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Glenoid reconstruction with autologous humeral head for glenoid dysplasia in reverse shoulder arthroplasty

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Reverse total shoulder arthroplasty (rTSA) is one management option that has been successful for treating glenohumeral arthritis with and without rotator cuff tears.[1,3,6,12,16,19,20] Initially used exclusively for rotator cuff tear arthropathy, rTSA indications have expanded to include pseudoparalysis caused by irreparable rotator cuff tears, immunologic arthritis, proximal humerus fractures, failed shoulder arthroplasty, and glenohumeral arthritis with substantial glenoid bone loss.[7,9,11,15] Although initial contraindications for the procedure included insufficient glenoid bone stock, this has become a relative contraindication with better understanding of glenoid reconstruction.

The management of glenoid bone loss is particularly challenging in the setting of rTSA. Drake et al[5] noted that severe glenoid bone erosion was considered a contraindication owing to insufficiency stock for baseplate fixation. High complication rates have been associated with rTSA and severe glenoid wear.[14,16] The most common complications of rTSA and glenoid bone loss include glenosphere malpositioning, component instability, scapular notching from prosthesis impingement, pain, loss of function, decreased range of motion, and arthroplasty failure. In the setting of severe glenoid wear patterns, component malpositioning can lead to excessive retroversion. In turn, alteration of the balanced forces of the shoulder may result in clinical dysfunction. Shapiro et al[16] performed a cadaveric study looking at shoulder forces with glenoid components in neutral position as well as in 15 degrees of retroversion. Force changes were noted in the retroverted group that predisposed them to glenoid loosening and wear.

The Walch classification, later expanded in 2016 by Bercik et al,[2] described glenoid bone loss seen in osteoarthritic shoulders as a method of quantifying resultant abnormal glenoid morphology.[19] The severity of the deformity was subdivided to provide reproducible understanding of the pathology and potentially aid in devising appropriate treatment plans. Walch B2 and B3 glenoids demonstrate acquired posterior bone loss, and Walch C demonstrates severe retroversion of the glenoid of > 25° and the result of glenoid dysplasia (Fig. 1).[16] Walch B3 and C glenoids are more challenging because of both substantial glenoid retroversion and medialization.

Reports of glenoid bone grafting during rTSA have mixed results. Namdari et al retrospectively reviewed 44 patients who underwent structural allografting for bone loss with rTSA with a minimum of 1-year follow-up. They concluded that this procedure yielded higher than previously reported baseplate looseing.[8] Conversely, Walch et al examined a similar cohort at 2 years both radiographically and clinically and found no evidence of baseplate loosening or graft failure.[10] Variability in graft selection and technique may be reasons for disparate results.[13,17] Boileau et al[4] described their technique for increasing glenoid offset and correction of glenoid dysplasia in the setting of shoulder arthroplasty. Angled bony-increased offset-reserve shoulder arthroplasty used humeral head autografting with great success to both lateralize and correct severe dysplasia of the glenoid. The purpose of this manuscript is to describe our preferred technique to manage glenoid dysplasia using humeral head autograft for single-stage glenoid bone grafting in primary rTSA. Unique to our technique is the combination of preoperative computed tomography (CT) planning with utilization

