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REVIEW ARTICLES

Glenoid bone grafting in primary reverse total shoulder arthroplasty: a systematic review

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Background: Reverse total shoulder arthroplasty (RSA) with glenoid bone grafting has become a common option for management of glenoid bone loss associated with glenohumeral osteoarthritis. The objectives of this review were to determine (1) the rate of graft union, (2) the revision and complication rates, and (3) functional outcomes following primary RSA with glenoid bone grafting.
Methods: A comprehensive search of the MEDLINE, Embase, and CINAHL (Cumulative Index to Nursing and Allied Health Literature) databases was completed for studies reporting clinical outcomes following primary RSA with glenoid bone grafting. Pooled and frequency-weighted means were calculated where applicable.
Results: Overall, 11 studies and 393 patients were included in the study. The mean patient age was 73 ± 2.2 years, and the mean follow-up period was 34 ± 10 months. The overall graft union rate was 95%, but the rate was 97% among cases using autograft bone (8 studies, n = 254). When stratified by technique, concentric bone grafts had a 100% union rate (4 studies, n = 139). Conversely, eccentric grafts had an overall union rate of 92% (7 studies, n = 240), which improved to 94% when using autograft bone (4 studies, n = 115). At final follow-up, the revision rate was 2%, the complication rate was 18%, and there was consistent improvement in range of motion and functional outcome scores.
Conclusion: Glenoid bone grafting during primary RSA results in excellent early-term clinical outcomes, low complication and revision rates, and high rates of graft union.
Level of evidence: Level IV; Systematic Review

Keywords: Reverse; shoulder; arthroplasty; RTSA; RSA; bone graft; glenoid

When reverse total shoulder arthroplasty (RSA) is being performed, the management of glenoid bone loss and deformity represents a significant reconstructive challenge for surgeons. Inadequate glenoid reconstruction raises several potential issues including component instability, mechanical impingement and scapular notching, poor soft-tissue tensioning, and limited options for revision procedures.

Given these limitations, several surgical options have been suggested for reconstruction, including eccentric reaming, glenoid bone grafting, and augmented glenoid

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components. Primary glenoid bone grafting has become more common, especially following the advent of the bony increased-offset reversed shoulder arthroplasty (BIO-RSA) technique described by Boileau et al.[3] With increasingly complex deformities, the need for glenoid reconstruction is essential and bone grafting becomes a central consideration.

Despite the increasing utilization of glenoid bone grafting, our understanding of the rates of graft union, complications, and outcomes is limited. To date, several techniques and results have been published with early-term outcomes.[1,3-5,10,12-14,16,19,20] The objectives of this systematic review were to determine (1) the overall rate of bone graft union; (2) the rate of union stratified by graft type and technique; (3) the revision and complication rates; and (4) functional outcomes, including range of motion (ROM) and functional outcome scores, following primary RSA with glenoid bone grafting. Our hypothesis was that bone grafting in primary RSA would result in a high rate of union, low complication and revision rates, and acceptable functional outcomes.

Methods

This systematic review was performed following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines (Supplementary Figure S1).[15]

Search strategy

A comprehensive search of MEDLINE, Embase, and CINAHL (Cumulative Index to Nursing and Allied Health Literature) was performed from database inception to September 9, 2018, for articles addressing RSA with bone graft. Search terms included reverse total shoulder arthroplasty, reverse shoulder, reverse shoulder arthroplasty, reverse arthroplasty, shoulder arthroplasty, and bone grafting. Medical Subject Headings (MeSH) and Emtree terms were used in various combinations and supplemented with free text to increase search sensitivity. The search strategy was adopted for CINAHL. A review of conference abstracts from recent major annual orthopedic conferences and reference lists of articles that fulfilled the eligibility criteria was also performed. The search strategy is provided in Supplementary Figure S2.

Assessment of study eligibility

The inclusion and exclusion criteria for this study were determined a priori. The criteria for inclusion were as follows: RSA performed with at least 1 study arm consisting of primary cases with bone graft, studies with at least 10 patients, minimum 12 months' follow-up, English-language studies, adult patients aged 18 years or older, and human studies. The exclusion criteria included systematic reviews, animal or cadaveric models, studies that did not report outcomes, and studies in which primary bone grafting could not be isolated from other techniques or indications.

