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Structural glenoid allograft reconstruction during reverse total shoulder arthroplasty

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Background: Large glenoid defects present a challenge during primary and revision reverse total shoulder arthroplasty (RTSA) especially when humeral head autograft is not available as a bone graft source. The purpose of this study was to evaluate the clinical and radiographic outcomes of RTSA with concomitant structural allografting to reconstruct large glenoid defects.
Methods: From May 2008 to July 2016, 22 patients underwent primary or revision RTSA with structural glenoid allografting. Of 22 patients, 19 (86%) were available for a minimum 2-year clinical follow-up (average, 2.8 ± 1.3 years), and 17 of 22 (77%) were available for a minimum 1-year radiographic follow-up. Functional outcomes, range of motion, radiographic deformity correction, allograft incorporation, and complication rates were determined.
Results: From preoperatively to postoperatively, significant improvements in the average Simple Shoulder Test score (2 ± 2 preoperatively vs. 10 ± 8 postoperatively, $P = .002$), the average American Shoulder and Elbow Surgeons score (31 ± 19 preoperatively vs. 70 ± 25 postoperatively, $P < .001$), and average active forward elevation ($71° \pm 41°$ preoperatively vs. $128° \pm 28°$ postoperatively, $P < .001$) were noted. Coronal-plane radiographic correction was $29° \pm 12°$ as measured with the reverse shoulder arthroplasty angle ($P < .001$) and $14° \pm 11°$ as measured with the β angle ($P < .001$). Postoperatively, of 17 patients with a minimum 1-year radiographic follow-up, 14 (82%) had complete radiographic incorporation of the graft. Acromial fracture nonunions developed in 2 patients and loosening and migration of the baseplate were found in 2 patients, although no patients elected to undergo further surgery.
Conclusions: RTSA with allograft reconstruction of severe glenoid defects allows restoration of glenoid anatomy and leads to high rates of bony incorporation with low rates of glenoid loosening or requirement for revision. Structural allograft is an excellent alternative to autograft in revision RTSA to avoid graft-site morbidity.
Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Reverse total shoulder arthroplasty; glenoid bone loss; bone grafting; shoulder arthroplasty; shoulder replacement; allograft

Institutional review board approval was obtained from the University of Utah School of Medicine prior to initiation of this study (no. 101394).

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Glenoid vault defects can be extremely challenging to treat in the setting of reverse total shoulder arthroplasty (RTSA). Various surgical options exist including acceptance of incomplete baseplate seating, metallic

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augmentation, and bone augmentation (autograft or allograft).[2,4,5,8,19] The optimal method of treatment often depends on defect size, residual patient bone quality, primary or revision arthroplasty, and surgeon preference. Most clinical series reporting large structural grafting of glenoid defects have focused on autograft techniques from either the humeral head or iliac crest.[7,16,19] Very few series have reported on allograft reconstruction of large glenoid defects in the setting of RTSA.[6,9,10,12]

Glenoid bone defects are commonly encountered during RTSA. Klein et al[8] reported that 39% of patients had abnormal glenoid morphology at the time of RTSA, with 15% of glenoids requiring bone grafting. Restoration of the joint line is critical to tension the deltoid to maximize function and limit instability, as well as limit impingement, which can lead to scapular notching. Smaller glenoid defects can be effectively treated with commercially available augmented baseplates, whereas larger defects require custom implants.[2] Consequently, most larger defects are currently treated with structural bone grafting instead of metallic augmentation. Various graft sources are available including autograft (humeral head, iliac crest, or distal clavicle) or allograft. Most series have reported on the results of autograft as opposed to allograft reconstruction, although in revision arthroplasty, allograft is often the most readily available and least morbid graft source. Lorenzetti et al[10] reported on 5 patients undergoing femoral head allograft augmentation in the setting of RTSA. Jones et al[6] reported on the largest series, comprising 14 patients undergoing RTSA with allograft augmentation, and reported that grafts were fully incorporated in 41.7%, were partially incorporated in 25%, and did not incorporate in 13.8%. One allograft baseplate loosened, requiring revision RTSA. Ozgur et al[12] reported on 20 patients treated with femoral shaft or neck allografts for structural glenoid defects at the time of RTSA. Only 9 of 20 patients (45%) still had their grafts in place at a minimum of 1 year postoperatively. Finally, Lopiz et al[9] reported on 13 structural allografts with RTSA and noted that 12 of 13 (92%) healed. No studies have specifically reported on the amount of correction achieved with the graft comparing the initial postoperative baseplate position of the allograft RTSA constructs with the preoperative deformity.

