Avoiding superior tilt in reverse shoulder arthroplasty: a review of the literature and technical recommendations

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Superior tilt of the baseplate component in reverse total shoulder arthroplasty leads to tensile baseplate forces and may be a contributor to early loosening. The risk factors for this implant malposition include inadequate exposure through a superior approach and superior glenoid bone deficiency that obscures the native glenoid tilt. Here we review our preoperative evaluation and surgical management strategies to avoid superior tilt. Adequate exposure with a superior approach can be achieved but requires not just proper surgical technique but also careful patient selection. We propose that the superior approach be considered only for acute proximal humerus fractures or in patients when the following criteria are met: no prior open surgery on the shoulder; more than 30° of passive external rotation at 0° of abduction; no medial humeral osteophytes; and any superior migration must be reducible with a sulcus test during examination under anesthesia. Avoiding superior tilt when there is significant superior glenoid erosion can be accomplished with humeral head autograft, most easily performed through a deltopectoral approach. Preoperative templating is critical to determine proper graft thickness, inclination, reaming depth, and harvest technique.

Level of evidence: Narrative Review.

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Keywords: Reverse; total; shoulder; arthroplasty; bone; graft

Since the introduction of the Grammont arthroplasty in 1985, reverse total shoulder arthroplasty (RSA) has provided an excellent solution for patients suffering from a variety of complex shoulder disorders. These include issues associated with rotator cuff dysfunction, bone loss, and instability such as cuff tear arthropathy, massive rotator cuff tears without arthritis, proximal humerus fractures, osteoarthritis with glenoid bone loss, rheumatoid arthritis, and revision arthroplasty with soft tissue or bone compromise. However, favorable results with this prosthesis in these challenging scenarios have not come without complications.

Glenoid baseplate loosening is a dreaded complication, and superior tilt of the baseplate component at the time of implantation is thought to be a risk factor for this challenging problem. Whereas debate continues as to whether neutral or slight inferior tilt is preferable, superior tilt should be strictly avoided as this position is known to increase tensile baseplate forces and early loosening.

Risk factors for superior tilt of the baseplate are related to surgical approach and to the extent and location of glenoid erosion. Here we review these risk factors...
Factors and propose practical solutions to avoid superior tilt in RSA.

**Surgical approach: anterosuperior vs deltopectoral**

Currently, 2 surgical approaches are most commonly used for RSA, anterosuperior (AS) and deltopectoral (DP). The choice of and success with each approach have much to do with the surgeon’s comfort and training with the particular approach, and this factor is likely to be underestimated in the available nonrandomized studies comparing these techniques. During the last 4 decades, the DP approach has been the most commonly used approach for shoulder arthroplasty. The DP approach has several advantages for RSA, including deltoid origin preservation, extensile exposure through an internervous plane, and improved visualization and access to the inferior glenoid.

The AS approach to the glenohumeral joint, originally described by Mackenzie and later modified for RSA, by definition involves approaching the joint from above. The remaining humerus and soft tissue constraints must be retracted distally, potentially making proper positioning of the glenoid baseplate low and without superior tilt challenging by the AS approach. In addition, deltoid dehiscence and neurapraxia of the anterior branch of the axillary nerve are potential issues with the AS approach.

One important potential advantage of the AS approach, however, is the ability to work through the massive rotator cuff defect while leaving any remaining subscapularis potentially intact. Whereas the role of the subscapularis in stability and function after RSA is debated even in cases of the DP approach, we believe that an intact anterior force couple may have some stability benefit. The AS approach has a reported rate of dislocation lower than that of the DP approach (0% vs 4%-5%), which may be due to preservation of soft tissue stabilizing structures, although there is considerable variability in which structures are divided by surgeons using this approach.

In a multicenter French study, which reported on 527 primary RSAs for massive rotator cuff tears or cuff tear arthropathy, Molé et al compared the AS and DP approaches. In this large series, loosening tended to occur more frequently in cases in which an AS approach was used than in those in which a DP approach was used, 11 of 227 (4.8%) vs 7 of 300 (2.3%), respectively. There was an association between superior baseplate tilt and baseplate loosening (Fig. 1).

