Reverse Shoulder Arthroplasty

Indications, Technique, and Results

Armodios M. Hatzidakis, MD
Western Orthopaedics P.C.
Denver, CO

Tom R. Norris, MD
California Pacific Medical Center
Department of Orthopaedic Surgery
San Francisco, CA

Pascal Boileau, MD
Hôpital de L’Archet—University of Nice
Department of Orthopaedic Surgery & Sports Traumatology
Nice, France

ABSTRACT

The surgical treatment of glenohumeral arthritis with rotator cuff deficiency is a difficult challenge. Hemiarthroplasty, the standard treatment at this time, is associated with satisfactory results in a “limited goals” perspective, but often the clinical results are unpredictable. Elevation after hemiarthroplasty approximately 90°. Pain relief can be inconsistent and can deteriorate over time. Constrained prostheses, including ball and socket and reverse ball and socket designs, were introduced in the 1970s to improve upon the results of arthroplasty in this challenging population. Unfortunately, clinical results were inconsistent using these designs, and rates of mechanical loosening and revision were high. The only design that survived has been the prosthesis of Paul Grammont (Dijon, France). His Delta III Prosthesis (DePuy, Warsaw IN) has been in use in its current form since 1992, with good clinical results and relatively low mechanical loosening rates compared with the ball and socket and reversed ball and socket designs of the past. This design is also utilized by the Tornier Aequalis Reversed Prosthesis (Tornier SA, Montbonnot, FR). In Europe, and more recently in the United States, this prosthetic design has proven useful in treating patients with glenohumeral arthritis with extensive cuff deficiency, proximal humeral fracture nonunions and malunions, and failed arthroplasty with a deficient rotator cuff. Predictably good results can be obtained in these difficult circumstances, with good pain relief and elevation often exceeding the horizontal. Active rotation, however, is usually not improved. Complication rates are low in patients with cuff tear arthritis and relatively high in revision arthroplasty cases. As with all revision operations, be they failed cuff repairs or failed prosthetic replacements, there is a higher risk of lingering low grade infections. Results can be optimized and complications minimized with proper patient selection, fastest surgical technique, and proper postoperative rehabilitation.

HISTORICAL PERSPECTIVE

Treatment of the rotator cuff deficient shoulder with arthritis has proven a difficult surgical challenge. Because pain relief was the goal and results of function were usually poor, Neer stated that arthroplasty for rotator cuff arthropathy should be judged by “limited goals” criteria. Multiple studies have confirmed empirical evidence that hemiarthroplasty for cuff deficient arthritis has somewhat unpredictable results.1–8 Total shoulder arthroplasty has been abandoned for this group due to the loss of force couple of the supraspinatus-deltoid and subsequent early glenoid loosening. This is attributable to the “rocking horse phenomenon” with upward subluxation onto the glenoid rim, leading to loosening.9 Although hemiarthroplasty...
provides a smooth surface for articulation with the native glenoid and acromion, the biomechanical stabilization of the fulcrum for elevation is still deficient. Sometimes the intact remaining cuff, deltoid, and “acetabularized” acromial arch can compensate for this lack of fulcrum, but good early results can deteriorate secondary to progressive erosion of the prosthetic head into the glenoid and acromion (Fig. 1). Pain relief is often good initially, but can deteriorate over time with glenoid arthritis and acromial wear or fracture. The results of hemiarthroplasty are even more inconsistent in patients who have a “pseudoparalytic” shoulder, in whom attempts at elevation are rewarded only with an ineffective shrug. As we have gained more experience in teasing out subtle causes of this ineffectual shrug associated with massive rotator cuff tears, we wish to differentiate between those with irreparable cuff tears with true pseudo paralysis of the shoulder (PPS) and anterior superior subluxation due to muscle imbalance, and those patients with painful loss of elevation (PLE) due to an hourglass or otherwise painful biceps. With PPS humeral head arthroplasty and tendon reconstructions have been ineffectual, whereas with PLE arthroscopic biceps tenotomy has allowed many to regain overhead elevation.

