38-40] and have an incidence of 23% after anterior glenohumeral instability events.[41] Although the incidence of cartilage lesions associated with posterior glenohumeral instability is unknown, inappropriate treatment of cartilage defects may represent a significant reason for reoperation or continued symptoms after surgery. Micronized allogenic cartilage scaffold use for posterior glenoid cartilage defects has been described previously,[42] and the present study further demonstrates its clinical application and associated favorable short-term outcomes. This is an important finding considering the limitations associated with microfracture and other cartilage restoration techniques as discussed previously.

Patients in our series demonstrated a significant improvement in their SSV and VAS after surgery and did not experience recurrent instability or require reoperation with mean 2.6 years' follow-up. Both patients undergoing index and revision arthroscopic posterior stabilization experienced improvements in SSV, although the revision cases did not reach statistical significance. A possible explanation for this is that patients in the revision setting had experienced some improvement after their index procedure and therefore were starting from a higher baseline (Table 2). There was also a trend toward significance indicating a larger defect size in the reoperation group (Table 1), which would suggest that cartilage defects may increase in size if inadequately addressed at the index procedure. Performing a labral repair to the stable cartilage rim may overconstrain the joint and accelerate this process. For this reason, the senior authors were more aggressive about using this technique for glenoid cartilage defects in the primary setting during the study period.

These patients fit the prototype for posterior instability-young males with daily activities that place significant repetitive stress on the shoulder (i.e., pushups, pullups, overhead lifting, etc.) leading to straining of the static and dynamic joint stabilizers and creating shear stress on the cartilage.[12,43] Only 1 patient described a discreet traumatic event. Additionally, a significant proportion of patients described painful crepitus particularly with loading or external

