



Operative Treatment of Chondral Defects in the Glenohumeral Joint

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Purpose: The objectives of this study were to conduct a systematic review of clinical outcomes after cartilage restorative and reparative procedures in the glenohumeral joint, to identify prognostic factors that predict clinical outcomes, to provide treatment recommendations based on the best available evidence, and to highlight literature gaps that require future research. **Methods:** We searched Medline (1948 to week 1 of February 2012) and Embase (1980 to week 5 of 2012) for studies evaluating the results of arthroscopic debridement, microfracture, osteochondral autograft or allograft transplants, and autologous chondrocyte implantation for glenohumeral chondral lesions. Other inclusion criteria included minimum 8 months' follow-up. The Oxford Level of Evidence Guidelines and Grading of Recommendations Assessment, Development and Evaluation (GRADE) recommendations were used to rate the quality of evidence and to make treatment recommendations. **Results:** Twelve articles met our inclusion criteria, which resulted in a total of 315 patients. Six articles pertained to arthroscopic debridement ($n = 249$), 3 to microfracture ($n = 47$), 2 to osteochondral autograft transplantation ($n = 15$), and 1 to autologous chondrocyte implantation ($n = 5$). Whereas most studies reported favorable results, sample heterogeneity and differences in the use of functional and radiographic outcomes precluded a meta-analysis. Several positive and negative prognostic factors were identified. All of the eligible studies were observational, retrospective case series without control groups; the quality of evidence available for the use of the aforementioned procedures is considered "very low" and "any estimate of effect is very uncertain." **Conclusions:** More research is necessary to determine which treatment for chondral pathology in the shoulder provides the best long-term outcomes. We encourage centers to establish the necessary alliances to conduct blinded, randomized clinical trials and prospective, comparative cohort studies necessary to rigorously determine which treatments result in the most optimal outcomes. At this time, high-quality evidence is lacking to make strong recommendations, and decision making in this patient population is performed on a case-by-case basis. **Level of Evidence:** Level IV, systematic review of Level IV studies.

Although much has been written regarding the treatment of chondral lesions in the knee,¹ until recently, glenohumeral articular cartilage lesions have remained a poorly understood and usu-

ally incidentally diagnosed entity.²⁻⁶ However, increased awareness, as well as the widespread use of magnetic resonance imaging⁷⁻¹¹ and arthroscopy, has allowed for a more conscientious and thorough evaluation of the articular surfaces,¹² which in turn has shown that chondral defects in the shoulder are more common than previously recognized. Although the incidence of glenohumeral articular cartilage lesions in the general population is unknown, arthroscopies performed for other indications show an incidence rate of 6% to 17%.^{3,13,14} After an anterior instability event, these lesions are even more common, with an incidence of 23% on the glenoid side and 8% on the humeral side, excluding Hill-Sachs lesions.¹⁵

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Numerous factors may incite a chondral lesion, including trauma, instability, previous surgical intervention with associated chondrolysis, osteonecrosis, rotator cuff arthropathy, septic arthritis, inflammatory arthritis, osteoarthritis, and osteochondritis dissecans. Chondral lesions are generally identified in association with other intra-articular glenohumeral pathology.²⁻⁶ For instance, the presence of a SLAP tear increases the likelihood of identification of a chondral lesion from 4% to 20% on the humeral side and from 5% to 18% on the glenoid side.^{16,17} In young patients the glenohumeral pathology most commonly leading to the discovery of chondral lesion is instability.²⁻⁶ A dislocation event increases the risk of the development of glenohumeral osteoarthritis 10 to 20 times,¹⁸ and the incidence of glenohumeral osteoarthritis is 10% to 20% in patients who have an instability event at mid-term to long-term follow-up.¹⁹

Although the natural history of these chondral lesions is largely unknown, they may progress to glenohumeral osteoarthritis.²⁻⁶ While rare,²⁰ glenohumeral osteoarthritis can have significant effects on a patient's global function, with declines in health-related quality of life on par with diabetes and coronary artery disease.^{21,22}

The factors that lead to progression are largely unknown and possibly different from those within the knee, given that the glenohumeral joint is not a classic weight-bearing joint in the same sense that the lower extremity diarthrodial joints experience load. Shear stresses related to physiologic glenohumeral translation may contribute to progression. In comparison with the knee, the articular cartilage of the humeral head and glenoid fossa is thin, at 1.24 and 1.88 mm thick, respectively, which leaves less margin before exposure of the subchondral bone.²³ It should be noted that this margin is even thinner at the periphery of the humeral head and at the center of the glenoid fossa. Systematic chondral degenerative changes related to age likely also contribute to progression, as do osseous lesions leading to articular incongruity.¹⁹ Finally, chondral defects of the glenohumeral joint are generally very well tolerated and often asymptomatic; thus it is incumbent on the evaluating physician to properly determine and treat other, more common sources of shoulder pain before embarking on cartilage-specific treatment.

