

# THE REVERSE SHOULDER PROSTHESIS FOR GLENOHUMERAL ARTHRITIS ASSOCIATED WITH SEVERE ROTATOR CUFF DEFICIENCY

A MINIMUM TWO-YEAR FOLLOW-UP STUDY OF SIXTY PATIENTS

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**Background:** Patients who have pain and dysfunction from glenohumeral arthritis associated with severe rotator cuff deficiency have few treatment options. The goal of this study was to retrospectively evaluate the short-term results of arthroplasty with use of the Reverse Shoulder Prosthesis in the management of this problem.

**Methods:** We report the results for sixty patients (sixty shoulders) with a rotator cuff deficiency and glenohumeral arthritis who were followed for a minimum of two years. Thirty-five patients had no previous shoulder surgery, whereas twenty-three had had either an open or arthroscopic rotator cuff repair, one had had a subacromial decompression, and one had had a biceps tendon repair. All patients were assessed preoperatively and postoperatively with the American Shoulder and Elbow Surgeons scoring system for pain and function and with visual analog scales for pain and function. They were also asked to rate their satisfaction with the outcome. The shoulder range of motion was measured preoperatively and postoperatively.

**Results:** The average age of the patients was seventy-one years. The average duration of follow-up was thirty-three months. All measures improved significantly ( $p < 0.0001$ ). The mean total score on the American Shoulder and Elbow Surgeons system improved from 34.3 to 68.2; the mean function score, from 16.1 to 29.4; and the mean pain score, from 18.2 to 38.7. The score for function on the visual analog scale improved from 2.7 to 6.0, and the score for pain on the visual analog scale improved from 6.3 to 2.2. Forward flexion increased from 55.0° to 105.1°, and abduction increased from 41.4° to 101.8°. Forty-one of the sixty patients rated the outcome as good or excellent; sixteen were satisfied, and three were dissatisfied. There were a total of thirteen complications in ten patients (17%). Seven patients (12%) had eight failures, requiring revision surgery to another Reverse Shoulder Prosthesis in five patients (one shoulder had two revisions) and revision to a hemiarthroplasty in two patients because of deep infection.

**Conclusions:** The data from this study suggest that arthroplasty with the Reverse Shoulder Prosthesis may be a viable treatment for patients with glenohumeral arthritis and a massive rotator cuff tear. However, future studies will be necessary to determine the longevity of the implant and whether it will provide continued improvement in function.

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



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A commentary is available with the electronic versions of this article, on our web site ([www.jbjs.org](http://www.jbjs.org)) and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM).

A certain number of patients with rotator cuff deficiency<sup>1,2</sup> progress to end-stage osteoarthritic disease with concomitant pain and loss of function and independence. This disease entity, which was first clinically described, as far as we know, by Adams<sup>3</sup> in 1873 and was termed cuff tear arthropathy by Neer et al.<sup>1</sup> in 1983, continues to pose

unique challenges to the orthopaedic surgeon attempting shoulder reconstruction in this patient population. The ball-and-socket kinematics of the glenohumeral joint depend on the muscles of the rotator cuff to maintain stability through concavity-compression<sup>4</sup>. Active muscular contraction of the rotator cuff produces a perpendicular force vector and hence a compressive load within the glenoid concavity, thereby increasing resistance to joint subluxation<sup>5,6</sup>.

As a result of the altered mechanics of a shoulder with a deficiency of the rotator cuff, traditional designs of total shoulder arthroplasty components have had early failures because of the changing instant center of rotation and eccentric loading of the glenoid component<sup>6-8</sup>. Hemiarthroplasty, the current standard of care for this condition, offers only "limited goals" for functional improvement<sup>9</sup> and only modest improvements in pain relief<sup>10-12</sup>. Likewise, bipolar implants, used in an effort to improve stability, have produced results that are not significantly better than those after hemiarthroplasty<sup>13,14</sup>.