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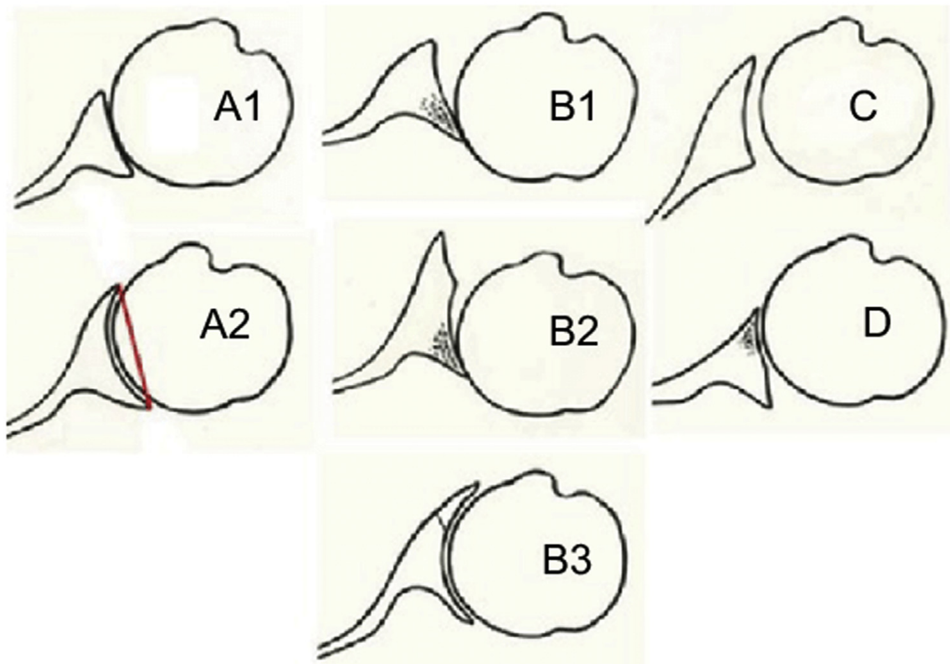

Figure 1 The modified Walch Classification of glenoid morphology. (**A1**)Centered humeral head with minor erosion; (**A2**) centered humeral head, major central erosion; (**B1**) posterior subluxated head without bony erosion; (**B2**) posterior subluxated head, posterior erosion with biconcavity of the glenoid; (**B3**) monoconcavity with retroversion > 15 degrees; (**C**) dysplastic glenoid with at least 25° of retroversion regardless of erosion; (**D**) glenoid anteversion and/or anterior subluxation. Reprinted through Creative Commons Attribution-Noncommercial 4.0 International.

of an entire humeral head autograft fixated through baseplate compression.

Technique and methods

Preoperative planning

Preoperative imaging, consisting of anterior-posterior and axillary radiographs (Fig. 2, *A* and *B*), as well as a CT scan (Fig. 3) was obtained. A review of these images revealed a Walch type C glenoid, with approximately 49° of retroversion. The CT images were uploaded to a preoperative planning software program (TRUMATCH, Rayhnam, MA, USA). This system allows optimal virtual placement of the glenoid baseplate and bone graft using 2-dimensional (Fig. 4) and 3-dimensional images (Fig. 5).

Surgical technique (Supplementary Video S1)

A standard deltopectoral approach is used. The anterior humerus is exposed. When necessary, a biceps tenodesis is performed. A subscapularis peel is preferred although a tenotomy could be performed. The subscapularis tendon and capsule are divided from their insertion on the lesser tuberosity and a traction suture is placed.

The proximal humerus is circumferentially exposed. Any remaining humeral articular cartilage is removed with a motorized barrel bur, and punctate bleeding is created (Fig. 6, *A*). Care is taken to avoid removal of excessive subchondral bone. Component system variability may influence the osteotomy. In cases of a very small humeral head, a free-hand cut may be performed. If the head is large, an entry hole is made in the proximal humerus directly above the humeral diaphysis. After humeral diaphyseal preparation, guides may be attached for osteotomy. Once osteotomized, the humeral head autograft is protected on the back table.

A protector plate is placed on the resected humeral surface to safeguard the bone during retraction for glenoid exposure. A lamina distractor is placed between the glenoid and humeral protector plate. With the humerus distracted laterally and the axillary nerve well protected by placing a finger between the capsule and the nerve, the well-visualized inferior capsule is divided to the 9:00 position of the glenoid. Periarticular soft tissue releases are performed to circumferentially expose the glenoid (Fig. 6, *B*). Owing to the substantial retroversion, it will be challenging to have a perpendicular, *en face* view of the glenoid. If a coracoid-based patient-specific guide has been fabricated from preoperative planning, the coracoid is exposed as well. The glenoid defect is prepared by gently decorticating the eburnated bone to create a bleeding surface. Either the glenoid base plate or patient-specific guide is used to insert the guide pin eccentrically into the glenoid articular surface. The guide pin should exit just anterior to the scapular body. A small portion of the noneroded, anterior glenoid may be prepared with a circular power reamer. A cannulated drill stop then creates the center hole.