In addition to baseplate loosening, the superior approach and superior baseplate tilt have also been associated with scapular notching. There is ongoing controversy as to the clinical relevance of scapular notching; some authors report no effect on outcomes, and others describe a negative correlation between scapular notching and RSA results. Notching is likely to be due to craniocaudal positioning of the baseplate, especially if a Grammont-style design is used, more than to the baseplate tilt. However, the difficulty with exposure and implantation trajectory of the inferior glenoid in the AS approach may be a risk for both superior baseplate tilt and superior position of the baseplate on the glenoid. These implant malpositions lead to a higher incidence of baseplate loosening and scapular notching. The necessity to retract the proximal humerus inferiorly instead of posteriorly to access the glenoid for preparation and component implantation is a major reason that the AS approach may be more prone to implantation of the glenoid component in superior tilt. Lévine et al noted that cases treated with an AS surgical approach resulted in a higher incidence of scapular notching than those treated through a DP approach (86% vs 56%).

Recently, Gillespie et al described a single-surgeon review of a DP vs subscapularis-sparing AS approach, evaluating 93 patients (31 DP and 62 AS) with an average of 22 months of follow-up. Contrary to the experience of Lévine et al, they showed excellent baseplate position (low and without superior tilt) and similar incidence of scapular notching with both approaches.

The critical difference explaining the results of Lévine et al vs those of Gillespie et al seems to be the difference in patient selection. The criteria for the AS approach of Gillespie et al were strict and specific:

- No prior open shoulder surgery on the operative side
- At least 30° of passive external rotation with the arm at the side
- No significant medial humeral osteophytes
- Superior migration must be reducible with a sulcus test during examination under anesthesia immediately before incision

If any of these criteria were not satisfied, a DP approach was chosen. This checklist essentially excludes from the AS approach cases in which scarring, stiffness, or fixed superior migration will make retraction of the humerus inferiorly to allow proper baseplate position without superior tilt difficult. In addition, the medial humeral osteophytes cannot be well addressed with a subscapularis-sparing AS approach, and this is another contraindication.

Choosing the proper indication may be just as critical as choosing the proper patient. Successful results with use of the superior approach for RSA have been shown in treatment of acute proximal humeral fractures in a recent systematic review. The results of the systematic review did not show superiority of any specific approach for this indication. In scenarios in which the proximal humerus is fractured, achieving proper baseplate tilt is aided by the lack of intact proximal humeral bone that otherwise hinders correct positioning of the component.

The AS approach appears to predispose to superior tilt of the baseplate as the soft tissue and bone anatomy make...
positioning of the baseplate low and without superior tilt a challenge. However, with proper patient selection, superior tilt can be avoided with the AS approach. We recommend use of the algorithm proposed by Gillespie et al to determine suitability for patients with cuff tear arthropathy or massive rotator cuff tears. In addition, patients with proximal humerus fractures may be well treated with the AS approach. The surgeon’s experience with the particular approach is another critical factor, regardless of whether the AS or DP approach is chosen.

Managing glenoid erosion

Assessment and preoperative evaluation

Glenoid morphology and glenoid erosion have been previously reported to affect the outcomes of primary and revision anatomic total shoulder arthroplasty. In RSA, glenoid bone loss may similarly obscure local landmarks for glenoid version and inclination, predisposing to errors of assessment and improper placement of the baseplate. Even if the proper position is well understood by the surgeon, the bone loss may also present a structural problem as the bone stock is compromised and reaming of the native bone back to a neutral position may remove an unadvisable amount of glenoid bone.

Favard suggested a classification of types of glenoid erosion associated with rotator cuff arthropathy based on the location of the erosion and its extent in the coronal/superior-inferior plane (Fig. 2). The type of degenerative erosion of the glenoid affects the development of postoperative scapular notching, with superior glenoid erosion (type E2 glenoid wear) associated with the highest incidence, and no erosion (E0) or inferior erosion (E4) resulting in the lowest percentage.

