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Comparison of radiographic and clinical outcomes of revision reverse total shoulder arthroplasty with structural versus nonstructural bone graft

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Background: Revision shoulder arthroplasty in the setting of glenoid bone loss poses substantial surgical challenges. This study's purpose was to compare radiographic and clinical results of patients requiring structural iliac crest bone autograft (ICBA) for severe bone loss versus patients with less severe bone loss treated with nonstructural bone allograft (NSBA) in the setting of revision reverse total shoulder arthroplasty (RSA).

Methods: A retrospective cohort of 30 patients (70% of the 43 patients who met the inclusion criteria) undergoing revision RSA with ICBA (n = 15) or NSBA (n = 15) between 2007 and 2015 were analyzed at a minimum 2-year follow-up. Radiographic assessment included bone graft integration, bone graft resorption, glenosphere tilt, glenosphere version, and the presence of scapular notching. Clinical assessment included active range of motion, Penn Shoulder Score, Veterans RAND 12-item health survey, and need for revision surgery.

Results: No radiographic difference was found between the ICBA and NSBA groups with regard to implant position, graft integration, scapular notching, implant shift, or failure of fixation ($P > .05$). Of 15 patients with ICBA, 14 (93%) had at least partial integration of the bone graft. Some degree of resorption of the bone graft was noted in 6 of 15 patients (40%). There was no significant difference in postoperative active range of motion, Penn Shoulder Score, or Veterans RAND 12-item health survey score ($P > .05$ for all comparisons). One patient in the ICBA group underwent revision surgery for glenoid baseplate failure.

Conclusion: Revision RSA with glenoid bone grafting resulted in good clinical and radiographic outcomes at short-term follow-up. Patients requiring structural ICBA were not at increased risk of component failure, radiographic or clinical complications, or inferior clinical outcomes.

Level of evidence: Level III; Retrospective Cohort Design; Treatment Study

Keywords: Revision arthroplasty; reverse total shoulder; bone autograft; bone allograft; glenoid bone grafting; shoulder

Institutional review board approval was obtained for this study (Cleveland Clinic IRB No. 15-472).

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Revision shoulder arthroplasty poses significant challenges in the setting of severe glenoid bone loss.[32] Glenoid loosening after total shoulder arthroplasty and progressive glenoid wear with failed hemiarthroplasty are common causes of severe glenoid defects at the time of revision arthroplasty.[1,8,22,23,26] A number of methods have been used to address significant glenoid bone loss during revision surgery, including removal of the glenoid component without bone grafting, bone grafting without replacement of the glenoid component, and 2-stage revision arthroplasty.[5,7,21,23,26] Reverse total shoulder arthroplasty (RSA) has emerged as a successful treatment method for complex revision surgery, including the ability to perform a 1-stage revision with structural bone grafting in the setting of severe bone loss.[2,6,15,24,31] Despite RSA's success, concern remains regarding the risk of glenoid component loosening due to failure of fixation in cases of severe glenoid bone loss.[27]

In cases with a large glenoid bone defect, structural bone grafting offers the potential to improve component positioning and may reduce the risk of component loosening.[26] Previous analysis has suggested use of bone graft in the setting of RSA when less than 80% of the baseplate is supported by native bone.[16] The type of bone graft used for shoulder arthroplasty varies but most broadly encompasses either nonstructural or structural graft. Nonstructural bone graft typically includes cancellous allograft bone chips or local cancellous autograft. Structural bone grafting options have included allograft, hybrids of allograft, and autograft. Structural autograft is commonly obtained as a tricortical segment of bone from the iliac crest.[3,12,15] However, there have been a limited number of studies evaluating outcomes of bone grafting with revision RSA, with many combining their analyses of both primary and revision procedures.[4,13,19,22] Wagner et al[30] recently reported on 40 patients who underwent bone grafting at the time of revision RSA, with significant improvements in range of motion, American Shoulder and Elbow Surgeons scores, and Simple Shoulder Test scores but with an 18% revision rate at a mean follow-up of 13 months. Other studies of revision RSA with bone graft have shown good clinical results but a wide range of radiographic outcomes.[15,20] These prior studies have reported their clinical findings as a single cohort and have not compared patients with more extensive glenoid bone loss requiring structural bone graft with patients with smaller contained bone loss requiring nonstructural bone graft at the time of revision RSA.[15,20,30]

Because of the limited published data on this comparison, the purpose of this study was to evaluate the radiographic and clinical results of revision RSA with structural iliac crest bone autograft (ICBA) used for severe glenoid bone loss compared with patients having less severe bone loss treated with nonstructural bone allograft. We hypothesized that patients requiring ICBA would have similar clinical results (range of motion, patient-reported outcomes, and revision) and radiographic outcomes (glenoid component position, radiographic failure or loosening, and graft resorption) at a minimum 2-year follow-up to those patients needing only nonstructural allograft.