Multiple constrained and semiconstrained prostheses have been designed to compensate for the loss of rotational fulcrum caused by severe degeneration of the rotator cuff. Previous reverse prostheses were designed by Reeves, Liverpool, Bayley, Neer and Averill, Kolbel, Kessel, Fenlin, and Gerard in the 1970s and 1980s. Disappointing results and high complication rates led to abandonment of these prostheses.\textsuperscript{10,11} The common denominator for failure was loosening of the glenoid component. The center of rotation was lateral to the glenoid and created high torque on the relatively frail glenoid. The reverse prosthesis (RP) of Professor Paul Grammont (Dijon, France) was also designed specifically for the rotator cuff deficient shoulder.\textsuperscript{12–14} It differed from previous prostheses in that the glenoid component was larger, and its center of rotation was medialized on to the glenoid face, thus decreasing torque on the component-bone fixation. The humeral neck angle is nonanatomic and made more horizontal. This increases stability of the new glenohumeral joint. In short to medium term studies up to 10 years, this prosthesis has succeeded where others have failed, predominately because of its favorable biomechanical characteristics. Short and medium-term follow-up studies in Europe have determined that this specific design leads to functional restoration of elevation and favorable survivorship, with relatively low rates of early glenoid loosening.\textsuperscript{15–22} Two current versions of the prosthesis have been used in Europe; since 1992 for the Delta and since 1998 for the Tornier. Respectively, these prostheses have been available in the United States since FDA approval in November 2003 (DePuy, Warsaw IN) and May 2004 (Tornier SA, Montbonnot, FR).

**Biomechanics**

The RP design of Grammont combines a large hemispherical glenoid component (36 or 42 mm diameter) that has a medialized center of rotation and secure screw fixation to the glenoid, with a cemented humeral component that has a more horizontally aligned ($155^\circ$) metaphyseal neck with a reverse hemispherical polyethylene cup that perfectly conforms to the glenosphere (Fig. 2).
This design allows for more range of motion than reverse ball and socket designs of the past (Fig. 3). With proper placement of this prosthesis, the center of humeral rotation is made more distal, placing the deltoid muscle at greater tension (Fig. 4), and medialized, which recruits more deltoid muscle fibers for elevation and increases the deltoid lever arm. These factors increase the deltoid’s biomechanical ability to generate rotational torque, elevating the arm on a new stable fulcrum (the glenosphere). The medialized center of rotation decreases torsional forces on glenosphere fixation, decreasing the tendency of the glenoid component to loosen (Fig. 5).

### INDICATIONS/CONTRAINdications

There are 3 specific circumstances where we have found the RP to be useful. The common characteristic of these indications is that the biomechanical fulcrum for elevation is lost, either via irreparable loss of the rotator cuff or severe malposition of the tuberosities.

The first indication is primary osteoarthritis of the shoulder with massive irreparable cuff tear, in patients with secondary osteoarthritis or osteonecrosis who have a “decompensated” cuff deficiency (“Cuff Tear Arthritis,” CTA). These patients typically suffer from significant pain and cannot lift their arms to the horizontal despite attempts to strengthen the deltoid and remaining intact cuff. Many of these patients have had one or many attempts to repair the rotator cuff, and some may exhibit
marked anterosuperior escape of the humeral head with attempted elevation. Patients with anterosuperior escape are usually not helped by humeral hemiarthroplasty, even with attempted coracoacromial arch reconstruction, making them ideal candidates for reversed shoulder arthroplasty.

The second indication is severe fracture sequelae (FS). These patients have had a displaced, usually comminuted fracture of the proximal humerus with tuberosity malposition or nonunion. Although an unconstrained prosthesis can reliably provide pain relief and restore function in those cases where the prosthesis can be “adapted” to slight tuberosity malalignment, patients who have unhealed tuberosities or require osteotomy of the greater tuberosity do not typically fare as well. An RP can consistently provide both pain relief and restoration of active elevation in this specific patient group.

The third indication for reverse shoulder arthroplasty is revision of previously failed arthroplasty. Typically these patients have had a hemiarthroplasty placed for CTA or comminuted proximal humerus fracture. In CTA cases, common causes for failure are loss of the

FIGURE 4. A, Deltoid elevation torque in the cuff deficient shoulder is decreased secondary to proximal humeral migration, whereas elevation torque in the Grammont reverse shoulder (B) is increased because of a medialized and lowered center of rotation (L2 × F2 > L1 × F1).