Whereas management of glenoid bone loss in revision RSA is beyond the scope of this manuscript, glenoid bone erosion in primary RSA is also frequently encountered and may often necessitate alterations in surgical technique to allow stable baseplate implantation, to avoid over-reaming of remaining bone stock, and especially to avoid superior baseplate tilt.

Preoperative planning is essential not only for proper assessment of glenoid erosion to determine the need for a bone graft but also to aid in bone graft preparation. Assessment of the remaining bone stock is also important to guide placement of the central screw or peg into adequate bone for initial fixation while the bone graft is being incorporated. Plain radiographic assessment includes true (Grashey) anteroposterior view, axillary lateral view, and scapular Y view. A calibrated marker should be used for later templating.

Axial imaging is essential for complete glenoid assessment when bone loss is suspected. Computed tomography (CT) is currently the modality of choice as it offers accurate
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bone anatomic detail and assessment of version and bone loss severity. A CT is less expensive and faster to obtain compared with magnetic resonance imaging. However, if the patient presents with a magnetic resonance imaging study, it alone is sufficient as long as the bone contours and landmarks can clearly be identified on the sequences used. Clear communication with the radiologist is required as the standard coronal and sagittal reformats for CT should be in the scapular plane and perpendicular to the scapular plane (not orthogonal to the CT gantry) to facilitate interpretation. The value of 3-dimensional CT to accurately characterize glenoid morphology has been demonstrated compared with standard 2-dimensional CT. As 2-dimensional CT images show only a portion of the anatomy in any given image, pathologic changes and true glenoid morphology may be easier to evaluate with use of the global views provided by 3-dimensional images.

In performing preoperative planning, it is important to first define the neutral spinal scapular axis, using the Grashey anteroposterior view with the marker template included. This is performed by a simple method that can be used on both plain radiographs and CT images, whereby a line is drawn from the medial scapular trigone (coalescence of the medial scapular spine and scapular body) and extended, parallel to the scapular spine origin on the scapular body through the center of the glenoid.

To ensure a neutral tilt on the glenoid component, we use the T-square method (Fig. 3). The T-square line is drawn orthogonal to the neutral scapular axis intersecting the inferior rim of the glenoid. This line is helpful in 3 ways: the distance between the line and the deepest part of the glenoid defines the thickness of bone graft needed before reaming; the angle of this line with the shaft of the humerus provides a guide to the angle for the humeral head cut; and templating for a baseplate parallel with this line will be in neutral tilt.

Templating can be done with digital templates or more traditional transparent acetate overlays on radiographic film images. The surgeon must decide how much of the baseplate should be resting on native bone. This is a current area of debate, with data showing excellent outcomes for RSA baseplates resting completely on bone graft, provided some of the central peg is in native bone. We prefer to have at least a small part of the baseplate resting on native bone.

In a glenoid with superior erosion, reaming extensively with neutral tilt can lead to neutral tilt on the baseplate without the use of bone graft, but depending on the lateralizing options available with the prosthesis, over-medialization is a concern. Excessive medialization of the center of rotation can lead to prosthetic instability in multiple ways. First, impingement on the lateral pillar of the scapula can cause prosthetic instability in abduction and notching. Excessive medialization also decreases the medial force vector of the deltoid, potentially also contributing to instability with attempts at abduction. Last, the compressive force of any remaining rotator cuff or capsular tissue is decreased, potentially further contributing to instability.

If the amount of superior erosion is minimal or confined to the superior portion of the glenoid above the baseplate (E2), the template can be used to determine whether bone graft is needed. In cases with superior erosion of the glenoid in which a graft is chosen, the amount of required bone graft will diminish and the amount of exposed native glenoid will increase as the reaming proceeds medially. Measuring on the template, the amount of native glenoid from the inferior glenoid to the bone graft can thus be used as a visual cue for appropriate reaming depth.

Humeral head autograft

Humeral head autograft is an ideal graft choice in primary RSA when superior glenoid erosion is severe enough to leave a portion of the baseplate unsupported. Humeral head autograft is readily available, otherwise is discarded, and conforms well to the shape of the defect. There are two main methods for graft harvesting and preparation: the burr and cut and the core harvesting techniques.