Materials and methods

Patient group

We identified patients from our shoulder arthroplasty database. Between 2007 and 2015, 54 patients who underwent revision RSA with glenoid defects that required bone grafting were identified. The inclusion criteria were patients requiring either ICBA or nonstructural bone allograft at the time of revision RSA with a minimum 2-year follow-up. Of the 54 patients, 43 were treated with either structural ICBA or nonstructural bone allograft at the time of revision surgery. We excluded 11 patients from analysis because of treatment with other structural bone grafts (femoral head allograft in 4, coracoid autograft in 2, and proximal humeral autograft in 5). Structural ICBA was indicated for large, uncontained defects in which less than 50% of the baseplate was supported by native glenoid bone. Nonstructural allograft was indicated for smaller, central, contained defects of the glenoid that surrounded the central post but still permitted at least 50% of the baseplate to be supported by native bone. Thus, the nonstructural bone allograft group was considered a less severe comparative group. Of the 43 patients, 13 (30%) were not available for 2-year follow-up, 4 patients in the structural ICBA group and 9 in the nonstructural bone allograft group, and were excluded from this study. One of the excluded ICBA patients did not have contact information and was lost to follow-up, and one died of unrelated causes prior to the 2-year follow-up. Four of the nonstructural allograft group patients did not have contact information and were thus lost to follow-up. Finally, 7 patients (2 ICBA and 5 nonstructural allograft patients) were contacted multiple times but did not complete follow-up, even when offered to have standardized plain radiographs obtained locally and to reply to mailed patient-reported outcome questionnaires. Therefore, 30 patients (70%), 15 patients with ICBA and 15 patients with nonstructural bone allograft, achieved a minimum 2-year radiographic and clinical follow-up, with a median of 2.9 years (range, 2-6.7 years), and were included in this study for analysis.

The demographic characteristics of the 30 patients analyzed in this study are summarized in Table I. There were 8 patients who underwent revision RSA with bone grafting as the second stage of a 2-stage revision because of periprosthetic joint infection (PJI). These patients all underwent a first-stage procedure including removal of the prior prosthesis, irrigation and débridement, and placement of an antibiotic spacer, followed by a 6-week course of bacteria-specific intravenous (IV) antibiotics. Of these patients, 1 had a hemiarthroplasty, 5 had a standard total shoulder arthroplasty, and 2 had an RSA removed at the first-stage surgical procedure. After antibiotic completion, persistent infection was ruled out based on the serum erythrocyte sedimentation rate, C-reactive protein level, and joint aspiration findings (if fluid was obtained) prior to the second-stage procedure and frozen section analysis and intraoperative culture findings at the time of the second-stage procedure, as previously described.[9]

Operative technique

All surgical procedures were performed by 2 shoulder specialists (J.P.I. and E.T.R.). Surgery was performed through a deltopectoral approach with arthrotomy performed via subperiosteal peeling of the subscapularis tendon when it was intact. The glenoid defect was evaluated and classified according to Williams and Iannotti[32] (Fig. 1) after removal of the glenoid component (Fig. 2, *A*). When patients

Table I Patient demographic characteristics for all study patients and by bone graft group

Variable	All patients	ICBA	NSBA
No. of patients	30	15	15
Mean age, yr	67.4 (11.4; 34.8-85.9*)	66.8 (11.2; 34.8-81.4*)	68.1 (11.5; 35.2-85.9*)
No. of female patients (%)	14 (46.6)	6 (40)	8 (53.3)
Mean time between index arthroplasty surgery and final revision arthroplasty surgery, yr	6.2 (5.4; 1-21*)	6.1 (5.3; 1-20*)	6.3 (5.5; 2-21*)
Implant prior to revision surgery, n (%)			
Hemiarthroplasty	6 (20)	3 (13)	3 (20)
TSA	21 (70)	10 (67)	11 (73)
RSA	3 (10)	2 (20)	1 (7)
Indication for surgery, n (%)			
Aseptic failure	22 (73)	10 (67)	12 (80)
Progressive glenoid arthrosis	4 (18)	2 (20)	2 (17)
Glenoid polyethylene loosening	12 (55)	5 (50)	7 (58)
Rotator cuff insufficiency	5 (22)	2 (20)	3 (25)
Glenoid baseplate loosening	1 (5)	1 (10)	0
Infection	8 (27)	5 (33)	3 (20)
No. of revision surgery stages (%)			
1	22 (73)	10 (67)	12 (80)
2	8 (27)	5 (33)	3 (20)

ICBA, iliac crest bone autograft group; *NSBA*, nonstructural bone allograft group; *TSA*, total shoulder arthroplasty; *RSA*, reverse total shoulder arthroplasty.
* Numbers with *asterisks* are presented as (standard deviation; range).

