SUBSPECIALTY PROCEDURES

GLENOID BONE-GRAFTING IN REVISION TO A
REVERSE TOTAL SHOULDER ARTHROPLASTY:
SURGICAL TECHNIQUE

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Published outcomes of this
procedure can be found at: *J Bone
Joint Surg Am.* 2015 Oct 21;
97(20):1653-60.

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JOURNAL OF BONE AND JOINT
SURGERY, INCORPORATED

Introduction

Reverse shoulder arthroplasty has emerged as a very good treatment option for patients in salvage situations, such as the revision setting with glenoid bone loss. Managing glenoid bone loss in shoulder arthroplasty represents a difficult challenge because of increased rates of glenoid component malposition, increased rates of component loosening, and bone graft resorption^{1,2}. With the increasing annual number of shoulder arthroplasties in the primary setting, the need to manage glenoid bone loss in the revision setting will continue to increase as well. One important technique for managing glenoid bone loss involves utilizing the reverse prosthesis augmented with various techniques of glenoid bone-grafting. The potential advantages of utilizing bone graft to augment glenoid component implantation include preservation of remaining bone stock and maintenance of satisfactory shoulder offset without the need for a laterally offset prosthesis³. It also augments implant-bone contact, potentially increasing component stability after graft incorporation. In this report, we describe the technical details of the revision of a prior shoulder arthroplasty with a reverse prosthesis augmented with glenoid bone graft.

Utilizing either structural or corticocancellous bone graft to augment glenoid bone stock and subsequent component fixation provides an important tool for surgeons, particularly in the revision setting. The extent, location, and size of the defect impact the choice of bone graft and the technique utilized to augment the bone loss. The graft is primarily used to add additional bone for glenoid component fixation, but it also can help to correct inferior tilt, or altered version. With the increasing utilization of structural bone grafts, we have improved our ability to successfully treat patients with large glenoid defects.

Disclosure: On the **Disclosure of Potential Conflicts of Interest** forms, which are provided with the online version of the article, one or more of the authors checked "yes" to indicate that the author received payment or services from a third party (government, commercial, private foundation, etc.) for an aspect of the submitted work and "yes" to indicate that the author had a relevant financial relationship in the biomedical arena outside the submitted work.

Indications & Contraindications

Indications

- A peripheral defect with $\geq 50\%$ contact and either glenoid anteversion (anterior) or retroversion (posterior). In such shoulders, consider a structural allograft or autograft from the local humerus (if available).
- A peripheral defect with $< 50\%$ contact with native glenoid and substantial alterations in glenoid version. In such shoulders, consider structural autograft.
- A central defect with $\geq 30\%$ contact between the baseplate and the native glenoid, with adequate primary stability of the central screw or peg. In such shoulders, consider morselized local autograft (if available) or allograft.
- A large central or global deficiency, causing excessive glenoid medialization. In such shoulders, use structural tricortical autograft from the iliac crest to increase the offset of the glenoid component, enhancing stability and potentially reducing the risk of scapular notching.
- Superior deficiencies with $< 50\%$ contact between the implant and native bone and a loss of neutral tilt. In such shoulders, avoid superior tilt. It is critical to obtain either neutral or inferior tilt. A superior autograft can be utilized to restore the superior defect and prevent superior tilt.

Contraindications

- Inadequate glenoid bone stock to obtain any native bone contact with autograft or implant, as well as any purchase from the central peg or screw of the baseplate.

Step 1: Preoperative Evaluation and Planning

For patients undergoing revision shoulder arthroplasty, perform the preoperative evaluation with radiographs, computed tomography (CT), and digital templating software as they play a key role (Video 1).

- Perform preoperative radiographic evaluation with anteroposterior internal and external rotation views, axillary views, and a CT scan.
  - Assess the axillary radiograph for central, anterior, and posterior glenoid bone loss that might predispose to excessive anteversion or retroversion.
  - Examine the anteroposterior radiographs to estimate the size of central defects that could lead to excessive medialization or superior defects that might lead to implantation of the glenoid component with a superior tilt.
- Perform a 2-dimensional CT scan (with a slice thickness of < 1.5 mm) to assess glenoid bone stock. The technique of the CT should be designed for the shoulder and should ensure that correct image planes are obtained to properly evaluate glenoid morphology.

