Autografting for B2 Glenoids

Journal of Shoulder and Elbow Arthroplasty
Volume 3: 1–10

DOI: 10.1177/2471549219865786
journals.sagepub.com/home/sea
SAGE

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Abstract

The Walch B2 glenoid is characterized by a biconcave glenoid deformity, acquired glenoid retroversion, and posterior subluxation of the humeral head. Surgical reconstruction of the B2 glenoid is often challenging due to the complexity of the deformity. Bone graft augmentation using humeral head autograft is a valuable adjunct to anatomic total shoulder arthroplasty in the B2 glenoid, particularly in the young, highly active patient with severe glenoid retroversion (>25°–30°). Although this technique affords the ability to correct glenoid version and simultaneously enhances glenoid bone stock, it is technically challenging. The potential for graft-related complications also exists, which may further impact glenoid implant longevity and functional outcome. This review article aims to describe the B2 glenoid morphology, discuss the challenges in managing the B2 deformity, and provide further insight specifically regarding autografting at the time of anatomic total shoulder arthroplasty for reconstruction of the B2 glenoid.

Keywords

Walch B2 glenoid, biconcave glenoid, bone grafting, autografting, anatomic total shoulder arthroplasty

Date received: 25 February 2019; revised: received 5 June 2019; accepted: 30 June 2019

Background

Primary glenohumeral arthritis can be a debilitating process that results in significant pain, limited function, and poor quality of life. In patients refractory to nonoperative treatment, glenohumeral arthritis can be addressed reliably with anatomic total shoulder arthroplasty (TSA), with the goals of alleviating pain and restoring function. Glenoid morphology has been shown to affect the outcome after shoulder arthroplasty. The B2 glenoid, characterized by a biconcave glenoid deformity, glenoid retroversion, and posterior subluxation the humeral head, can be challenging to address at the time of surgical reconstruction. Several techniques have been described to overcome such challenges, including eccentric reaming, bone grafting, and the use of augmented glenoid implants. Often times, multiple factors dictate the optimal treatment strategy for surgical management in these patients. These factors include the degree of glenoid retroversion and posterior head subluxation as well as patient age, level of activity, and rotator cuff integrity. This review article aims to describe the B2 glenoid morphology, discuss the challenges in managing the B2 deformity, and provide further insight specifically regarding the use of bone grafting using humeral head autograft to manage the B2 glenoid.

The B2 Glenoid

Neer first described glenohumeral changes in primary osteoarthritis and noted advanced cases were found to have a posteriorly sloped glenoid and associated posterior subluxation of the humeral head (Figure 1).[1,2] Walch et al.[3,4] later developed a formal classification of glenoid morphology based on preoperative computed tomography scans with consideration of glenoid wear pattern and the presence or absence of humeral head subluxation. The Type B glenoid is characterized by posterior humeral head subluxation with asymmetric wear. In contrast to the B1 subgroup in which there is posterior joint space narrowing, subchondral sclerosis, and osteophytes without erosion, the B2 subgroup is found to have a posterior glenoid wear pattern, giving a characteristic biconcave glenoid appearance. There is a wide range in the severity of glenoid erosion seen within the

