Reverse Shoulder Arthroplasty for the Treatment of Rotator Cuff Deficiency

Derek Cuff, Derek Pupello, Nazeem Virani, Jonathan Levy and Mark Frankle


This information is current as of June 8, 2008

**Supplementary material**
Commentary and Perspective, data tables, additional images, video clips and/or translated abstracts are available for this article. This information can be accessed at [http://www.ejbjs.org/cgi/content/full/90/6/1244/DC1](http://www.ejbjs.org/cgi/content/full/90/6/1244/DC1)

**Reprints and Permissions**
Click here to [order reprints or request permission](http://www.ejbjs.org/cgi/content/full/90/6/1244/DC1) to use material from this article, or locate the article citation on [jbjs.org](http://jbjs.org) and click on the [Reprints and Permissions] link.

**Publisher Information**
The Journal of Bone and Joint Surgery
20 Pickering Street, Needham, MA 02492-3157
[www.jbjs.org](http://www.jbjs.org)
Reverse Shoulder Arthroplasty for the Treatment of Rotator Cuff Deficiency

By Derek Cuff, MD, Derek Pupello, MBA, Nazeem Virani, MD, Jonathan Levy, MD, and Mark Frankle, MD

Investigation performed at the Florida Orthopaedic Institute, Tampa, Florida

Background: Early designs of reverse shoulder arthroplasty components for the treatment of glenohumeral arthritis associated with severe rotator cuff deficiency in some cases have been associated with mechanical failure. The purpose of this study was to perform a prospective outcomes study of reverse shoulder arthroplasty performed with use of 5.0-mm peripheral locking screws for baseplate fixation and a lateralized center of rotation for the treatment of a rotator cuff deficiency.

Methods: From February 2004 to March 2005, 112 patients (114 shoulders) were treated with a reverse shoulder arthroplasty as part of a United States Food and Drug Administration Investigational Device Exemption study. Ninety-four patients (ninety-six shoulders) were available for a minimum follow-up of two years. Of the ninety-six shoulders, thirty-seven had a primary rotator cuff deficiency, thirty-three had a previous rotator cuff operation, twenty-three had a previous arthroplasty, and three had a proximal humeral nonunion. The patients were prospectively followed clinically (the American Shoulder and Elbow Surgeons [ASES] score, the Simple Shoulder Test [SST], and self-reported satisfaction) and radiographically (mechanical failure, loosening, and notching). Patients were videotaped while performing a standard active range-of-motion protocol before and after treatment. These videos were then analyzed in a blinded fashion by three independent observers using a digital goniometer.

Results: At two years, the average total ASES scores had improved from 30 preoperatively to 77.6; the average ASES pain scores, from 15 to 41.6; and the average SST scores, from 1.8 to 6.8 (p < 0.0001 for all). Blinded analysis of range of motion showed that average abduction improved from 61° preoperatively to 109.5° (p < 0.0001); average flexion, from 63.5° to 118° (p < 0.0001); and average external rotation, from 13.4° to 28.2° (p < 0.0001). The patients rated the outcome as excellent in fifty-three shoulders (55%), good in twenty-six (27%), satisfactory in eleven (12%), and unsatisfactory in six (6%). There was no evidence of mechanical failure of the baseplate or scapular notching in any of the patients. Six of the ninety-four patients in this study had a complication.

Conclusions: Recent advances in reverse shoulder arthroplasty have allowed for improvement in patient outcomes while minimizing early mechanical failure and scapular notching and decreasing the overall complication rate at short-term follow-up.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

Previously, Frankle et al. reported on the results of reverse shoulder arthroplasty at our institution with use of 3.5-mm peripheral screws for baseplate fixation and a lateralized center of rotation in order to treat patients with glenohumeral arthritis associated with severe rotator cuff deficiency1. In that series, patients had improvement in the range of motion, pain scores, and functional outcome scores. Additionally, there was no radiographic evidence of scapular notching. However, 12% (seven) of the sixty patients had early mechanical failure of the implant, necessitating revision. This was most likely due to the greater forces generated at the baseplate-bone interface by the lateralized center of rotation used with this implant1-2.