The graft is fashioned from the resected humeral head (Fig. 6, *C*). It may be preferable to use the portion of the humeral head that corresponds to the glenoid defect. The graft is contoured to fit within the glenoid defect and restore glenoid version and/or inclination. The graft should be large enough peripherally that it can be provisionally secured with guide pins and proud enough laterally that excellent compression and baseplate support will be achieved (Fig. 6, *D*). A guide pin is placed through the graft and into the center drill hole in the glenoid. The graft is reamed for the baseplate (Fig. 6, *E*), then drilled for the central base plate hole (Fig. 6, *F*). The glenoid baseplate with an extended central post is impacted so that is sits securely on the paleoglenoid and compresses the bone graft. Peripheral screws are placed, through and outside the graft, as needed (Fig. 6, *G*). The definitive glenosphere is attached to the metaglene. The humeral portion of the procedure is

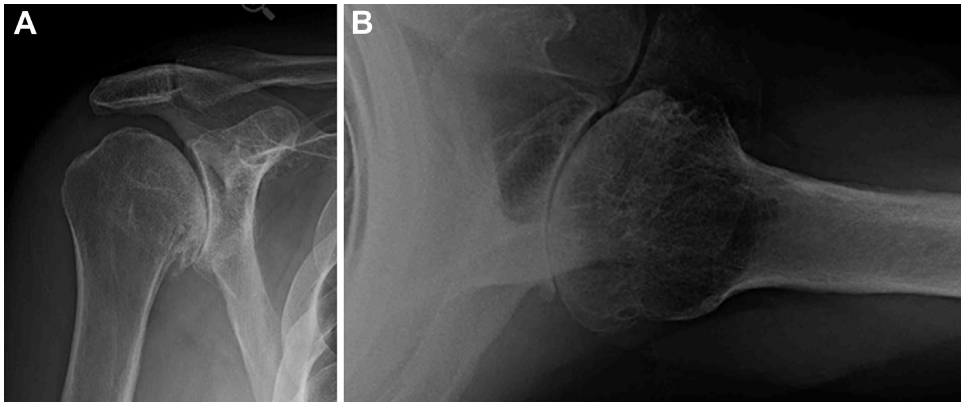

Figure 2 (**A** and **B**) Preoperative true anterior-posterior and axillary radiographs of a right shoulder demonstrating glenohumeral arthritis with a Walch Type C glenoid morphology.

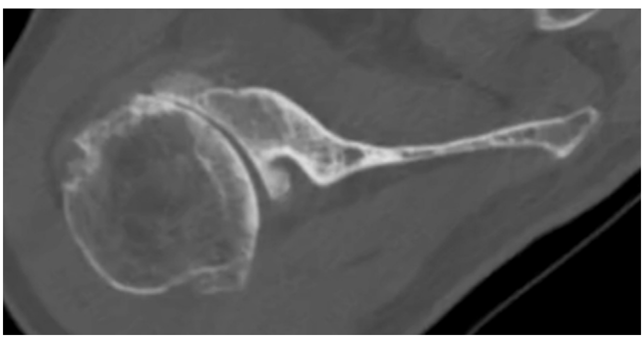

Figure 3 Preoperative axial CT scan of a right shoulder demonstrating excessive posterior glenoid wear. *CT*, computed tomography.