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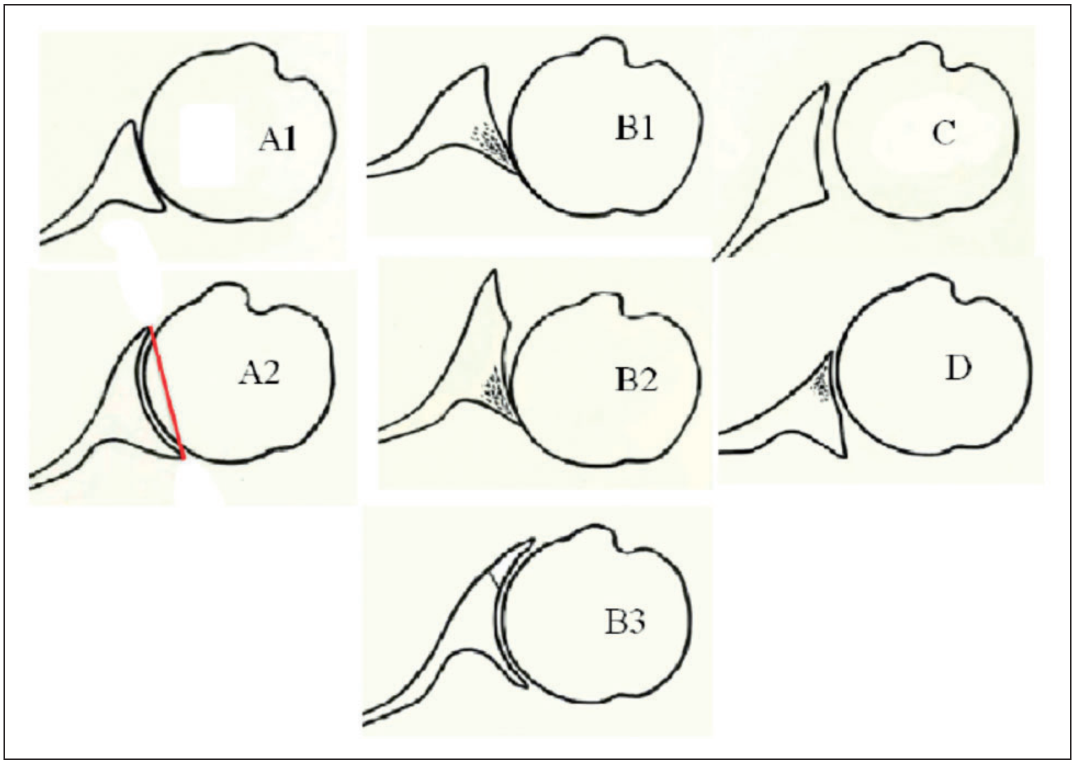

Figure 1. Walch classification of glenoid morphology in primary osteoarthritis.[4] (Figure 2, page 1602 from referenced article.) The B2 shoulder is associated with posterior humeral subluxation and posterior glenoid wear (biconcavity).

B2 arthritic groups, which dictates various reconstructive options.

Deformity Severity

The deformity associated with the B2 glenoid is due to asymmetric cartilage and bone wear. This occurs secondary to posterior humeral head subluxation. Progressive wear over time leads to posterior glenoid bone loss, which results in a biconcave shape of the glenoid surface that is pathognomonic for the B2 glenoid deformity. This biconcavity consists of the native paleoglenoid and the neoglenoid which represents the eccentrically worn portion of the glenoid. An acquired increase in the glenoid retroversion is also observed in the B2 glenoid, with mean values reported to be 16° to 23°.[3,5–7] The posteroinferior quadrant is typically eroded in the B2 glenoid, with a biconcavity demarcation line from posterosuperior to anteroinferior.[7–10] This is observed at the 8 o'clock position for a right shoulder oriented at a mean of 28° from the superoinferior axis as demonstrated by Knowles et al.[10] The neoglenoid occupies a mean of 44% of the glenoid surface area, but there is a wide range in relative size of the neoglenoid in reference to the paleoglenoid. Several radiographic and clinical studies have demonstrated the depth of the erosion to be a mean of 4 to 5 mm.[7,8,11] Changes to the surface morphology of the glenoid and humeral head occur secondary to asymmetric loading, with a mismatch in the radius of curvature of the neoglenoid (mean, 37 mm), paleoglenoid (mean, 34 mm), and humeral head (mean, 32 mm).[10] In addition, bone mineral density is also affected by the asymmetric wear pattern such that the neoglenoid has a significantly greater bone mineral density with less subchondral bone porosity compared to the paleoglenoid.[12]

Humeral head subluxation in B2 shoulders has been reported to be variable and depends upon the point of reference of the humeral head position, either along the scapular plane (humeroscapular) or perpendicular to the glenoid center (humeroglenoid). Subluxation and version measurements can be affected by variable morphology of the glenoscapular anatomy, particularly to the orientation and shape of the glenoid vault in relation to the scapular body.[9] Furthermore, a strong correlation has been demonstrated between glenoid retroversion and humeral head subluxation relative to the centerline of the scapula.[13]

Figures 2 and 3 demonstrate preoperative imaging findings in a relatively young and active patient with preserved range of motion and rotator cuff strength with primary glenohumeral arthritis.

Figure 2. Preoperative radiographs of a 60-year-old right-hand dominant male with primary glenohumeral arthritis with progressively worsening pain refractory to conservative treatment. Physical examination revealed active forward elevation to 140°, external rotation to 30° with the arm adducted, internal rotation to the low lumbar level, and preserved rotator cuff strength and function. Axillary lateral radiographs demonstrate posterior humeral head subluxation with a biconcave glenoid consistent with a Walch B2 glenoid.