Study screening

Systematic article screening and data abstraction were performed independently by 2 authors (R.A.P. and T.L.). Throughout the screening stages, any articles with discordance between reviewers were included to ensure that no relevant articles were omitted. The reviewers discussed any persistent disagreements at the full-text stage, and consensus was reached regarding each article's eligibility. The reference lists of included studies were screened for additional relevant articles. A methodologic quality assessment was performed for each study using the MINORS (Methodological Index for Non-Randomized Studies) scale[18] or the Detsky quality assessment scale.[8]

Outcomes

The primary outcome of interest was the rate of bone graft union. Secondarily, we analyzed complications and revisions, scapular notching, and functional outcomes (ROM and functional outcome scores). Complications were divided into major and minor categories. Major complications included any component failure or significant evidence of loosening (eg, migration or complete lucent lines), fractures, dislocations, infections, neurologic injury, or pulmonary embolism. Minor complications included heterotopic ossification, traction spurs, bone resorption or fragmentation without loosening, and persistent pain.

Statistical analysis

Outcome measures were pooled, and frequency-weighted means and standard deviations were calculated where applicable. The frequency-weighted mean represents the mean from each individual study weighted by the number of patients in that study.

Results

Search

The original search yielded 615 results after duplicates were removed. Following title and abstract screening, 28 studies progressed to full-text review. A total of 18 studies were removed after full-text review, leaving 10 studies[3-5,10,12-14,16,19,20] (Fig. 1). One additional article was retrieved through a manual reference search of included studies,[1] yielding a total of 11 studies for final analysis.

Study characteristics and demographic characteristics

Overall, 11 articles assessing RSA with primary bone grafting were included, of which 6 were retrospective case series (level IV). Comparative studies included 4 retrospective cohort studies (level III) and 1 randomized controlled trial (level I) comparing lateralizing bone graft with standard techniques (Table I).

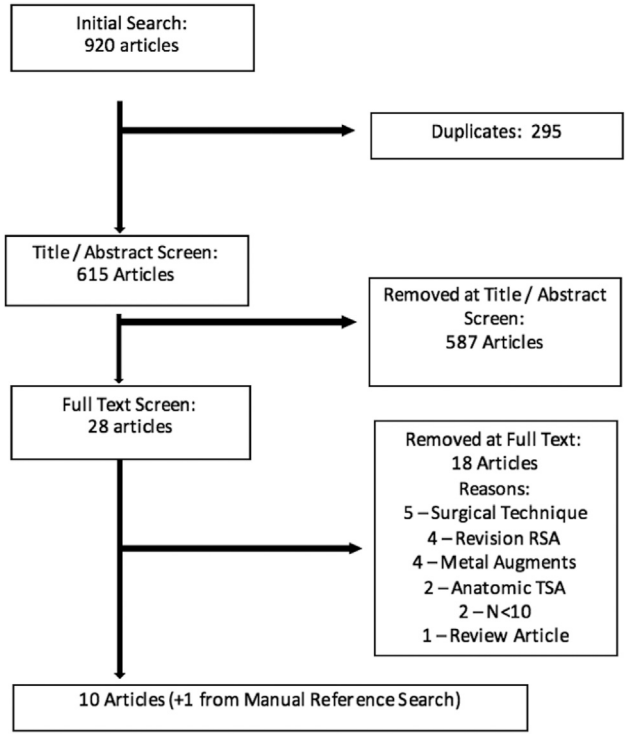

Figure 1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) flow diagram. *RSA*, reverse total shoulder arthroplasty; *TSA*, total shoulder arthroplasty.

The mean sample size of the included studies was 36 ± 17 patients, with a pooled total of 393 cases of primary RSA with bone grafting. The mean age of included patients was 73 ± 2.2 years, and 70% were women. The mean follow-up period was 34 ± 10 months. Four studies (n = 139) addressed only concentric grafts with minimal glenoid bone loss, whereas 7 studies (n = 254) addressed only eccentric grafts with varying degrees of advanced bony deficiency.

Among the 7 noncomparative studies, the mean MINORS score was 10.43 (range, 9-14) out of a maximum of 16. Among the 3 comparative studies, the mean MINORS score was 17.6 (range, 14-20) out of a maximum of 24. For the randomized controlled trial, the Detsky score was 15 out of a maximum of 21 (Supplementary Figure S3).

Union

Graft incorporation was assessed radiographically in each study. This was most commonly performed using plain radiographs; however, 4 studies additionally used computed tomography (CT).[3,4,13,20] Graft incorporation was considered complete when there was radiographic evidence of union; no complete radiolucent lines at the interfaces between the baseplate, bone graft, and/or glenoid; and no evidence of component loosening at final follow-up. Two studies described a total of 5 patients with partial incorporation and good outcomes at final follow-up.[1,4] These patients were considered to have union for the purposes of this review. Glenoid fixation was achieved with a central post and multiple peripheral screws in all studies that described their technique. The number of screws was not standardized, and no study specifically assessed the use of a central threaded screw.

