Patient-Specific Implants in Severe Glenoid Bone Loss

Publish date: February 8, 2018
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Authors’ Disclosure Statement: Dr. De Martino reports that he is a consultant to Lima Corporate. Dr. Dines and Dr. Craig report that they receive royalties from Zimmer Biomet for the development of the product (Comprehensive Shoulder VRS) discussed in this article. Dr. Gulotta reports that he is a consultant to Zimmer Biomet. Dr. Warren reports no actual or potential conflict of interest in relation to this article.

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Take-Home Points

- With the increasing number of arthroplasties performed, and the expanding indication for shoulder arthroplasty, the number of revision shoulder arthroplasties is also increasing.
- Complex glenoid bone defects are sometimes encountered in revision shoulder arthroplasties.
- Glenoid reconstructions with bone graft have reported encouraging short- to mid-term results, but the high number of complications is a concern.
- Using the CAD/CAM technology patient-specific glenoid components have been created to reconstruct the glenoid vault in cases of severe glenoid bone loss.
- Short-term clinical and radiographic results of patient-specific glenoid components are encouraging, however longer-term follow-up are needed to confirm the efficacy of this type of reconstruction.

Total shoulder arthroplasty (TSA) is an effective operation for providing pain relief and improving function in patients with end-stage degenerative shoulder disease that is nonresponsive to nonoperative treatments. 14 With
the increasing number of arthroplasties performed, and the expanding indication for shoulder arthroplasty, the number of revision shoulder arthroplasties is also increasing.\textsuperscript{5-14} Complex glenoid bone deformities present the treating surgeon with a complex reconstructive challenge. Although glenoid bone loss can be seen in the primary setting (degenerative, congenital, and post-traumatic), severe glenoid bone loss is encountered mostly in revision TSAs.

Historically, patients with severe glenoid bone loss were treated with a hemiarthroplasty.\textsuperscript{15-17} However, due to inferior outcomes associated with the use of shoulder hemiarthroplasties compared with TSA in these cases,\textsuperscript{18-20} various techniques were developed with the aim of realigning the glenoid axis and securing the implants into the deficient glenoid vault.\textsuperscript{21-25} Options have included eccentric reaming, glenoid reconstruction with bone autografts and allografts, and more recently augmented components and patient-specific implants. Studies with eccentric reaming and reconstruction with bone graft during complex shoulder arthroplasty have reported encouraging short- to mid-term results, but the clinical and radiographic outcomes remain inconsistent, and the high number of complications is a concern.\textsuperscript{25-28}

Complications with these techniques include component loosening, graft resorption, nonunion, failure of graft incorporation, infection, and instability.\textsuperscript{25-28}

Computer-aided design and computer-aided manufacturing (CAD/CAM) of patient-specific implants have been used successfully by hip arthroplasty surgeons to deal with complex acetabular reconstructions in the setting of severe bone loss. More recently, the same technology has been used to reconstruct the glenoid vault in cases of severe glenoid bone loss.

In this article, we describe a patient-specific glenoid implant, its indication, and both technical aspects and the surgical technique, based on the authors’ experience as well as a review of the current literature on custom glenoid implants.

**Patient-Specific Glenoid Component**

The Vault Reconstruction System ([VRS], Zimmer Biomet) is a patient-specific glenoid vault reconstruction system developed with the use of CAD/CAM to address severe glenoid bone loss encountered during shoulder arthroplasty. For several years, the VRS was available only as a custom implant according to the US Food and Drug Administration rules, and therefore its use was limited to a few cases per year. Recently, a 510(k) envelope clearance was granted to use the VRS in reverse TSA to address significant glenoid bone defects.

The VRS is made of porous plasma spray titanium to provide high strength and flexibility, and allows for biologic fixation. This system can accommodate a restricted bone loss envelope of about 50 mm × 50 mm × 35 mm according to the previous experience of the manufacturer in the custom scenario, covering 96% of defects previously addressed. One 6.5-mm nonlocking central screw and a minimum of four 4.75-mm nonlocking or locking peripheral screws are required for optimal fixation of the implant in the native scapula. A custom boss can be added in to enhance fixation in the native scapula when the bone is sufficient. To facilitate the surgical procedure, a trial implant, a bone model of the scapula, and a custom boss reaming guide are 3-dimensional (3-D) and printed in sterilizable material. These are all provided as single-use disposable instruments and can be available for surgeons during both the initial plan review and surgery.
Preoperative Planning

Patients undergo a preoperative fine-cut 2-dimensional computed tomography scan of the scapula and adjacent humerus following a predefined protocol with a slice thickness of 2 mm to 3 mm. An accurate 3-D bone model of the scapula is obtained using a 3-D image processing software system (Figure 1). The 3-D scapular model is used to create a patient-specific glenoid implant proposal that is approved by the surgeon (Figure 2). Implant position, orientation, size, screw trajectory, and recommended bone removal, if necessary, are determined to create a more normal glenohumeral center of rotation and to secure a glenoid implant in severely deficient glenoid bone (Figure 3). Once the implant design is approved by the surgeon, the final patient-specific implant is manufactured.