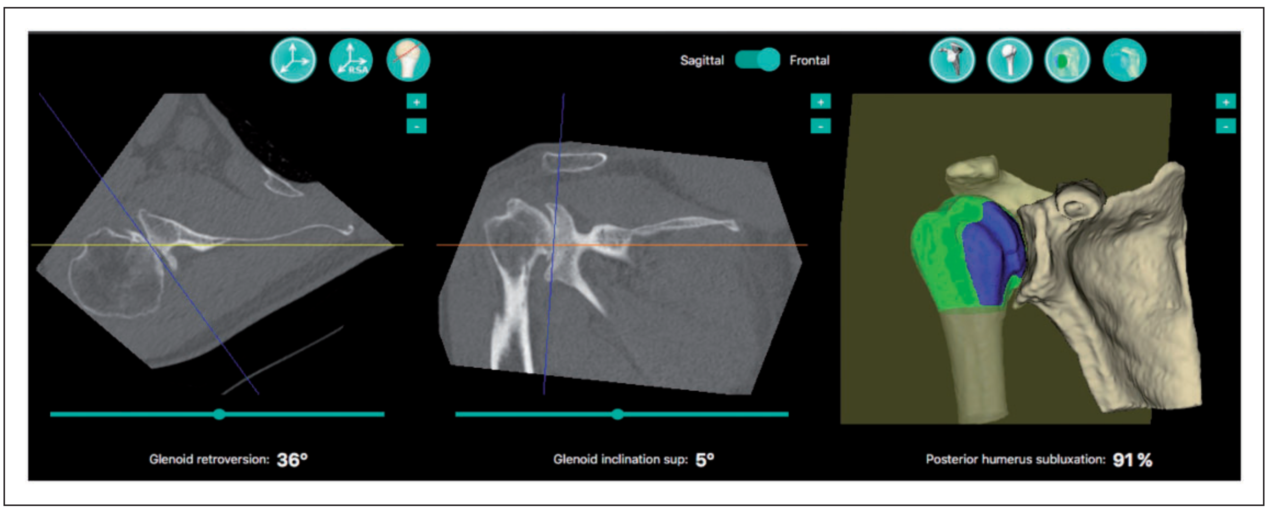

Figure 3. Preoperative 2- and 3-dimensional computed tomography images. A deformity analysis using 3D planning software measured 36° of glenoid retroversion, 5° of glenoid superior inclination, and 91% posterior humeral head subluxation index.

Challenges in Managing the B2 Glenoid

The findings associated with the B2 glenoid, namely posterior glenoid bone loss, increased glenoid retroversion, and posterior humeral head subluxation present significant challenges at the time of surgical reconstruction. Several authors have demonstrated that asymmetrically worn glenoids with associated posterior humeral head subluxation have inferior outcomes after shoulder arthroplasty. Iannotti and Norris[14] reported lower ASES scores, decreased external rotation, and more pain after TSA in patients found to have posterior humeral head subluxation radiographically. Similarly, Levine et al.[15] showed worse functional outcomes of hemiarthroplasty in asymmetrically worn shoulders, with satisfactory results achieved in only 63% of cases, compared to 86% in those with a concentric erosion pattern. Walch et al.[16] demonstrated a relatively high risk of posterior instability and early radiographic component loosening in advanced B2 deformities managed with high side reaming with anatomic arthroplasty. In his series, there were greater risks of early complications with retroversion greater than 27° to 30° and posterior humeral head subluxation of greater than 80% when measured with 2-dimensional CT scan axial cuts. Ho et al.[17] have shown that glenoid component implantation in a retroverted position (retroversion exceeding

15°) can result in early radiolucencies and the potential for early glenoid implant failure. In addition, obtaining adequate implant seating in the setting of posterior bone loss can be difficult. Furthermore, achieving a recentered humeral head is important to avoid early polyethylene wear, glenoid implant loosening, and prosthetic instability, but doing so can be challenging in the setting of a B2 glenoid.[18,19]

Indications

Bone grafting is a useful adjunct for the management of the B2 glenoid. This technique affords the ability to achieve glenoid version correction while minimizing the potential of excessively reaming and medializing the joint line, thus preserving and in fact enhancing bone stock. This theoretically yields more optimal rotator cuff function and stability of the glenohumeral joint. The surgical indications for bone grafting at the time of TSA include young, highly active patients with severe glenoid retroversion (>25°–30°) where version correction through partial eccentric reaming would be inadequate, and placement of a reverse TSA would be less desirable. Usually, these shoulders are also associated with severe posterior humeral head subluxation (>80%–90%) in reference to the scapular plane.[20]