Once a symptomatic chondral lesion has been identified, a trial of nonoperative therapy is warranted, including ice, nonsteroidal anti-inflammatory medications, and physical therapy. Therapy with a focus on

strengthening of the periscapular musculature and rotator cuff may be particularly effective to address any concomitant scapular dyskinesis. In overhead throwers stretching can be useful to address any glenohumeral internal rotation deficit that may be contributing to microinstability and may be placing abnormal stress on the articular cartilage and therefore possibly contributing to progression. Intra-articular corticosteroid injections in patients with an inflammatory component to their discomfort may be warranted. Hyaluronic acid injections may also be used, although their use in glenohumeral lesions remains off-label.²⁴ The efficacy of nonoperative treatment protocols in the short-term and long-term with regard to symptomatic management and alteration of natural history remains to be determined.

In patients who have attempted a comprehensive course of nonoperative treatment with residual discomfort, operative treatment can be considered. A variety of operative treatment options exist for chondral lesions in the glenohumeral joint. These options can generally be classified into reparative, restorative, and salvage treatments. Reparative options include microfracture techniques.^{2,25-28} Restorative options include cellular-based techniques such as autologous chondrocyte implantation (ACI),²⁹ osteochondral autograft transplantation (OATS),³⁰ and osteochondral allograft transplantation.³¹ Salvage techniques include debridement techniques with or without capsular release, chondroplasty,^{3,32-37} and subacromial decompression³⁸; biological resurfacing techniques with meniscal allograft, anterior capsule, periosteum, or another biological interposition material³⁹⁻⁴³; and prosthetic resurfacing and arthroplasty techniques. Whereas total shoulder arthroplasty generally provides excellent pain relief and function, the limited lifespan of prosthetic replacements limits application in younger patients, and thus our review is limited to non-arthroplasty techniques.^{44,45}

Given the plethora of treatment options, the treating surgeon who encounters a chondral defect is left without clear guidelines on which option might provide his or her patient with the best outcome. Although several reviews have been written,²⁻⁶ no inclusive, recent systematic reviews exist within the literature to provide the surgeon with evidence-based recommendations for treatment of these lesions. In addition, most of the evidence on the subject has been released within the past 2 years, which may make prior conclusions less pertinent today.

The objectives of this study were (1) to conduct a systematic review of clinical outcomes after cartilage

restorative and reparative procedures in the glenohumeral joint, (2) to identify patient-specific prognostic factors that predict clinical outcome after cartilage surgery of the shoulder, (3) to provide treatment recommendations based on the best currently available evidence, and (4) to highlight gaps in the literature that require future research.

METHODS

Literature Search

We searched Medline (1948 to week 1 of February 2012) and Embase (1980 to week 5 of 2012) using the following key words: (glenohumeral OR shoulder) AND (cartilage OR osteochondral OR arthritis OR degenerative) AND (arthroscop* OR debridement OR osteochondral OR microfracture OR autologous OR implantation). Search terms were broad to encompass all possibilities for applicable studies. All review articles were then manually cross referenced to make certain that no relevant studies were missed.

Inclusion criteria were (1) studies that reported on clinical outcomes after non-arthroplasty treatment for the spectrum of chondral lesions of the glenohumeral joint, including focal and diffuse articular disease on the humerus and/or glenoid; (2) patients 16 years or older; and (3) minimum 6 months' follow-up. We excluded (1) technique articles, (2) case reports, (3) review articles, and (4) articles regarding biological resurfacing of the glenohumeral joint because of a recently published comprehensive systematic review on this topic.⁴⁶ Our preferred techniques for various chondral reparative and restorative procedures in the glenohumeral joint are shown in [Video 1](#) (available at www.arthroscopyjournal.org).

Data Abstraction

The data from each study that met the inclusion criteria were abstracted by 1 reviewer and verified by a physician with advanced training in epidemiology. Study data that were determined to be of interest a priori included the type of treatment, year of publication, study period, type of clinical study, inclusion/exclusion criteria, number of patients enrolled, number of patients available for follow-up, age, minimum follow-up, length of follow-up, proportion of dominant extremities involved, sex, concomitant procedures, number of Workers' Compensation patients, classification of preoperative arthritis, postoperative rehabilitation, and statistical analysis used. Preoperative and postoperative data of interest were range of

motion, patient satisfaction, and clinical outcome scores, and the number of patients in whom treatment ultimately failed (requiring resurfacing or arthroplasty) was also recorded. Functional outcomes that were of interest included the University of California, Los Angeles outcome score⁴⁷; Constant-Murley outcome score⁴⁸; American Shoulder and Elbow Surgeons (ASES) outcome score⁴⁹; Simple Shoulder Test (SST)⁵⁰; visual analog scale (VAS) for pain; and overall patient satisfaction rates. The presence of bias was determined and analyzed for each eligible study. Finally, the level of evidence (Level I to Level IV) of each included study was determined according to the Oxford Level of Evidence Guidelines.⁵¹

Statistical Analysis

Although weighted means and results of combined dichotomous variables were used when applicable, a comparison of weighted means could not be performed with statistical integrity. A majority of these studies reported their results as mean values without standard deviations. In addition, whereas some studies used validated outcome scores, others used subjective personal assessments based on the clinicians' own functional and pain scores. A meta-analysis was unable to be performed.