Video 1 Bone-grafting in revision to a reverse total shoulder arthroplasty. (Illustration of bone-grafting algorithm used with permission of the Mayo Foundation for Medical Education and Research. All rights reserved.)

- Scrutinize the CT scans, particularly when shoulders have moderate or severe glenoid bone loss, as the scans can help the surgeon to understand the extent of central, peripheral, or superior defects, as well as the bone available for central screw purchase. Important aspects of the CT evaluation include determining the following factors:
  - The center line¹, which is a line perpendicular to the glenoid surface that exits on the anterior aspect of the scapular neck. This determines the location and extent of the defect and the area available for central screw and post placement.
  - The location of the defect, which should be noted to be peripheral, central, or superior, as well as contained or uncontained.
    - The location of the defect relative to the center line will determine the type of glenoid augmentation needed (discussed later and demonstrated in Figure 1).
  - The size of the defect, relative to the native size of the glenoid, should be estimated on the axial (peripheral or central defect) or coronal (superior or central defect) images.
- Use digital templating software as it can help in estimating whether grafting is necessary, the type of grafting technique that is needed to optimize the position of the baseplate, and the different sizing options.
- Specifically, use preoperative digital templating to determine (1) the ideal baseplate position on the axillary radiograph and the type and amount of graft needed to avoid retroversion (posterior defect), anteversion (anterior defect), or medialization (central defect); (2) the ideal baseplate position on the anteroposterior radiograph and the type and amount of graft needed to avoid superior tilt (superior defect) and medialization (central defect); and (3) the baseplate sizing options for different types of grafting techniques (structural versus corticocancellous).
  - It is important to note that, in revision surgery, the surgeon often will have to deviate from his or her plan according to intraoperative assessment of glenoid bone stock.
- In addition to a preoperative imaging evaluation, it is critical to evaluate any patient seen for revision surgery for evidence of an infection as follows:
  - Assess the erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), and complete blood-cell count with differentiation.
  - Consider a shoulder aspiration if the patient has an elevated ESR or CRP or if there are any clinical signs of an infection, such as erythema, pain that has persisted since surgery, fever, or drainage.
  - If the patient appears to have an infection (positive cultures or clinical signs), a 2-stage resection and replantation is our preferred method of management.

Fig. 1

Fig. 1 Algorithm for glenoid bone-grafting in the setting of revision to a reverse shoulder arthroplasty. This algorithm represents our current approach to glenoid deficiency if the surgeon decides to utilize bone-grafting in the revision setting. (Used with permission of the Mayo Foundation for Medical Education and Research. All rights reserved.)

Step 2: Surgical Approach and Humeral Component Management

Perform all operations with the patient in the beach-chair position.

- Use a deltopectoral approach through the previous incision.
  - Perform meticulous dissection, which is required in the revision setting, and take great care to avoid injury to the anterior deltoid muscle and axillary nerve on the undersurface of the muscle.
  - Release spaces underneath the deltoid, coracoid, and acromion.
  - If it is present, release the subscapularis by means of (1) a tenotomy 1 cm medial to the lesser tuberosity, (2) a subscapularis peel, and (3) an osteotomy of the lesser tuberosity.
  - To gain maximal exposure, perform an inferior capsular release from the humeral neck in a vertical fashion, extending posteriorly to release much of the scar tissue that has built up.
  - Use an extensile approach, if needed for glenoid exposure, by performing a release of the pectoralis major and latissimus dorsi muscles and, if necessary, part of the anterior deltoid insertion.
- Humeral component.
  - If the humeral component is loose or malaligned, extract it using standard implant extraction devices.
  - If there is difficulty with component removal, perform the following stepwise methodical technique:
    - Release fibrous tissues circumferentially around the stem to expose the implant-bone (or cement-bone) interface.
    - Open the proximal interface using either osteotomes or a pencil tip burr circumferentially to free up the proximal fixation of the component.
    - Insert flexible osteotomes to further free up the implant-bone interface.
    - Remove the component with a square-tip impactor. However, in selective shoulders, the humeral shaft needs to be longitudinally divided or windowed to facilitate component removal.
  - After component removal, thoroughly debride all remaining fibrous tissue.
  - When the humerus needs to be shortened or to be recut to change version, save the bone obtained from the osteotomy so it can be used in autografting.
    - Do this prior to working around the upper part of the component in order to preserve as much bone for grating as possible.
  - In shoulders with compromised proximal humeral bone stock, place a broach or humeral neck protector during glenoid exposure to avoid crushing the proximal humeral bone with retractors.