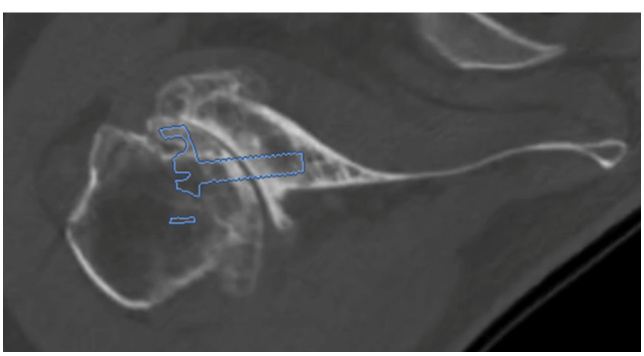

Figure 4 Axial CT scan with superimposed glenoid baseplate for positioning optimization. *CT*, computed tomography.

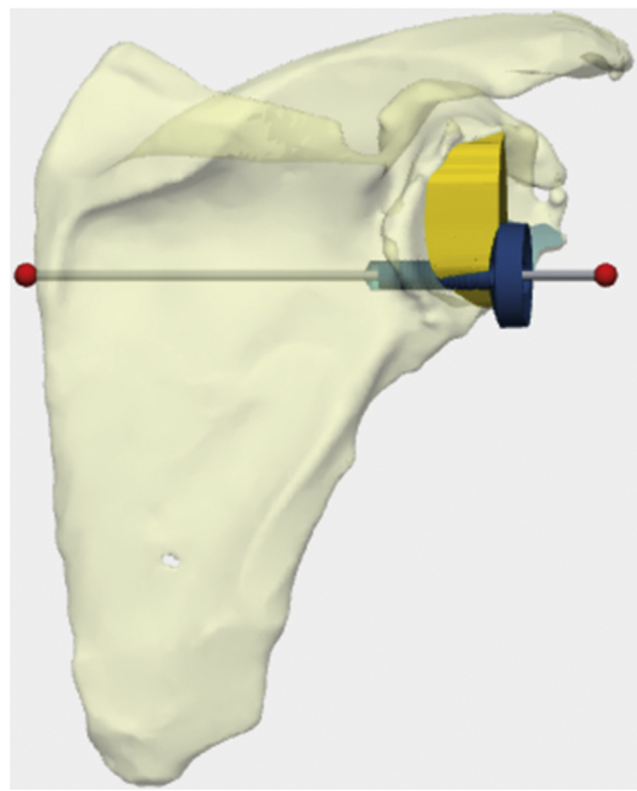

Figure 5 Posterior view from 3D imaging software program. Glenoid baseplate with extended central post traversing the graft (yellow) and native glenoid. *3D*, 3-dimensional.

completed followed by subscapularis management and wound closure.

Postoperative management and results

A sling with abduction pillow is placed. Radiographs are obtained at the first office visit approximately 2 weeks postoperatively, then at 6 weeks, 3 months, and yearly. The sling is removed at 2 weeks, and full, unrestricted range of motion is allowed.

Preoperative retroversion of 49° was corrected to approximately 18° degrees. Postoperative radiographs (Fig. 7, *A* and *B*) at 1 year demonstrate complete incorporation of the graft without evidence of baseplate loosening. Yearly follow-up with radiographing evaluation is recommended thereafter.

Discussion

Glenoid bone loss presents unique challenges when performing rTSA.[5] Failure to recognize the significance of the bone loss may result in unsatisfactory outcomes because of persistent pain, loss of motion, component instability, or prosthesis loosening. Structural bone grafting provides a biologic alternative for patients with deficient glenoid bone stock.

Glenoid bone graft with humeral head autograft for primary total and reverse shoulder arthroplasty has demonstrated