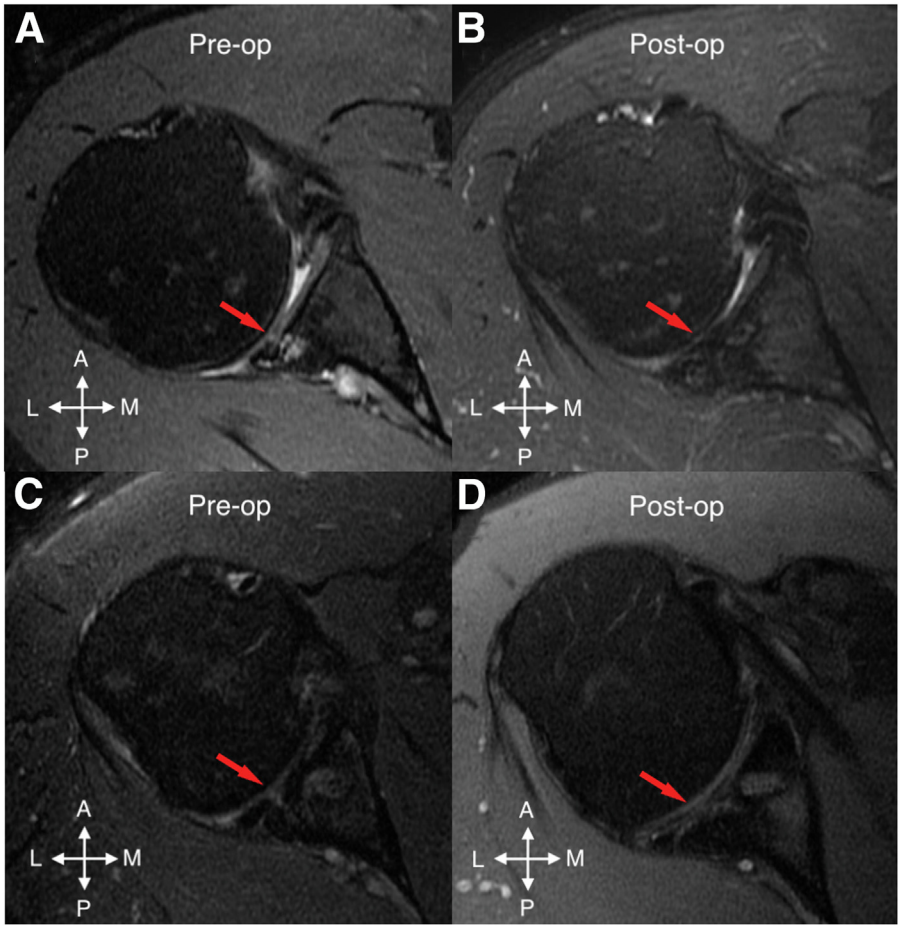

Fig 4. Top row images show preoperative **(A)** and 8-month postoperative **(B)** proton-dense fat-saturated axial magnetic resonance imaging (MRI) cuts at the mid portion of the glenoid in a 40 year-old male with pain and instability demonstrating micronized allogenic cartilage graft (**B**, arrow) in prior posterior glenoid cartilage defect (**A**, arrow) as well as resolution of the glenoid cyst. Bottom row images show preoperative **(C)** and 11-month postoperative **(D)** proton-dense fat-saturated axial MRI at the mid portion of the glenoid in a 35 year-old male with continued pain and mechanical symptoms after prior posterior labral repair showing similar durability of micronized allogenic cartilage graft (**D**, arrow) in area of cartilage defect (**C**, arrow). A, anterior; L, lateral, M, medial; P, posterior.

rotation. In the revision setting, this occurred with a negative Kim test. Furthermore, 1 patient who had no improvement in SSV had developed adhesive capsulitis because of a delay in physical therapy, highlighting the importance for appropriate postoperative rehabilitation.

The use of micronized allogenic cartilage scaffold has the potential advantage over other treatment options in that its end-product most closely resembles articular cartilage.[28] We found on MRI at 11 months after surgery that the scaffold remained intact and resembled the appearance of normal articular cartilage in 2 patients (Fig 4). We do not feel that the additional operative time necessary to perform micronized allogenic cartilage scaffold is clinically significant. When comparing the mean index case length for the 3 patients in our series who underwent revision surgery (i.e., the operative time of their index isolated posterior labral repair) to the 4 index cases with micronized allogenic cartilage scaffold, there was a difference of about 5 minutes per case that did not reach statistical significance (121.3 $\pm$ 5.2 minutes, 95% CI = 111.2-131.5 vs 125.3 $\pm$ 21.2 minutes, 95% CI = 104.5-146.0), although this study is underpowered to detect this difference. We propose this technique as a viable treatment for contained glenoid lesions amenable to microfracture.

Limitations

There are several limitations to this study. The short-term duration of follow-up is in part due to how relatively new the micronized allogenic cartilage scaffold technique is, with the earliest reports in humans being from 2014.[29,42] However, the comparable short term clinical improvements of glenoid microfracture alone described by Wang et al.[25] suggest that the addition of micronized allogenic cartilage scaffold is not inferior to microfracture alone. Additional limitations include a lack of a comparison group, which makes it impossible to determine whether the clinical improvement seen would be superior to other treatments such as microfracture alone. In addition, internal rotation was not uniformly recorded in a manner that was conducive to statistical analysis, with some clinical notes recording a measurement of degrees and some reporting vertebral level. Finally, the homogeneity of the patient population (30- to 40-year-old males) may not be generalizable to other populations. Long-term, comparative

analysis between microfracture with or without micronized allogenic cartilage scaffold with determination of the cost-benefit relationship are necessary to determine the effectiveness of micronized allogenic cartilage scaffold in glenohumeral joint preservation.

Conclusions

The use of micronized allogenic cartilage scaffold for glenoid cartilage defects is associated with clinical improvement at 2-year follow-up. This is the case when performed in conjunction with index posterior labral repair when there is a concomitant glenoid cartilage defect or when performed in the setting of persistent pain and mechanical symptoms after prior posterior labral repair.