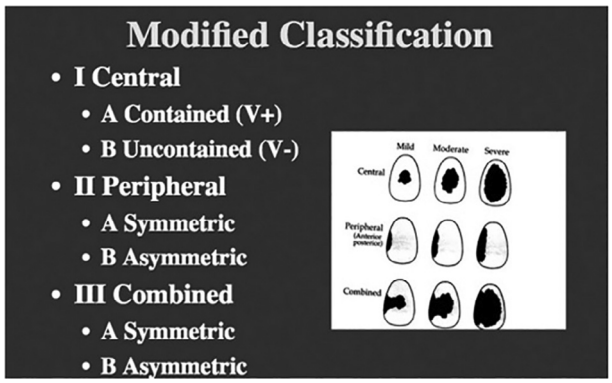

Figure 1 Modified classification of glenoid bone loss.[32] *V*, vault (glenoid vault). Reprinted with permission from Williams GR Jr, Iannotti JP. Options for glenoid bone loss: composites of prosthetics and biologics. J Shoulder Elbow Surg 2007;16(Suppl):S267-72.

were found to have loss of the glenoid surface that would leave more than 50% of the backside of the baseplate unsupported, iliac crest was harvested. The size of the defect was measured, and a longitudinal incision was made just posterior to the anterior superior iliac spine overlying the iliac crest. A piece of tricortical iliac crest corresponding to the size of the glenoid defect was then harvested. The glenoid defect was burred to create a uniform shape that would accept the similarly sized and shaped iliac crest graft (Fig. 2, *B*). The graft was impacted into the defect. A guide pin was placed in the graft with a pin guide having the same size and shape as the baseplate, with the intention of having the baseplate align at the glenoid neck inferiorly and at a neutral to slightly inferior tilt. The baseplate and guide pin position was evaluated by fluoroscopic imaging, and adjustments were made to the guide pin to achieve the desired position (Fig. 2, *C*). The graft and remaining glenoid were then reamed to match the backside of the baseplate. The center peg hole was drilled for a 15-mm standard-peg or 25-mm long-peg baseplate, based on the availability of the longer peg and the discretion of the treating surgeon (Fig. 2, *D*). In this study, 15 standard-peg (9 nonstructural bone allograft and 6 ICBA) and 15 long-peg (6 nonstructural bone allograft and 9 ICBA) glenoid baseplates were used. When a standard-peg baseplate was used with ICBA, long peripheral locking screws were used to ensure that the screws passed from the graft into the native glenoid vault. The baseplate was then impacted into place and compressed against the graft and native bone (Fig. 2, *E*). A combination of locking and nonlocking screws was placed through the glenoid baseplate for secure fixation, at the discretion of the treating surgeon, with 2 to 4 locking screws used per case. When there were contained, central defects in which the periphery of the intact glenoid bone allowed for at least 50% support of the backside of the baseplate, cancellous allograft bone chips (Musculoskeletal Transplant Foundation, Edison, NJ, USA) were impacted into the defect with a bone tamp, followed by impaction of the glenoid baseplate and placement of locking and/or nonlocking screws for baseplate fixation. Two RSA implants, of similar design, were used during the study period: DePuy Delta Xtend (DePuy Synthes, Warsaw, IN, USA) in 21 patients and Aequalis Reversed Shoulder (Tornier, Edina, MN, USA) in 9.

Radiographic assessment

Postoperative plain radiographs were obtained during the follow-up period and included Grashey anteroposterior (AP), standard AP, and axillary views. Radiographic images obtained at a minimum 2-year follow-up were reviewed for bone graft integration, the presence of bone graft resorption, glenosphere tilt and version, and the presence of scapular notching, with these assessments made by consensus reading of 3 of the authors (J.C.H., J.P.I., and E.T.R.). Images were viewed on a picture archiving and