The burr and cut technique

The burr and cut technique is our preferred method as it retains the shape of the humeral head to fit the defect. After inferior capsular release from the humerus, the humeral head is dislocated in the standard fashion and any osteophytes are removed. Many of these patients with superior wear have an inflammatory arthritic pattern, so the amount of osteophytes may be minimal. Any remaining cartilage is removed from the humeral head, and an oval burr is used to thin the cortex to create a healing surface.

The humerus is cut on the basis of the preoperative template with the angle specified by the T-square method (Figs. 3 and 4). The thickness of the cut portion of the humeral head is checked to confirm the proper cut depth with the preoperative template. The next step involves glenoid preparation with use of a burr until a bleeding surface is achieved (“paprika sign”). Multiple 2-mm holes are drilled en face to create further areas for healing. The graft is then placed into the glenoid defect and can be left slightly proud anteriorly or posteriorly (if glenoid version is to be corrected), but it should be positioned flush inferiorly. The cut face of this graft is meant to recreate the neutral glenoid face defined by the T-square method.

Kirschner wires are placed anteriorly and superiorly to hold the graft in place. These wires transfix the graft to the glenoid but must be placed outside the future path of the reamer. Next, depending on the technique for the system chosen, a cannulated system is used for reaming until the desired amount of native bone is visible inferiorly. At this stage, reaming must be done slowly and carefully to avoid spinning or fracturing of the graft. The baseplate is placed
with emphasis on good compression to improve graft healing. From this stage, standard RSA is continued.

The core harvesting technique
The core harvesting technique is an alternative method, described by Norris et al, that uses a Cloward drill to remove a core of humeral head. If the sphericity of the humeral head is maintained and matches the defect, a reamer from the humeral head resurfacing set can be used to decorticate the humeral head. A cannulated Cloward drill is then used to create a cylinder of cancellous bone. Boileau et al described the BIO-RSA technique (bony increased-offset reverse shoulder arthroplasty), which uses specific instrumentation to machine a cylindrical, autogenous bone graft harvested from the humeral head. This is placed on a baseplate with a longer central peg, elongating the neck of the scapula to lateralize the prosthesis and thereby reduce inferior scapular notching. Unlike the BIO-RSA reamer/technique, the Cloward drill does not have a terminal reamer, so the spherical shape created by the resurfacing reamer is maintained. The graft is drilled to accept the central peg, then the humeral head is cut at the desired graft thickness. The graft can be positioned on a long-post baseplate with the flat side against the baseplate and the curved side into the glenoid defect.

Alternatively, the Cloward drill with a terminal reamer can be used as described by Boileau et al. However, Norris has described a freehand cut on an angle to create a bone graft core that is angled on the surface and contacts the glenoid (Fig. 5). This method can be useful for the dysplastic glenoid where severe retroversion is present.

No matter which method is chosen, the glenoid is prepared with a burr and 2-mm drill holes to create a flush and biologically active surface to mate with the humeral head autograft.

Discussion
Superior baseplate tilt in RSA can lead to early aseptic loosening and failure. It can also increase the risk of scapular notching, the most common radiologic complication with this procedure, which has been reported in 56% to 96% of cases.
Early stability of the baseplate is crucial for the success of the procedure. Initial fixation of the central axis of the glenoid baseplate is critical and can allow the addition of peripheral bone support with a bone graft. The goal of initial fixation is to limit the amount of baseplate motion and to provide a favorable biologic environment, hence promoting osseous integration. This can be achieved by screw fixation baseplate designs or central peg baseplate designs; both design types provide satisfactory results, as long as adequate graft compression and stability are achieved.19

At this time, it is unclear how much of the baseplate needs to be resting on native bone if the central peg or screw is well seated. In cases without glenoid deformity, promising results have been presented with the BIO-RSA technique by Boileau.3,4 If the prosthesis chosen allows lateralization of the center of rotation, this may provide the surgeon more flexibility in obtaining fixation in native glenoid as medialization with reaming can be corrected with a lateralized prosthesis, potentially without the use of bone graft.17,29 Some systems also allow soft tissue tension to be maintained with a variably medialized humerosocket—effectively lateralizing the humerus in relation to the prosthesis; but to the best of our knowledge, the biomechanical and clinical effects of this type of design are not well studied. Similarly, it is unclear at this time if a central screw or central peg is preferable in these bone erosion scenarios, but in our experience, either seems satisfactory as long as stable baseplate initial fixation and compression of the bone graft can be achieved.29

Aside from using bone graft augments or medializing with correct version and tilt and using a lateralized glenosphere, a third option is the use of glenosphere baseplates with superior augments.45 As clinical data are currently scarce, it remains to be seen if this implant design is a prosthetic solution that will eliminate the need for bone grafting in some cases of superior erosion.