References

1. Kaplan LD, Flanigan DC, Norwig J, Jost P, Bradley J. Prevalence and variance of shoulder injuries in elite collegiate football players. *Am J Sports Med* 2005;33:1142-1146.
2. Mair SD, Zarzour RH, Speer KP. Posterior labral injury in contact athletes. *Am J Sports Med* 1998;26:753-758.
3. Provencher MT, LeClere LE, King S, et al. Posterior instability of the shoulder: Diagnosis and management. *Am J Sports Med* 2011;39:874-886.
4. Tannenbaum E, Sekiya JK. Evaluation and management of posterior shoulder instability. *Sports Health* 2011;3:253-263.
5. Yow BG, Wade SM, Bedrin MD, Rue JH, LeClere LE. The incidence of posterior and combined AP shoulder instability treatment with surgical stabilization is higher in an active military population than in the general population: Findings from the US Naval Academy. *Clin Orthop Relat Res* 2021;479:704-708.
6. Owens BD, Duffey ML, Nelson BJ, DeBerardino TM, Taylor DC, Mountcastle SB. The incidence and characteristics of shoulder instability at the United States Military Academy. *Am J Sports Med* 2007;35:1168-1173.
7. Antoniou J, Harryman DT. 2nd. Posterior instability. *Orthop Clin North Am* 2001;32:463-473. ix.
8. DeLong JM, Jiang K, Bradley JP. Posterior instability of the shoulder: A systematic review and meta-analysis of clinical outcomes. *Am J Sports Med* 2015;43:1805-1817.
9. Dickens JF, Kilcoyne KG, Haniuk E, Owens BD. Combined lesions of the glenoid labrum. *Phys Sportsmed* 2012;40:102-108.
10. Song DJ, Cook JB, Krul KP, et al. High frequency of posterior and combined shoulder instability in young active patients. *J Shoulder Elbow Surg* 2015;24:186-190.
11. Javed S, Gheorghiu D, Torrance E, Monga P, Funk L, Walton M. The incidence of traumatic posterior and combined labral tears in patients undergoing arthroscopic shoulder stabilization. *Am J Sports Med* 2019;47:2686-2690.
12. Millett PJ, Clavert P, Hatch GF 3rd, Warner JJ. Recurrent posterior shoulder instability. *J Am Acad Orthop Surg* 2006;14:464-476.
13. Pennington WT, Sytsma MA, Gibbons DJ, et al. Arthroscopic posterior labral repair in athletes: Outcome analysis at 2-year follow-up. *Arthroscopy* 2010;26:1162-1171.
14. McClincy MP, Arner JW, Bradley JP. Posterior shoulder instability in throwing athletes: A case-matched comparison of throwers and non-throwers. *Arthroscopy* 2015;31:1041-1051.
15. Bradley JP, McClincy MP, Arner JW, Tejwani SG. Arthroscopic capsulolabral reconstruction for posterior instability of the shoulder: A prospective study of 200 shoulders. *Am J Sports Med* 2013;41:2005-2014.
16. Chan S, O'Brien LK, Waterman BR, Chan AG, Pallis M, Kilcoyne KG. Low risk of recurrence after posterior labral repair of the shoulder in a high-risk united states military population. *Arthrosc Sports Med Rehabil* 2020;2:e47-e52.
17. Nourissat G, Hardy MB, Garret J, Mansat P, Godeneche A, Societe Francophone dA. Glenoid cartilage lesions compromise outcomes of surgical treatment for posterior shoulder instability. *Orthop J Sports Med* 2020;8:2325967119898124.
18. Gross CE, Chalmers PN, Chahal J, et al. Operative treatment of chondral defects in the glenohumeral joint. *Arthroscopy* 2012;28:1889-1901.
19. Mithoefer K, Williams RJ 3rd, Warren RF, Wickiewicz TL, Marx RG. High-impact athletics after knee articular cartilage repair: A prospective evaluation of the microfracture technique. *Am J Sports Med* 2006;34:1413-1418.
20. Falah M, Nierenberg G, Soudry M, Hayden M, Volpin G. Treatment of articular cartilage lesions of the knee. *Int Orthop* 2010;34:621-630.
21. Riyami M, Rolf C. Evaluation of microfracture of traumatic chondral injuries to the knee in professional football and rugby players. *J Orthop Surg Res* 2009;4:13.
22. Namdari S, Baldwin K, Anakwenze O, Park MJ, Huffman GR, Sennett BJ. Results and performance after microfracture in National Basketball Association athletes. *Am J Sports Med* 2009;37:943-948.
23. 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.
24. Millett PJ, Huffard BH, Horan MP, Hawkins RJ, Steadman JR. Outcomes of full-thickness articular cartilage injuries of the shoulder treated with microfracture. *Arthroscopy* 2009;25:856-863.
25. Wang KC, Frank RM, Cotter EJ, et al. Long-term clinical outcomes after microfracture of the glenohumeral joint: Average 10-year follow-up. *Am J Sports Med* 2018;46:786-794.
26. Xing L, Jiang Y, Gui J, et al. Microfracture combined with osteochondral paste implantation was more effective than microfracture alone for full-thickness cartilage repair. *Knee Surg Sports Traumatol Arthrosc* 2013;21:1770-1776.
27. Farr J, Tabet SK, Margerrison E, Cole BJ. Clinical, radiographic, and histological outcomes after cartilage repair with particulated juvenile articular cartilage: A 2-year prospective study. *Am J Sports Med* 2014;42:1417-1425.
28. Malinin TI, Temple HT. *Musculoskeletal tissue transplantation and tissue banking*. New Delhi: Jaypee Brothers Medical Publishers, 2013.