In total, 379 patients underwent postoperative radiographic assessment. This involved radiographs alone in 7 studies (n = 246) and radiographs plus CT in 4 studies (n = 133). Evidence of graft incorporation was found in 360 patients, yielding a pooled mean union rate of 95% (Fig. 2). When studies that used autograft bone exclusively were examined, this increased to 97% (8 studies, n = 254). Four studies described the results of only concentric bone grafts; the union rate was 100% (n = 139), which included 5 partially incorporated grafts that did not require revision.[1,3,5,13] Seven studies described the results of eccentric bone grafts, showing a pooled union rate of 92% (n = 240).[4,10,12,14,16,19,20] When studies that included allograft were excluded, eccentric bone grafts using autograft only resulted in a pooled union rate of 95% (4 studies, n = 115). The pooled union rate in studies using CT plus radiographs was 96%, whereas the union rate in studies using radiographs alone was 94%. Overall, the union rate did not vary significantly when 155° implants (97%, n = 214) were compared with 135° implants (98%, n = 57).

Revisions

In total, 7 patients required component revision, yielding an overall pooled mean revision rate of 2%. No revisions were observed with concentric grafts (4 studies, n = 139), whereas 7 revisions (3%) were observed with eccentric grafts (7 studies, n = 254) (Table II). There were 5 glenoid revisions: 2 subsequent to patient falls, 2 glenoid failures due to technical errors (uncorrected humeral inclination and inadequate central post length), and 1 case of idiopathic component loosening with screw breakage. There were 3 humeral revisions from a single study[16]: 2 cases of idiopathic humeral component loosening and 1 periprosthetic fracture requiring fixation. All of the glenoid failures occurred with the use of a medialized implant (150° or 155°), with an incidence of 2% (n = 228); on the other hand, the humeral failures came from the only study exclusively using a lateralized 135° implant, with an incidence of 4% (n = 57).

Complications

A total of 6 intraoperative complications occurred (4 humeral fractures and 2 glenoid fractures). The overall rate of intraoperative fractures was approximately 2%.

Postoperative complications (excluding notching) were divided into major and minor complication categories. Major complications included 9 glenoid component issues comprising failure, migration, or significant radiographic evidence of loosening including complete lucent lines. In

Table I Summary of studies

Study	Study design	Patients, n	Mean age, yr	Mean FU, mo	Allograft, %	Union rate, %	Revisions, n	Notching, %	Complications, n	Autograft source	Allograft source
Eccentric bone grafts											
Werner et al,[20] 2014	Retrospective case series	21	71	60	—	91	2	29	7	Humeral head	—
Jones et al,[14] 2015	Retrospective cohort	41	71.2	34	12	93	—	19	4	Humeral head	Femoral head
Garofalo et al,[12] 2016	Retrospective case series	26	68.5	32	—	100	—	0	3	Humeral head	—
Boileau et al,[4] 2017	Retrospective case series	54	73	36	—	94	2	24	5	Humeral head	—
Ernstbrunner et al,[10] 2017	Retrospective case series	41	73.5	34	5	76	—	29	7	Humeral head/iliac crest (1)	Femoral head/ cancellous
Lorenzetti et al,[16] 2017	Retrospective case series	57	73	46	9	98	2	7	9	Humeral head	Femoral head
Tashjian et al,[19] 2018	Retrospective case series	14	75	31	—	93	1	69	4	Humeral head	—
Concentric bone grafts											
Boileau et al,[3] 2011	Prospective cohort	42	72	28	—	100	—	19	1	Humeral head	—
Athwal et al,[1] 2015	Retrospective cohort	20	76	31	—	100	—	40	0	Humeral head	—
Greiner et al,[13] 2015	Randomized controlled trial	16	75.4	22	—	100	—	—	2	Humeral head	—
Collin et al,[5] 2018	Retrospective cohort	61	74.4	24	—	100	—	11	10	Humeral head	—
Total		393	73	34	3	95	7 (2%)	20	52 (13%)		

MINORS, Methodological Index for Non-Randomized Studies; *FU*, follow-up.

addition, 3 cases of humeral component loosening or failure, 3 infections, 3 dislocations, 1 periprosthetic humeral fracture, 10 acromial or scapular fractures, 1 neurologic injury, and 1 pulmonary embolism were all considered major complications. Minor complications included 9 cases of heterotopic ossification, 26 traction spurs, 2 cases of proximal humeral bone resorption or fragmentation without loosening, and 1 case of persistent pain.

The overall pooled mean complication rate was 18%. Of these, 8% were considered major complications and 10% were considered minor complications (Table II). The overall complication rate was similar when 155° implants (19%, n = 214) were compared with 135° implants (16%, n = 57).