The purpose of this study was to describe the short-term clinical and radiographic results of structural bone grafting using femoral head allograft in the setting of primary or revision RTSA. We hypothesized that structural bone grafting would result in significant improvements in range of motion and patient-reported outcomes with high rates of graft incorporation and low rates of revision.

Materials and methods

This was a retrospective study. The operative log of the senior author (R.Z.T.) from May 2008 to July 2016 was reviewed. We included patients who underwent primary or revision RTSA with concomitant structural glenoid bone grafting with femoral head allograft for severe glenoid erosion. We excluded patients who underwent RTSA using autograft reconstruction and patients with less than 2 years' follow-up. The surgeon made the decision to perform an RTSA with a structural graft based on the ability to correct baseplate inclination to at least the neutral tilt on a standing true anteroposterior radiograph of the shoulder and to within 10° of neutral version on an axillary radiograph without significantly reaming beyond 5 to 10 mm of glenoid bone stock to gain correction. The goal of reaming was to correct to 100% baseplate seating and to restore the joint line back to the native joint line. If these goals could not be achieved with reaming alone, then RTSA with structural bone grafting was selected. Bone grafting was not performed if only lateralization of the joint line was desired and reaming could achieve correction to the limits previously mentioned. A total of 22 eligible patients who met the inclusion criteria were identified and contacted for re-evaluation.

Operative protocol

In all cases, a deltopectoral approach was used. Both the Trabecular Metal RTSA system (Zimmer, Warsaw, IN, USA) (6 patients) and Aequalis Reversed Shoulder Arthroplasty system (Tornier, Bloomington, MN, USA) (13 patients) were used. In the setting of primary RTSA, the humeral head was cut using the cutting guide, and the humerus was prepared per the manufacturer's recommendations. In the setting of revision RTSA, the humeral head and stem were removed, and the remaining humeral shaft was then prepared using the manufacturer's recommendations. The glenoid component was exposed (either RTSA or anatomic total shoulder arthroplasty) and removed with osteotomes and the instruments associated with the implantation. At this point, the glenoid was assessed and the defect was decorticated with a high-speed burr and drilled using a small Kirschner wire. Approximately 10 to 15 perforations were made across the glenoid surface. The decision to use femoral head allograft in the primary cases was because of poor-quality humeral head bone subjectively assessed by the surgeon. In revision cases, allograft was used because of a lack of humeral head bone (Figs. 1 and 2).

After preparation of the glenoid, the central guide pin for the baseplate was placed at the appropriate height based on the inferior edge of the native glenoid. Both retroversion and inclination were corrected in an attempt to reduce retroversion to less than 10° and superior inclination to 0° based on the floor of the supraspinatus fossa (Fig. 3). Commercially available 3-dimensional planning software was not available during the study period and therefore could not be used. Coronal and sagittal images showing maximal deformity were available in the operating room during the cases, and restoration of version and inclination was attempted by viewing these images intraoperatively. If the defect was primarily central and superior, the femoral head allograft was then provisionally cut and shaped into the dimensions of the glenoid defect to restore the vault approximately back to its native size (Fig. 4). The graft was oriented such that the articular surface of the head rested against the glenoid and the cancellous surface of the head rested against the baseplate. The graft was perforated approximately 10 to 15 times with a Kirschner wire to aid in bony ingrowth. A slot was created in the inferior portion of the graft, and the graft was then slid over the previously placed central guide