Goals of Implant Placement

It is of paramount importance to understand the degree of glenoid deformity that is present at the time of surgery, as this varies greatly between shoulders and influences appropriate component positioning. The primary goals at the time of TSA include anatomic reconstruction with placement of implants that will optimize long-term survivability. To do so, the surgeon must prioritize achieving adequate implant seating and stability of the prosthetic joint.[21] The B2 glenoid is associated with adaptive bony and soft tissue changes, such that soft tissue balancing must be combined with correction of excessive glenoid retroversion to an acceptable degree. In general, it is recommended to obtain a minimum of 80% to 90% glenoid implant support, with correction of glenoid retroversion to within 10° to 15° of neutral version (as defined by the scapular plane) and avoiding medial glenoid vault perforation. Medialization by corrective reaming in order to obtain adequate glenoid seating can lead to removal of excessive cortical bone and/or violation of the medial glenoid vault.[7,22] It is generally felt that the maximum amount of anteversion correction possible by reaming alone is around 12° to 15°.[22–25] Inadequate version correction can result in excessive eccentric loads placed on the glenoid implant that can impact glenoid fixation[26–30] and fatigue the cement mantle.[27,31,32]

Achieving implant stability with a well-centered humeral head is among the goals of surgical reconstruction of a B2 glenoid. The humeral osteotomy should be performed with recreation of native humeral version. Placement of the humeral component anteverted in relation to the native version has not been shown to positively impact stability of the prosthetic implant in the setting of experimental posterior glenoid loss.[21,33] Furthermore, intraoperative trialing should be performed carefully to assess implant stability. In cases where excessive posterior humeral head subluxation has been identified during trialing, the humeral head size or thickness can be increased, plication sutures can be placed in the posterior capsule, or the humeral head eccentricity can be dialed to an anterior offset position. Biomechanical studies show that dialing the humeral head eccentricity anteriorly may reduce posterior eccentric loading and increase the force required to posteriorly dislocate the shoulder.[34] Theoretically, anterior overhang of the humeral head may potentially increase pressure on the subscapularis repair, although this has not been reported as a cause for subscapularis failure postoperatively.[35]

Bone grafting of the posterior glenoid allows for glenoid version correction and decreased edge loading at the implant–bone interface, while enhancing bone stock. Goals for surgery using this technique focus on maximizing the chances of graft incorporation. This can be achieved with careful autograft harvest and preparation techniques such that there is precise matching of the cortical surfaces of the humeral head graft on the glenoid face. In addition, compression of the prepared surfaces is necessary to minimize cement extrusion between the surfaces and optimize osseous healing.

Surgical Technique

Anatomic TSA is performed through a standard deltopectoral approach. The authors prefer to manage the subscapularis with a lesser tuberosity osteotomy. An inferior capsular release is performed and the humeral head is dislocated anteriorly. A humeral head cut is performed followed by a 360° subscapularis release. After placement of glenoid retractors and ensuring adequate visualization, a central guide pin is placed down the center of the glenoid vault using either a free-hand technique or assisted with a patient-specific glenoid guide. Next, the anterior paleoglenoid is reamed at the angle of desired version correction using a cannulated reamer. Reaming is performed to the point of typically achieving 40% to 50% implant support with the goal of bone preservation. Generally, minimal exposure of the subchondral bone is desired. Next, attention is turned to preparing the humeral head autograft to match the size of posterior bone defect. Given that the radius of curvature of both arthritic joint surfaces match well (the neoglenoid and the worn humeral head surface), a size-matched portion of the resected humeral head is utilized for grafting. The authors prefer to use the worn portion of the humeral head which provides dense bone and a radius of curvature that matches the neoglenoid defect. Using a small oscillating saw, the resected humeral head is fashioned such that the graft fits the glenoid defect in a fan shape. Typically, the graft is slightly oversized in thickness initially. After confirming the cortical surface of the graft can be positioned flush with the glenoid defect, any remaining cartilage on both cortical surfaces is denuded using a burr. Figure 4 depicts the described technique for graft preparation. Small perforations in the neoglenoid are then made with a small k-wire to promote graft healing. The graft is then provisionally secured in the desired position using a smooth k-wire, placed in line with the glenoid face (Figure 5). Two screw holes are drilled and 2.7 and/or 3.5 cortical screws are placed from lateral to medial perpendicular to the glenoid surface through the graft and into native glenoid bone as described by Nicholson et al.[36] (Figure 6). The authors prefer medial to lateral screw placement to optimize graft compression for healing. Care is taken to ensure that the screws are tightened down in a countersunk position such that they rest below the cancellous surface and do not come in contact with the polyethylene glenoid implant, while still providing compression across the cortical surfaces of the humeral head autograft and matching glenoid surface. Noncannulated reaming of the new glenoid surface is performed until the reamed surface matches the radius of curvature of the backside of the glenoid implant in order to maximize the implant support. Subsequent preparation of the glenoid and humerus is performed in routine fashion based on the chosen implant. The authors prefer an all polyethylene in-line pegged cemented component.