Scapular notching

Scapular notching was assessed in 10 of 11 studies, with the presence or absence reported in each. When specified, notching was graded according to the Sirveaux classification.[17] One study described patients with notching of the scapula and/or the bone graft, both of which were included as cases.[5]

In total, 362 patients were assessed for notching. Scapular notching was reported in 72 patients, yielding a pooled mean rate of 20%. There was little difference between techniques, with notching rates of 19% for concentric grafts and 21% for eccentric grafts.

The rate of notching in each study ranged from 0% to 69%. The highest rate was found by Tashjian et al,[19] in 9 of 13 patients; however, 7 of these patients demonstrated grade 1 notching, with only 2 patients classified as showing grade 3 or 4. When the classification was reported by specific grade or by low vs. high grade (≤2 vs. >2), notching was found to be grade 2 or less in 51 of 55 patients (93%).

On the basis of the implants used, the humeral inclination angle was 155° in 65% of cases, whereas inclination angles of 145° and 135° were less common (20% and 15%, respectively). Three studies used multiple implants with varying humeral angles; however, the results were not stratified by implant type. Of the remaining studies, 6 used implants with a 155° inclination (n = 214), showing a pooled mean notching rate of 25%; 1 used an implant with a 145° inclination (n = 41), showing a notching rate of 19%; and 1 used an implant with a 135° inclination (n = 57), showing a notching rate of 7%. The

influence of other specific technical factors on notching (eg, graft size, implant size, degree of lateralization, and component positioning) was unable to be assessed because these were often unstated or varied based on each patient's pathology.

Range of motion

Preoperative and postoperative forward elevation and external rotation were specifically assessed in 7 studies in a total of 276 patients (Fig. 3). Assessment of external rotation was performed in adduction in 4 studies and was unspecified in 3. The frequency-weighted mean forward elevation significantly increased from 77.5° (range, 35°-86°) preoperatively to 141.1° (range, 125°-148°) postoperatively. The frequency-weighted mean external rotation modestly increased from 14.2° (range, 2.4°-29.4°) preoperatively to 27.3° (range, 8.4°-53.7°) postoperatively. Two studies (n = 26 and n = 20) reported only postoperative values. Their results demonstrated average postoperative forward elevation of 135° and 140°, respectively, with external rotation of 30° and 23°, respectively.

Preoperative and postoperative abduction was assessed in 4 studies in a total of 146 patients (Fig. 3). The frequency-weighted mean abduction significantly increased from 57.9° (range, 25°-67°) preoperatively to 121.0° (range, 102°-149°) postoperatively. One study (n = 26) reported only postoperative values and found a similar average result of 129.3° (range, 105°-149°).

Internal rotation was assessed specifically in 6 studies and via a Constant score subscale in another. The average value increased postoperatively in all studies but was graded differently in each, preventing direct comparison or pooling of results.

Functional and patient-reported outcomes

Preoperative and postoperative Constant scores were evaluated in 6 studies in a total of 221 patients (Fig. 4, Table III). The frequency-weighted mean score was 27.0 (range, 5.7-31) preoperatively and increased to 66.3 (range, 57.2-69) postoperatively. In addition, 2 studies (n = 20 and n = 26) reported only postoperative values, reporting scores of 61.0 and 68.2, respectively.

Preoperative and postoperative American Shoulder and Elbow Surgeons (ASES) scores were evaluated in 3 studies involving a total of 98 patients (Fig. 4, Table III). The frequency-weighted mean score was 34.1 (range, 22-36.7) preoperatively and increased to 75.3 (range, 66-80.2) postoperatively. In addition, 2 studies (n = 20 and n = 41) reported only postoperative values. They found average postoperative ASES scores of 68 and 77, respectively.

Preoperative and postoperative Simple Shoulder Test (SST) scores were evaluated in 3 studies in a total of 98 patients (Fig. 4, Table III). The frequency-weighted mean score was 1.95 (range, 1.6-2.8) preoperatively and increased to 7.47 (range, 6-9.3) postoperatively. In addition, 2 studies (n = 20 and n = 41) reported only postoperative values. They found average postoperative SST scores of 9.3 and 9.0, respectively.

Several other functional outcome measures were collected (Subjective Shoulder Value; Shoulder Pain and Disability Index; Disabilities of the Arm, Shoulder and Hand score; University of California, Los Angeles score; and Activities of Daily Living requiring active External Rotation [ADLER]); we did not analyze scores that were reported in 2 or fewer studies.

