

# Novel Solution for Massive Glenoid Defects in Shoulder Arthroplasty: A Patient-Specific Glenoid Vault Reconstruction System

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## Abstract

Complex glenoid deformities present the most difficult challenges in shoulder arthroplasty. These deformities may be caused by severe degenerative or congenital deformity, posttraumatic anatomy, tumor, or, in most cases, bone loss after glenoid failure in anatomical total shoulder arthroplasty. Methods of treating severe bone loss have included inlay and onlay bone-graft options with augmented fixation and, in severe cases, salvage hemiarthroplasty with limited goal expectations. Unfortunately, none of these methods has provided consistently satisfactory reproducible results. In fact, each has had high rates of failure and complications.

Borrowing from hip and knee arthroplasty surgeons' experience in using CAD/CAM (computer-aided design/computer-aided

manufacturing) patient-specific implants to fill significant bony defects, Dr. D. M. Dines developed a glenoid vault reconstruction system (VRS) in conjunction with the Comprehensive Shoulder Arthroplasty System (Zimmer Biomet) to treat severe glenoid bone deficiency. The VRS is patient-specific; each case involves making a preoperative plan based on 3-dimensional reconstruction of a 2-dimensional computed tomography scan. The patient-specific implant and instrumentation that are created are used to reconstruct the deformed glenoid in an anatomical position without the need for additional bone graft.

In this article, we describe the implant and its indications, technical aspects of production, and surgical technique.

Early results of this vault reconstruction system have been promising in these most difficult clinical situations. Complex glenoid deformities present the most difficult challenges in shoulder arthroplasty (SA). These deformities may be caused by severe degenerative or congenital deformity, posttraumatic anatomy, tumor, or, in most cases, bone loss after glenoid failure in anatomical total SA.

Walch and colleagues<sup>1</sup> described the pathologic glenoid lesions seen in progressive degenerative arthritis and some congenital defects. The most severe were initially characterized

as Walch B2 and Walch C deformities. These lesions have been further classified to include Walch B3 posteroinferior glenoid deformities.<sup>2,3</sup> Each of these deformities can result in severe glenoid vault deficiency.

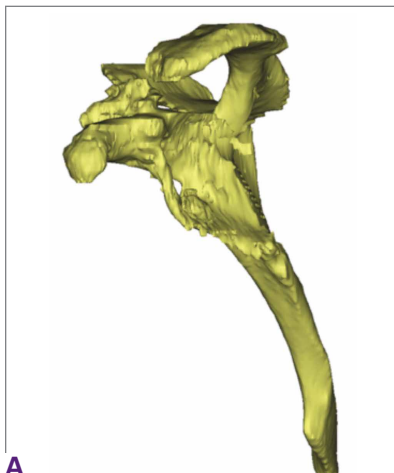
In some revision cases and in severe rheumatoid cases, these deformities can present as cavitory lesions with or without failure of the glenoid rim or wall resulting in significant compromise of glenoid vault lesions.<sup>4,5</sup> In these cases, the degree of "medialization" of the native glenohumeral joint line and the amount of peripheral bone loss can have profound effects

**Authors' Disclosure Statement:** Dr. D. M. Dines reports that he is a paid consultant to and receives royalties and advisory board compensation from Zimmer Biomet for his development of its Comprehensive Shoulder Arthroplasty System, which relates directly to this article. He also receives royalties on textbooks published by Thieme and is a shareholder in VuMedi. Dr. Gulotta reports that he is a consultant to Zimmer Biomet. Dr. Craig reports that he receives royalties from Zimmer Biomet. Dr. J. S. Dines reports that he is a consultant to Arthrex.



**Figure 1.** Vault reconstruction system implant on pathologic glenoid patient-specific model.

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**A**



**B**

**Figure 2.** (A) Three-dimensional computed tomography and (B) proposed vault reconstruction system component preoperatively determine size and positioning of implant as well as screw configuration and trajectories.

on the amount of bone available for fixation and on the ability to allow component positioning for best surgical and biomechanical outcomes.