RESULTS

The results of the search strategy are illustrated in [Figure 1](#). We obtained 774 articles from Medline and 730 articles from Embase, for a total of 1,504 articles. Once duplicate articles were manually removed, 894 unique articles remained from the combined pool of Medline and Embase. Duplicates were confirmed using EndNote bibliographic software (Thomson Reuters, Carlsbad, CA). After we screened these articles by article title relevance, 56 studies were left. We then further screened these articles to remove case reports, technique reports, and reviews by reviewing their abstracts. The full manuscripts of 13 studies were reviewed to ensure that they met our inclusion criteria. One was removed because of a follow-up period of 3 months and a patient age of 13 years.⁴² Two authors then independently reviewed 12 articles that met the inclusion criteria. Of these articles, 6 pertained to arthroscopic debridement for diffuse glenohumeral arthritis, 2 to microfracture, 1 to microfracture plus periosteal flap transfer, 2 to OATS, and 1 to ACI. Within the microfracture studies, associated pathologies included subacromial bursitis, subacromial impingement, biceps tendonitis, SLAP tears, acromioclavicular

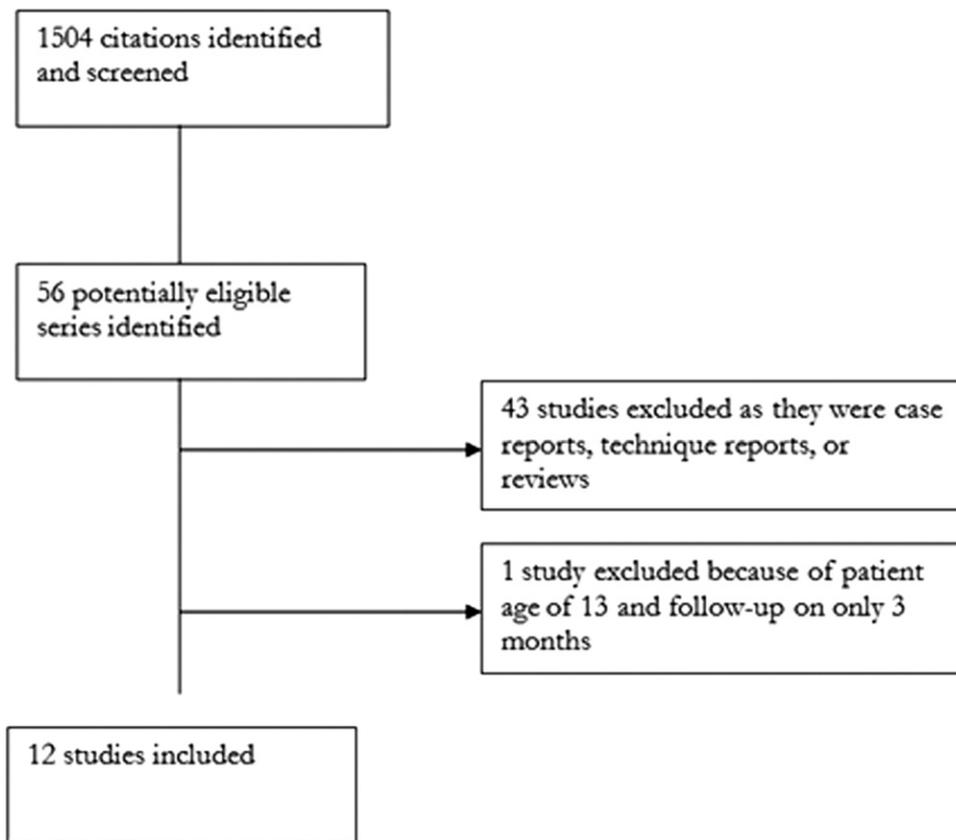


FIGURE 1. The Consolidated Standards of Reporting Trials (CONSORT) flow chart shows the effect of exclusion criteria on the number of included studies. The initial literature searches revealed 56 citations; 12 ultimately were included.

vicular degenerative joint disease, and glenohumeral instability.^{25,26,36}

General Characteristics of Included Studies

The general characteristics of the included studies are highlighted in Table 1. All of the eligible studies were unblinded prospective²⁷ or retrospective^{12,25-27,30,32,33,36,37,52-54} case series without comparative control groups. The level of evidence assigned to each study was Level IV. The patient populations in each subgroup of treatment options are pooled and presented separately in this report where appropriate.

Operative Procedures

Overall, there were 315 shoulders at final follow-up across all 12 included studies. Of the studies, 6 involved arthroscopic debridement ($n = 249$), 2 involved microfracture ($n = 42$), 1 involved microfracture and periosteal flap transfer ($n = 5$), 2 involved OATS ($n = 15$, though 7 of these are the same patients at 2 different times), and 1 involved ACI ($n = 5$).