Pain scores were specifically assessed in 2 studies in a total of 71 patients via a 10-point visual analog scale (in which 10 indicates the most pain) (Table III). The frequency-weighted mean pain score was 6.5 (range, 6.2-8.1) preoperatively and decreased to 1.8 (range, 1.6-2.5) postoperatively. In addition, 1 study (n = 41) reported pain scores on a 5-point scale, finding that all patients reported pain scores of 4 or 5 out of 5 preoperatively and this decreased to only 2 patients postoperatively.

Postoperative satisfaction was reported in 2 studies in a total of 71 patients via a 10-point visual analog scale (in which 10 indicates the most satisfied) (Table III). The frequency-weighted mean satisfaction score was 8.5 (range, 8.3-8.6). In addition, 1 study (n = 41) reported a 93% rate of satisfaction with the operative result and postoperative function.

Discussion

The results of this review demonstrate that glenoid bone grafting in primary RSA results in excellent early-term clinical and radiographic outcomes. Overall, high rates of radiologic union can be expected following glenoid bone grafting using both allograft and autograft in primary reverse arthroplasty, with a trend toward superior bone graft union using autograft. Despite this, some of the findings of this review suggest that there is still room to optimize results in specific clinical situations.

Overall, we found that the pooled union rate of glenoid bone grafts was 95%, but this value did appear to depend on graft type and technique. For instance, the union rate following the use of autograft or when using a concentric bone graft was 97% and 100%, respectively. This finding is very encouraging given that most of the bone grafts used in primary RSA cases will be autografts with some element of lateralization. Unfortunately, there are situations in which humeral bone stock will be insufficient to provide an appropriate bone graft, such as poor-quality humeral bone or an absence of humeral bone. In these situations, alternatives such as allograft and metal may be

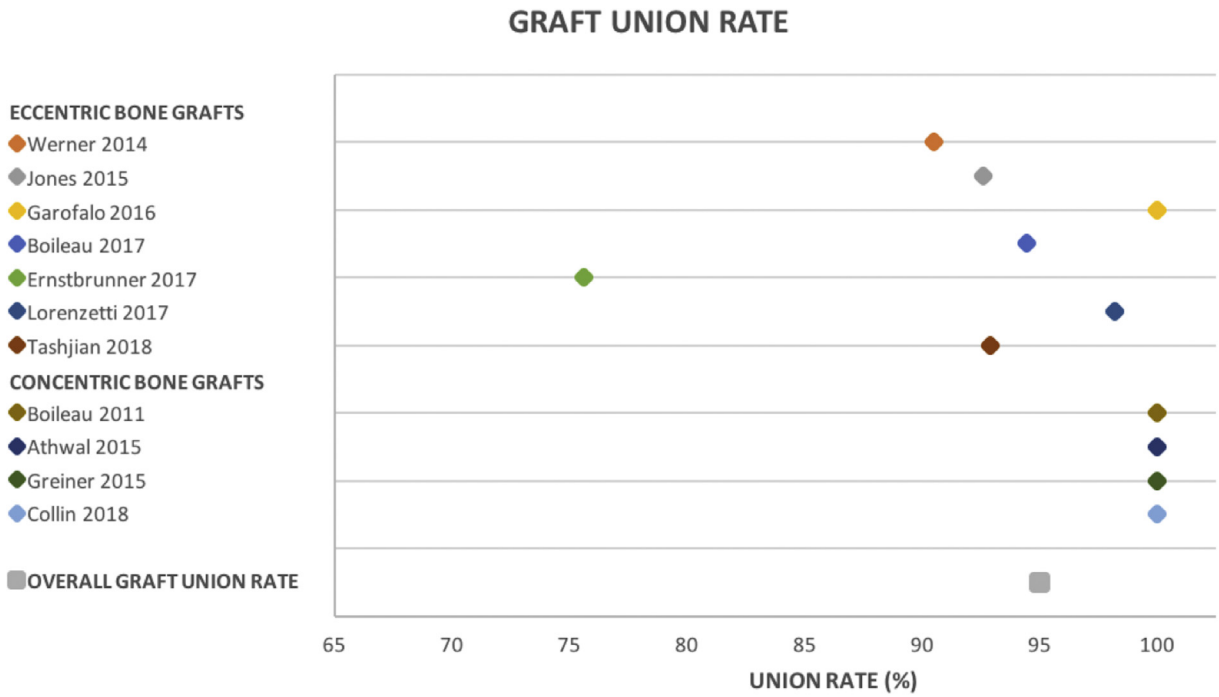

Figure 2 Graft union rate.