Step 3: Glenoid Component Removal and Preparation

Glenoid exposure is the key to the operation.

- Remove the glenoid component.
  - Expose the glenoid component circumferentially, removing any scar tissue or any capsular adhesions to the glenoid.
    - It is important to identify and protect the axillary nerve traversing inferiorly.
  - Obtain ample glenoid exposure by (1) achieving circumferential exposure of the glenoid, removing excess fibrous or capsular tissue; (2) performing an inferior capsular release (staying on bone to avoid axillary nerve injury); (3) mobilizing the subdeltoid and subacromial space; and (4) removing all heterotopic ossification or osteophytes.
  - Extensile exposure options include (1) a pectoralis major release (<2 cm), (2) division of the coracohumeral ligament, (3) partial release of the conjoined tendon, (4) partial release of the deltoid off the humeral shaft and/or clavicle or acromion, and (5) an extended capsular release.
  - Remove the glenoid component using either generic or implant-specific extraction techniques.
  - When removing the glenoid component, if it is not grossly loose, it is critical to use an oscillating saw, osteotome, or pencil tip burr to circumferentially divide the implant-bone interface and minimize bone loss.
  - After glenoid component removal, perform a meticulous synovectomy and remove any heterotopic ossification or excess scar formation around the glenohumeral articulation. This includes a thorough debridement of any fibrous tissue coating the glenoid or the proximal part of the humerus.
  - Expose the bone of the remaining glenoid in all 4 quadrants, enabling an intraoperative assessment of the remaining glenoid bone stock.
  - When an uncontained glenoid defect is anticipated, preserve the thick fibrous tissue around the defect so that bone graft may be contained during graft and component implantation, especially if particulate graft is to be used.
- Prepare the glenoid (central peg)^{1,4-7}.
  - Identify the central aspect of the glenoid, being sure to adjust the trajectory and location of the centering guide pins according to the glenoid bone defects.
    - Use the center line, which is a line perpendicular to the glenoid surface (it exits on the anterior aspect of scapular neck at the base of the glenoid vault)¹, from the preoperative CT scan to judge glenoid version.
    - Conversely, use of an “alternative center line” is potentially appropriate in certain shoulders in the revision setting⁷. In revisions that are due to compromised bone, it might be more appropriate to direct the central fixation slightly posterior and toward the scapular body as it may improve fixation.
  - Even though the centering guide pin is usually introduced perpendicular to the glenoid surface on the anteroposterior plane¹, this may be modified in slightly more anteversion or retroversion in order to increase the amount of native bone in contact with the baseplate.
    - The ideal glenoid anteversion is between 0° and 15°, as this facilitates the screw fixation into the remaining scapular bone.

- When preparing the high side, first determine the location and trajectory of the central peg and/or screw. Then it is important to eccentrically ream the high side of the glenoid down to the subchondral bone, with the goal being to achieve the largest possible contact area between the native glenoid and the baseplate while avoiding excessive reaming.
  - Identify the central aspect of the native glenoid and eccentrically ream the high side of the glenoid to the level of subchondral bone.
  - In shoulders with moderate or severe glenoid bone loss, perform the reaming slowly and carefully to preserve as much native bone as possible.
- When preparing the low side, or the area of glenoid deficiency, roughen the sclerotic bone with a high-speed burr or drill to expose bleeding bone.

Step 4: Assessment of Glenoid Bone Stock and Bone-Grafting Algorithm

Use bone graft if the glenoid is thought to be inadequate for stable fixation in an acceptable position.