Reverse shoulder arthroplasty, as described by Grammont et al.<sup>15</sup>, in which the humerus is converted to a socket and the glenoid to a ball, addresses these problems by providing a stable fulcrum for glenohumeral articulation. This is achieved through maximization of the length-tension relationship of the deltoid and remaining cuff musculature<sup>16</sup>. Early designs of reversed shoulder implants, however, were plagued with difficulties related to glenoid failure and soon fell out of favor<sup>17</sup>. The introduction of the Grammont prosthesis (Delta III; DePuy, Warsaw, Indiana) in Europe produced a renewed interest in reverse shoulder arthroplasty. The Delta III has demonstrated good outcomes in the medium term, with improvements in both pain and function compared with tra-

ditional methods for the treatment of shoulders with a deficiency of the rotator cuff<sup>18-24</sup>. The purpose of this study was to retrospectively evaluate the short-term results of arthroplasty with the Reverse Shoulder Prosthesis (Encore Medical, Austin, Texas) in shoulders with a rotator cuff deficiency and glenohumeral arthritis.

### Materials and Methods

Between December 1998 and September 2002, sixty procedures with the Reverse Shoulder Prosthesis were performed by one surgeon in sixty consecutive patients for the treatment of a rotator cuff deficiency associated with glenohumeral arthritis. There were forty-one women and nineteen men. The average age at the time of surgery was seventy-one years (range, thirty-four to eighty-six years). The average duration of follow-up was thirty-three months (range, twenty-four to sixty-eight months). All patients in this study had glenohumeral arthritis and a deficient rotator cuff, but we further classified them according to the method used by Walch<sup>25</sup>, who recently described patients he had managed with a reversed ball-and-socket prosthesis. Eleven patients had primary cuff tear arthropathy with collapse of the humeral head as described by Neer et al.<sup>1</sup>. The collapse of the humeral head was determined on examination of the radiographs. Seventeen patients had primary cuff tear arthropathy without collapse of the humeral head, twenty-three patients had failed rotator cuff surgery, seven patients had a massive rotator cuff tear with chronic pseudoparalysis of the shoulder (pseudoparalysis with or without anterior-superior dynamic instability of the humeral head for more than six months), one patient had post-traumatic arthritis, and one had rheumatoid arthritis. Five



Fig. 1

Preoperative radiograph of the shoulder of a thirty-four-year-old patient.

TABLE I Clinical Results for Pain, Function, and Range of Motion\*

	Preoperative	Follow-up	Improvement
American Shoulder and Elbow Surgeons system scores ( <i>points</i> )			
Total	34.3 (0 to 65)	68.2 (15 to 100)†	33.9
Pain	18.2 (0 to 45)	38.7 (10 to 50)†	20.5
Function	16.1 (0 to 40)	29.4 (0 to 50)†	13.3
Visual analog scale scores ( <i>points</i> )			
Pain	6.3 (1 to 10)	2.2 (0 to 8)†	4.1
Function	2.7 (0 to 9)	6.0 (1 to 10)†	3.3
Range-of-motion measurements ( <i>deg</i> )			
Forward flexion	55.0 (0 to 120)	105.1 (30 to 180)†	50.1
Abduction	41.4 (0 to 110)	101.8 (30 to 180)†	60.4
External rotation	12.0 (-15 to 45)	41.1 (10 to 65)†	29.1

\*The values are given as the mean, with the range in parentheses. †The difference was significant ( $p < 0.0001$ ).

patients were less than sixty years old, and one of those was less than forty years old. This thirty-four-year-old woman had cuff tear arthropathy with collapse of the humeral head (Fig. 1). She also had systemic lupus erythematosus and severe osteonecrosis. Thirty-five patients had no previous shoulder surgery, while twenty-three had had either an open or an arthroscopic rotator cuff repair (six of them had multiple repairs of the rotator cuff), one had had a subacromial decompression, and one had had a biceps tendon repair.

Preoperatively, all patients were found to have a rotator cuff deficiency on physical examination and on computerized tomography scans. Most of them had had a magnetic resonance imaging scan, which also demonstrated the deficiency. All patients had a complete tear of the supraspinatus with variable involvement of the subscapularis and the infraspinatus. The computerized tomography scans were analyzed to verify that there was at least 25 mm of bone from the glenoid face to the most medial cortex of the scapula to provide proper seating of the implant. In patients who had insufficient bone stock because of substantial medial erosion of the glenoid, the Reverse Shoulder Prosthesis was not recommended. Preoperative radiographs revealed superior migration of the humeral head, along with erosion of the humeral head, glenoid, and acromion in all patients. All patients who received a Reverse Shoulder Prosthesis previously underwent nonoperative treatment, such as physical therapy and cortisone injections that were unsuccessful, as well as arthroscopic or open rotator cuff repair. In addition, it was thought that no other treatment except arthroplasty with the Reverse Shoulder Prosthesis would provide a reliable method of improving function and diminishing pain. Exclusion criteria were active infection, axillary nerve palsy, a nonfunctioning deltoid muscle, insufficient bone to seat the implant components, or a very high level of physical activity (e.g., participation in competitive sports or heavy physical labor).