FIGURE 5. A, The lateralized center of rotation and constrained design of previous reverse designs leads to more shear forces on glenoid fixation compared with the less constrained, medialized center of rotation of the Grammont design (B).
fulcrum for elevation (dysfunctional cuff or postoperative subscapularis rupture with resulting instability) and progressive erosion into the glenoid and/or acromion. This leads to increased pain and decreased function. Common causes for failure in fracture cases are malposition of the component and tuberosity malunion or nonunion. In CTA and post-fracture cases, revision hemiarthroplasty or conversion to total shoulder arthroplasty with soft tissue and/or bony procedures is either unpredictable or contraindicated. At times, even with apparent cuff restoration, the scarring and multiple operations result in the cuff not functioning effectively. Motion and function are lost despite heroic efforts with surgery and rehabilitation. In our experience, RP placement in these cases is less beneficial than in primary CTA patients, but the results seem to be more satisfactory than with other procedures that have been described. With the revision prosthesis cases, particularly those with multiple previous operations, low grade infections are more common. All precautions are observed to anticipate, diagnose, and treat any potential sepsis.

Relative Indications
Acute fractures and old nonunions in the very elderly where rotator cuff rehabilitation is suboptimal is an example where early results are reported to be good, but longer follow-up is lacking. Early European (D. Mole) and U.S. experience with the RP have been encouraging for the very elderly patient with acute proximal humeral 4-part fractures. Using the prosthesis in these patients can be beneficial, as the need for tuberosity union is bypassed and post operative rehabilitation is expedited.

Contraindications
This prosthesis should not be used in primary osteoarthritis or osteonecrosis of the shoulder when the articular surface–tuberosity relationships are normal and the rotator cuff is intact and functional. These patients are best served with a third generation anatomic unconstrained total shoulder arthroplasty. The RP also should not be used if the patient exhibits marked deltoid deficiency, as the shoulder will not function well and will be prone to dislocate. A history of previous infection is a relative contraindication, as recurrence in these patients is high. Finally, the RP should be used only sparingly in patients less than 65 years old, as long-term survivorship and complication rates are unknown.

COMPONENTS AND MANUFACTURERS
Currently the RP design of Grammont is offered by two prosthetic manufacturers. The Delta III™ prosthesis is available through DePuy (Warsaw IN), and the Aequalis Reversed Shoulder Prosthesis™ is available through Tornier SA, (Montbonnot, FR). For practical purposes of this technique description, the Aequalis Reversed Shoulder Prosthesis will be referenced, although the steps are somewhat similar for the Delta III. The glenoid component consists of a circular baseplate (metaglene), which is fixed to the native glenoid with 2 compression screws and 2 locked screws (Fig. 6). In the United States, the surface of the plate that contacts the glenoid bone is grit blasted and roughened to aid with ongrowth. The superior and inferior holes in the baseplate are threaded and angled 20° superiority and inferiorly, respectively. The anterior and posterior screw holes are not threaded, leaving flexibility to place the anterior and posterior compression screws into the best bone that is available. The articulating glenoid component, or glenosphere, is a smooth cobalt-chrome hemisphere that is fixed to the baseplate via a Morse taper and countersunk set screw (Fig. 7), placing the center of rotation at the level of the glenoid/baseplate interface.

The humeral component is designed for cemented use only, with a cup shaped metaphyseal component that is fixed to stems of variable lengths via a screw-on mechanism. The metaphyseal cut–shaft angle is 155°. This horizontal inclination leads to stability of the metaphyseal polyethylene cup when articulating with the glenosphere. In the Aequalis Reversed Shoulder™ system, polyethylene inserts of increasing diameter (6 mm, 9 mm, and 12 mm) (Fig. 8) are available, in addition to a metal metaphyseal offset extension (9 mm). With the metaphyseal extension, 15 mm, 18 mm, and 21 mm offsets become available. Availability of these different polyethylene thicknesses and offset lengths are particularly useful in the revision situation, when bone loss makes prosthetic tension more difficult to set precisely via cementation of the humeral component. At the time of this writing, the Delta III prosthesis (DePuy, Warsaw IN) has a 6 mm and 9 mm insert, the 9 mm metal extension, and a deeper “retentive” cup option (6 mm) with a deeper thinner polyethylene insert.
PREOPERATIVE PLANNING