Demographics

Demographic information from the included studies is highlighted in Table 2. All studies provided data regarding mean patient age and patient sex, with the exception of 1 study.⁵⁴ Only 3 studies provided data regarding involvement of the dominant extremity.^{12,25,32} Concomitant surgeries were reported in all the microfracture patients and all but 1 of the arthroscopic debridement studies³⁷; they were performed rarely in the other studies.^{27,30,52,53} The debridement and microfracture procedures were all performed arthroscopically,^{12,25,26,32,33,36,37,54} whereas patients who underwent OATS, periosteal transfer, and ACI had to undergo an additional open procedure.

Combining data from the arthroscopic debridement studies resulted in a total of 249 patients. Their weighted mean age was 46.8 years (range, 16 to 77 years). Among the studies that reported sex, there were 130 male patients (67%) and 64 female patients (33%). The dominant extremity was involved 60% of the time. Although insufficient data are available in the source studies to specify the

TABLE 1. Characteristics of Included Studies

Author	Technique	Type of Study	Level of Evidence	No. of Shoulders at Final Follow-up	Effective Follow-up (%)	Follow-up Length [Mean (Range)] (mo)	Bias
Cameron et al. ³²	Debridement	RCS	IV	61	87%	34 (12-79)	Selection
Ellman et al. ¹²	Debridement	RCS	IV	10	56%	NA (6-18)	Selection
Kerr and McCarty ³³	Debridement	RCS	IV	20	100%	20 (12-33)	Selection
Ogilvie-Harris and Wiley ⁵⁴	Debridement	RCS	IV	54	100%	36	Selection
Van Thiel et al. ³⁶	Debridement	RCS	IV	71	88%	47 (18-77)	Selection
Weinstein et al. ³⁷	Debridement	RCS	IV	25	100%	34 (12-63)	Selection
Frank et al. ²⁵	Microfracture	RCS	IV	17	88%	28 (12-89)	Selection
Millett et al. ²⁶	Microfracture	RCS	IV	25	100%	34 (12-63)	Selection
Siebold et al. ²⁷	Microfracture + periosteal flap	PCS	IV	5	100%	26 (24-31)	Selection
Scheibel et al. ³⁰	OATS	RCS	IV	8	100%	33 (8-47)	Selection
Kircher et al. ⁵³	OATS	RCS	IV	7	100%	105 (91-117.6)	Selection
Buchmann et al. ⁵²	ACT-Cs	RCS	IV	4	100%	41 (11-71)	Selection

Abbreviations: ACT-Cs, autologous chondrocyte transplantation with collagen membrane seeding; NA, not available; OATS, osteochondral autologous transplantation; PCS, prospective case series; RCS, retrospective case series.

mean lesion size or extent, authors reported on the use of arthroscopic debridement for both mild and severe disease.^{12,32,33,36,37}

Of the studies that reported concomitant procedures, 142 of 223 patients (64%) had other procedures performed at the same time. The most common procedures were subacromial decompression, acromioplasty, capsular release, and biceps tenodesis. The mean follow-up was 30.2 months.

Among the 47 patients who underwent microfracture, the weighted mean age was 42 years (range, 18 to 59 years) and 33 patients (75%) were men. The mean follow-up was 37 months. Only Frank et al.²⁵ listed concomitant procedures, which were performed in 65% of cases and included capsular release (12%), subacromial decompression (47%), biceps tenodesis (24%), distal clavicular resection (6%), and loose body removal (6%). They also reported that the dominant upper extremity was involved in 53% of cases.

Data from the OATS studies cannot be pooled because they represent the same patients at 2 different periods, and therefore only their functional outcomes are able to be studied. In addition, weighted mean ages and other pooled data cannot be collected from the ACI and microfracture/periosteal flap transfer studies because they each have 1 representative study that fits the inclusion criteria.

Wear Characteristics

Each study had its own inclusion criteria regarding which patients were deemed to need an operation. More of the recent studies used the Outerbridge clas-

sification.⁵⁵ Kerr and McCarty³³ looked at the functional and pain differences in patients with Outerbridge stage II/III versus stage IV, as well as unipolar versus bipolar lesions. Cameron et al.³² compared the differences between lesions greater than or less than 2 cm², as well as location of each lesion. Although Ogilvie-Harris and Wiley⁵⁴ did not overtly use the Outerbridge classification, their descriptions of mild and severe arthritis are comparable to Outerbridge stage II/III and stage IV, respectively. Weinstein et al.³⁷ only reported on patients with Outerbridge stage II or III lesions. The remaining studies had inclusion criteria requiring a full-thickness cartilage lesion on the humeral head, glenoid, or both sides. Only 2 studies looked at patients with a minimum size requirement for cartilage lesions (>100 mm²).^{30,53}

Functional Scores and Outcome Measures

Outcome data is reported in Table 3. Of the 6 arthroscopic debridement articles, 4 reported on their own subjective outcome measures in terms of function, pain, and satisfactory result.^{12,32,37,54} The remaining studies used a validated outcome measure.^{25,27,30,33,34,36,52,53} These outcome measures included the Western Ontario Osteoarthritis Score (WOOS) score, Marx Activity Level, Constant score, ASES score, Single Assessment Numeric Evaluation (SANE) score, SST score, Short Form 12 score, VAS score, and University of California, Los Angeles score.^{32,36} Kerr and McCarty³³ reported that the mean WOOS, ASES score, and SANE score were 0.64