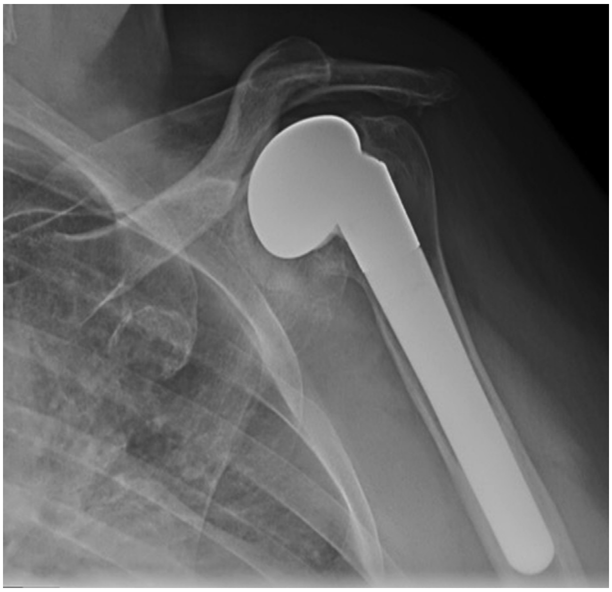

Figure 1 Failed hemiarthroplasty with superior glenoid erosion.

pin. At this point, the graft was fixated with multiple Kirschner wires (Fig. 5). In the case of a chronic anterior dislocation, the defect was primarily anterior; therefore, a wedge of femoral head was prepared after the dimensions of bone loss were measured. The graft was temporarily stabilized with Kirschner wires and

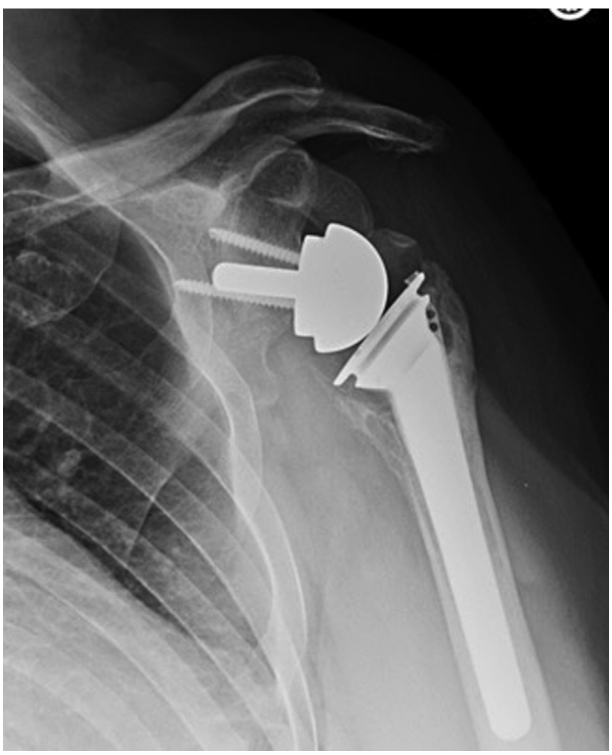

Figure 2 Healed structural glenoid allograft after revision of failed hemiarthroplasty and placement of reverse total shoulder arthroplasty with glenoid allografting.

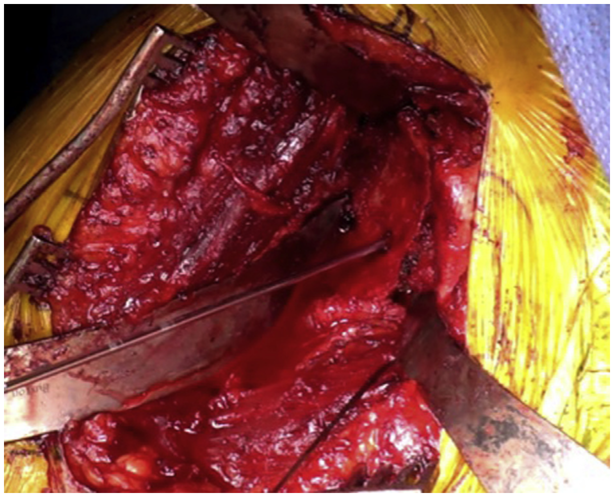

Figure 3 Exposed glenoid with baseplate central guide pin in place restoring version and inclination.

then definitively fixed with two 3.5-mm fully threaded cortical screws in lag fashion.