Figure 7 demonstrates postoperative radiographs in the case presented earlier after bone graft augmentation with humeral head autograft at the time of anatomic TSA.

Outcomes and Complications

The outcomes of bone grafting to address posterior glenoid wear patterns at the time of TSA have been described in several studies. However, surgical indications in the current available literature have varied, as have the surgical techniques in obtaining and securing the bone graft. Thus, it is difficult to draw strong conclusions regarding the role of bone grafting for the B2 glenoid and higher quality long-term outcome studies are lacking. Complications reported with the use of this technique include radiolucency around the glenoid component, incomplete graft incorporation or nonunion, graft resorption, and screw failure. Although these complications may be inconsequential in some cases, if there is associated glenoid implant loosening and migration, this can be a devastating situation necessitating revision surgery.

Neer and Morrison[37] retrospectively reviewed 19 shoulders in 18 patients who underwent bone graft augmentation due to deficient glenoid bone stock at the time of anatomic total shoulder replacement. This case series included glenohumeral arthritis of various etiologies, including rheumatoid arthritis, primary osteoarthritis, arthritis secondary to instability, posttraumatic arthritis, glenoid dysplasia secondary to brachial plexopathy, cuff tear arthropathy, and a failed humeral-head replacement. At a mean postoperative follow-up of 4.4 years, they reported 16 excellent (84%) and 1 satisfactory (5%) outcomes, and 2 patients (11%) in the limited-goals category. Radiographic analysis showed no radiolucent lines in 13 cases (68%), while incomplete radiolucent lines were observed in 6 cases (32%). They concluded that sufficient osseous support was achieved with bone graft augmentation to allow for glenoid implantation.

Steinmann and Cofield[38] reported similar results on their experience using humeral head bone grafting for the management of segmental glenoid wear at the time of anatomic TSA in 28 patients. Nineteen of 28 patients suffered from primary osteoarthritis. The graft (27 autografts, 1 allograft) was transfixed predominantly with 3.5 mm cortical screws, but in 1 case, the bone graft was impacted. Three different types of glenoid prostheses were used, including cemented and uncemented. At a mean follow-up of 5.25 years, the authors reported improvement in range of motion in all shoulders with 13 excellent (46%), 10 satisfactory (36%), and 5 (18%) unsatisfactory outcomes. Radiographically, 15 shoulders (54%) demonstrated radiolucency, of which 3 shoulders were considered to have a loose glenoid implant. However, only 2 of the 3 radiographically loose glenoid implants were symptomatic. Although it was unclear what glenoid implant is ideal for use with bone grafting, the authors supported bone graft augmentation as a reasonable option in restoring glenoid bone stock and correcting joint position.

Hill and Norris[39] evaluated the long-term results of bone grafting in 17 shoulders in 16 patients for restoration of glenoid volume and version correction at the time of anatomic TSA with an average follow-up of 5.8 years. The etiology of glenohumeral arthritis and need for surgery was primary osteoarthritis (5 shoulders), chronic anterior fracture-dislocation (5 shoulders), capsulorrhaphy arthropathy (3 shoulders), inflammatory arthritis (2 shoulders), recurrent instability (1 shoulder), or failed arthroplasty (1 shoulder). Preoperative imaging revealed that 5 shoulders had an anterior glenoid defect with a mean anteversion of 47°, and 12 shoulders demonstrated