29. Clanton TO, Johnson NS, Matheny LM. Use of cartilage extracellular matrix and bone marrow aspirate concentrate in treatment of osteochondral lesions of the talus. *Tech Foot Ankle Surg* 2014;13:212-220.
30. Desai S. Surgical treatment of a tibial osteochondral defect with debridement, marrow stimulation, and micronized allograft cartilage matrix: Report of an all-arthroscopic technique. *J Foot Ankle Surg* 2016;55:279-282.
31. Brusalis CM, Greditzer HGt, Fabricant PD, Stannard JP, Cook JL. BioCartilage augmentation of marrow stimulation procedures for cartilage defects of the knee: Two-year clinical outcomes. *Knee* 2020;27:1418-1425.
32. Milano G, Sanna Passino E, Deriu L, et al. The effect of platelet rich plasma combined with microfractures on the treatment of chondral defects: An experimental study in a sheep model. *Osteoarthritis Cartilage* 2010;18:971-980.
33. Irwin RM, Bonassar LJ, Cohen I, et al. The clot thickens: Autologous and allogeneic fibrin sealants are mechanically equivalent in an ex vivo model of cartilage repair. *PLoS One* 2019;14:e0224756.
34. Gilbart MK, Gerber C. Comparison of the subjective shoulder value and the Constant score. *J Shoulder Elbow Surg* 2007;16:717-721.
35. Sullivan KM, Dean A, Soe MM. OpenEpi: A web-based epidemiologic and statistical calculator for public health. *Public Health Rep* 2009;124:471-474.
36. Bradley JP, Arner JW, Jayakumar S, Vyas D. Risk factors and outcomes of revision arthroscopic posterior shoulder capsulolabral repair. *Am J Sports Med* 2018;46:2457-2465.
37. Bradley JP, Arner JW, Jayakumar S, Vyas D. Revision arthroscopic posterior shoulder capsulolabral repair in contact athletes: Risk factors and outcomes. *Arthroscopy* 2020;36:660-665.
38. Elser F, Braun S, Dewing CB, Millett PJ. Glenohumeral joint preservation: Current options for managing articular cartilage lesions in young, active patients. *Arthroscopy* 2010;26:685-696.
39. Gartsman GM, Taverna E. The incidence of glenohumeral joint abnormalities associated with full-thickness, reparable rotator cuff tears. *Arthroscopy* 1997;13:450-455.
40. Paley KJ, Jobe FW, Pink MM, Kvitne RS, ElAttrache NS. Arthroscopic findings in the overhand throwing athlete: Evidence for posterior internal impingement of the rotator cuff. *Arthroscopy* 2000;16:35-40.
41. Hintermann B, Gächter A. Arthroscopic findings after shoulder dislocation. *Am j Sports Med* 1995;23:545-551.
42. Shin JJ, Mellano C, Cvetanovich GL, Frank RM, Cole BJ. Treatment of glenoid chondral defect using micronized allogeneic cartilage matrix implantation. *Arthrosc Tech* 2014;3:e519-e522.
43. Paul J, Buchmann S, Beitzel K, Solovyova O, Imhoff AB. Posterior shoulder dislocation: Systematic review and treatment algorithm. *Arthroscopy* 2011;27:1562-1572.