With the graft and central guide pin in place, the glenoid was prepared for the baseplate per the manufacturer's recommendations, including reaming and central-post drilling. A long-post (25 mm) baseplate was used in all cases to engage at least 5 mm of native bone. The baseplate was then impacted into place, and screws were placed through the baseplate and graft and into the native glenoid to fixate the graft, with placement of nonlocking screws first to compress the graft, followed by locking screws (Figs. 6 and 7). At this point, the remainder of the RTSA was performed.

Clinical data collection

For each patient, the following data were collected based on the preoperative documentation: operative side, side of dominance,

Figure 4 Femoral head allograft shaped to re-create glenoid defect.

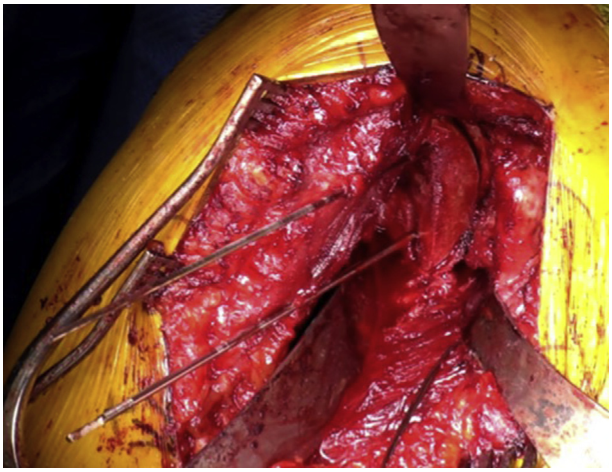

Figure 5 Femoral head allograft, with inferior slot, positioned over central guide pin and temporarily fixed with Kirschner wire.

sex, whether the patient had an active workers' compensation claim, whether the patient underwent a prior rotator cuff repair and whether this repair was performed through an open or arthroscopic approach, passive forward elevation, active forward elevation (AFE), external rotation in adduction, visual analog scale (VAS) pain score, Simple Shoulder Test (SST) score, and American Shoulder and Elbow Surgeons (ASES) score. For each patient, the following data were collected based on the intraoperative documentation: diagnosis, procedure, whether a constrained polyethylene liner was used, glenosphere size, glenoid baseplate peg length, and whether any intraoperative complications were noted. For each patient, the following data were collected at final follow-up: whether any postoperative complications had been encountered, whether the patient underwent revision, AFE, external rotation in adduction, VAS pain score (0, no pain; 10, severe pain), SST score, ASES score, VAS satisfaction score (0, not satisfied at all; 10, very satisfied), whether the patient would undergo the procedure again if given the chance, and length of follow-up.

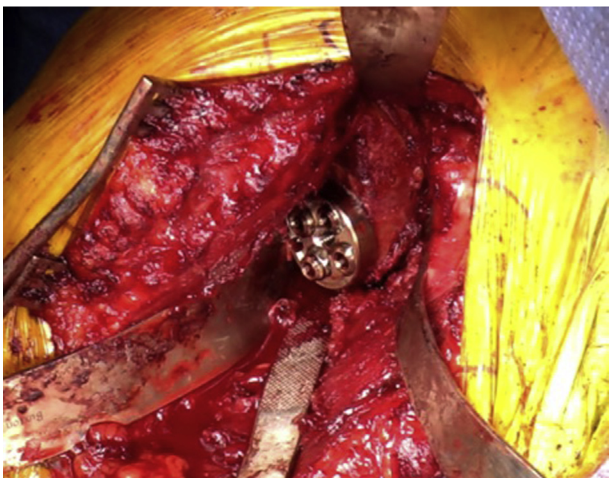

Figure 6 Final baseplate position compressing allograft into position.

