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Early clinical and radiographic outcomes of an augmented baseplate in reverse shoulder arthroplasty for glenohumeral arthritis with glenoid deformity

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Background: Glenoid deformity is commonly encountered in patients undergoing reverse shoulder arthroplasty (RSA). Augmented baseplates can correct glenoid deformity while potentially avoiding certain complications encountered with structural bone graft. Limited evidence exists to support the use of metallic augmented baseplates in RSA.

Methods: We performed a retrospective review to identify all patients treated with an augmented baseplate during primary RSA with a minimum of 1 year of clinical and radiographic follow-up. Preoperative radiographs and advanced imaging were used to determine glenoid morphology and deformity. Postoperative radiographs were used to evaluate for deformity correction, radiographic complications, and early baseplate loosening or failure. Prospectively collected clinical data and patient-reported outcome scores were determined.

Results: Primary RSA was performed with an augmented baseplate in 44 patients (mean age, 72 ± 6 years; 15 half-wedge and 29 full-wedge augmentations). Glenoid retroversion was significantly improved for the entire cohort ($P = .001$). Among the 22 patients with either Walch type B2, B3, or C glenoid morphology, glenoid version improved from 28° ± 8° to 16° ± 8° ($P = .001$). Glenoid inclination, as determined by the β angle, was significantly improved for the entire cohort ($P < .001$). Among the 18 patients with Favard type E2 or E3 glenoid morphology, glenoid inclination improved from 67° ± 7° to 81° ± 8° ($P < .001$). Postoperative range of motion and functional outcome scores including the American Shoulder and Elbow Surgeons score, Simple Shoulder Test score, Single Assessment Numeric Evaluation score, and visual analog scale score for pain significantly improved within the entire cohort ($P < .05$). No patients had evidence of baseplate loosening or failure of the glenoid component. Acromial stress fractures developed in 5 patients (11.4%), and 2 patients (4.5%) underwent a reoperation unrelated to the glenoid component.

Discussion and conclusion: Primary RSA with an augmented baseplate results in excellent short-term clinical outcomes and significant deformity correction in patients with advanced glenoid deformity. There were no complications related to the augmented baseplate or glenoid component. The rate of acromial stress fractures appears higher than typically reported and warrants further investigation.

This study was approved by the Thomas Jefferson University Institutional Review Board (no. 19D.732).

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Glenoid bone loss with deformity presents unique reconstructive challenges during reverse shoulder arthroplasty (RSA). Approximately 40% of patients undergoing primary RSA will have glenoid bone loss.[5,13] The pattern of glenoid-based bone loss can be variable, and often, more advanced shoulder pathology is associated with multiplanar glenoid deformity.[4,13] The location and extent of glenoid bone loss can significantly impact the position and fixation of the baseplate during RSA.[5] Eccentric reaming of significant glenoid retroversion may result in excessive bone loss, which may over-medialize the joint line and compromise fixation of the baseplate. Additionally, failing to address glenoid inclination may compromise the biomechanical stability of the baseplate,[6,7,17] resulting in prosthetic impingement[26] and potentially early loosening.[4,14]

Various strategies exist to manage glenoid bone loss and deformity during RSA. Structural bone grafts have demonstrated promising functional results with high rates of graft incorporation in several studies.[3,4,10,16] Boileau et al[4] reported complete radiographic incorporation in 94% of bone grafts with excellent deformity correction in patients with significant coronal- and axial-plane glenoid deformity using bony increased-offset RSA. Lorenzetti et al[16] reported similarly high rates of graft incorporation using a structural bone graft behind the baseplate of a lateralized glenosphere. However, other recent literature has reported graft resorption in 20%-25% of patients treated with a structural graft during RSA.[8,11] Augmented baseplates have also recently been used to address glenoid deformity, which potentially can avoid some of the complications encountered with a structural bone graft.[10,28]

The purpose of this study was to evaluate the early clinical and radiographic outcomes of an augmented baseplate during primary RSA in patients with significant glenoid deformity. We also sought to evaluate the early complications associated with augmented baseplates. Our hypothesis was that augmented baseplates would be associated with excellent clinical and radiographic outcomes with low rates of complications while also resulting in significant deformity correction.