- Select the glenoid baseplate on the basis of maximizing implant-bone contact while preserving stability and shoulder motion.
  - For small glenoid defects, use a smaller baseplate to maximize contact with the glenoid surface, filling in the remaining defect with corticocancellous graft.
  - For larger glenoid defects, use a larger baseplate in combination with a structural graft.
- Humeral structural autograft can be obtained in shoulders in which the humeral component is removed and adequate humeral bone stock remains for a reasonably sized neck cut. In such shoulders, a new cut in an appropriate inclination will help to preserve as much structural autograft as possible
- Bone-graft algorithm.
  - Overall, if $\geq 80\%$ of the undersurface of the glenoid baseplate is not in contact with the baseplate, consider using morselized bone graft. When $\leq 50\%$ of the component is in contact with the glenoid, consider using structural graft to augment the glenoid contact and fixation.
    - For a peripheral defect with $\geq 50\%$ contact, use structural allograft or humeral autograft to improve implant-bone contact.
    - For a peripheral defect with $< 50\%$ contact, use a structural autograft from the iliac crest or the proximal part of the humerus to restore version and improve implant-bone contact.
    - For superior defects with $< 50\%$ contact, loss of inferior tilt of the glenoid predisposes to superior glenoid tilt; therefore, use structural autograft (iliac crest or proximal part of the humerus) to restore neutral or inferior tilt and reduce the risk of scapular notching.
    - For a central defect with $\geq 30\%$ contact, use morselized allograft or autograft to improve implant-bone contact.
    - For a central defect with $< 30\%$ contact, which predisposes to medialization if the baseplate is fixed into the large defect, use structural grafts (iliac crest or proximal part of the humerus) to restore the natural position of the glenoid.
- Determine the source of the graft and the technique of grafting according to our bone-grafting algorithm (Fig. 1).

Step 5-A: Manage a Peripheral Defect with $\geq 50\%$ Implant-Bone Contact with a Structural Allograft or Humeral Autograft

When a peripheral defect contributes to either glenoid anteversion (anterior) or retroversion (posterior), but the implant has $\geq 50\%$ contact with the native bone, consider using a structural autograft from the local humerus (preferred), if available, or a structural allograft (Video 1).

- Use a structural autograft from the humerus or a structural allograft as it can augment component fixation, while also restoring normal glenoid version.
- Obtain the graft and contour it to match the defect.
  - Perform the contouring with a combination of a burr, saw, and rongeurs.
  - Once the shape perfectly matches the defect, place the graft into the defect and hold it in place with 1 or 2 Kirschner wires.
  - It is important to place these Kirschner wires outside the path of the reamer.
  - Once the graft is secured in place, apply the baseplate centering guide.
  - Very cautiously and slowly ream the graft and native glenoid to conform to and perfectly match the back of the baseplate.
    - As noted in Step 3, it is critical to ream the native glenoid prior to placing the graft, thus allowing very gentle reaming of the glenoid-graft construct to avoid fracturing the graft.
    - If it is needed, use a burr to optimize the perfect contour between the graft and the native glenoid, as well as the soon-to-be-placed baseplate.
  - Insert the baseplate tightly to compress the graft to the native glenoid.
  - Then place the peripheral locking screws, with careful attention to obtain purchase in the anteromedial aspect of the scapular neck (the strongest bone of the scapular neck).
    - Often, baseplate impaction and screw fixation alone are enough to compress and stabilize the graft.
    - Certain cases require 1 or 2 additional 3.5-mm cortical interfragmentary screws to secure the graft to the native glenoid, usually in the direction of the Kirschner wires that were placed for the initial fixation. These are placed prior to baseplate implantation.
  - After baseplate placement, use a burr to contour any of the graft that overhangs the periphery of the glenoid baseplate.

Step 5-B: Manage a Peripheral Defect with <50% Implant-Bone Contact with a Structural Autograft from the Iliac Crest or Proximal Part of the Humerus

In shoulders with a peripheral defect with <50% contact with the native glenoid and substantial alterations in glenoid version, consider using a structural autograft from the proximal part of the humerus (preferred), if available, or the iliac crest (Figs. 2-A, 2-B, 2-C, and 3; Video 1).