Disclosure: In support of their research for or preparation of this work, one or more of the authors received, in any one year, outside funding or grants in excess of $10,000 from Encore Medical. In addition, one or more of the authors or a member of his or her immediate family received, in any one year, payments or other benefits in excess of $10,000 or a commitment or agreement to provide such benefits from a commercial entity (Encore Medical). Also, a commercial entity (Encore Medical) paid or directed in any one year, or agreed to pay or direct, benefits in excess of $10,000 to a research fund, foundation, division, center, clinical practice, or other charitable or nonprofit organization with which one or more of the authors, or a member of his or her immediate family, is affiliated or associated.
Biomechanical studies have since shown that the use of 5.0-mm peripheral locking screws and implantation of the baseplate with an inferior tilt resulted in improved fixation and reduced micromotion at the baseplate-bone interface. Thus, modifications have subsequently been made to the surgical technique and prosthetic design of the Reverse Shoulder Prosthesis (Encore Medical, Austin, Texas). The surgical technique was modified to encourage inferior tilt of the glenosphere, and 5.0-mm peripheral locking screws were designed for use with the baseplate. The goal of these modifications was to decrease the mechanical failure of the baseplate while continuing to allow for improved range of motion and outcome scores while minimizing scapular notching. Our purpose was to perform a prospective outcomes study examining the use of reverse shoulder arthroplasty with use of 5.0-mm peripheral locking screws for baseplate fixation and a lateralized center of rotation for the treatment of shoulders with a rotator cuff deficiency. Blinded analysis of the preoperative and postoperative range of motion was performed in an effort to evaluate the effectiveness of this treatment.

Materials and Methods

During a twelve-month period starting in February 2004, 112 consecutive patients (114 shoulders) were enrolled in a United States Food and Drug Administration Investigational Device Exemption study of the modified Reverse Shoulder Prosthesis. The patients included in the study demonstrated rotator cuff deficiency of the shoulder along with glenohumeral subluxation, glenohumeral arthritis, or pseudoparesis (<90° of elevation) of the shoulder as described by Werner et al. This assessment was based on a combination of findings on physical examination (rotator cuff weakness, dynamic instability, and limited range of motion) and radiographs (decreased joint space and abnormal joint position). Patients with this diagnosis were eligible for surgical treatment if they met the remaining inclusion criteria, which consisted of evidence of a functional deltoid muscle on physical examination, a visual analog pain scale score of ≥5, consent to be involved in the study, availability for all follow-up evaluations, and failure of a course of nonoperative treatment. Exclusion criteria for this study consisted of an active infection, a nonfunctioning deltoid, a visual analog pain scale score of <5, a neurological condition (Parkinson disease, multiple sclerosis, or a previous stroke), a mental condition that might interfere with the ability to give informed consent and follow the postoperative protocol, or a known metal allergy. Prisoners were also excluded. Patients less than sixty years old who had not had a previous shoulder arthroplasty and had >90° of forward elevation of the affected arm were not treated with reverse shoulder arthroplasty. Each shoulder in the two patients with bilateral involvement was analyzed independently.

Nine patients died and nine were lost before twenty-four months of follow-up, leaving a total of ninety-four patients (ninety-six shoulders) available for study. There were sixty-three women (sixty-four shoulders) and thirty-one men (thirty-two shoulders), and the average age of the patients was seventy-two years (range, fifty-two to eighty-eight years). The average duration of follow-up for these patients was 27.5 months (range, twenty-four to thirty-eight months). Of the ninety-six shoulders, thirty-seven had a primary rotator cuff deficiency, thirty-three had a previous rotator cuff repair, twenty-three had a previous arthroplasty (a hemiarthroplasty or a total shoulder arthroplasty), and three had a proximal humeral nonunion. Each patient underwent a preoperative physical examination and a radiographic series (true anteroposterior, axillary, internal and external rotation, and scapular Y views). All patients also had a preoperative computed tomography scan to evaluate glenoid bone stock. Prior to surgery, a videotape recording of each patient was made while he or she performed a standardized examination of the range of motion with the patient’s best effort at active direct forward flexion, abduction, and external rotation. The video camera was placed at the height of the shoulder and was directly in line with the patient. Abduction of the arm was videotaped in the coronal plane, and then the patient was instructed to turn 90° so that forward flexion could be videotaped in the sagittal plane. External rotation was videotaped with the camera held overhead so that trunk rotation could be taken into account (see Appendix). Patients performed forward elevation and abduction while standing and actively moving each outstretched arm simultaneously. External rotation was performed while the patient was seated with the elbows at the side in adduction and in 90° of flexion. All patients were required to complete questionnaires to determine the American Shoulder and Elbow Surgeons (ASES) and Simple Shoulder Test (SST) scores.