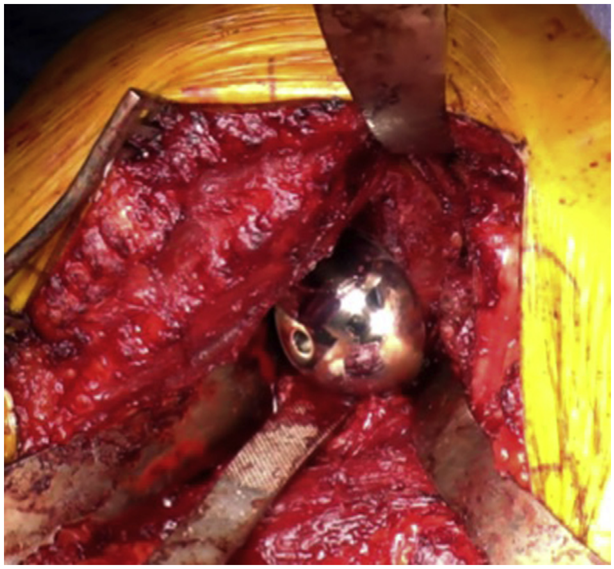

Figure 7 Final glenoid construct with baseplate, glenosphere, and allograft.

Radiographic evaluation

Preoperative radiographs and final follow-up radiographs were independently evaluated by an attending surgeon (P.N.C.) fellowship trained in shoulder and elbow surgery who did not perform any of the index procedures. In patients with rotator cuff arthropathy who underwent primary RTSA, the Favard classification was used to classify the glenoid deformity.[14] On the Grashey anteroposterior views preoperatively and at final follow-up, the β angle and reverse shoulder angles were measured as previously described.[11,14] A β angle of 90° indicates neutral inclination, with a β angle greater than 90° denoting inferior inclination and a β angle of less than 90° denoting superior inclination. Conversely, a RSA angle of greater than 90° denotes superior inclination and an RSA angle of less than 90° denotes inferior inclination. The allograft was evaluated on final follow-up radiographs for incorporation or resorption. The baseplate was evaluated on final follow-up radiographs for migration of subsidence. Scapular notching was graded on final follow-up radiographs using the Nerot-Sirveaux system.[15]

Statistical methods

Descriptive statistics were calculated and are presented as mean ± standard deviation (range). Data normality was evaluated using the Kolmogorov-Smirnov test. Preoperative and postoperative variables (SST score, ASES score, AFE, active adducted external rotation, RSA angle, and β angle) were compared using paired statistical tests as appropriate depending on data normality (paired Student *t* tests and Wilcoxon signed rank tests). The postoperative RSA angle, postoperative β angle, and change in the RSA angle and β angle from preoperatively to postoperatively were compared between patients with a stable baseplate and those with a loose baseplate at final follow-up. All analyses were conducted in Excel (version 16; Microsoft, Redmond WA, USA) and SPSS (version 25; IBM, Armonk, NY, USA).

Table I Preoperative and final follow-up data

Variable	Preoperative	Final follow-up	*P* value
SST score	2 ± 2	10 ± 8	.002
ASES score	31 ± 19	70 ± 25	<.001
VAS pain score	NA	1.4 ± 2.2	NA
VAS function score	NA	4.7 ± 4.2	NA
VAS satisfaction score	NA	6.8 ± 4	NA
AFE, °	71 ± 41	128 ± 28	<.001
AER, °	23 ± 14	27 ± 12	.368
RSA angle, °	114 ± 12	86 ± 9	<.001
β angle, °	81 ± 9	94 ± 8	<.001

SST, Simple Shoulder Test; *ASES*, American Shoulder and Elbow Surgeons; *VAS*, visual analog scale; *NA*, not available; *AFE*, active forward elevation; *AER*, active adducted external rotation; *RSA*, reverse shoulder arthroplasty.
Data are presented as mean ± standard deviation.