Preoperative radiographs include a true AP of the shoulder with the arm in neutral rotation (Grashey view), an axillary lateral view, and a scapular lateral view. We typically obtain a long AP of the humeral shaft with the AP shoulder view to ensure that the humeral canal is normal and a cemented humeral component can be inserted without complication. In addition, a Computerized Tomography scan is obtained of the shoulder, including the entire scapula with 2 mm cuts, so that fatty atrophy of the cuff can be examined and accurate 2-dimensional coronal reconstructions can be obtained. The axial cuts give the surgeon an estimate of glenoid size and the feasibility of glenoid implantation, as the glenoid can occasionally be asymmetrically worn. The axial cuts also are good indicators of the degree of fatty infiltration that has occurred in the posterior cuff, an important prognostic indicator for regaining some functional external rotation. The coronal reconstructions show the amount of superior wear of the glenoid, giving the surgeon an idea of how much reaming is required inferiorly to create ideal glenosphere inferior tilt (0–15°). In cases of very severe superior glenoid erosion, an iliac crest bone graft can be planned to fill the bony deficiency. In special circumstances, the humeral head may also be harvested after removing any remaining articular cartilage and then used to bone graft the glenoid defect with or without supplemental iliac crest graft (Fig. 9).

TECHNIQUE

For the purposes of this paper, our technique for implantation will be described for the "virgin" CTA case. Although Grammont initially described a transacromial approach for placement of this prosthesis, most surgeons now use a deltopectoral or anterosuperior approach. We prefer the deltopectoral approach, as it spares the deltoid insertion and axillary nerve and is highly useful in prosthetic revision surgery.

Exposure and Humeral Preparation

The deltopectoral approach is standard, with an incision started just superior and medial to the coracoid process and extended obliquely distally to the deltoid insertion at the mid-arm. The subcutaneous tissues are dissected with knife and electrocautery. The cephalic vein is retracted laterally with the deltoid and the deltopectoral interval fully dissected from the clavicle to the insertion of the pectoralis major on the proximal humerus. The proximal humerus has typically migrated superiorly. The coracoacromial ligament is visualized, followed by removal of the subscapularis bursa and identification of the conjoint tendon. The deltoid is retracted laterally using a broad Richardson retractor, and the conjoint tendon gently retracted medially using a narrow blunt Richardson retractor. The remaining subscapularis is tagged with medially placed #5 braided suture, and the subscapularis is tenotomized 1 cm from its insertion. Release of the subscapularis continues inferiorly, releasing the inferior muscular fibers and inferior capsule from the humerus while an assistant provides gentle progressive external rotation to the arm. The superior 1 cm of the pectoralis insertion is also occasionally released to assist in ease of exposure.

Superiorly, the cuff is usually absent. In cases of previous failed cuff repair, suture and scar are removed, and the interval between the cuff and acromion dissected sharply or with electrocautery. The posterior cuff and tuberosity is freed from the overlying deltoid sharply or with electrocautery, taking care not to injure the axillary nerve inferiorly.

At this point the humerus is readily dislocated anteriorly and superiorly for humeral preparation. The
The highest, most lateral point on the humeral head is identified as a reference point. A hole is created with an awl; the head cutting guide is inserted into the humeral shaft via this hole, and retroversion is determined using a pin set at the desired degree. Grammont advocated a version of $0^\circ$. We typically set the cut between $0^\circ$ and $20^\circ$ of retroversion, as this version seems to allow “filling” of the metaphysis without anterior cortical protrusion, and may allow for slightly improved functional external rotation. Nonetheless, the optimal retroversion for this component has yet to be defined. A minimal head cut is made parallel to the undersurface of the neck cutting guide, taking care not to hit the shaft of the cutting guide with the saw (Fig. 10). The guide is removed and the cut completed with either the saw or an osteotome. Cancellous bone is harvested from the remaining humeral head and saved to graft the glenoid central hole prior to inserting the baseplate. Then the metaphyseal “cheese grater” reamer is used to remove remaining cancellous bone from the proximal humerus to allow metaphyseal component placement (Fig. 11). There are 2 sizes of reamers, 36 and 42 mm. The size that fits best is usually 36 mm.
but for larger individuals or those with previous prosthetic instability, preparation for a 42 mm component may be preferred. The decision on reamer size is based on preoperative planning and intraoperative estimation of humeral and glenoid size.