Surgical Technique and Postoperative Protocol

The surgical technique for this procedure has been previously described in detail. All procedures were performed by the senior author (M.F.) using the Reverse Shoulder Prosthesis with a center of rotation lateral to the glenoid. All baseplates were implanted with a slight inferior tilt (Fig. 1). The device used in this study offered modularity with respect to the amount of center-of-rotation offset that could be selected (either a 6 or 10-mm offset) and was dependent on the glenosphere that was chosen for implantation. Glenosphere selection was based on the soft-tissue tension, which would allow a gentle reduction of the glenohumeral joint with the greatest degree of glenohumeral motion and was stable especially when testing stability with the arm adducted and internally rotated and extending the shoulder. The average center-of-rotation offset used in this series was 6.4 mm (eleven shoulders had a 10-mm offset and eighty-five had a 6-mm offset). The patients with substantial proximal humeral bone loss were treated with proximal humeral allografts along with the reverse shoulder arthroplasty (thirteen patients), and those deemed to have a glenoid deficiency had bone-grafting of the defect as well with either a portion of a femoral head allograft, or the patient’s own humeral head (six patients). Postoperatively, the patients were managed with a shoulder immobilizer. According to protocol, the patient wore the immobilizer for six weeks and performed pendulum exercises on a daily basis. Six weeks after surgery,
the immobilizer was discontinued, passive range-of-motion exercises were begun, and the patient was permitted to use the extremity for activities of daily living. At the three-month period, patients were allowed to begin strengthening the shoulder.

**Range-of-Motion Analysis**

Three independent observers who were not involved with the treatment of these patients used a digital goniometer (Screen Protractor; Iconico, New York, NY) to measure the digital videos of each patient. Eighty-eight of the ninety-six shoulders had preoperative and postoperative videos available for evaluation. The observers were blinded to the identity of the patient as well as to the date of the video so they were not aware if it was a preoperative or a postoperative video. All postoperative videos were evaluated at a minimum of one year after the index procedure. The three observers initially measured a cohort of thirty patient videos on two separate occasions. A Pearson correlation coefficient was calculated to determine interobserver reliability in measuring forward elevation, abduction, and external rotation. A value of >0.7 demonstrates strong agreement. The respective correlation coefficient average for each of these motions was 0.96, 0.94, and 0.80 between observers. Because of the strong degree of agreement among the three observers, a single observer was used to measure all of the digital videos twice in order to establish intraobserver reliability for the entire series of patients.

**Radiographic Analysis**

An independent observer reviewed each patient’s radiographic studies. All preoperative radiographs were examined to grade the joint position with respect to the degree and the direction of instability on the basis of the criteria previously described by Rispoli et al. Grade 0 represented no subluxation of the humeral head; grade 1, subluxation of the humeral head from 0% to 25% with respect to the glenoid; grade 2, subluxation from 25% to 50%; and grade 3, subluxation of >50% of the humeral head. The degree and location of glenoid bone loss was graded on all preoperative radiographs. Grade 0 represented no erosion with a visible subchondral plate; grade 1, <5 mm of erosion; grade 2, 5 to 10 mm of erosion approaching the lateral aspect of the base of the coracoid; and grade 3, severe erosion beyond the base of the coracoid. For patients who had a previous arthroplasty, evidence of humeral loosening was measured with use of the grading system described by Sperling et al., and the status of the glenoid component was graded with use of the system described by Lazarus et al. Preoperative computed tomography scans were reviewed to estimate the amount of glenoid bone loss. This was done by measuring the distance from the most medial aspect of the remaining glenoid surface to the medial base of the coracoid in millimeters for each patient. The most recent postoperative radiographic series was evaluated for humeral loosening with use of the criteria of Sperling et al.

Baseplate fixation was graded as stable (no evidence of radiolucency at the baseplate-bone interface or around any screw), at risk (>1 mm of circumferential radiolucency at the baseplate-bone interface or around any one screw), or loose (>1 mm of radiolucency around the baseplate-bone interface and around all screws or there was a shift in the position of the baseplate). Radiographs were also evaluated for dislocation, scapular notching on the basis of the criteria of Sirveaux et al., and screw breakage.