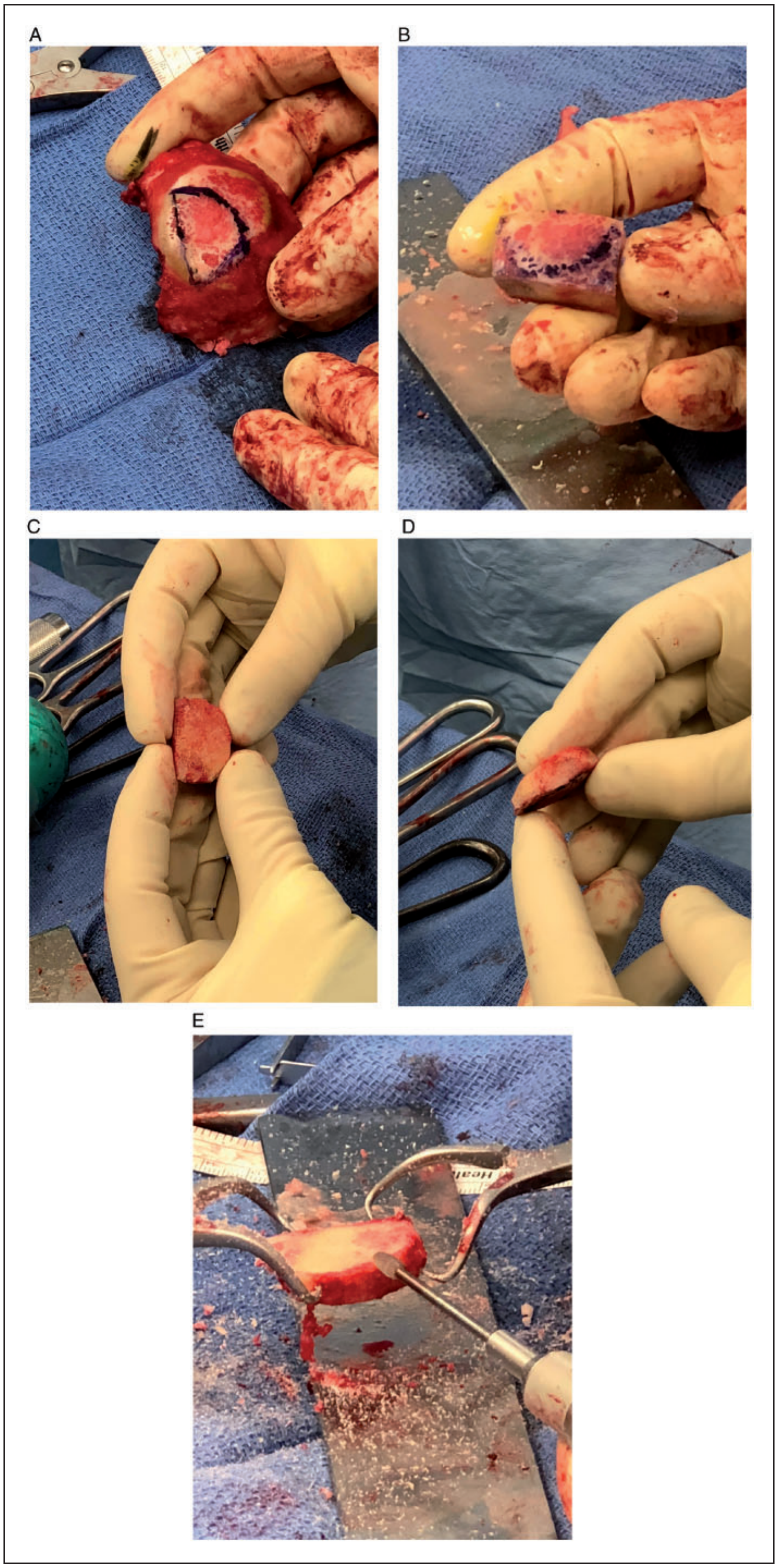

Figure 4. Graft preparation. A, A size-matched portion of the resected humeral head is marked for further graft preparation. B and C, A small oscillating saw is used to fashion the humeral head such that the graft fits the glenoid defect in a fan shape. D, The graft is prepared such that its thickness is oversized initially. E, Cartilage remaining on the cortical surface of the graft is denuded using a burr.