Distal metaphyseal reaming is then performed with a long conical reamer, inserting the reamer so that the height landmark is level with the highest part of the humeral cut. Diaphyseal reaming is then performed sequentially with reamers of 6.5, 9, 12, and 15 mm until the reamer comes into contact with diaphyseal cortical bone. If the reamer of a specific size reaches the appropriate depth as noted by the height landmark with chatter, reaming is stopped. Preparing the canal more aggressively risks fracturing the humerus as well as not having an adequate cement mantle.

The humeral trial is then assembled and retroversion rod set to 0 to 20°, according to the preference of the surgeon. The trial is then inserted with manual pressure, followed by light impaction with a mallet. A plastic cut protector is then placed into the metaphysis of the component to protect the trial component during glenoid preparation. At times the medial head still protrudes and needs trimming to facilitate retraction and glenoid exposure.

Glenoid Preparation

Homan and Kolbel retractors are used to retract the soft tissues and proximal humerus while a circumferential capsulotomy and labral excision are performed. The origin of the long head of the triceps is released from the inferior glenoid, and the lateral pillar of the scapula is palpated. A 2-prong Tiemann Capsular retractor is placed against the lateral pillar/scapular neck. This serves as a reference guide later for the superior-inferior orientation of the baseplate, so that the inferior screw be placed down the center of the axial border of the scapula. Glenoid osteophytes are removed to reveal the true glenoid anatomic shape and more correctly identify the base of glenoid bone that is most solid for baseplate (metaglene) placement. The central hole guide is assembled and placed with the handle inferior for the deltopectoral approach. The inferior most edge of the guide is placed against the inferior most edge of the glenoid. This ensures that the metaglene is placed against the glenoid as inferior as possible. Alternatively, one may prefer to invert the baseplate and use it as a guide to ensure more inferior placement. The goal is to have the glenosphere inferior enough and tilted inferiorly a few degrees to decrease any contact of the polyethylene insert with the scapula. This nuance is the recent attempt to prevent scapular notching. Based on preoperative CT scanning the guide is angled inferiorly to create an inferior tilt to the reamed surface of 0–15°. The central hole is then drilled with a 6 mm bit, which has a self-stop (Fig. 12). The guide is then removed, followed by placing the flat glenoid reamer (Fig. 12). The reamer is started away from the bone, then pushed slowly into the glenoid to gently flatten the glenoid face, conservatively removing bone to preserve as much of the subchondral plate as possible. Once a uniformly flat surface has been created and a 1–2 mm groove is created circumferentially, the reaming is complete. The groove must be created to allow placement of the baseplate flush against the bone. The reamer is removed and the glenoid central hole drill guide placed, followed by over-drilling of the central hole with a 7.5 mm drill with a self-stop (Fig. 13). The cancellous bone graft is impacted in the post hole. The baseplate inserter is assembled and the 8.0 mm baseplate central post is impacted into the 7.5 mm drilled hole for a press-fit into the scapula.

There is an “up” and “down” marker on the inserter with a vertical line that allows orientation of the baseplate so that the inferior drill hole is aligned with the inferior pillar of the scapular neck (Fig. 14). This ensures placement of an inferior screw that is as long as possible. The baseplate is impacted against the glenoid bone with several sharp blows with a mallet. The inserter is gently removed, leaving the baseplate in place. The positioning of the superior and inferior locking screws is most critical. We prefer to place the inferior screw first to set the rotation of the baseplate. The threaded drill guide is screwed into the metaglene screw hole. A long 3 mm drill bit is inserted into the guide, drilling through the face of