**Statistical Analysis**

Outcome measures made preoperatively and postoperatively were compared for all patients as well as within the preoperative diagnosis groups (a primary rotator cuff deficiency, a failed rotator cuff surgery, or a failed arthroplasty) with use of a paired t test. A one-way analysis of variance was performed to determine if there were differences in preoperative and post-
operative ASES scores and SST scores as well as preoperative and postoperative range of motion within the preoperative diagnosis groups. If a significant difference (p < 0.05) was found, a Student-Newman-Keuls post hoc test for all pairwise comparisons was performed.

**Results**

**All Patients**

Table I summarizes the comparison of preoperative and postoperative scores of all patients as well as the preoperative to postoperative scores for the three groups. Additionally, all preoperative and postoperative data are listed in a table in the Appendix. The average total ASES scores improved from 30 preoperatively to 77.6 postoperatively (p < 0.0001). The average ASES pain scores improved from 15 preoperatively to 41.6 postoperatively (p < 0.0001). The average SST scores improved from 1.8 preoperatively to 6.8 postoperatively (p < 0.0001). In a comparison of the preoperative and postoperative scores, ninety-one (95%) of the ninety-six shoulders showed an improvement in the total ASES score and eighty-seven shoulders (91%) showed an improvement in the SST scores. The patients rated the outcomes as excellent in fifty-three shoulders (55%), good in twenty-six (27%), satisfactory in eleven (12%), and unsatisfactory in six (6%).

Blinded analysis of range of motion (Table I) revealed that the mean forward elevation improved from 63.5° preoperatively to 118° postoperatively (p < 0.0001). Mean abduction improved from 61° preoperatively to 109.5° postoperatively (p < 0.0001). The mean external rotation improved from 13.4° preoperatively to 28.2° after surgery (p < 0.0001). The Pearson correlation coefficient for the primary reviewer was 0.99 for forward elevation, 0.99 for abduction, and 0.99 for external rotation, indicating a very strong level of intraobserver reliability between the two sets of measurements as each patient had his or her digital videos measured twice by this reviewer.

**Stratification of Patients**

Patients were further stratified on the basis of the preoperative diagnosis (Table I). In a comparison of the total ASES scores, the patients with a primary rotator cuff deficiency had significantly better average postoperative scores than those who had a failed arthroplasty (p < 0.001). In a comparison of the ASES pain scores among the three groups, the patients who had a primary rotator cuff deficiency had higher average postoperative scores than those who had a failed arthroplasty (p = 0.018). With respect to average SST scores, the patients who had a primary rotator cuff deficiency had the highest average postoperative scores compared with those who had a failed arthroplasty (p = 0.009). With respect to range of motion, both the group that had a primary rotator cuff deficiency and the group that had a failed rotator cuff surgery had significantly greater preoperative and postoperative motion compared with the group that had a failed arthroplasty.

**Radiographic Analysis**

Ninety-five of the ninety-six shoulders had preoperative radiographs available for evaluation. One patient who was first seen at our institution with a spacer after removal of the hemiarthroplasty implant because of infection did not have radiographs that preceded the implantation of the spacer. With respect to joint position and instability, twenty-four (25%) of the ninety-five shoulders had grade-3 subluxation of the humeral head, thirty-six shoulders (38%) had grade-2 subluxation, thirty-three shoulders (35%) had grade-1 subluxation, and two shoulders had no radiographic evidence of instability; however, both of these patients had a proximal humeral non-union preoperatively and had instability through the fracture site on physical examination. The direction of instability was superior in seventy-four shoulders (75%), anterior-superior in fourteen shoulders (15%), and anterior in two shoulders (2%). Fifty-seven shoulders (60%) showed radiographic evidence of glenoid erosion, and it was classified as grade 2 (5 to 10 mm of erosion) in ten shoulders and grade 1 (<5 mm) in forty-seven shoulders. Seventy-nine shoulders had preoperative computed tomography scans available for independent

---

**Fig. 1-B**

A true anteroposterior postoperative radiograph of a reverse shoulder prosthesis demonstrating the inferior tilt of the baseplate and glenosphere.
An examination of the most recent postoperative radiographs at the time of radiographic follow-up was twenty-four months. Radiographs available for independent review. The average time from the most medial portion of the remaining glenoid surface to the medial base of the coracoid, the average remaining bone stock for these seventy-three shoulders was 24.1 mm (range, 7.5 to 36 mm). Fifty-one of the seventy-three shoulders appeared to demonstrate some amount of glenoid erosion. In these fifty-one shoulders with erosion, the average remaining bone stock was 22.1 mm and eight shoulders had severe bone loss with <15 mm of remaining bone stock.