- If bone stock in the proximal part of the humerus is not adequate, as in many revision cases, harvest a tricortical iliac crest autograft.
  - Perform the iliac crest harvest in a standard fashion, from the ipsilateral side, to allow for gait aid utilization in a more biomechanically favorable position.
- After obtaining the graft, contour it in a manner similar to the allograft, using burrs, saw, rongeurs, and osteotomes.
  - Contour the graft in a wedge shape to perfectly match the defect.
  - Secure the graft into the defect with 1 or 2 Kirschner wires, ensuring that they are out of the path of the reamer.
  - Then place the reaming guide down the center of the glenoid.
  - Ream the graft and native glenoid to conform their shape to match the baseplate.

Fig. 2-A

Fig. 2-B

Fig. 2-C

Fig. 3

Figs. 2-A, 2-B, and 2-C Iliac crest structural autograft for a posterior glenoid defect. **Fig. 2-A** Axillary radiograph (left) and axial CT scan (right) demonstrating a posterior glenoid bone defect. The standard center line (long red line), perpendicular to the glenoid surface (short red line) exiting on the anterior scapular neck, enables an evaluation of the location and extent of the defect (yellow lines). **Fig. 2-B** After glenoid exposure and debridement, the so-called high side of the glenoid is reamed to the subchondral plate. Then a wedge of bone graft is contoured to fill the defect and is secured in place behind the baseplate with screw and press-fit fixation. **Fig. 2-C** Postoperative radiograph made after structural bone-grafting during revision of a hemiarthroplasty to a reverse component.

Fig. 3 Drawing of structural bone-grafting in revision of an anatomic shoulder replacement with a reverse prosthesis. Revision of an anatomic shoulder replacement often leads to substantial glenoid defects. Autologous wedge bone grafts from the proximal part of the humerus can be utilized to correct tilt or version. The graft is shaped to correct the defect and then is secured behind the glenoid baseplate.

- If it is needed, use a burr to further contour the graft to improve its match with the baseplate.
- Insert the baseplate to compress the graft to the glenoid, and then further compress it with central and peripheral screws, attempting to engage the strong bone at the anteromedial aspect of the scapular neck (Figs. 2-A, 2-B, 2-C, and 3).
  - If they are needed, one or two 3.5-mm cortical screws are inserted to secure the graft to the native glenoid, in the trajectory of the initial Kirschner wires. A burr can then be used to contour the graft around the baseplate to ensure that it is flush.
- Pack morselized graft in any areas under the baseplate of the graft in any small remaining defects as needed.
- Alternatively, place the screws prior to baseplate implantation. In this case, insert the Kirschner wires in the same trajectory as the eventual 3.5-mm cortical screws.
  - Prior to baseplate insertion, place one or two 3.5-mm cortical screws to secure the graft impacted between the glenoid component and the native glenoid. Once the screws are placed, countersink the heads.
  - Ream the glenoid and graft to contour to the shape of the baseplate, and place the baseplate tightly to compress the graft and native glenoid.

Step 5-C: Manage a Central Defect with $\geq 30\%$ Implant-Bone Contact with Morselized Bone-Grafting (Allograft or Autograft)

In shoulders with a central defect with $\geq 30\%$ contact between the baseplate and the native glenoid, with adequate primary stability of the central screw and/or peg, use morselized local autograft (preferred), if available, or corticocancellous allograft, to restore the lateral offset of the native glenoid and implant-bone contact area.

- In these central defects, the graft is packed centrally into the defect, completely filling the defect.
  - Reverse reaming can be used to help to compress the morselized graft into the central glenoid defect and shape it to fit the baseplate.
  - The glenoid baseplate is then secured into place with the central and peripheral screws.

Step 5-D: Manage a Central (Global) Defect with <30% Implant-Bone Contact with a Structural Autograft from the Iliac Crest or Proximal Part of the Humerus

As a large central or global deficiency can lead to excessive glenoid medialization (Figs. 4-A, 4-B, and 4-C), use a structural tricortical autograft from the iliac crest to restore glenoid structure and support implantation, as well as increase the offset of the glenoid component, enhancing stability and potentially reducing the risk of scapular notching⁸.