#### Operative Technique

The senior author (M.F.) performed all operations. Patients were positioned in the upright beach-chair position with the

head firmly secured and the arm draped free. The operative arm was positioned sufficiently off the side of the table to allow for unobstructed movement of the shoulder in adduction and hyperextension. All patients were given general anesthesia in addition to a scalene block. An extended deltopectoral approach was used, and approximately two-thirds of the pectoralis major tendon was released. The subdeltoid, subacromial, and subcoracoid spaces were released. If the subscapularis tendon was intact, it was released just medial to the long head of the biceps, allowing atraumatic dislocation of the humeral head with gentle external rotation and extension of the arm. Osteophytes were resected, a neck cut was made in 30° of retroversion, and the canal was reamed and broached.

The broach was tapped until it was distal to the neck cut, and this was followed by reaming of the proximal humeral metaphysis. Next, the glenoid was exposed with use of thorough capsular releases. A centering hole was drilled, and the glenoid was prepared with a convex reamer. A fixed-angle glenoid baseplate was then screwed into place, ensuring at least 60 in-lb (6.8 N-m) of torque. Additional 3.5-mm peripheral fixation screws were then attached to the glenoid baseplate. A 29-mm or a 25-mm offset glenosphere was chosen, depending on the degree of soft-tissue contracture, and was fit onto the baseplate by means of a Morse taper (Figs. 2-A and 2-B). After reduction with the humeral broach and a trial polyethylene component, the appropriate size of humeral implant that would allow a 2-mm circumferential cement interface around the component was selected and routinely cemented in place. The reduction was checked for stability, especially in abduction, extension, and internal rotation, and achievement of full passive elevation was confirmed. Finally, the subscapularis was repaired through drill-holes followed by routine closure with use of number-2 braided polyester sutures.

#### Postoperative Rehabilitation

A shoulder immobilizer was worn for four weeks, and passive range-of-motion exercises were performed. The passive range-of-motion exercises, performed with the patient supine, were

TABLE II Review of the Literature on Hemiarthroplasty for the Treatment of Rotator Cuff Deficiency

Study	No. of Shoulders	Mean Duration of Follow-up (Range)	Pain
Sanchez-Sotelo et al. <sup>12</sup> (2001)	33	5 yr (2-11 yr)	Mean pain score decreased from 4.2 to 2.2; 9 (27%) had moderate pain
Zuckerman et al. <sup>32</sup> (2000)	15	28.2 mo (12-66 mo)	14 had substantial pain relief; 7 had minimal or no pain
Field et al. <sup>11</sup> (1997)	16	33 mo (24-55 mo)	—
Williams and Rockwood <sup>30</sup> (1996)	21	4 yr (2-6.6 yr)	Mean pain score decreased from 2.9 to 0.6; 12 (57%) had no pain
Arntz et al. <sup>10</sup> (1993)	18	39 mo (25-122 mo)	11 had no or slight pain, 4 had pain after unusual activity, and 3 had moderate or marked pain

started the day after surgery with a physical therapist. The standard limits of 90° of elevation and 0° of external rotation were used. After the first four to six weeks, the patient was managed with a sling and active-assisted activities were initiated. Active range of motion was not started until eight to ten weeks postoperatively. Resistive exercises were delayed until the subscapularis tendon was healed, usually at twelve weeks.

#### Preoperative and Postoperative Clinical Assessment

Several validated scoring instruments were used to assess the patients clinically.<sup>26</sup> Patients completed forms for the American Shoulder and Elbow Surgeons assessment for pain and function, a visual analog scale for pain and function, and a rating of overall satisfaction. Patients were asked to indicate their personal satisfaction with the outcome of the surgery as dissatisfied, satisfied, good, or excellent. An orthopaedic surgeon who was not involved in the treatment of any of the patients measured the range of motion preoperatively and postoperatively using a goniometer while digital clinical videos were played back on a computer. Preoperative and

postoperative flexion and abduction data were available for all patients. Postoperative external rotation data were available for all patients, but preoperative values were available for only sixteen patients.