Materials and methods

We performed a retrospective review to identify all patients who underwent primary RSA with an augmented baseplate (Tornier Perform +; Wright Medical, Bloomington, MN, USA) at a single institution. Patients who underwent primary RSA with an augmented baseplate (either half wedge or full wedge) performed by 1 of 6 fellowship-trained shoulder and elbow surgeons between November 2017 and March 2019 were included. Patients were excluded if they had a history of non-arthroscopic shoulder surgery, infection, neurologic etiology of shoulder pathology, or poor-quality radiographs or if they did not undergo a minimum of 1 year of follow-up including radiographic and clinical data. All procedures were performed using a deltopectoral approach. The decision to use either a half- or full-wedge augmentation was at the discretion of the treating surgeon. Glenosphere size, humeral tray offset, and polyethylene thickness were all based on intraoperative trialing and the preference of the treating surgeon. Three patients included in this study received an inlay humeral prosthesis (AltiVate Reverse; DJO Surgical, Austin, TX, USA) in an off-label manner. After application of our exclusion criteria, 26 patients were eliminated, leaving 44 patients for inclusion. We excluded 22 patients who were missing either clinical or radiographic follow-up, as well as 4 patients who had inadequate radiographs, which precluded accurate measurements.

Clinical data collection

Patient demographic characteristics, underlying primary diagnosis, range of motion, implant data, and intraoperative and postoperative complications were obtained from a retrospective review of the electronic medical record. Internal rotation was determined at the highest midline area of the back that could be reached and was converted to a 10-point scale.[27] Patient-reported outcome scores including the American Shoulder and Elbow Surgeons (ASES) score, Single Assessment Numeric Evaluation (SANE) score, Simple Shoulder Test (SST) score, and visual analog scale (VAS) score for pain were prospectively recorded preoperatively and at various time intervals postoperatively. Functional outcome scores at a minimum of 1 year postoperatively were used to assess differences compared with preoperative scores.

Radiographic data collection

Standardized plain radiographs, as well as advanced imaging (either computed tomography or magnetic resonance imaging), were used to evaluate and characterize glenoid morphology and various glenohumeral relationships. Computed tomography or magnetic resonance imaging was used to classify the primary glenoid deformity according to the Walch[2,29] or Favard[15] classification system, glenoid version, humeral head subluxation relative to the plane of the scapula,[20] and posterior bone loss for patients with Walch type B2 glenoids. Immediate preoperative radiographs of interest consisted of the true anteroposterior (Grashey) and axillary views, which were used to determine the global glenoid inclination as measured by the β angle,[4,18] the acromiohumeral distance (AHD),[12] and the lateral humeral offset

(LHO).[12] The same series of radiographs was reviewed within 3 months of surgery to assess for very early radiographic failure and determine overall deformity correction as measured by the β angle, AHD, LHO, and glenoid version.[8,9] The radiographic difference between these variables compared with preoperative measurements was used to calculate deformity correction. Postoperative radiographs at a minimum of 1 year were used to assess for acromial stress fractures, scapular notching,[26] and baseplate loosening or failure. Baseplate loosening or failure was defined as any noticeable change in position from prior radiographs either with or without radiolucency.

Statistical analysis

Descriptive statistics were determined and expressed as means, ranges, and percentages. Preoperative and postoperative clinical outcomes were compared using the Wilcoxon signed rank test, and differences in postoperative measurements were compared via the Mann-Whitney *U* test. Functional assessment was performed by grouping patients according to whether they achieved the minimal clinically important difference (MCID) and substantial clinical benefit (SCB) for the ASES or SST score.[24,25] All statistical analyses were carried out using SPSS software (version 26; IBM, Armonk, NY, USA). The α risk was set to .05 for all tests to estimate statistical significance.

Results

A total of 44 patients (23 women and 21 men) underwent primary RSA with an augmented baseplate, with a mean age of 72 ± 6 years at the time of surgery and a mean clinical follow-up period of 16.2 months (range, 12-27 months). A half-wedge augmentation was implanted in 15 patients, whereas a full-wedge augmentation was implanted in 29. The primary diagnosis was cuff tear arthropathy in 59.1% and primary osteoarthritis in 38.6%; 1 additional patient had a chronic anterior dislocation. Full-wedge augmentations were most commonly used in patients with type B3, E3, or C glenoids (88%), whereas half-wedge augmentations were implanted in 53% of patients with either type B2 or E2 glenoids. Full-wedge augmentations were used more commonly in patients with a primary diagnosis of cuff tear arthropathy (65%) and primary osteoarthritis (70.5%).