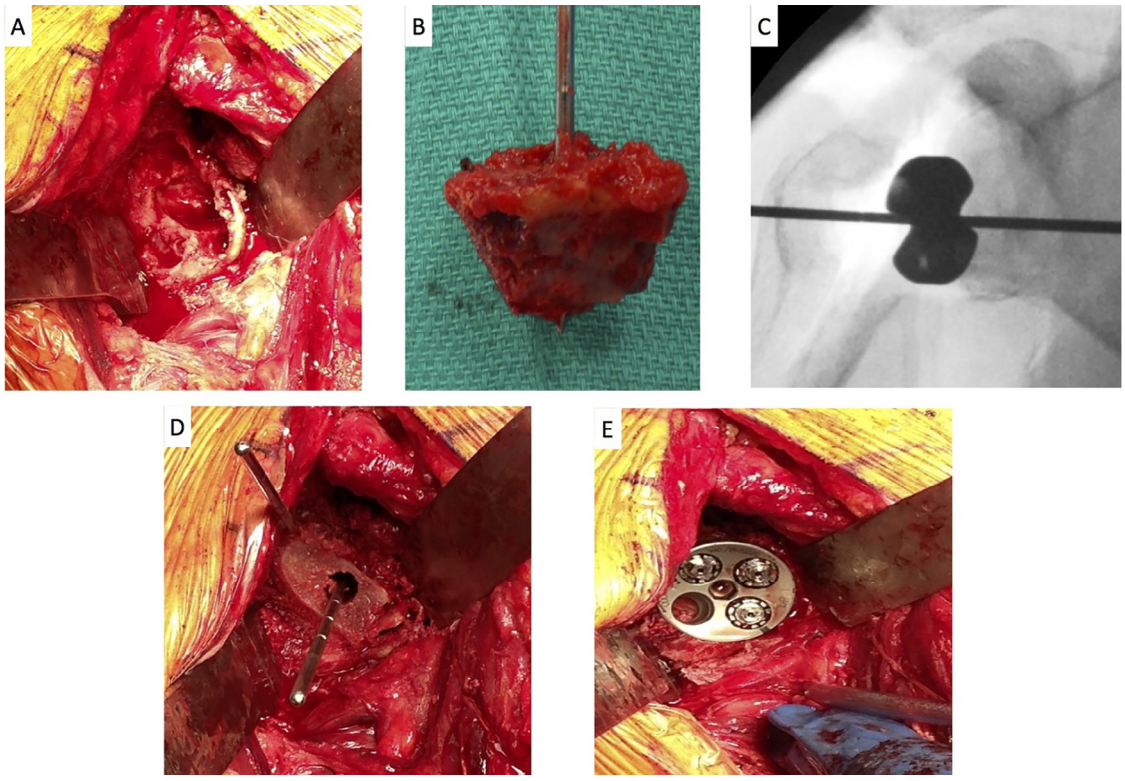

Figure 2 Intraoperative photographs and fluoroscopy for iliac crest bone autograft (ICBA) surgical technique. (**A**) Intraoperative photograph of uncontained glenoid defect. (**B**) Harvested ICBA contoured to fit uncontained glenoid defect. (**C**) Intraoperative fluoroscopic image demonstrating appropriate guide pin and planned baseplate location prior to ICBA placement. (**D**) Glenoid defect after impaction of ICBA and in situ reaming prior to baseplate implantation. (**E**) Final glenoid baseplate impacted into position within ICBA-reconstructed glenoid.

communication system (AFGA Health Care, Mortsel, Belgium) with contrast adjusted to obtain the best possible images for analysis. By use of a modification of methods described by Iannotti and Frangiamore,[12] ICBA integration was considered present on the AP view when there was at least a partial disappearance of the interface between the graft and native bone when comparing the immediate postoperative and minimum 2-year follow-up images. The amount of ICBA resorption was estimated to be more than 50% or to be 50% or less on AP and, when possible, axillary views when comparing the earliest postoperative and minimum 2-year follow-up images (Fig. 3). For the nonstructural bone allograft group, radiolucency greater than 2 mm around the entire central peg of the baseplate was used as a surrogate for graft resorption. Glenosphere version was measured with a modification of the method of Friedman et al.[10] On the axillary view, a line was drawn parallel to the axis of the body of the scapula and a second line was drawn along the central peg of the glenosphere baseplate, which was perpendicular to the baseplate surface.[11] The angle between these 2 lines represented glenosphere version (Fig. 4). In some instances, the line drawn parallel to the axis of the body of the glenoid did not extend to the medial border if the entire scapula was not included on the axillary view.[11] Glenosphere tilt was radiographically measured according to the method described by Lévigne et al.[18] Scapular notching was classified according to the system described by Sirveaux et al.[29]

Implant shift was defined as radiographic evidence of a change in glenoid implant position with continued contact of the baseplate on the glenoid bone. Failure of fixation was defined as a loss of contact of the glenoid baseplate from the bone.

Clinical assessment

Clinical assessment at 2 years was performed using a validated shoulder score and general health assessment questionnaire, and the findings were compared with preoperative values. The Penn Shoulder Score (PSS) is a 24-item questionnaire with 3 domains: pain (30 points), shoulder function (60 points), and satisfaction (10 points).[17] The Veterans RAND 12-item health survey (VR-12) is a 12-item questionnaire that is divided into mental and physical components for general health assessment.[14,28] Active forward elevation (aFE) and active external rotation (aER), measured in degrees, were determined by physical examination at the last follow-up with the patient in the standing position. Four patients included in the analysis were unable to return for an in-office follow-up visit but had standardized radiographs (Grashey AP, standard AP, and axillary views) obtained at their local hospital and completed both the PSS and VR-12 via mail.

Statistical analysis

Preoperative and postoperative variables were compared by use of the paired *t* test or Wilcoxon signed rank test. Univariate analysis comparing infection, bone graft type, and baseplate peg length was conducted using the Student *t* test, Wilcoxon rank sum test, χ^2 test, or Fisher exact test.

Radiographic measurements were normally distributed and were reported as means and standard deviations, while clinical range-of-motion measurements and patient-reported outcome scores demonstrated a non-normal distribution and were reported as medians