Results

Of the 22 patients who met the inclusion and exclusion criteria, 3 were lost to follow-up. The remaining 19 patients all had patient-reported outcomes collected at an average of 2.8 ± 1.3 years (range, 2-7 years), providing an 86% rate of follow-up. Of 22 patients, 17 (77%) had radiographs at a minimum of 1-year follow-up, with an average period of 2.7 ± 1.3 years (range, 1.3-7 years) since surgery. The mean age of the 19 patients included in this study was 69 ± 12 years (range, 46-91 years), and 10 of 19 (53%) were women. The indications for RSA varied, with 2 patients having chronic dislocations with glenoid bone loss, 5 having rotator cuff tear arthropathy with severe glenoid deformity, 3 undergoing revision of a cement hemiarthroplasty spacer placed for the treatment of periprosthetic sepsis, and 9 undergoing revision of a failed arthroplasty (failed RTSA in 1, failed anatomic total shoulder arthroplasty in 3, and failed hemiarthroplasty in 5). Thus, 12 of 19 (63%) underwent revision replacements. Preoperatively, according to the Favard classification, of the 5 patients with rotator cuff tear arthropathy, 2 had type E1 glenoids and 3 had type E3 glenoids.

Intraoperatively, all patients underwent a deltopectoral approach with placement of an RSA with a femoral head allograft on the glenoid. Regarding the implants, 6 patients (32%) underwent placement of a Zimmer Trabecular Metal RSA and 13 patients (68%) underwent placement of a Tornier Aequalis Reversed II Shoulder Arthroplasty. In 18 of 19 cases (95%), a nonconstrained polyethylene component was placed. In 14 cases, a 36-mm glenosphere was used, whereas in 5 cases, a 42-mm glenosphere was used. In all cases, a 25-mm baseplate post was used. No intraoperative complications occurred.

From preoperatively to postoperatively, significant improvements in the SST score, ASES score, and AFE were noted ($P = .002$, $P < .001$, and $P < .001$, respectively) (Table I). Active adducted external rotation did not significantly change. All patients stated that they would undergo the surgical procedure again if given the chance.

Average coronal-plane correction was 29° ± 12° (range, 6°-45°) as measured with the RSA angle ($P < .001$) and 14° ± 11° (range, 3°-35°) as measured with the β angle ($P < .001$). Postoperatively, of 17 patients with a minimum 1-year radiographic follow-up, 14 (82%) had complete radiographic incorporation of the graft, 2 (12%) had radiographic evidence that the graft did not incorporate, and 1 (6%) had evidence of nearly complete resorption of the graft. Postoperatively, by use of the Nerot-Sirveaux classification, 3 patients (18%) did not have any notching, 9 (53%) had grade 1 notching, 2 (12%) had grade 2 notching, and 3 (18%) had grade 4 notching.

No revision procedures were performed. Several patients had complications, including 2 patients with acromial fractures that progressed to nonunion and 2 patients with loosening and migration of the baseplate (1 of whom was also 1 of the patients with acromial nonunion). Both patients with baseplate migration had grafts that did not incorporate. Radiographically, the average postoperative RSA angle, postoperative β angle, change in RSA angle from preoperatively, and change in β angle from preoperatively for the patients with baseplate loosening vs. those without loosening were 95° vs. 83°, 95° vs. 92°, 24° vs. 29°, and 3° vs. 13°, respectively. The group with baseplate loosening had significantly less correction in the RSA angle ($P = .03$) and β angle ($P = .003$) than the group with a stable baseplate. All patients with complications declined further surgery.