Other bone loss deformities, which have been described by Antuna and colleagues<sup>6</sup> and Seebauer and colleagues,<sup>7</sup> often accompany disease processes with severe cuff deficiency. These deformities historically have been treated with intercalary-type bone grafts in 1- or 2-stage revision of reverse SA or in salvage to hemiarthroplasty. Treatment of these pathologies with the technique described produced only fair results in short-term to midterm follow-up. The most commonly reported complications have been component loosening, bone graft failure, infection, and instability.<sup>8-11</sup>

Borrowing from hip and knee arthroplasty surgeons' experience in using CAD/CAM (computer-aided design/computer-aided manufacturing) patient-specific implants to fill significant bony defects, Dr. D. M. Dines and Dr. Craig developed a patient-specific glenoid vault reconstruction system (VRS) in conjunction with the Comprehensive Shoulder Arthroplasty System (Zimmer Biomet). For a number of years, the Food and Drug Administration allowed this patient-specific glenoid VRS component to be made available only as a custom implant. Recently, however, full 510K clearance was granted to use the VRS in reverse SA patients with severe soft-tissue deficiency and significant glenoid bone loss.

In this article, we describe the implant and its indications, technical aspects of production, and surgical technique.

### Vault Reconstruction System

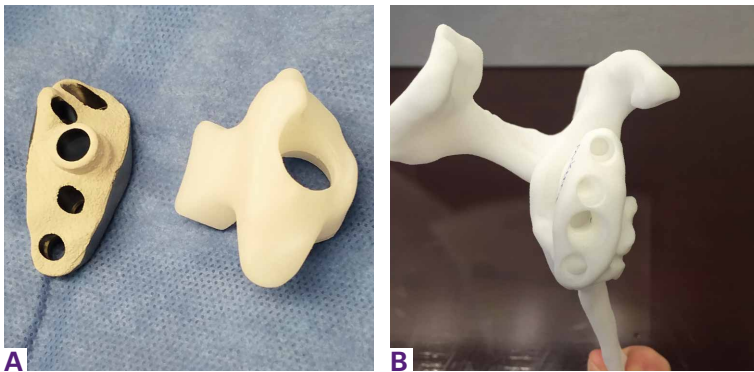
Severe glenoid bone loss often requires an implant that specifically matches the patient's anatomy.

The patient-specific glenoid VRS (**Figure 1**) is made from a 3-dimensional reconstruction of a 2-dimensional computed tomography image. CAD/CAM reconstruction allows for preoperative planning, visualization, and development of patient-specific implants. The patient-specific images used for the glenoid VRS detail implant position, orientation, and size to create a more normal glenohumeral center of rotation. The model allows for the planning, placement, size, and trajectory of the central and peripheral fixation screws, ensuring the best possible fixation (**Figures 2A, 2B**). Most important, the model is used to create patient-matched implants that fill bone voids with porous plasma spray-coated titanium, which provides high strength and flexibility and allows for biological fixation. This system can accommodate a bone loss envelope of about 50 mm × 50 mm × 35 mm based on evaluation of all implants created in the custom scenario.

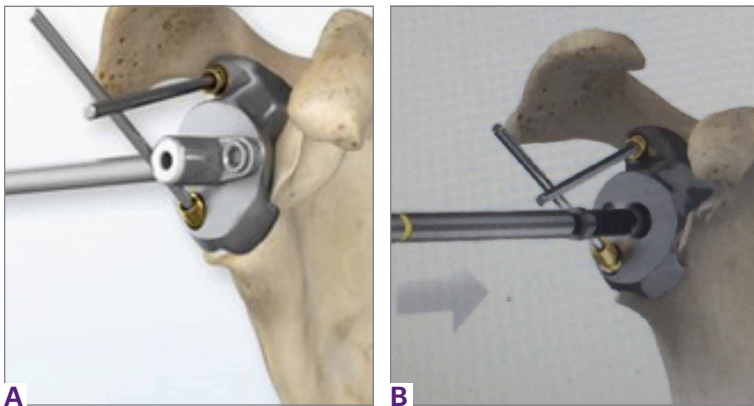
In some cases in which the bone is sufficient to enhance

### Take-Home Points

- With more shoulder arthroplasties being performed on younger patients, we can expect more revisions in the future.
- Many of these revision cases will have profound glenoid bone loss.
- Bone grafting the glenoid defects in shoulder arthroplasty has been less successful especially with significant vault defects.
- Based on the CAD-CAM success in total hip and knee replacement surgery, a patient-specific glenoid vault reconstruction system has been developed by Zimmer Biomet to deal with profound glenoid bone loss and cuff insufficiency.
- Early results of this vault reconstruction system have been promising in these most difficult clinical situations.



**Figures 3.** (A) Dummy implant and (B) disposable patient-specific guides facilitate surgery.



**Figure 4.** (A) Real implant on attached holder is positioned and fixed provisionally with pins through predetermined screw holes with special attachments (B) and then the central 6.5-mm compression screw is inserted.