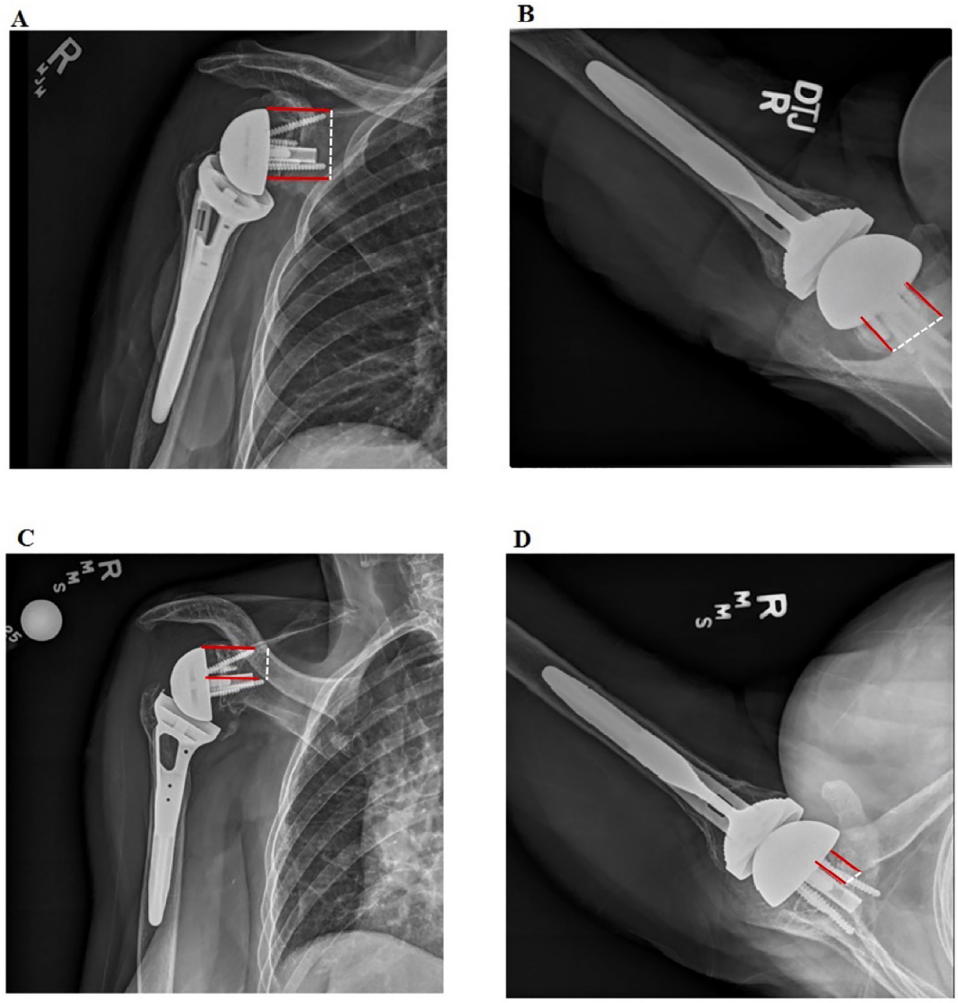

Figure 3 Radiographs in a 63-year-old patient after revision reverse total shoulder arthroplasty with iliac crest bone autograft (ICBA). (**A, B**) Six-week postoperative anteroposterior (AP) and axillary radiographs. The superior and inferior borders of ICBA on the AP radiograph and the anterior and posterior borders of ICBA on the axillary radiograph are demarcated by the *parallel red lines* (34-mm radiographic superoinferior height and 24-mm radiographic AP width). (**C, D**) Two-year postoperative AP and axillary radiographs showing superoinferior and AP borders of ICBA, respectively, demarcated by the *parallel red lines* (16-mm radiographic superoinferior height and 12-mm AP width). Loss of the interface between the native bone and ICBA occurred, indicating graft integration. The patient's average estimated bone resorption seen between the immediate postoperative and 2-year follow-up radiographs was 49%; thus this patient was classified as having resorption of 50% or less. The *dashed lines* represent the linear measurement between the parallel red lines in each figure. This measurement was 34 mm in (**A**), 24 mm in (**B**), 16 mm in (**C**), and 12 mm in (**D**). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

and interquartile ranges (IQR). All data analysis was conducted using JMP Pro (version 13; SAS Institute, Cary, NC, USA). $P < .05$ was considered statistically significant.

Results

Radiographic results

Radiographic results are summarized in Table II. No radiographic differences were found between the ICBA group and nonstructural bone graft group with regard to bone graft integration, implant position (glenosphere version and inclination), scapular notching, or implant shift or failure. At least partial integration of the bone graft was noted in 14 of 15 patients with ICBA. Of the 15 ICBA patients, 9 had no resorption of the graft, 3 had some resorption but 50% or less, and 3 had resorption greater than 50%. In the nonstructural bone allograft group, there were no cases of central peg radiolucency, representing no visible radiographic signs of resorption of the bone allograft. The 2 groups showed no difference in the grading of scapular notching at 2 years' follow-up ($P > .99$). Implant shift or failure was found in 3 patients in the ICBA group but no patients in the nonstructural bone allograft. This difference was not statistically significant.