TABLE 2. Patient Demographics

Author	Age [Mean (Range)] (yr)	Male Sex (n [%])	Dominant Extremity (n [%])	Concomitant Procedures (n [%])	Open v Arthroscopic	Postoperative Rehabilitation
Arthroscopic debridement						
Cameron et al. ³²	50 (21-73)	41 (67%)	29 (48%)	29 (48%)	Arthroscopic	Sling, PROM on first day, AROM when pain allowed (except SLAP repair, for which no AROM was allowed for 6 wk)
Ellman et al. ¹²	NA	11 (61%)	8 (44%)	15 (83%)	Arthroscopic	
Kerr and McCarty ³³	38 (20-54)	12 (63%)	NA	16 (84%)	Arthroscopic	
Ogilvie-Harris and Wiley ⁵⁴	NA	NA	NA	27 (50%)	Arthroscopic	Sling, PROM on first day, AROM as tolerated; return to activities within 4-6 wk
Van Thiel et al. ³⁶	47 (18-77)	47 (66%)	NA	55 (78%)	Arthroscopic	
Weinstein et al. ³⁷	46 (27-42)	19 (76%)	NA	NA	Arthroscopic	
Microfracture						
Frank et al. ²⁵	37 (18-55)	7 (54%)	9 (52.9%)	11 (65%)	Arthroscopic	Sling at 2-4 wk, PROM immediately, unrestricted strength at 12 wk, unrestricted activity at 16 wk, overhead activity at 6 mo
Millett et al. ²⁶	43 (19-59)	25 (83%)	NA	25 (100%)	Arthroscopic	Sling at 48 h, abduction pillow at 3 wk, PROM on third day, AROM at 4-6 wk and then unrestricted activity
Microfracture and periosteal flap						
Siebold et al. ²⁷	32 (16-56)	3 (60%)	NA	0	Arthroscopic and open	
OATS						
Scheibel et al. ³⁰	43 (23-57)	6 (75%)	NA	0	Arthroscopic and open	Sling, abduction pillow at 3 wk, PROM on postoperative day 3, no ER until 6 wk, AROM and strengthening at 4-6 wk
Kircher et al. ⁵³	NA	6 (86%)	NA	0	Arthroscopic and open	Sling, abduction pillow at 3 wk, PROM on postoperative day 3, no ER until 6 wk, AROM and strengthening at 4-6 wk
ACI						
Buchmann et al. ⁵²	29 (21-36)	4 (100%)	NA	0	Arthroscopic and open	

Abbreviations: AROM, active range of motion; ER, external rotation; NA, not available; PROM, passive range of motion.

(range, 0.12 to 0.98), 12.6 (range, 9.0 to 18.0), and 71%, respectively. Cameron et al.³² showed pain relief in 88% of their patients with the mean time to pain relief being 5 weeks after surgery. The mean duration of pain relief was 28 months. Functional scores also significantly improved from a preoperative level. Eighty-seven percent of the total number of patients also noted improvement in

their shoulders after surgery. In patients with mildly arthritic shoulders, Ogilvie-Harris and Wiley⁵⁴ showed that 66% had satisfactory outcomes. With regard to ASES and SST scores, Van Thiel et al.³⁶ reported a significant increase in preoperative values as well as a significantly lower VAS score. Weinstein et al.³⁷ showed excellent or good results in 80% of patients.

TABLE 3. Outcomes After Various Treatment Modalities for Cartilage Lesions

Author	First Outcomes Measure	Preoperative Value	Postoperative Value	Second Outcome Measure	Preoperative Value	Postoperative Value	Preoperative VAS Score*	Postoperative VAS Score	Satisfaction	Resurfacing/Arthroplasty [n (%)]
Arthroscopic debridement										
Cameron et al. ³²	Self-assessment (functional)	24 ± 2†	39 ± 2†	Improvement		87% noted improvement	5 (at rest)	2 (at rest)	6/10	6 (10%)
Ellman et al. ¹²	Satisfaction	NA	NA	NA	NA	NA	NA	NA	9 (90%)	0
Kerr and McCarty ³³	WOOS	NA	0.63 (range, 0.12-0.98)	ASES		75 (range, 24-100)	NA	NA	NA	3 (15%)
Ogilvie-Harris and Wiley ⁵⁴	NA	NA	NA	NA	NA	NA	NA	NA	Good results in 66% (mild) and 33% (severe)	NA
Van Thiel et al. ³⁶	ASES	52 (range, 8-85)	73 (range, 10-100)	SST	6.1 (range, 0-12)	9 (range, 3-12)	5 (range, 1-9)	3 (range, 0-9)	NA	16 (22%)
Weinstein et al. ³⁷	Pain relief		76%	Good/excellent		80%	NA	NA	92%	1 (4%)
Microfracture										
Frank et al. ²⁵	ASES	44 ± 15	86 ± 11	SST	5.7 ± 2.1	10 ± 1	6 ± 2	2 ± 1	NA	2 (14%)
Millett et al. ²⁶	ASES	60 (range, 20-80)	80 (range, 45-100)	Painless use of arm above neck	22%	55%	4 (range, 0-7)	2 (range, 0-5)	9.5/10	3 (10%)
Microfracture and periosteal flap										
Siebold et al. ²⁷	Constant	43	82	NA	NA	NA	NA	NA	NA	0
OATS										
Scheibel et al. ³⁰	Constant	74 (range, 57-90)	89 (range, 82-95)	Good/excellent		88%			7 (88%)	0
Kircher et al. ⁵³	Constant	76 (range, 66-90)	91 (range, 80-97)	Good/excellent		100%			7 (100%)	0
ACI										
Buchmann et al. ⁵²	Constant		83	ASES		95		0.25 (range, 0-1)	100%	0