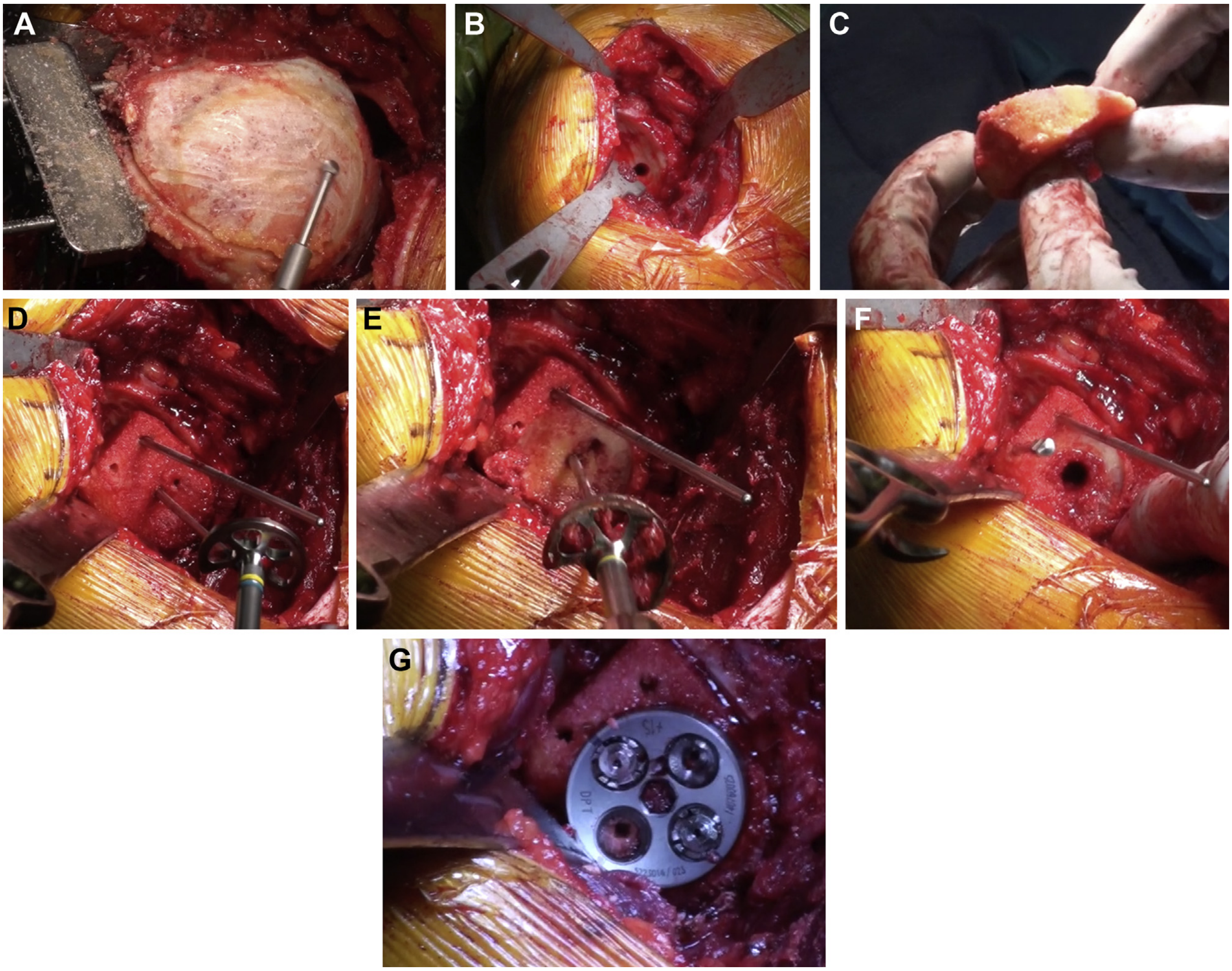

Figure 6 (**A**) Preparing humeral head with a high speed bur. (**B**) Optimizing glenoid exposure through obtaining perpendicular access to the glenoid. (**C**) Humeral head graft graft shaped to fit the glenoid defect. (**D**) Graft positioned in the glenoid and secured with the superior pin. The inferior pin is traversing the graft and entering the previously drilled center hole. (**E**) Reaming the autograft to accept the glenoid baseplate. The superior pin is positioned to avoid the reamer. (**F**) The humeral head graft is reamed and the central hole is drilled for the baseplate. (**G**) The glenoid baseplate is secured with peripheral screws.