Table II Complications

Study	Mean FU, mo	Total complications, n	Major complications, n	Minor complications, n	Component revision, n	Other revision surgery, n	Description of revisions
Eccentric bone grafts							
Boileau et al,[4] 2017	36	6	6	—	2	—	2 glenoid revisions
Ernstbrunner et al,[10] 2017	34	7	4	3	—	—	
Garofalo et al,[12] 2016	32	3	1	2	—	—	
Lorenzetti et al,[16] 2017	46	9	9	—	2	1	2 humeral revisions, 1 humeral ORIF
Tashjian et al,[19] 2018	31	3	3	—	1	—	1 glenoid revision
Werner et al,[20] 2014	59	7	2	5	2	—	2 glenoid revisions
Jones et al,[14] 2015	34	4	3	1	—	—	
Concentric bone grafts							
Boileau et al,[4] 2011	28	18	1	17	—	—	
Collin et al,[5] 2018	24	10	—	10	—	—	
Greiner et al,[13] 2015	22	2	2	—	—	—	
Athwal et al,[1] 2015	31	—	—	—	—	—	
Total	34	69 (18%)	31 (8%)	38 (10%)	7 (2%)	1 (0.3%)	

FU, follow-up; *ORIF*, open reduction–internal fixation.

reasonable options, although the data to support either are limited. Outside of these rare situations, our data would suggest that routine use of allograft or metal is not necessary. We do, however, believe that given the increased interest in metal augmentation in RSA, there is a need to directly compare autograft bone with metal augmentation for the correction of glenoid deformity in the setting of primary RSA.

It is interesting to note that the overall union rate of eccentric bone grafts was slightly lower than expected (92%). This may be partially attributable to the use of allograft given the improved results when we analyzed only

autograft cases (95%). In addition, eccentric grafts are commonly being used for increasingly severe glenoid deformities, as was the case in our review in which the indications for eccentric grafting included complex primary cases with advanced glenoid erosion and glenohumeral dislocation with loss of anterior bone stock. Managing this complex pathology may result in predictably poorer outcomes compared with more straightforward primary cases; as such, the observed rate of union reported in this study, particularly with autograft bone, is reassuring.

Another important consideration is the influence of the humeral inclination angle (155° vs. 135°) on bone graft union. On the one hand, one may expect greater shear force on the glenoid component and bone graft with increasing lateralization; on the other hand, there is evidence to suggest that a lateralized position increases the compressive forces on the glenoid, which may be beneficial for fixation and stability.[7] On the basis of the available clinical evidence summarized in this study, it appears that humeral inclination does not influence the bone union rate in RSA.

The overall pooled scapular notching rate was 20%, which is lower than typically reported in the literature (Zumstein et al[21] reported an overall notching rate of 35% in their systematic review). Furthermore, when notching was present, we found that it was generally low grade, with only 4 of a total of 340 patients (1%) showing notching of grade 3 or greater by the Sirveaux classification. This result adds further evidence that increasing lateral offset (in this case through bony augmentation) likely reduces the overall rate and severity of scapular notching.

There was also a trend toward reduced notching rates at lower humeral inclination angles, which has previously been described in the literature.[9] We found a slightly higher notching rate in studies using 155° implants (25%, n = 214) compared with 145° (19%, n = 41) and 135° (7%, n = 57) implants. However, inference based on these results is limited because of smaller numbers of 145° and 135° implants (each from a single study).

We found a very low rate of revision at early-term follow-up. This is likely to be multifactorial, with the potential of bone grafting to better optimize reverse biomechanics and also given that the surgeons included have a wealth of experience in performing RSA in high volumes. However, longer-term follow-up is needed to assess for potential revision risk associated with bone grafting at the index procedure.

Despite the overall low revision rate, we did find a trend in the type and frequency of revisions when comparing 155° and 135° implants. Overall, the revision rate was lower with 155° implants (2% vs. 4%) and consisted of glenoid-sided failures. In contrast, despite being limited to a single study, the revision rate was higher with a 135° implant, and these revisions appeared to be exclusively on the humeral side. Although this observation is interesting, we do caution that it is based on only a few studies, and further work is needed to verify whether humeral inclination truly impacts the revision rate following RSA with glenoid bone grafting.