Early radiographic analysis demonstrated excellent coronal- and axial-plane deformity correction. Glenoid version for the entire cohort significantly improved from 18° ± 17° to 12° ± 9° ($P = .001$). Subgroup analysis performed only on those patients with Walch type B2, B3, or C glenoids (22 patients) demonstrated significant improvement from 28° ± 8° to 16° ± 8° ($P = .001$). Global glenoid inclination as measured by the β angle also significantly improved for the entire cohort from 73° ± 10° to 83° ± 8° ($P < .001$). Subgroup analysis performed only on those patients with Favard type E2 or E3 glenoids (18 patients) demonstrated significant improvement from 67° ± 7° to 81° ± 8° ($P < .001$) (Fig. 1). There was also a significant increase in the postoperative AHD (from 8.9 ± 4.9 mm to 34.0 ± 7.0 mm, $P < .001$) and the LHO (from 8.91 ± 5.23 mm to 12.73 ± 6.90 mm, $P = .002$) (Fig. 2). No patients had early (<3 months) radiographic failure.

Radiographic analysis at a mean of 14 months (range, 12-27 months) demonstrated no evidence of radiographic baseplate loosening or glenoid component failure. Scapular notching was not present in 25 patients (89.3%); 2 patients (7.1%) had grade 1 notching, whereas 1 patient (3.6%) had grade 2 notching.

Range of motion at a mean of 13 months (range, 12-27 months) was significantly improved across the entire cohort (Table I). Forward elevation significantly improved from 82° ± 34° to 140° ± 24° postoperatively ($P < .001$). Subgroup analysis of patients with Walch type B2, B3, and C glenoids and patients with Favard type E2 and E3 glenoids also demonstrated significant improvement in postoperative forward elevation ($P = .001$). Moreover, external rotation was significantly improved across the entire cohort from 19° ± 14° to 34° ± 10° postoperatively ($P < .001$). Similarly, subgroup analysis of patients with Walch type B2, B3, and C glenoids and those with Favard type E2 and E3 glenoids demonstrated significant improvement in postoperative external rotation ($P = .001$ and $P = .003$, respectively). Internal rotation for the entire cohort was significantly improved from 3.7 ± 1.9 points to 5.3 ± 2.5 points postoperatively ($P = .021$); however, when we performed subgroup analysis of patients with Walch type B2, B3, and C glenoids and those with Favard type E2 and E3 glenoids, the change in internal rotation was not significant ($P = .058$ and $P = .490$, respectively).

The ASES score improved from a mean of 35.7 ± 20 to 82.3 ± 17.9 ($P < .001$), the SST score improved from 2.9 ± 2.9 to 8.9 ± 2.2 ($P < .001$), the SANE score improved from 29.1 ± 20 to 82.1 ± 22.4 ($P < .001$), and the VAS pain score improved from 6.3 ± 2.5 to 0.9 ± 1.9 ($P < .001$) (Table II). Significant improvement was also seen across all outcome variables during subgroup analysis of patients with Walch type B2, B3, and C glenoids and patients with Favard type E2 and E3 glenoids ($P < .05$). In total, 93.5% of patients achieved the MCID and 90.3% achieved the SCB value for the ASES score. Additionally, 92.6% of patients achieved the MCID and 81.5% achieved the SCB value for the SST score.

A total of 14 postoperative complications (31.8%) occurred (Table III). Most notably, acromial stress fractures were observed in 5 patients (11.4%) (3 women and 2 men; mean age, 72.41 ± 5.86). Of the 5 patients with acromial stress fractures, 4 had either Favard type E2 or E3 glenoid morphology. We found no significant difference in mean age, sex, or body mass index of patients with stress fractures vs. patients without them ($P > .05$). Patients with stress fractures did not show significant improvement in global range of motion and had significantly decreased postoperative active forward elevation compared with

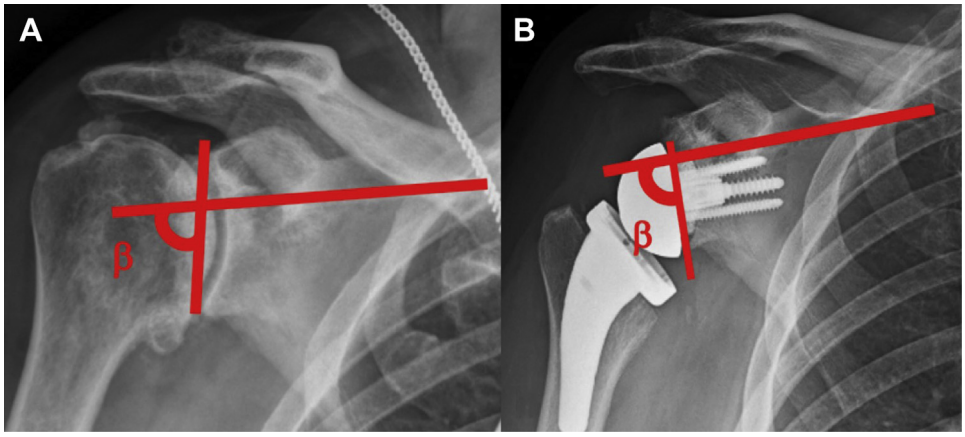

Figure 1 Anteroposterior radiographs in native shoulder (**A**) and after augmented reverse shoulder arthroplasty (**B**) demonstrating measurement of global glenoid inclination via β angle.