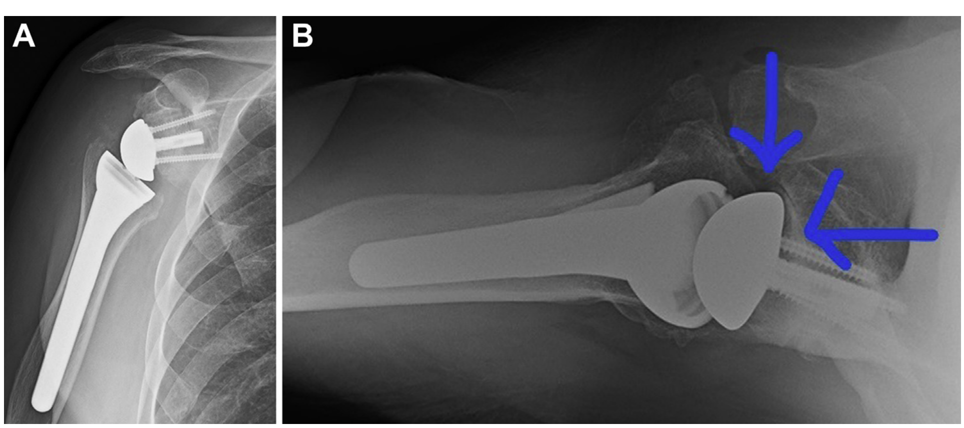

Figure 7 (**A** and **B**) Postoperative anterior-posterior and axillary radiographs demonstrating appropriate component positioning with correction of the glenoid dysplasia. The ← demonstrate the bone graft.

Table 1
Pearls and pitfalls.

Pearls	Pitfalls
1. Prepare humeral head before osteotomy	Excessive humeral head or bone removal.
2. Excellent exposure and capsular releases to allow perpendicular access to the glenoid	Poor glenoid exposure, particularly posteriorly may force pin placement off target
3. Prepare glenoid defect with high speed bur or drill bit	Insufficient humeral head graft (humeral head cyst, deformity, avascular necrosis)
4. Contour graft to fit within glenoid defect	A baseplate with central post or screw that does not have secure fixation in the native glenoid
5. Oversize graft to allow peripheral fixation with K-wires or screws	
6. Using preoperative planning and/or patient specific guides may improve accuracy of guide pin placement	

promising results to date. Tashjian et al[18] reported on 14 patients who underwent primary rTSA with concomitant humeral head autografting for glenoid deficiency. At an average of 2.6-year follow-up (range, 2.0-5.4 years), mean inclination correction was 19° ± 12° (range, 3°-35°). There was 100% radiographic graft incorporation, and 13 of 14 (93%) of the baseplates were stable. Global improvement was seen in motion and patient-reported outcomes. One of the largest series using humeral head autografting was reported by Boileau et al[4] in their description of the bony-increased offset-reserve shoulder arthroplasty. At a mean follow-up of 36 months (range 24-81 months), 54 patients underwent glenoid correction for either E2/E3, B2/C, or combined vertical and horizontal wear patterns. Inclination correction in the E2/E3 group improved from 37° (range, 14° to 84°) to 10.2° (range −28° to 36°, $P < .001$). Among B2/C glenoids, retroversion improved from −21° (range, −49° to 0°) to −10.6° (−32° to 4°, $P = .06$). They reported complete radiographic incorporation of the graft in 51 of 54 (94%). Of the 3 that did not incorporate, there was 1 infection and 2 cases of aseptic baseplate loosening.