- Restore the glenoid close to its anatomic location as it has the biomechanical advantages of improving stability and function by restoring the lever arm of the deltoid and the tension on the other soft tissue.
- After obtaining the graft, contour it to exactly match the glenoid baseplate.
- Drill a central hole in the center of the graft to facilitate central screw placement.
  - Place corticocancellous graft (allograft or autograft) around the periphery to fill in any remaining defects between the graft and native glenoid.
- Secure the graft in place utilizing Kirschner wires.
- Prepare the glenoid with the technique described above, drilling the central hole, reaming and contouring the graft to maximize baseplate contact, and placing the baseplate, secured in place with peripheral screws, attempting to obtain purchase in the medial scapular neck (Figs. 4-A, 4-B, and 4-C).

Fig. 4-A

Fig. 4-B

Fig. 4-C

Figs. 4-A, 4-B, and 4-C Structural bone-grafting for a superior and central defect in revision of an anatomic shoulder replacement. (The arrows in the images are cursors and are not indicating a specific feature.) **Fig. 4-A** An anteroposterior radiograph (left) and axial CT scan (right) demonstrating central and superior glenoid bone loss. **Fig. 4-B** The glenoid component is removed using an oscillating saw, osteotomes, and rongeurs to reveal the large central defect. Then the central wire is placed and the glenoid is prepared. The bone graft is placed underneath the baseplate and is secured in place by the central screw and 4 peripheral screws. **Fig. 4-C** Postoperative radiograph made after revision of an anatomic total shoulder replacement to a reverse shoulder replacement with the use of central structural bone graft.

- Use additional 3.5-mm cortical screws to secure the graft to the native scapula if desired.
- Furthermore, use a glenosphere with a lateral center of rotation if more lateral offset is needed.
  - However, an advantage of this technique is that it avoids the need to use implants with a lateral center of rotation that potentially increase glenoid failure rates in the setting of revision arthroplasty².
- Alternatively, implant the baseplate in the patient's iliac crest and harvest the component-baseplate construct as a single structure.
  - This avoids the need to ream and prepare for central peg or screw fixation a graft that may have questionable stability during the glenoid preparation phase.
- With both grafting techniques, it is important to obtain peg or screw fixation across the graft into the native glenoid.

Step 5-E: Manage a Superior Defect with <50% Implant-Bone Contact and Loss of Tilt with a Structural Autograft from the Iliac Crest or Proximal Part of the Humerus

For a superior deficiency with <50% contact between the implant and the native bone and a loss of neutral tilt, avoid superior tilt as it is critical to obtain either neutral or inferior tilt of the glenoid (keep this in mind when placing the central cannulated Kirschner wire for drilling the central screw) and use structural autograft for larger defects to prevent superior tilt, with the source of the graft preferentially from the humeral neck resection; however, if there is not adequate proximal humeral bone, a tricortical graft from the ipsilateral iliac crest can be used.

- Contour the structural autograft to match the shape and depth of the superior defect.
  - The graft can be slightly proud anteriorly or posteriorly if there is a combined superior and anterior-posterior defect.
  - Secure the graft in place with superior and anterior Kirschner wires.
- After cannulating the central hole, begin reaming in a methodical fashion, being careful to compress the graft, but not split or fracture it (Figs. 4-A, 4-B, and 4-C).
  - If desired, use reverse reaming to help with the initial compression and contouring of the graft.
- After the graft and native bone are conformed to match the baseplate, insert the baseplate in neutral or slight inferior tilt and compress it with a central screw or peg and multiple peripheral screws, paying attention to obtaining purchase in the medial aspect of the scapular neck.

Step 6: Placement of Baseplate Screws and Glenosphere and Implantation of the Humeral Component

- Place baseplate screws and glenosphere.
  - After performing the grafting technique and placing the baseplate over the graft, insert additional peripheral screws to secure the baseplate.
    - Although screw insertions will vary in their locations and trajectory, place them to capture the anteromedial cortex of the scapular neck for the strongest cortical purchase.
  - Impact the glenosphere into place after insertion of all of the screws.
- Implant the humeral component.
  - After the glenoid component has been placed (as detailed in the following section) with the appropriate bone graft, implant the humeral component with or without cement in a standard fashion, according to surgeon preference, prior to component fixation and remaining humeral bone stock.
  - Place humeral components in 20° to 30° of retroversion.
  - After implantation of the humeral component, reduce the shoulder and test shoulder stability and motion.
    - Modify the humeral head and glenosphere size to achieve the best balance between stability and motion. The humerus should translate approximately 50% of the width of the glenoid.