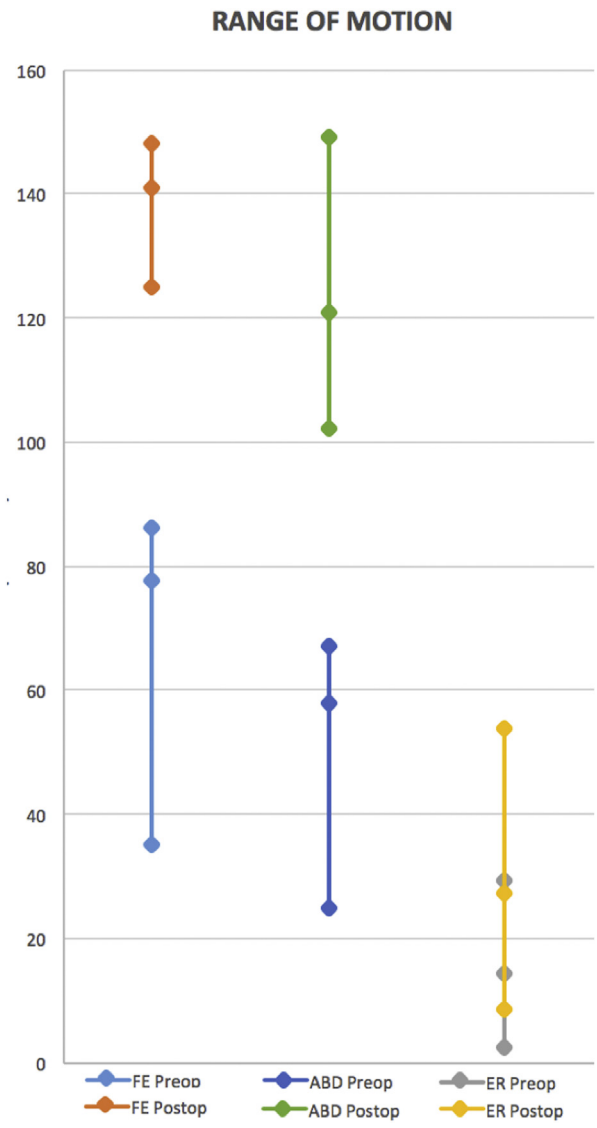

Figure 3 Range of motion (in degrees). *FE*, forward elevation; *Preop*, preoperatively; *ABD*, abduction; *ER*, external rotation; *Postop*, postoperatively.

In terms of complications, the overall rate found in this review is similar to published values for primary reverse arthroplasty in general.[2] This would indicate that the addition of a bone grafting procedure does not significantly alter the risk of short-term complications.

Preoperative and postoperative functional outcome scores showed considerable improvement in all studies. They were inconsistently reported, which limited the numbers for pooled analysis. The Constant score was reported most commonly, followed by ASES and SST scores. When measured, all 3 showed significant improvement postoperatively and were well above the commonly

reported minimal clinically important differences for these outcomes.[6]

This study has several limitations. Primarily, the results are only as reliable as the quality of the individual studies. We found 1 prospective randomized trial, with the remainder being case series or cohort studies of level II to IV evidence with overall study quality being moderate as assessed by MINORS and Detsky scores.

Another source of bias is the variability in surgical techniques, implants, and indications between studies. Although several studies have described similar methods of autograft humeral head harvest and implantation (eg, the bony increased-offset reversed shoulder arthroplasty [BIO-RSA] technique), there are certainly a number of alternative bone grafting procedures included. These included 1 iliac crest autograft procedure,[10] 10 femoral head allograft procedures,[10,14,16] and 1 cancellous allograft procedure.[10] In addition, at least 6 different implants were used in the included articles (Table I). Indications varied from cuff tear arthropathy to post-traumatic deformity and chronic dislocation.

Moreover, specific patient and technical factors were unable to be assessed in this study despite being commonly discussed when considering glenoid bone grafting. These include age and bone quality, size of the graft, implant-specific factors (glenosphere size, orientation, shape, and so on), and fixation factors (central screw vs. post; purchase in native bone; and number, size, and/or length of peripheral screws). Being unable to stratify by these individual factors adds to the heterogeneity between studies; however, given the overall positive results described, this may be more readily attributed to the effectiveness of primary bone grafting in a broader context rather than specific to any individual technique. There are certainly a number of factors to consider, particularly at the individual patient level, that may further optimize results beyond what is observed in our study.

In addition, relatively little information was available for the use of allograft bone in this series, comprising only 3% of cases—as such, we were unable to formally assess its use. However, a modest increase in outcomes was found when we excluded studies involving allograft. Further study is needed to make more definitive assessments regarding the use of allograft going forward, particularly in revision scenarios in which autograft is less likely to be an easily accessible option.

A primary outcome of this review was assessment of bone graft union. This was most commonly performed by radiologic assessment alone, with CT used as an adjunct in 4 studies. Evaluation of glenoid incorporation can be difficult using plain films, and this may limit the reliability of these assessments. However, we did not find a significant difference in union rates when CT was used as an adjunct. In fact, the union rate in these studies (96%) was slightly higher than the overall average (95%). In the future, we must carefully consider the value of advanced imaging, especially if it fails to offer significant benefits compared with clinical and radiographic assessment alone.