Abbreviations: NA, not available; UCLA, University of California, Los Angeles.

*VAS from 0 to 10, with 0 being no pain and 10 being severe pain.

†Subjective functional scale out of 60 points.

Microfracture has also been shown to be an effective surgical treatment for isolated full-thickness cartilage defects. Patients undergoing microfracture had overwhelmingly positive outcomes.^{25,26} Frank et al.²⁵ reported a significant decrease in VAS score after surgery (from 5.6 ± 1.7 to 1.9 ± 1.4). The SST score improved from 5.7 ± 2.1 to 10.3 ± 1.3 , with 93% of patients stating that they would have had the surgery again. Similar results were reported by Millett et al.²⁶ Their patients had significant reductions in pain with improvements in ASES scores (from 60 to 80). Of those patients who participated in sports, all reported that their ability to compete improved significantly. Siebold et al.²⁷ reported functional and pain improvements in patients treated with microfracture and periosteal flap. The Constant score significantly improved over the preoperative level (from 43.4% to 81.8%). Pain was also reduced significantly to 18.6 points.

All patients who underwent an OATS procedure were satisfied with the results at 9 years' follow-up.⁵³ The mean Constant score improved from 76 preoperatively to 90 postoperatively. This score reflects improvements in both pain and function. After ACI, 3 of 4 patients were satisfied with the results, although all had good to excellent outcomes as reflected by the Constant score.⁵²

Constant scores (unadjusted for age and sex) were reviewed only in the patients who underwent microfracture and periosteal flap, OATS, and ACI procedures.^{27,30,52,53} Whereas the weighted mean preoperative Constant scores in those groups were dissimilar, their postoperative Constant scores were similar. Statistical significance could not be determined based on the data presented in the articles because of the lack of distribution characteristics. The weighted mean preoperative Constant score for the microfracture and periosteal flap, OATS, and ACI procedures was 67. The weighted mean postoperative Constant score was 87.

Unfortunately, given the wide array of shoulder outcomes measured, as well as the heterogeneous patient populations across included studies, outcomes could not be pooled in a statistically reliable manner.

Prognostic Factors

Among the patients undergoing arthroscopic debridement, all studies found no correlation between age and sex with functional or pain outcomes (Table 4). Kerr and McCarty³³ noted that among patients treated with debridement, unipolar lesions statistically

TABLE 4. Prognostic Factors

Author	Prognostic Factors		
	Positive	Negative	Null*
Arthroscopic debridement			
Cameron et al. ³²	Lesions <2 cm	Lesions >2 cm	Preoperative pain and lesion size, radiographic grade of joint, bipolar lesions
Ellman et al. ¹²	NA	NA	
Kerr and McCarty ³³	Unipolar lesions	Bipolar lesions	Size of lesion
Ogilvie-Harris and Wiley ⁵⁴	Mild arthritis		
Van Thiel et al. ³⁶	NA	NA	Arthroscopic or radiographic grade
Weinstein et al. ³⁷	NA	NA	Arthroscopic or radiographic grade
Microfracture			
Frank et al. ²⁵	Patients who had both physical and surveys	NA	Lesion size, arthritic grade
Millett et al. ²⁶	Isolated lesions of humerus	Prior surgery, size of lesion	
Microfracture and periosteal flap			
Siebold et al. ²⁷	NA	NA	NA
OATS			
Scheibel et al. ³⁰	NA	NA	NA
Kircher et al. ⁵³	NA	NA	NA
Buchmann et al. ⁵²	NA	NA	NA

Abbreviation: NA, not available.