Step 7: Postoperative Care

- Place the arm in a shoulder immobilizer.
- Adapt the program of physical therapy to each patient.
  - When overall component fixation is good but frail, delay motion for 6 to 8 weeks to allow ingrowth. On the contrary, when outstanding primary stability of both components and the graft are achieved, have the patient start motion earlier.
- Typically, have patients progress through a program of passive, then active-assisted, and lastly strengthening exercises.
- Make radiographs at 3 months postoperatively to evaluate component alignment and graft incorporation.

Results

In our practice, glenoid bone-grafting was performed in 29% of the 143 shoulders revised using reverse components². Although most patients achieved reasonable pain relief and shoulder function, the data from our study seem to indicate that glenoid loosening and repeat revision surgery are more common in shoulders requiring bone-grafting at the time of revision. The 5-year survival rate for the shoulders that had required glenoid grafting was 89% with glenoid loosening as the end point and 76% with repeat revision as the end point. The shoulders that needed glenoid grafting may have been generally more complex cases, which might explain their overall higher rate of failure. In addition, areas of bone graft may not have supported some components properly or may have been resorbed, facilitating component failure.

Several patient-related factors that influenced the outcomes included smoking status (implant survival, revision for glenoid loosening, and glenoid lucencies), increasing body mass index (BMI; glenoid lucency), and increasing age (glenoid lucency). Smoking status and increasing BMI, which are potentially modifiable risk factors, should be considered before revision surgery. Also, the failure rate after revision of failed hemiarthroplasties was lower than that after revision of anatomic or reverse arthroplasties. With respect to surgical technique, the use of

structural grafts or the type of graft used (allograft or autograft) did not have an effect on the outcomes; however, we realize that the patients in our series who needed a structural graft had more complex glenoid abnormalities than those who did not require such a graft. It is possible that an increased use of structural grafts might lead to decreased rates of glenoid loosening. Our current practice with regard to glenoid bone-grafting as a result of these early findings is reflected in our algorithm (Fig. 1).

Pitfalls & Challenges

- For graft impaction, it is critical to compress the graft prior to baseplate placement. One technique involves reverse reaming prior to regular meticulous contouring of the graft and glenoid through standard reaming.
- For optimal glenoid bone stock, it is very important to obtain screw purchase in the anteromedial cortex of the scapular neck as it provides the strongest cortical purchase.
- Aggressive augmentation of glenoid bone stock with either porous metal or structural bone graft is critical to achieve stability. In our study, more nonstructural grafts were utilized, potentially leading to a higher failure rate.
- Lateralized implants should also be used with caution. The lateral center of rotation increases the lever arm of the superiorly directed load of the humeral implant against the glenoid and imparts greater stress on the baseplate fixation, which is probably suboptimal in shoulders with compromised glenoid bone undergoing revision. Additionally, a more medial center of rotation might lead to improved postoperative shoulder function, given the decreased shear stresses on the graft. However, this is also difficult to definitively assess, given that most patients in our study who received implants with a lateral center of rotation had greater degrees of medial glenoid wear.
- Certain modifiable patient-related factors, including smoking status, increasing age, and increasing BMI, should be considered prior to revision surgery.
- In a patient with a prior glenoid component (anatomic or reverse shoulder replacement), the glenoid bone stock and subsequent glenoid fixation will be more challenging, with potentially more aggressive fixation needed to overcome this deficiency.
- We believe that it is necessary to achieve at least 30% to 50% host bone contact after reaming. Lesser defects can be filled in with corticocancellous bone graft. Superior defects should be grafted to prevent inferior glenoid tilt. Anterior or posterior defects should be augmented with bone graft to correct version and improve stability. In any shoulder with a large defect, structural bone grafts should be considered.

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