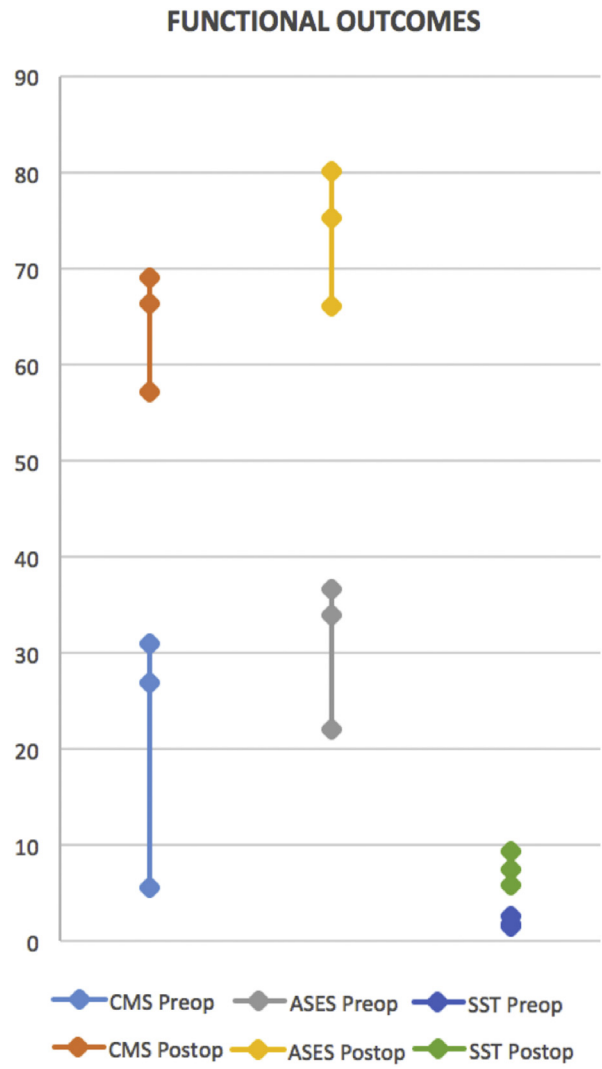

Figure 4 Functional outcomes. *CMS*, Constant score; *Preop*, preoperatively; *Postop*, postoperatively; *ASES*, American Shoulder and Elbow Surgeons score; *SST*, Simple Shoulder Test score.

Finally, the indications for glenoid bone grafting in primary RSA remain somewhat controversial. In certain instances, bone graft is used for the purposes of lateralization, which has the potential to improve rotational motion through soft-tissue tensioning, reduce scapular notching or impingement, increase stability, and improve cosmesis. In addition, bone grafting may be useful with more advanced glenoid deformity and bony deficiency. There is some evidence that even in these situations, full seating of the glenoid component is not necessary to obtain stability. Formaini et al[11] performed a biomechanical study demonstrating that less than 50% seating of the baseplate on host bone was sufficient to prevent significant micromotion. However, beyond stability, the addition of glenoid bone graft has the potential to correct deformity, reduce the need for reaming, and restore bone stock in the event of future revision. Given that there is little morbidity, particularly with the use of humeral head autograft, the additional

Table III Patient-reported outcomes

	Constant score (6 studies, n = 221)		ASES score (3 studies, n = 98)		SST score (3 studies, n = 98)		Pain score (out of 10 points) (2 studies, n = 71)		Postop satisfaction score (out of 10 points) (2 studies, n = 71)
	Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop	
Frequency-weighted mean	27	66.3	34.1	75.3	1.95	7.47	6.5	1.8	8.5
Range	5.7-31	57.2-69.0	22.0-36.7	66.0-80.2	1.6-2.8	6.0-9.3	6.2-8.1	1.6-2.5	8.3-8.6

ASES, American Shoulder and Elbow Surgeons; *SST*, Simple Shoulder Test; *Preop*, preoperatively; *Postop*, postoperatively.

operative time required for bone grafting is likely justified. Alternative options such as lateralized glenoid components and metallic augmentation require further investigation to establish their specific indications and role.

Conclusion

This review demonstrates that glenoid bone grafting with primary RSA results in excellent early-term clinical and radiographic outcomes. Overall, we found high rates of union, low rates of scapular notching, and acceptable complication and revision rates. Consistent improvements in pain, ROM, and functional outcomes are described over a variety of techniques and indications. Union rates appear to vary depending on graft type and technique, whereby the highest union rates were seen following the use of autograft bone for the purposes of concentric lateralization. On the basis of these findings, reconstruction of glenoid bone loss and deformity during primary RSA should be performed with autograft bone whenever possible.

Disclaimer

Gregory Nicholson reports that he has received royalties from and is a designer and consultant for Wright Medical for work related to the subject of this article. All the other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jse.2019.05.011.

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