Discussion

Treatment of severe glenoid defects in RTSA is challenging, and data regarding the use of allografts for reconstruction are limited. In this study, we have shown that large structural allografts in the setting of primary and revision RTSA have a high rate of complete bony incorporation (82%). RTSA with allografting can correct severe superior and central erosions with up to 45° of correction in inclination with low complication and revision rates. Range of motion and final clinical outcomes are comparable to those in prior series reporting clinical and functional outcomes after primary RTSA without bone grafting.[13,17]

Most series reporting outcomes of correction of glenoid deformity using bone graft have used autograft.[1,3,7,16,18,19] Very few articles have reported the outcomes of structural glenoid bone grafting using allograft for severe glenoid deformity at the time of RTSA.[3,5,6,8,9,12,18] In the series of Wagner et al,[18] Ernstbrunner et al,[3] Klein et al,[8] Lorenzetti et al,[10] and Jones et al,[5] fewer than 5 procedures were performed using structural allograft in each, and in many of the series, it was difficult to separate the clinical and structural results of the autograft and allograft cases.

Three series have reported outcomes of a larger number of patients in whom structural allografts were used to treat large glenoid defects at the time of RTSA.[6,9,12] Jones et al[6] originally reported on a series of 44 patients who underwent bulk structural bone grafting for glenoid defects in the setting of RTSA, with 14 of these patients undergoing femoral head allografting. In the allograft cohort, the ASES score improved to 72 and flexion improved to 116°, with no improvements in external rotation; all of these findings are directly comparable to those in our cohort. In terms of radiographic findings, 41.7% of grafts were fully incorporated, 25% were partially incorporated, and 33.3% did not incorporate, which was slightly worse than our currently reported results.

Ozgur et al[12] reported on 20 patients undergoing RTSA with structural allograft and found an even worse healing rate, with only 9 of 20 grafts (45%) still in place at final follow-up. Moreover, 70% of patients required further surgical treatment after their glenoid allograft procedure. This group of patients was much more complex than the cohort of Jones et al, with an average of 3.9 procedures prior to allografting, and this may be a reason for the sobering results. Ozgur et al also used a mix of femoral shaft and femoral neck allografts and concluded that femoral shaft allografts fare very poorly, with only 1 of 8 (12.5%) surviving; therefore, if allograft is selected, the femoral head or neck is recommended. The use of femoral shaft allografts in the study of Ozgur et al may be another reason for the differences between their healing rate and that of Jones et al.[6]

Lopiz et al[9] recently reported on 13 patients undergoing structural allografting for severe glenoid erosion with RTSA. Tibial plateau allograft was used in 11 cases, whereas proximal femoral allograft was used in 2. The technique used was similar to a previously described technique harvesting iliac crest autograft with RTSA.[7] Of 13 patients, 12 (92%) had confirmed radiographic allograft incorporation determined by computed tomography (CT) scans. No study to date has clearly documented the severity of glenoid erosion requiring grafting or the amount of correction obtained using allograft in these severe cases. Our data would support that correction in inclination up to 45° can be obtained using the currently described technique. In addition, our data support that lower degrees of correction of inclination may be associated with baseplate loosening.

Limitations include that this was a retrospective review of a small series of patients. Nevertheless, this is one of the largest series of allograft reconstructions of the glenoid with RTSA. Healing and correction of version, inclination, and joint line lateralization were based on radiographs as opposed to CT scans and therefore may not be as accurate as those in prior studies using CT. Only short-term (2-year minimum) clinical follow-up was obtained and graft collapse or baseplate loosening could occur at a later point, although changes would likely have occurred prior to this time point if the graft did not heal.

Conclusion

RTSA with allograft reconstruction of severe glenoid defects allows restoration of glenoid anatomy and leads to high rates of bony incorporation with low rates of glenoid loosening or requirement for revision. RTSA with allografting can correct severe superior and central erosions with up to 45° of correction in inclination. Structural allograft is an excellent alternative to autograft in revision RTSA to avoid graft-site morbidity.

Disclaimer

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