Three of the ninety-six shoulders did not have radiographs available for independent review. The average time from surgery to radiographic follow-up was twenty-four months. An examination of the most recent postoperative radiographs of two shoulders showed radiolucencies around the humeral component, but the shoulders were not considered at risk for clinically symptomatic loosening according to the criteria of Sperling et al.11. One shoulder had radiolucencies around the baseplate or screws. No shoulder had screw breakage or a shift in the baseplate. There was no evidence of scapular notching in any shoulder. One shoulder was dislocated on the last available radiograph.

Complications
Nine complications occurred in six patients in this study, with dislocation being the most common. One patient who had a bilateral reverse arthroplasty of the shoulder (Cases 1 and 2) fell three months after surgery and sustained a minimally displaced fracture of the acromion. The shoulder (Case 2) was treated nonoperatively with a period of immobilization. Twenty-seven months after the index procedure, the patient fell and sustained a traumatic dislocation of the contralateral shoulder (Case 1), which was treated with a closed reduction.
The patient had no further complications and went on to rate the outcome as excellent. One shoulder (Case 77) had an acute postoperative infection seven weeks after the index procedure. It was treated with irrigation and débridement with a polyethylene exchange. The patient had a postoperative hematoma develop after this procedure and underwent a second irrigation and débridement to evacuate the hematoma. Cultures of specimens from this surgery grew methicillin-sensitive *Staphylococcus aureus*, and the patient was treated with a six-week course of intravenous antibiotics. There was no recurrence of infection at the last follow-up evaluation twenty-four months postoperatively, and the patient rated the outcome as excellent. Three other shoulders had complications related to instability. The first shoulder (Case 15) had a dislocation without a specific traumatic event three months after the index procedure. Attempts at closed reduction were unsuccessful, and the patient underwent revision surgery and implantation of a larger glenosphere (40-mm diameter with neutral offset) and a semiconstrained socket. The patient had no recurrent instability at the time of the last follow-up at twenty-five months postoperatively and rated the outcome as excellent. Another shoulder (Case 91) was in a patient who fell and sustained a dislocation seven months after surgery. Attempts at closed reduction failed, but no revision surgery was attempted because the patient had poor medical health and a lack of substantial pain. This patient rated the outcome as unsatisfactory. The final shoulder with an instability complication (Case 51) dislocated while the patient was noncompliant in the early postoperative period and performing active-assisted range of motion against instructions. An attempt at closed reduction failed, and a revision to a larger glenosphere (36 neutral) and a semiconstrained socket was performed. The patient had had no further episodes of dislocation at the time of the last follow-up at twenty-four months postoperatively and rated the outcome as unsatisfactory. The sixth patient (Case 53) was the only one who had a baseplate complication in this study. This patient had an infection at the site of a total shoulder arthroplasty that was treated with irrigation and débridement and placement of a cement spacer seven months after the original arthroplasty. Four months later, the shoulder was converted in a second stage to a reverse shoulder arthroplasty. One year later, pain developed and radiographs demonstrated gross loosening of all of the screws that originally secured the baseplate as well as the humeral component. The patient was subsequently treated with revision of the glenoid components and conversion to a long-stemmed humeral component. Interestingly, at the time of revision surgery, intraoperative histological analysis and cultures were negative for infection. The patient had no further complications and, at the time of the last follow-up at twenty-seven months, rated the outcome as good.

**Patients Lost to Follow-up**

Eighteen patients did not have the required two-year follow-up. Numerous attempts were made to contact them by telephone and certified letter. In addition, tracking software was used to obtain updated contact information, and the Social Security death index was searched. Despite these efforts, we could not contact nine patients. In addition, nine patients died before they had been followed for two years. We inquired of the device manufacturer, and they had not had any reported information from or about any of these patients. The clinical information that was available at the last follow-up visit is included in the Appendix but was not included for data analysis.