Subgroup analysis comparing the use of the 15 long-peg (6 nonstructural bone allograft and 9 ICBA) versus 15

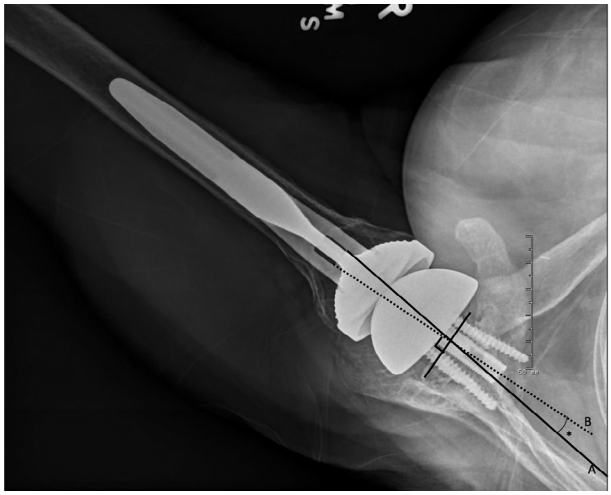

Figure 4 Axillary view of shoulder, demonstrating measurement of glenosphere version. A line is drawn along the body of the scapula (*solid line*, *A*), similarly to the technique described by Friedman et al[10] for computed tomography measurement, and a second line is drawn along the central peg of the glenoid baseplate (*dotted line*, *B*). The angle between these 2 lines (*asterisk*) represents the amount of version of the glenoid implant.[11]

standard-peg (9 nonstructural bone allograft and 6 ICBA) glenoid baseplates showed no significant difference with regard to mean glenosphere tilt (Table II). The mean glenosphere version between the groups approached but did not reach statistical significance ($P = .07$, Table II). There was no significant difference in scapular notching when compared by central peg length ($P > .99$). The number of patients with either implant shift or fixation failure was not significantly different between groups. A single patient in the long-peg group had implant shift, and 2 patients in the standard-peg group had radiographic evidence of shift or failure of the glenosphere and baseplate (1 shift and 1 failure of fixation) ($P > .99$, Table II). When comparing ICBA integration in patients with standard versus long pegs, we found no significant difference between groups, with 9 of 9 patients in the long-peg group and 5 of 6 patients in the standard-peg group showing graft integration ($P = .47$). Similarly, there was no difference in the presence of resorption of structural bone graft (ICBA) ($P = .12$) or the number of patients with greater than 50% ICBA resorption ($P > .99$) between patients with long and standard central peg implants. A single patient in the standard-peg group had complete resorption (100%) of the ICBA associated with implant failure, while 5 patients in the long-peg group had partial graft resorption (≤50% resorption in 3 and >50% resorption in 2). None of these 5 patients had implant shift or failure.

Clinical results

Clinical results are summarized in Table III. Of the 30 patients, 26 underwent range-of-motion assessments at 2-year follow-up, and all 26 showed significant improvements in median aFE ($P < .001$) and aER ($P < .001$) at 2-year follow-up, with no significant difference between the ICBA and nonstructural bone allograft groups ($P > .05$). All 30 patients had PSS and VR-12 outcome scores available at 2-year follow-up. All showed a significant improvement in median PSS, with an increase from 16 points (IQR, 13-38 points) preoperatively to 81 points (IQR, 70-91 points) postoperatively

Table II Postoperative radiographic outcome measurements by bone graft group and by central peg group

Outcome measure	Bone graft group			Central peg group		
	ICBA (n = 15)	NSBA (n = 15)	*P* value*	Long peg (n = 15)	Standard peg (n = 15)	*P* value*
Mean glenosphere version, °	−5 (12; −32 to 12§)†	−7 (10; −23 to 6§)†	.61	−2 (9; −25 to 11§)†	−9 (11; −32 to 10§)†	.07
Mean glenosphere tilt, °	−5 (4; −11 to 7§)‡	−4 (3; −9 to 2§)‡	.93	−5 (4; −11 to 2§)‡	−4 (4; −8 to 7§)‡	.64
Scapular notching			>.99			>.99
Grade 0	10	11		10	10	
Grade 1	3	3		4	3	
Grade 2	2	1		1	2	
Implant shift or failure of fixation	3	0	.22	1	2	>.99
ICBA incorporation, n/total (%)	14/15 (93)	NA	—	9/9 (100)	5/6 (83)	.47
Presence of ICBA resorption, n/total (%)	6/15 (40)	NA	—	5/9 (55)	1/6 (16)	.12
ICBA resorption > 50%, n/total (%)	3/15 (20)	NA	—	2/9 (22)	1/6 (16)	>.99
Central peg radiolucency in NSBA, n/total (%)	NA	0/15 (0)	—	0/6 (0)	0/9 (0)	>.99

ICBA, iliac crest bone autograft group; *NSBA*, nonstructural bone allograft group; *NA*, not applicable.

* $P < .05$ is defined as statistically significant.

† A negative number indicates retroversion.

‡ A negative number indicates inferior tilt.

§ Numbers with *section sign* are presented as (standard deviation; range).