#### Radiographic Analysis

An orthopaedic surgeon who was not involved in the treatment of any of the patients performed the radiographic evaluation. The initial preoperative and the most recent (at least two-year) postoperative radiographs of the shoulder, which included anteroposterior, axillary, scapular Y lateral, and Grashey<sup>27</sup> radiographs with the shoulder in both internal and external rotation, were evaluated. Complete radiographic data were available for all patients.

Preoperative radiographs demonstrated subluxation of the humeral head as well as erosion of the glenoid and humeral head in all patients. Erosion of the acromion was present in all but two patients. The subluxation and erosion were usually directed anteriorly and superiorly. The preoperative acromiohumeral distance measured from the Grashey radiographs was an average (and standard deviation) of 2.6 ±



Fig. 2-A



Fig. 2-B

**Fig. 2-A** The baseplate of the Reverse Shoulder Prosthesis with the peripheral screws. The Morse taper can also be seen. **Fig. 2-B** The baseplate of the Reverse Shoulder Prosthesis with the glenosphere fixed onto the Morse taper.

TABLE II (continued)

Increase in Elevation	Overall Result	Complications
72° to 91°	22 (67%) successful; 11 (33%) unsuccessful	Anterosuperior instability (7), glenoid erosion (8), acromial erosion (14), medial humeral notching (9), acromial fracture (2)
69° to 86°	13 satisfactory	Anterior instability (1)
60° to 108° (for 10 with successful result); 58° to 86° (for 6 with unsuccessful result)	10 successful; 6 unsuccessful	Anterosuperior instability (2), anterior instability (1), medial prosthetic migration (2)
70° to 120°	18 (86%) satisfactory; 3 (14%) unsatisfactory	No postoperative instability
66° to 112°	—	Anterior instability (1), glenoid erosion (2)

1.68 mm (range, 0 to 6 mm). An acromial fracture was seen preoperatively in five patients; four were distal and one was at the acromial base.

#### Statistical Analysis

Pain and function scores and range of motion were compared preoperatively and postoperatively by an independent statistician using a difference-of-means test (StatView; SAS Institute, Cary, North Carolina). The influence of a previous operation on the results was also analyzed with use of a difference-of-means test. The subset of thirty-five patients who had no previous shoulder surgery and the subset of twenty-five patients who had previous shoulder surgery were compared with use of the Levene test for equality of variances and a t test for equality of means.

#### Results

The clinical results including the scores on the American Shoulder and Elbow Surgeons assessment and the visual analog scale, as well as the range-of-motion measurements, are summarized in Table I. Data for external rotation at 0° of abduction were not complete. Postoperative data on external rotation were available for all patients, but only sixteen had preoperative measurements. The mean external rotation for the sixteen patients for whom we had complete data improved from 12° preoperatively to 41° postoperatively; the difference was significant ( $p < 0.0001$ ). For all sixty patients, the mean postoperative external rotation measured 35.9° (range, 5° to 60°). Forty-one (68%) of the sixty patients rated the outcome as good or excellent, sixteen (27%) were satisfied, and three (5%) were dissatisfied.

The patients were also divided into two groups with respect to those who had had previous shoulder surgery and those who had not. No difference between the groups was detected in terms of demographic data, preoperative scores, postoperative visual analog scale scores, or range of motion. However, the postoperative mean total score and mean pain and function scores according to the American Shoulder and Elbow Surgeons system were significantly higher for the group

that had not had previous shoulder surgery than for the group that had had previous shoulder surgery ( $p = 0.015, 0.047, 0.044$ , respectively).