**Discussion**

Reverse shoulder arthroplasty continues to evolve as newer implants and surgical techniques are developed to treat shoulders with a rotator cuff deficiency. Many of the initial larger studies performed by experienced shoulder surgeons who evaluated the use of reverse shoulder replacement have demonstrated decreased pain and improved function; however, all of the reported substantial complication rates may have been associated with the learning curve of this relatively new procedure	extsuperscript{4,12,13}. In 2005, Werner et al. reported on the results of the use of the reverse shoulder arthroplasty for the treatment of pseudoparalysis of the shoulder. Patients included in that study had a primary rotator cuff deficiency and glenohumeral arthritis, a previous rotator cuff surgery that had failed, a previous arthroplasty, or a prior fracture	extsuperscript{1}. The authors reported that twenty-nine (50%) of the fifty-eight patients had a complication and nineteen patients (33%) underwent reoperation. The prevalence of scapular notching noted radiographically in that study was 96%. In 2006, Boileau et al. reported on the results of reverse shoulder arthroplasty in forty-five patients for the treatment of a primary rotator cuff deficiency in the presence of glenohumeral arthritis, for fracture sequelae, or as a revision arthroplasty. Fourteen complications occurred in eleven patients (24%), and ten patients (22%) required revision surgery. The prevalence of scapular notching was 68%.

In our previous study in 2005, sixty patients were treated with reverse shoulder arthroplasty for a primary rotator cuff deficiency and glenohumeral arthritis or a previously failed rotator cuff repair	extsuperscript{1}. There were ten complications in thirteen patients. Seven of the patients went on to require surgical revision of the implant, and the predominant cause for revision was mechanical failure of the prosthesis. The device used in our initial study differs from the implant used in the European studies in that the glenosphere in the device we used had a center of rotation lateral to the glenoid. The potential benefit of the lateral center of rotation is that it more closely reproduces the normal shoulder anatomy and diminishes scapular notching by moving the humerus away from the scapula	extsuperscript{1}. There was no radiographic evidence of scapular notching in our initial series or in the patients in the current study. This is important as other studies have demonstrated that patients with notching have lower Constant scores, lower subjective shoulder values, and lower amounts of postoperative active flexion and abduction in comparison with those who have no evidence of notching	extsuperscript{2,4,14}. However, a potential negative effect of the use of a lateral center of rotation with 3.5-mm non-
locking peripheral screws for fixation became evident in our initial study. The use of a lateral center of rotation increases the moment at the baseplate-bone interface on the glenoid and can lead to failure of the fixation when these 3.5-mm screws are used for fixation. In our initial study, seven of the sixty patients had mechanical failure of the baseplate at an average of 21.4 months after surgery. It was the complication that prompted us to investigate ways to improve the fixation while maintaining a lateral center of rotation.

Harman et al. performed a biomechanical study examining initial glenoid component fixation in reverse shoulder arthroplasty. They found that the use of 5.0-mm peripheral locking screws in conjunction with a lateral center of rotation reduced the micromotion at the baseplate-bone interface to <150 μm, which is generally accepted as the threshold for osseous ingrowth. Modifications were subsequently made to the Reverse Shoulder Prosthesis, and the biomechanical data seem to have been confirmed in our current study. All patients in the study were treated with a glenosphere with a center of rotation lateral to the glenoid along with 5.0-mm peripheral locking screws, and none of the patients had had mechanical failure of the baseplate at the time of the last follow-up. Although our results are short term, as noted in our previous work, the average time to failure was early at 21.4 months. Our hope is that the locking screws may provide improved early fixation and allow for osseous ingrowth into the baseplate in order to achieve good long-term fixation.

Another important factor that may have decreased the mechanical failure of these implants is the placement of the glenoid in an inferiorly tilted position. In a biomechanical study, Gutiérrez et al. found that inferiorly tilting the glenosphere 15° produced the most uniform compressive forces and the least amount of tensile forces at the baseplate-bone interface compared with glenospheres placed in neutral or superiorly tilted positions. In addition, inferiorly tilting the glenosphere was most successful at limiting the micromotion at the baseplate-bone interface. In this study, we made an attempt to inferiorly tilt the glenosphere intraoperatively in each patient.