Table III Preoperative and postoperative outcome scores and range of motion for all study patients and by bone graft group

	All patients			Preoperative by group			Postoperative by group		
	Preoperative	Postoperative	*P* value	ICBA	NSBA	*P* value	ICBA	NSBA	*P* value
Median PSS (IQR)	16 (13-38)	81 (70-91)	<.0001*	16 (13-40)	16 (12-34)	.61	77 (47-91)	83 (76-90)	.62
Median VR-12 MCS (IQR)	49 (22-54)	55 (26-66)	.02*	50 (16-64)	49 (23-64)	.83	57 (35-67)	54 (29-66)	.35
Median VR-12 PCS (IQR)	30 (12-44)	38 (19-54)	<.0001*	31 (15-44)	29 (23-64)	.54	37 (19-54)	39 (28-53)	.71
Median aFE (IQR), °	78 (49-90)	150 (138-160)	<.0001*	77 (62-90)	80 (60-110)	.85	155 (135-162)	150 (132-155)	.39
Median aER (IQR), °	18 (10-50)	34 (15-60)	<.0001*	19 (0-33)	23 (12-30)	.22	32 (21-40)	36 (27-41)	.48

ICBA, iliac crest bone autograft group; *NSBA*, nonstructural bone allograft group; *PSS*, Penn Shoulder Score; *IQR*, interquartile range; *VR-12*, Veterans RAND 12-item health survey; *MCS*, mental component score; *PCS*, physical component score; *aFE*, active forward elevation; *aER*, active external rotation.
* Statistically significant ($P < .05$).

Table IV Postoperative outcome scores and range of motion based on surgical diagnosis

	Diagnosis/surgical indication		*P* value
	Prosthetic joint infection	Aseptic failure	
Median PSS (IQR)	91 (77-92)	81 (57-90)	.19
Median VR-12 MCS (IQR)	57 (35-66)	55 (29-66)	.61
Median VR-12 PCS (IQR)	38 (19-54)	37 (28-53)	.86
Median aFE (IQR), °	150 (120-170)	150 (142-160)	.63
Median aER (IQR), °	44 (40-50)	30 (20-40)	.02*

PSS, Penn Shoulder Score; *IQR*, interquartile range; *VR-12*, Veterans RAND 12-item health survey; *MCS*, mental component score; *PCS*, physical component score; *aFE*, active forward elevation; *aER*, active external rotation.
* Statistically significant ($P < .05$).

($P < .0001$). There was no significant difference in 2-year PSS between the ICBA and nonstructural bone allograft groups ($P = .62$). Similarly, all patients showed improvements in both the VR-12 mental component score (MCS) and VR-12 physical component score (PCS). There was no significant difference in median postoperative VR-12 MCS ($P = .35$) and VR-12 PCS ($P = .71$) between the ICBA and nonstructural bone allograft patients.

Table IV shows the outcomes of subgroup analysis based on indication for surgery between the 8 patients treated for PJI and the 22 patients treated for aseptic failure. No significant differences in median postoperative aFE ($P = .63$), median PSS ($P = .19$), median VR-12 MCS ($P = .61$), and median VR-12 PCS ($P = .86$) were found between groups. A significant difference in postoperative aER was noted between patients with failure due to PJI and those with aseptic failure, with median aER of 44° (IQR, 40°-50°) in those with PJI versus 30° (IQR, 20°-40°) in those with aseptic failure ($P = .02$).

Complications

Two patients in the ICBA group demonstrated a shift of the glenoid baseplate without failure during the follow-up period. One baseplate had a standard central peg, and one had a long central peg. In both patients, the shift occurred in the early postoperative period, with the baseplate eventually remaining stable at both 1- and 2-year follow-up points. Neither patient required revision; both noted good shoulder function, with aFE of 120° and aER of 30° in one and aFE of 160° and aER of 40° in the other. In addition, these 2 patients had moderate PSS values of 78 points and 70 points, respectively, at their 2-year follow-up evaluation. A single patient in the ICBA group sustained a dislocation, without an associated fracture of the scapula or humerus, due to a ground-level fall 15 months after surgery. The patient was successfully treated with closed reduction and had no further sequelae. One patient in the ICBA group required revision because of infection after revision surgery, with subsequent failure of a standard-length central peg baseplate and complete graft resorption. This patient was treated with a 2-stage revision and IV antibiotics, with eventual glenoid bone grafting by use of structural femoral allograft and repeated revision RSA with a long central peg baseplate during the second stage. A single patient in the nonstructural bone allograft group required repeated surgery at 27 days postoperatively to remove a small portion of a retained surgical drain and showed no signs of infection at any point during follow-up. A single patient in the ICBA group died of unrelated causes 6 months after achieving his 2-year clinical and radiographic follow-up.

Discussion

The purpose of this study was to evaluate the radiographic and clinical results of revision RSA with structural ICBA used for severe glenoid bone loss compared with patients requiring only nonstructural bone allograft for less severe glenoid defects. Our analysis demonstrated no significant differences in radiographic or clinical outcomes between these 2 patient groups. Glenoid bone defects are associated with worse clinical outcomes in revision shoulder arthroplasty, posing a risk of implant loosening, malposition, and subsequent failure.[8,22] Bone grafting allows for improved implant support and, when combined with RSA, permits multiple points of fixation of the implant into the graft and native bone.[19] While good clinical outcomes have been seen with revision RSA,[2,6,15,24,31] data on its outcomes with use of bone graft for

glenoid bone loss remain limited, with no comparison of outcomes in patients requiring nonstructural bone graft for contained defects versus those requiring structural graft owing to larger, uncontained defects.[15,20,30] Data from our study indicate that despite more advanced glenoid bone loss, patients requiring ICBA at the time of revision RSA are not at increased risk of component failure, radiographic or clinical complications, or inferior clinical outcomes when compared with patients requiring only nonstructural bone allograft for contained defects.