There were thirteen complications in ten patients (17%) in this study. One patient had a scapular fracture at three months and an acromial fracture at twelve months, neither of which were believed to be related to the surgery. The scapular fracture occurred during therapy while the patient was undergoing passive flexion in the supine position. The acromial fracture occurred as the result of a fall. Both fractures were treated nonoperatively and healed uneventfully. Another patient had an acromial fracture at thirteen months postoperatively. It was treated with open reduction and internal fixation and healed uneventfully. Both of these patients rated the outcome as excellent. One patient had a hardware failure from a preexisting acromial fracture with an infection five months postoperatively. The patient underwent a revision open reduction and internal fixation along with irrigation and débridement. The patient rated the overall outcome as satisfactory. There were no nerve or vascular injuries.

Postoperatively, progression of subluxation or erosion was not seen radiographically. Glenoid radiolucency was seen in three of the sixty patients, with a radiolucency of >2 mm in a patient with glenoid baseplate failure (Fig. 3) and a radiolucency of 1 to 2 mm in two patients. Scapular notching was absent in all patients. No humeral component showed any evidence of loosening or failure on postoperative radiographs. However, radiolucent lines that did not progress were seen around the humeral component and were most often located along the inferior-lateral margin of the prosthesis. These radiolucencies were 1 to 2 mm in width, and none was >2 mm.

#### Revision Operations

Seven patients in whom the device failed required eight revisions at an average of 21.4 months (range, eleven to thirty-three months) after the index procedure. In all eight revisions, inspection of the porous surface of the glenoid baseplate revealed no evidence of osseous ingrowth. Two shoulders were converted to a hemiarthroplasty because of insufficient bone



Fig. 3

A radiograph of the shoulder of a patient with baseplate failure and broken screws, showing a radiolucent line of  $>2$  mm.

stock and a deep infection. One of these patients had a humeral dissociation with glenoid loosening, and the other patient had glenoid baseplate failure. Both were treated with six weeks of intravenous antibiotics and implantation of an antibiotic spacer followed by a hemiarthroplasty. The other five patients had baseplate failure and were managed with a revision to another Reverse Shoulder Prosthesis. One of these five patients had a second baseplate failure and had revision to a third Reverse Shoulder Prosthesis. Of the five patients who had a revision to another Reverse Shoulder Prosthesis, four rated the outcome as excellent and one rated it as good at the time of the most recent follow-up. These five patients were followed for an average of thirty-six months (range, twenty-eight to forty-seven months) after the initial surgery and 13.6 months (range, eight to twenty-one months) after the revision surgery. The two patients whose shoulders were converted to a hemiarthroplasty rated the outcome as good and satisfactory at the most recent follow-up examination.

### Discussion

The treatment of glenohumeral arthritis in the setting of advanced rotator cuff disease has long been a perplexing problem for the upper-extremity surgeon. Early attempts to manage this problem with a constrained prosthesis proved disappointing<sup>17,28,29</sup>.

Hemiarthroplasty, the “nonconstrained” option, has

long been the standard of care for cuff tear arthropathy. However, careful examination of the literature revealed that the results have not been uniform (Table II). Even though our patients had a clinical complex of glenohumeral arthritis and massive rotator cuff tears not classically described as rotator cuff arthropathy, surgical management of these patients would historically entail hemiarthroplasty as seen in the series described by Williams and Rockwood<sup>30</sup>. Other authors have shown less successful outcomes, and relief of pain has been inconsistent<sup>10,11,31-33</sup>.

Early reversed shoulder arthroplasties, in effect a “semi-constrained” design, were plagued with difficulties related to glenoid failure and soon fell out of favor<sup>17</sup>. Our study demonstrates that, in the short term at least, the Reverse Shoulder Prosthesis may be a viable alternative for the treatment of glenohumeral arthritis and rotator cuff deficiency.

The authors of several studies conducted in Europe have reported promising results in the short and medium term with use of a reversed or inverted shoulder implant<sup>22,24,34,35</sup>. The most recent investigation<sup>34</sup>, a multicenter study in Europe in which seventy-seven patients (eighty shoulders) with glenohumeral osteoarthritis and a massive rupture of the cuff were treated with the Delta-III prosthesis, described an improvement in the mean constant score of 42 points, an increase of 65° in forward elevation, and minimal or no pain in 96% of the patients. However, forty-nine patients (63.6%) were noted