*Includes age and sex.

fared better than bipolar lesions with respect to SANE score, Marx Activity Level, WOOS, and ASES score.³³ This study found that regardless of the size of the osteochondral lesion, each patient had similar improvements in all their outcome measures. On the other hand, lesions greater than 2 cm² were reported by Cameron et al.³² to be a negative prognostic factor with regard to time with pain relief and failure after debridement. Cameron et al. did not find any correlation between preoperative pain and the size of the lesion or radiographic appearance of the glenohumeral joint. Although lesions that were bipolar tended to have worse outcomes, there was no statistical significance. Ogilvie-Harris and Wiley⁵⁴ reported that patients who had “mild” arthritis had a 66% chance of having a satisfactory outcome after debridement, although they did not report whether this was statistically significant. Both Weinstein et al.³⁷ and Van Thiel et al.³⁶ reported that there was no correlation between arthritic grade, radiographically or arthroscopically, and outcomes. Van Thiel et al. did note that all 16 patients who eventually underwent arthroplasty had grade 4 articular changes, with the majority having bipolar lesions.

In patients who underwent microfracture, outcomes were not affected by either their sex or their age. Frank et al.²⁵ saw improvements in patients with all different sizes and locations of lesions; they did not compare groups of different locations or sizes. They did note, however, that less pain was reported in patients who underwent physical examination and surveys at follow-up compared with the survey group alone. Millett et al.²⁶ found that patients with isolated osteochondral defects of the humerus had better outcomes. Prior surgery was considered a negative prognostic indicator. Although there was a negative correlation between the size of lesions and ASES score, the results were not significant. However, pain scores showed a statistically significant correlation with lesion size, with larger lesions faring worse.

No prognostic factors could be garnered from microfracture and flap, OATS, or ACI studies because the number treated was too small to perform an adequately powered statistical analysis.

Failure Rate

A treatment failure in this systematic review was defined as a patient who needed to undergo resurfacing (biological or with hardware) or arthroplasty. Failure rates in the arthroscopic debridement studies were generally well reported. Of note, some studies such as

that of Van Thiel et al.³⁶ excluded patients who underwent arthroplasty from their outcome scores and statistical analysis. Of the studies examining debridement that reported failure rates,^{32,33,36} there were 26 reported failures (15%). The patients who underwent microfracture had a failure rate of 11% (n = 5 failures). The other treatment modalities had a limited number treated and did not report any failures.

Of the patients in whom arthroscopic debridement eventually failed, the mean time to arthroplasty, resurfacing, or allograft transplantation was 14 months. The mean time to arthroplasty in the microfracture group was 28 months.

DISCUSSION

Assigning Level of Evidence and Providing Evidence-Based Treatment Recommendations

The guidelines put forth by the Grading of Recommendations Assessment, Development and Evaluation (GRADE) Working Group⁵¹ were used to determine the quality of available evidence and strength of recommendation for the cartilage therapies of interest in this review (Table 5). On the basis of this system, the best study design available for all interventions was observational case series without comparative control groups. Although several studies reported important and validated outcomes (SST scores, Constant-Murley scores, ASES scores, and so on), several other studies reported nonvalidated, subjective, and study-specific outcome assessment tools (e.g., excellent, good, fair, and poor outcomes). There are serious limitations in study quality, mostly related to retrospective design, short follow-up, sample heterogeneity, and limited cohort sizes. There are important inconsistencies in the prognostic factors identified among studies, specifically with respect to whether lesion size and grade of arthritis affect the ability of debridement or microfracture to provide symptomatic benefit for focal and diffuse chondral lesions, respectively. There is also some uncertainty about the internal validity of the studies, mostly because of the inclusion of concomitant procedures and the use of nonvalidated outcome measures by some authors. Data are both imprecise and sparse, and the probability of reporting bias is high. Therefore the quality of evidence available for the use of debridement, microfracture, osteochondral autogenous transplantation, and ACI in the treatment of glenohumeral chondral lesions is considered “very low” using the GRADE system. Using the GRADE system, these determinations suggest that “any esti-

TABLE 5. Recommendations for Each Possible Surgical Intervention for Treatment of Glenohumeral Articular Cartilage Lesions Graded Based on Level of Evidence Available

Recommendations	Quality Assessment				Summary of Findings			
	Design	Quality	Consistency	Directness	Other Modifying Factors	No. of Patients	Effect	Quality ^{5,1}
Arthroscopic debridement	Observational case series without comparative control groups	Serious limitations	Some important inconsistencies	Some uncertainty about directness	None	249	Not applicable; meta-analysis not appropriate	Very low
Microfracture						47		Very low
Autogenous chondrocyte implantation/cellular-based techniques						5		Very low
Osteoarticular autograft transplantation						8		Very low

mate of effect is very uncertain”⁵¹; that is, our understanding of the proper surgical treatment of these lesions will likely be considerably altered by higher-quality studies. In addition, because of the lack of a high quality of evidence, the balance of benefit and harm, as well as the societal balance of net benefits and net costs, cannot be determined.