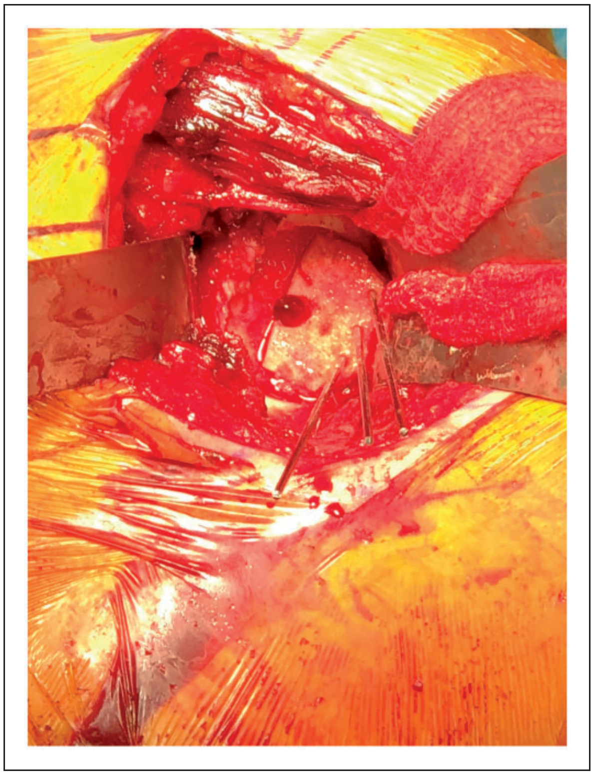

Figure 5. After cannulated reaming of the paleoglenoid over a central guide pin placed down the center of the glenoid vault, the prepared graft is then provisionally secured over the neoglenoid with Steinmann pins placed in line with the glenoid face.

Figure 6. The graft is definitively secured with 2.7 mm screws placed from lateral to medial perpendicular to the glenoid surface through the graft and into native glenoid bone. The screws are tightened down in a countersunk position such that they rest below the cancellous surface.

a posterior glenoid defect with a mean retroversion of 27°. At the time of surgery, all glenoid implants were cemented, with 12 metal-backed and 5 all-polyethylene implants. Autograft was used in all cases and was transfixed with screws in all but one case in which it was impacted. With respect to graft healing, 14 of 17 cases were noted to have healed grafts in proper position, with nonunion or compromise of graft fixation being the modes of graft failure (18%). They reported failure in 5 shoulders (29%) which were associated with symptomatic glenoid loosening. Functional outcomes in the remaining 12 shoulders were noted to be excellent in 3 cases, satisfactory in 6 cases, and unsatisfactory in 3 cases. Their outcomes demonstrated that bone grafting is a technically demanding procedure but has the potential to restore bone stock and correct version.

Sabesan et al.[40] also reported acceptable clinical outcomes with bone grafting. They studied 12 patients with severe glenoid retroversion treated with anatomic TSA and autogenous bone grafting. The mean glenoid retroversion was 44°. With regard to their surgical technique, anterior glenoid reaming was performed followed by a step-cut glenoid preparation to a depth approximating the deepest part of the glenoid defect posteriorly. After the autograft was tailored and secured, the graft and anterior glenoid were then subsequently prepared and a cemented all-polyethylene glenoid component was placed. The mean duration of follow-up was 4.4 years. The authors reported a good or excellent clinical outcome based on Penn scores in 10 patients (83%), with significant improvement in range of motion. However, 2 of 12 patients (17%) had complications associated with graft healing and fixation requiring revision surgery. In addition, 2 patients experienced hardware complications at 1 and 9 years after index procedure, respectively. These early and mid-term results were consistent with prior studies demonstrating that the clinical and radiographic improvement afforded with bone grafting were substantial, but a concern for graft-related complications existed.

Klika et al.[41] similarly described outcomes of bone grafting with longer term follow-up (mean follow-up of 8.7 years). In their study, 25 shoulders in 24 patients underwent structural bone grafting for glenoid deficiencies during primary anatomic TSA. A wedge-shaped humeral autograft was fixed to the glenoid with screws and a metal-backed (12 cases) or all polyethylene (13 cases) glenoid component was placed. Of the 12 shoulders that were identified as B2 glenoids, clinical