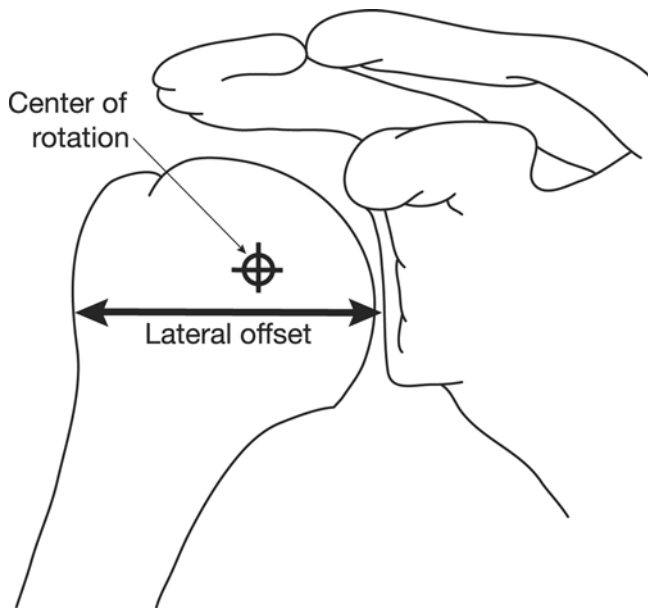


Fig. 4-A

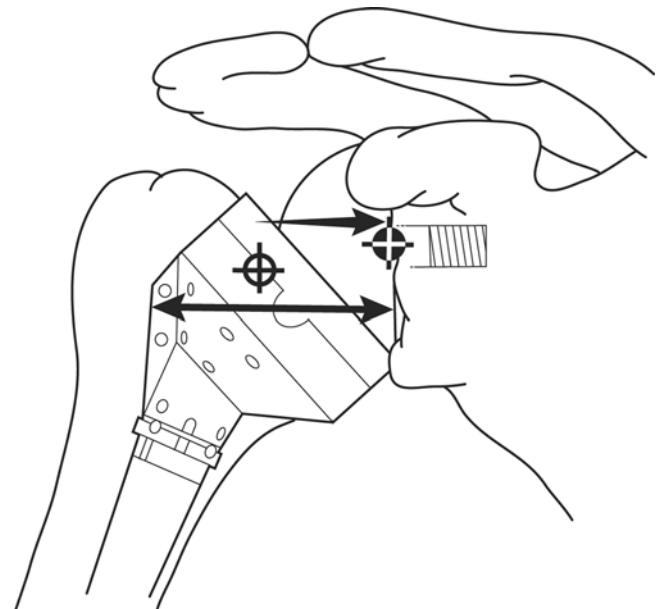


Fig. 4-B

**Fig. 4-A** Anatomic drawing of a shoulder, depicting the center of rotation with the bull's-eye and the lateral offset with the bold arrow. **Fig. 4-B** A drawing of a Delta-III device implanted in a shoulder, demonstrating how it causes the center of rotation and lateral offset to shift medially with respect to the anatomic shoulder.

to have medial component encroachment and scapular notching without evidence of loosening. Progressive loosening was noted in five glenoid components, two of which had been revised at the time of publication. In seven patients, the glenosphere and baseplate dissociated. This uncoupling was progressive in three patients, with one requiring revision.

In our study, we found similar improvements in active elevation, which increased from 55° preoperatively to 105° postoperatively, with use of the Reverse Shoulder Prosthesis. Even though the preoperative external rotation data were incomplete, the average postoperative measurement of 35.9° in our study is encouraging, especially compared with the 11.2° of external rotation reported in the study by Sirveaux et al.<sup>34</sup>. No patient in the present study had medial encroachment or progressive erosion of the glenoid.

Eight shoulders in seven patients needed revision because of failure of the glenoid baseplate at a mean of 21.4 months postoperatively. In these failures, it was observed intraoperatively that there was no osseous ingrowth into the baseplate. The lack of osseous ingrowth made the revision of these devices to another Reverse Shoulder Prosthesis possible because of minimal loss of glenoid bone. In our experience, patients with noninfectious etiologies of symptomatic glenoid loosening and adequate bone stock should have a revision to another Reverse Shoulder Prosthesis.