FIGURE 11. A cup is made in the native proximal humerus using the power “cheese grater” reamer to accept the humeral metaphyseal component.
the glenoid and along the inferior pillar of the scapula (Fig. 15). After the far cortex is breached, the length is measured and the inferior screw placed. It is fully advanced temporarily, “locked” into the baseplate, keeping it from rotating during subsequent screw placement. The superior screw is then drilled, measured, and inserted. The anterior and posterior screws are then drilled and proper lengths measured (Fig. 16). These 2 screws are then inserted but not tightened until the superior and inferior screws are temporarily loosened, unlocking them from the baseplate. The anterior and posterior screws are then tightened sequentially to achieve compression of the baseplate against the prepared glenoid surface. Once full compression is obtained with the anterior and posterior screws, the superior and inferior screws are locked to achieve final baseplate fixation. The baseplate should be very well fixed to the bone. This requires at least 3 of the 4 screws having good purchase.

The glenosphere of choice (36 or 42 mm) is then guided to the metaglene using a screwdriver (Fig. 17). The glenosphere is gently pressed onto the Morse taper of the metaglene and the screwdriver is removed. The glenosphere is firmly seated onto the Morse taper of the metaglene using a polyethylene impactor and several sharp blows of the mallet. Final glenosphere fixation is secured by tightening the center set screw, which threads into a mating thread on the inside of the center peg of the metaglene (Fig. 17). Care is taken throughout these steps to ensure that soft tissue is completely cleared from the periphery of the glenoid so that incomplete glenosphere-metaglene fixation and postoperative lucent lines do not occur.
Glenohumeral Trialing, Humeral Component Implantation, and Final Reduction

After the glenosphere is firmly implanted, the humerus can be redislocated out of the incision. Care is taken not to scratch the glenosphere during the dislocation maneuver. A 6 mm trial humeral insert is then placed and impacted into the humeral trial metaphyseal cup (Fig. 18). A trial reduction is performed. The humeral component should rotate nicely without signs of instability. Gentle traction is applied to the arm to perform a “shuck” maneuver. There should be less than 1 mm of diastasis between the humeral cup and glenosphere during this maneuver to ensure proper stability. If the shoulder cannot be reduced with a 6 mm insert, then the trial is removed, adhesions lysed, and additional proximal humeral bone resected if necessary.

Once it is determined that the shoulder will reduce, the proximal humeral component is cemented. A cement restrictor is inserted and the humeral shaft meticulously dried. Cementing technique is very important for this prosthesis, as there may be more problems with humeral loosening with the Reverse Prosthesis than with unconstrained total shoulder replacement. Press fit placement of the humeral component is not recommended at this time following some earlier experience with subsidence.
After the humeral component is well fixed with cement, the 6 mm trial insert is placed into the metaphysis and the shoulder reduced. If the tension is adequate, the shoulder is redislocated and the final polyethylene liner impacted into the metaphyseal cup (Fig. 19). If there is insufficient tension, gradually increasing sizes of liner trials are used to obtain the optimum fit. In the primary CTA case it is rare that a liner over 9 mm is required, but the larger 12 mm liner and 9 mm metaphyseal extension are often essential for the revision situation.

After the shoulder is reduced with final implants in position, the subscapularis is repaired via 3 to 4 tendon to tendon sutures, occasionally augmenting the repair with transosseous sutures if the remaining tendon tag on the humerus is insufficient. The deltopectoral interval is closed over a drain, with a running absorbable suture. The skin is closed in routine fashion. Postoperative radiographs are obtained in the recovery room (Fig. 20).

**POSTOPERATIVE MANAGEMENT**

The shoulder is immobilized in slight abduction and in near-neutral rotation. Gentle passive motion in all planes is started immediately, taking care not to push the limit of intraoperative motion measurements. Active assisted motion is started at 3 to 4 weeks postoperatively, followed by active motion at approximately 6 weeks postoperative. The immobilizer is discontinued at this time.
RESULTS

We recently performed a retrospective review of 45 reverse shoulder arthroplasty patients, with an average follow-up of 42 months. The indication for the procedure was end-stage glenohumeral arthritis with massive irreparable rotator cuff tear in 21 patients, revision of failed hemiarthroplasty in 19 patients, and fracture sequelae with severe malunion or nonunion of the tuberosities in 5 patients. All 3 groups showed a significant increase in active elevation (from 55° pre-operatively to 121° post-operatively) and Constant Score (from 17 to 59), but no significant change in active external rotation (from 7° to 11°) or internal rotation (51 pre and postoperatively). Seventy-eight percent of patients were satisfied or very satisfied with the result, and 67% of patients had no or slight pain. However, the postoperative Constant Score, adjusted Constant Score, and ASES Shoulder Score were all significantly higher in the CTA group as compared with the revision group (P = 0.01, 0.004, and 0.002, respectively). Severe fatty infiltration of the teres minor was associated with lower external rotation (0° vs. 15°, P = 0.02) and lower functional results (Constant score: 46 vs. 66, P = 0.007).