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**Figure 5.** Central 6.5-mm compression screw is placed and then augmented with predetermined peripheral screws for rigid fixation.

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fixation in the deficient glenoid vault, a custom boss may be added to the implant, as well as a custom guide matching the implant. The implant model, the bone model, and the custom boss reaming guide are all constructed from a sterilizable material and are intended to be single-use disposable instruments as well as tools for the initial plan review (**Figures 3A, 3B**).

### Glenoid Exposure

In most cases of severe glenoid bone loss, the associated soft-tissue deficiency allows for easier glenoid exposure. In this implant system, however, maximal peripheral *en face* exposure of the glenoid is required. In addition, it is mandatory to avoid disturbing the remaining glenoid bone surfaces, which often are thin or fragile, because the patient-specific implant is referenced to this anatomy. Bone that is not maintained changes the orientation of the patient-specific guide and ultimately the fixation of the component. Using the correct retractors and meticulously excising soft-tissue scar tissue are crucial for success.

### Implant Positioning

With the glenoid surface properly exposed, the removable inserter handle and the built-in lip on the implant are used to position the patient-specific guide. Next, a central guide pin is placed through the inserter for temporary fixation and further instrumentation. If enough bone is present, a boss reamer can be used over the guide pin to prepare and increase the fixation surface. Next, the real implant is placed in the ideal position as defined in the preoperative plan. The implant is fixed provisionally through special guides in the peripheral screw holes (**Figures 4A, 4B**).

The central 6.5-mm nonlocking compression screw is placed to provide strong initial compressive fixation in best bone. Then, in sequence, the temporary fixation pins are removed and are replaced with the 4.75-mm locking or nonlocking screws in the real implant to secure the implant in the planned anatomical position (**Figure 5**).

With the patient-specific glenoid VRS implant now rigidly fixed in the glenoid, the sized and offset glenosphere is properly positioned, and the reverse SA is completed in routine fashion.

### Case Examples

A 49-year-old man underwent hemiarthroplasty for osteoarthritis. The procedure failed and, 3 years later, was revised to conventional total SA.



Unfortunately, the cemented all-polyethylene glenoid loosened secondary to active *Propionibacterium acnes* infection, which required excisional arthroplasty with antibiotic spacer. Significant cavitory bone loss was found with anterior glenoid wall bone loss compromising the glenoid vault. Given the history of bone loss and infection, patient-specific glenoid vault reconstruction was performed after infection eradication. Within 4 years after this surgery, the patient had resumed all activities. At age 57 years, he had restricted active forward elevation and abduction to 120° but was satisfied with the outcome. There was no evidence of infection or component loosening, but close monitoring was continued (Figures 6A-6D).

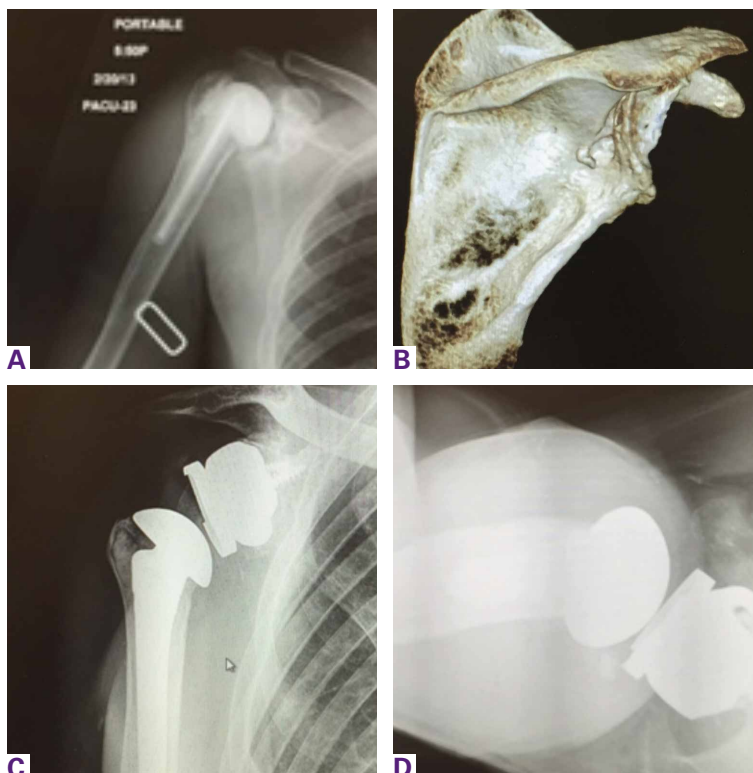
A 71-year-old man underwent reverse SA for rotator cuff-deficient osteoarthritis. After implant excision and spacer placement, he was left with severe soft-tissue deficiency and glenoid bone loss, which caused substantial disability. After treatment for infection, a work-up was performed for glenoid bone deficiency and insertion of a patient-specific glenoid VRS implant. Eighteen months after surgery, active range of motion was 130° forward elevation and limited (20°) external rotation (Figures 7A-7D).