Summary of Results

Despite significant limitations in study design, most studies included showed overall good results. When defined as need for subsequent biological resurfacing or prosthetic arthroplasty, failure rates were low, at 15% for debridement (diffuse lesions) and 11% for microfracture (focal lesions) at a mean of 14 and 28 months, respectively. It is possible that with longer follow-up, these rates might be increased. Although statistical significance could not be determined, when debridement, microfracture, and OATS outcomes were combined, weighted mean Constant scores for studies that used this outcome measure improved from 67 preoperatively to 87 at final follow-up. Because the minimum clinically important difference in Constant score with respect to glenohumeral chondral lesions has not yet been determined, the clinical importance of this finding is uncertain. In addition, satisfaction rates were high with all procedures (66% to 100%).^{12,26,30,37,52-54} However, high satisfaction rates do not imply that all of these procedures perform equally well. There is considerable selection bias for a specific procedure chosen to manage a symptomatic cartilage defect based on published suggested guidelines and algorithms.²

Several studies reported prognostic factors that could be used to counsel patients preoperatively (Table 4). Positive prognostic factors include lesion size less than 2 cm²,^{26,32} unipolar lesions,³³ less advanced lesions,⁵⁴ and isolated lesions of the humerus.²⁶ Negative prognostic factors include lesions larger than 2 cm in size,^{26,32} bipolar lesions,³³ and prior surgical intervention.²⁶ However, several other studies were unable to show any correlation with either the arthroscopic or radiographic grade of cartilage degeneration, suggesting that patients with advanced disease may also be well served with arthroscopic debridement.^{25,32,36,37} Similarly, other studies were also unable to show any connection between lesion size and prognosis of improvement with surgical intervention.^{25,33}

Past reviews have suggested algorithms to guide the operative treatment of glenohumeral articular cartilage lesions.^{2,3,5} These algorithms have suggested that fac-

tors to guide treatment should include (1) whether the lesion was encountered incidentally, in which case only arthroscopic debridement should be considered^{2,5}; (2) whether the lesion is bipolar, in which case biological resurfacing should be considered^{2,5}; (3) whether the lesion involves bone loss, in which case an osteoarticular graft or resurfacing prosthesis should be considered^{3,5}; (4) whether the lesion is small, in which case microfracture and osteoarticular autograft transplantation could be considered^{2,3,5}; and (5) whether the lesion is large, in which case ACI or osteoarticular allograft transplantation could be considered.^{2,3,5} Reviewing the literature in a systematic fashion allows us to evaluate these 5 principles of treatment. Overall, the evidence does suggest that bipolar lesions (second principle) and larger lesions (fifth principle) may be more likely to fail with microfracture and debridement and thus more alternatives should be considered; however, no evidence exists to suggest that the alternatives that previous reviews have proposed (ACI and osteoarticular allograft transplantation) have better outcomes for these lesions.^{2,3,5} Further research will be needed to evaluate these principles and to delineate refined treatment recommendations.

A number of limitations exist with our study. (1) The quality of our recommendations and the quality of our conclusions are limited by the quality of the original data from which these recommendations are drawn. No randomized clinical trials or prospective/retrospective cohort studies with comparative controls have been conducted to date to evaluate any of the surgical techniques used in the treatment of glenohumeral chondral defects. The highest-quality evidence produced to date is Level IV, and thus our conclusions are subject to considerable bias and the interpretation of our results is necessarily limited. (2) Our exclusion criteria may have eliminated evidence that could have altered our conclusions, in particular, limitation to studies in the English language may bias toward research performed in the United States and Europe to the exclusion of research performed in the rest of the world. (3) Our study design compares retrospective case series performed by different authors. Significant heterogeneity exists within these studies, with respect to preoperative evaluation, operative protocol, postoperative rehabilitation, and so on. The diversity among the studies from which our data are drawn limits our ability to aggregate their results into meaningful conclusions. (4) Only published data are included in this trial, and thus our conclusions must be interpreted in light of the publication bias. In clinical practice these

procedures may be less efficacious than it would appear in this review because less successful results might be less likely to be published.

Future Directions

A randomized clinical trial could more adequately determine treatment superiority of 1 technique over another. However, given the overall rarity of these procedures even in high-volume referral centers, such a trial may never be conducted without collaboration among centers. Alternatively, it may be feasible to perform multicenter studies with comparative control groups that are conducted in a prospective manner such that pertinent baseline variables are concomitantly documented and followed. We encourage high-volume centers to establish the necessary alliances to conduct the randomized clinical trials and prospective, comparative cohort studies necessary to rigorously determine whether debridement, microfracture, cellular-based techniques, OATS, osteochondral allograft transplantation, or prosthetic resurfacing provides patients with articular cartilage lesions of the glenohumeral joint with the optimal outcome. Each of these techniques may have a role depending on patient characteristics, such as age, lesion location, associated bone loss, and lesion size, and thus stratification and subgroup analysis may be important aspects of these trials.

CONCLUSIONS

A variety of options exist for the treatment of articular cartilage defects of the glenohumeral joint. For diffuse Outerbridge stage II and III lesions, arthroscopic debridement and chondroplasty reliably provide good outcomes, although the degree of pain relief and functional return may be incomplete and relatively short-lived. More research is necessary to determine which restorative technique—microfracture, cellular-based techniques, OATS, or osteochondral allograft transplantation—provides the best long-term function for focal chondral lesions. High-quality evidence is lacking to make strong recommendations.

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