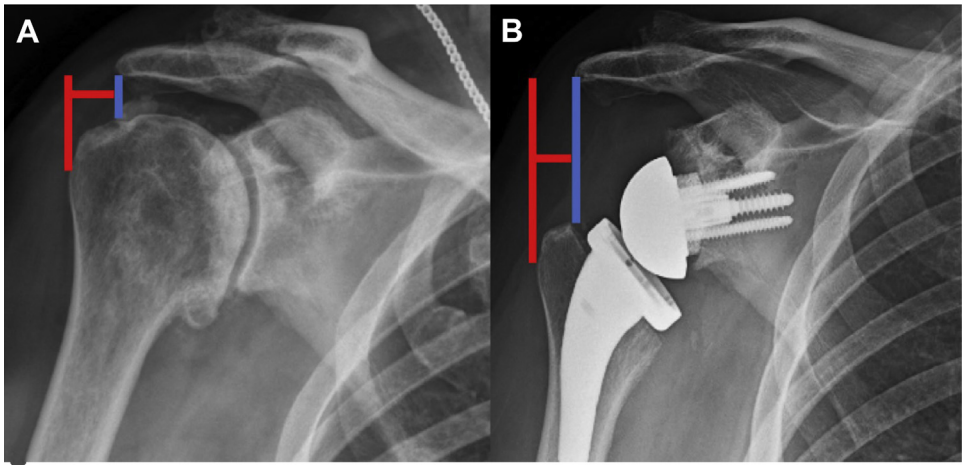

Figure 2 Anteroposterior radiographs of native shoulder (**A**) and after augmented reverse shoulder arthroplasty (**B**) demonstrating measurement of acromiohumeral distance *(blue lines)* and lateral humeral offset *(horizontal red lines)*. (*Vertical red lines* represent the lateral aspect of the greater tuberosity.)

Table I Comparison of preoperative and postoperative range of motion in patients undergoing reverse shoulder arthroplasty with augmented baseplate

Variable	No. of patients	Preoperative	Postoperative	*P* value
FE, °				
Full cohort	31	82 ± 34	140 ± 24	<.001
B2, B3, or C	14	93 ± 25	148 ± 15	.001
E2 or E3	15	80 ± 36	134 ± 27	.001
ER, °				
Full cohort	31	19 ± 14	34 ± 10	<.001
B2, B3, or C	14	13 ± 15	35 ± 8	.001
E2 or E3	15	22 ± 12	33 ± 11	.003
IR, points				
Full cohort	24	3.7 ± 1.9	5.3 ± 2.5	.021
B2, B3, or C	10	3.8 ± 2.0	5.4 ± 2.5	.058
E2 or E3	12	4.1 ± 2.1	5.0 ± 2.6	.49

FE, forward elevation; *ER*, external rotation; *IR*, internal rotation. Internal rotation as defined as the highest midline vertebral level reached converted to a 10-point scale.

Table II Comparison of preoperative and postoperative patient-reported functional outcome scores in patients undergoing reverse shoulder arthroplasty with augmented baseplate

Variable	No. of patients	Preoperative	Postoperative	*P* value
ASES score				
Full cohort	38	35.74 ± 20.0	82.3 ± 17.9	<.001
B2, B3, or C	20	38.8 ± 21.8	84.1 ± 18.4	<.001
E2 or E3	15	35.4 ± 17.0	77.9 ± 23.9	.002
SST score				
Full cohort	38	2.9 ± 2.9	8.9 ± 2.2	<.001
B2, B3, or C	20	3.7 ± 3.5	9.3 ± 2.3	.001
E2 or E3	15	2.5 ± 1.8	8.9 ± 2.2	.002
SANE score				
Full cohort	38	29.1 ± 20.0	82.1 ± 22.4	<.001
B2, B3, or C	20	28.1 ± 20.6	83.9 ± 23.3	<.001
E2 or E3	15	31.8 ± 21.8	74.3 ± 31.6	.011
VAS pain score				
Full cohort	38	6.3 ± 2.5	0.9 ± 1.9	<.001
B2, B3, or C	20	6.0 ± 2.8	0.9 ± 1.8	<.001
E2 or E3	15	6.4 ± 2.2	1.3 ± 2.5	<.001

ASES, American Shoulder and Elbow Surgeons; *SST*, Simple Shoulder Test; *SANE*, Single Assessment Numeric Evaluation; *VAS*, visual analog scale.