Surgical Technique

The exposure of the glenoid is a critical step for the successful implantation of the patient-specific glenoid implant. Soft tissue and scar tissue around the glenoid must be removed to allow for optimal fit of the custom-made reaming guide. Also, removal of the entire capsulolabral complex on the anteroinferior rim of the glenoid is essential to both enhance glenoid exposure and to allow a perfect fit of the guide to the pathologic bone stock. Attention should be paid during débridement and/or implant removal in case of revision, to make sure that no excessive bone is removed because the patient-specific guide is referenced to this anatomy. Excessive bone removal can change the orientation of the patient-specific guide and ultimately the fixation of the implant. Once the custom-made patient-specific guide is positioned, a 3.2-mm Steinmann pin is placed through the inserter for temporary fixation. The pin should engage or perforate the medial cortical wall to ensure that the subsequent reamer has a stable cannula over which to ream. After the glenoid is reamed, the final implant can be placed in the ideal position according to the preoperative planning. A central 6.5-mm nonlocking central screw and 4.75-mm nonlocking or locking peripheral screws are required to complete the fixation of the implant in the native scapula. Once the patient-specific glenoid component is positioned and strongly fixed to the bone, the glenosphere can be positioned according to the preoperative planning, and the reverse shoulder arthroplasty can be completed in the usual fashion.

Case Examples

A 68-year-old woman underwent a TSA for end-stage osteoarthritis in 2000. The implant failed due to a cuff failure. The patient underwent several surgeries, including an open cuff repair, with no success. She had no active elevation preoperatively. Because of the significant glenoid bone loss, a patient-specific glenoid reconstruction was planned. Within 24 months after this surgery, the patient was able to get her hand to her head and elevate to 90° (Figures 4A-4F).

In October 2013, a 68-year-old man underwent a TSA for end-stage osteoarthritis. After 18 months, the implant failed due to active Propionibacterium acnes infection, which required excisional arthroplasty with insertion of an antibiotic spacer. Significant glenoid bone loss (Figure 3) and global soft-tissue deficiency caused substantial disability and led to an indication for a reverse TSA with a patient-specific glenoid vault reconstruction (Figures 6A-6D) after infection eradication. Within 20 months after this surgery, the patient had resumed a satisfactory range of motion (130° forward elevation, 20° external rotation) and outcome.
Discussion

Although glenoid bone loss is often seen in the primary setting (degenerative, congenital, and post-traumatic), severe glenoid bone loss is encountered in most revision TSAs. The best treatment method for massive glenoid bone defects during complex shoulder arthroplasty remains uncertain. Options have included eccentric reaming, glenoid reconstruction with bone allograft and autograft, and more recently augmented components and patient-specific implants. The advent and availability of CAD/CAM technology have enabled shoulder surgeons to create patient-specific metal solutions to these challenging cases. Currently, only a few reports exist in the literature on patient-specific glenoid components in the setting of severe bone loss.

Chammaa and colleagues reported the outcomes of 37 patients with a hip-inspired glenoid component (Total Shoulder Replacement, Stanmore Implants Worldwide). The 5-year results with this implant were promising, with a 16% revision rate and only 1 case of glenoid loosening.

Stoffelen and colleagues recently described the successful use of a patient-specific anatomic metal-backed glenoid component for the management of severe glenoid bone loss with excellent results at 2.5 years of follow-up. A different approach was pursued by Gunther and Lynch, who reported on 7 patients with a custom inset glenoid implant for deficient glenoid vaults. These circular anatomic, custom-made glenoid components were created with the intention of placing the implants partially inside the glenoid vault and relying partially on sclerotic cortical bone. Despite excellent results at 3 years of follow-up, their use is limited to specific defect geometries and cannot be used in cases of extreme bone loss.

Conclusion

We have described the use of a patient-specific glenoid component in 2 patients with severe glenoid bone loss. Despite the satisfactory clinical and short-term radiographic results, we acknowledge that longer-term follow-up is needed to confirm the efficacy of this type of reconstruction. We believe that patient-specific glenoid components represent a valuable addition to the armamentarium of shoulder surgeons who address complex glenoid bone deformities.

Key Info

Figures/Tables

Figures / Tables:

[FIGURES/TABLES]
Figure 1. Disposable patient-specific glenoid reconstruction to assess the bone loss in 3-dimensional more accurately.

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Figure 2. Disposable patient-specific glenoid bone model and implant model to appreciate the reconstruction in 3-dimensional better.

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Figure 2. The 3-dimensional scapular model with the proposed patient-specific glenoid component. Implant position, orientation, size, and screw trajectory can be determined to reconstruct the glenoid vault more accurately.
Figure 4. Failed total shoulder arthroplasty. (A, B) Radiographic views of the failed implant. (C) Computed tomography shows the severe glenoid bone loss that can be expected once the glenoid component and cement are removed. (D) Three-dimensional reconstruction model of the glenoid without implant and cement. (E) Anteroposterior and (F) lateral radiographic views at 6 months.

Figure 5. Infected total shoulder arthroplasty. Computed tomography shows severe glenoid bone loss.
References


Multimedia
Product Guide

Product Guide

- Med4 Elite®
- GRPro 2.1®
- Shoulder Wrap
- Knee Wrap

Citation

Publish date: February 8, 2018

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