With respect to surgical technique, we believe that we have been better able to deal with glenoid bone loss in the current group of patients. In our initial study, we noted that at least 25 mm of bone stock medial to the glenoid centering line was necessary in order to obtain adequate purchase with the central screw of the baseplate. In patients with severe glenoid bone loss in the current series, a different orientation of the central screw was used to increase the amount of bone captured by this screw. In cadaver studies, as well as in our operative experience, we have observed that a dense column of bone is present in the area where the scapular spine meets the scapular body. In order to access it, we orient the drill slightly more posteriorly than we would for a patient with no glenoid bone loss. This posterior trajectory positions the glenosphere in slight anteversion and allows us to penetrate this thick osseous area at the base of the scapular spine in order to achieve excellent screw purchase. In this study, the available bone stock averaged 24 mm preoperatively. Eight patients had severe bone loss with <15 mm of medial bone remaining. Despite this level of bone loss, none of these patients had evidence of mechanical failure at the time of the last follow-up.

In examining the data from this study, there are several other points to highlight. First, as previously noted by Boileau et al., the patients who had a failed arthroplasty clearly presented the most difficult challenge. Overall, these patients consistently had an improvement in function and a decrease in pain; however, their outcomes and range of motion were worse compared with the other groups. The complication rate was higher in this group as well. The outcomes of total shoulder arthroplasty after proximal humeral nonunion have historically been reported as inferior compared with the outcomes in patients with no fracture sequelae.

Another interesting finding in this study was a significant increase in the average active external rotation from 13.4° to 28.2° (p < 0.0001). Recent studies have documented that selected patients may not have an increase in external rotation after reverse shoulder arthroplasty and have advocated for a concomitant latissimus dorsi transfer to regain active external rotation in these patients. As far as we know, studies examining this issue have involved patients who were treated with a reverse shoulder arthroplasty design that incorporates a medial center of rotation. In our study, the average amount of preoperative external rotation was 13.4° (range, −40° to 78°), similar to the amounts reported in other studies evaluating reverse shoulder arthroplasty. None of the patients in our study underwent a latissimus dorsi transfer, yet there was a noticeable improvement in their active external rotation. We hypothesize that the lateral center of rotation used in our patients may lengthen and improve tension on any residual posterior cuff and, thereby, supply the remaining posterior cuff muscle with some mechanical advantage to allow for some external rotation.

We believe the strength of this study is that it is prospective and examines a large number of patients with a wide range of pathology. We believe another strength was the efforts that were taken to limit bias. The concern of biased reporting of results related to potential conflict of interest has been previously published in this journal. The senior author (M.F.) is the designer of the study implant. To avoid bias, multiple steps were taken in order to make the data that were collected and recorded as objective as possible. With respect to measuring range of motion, each patient was videotaped while performing a standardized protocol of active forward flexion, abduction, and external rotation both preoperatively and at various points postoperatively. Three independent observers not involved in the treatment of the patients were blinded to the dates of the videos and then digitally measured the range of motion on each video with no idea as to whether the patients had been treated. We think that this was an effective attempt at eliminating measurement bias that can be seen when the operative surgeon measures and reports preoperative and postoperative range of motion. We also used an independent observer to evaluate all
radiographs in order to identify mechanical failure or scapular notching. Last, in obtaining our results, we used patient-reported outcomes and satisfaction that were recorded independently by the patient without the surgeon present.

The main weakness of the study is the short-term follow-up. Despite the success to date, the long-term survivorship of this device remains in question. We will continue to follow this group of patients closely in an effort to gain more information regarding the long-term survivability of this device. A potential weakness rests in the reproducibility of this study. The current series was performed by a surgeon with a high-volume experience in the use of reverse shoulder arthroplasty. Given his experience with this procedure, it may be difficult to extrapolate the results from this study to those of the general orthopaedic surgeon. A substantial learning curve with the reverse shoulder arthroplasty has been reported in the literature\(^1\).\(^2\),\(^3\),\(^4\).

In conclusion, a reverse shoulder arthroplasty with a center of rotation lateral to the glenoid and with 5.0-mm peripheral locking screws for baseplate fixation allows for improvement in patient outcomes while minimizing early mechanical failure and scapular notching and decreasing the overall complication rate in patients with a rotator cuff deficiency of the shoulder.

In the current series, the reverse shoulder prosthesis was used in patients with severe rotator cuff deficiency. A minimum two-year follow-up study of sixty patients. J Bone Joint Surg Am. 2005;87:1476-86.