Table III Postoperative complication profile

Postoperative complication	No. of patients	% of cohort (N = 44)
Clinical		
Hematoma requiring aspiration	2	4.50
Periprosthetic fracture	2	4.50
Acromial or scapular spine stress fracture	5	11.40
Proximal median nerve neurapraxia	1	2.30
Superficial infection	2	4.50
Reoperation	2	4.50
Radiographic		
Glenoid component		
Baseplate loosening	0	0.00
Glenoid failure	0	0.00
Scapular notching		
None	25	89.30
Grade 1	2	7.10
Grade 2	1	3.60

patients without stress fractures (101° ± 36° vs. 145° ± 16°, $P = .013$). We observed no significant differences in either preoperative or postoperative functional outcome scores when comparing patients in whom stress fractures developed vs. patients in whom they did not (Table IV). Furthermore, when comparing patients with stress fractures vs. those without them, we found no statistically significant differences in both preoperative and postoperative LHO ($P = .601$ and $P = .501$, respectively), AHD ($P = .196$ and $P = .775$, respectively), and glenoid inclination ($P = .571$ and $P = .223$, respectively). Patients in whom stress fractures developed had less mean retroversion preoperatively (7° vs. 20°, $P = .017$) but similar version postoperatively (7° vs. 13°, $P = .053$) vs. those in whom stress fractures did not develop. Two patients in the cohort underwent a reoperation: one for a superficial infection and one for a periprosthetic fracture that occurred after a ground-level fall.

Discussion

The results of this study demonstrate excellent short-term clinical and functional outcomes in patients with significant glenoid deformity treated with primary RSA via an augmented baseplate. We observed significant improvement in overall glenoid inclination and version compared with preoperative measurements. No short-term complications related to the baseplate or glenoid component were observed in this series. However, we observed a higher-than-anticipated rate of acromial stress fractures (11.4%) in this series that was not explained by any differences in radiographic parameters or patient factors. Despite the high rate of acromial stress fractures, patients demonstrated very good clinical and functional outcomes.

Augmented baseplates are a relatively new technique to manage glenoid deformity during RSA. The limited current body of evidence supporting the use of metallic augmented baseplates is based on small series using 1 particular component.[10,19,28,31] Most recently, Virk et al[28] reported on 67 patients with Walch type B2, B3, or C glenoid morphology undergoing primary RSA with an 8° posterior augmentation. Patients in their series demonstrated excellent clinical and functional outcomes with a very low complication rate and no baseplate or glenoid component

Table IV Range of motion and functional outcome scores in patients with vs. without acromial stress fractures

Variable	Stress fracture	No stress fracture	*P* value
FE, °			
Preoperative	45 ± 39	88 ± 30	.028
Postoperative	101 ± 36	146 ± 15	.013
P value	.109	<.001	
ER, °			
Preoperative	14 ± 21	20 ± 14	.458
Postoperative	26 ± 11	35 ± 10	.142
P value	.18	<.001	
IR, points			
Preoperative	3.0 ± 1.2	3.8 ± 2	.511
Postoperative	6.0 ± 3.5	5.24 ± 2.5	.752
P value	.180	.049	
ASES score			
Preoperative	34.7 ± 10.0	35.9 ± 21.2	>.999
Postoperative	83.5 ± 8.7	82.1 ± 19.0	.476
P value	.043	<.001	
SST score			
Preoperative	2.6 ± 1.8	2.9 ± 3.1	.844
Postoperative	8.8 ± 2.2	8.9 ± 2.3	.614
P value	.042	<.001	
SANE score			
Preoperative	29.9 ± 15.5	29.0 ± 20.9	.947
Postoperative	58.7 ± 39.8	82.5 ± 22.3	.100
P value	.080	<.001	
VAS pain score			
Preoperative	5.7 ± 2.1	6.5 ± 2.5	.328
Postoperative	0.4 ± 0.7	1.0 ± 2.0	.917
P value	.043	<.001	