A critical time-period for these devices is the first two years because, if ingrowth does not occur, mechanical failure may result from metal fatigue. The mode of failure of the baseplates in our study appeared to be metal fatigue in the screws. However, another cause of failure in the longer term may be the generation of wear debris particles, which could

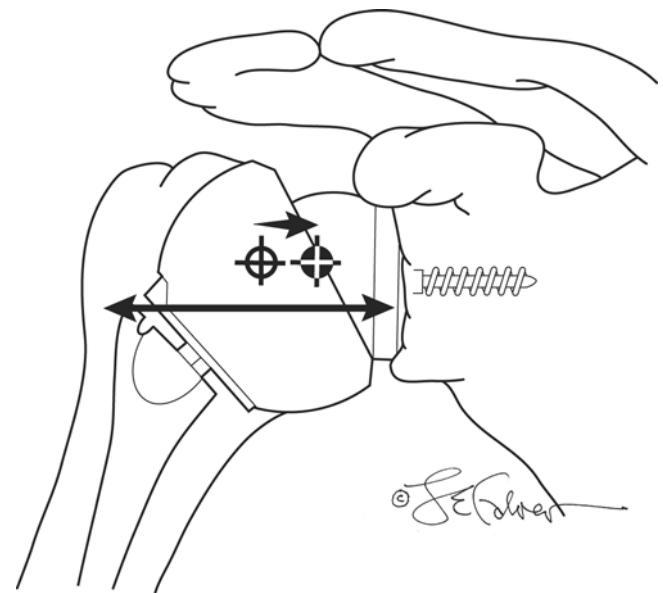


Fig. 4-C

A drawing of the Reverse Shoulder Prosthesis implanted in a shoulder, demonstrating how the device causes the center of rotation and lateral offset to shift medially with respect to the anatomic shoulder but to a smaller degree than with the Delta-III prosthesis. (Reprinted with permission of Lewis E. Calver.)

induce osteolysis. At this point, there has been no evidence of osteolysis in the form of scapular notching; however, long-term follow-up will be necessary to determine the prevalence of this problem.

The device in this study differs from the Delta III in sev-

eral ways that we believe are clinically important. The Reverse Shoulder Prosthesis has a more lateral center of rotation, approximately matching that found in the normal glenohumeral joint. It also more closely reproduces normal lateral offset and preoperative shoulder contour (Figs. 4-A, 4-B, and 4-C). In addition, this lateral center of rotation diminishes medial scapular notching, which is observed commonly with the Delta-III prosthesis<sup>19,23,24,34,36</sup>. Valenti et al.<sup>24</sup>, in a study of thirty-nine patients managed with the Delta-III prosthesis and followed for at least five years, reported that twenty-two had a scapular notch on the inferior part of the glenoid and eight of those had erosion of the inferior screw. Another study noted scapular notching in 65% of the patients and found that notching substantially affected the Constant score when the notch was over the screw or was extensive<sup>23</sup>. Favard et al.<sup>19</sup> found that fifty of the eighty shoulders with the Delta-III implant had scapular notching, which reached the inferior screw in thirteen of the fifty shoulders. An analysis of a Delta-III prosthesis retrieved post mortem at eight months after implantation revealed a large notch at the inferior pole of the scapular neck, which extended beyond the inferior fixation screw<sup>36</sup>. Scapular notching, when extensive, can negatively affect the Constant score<sup>37</sup>. The lateralized center of rotation produces an increased moment at the glenoid prosthesis interface. Design features, such as a central compressive 6.5-mm screw, options for multiple peripheral locking and non-locking screws, and a curved contoured interface, provide stability comparable with that of the Delta III with its more medial center of rotation.

In summary, the results of arthroplasty with the Reverse Shoulder Prosthesis in sixty patients with glenohumeral arthritis and severe rotator cuff deficiency at greater than two years of follow-up were good or excellent for forty-one patients and were satisfactory for sixteen. While it is too early to reliably predict the longevity for this "semiconstrained" implant, it is important to report on early complications and address theoretical concerns about this prosthesis with its nonanatomic design. ■

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In support of their research or preparation of this manuscript, one or more of the authors received grants or outside funding from Encore Medical Corporation. In addition, one or more of the authors received payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity (Encore Medical Corporation). Also, a commercial entity (Encore Medical Corporation) paid or directed, or agreed to pay or direct, benefits to a research fund, foundation, educational institution, or other charitable or nonprofit organization with which the authors are affiliated or associated.

doi:10.2106/JBJS.D.02813

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