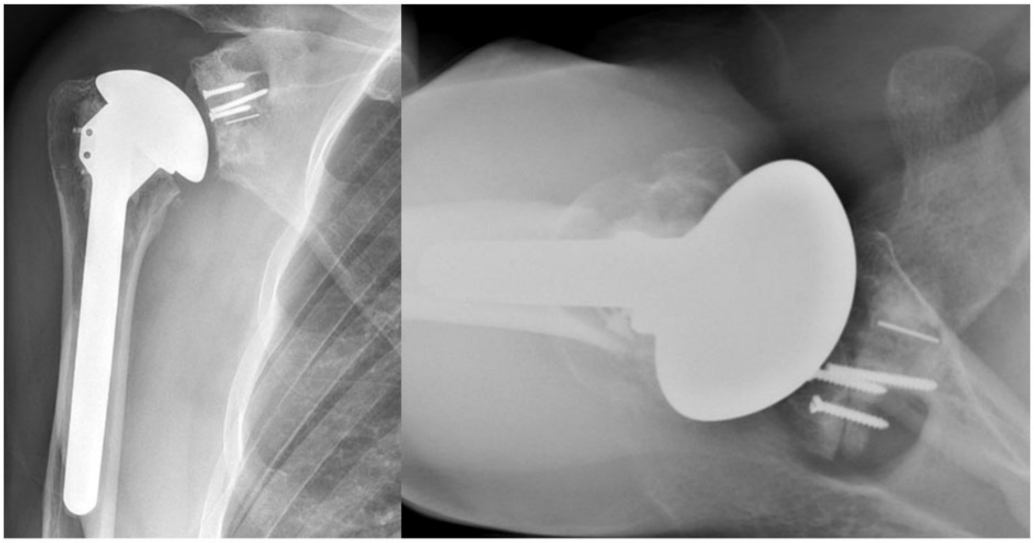

Figure 7. Postoperative radiographs demonstrating appropriate graft and screw position.

outcomes were noted as excellent in 8 cases and satisfactory in 2 cases. The remaining 2 cases developed aseptic glenoid loosening that required revision surgery and had an unsatisfactory outcome. With respect to graft healing, 5 of the 12 B2 glenoids (42%) were observed to have graft resorption or lack of incorporation, but all demonstrated excellent clinical outcomes.

Most recently, Nicholson et al.[36] reported favorable clinical and radiographic outcomes after posterior glenoid bone grafting in patients with undergoing TSA. In their series of 28 patients, there were 13 B1 glenoids and 15 B2 glenoids, with a mean retroversion of 28°. After reaming the glenoid using a cannulated system, the articulating portion of the humeral head whose radius of curvature matched that of the glenoid defect, was prepared and transfixed with two 3.5 mm cortical screws. The new glenoid was then prepared, and a glenoid implant with peripheral peg configuration was placed. Results demonstrated significant correction of glenoid retroversion and humeral head subluxation, and improvement in pain, range of motion, and functional outcome scores at a mean follow-up of 4 years. They reported a 100% graft incorporation rate with no revision surgery. Three patients were found to have broken screws, without functional impact.

Contrary to other reports, Walch et al.[16] reported a high rate of complications associated with bone grafting. They studied the outcomes of anatomic TSA performed on 92 B2 glenoids in 75 patients. The mean intermediate glenoid version was 19.2°. Seven of the 92 shoulders (7.6%) required posterior humeral head autografting based on preoperative planning and inability to correct glenoid retroversion to less than 10° with anterior reaming alone. Posterior bone grafting was associated with significantly worse results for active elevation, Constant score, mobility, strength, and radiolucent lines. Graft collapse was observed in 2 cases leading to glenoid migration, but these patients declined revision surgery. In addition, posterior dislocation was noted in 3 cases. Given the high rate of complications and inferior clinical outcomes associated with posterior bone grafting in biconcave glenoids, the authors cautioned against the use of this technique.

There are relative advantages and disadvantages of correction of B2 glenoid deformities with bone grafting versus augmented implants. Although augmented glenoid implants have performed favorably in the short term, long-term studies are lacking. The use of bone grafting has been associated with a modest rate of graft resorption and radiolucencies at mid-term follow-up in some studies raising concern for long-term survivability. However, bone grafting offers a theoretic advantage of restoring glenoid bone stock, which is particularly desirable in younger patients where a revision surgery is anticipated.

Bone graft augmentation can be a valuable adjunct to TSA for the B2 glenoid to correct version and enhance glenoid bone stock. Although it can yield favorable clinical outcomes, the surgeon must be aware of the potential graft-related complications that can occur and may impact implant longevity and extremity function.

Authors' Note

Patient consent was obtained to allow the authors to use imaging studies and intraoperative photographs after removing identifying data.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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