FE, forward elevation; *ER*, external rotation; *IR*, internal rotation; *ASES*, American Shoulder and Elbow Surgeons; *SST*, Simple Shoulder Test; *SANE*, Single Assessment Numeric Evaluation; *VAS*, visual analog scale.

failure. The subset of patients with Walch type B2, B3, and C glenoids in our series performed very similarly to the patients of Virk et al regarding improvement in range of motion and functional outcome scores. We reported nearly identical percentages of patients who achieved the MCID and SCB value for the ASES and SST scores. Two important differences distinguish our study: First, we also included patients with significant superior glenoid erosion (Favard type E2 or E3). Previous studies on the use of a superiorly augmented baseplate have demonstrated inferior outcomes compared with a posteriorly augmented baseplate[31] and higher rates of aseptic baseplate loosening.[19] Second, Virk et al did not evaluate postoperative deformity correction (coronal or axial plane); however, in their series, there were no differences in final range of motion or functional outcomes among the various glenoid types, despite Walch type C patients having 2 times the amount of preoperative retroversion as Walch type B2 patients.

The results of our study also compare favorably with the literature on structural bone grafting during RSA.[3,4,8,11,16] Boileau et al[4] used a trapezoidal graft from the humeral head to correct significant glenoid deformity. In a series of patients similar in age and glenoid morphology to our study patients, Boileau et al[4] reported excellent correction of glenoid inclination (measured by the RSA angle) in patients with type E2 or E3 morphology, in addition to axial-plane deformity in patients with Walch type B2 or C morphology. In our series, glenoid inclination as measured by the β angle improved by 14°, whereas Boileau et al[4] reported a 27° improvement in glenoid inclination as measured by the RSA angle. The correction of glenoid retroversion in patients with Walch type B2, B3, and C glenoids obtained in our series (12°) was similar to what was reported by Boileau et al[4] (10.5°). Structural bone graft has been associated with high rates of graft incorporation and excellent outcomes in some series[3,4,16]; however, other recent literature has reported graft resorption in 20%-25% of cases with high rates of baseplate failure and reoperation.[8,11]

Acromial stress fractures are an infrequent complication that is unique to RSA and can be associated with poor functional outcomes.[23] Acromial stress fractures are reported in anywhere from 1%-4% of patients following routine RSA.[1,21,32] The risk factors for the development of

acromial stress fractures after RSA are poorly understood; however, the most commonly identified is a history of osteoporosis.[22,30,32] Recently, Zmistowski et al[32] reported a 4.3% incidence of acromial stress fractures and identified greater preoperative center-of-rotation medialization as an independent risk factor. Limited evidence exists on acromial stress fractures in patients with significant preoperative glenoid deformity undergoing either concomitant bone grafting or augmented RSA. Lorenzetti et al[16] reported a 9% rate of acromial stress fractures in a retrospective series of 57 patients with significant glenoid deformity undergoing primary RSA with structural bone grafting. Our acromial stress fracture rate of 11.4% is higher than expected based on historical rates following routine RSA[1,21,32] but is similar to what was reported by Lorenzetti et al. Unlike the findings of Zmistowski et al, we were unable to identify any meaningful patient-related factors or radiographic relationships associated with an increased risk of acromial stress fractures, likely related to small patient numbers in our study.

This study has several limitations. The intention of our study was to focus on early outcomes and complications after RSA with an augmented baseplate; however, longer follow-up is necessary to understand the role of this technique in patients with advanced glenoid deformity. The retrospective nature of this study subjects it to possible bias, as does the relative percentage of patients lost to follow-up. In addition, these data reflect the early experience of several different surgeons using this particular component, which may introduce variability in technique and surgical philosophy. Furthermore, we did not include a control group of patients with similar glenoid morphology treated with standardized components, which may better identify outcomes or complications that are more unique to an augmented baseplate component. Another potential limitation was the reliance on plain radiographs for postoperative assessment of deformity correction and radiographic complications. Additionally, our subgroup analysis of patients with stress fractures is underpowered because of the small sample size and, therefore, limits our analysis of potential risk factors following RSA with an augmented baseplate.

Conclusion

Excellent short-term clinical and functional outcomes are associated with use of an augmented baseplate to address significant coronal- and axial-plane glenoid deformity during RSA. The augmented baseplate allows for significant multiplanar deformity correction, which appears comparable to the amount of correction obtained with structural bone grafting techniques. No augmented baseplate failures or loosening was observed in this series. The rate of acromial stress fractures appears higher than typically reported and warrants further follow-up.

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