Complications

In our series of 45 patients, 14 complications occurred in 11 patients (24%). The most common complications were dislocation (3 cases), deep infection (3 cases), periprosthetic humeral fracture (2 cases), and late acromial fracture (2 cases). One case of postoperative hematoma, axillary nerve palsy, and symptomatic humeral loosening were also observed. Complication and revision rates were highest in the revision group (47% and 26%, respectively).

Ten patients (22%) needed further surgery for treatment of a complication. All 3 dislocation patients (1 in the CTA group, 2 in the revision group) were brought back to the operating room for liner exchange or addition of the 9 mm metal spacer with retentive 6 mm liner.
patients in the revision group required prosthetic removal for infection. One infection in the revision group was treated successfully with 1-stage irrigation, debridement, and polyethylene liner exchange. One patient in the revision group developed aseptic humeral loosening. The humeral component was revised 1 year postoperatively. Another patient required revision for treatment of a peri-prosthetic humeral fracture sustained in a motor vehicle accident. Although no cases of glenoid loosening were observed, 1 patient required removal of the glenosphere on postoperative day number 1. The glenoid was fractured during reaming, but the metaglene and glenosphere appeared to be stable after implantation. The glenosphere was noted to lose fixation on postoperative radiographs, and the patient was brought back to the operating room for conversion to a humeral head replacement.

Scapular notching, or loss of inferior glenoid bone secondary to impingement of the prosthesis against the inferior glenoid neck (Fig. 21), was observed on final radiographs in 24 cases (74%). Twenty-eight percent of patients exhibited scapular notching that extended beyond the inferior screw. Despite the high percentage of cases that exhibited scapular notching, none were symptomatic and no cases of glenoid loosening were noted. Heterotopic ossification was noted on postoperative radiographs in 17 cases (45%), always occurring at the lower margin of the glenoid. Grade I ossification 18 was found in 11 cases, grade 2 in 2 cases, and grade III in 4 cases. Grade III ossification cases tended to have greater restriction in range of motion (passive and active) than patients with less severe heterotopic ossification. A bony spur at the inferior margin of the scapular neck was noted in 24 cases (63%) and was always associated with a scapular notch (Fig. 21).

**FUTURE OF THE TECHNIQUE**

Our most pressing concern regarding this prosthesis is that it is used for the correct indications, as outlined above. The *Tornier Aequalis Reversed Shoulder Prosthesis™* was designed based upon the principles of Paul Grammont, including a horizontal humeral neck cut, hemispherical glenoid component with secure locked screw fixation, and a medialized and lowered center of rotation that increases the effectiveness of the deltoid while minimizing glenoid loosening. The prosthesis is designed for individuals with end-stage glenohumeral arthritis with an extensive irreparable cuff deficiency. Although short and intermediate term data regarding the longevity of this prosthesis are quite favorable, long term data are
not available. Therefore, at this time we favor restricting the use of this prosthesis to older individuals. The major benefit of this prosthesis is that shoulder level function and above can reliably be achieved in patients with uncomplicated rotator cuff deficient arthritis (Fig. 22). This consistency of results has not been achieved in our or others’ hands with the use of conventional hemiarthroplasty. Although the prosthesis offers some hope of pain relief and restoration of function in patients who require revision of failed shoulder prosthesis, complication rates are high (approximately 50%). Dislocation rates may be decreased by the availability of multiple length options for the humeral polyethylene insert and with use of the larger component. We anticipate that this prosthetic design will continue to be a valuable tool in treating patients for whom satisfactory options have often been lacking in the past.

REFERENCES