## Discussion

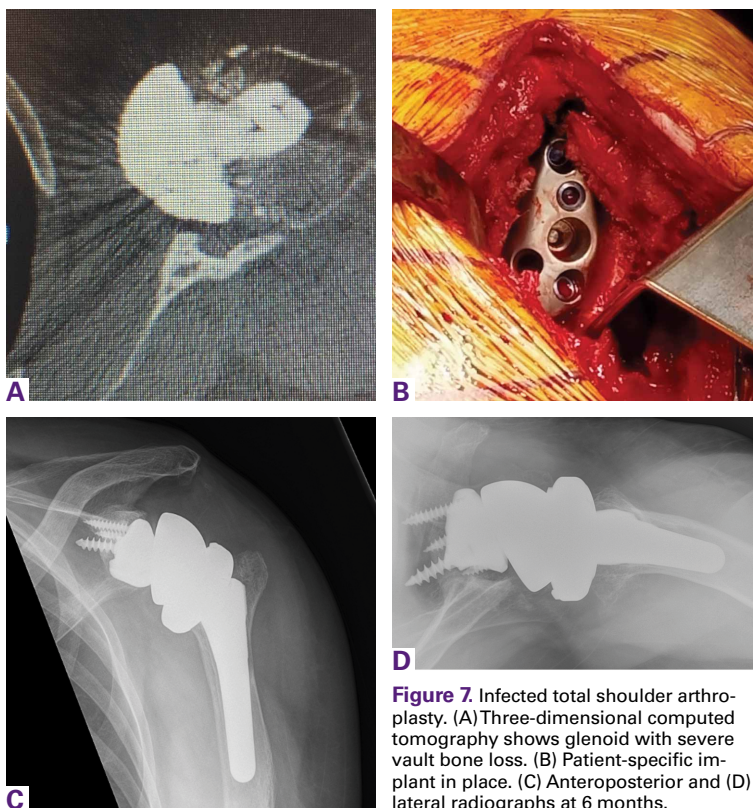
Glenoid bone deformity and deficiency are among the most difficult challenges in SA—a particularly compelling fact given the increasing number of SAs being performed in younger, more active patients. SA surgeons can now expect to be performing even more revisions with concomitant bone defects, which may be severe in some cases.

In addition to these causes of extreme bone loss, recent awareness of the importance of recognizing and treating bone deficits in osteoarthritis, rheumatoid arthritis, trauma, and instability has led to the development of patient-specific guides, instrumentation, and implants. Concepts from the use of CAD/CAM acetabular implants in total hip arthroplasty for severe acetabular bony defects were applied to the use of patient-specific glenoid reconstruction implants without bone graft augmentation.<sup>12</sup> In different form, this idea was reported by Chammaa and colleagues<sup>13</sup> in 30 cases, and clinical and durable results were very promising.

We have described use of this technique in 2 extreme cases of glenoid vault deficiency. In each case, short-term results were quite satis-



**Figure 6.** Infected total shoulder arthroplasty (TSA) in an active 57-year-old man. (A) Antibiotic spacer for infected TSA. (B) Three-dimensional computed tomography shows glenoid with severe vault bone loss. Three years after surgery, (C) anteroposterior and (D) axillary radiographs show vault reconstruction system in position in anatomical TSA.



**Figure 7.** Infected total shoulder arthroplasty. (A) Three-dimensional computed tomography shows glenoid with severe vault bone loss. (B) Patient-specific implant in place. (C) Anteroposterior and (D) lateral radiographs at 6 months.

factory. However, both patients were relatively young, and long-term clinical and radiographic follow-up is needed.

Many of the severe cases of glenoid bone loss require an implant that specifically matches the patient's anatomy. The glenoid VRS implant described here may be of great benefit in these difficult reconstructions and is a valuable addition to the armamentarium of treatments for distorted glenoid anatomy. Eventually, the idea may become useful in treating other, less significant defects by re-creating more-normal biomechanics in SA without bone graft.

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