In some cases, such as revisions after primary shoulder arthroplasty, the humeral head is not available. In other circumstances after proximal humeral fractures or if large humeral head cysts are present, the humeral head may not be a satisfactory graft source. Chalmers et al reported on the outcomes of 19 patients who underwent structural femoral head allografting with rTSA.[13] At a minimum of 2-year clinical follow-up, they noted high rates of bony incorporation and low rates of loosening. Furthermore, improvement was found in American Shoulder and Elbow Surgeons scores, Simple Shoulder Test scores, and forward flexion and coronal plane motion. Norris et al used a variety of allograft sources in 20 patients (24 surgeries) for their glenoid vault reconstruction.[12] Eight allograft femoral shafts, 11 allograft femoral neck/head, and 5 allograft proximal humerus were performed. The procedure was considered successful if there were 12 months of clinical and radiographic follow-up without subsequent surgical removal of the graft or radiographic failure. At an average of 24-month follow-up, 7 of the femoral shaft allografts were deemed to have failed. It was often noted in revision surgery that graft was cracked where peripheral screws had been drilled. Paul et al[13] performed a large meta-analysis consisting of 11 studies and 393 patients examining both autograft and allograft techniques. Their analysis demonstrated glenoid bone grafting during primary rTSA results in excellent early-term clinical outcomes, low complication and revision rates, and high rates of graft union across both graft options. Other considerations include the preference of single- versus two-staged grafting procedures and eccentric versus concentric grafting.[10,13] The work of Boileau et al,[4] Chalmers, and others have demonstrated good to excellent outcomes with both autografting and allografting of glenoids with excessive (>25°) wear.[17,18] However, this degree of success has not been reported consistently. Namdari et al retrospectively reviewed 44 patients who underwent rTSA with structural bone grafting for glenoid bone loss.[8] Thirty seven patients underwent primary rTSA and 7 had revision rTSA. Graft resorption was found in 11 of 44 patients (25%), and radiographic failure was found in 11 of 44 patients (25%) at a median of 8 months (range 3-51 months). Baseplate failures were associated with anteverted glenoids (11° correction in anteversion in failures vs. 0° in nonfailures) and larger degrees of retroversion (−26° vs. −15°, [$P = .06$]). Nevertheless, improvement in postoperative forward flexion, American Shoulder and Elbow Surgeons scores, SST scores, and SANE scores were noted. Baseplate failure was associated with graft resorption, more retroversion correction, and worse Single Assessment Numeric Evaluation scores. Their results highlight higher clinical failure rates than previously reported with structural grafting.

The surgical technique presented here demonstrates the authors' preferred method for performing glenoid bone grafting and single-stage rTSA in the setting of a glenoid dysplasia. The describing author (PF) has performed approximately 75 cases as described previously with excellent success. To his knowledge, there are no known graft failures within that cohort over a 5-year period of performing this technique. In time, a formal outcome article may be warranted. The technique also may be applicable for Walch type B2, B3, or C glenoids. Some tips for successful completion of the procedure include optimizing glenoid exposure through systematic capsular releases, proper graft contouring for optimal compression, preparing the glenoid for biologic incorporation, and using a base plate with a central post or screw that traverses both the graft and most of the native glenoid (Table I). Several components of the describe technique make this procedure unique. Preoperative 3-dimensional CT planning software was used to allow for optimal preparation of the graft and baseplate placement. The whole humeral head was incorporated to allow for lateralization and provide maximal baseplate coverage. Finally, the graft was fixated to the native glenoid and maintained in position through the compression of the baseplate stem. Cortical and locking screws were placed through the baseplate and graft into the native glenoid; however, fixation outside of the baseplate was not required.

The authors recognize that the optimal treatment for the management of severe glenoid dysplasia in the setting or rTSA is unknown. Preoperative recognition of the pathology and imaging evaluation is paramount to minimize intraoperative and postoperative complications. Humeral head autografting offers several advantages including low donor-site morbidity, low relative cost, and flexibility needed to simultaneously correct posterior and superior glenoid defects.[17]

Disclaimer

Paul Favorito, MD: I am a consultant for DePuy Synthes. The video that I narrated shows DePuy Synthes products. Sean Mc

Millan, DO: I am a consultant for DePuy Synthes, however I do not use the pre-op planning system described in the article and did not receive any financial benefit or gain from this article.

The other author, their immediate family, and any research foundation 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.

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Patient consent

Obtained.

Supplementary data

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