Radiographic assessment at 2 years demonstrated similar glenoid implant positions, with no significant differences in either version or tilt, between the 2 groups. Scapular notching was seen in 30% of all patients, which is lower than the 54% reported by Melis et al[20] but greater than the 8% seen in the study by Wagner et al.[30] While a large portion of patients, that is, 40%, demonstrated at least partial resorption of their structural ICBA, their clinical and radiographic outcomes showed no significant differences compared with the nonstructural bone allograft group. The presence of resorption of structural ICBA was greater than in previous studies, with Wagner et al and Melis et al demonstrating 23% and 21% of patients, respectively, with at least partial bone graft resorption at final follow-up. Although not statistically significant, the 2 cases of baseplate shift and the single case of baseplate failure of fixation occurred exclusively in the ICBA group. Two patients in the ICBA group demonstrated glenoid implant shift in the early postoperative period but did not undergo revision, as both baseplates were noted to be stable at 1- and 2-year follow-up. Of these 2 patients, 1 had a baseplate with a standard central peg whereas 1 had a long central peg. Both had good function, good patient-reported outcome scores, and no signs of component failure at 2 years, and thus these cases were not considered clinical failures. One patient in the ICBA group had glenoid implant failure of fixation in the setting of infection and required revision surgery. The baseplate in this case had a standard central peg, and complete resorption of the ICBA was noted. The infection was likely the primary cause of glenoid implant failure and graft resorption, but the central peg length may have contributed to the failure as well. Subgroup analysis of patients with standard and long central peg glenoid baseplates showed a nearly significant difference in glenosphere version between the 2 groups, but the remainder of the analysis between these groups showed no significant differences in radiographic or clinical outcomes, regardless of bone graft type. It should be noted that long locking screws in the native glenoid were used to ensure fixation of the implant and graft with a standard-peg baseplate. No study has defined the baseplate central peg length necessary to achieve stable fixation, but 1 study advocated 15 mm of central peg extending beyond the graft to achieve fixation in native bone.[15]

Clinically, patients in the ICBA group demonstrated similar improvements in active shoulder motion, as well as shoulder-specific (PSS) and general health quality (VR-12) patient-reported outcome measures, and no significant difference in the rate of failure or revision compared with the nonstructural bone allograft group. Our study patients showed comparable improvements in function to patients in previous investigations.[15,20,30] In their series of 28 patients, Kelly et al[15] showed similar improvements in Constant and American Shoulder and Elbow Surgeons scores, with no difference in patients requiring tricortical ICBA and those not requiring bone graft. Similarly, range of motion in our patients did not differ between groups and was slightly better than in previously reported studies.[13,15,20,22] Our overall complication rate was low, at 17%, and similar to the 10% complication rate seen by Lopiz et al[19] and the 18% complication rate seen by Wagner et al.[30]

When we compared the indication for revision surgery, patients treated for PJI showed no significant difference compared with patients with aseptic failure in reported outcome scores, radiographic measures, or functional motion with the exception of aER, which was significantly greater in the infection group. The reason for the difference is unclear and may be related to differing rotator cuff status between the 2 groups. All patients with a PJI diagnosis were treated with 2-stage revision and IV antibiotics. The functional motion and patient-reported outcomes of the PJI patients were superior to results seen by Sabesan et al,[25] who reported mean forward elevation of 123° ± 30°, mean external rotation of 26° ± 8°, and a mean postoperative PSS of 66 ± 20.8.

Our study had certain limitations. Each group included a relatively small number of patients, and although our total cohort size is similar to that in previous investigations,[15,19,20,30] the small sample size does allow for potential statistical error due to insufficient power. Glenoid defect sizes and bone graft sizes were not recorded intraoperatively to allow for a comparison between groups. In addition, the evaluation of graft incorporation and resorption in each group was qualitative and limited by the nature of plain radiographs. While structural graft can be visualized and followed with plain radiographs, the limited views do not allow for complete quantitative assessment of graft integration. For the nonstructural bone allograft group, baseplate central peg radiolucency was used as a surrogate for graft resorption because the nonstructural graft was difficult to directly visualize.

Despite these limitations, we believe the strength of this study lies in the consistent surgical technique and indications for use of each type of bone graft, allowing for comparison of ICBA for uncontained glenoid defects versus nonstructural bone allograft for contained glenoid defects. These data will add to the relatively limited literature on this topic.

Conclusion

Revision RSA with glenoid bone grafting results in good radiographic and clinical outcomes at short-term follow-up. While graft integration was high with both structural and nonstructural bone grafting, some degree of ICBA resorption was present in 40% of patients. Despite more

advanced glenoid bone loss, patients requiring ICBA for uncontained defects at the time of revision RSA are not at increased risk of component failure, radiographic or clinical complications, or inferior clinical outcomes compared with patients requiring only nonstructural glenoid bone grafting for contained defects at the time of revision surgery.

Disclaimer

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