In cases with deformity, templating can be extremely helpful to provide intraoperative guides to the surgeon when the normal landmarks are distorted. Computer-navigated surgery for shoulder arthroplasty is a newer direction that allows real-time feedback to directly correlate the surgical anatomy with the imaging in an attempt to improve implant positioning. Early promising results have been reported in cadaveric and clinical studies.12,28,51,53 Whereas the technology can improve both humeral and glenoid implant alignment in routine cases, it is especially useful in situations in which normal anatomy is distorted, such as with fractures, glenoid erosion, dysplasia, and revisions. Taken yet a step further, patient-specific instrumentation is now available for shoulder arthroplasty.24 This technology allows all the navigation and templating

Figure 4  The burr and cut technique used for cuff tear arthropathy with Favard type E3 superior glenoid erosion. (A) The T-square method is used to determine the proper angle at which to cut the humeral head and the initial graft thickness. (B) This case has significant glenoid retroversion. (C) The graft prepared after burring and placement of multiple 2-mm drill holes. Note the retroversion. (D) The burred humeral head is placed in situ with K-wires for provisional fixation. (E) The preoperative template shows graft thickness after reaming. (F) Postoperative film shows the template plan executed. Note the absence of superior tilt. The retroversion has also been corrected.
decisions to be made preoperatively, and a patient-specific set of guides is generated. This appears to have the benefits of computer-navigated surgery without the added surgical time required for registration or the placement of markers in the scapula. No matter which technology is used—preoperative templating, computer navigation, or patient-specific instrumentation—careful evaluation of the deformity and thoughtful consideration of management options, possibly to include bone grafting, are steps that cannot be overly emphasized.

Conclusions

Surgeons should take care to avoid superior tilt of the component baseplate in RSA. Strategies to avoid superior tilt include a DP approach and consideration of a superior approach only when patients meet specific criteria that will technically allow the surgeon to achieve proper baseplate positioning and orientation. Superior glenoid erosion is a risk factor for superior tilt of the baseplate, and careful consideration of any preoperative deformity is required. Thorough preoperative templating is critical, first to determine the necessity for a graft, and second to determine graft size, proper graft thickness, inclination, reaming depth, and harvest technique.

Figure 5  The core harvesting technique used for a dysplastic glenoid. 37 (A) The humeral head is cut to create a flat surface of cancellous bone. A custom combination Cloward drill is then used both to drill the hole for the central post and to core out a plug of cancellous bone graft. (B) A freehand saw cut is made to create an angled backside to the graft that matches the angle of retroversion. (C) The implant is inserted gently into the prepared graft. (D) The implant with angled humeral head autograft in place, ready for implantation. (E) Postoperative image showing graft incorporation. Note the absence of superior tilt. The retroversion has also been corrected. (Images courtesy of T. R. Norris, MD, used with permission.)

Humeral head autograft can be used in a variety of ways to augment initial stability of the baseplate in native bone, correcting any superior wear and avoiding superior tilt of the baseplate. Careful preoperative attention to approach selection and templating is critical for an optimal postoperative component position.

Acknowledgment

The authors wish to thank Dr. Tom R. Norris for providing pictures (Fig. 5) of his core harvesting technique.

Disclaimer

Grant E. Garrigues reports personal fees from Tornier during the conduct of the study; personal fees from Tornier, grants from Zimmer, grants from DJO, grants from Breg, grants from DePuy-Mitek, and personal fees from AO/DePuy-Synthes outside the submitted work. Lior Laver, his immediate family, and any research foundations with which they are affiliated have not
References


