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Revision arthroplasty with a hip-inspired computer-assisted design/computer-assisted manufacturing implant for glenoid-deficient shoulders

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Background: Revision arthroplasty for failed post-traumatic humeral head replacement associated with rotator cuff and glenoid deficiency is challenging. Current surgical solutions are fraught with complications, and no best-practice strategy has been established. We hypothesized that the computer-assisted design/computer-assisted manufacturing (CAD/CAM) shoulder (Stanmore Implants, Elstree, UK), a total shoulder design resembling a total hip prosthesis, can offer a reliable alternative in this surgically challenging subset of patients with rotator cuff deficiency and advanced glenoid bone loss.

Methods: Twenty-one patients with failed post-traumatic humeral head replacement associated with rotator cuff and glenoid deficiency underwent revision with CAD/CAM shoulders between 2005 and 2010. Clinical data were collected prospectively and analyzed at a mean follow-up of 3 years.

Results: After revision, the pain rating at rest (on a 0-10 numerical scale) decreased from 5.6 $\pm$ 1.3 to 1.1 $\pm$ 1.3 ($P < .001$) and pain during activity decreased from 7.4 $\pm$ 1.2 to 2.1 $\pm$ 1.8 ($P < .001$). The Oxford shoulder score improved from 47 $\pm$ 6 to 31 $\pm$ 9 ($P < .001$), and the subjective shoulder value (on a 0%-100% scale) improved from 22% $\pm$ 14% to 45% $\pm$ 18% ($P < .001$). Active shoulder range of motion was similar before and after revision. Postoperative complications occurred in 9 patients and included 1 infection, 2 periprosthetic fractures, 2 prosthetic dislocations, and 4 fixation screw fractures. No case of glenoid loosening occurred.

Conclusion: The CAD/CAM shoulder offers a reliable method of securing a glenoid component in shoulders with advanced glenoid deficiency and should be considered as an alternative to other surgical methods in these challenging cases. At 3 years' follow-up, pain and clinical scores improved significantly and no case of glenoid loosening occurred.

Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: Humeral head replacement; shoulder hemiarthroplasty; revision shoulder arthroplasty; glenoid deficiency; arthroplasty failure; CAD/CAM; custom implant; glenoid bone graft

The study was reviewed by the Royal National Orthopaedic Hospital National Health Service (NHS) Research and Development (R&D) Management board on August 23, 2012, under the name "Clinical Outcome of revision surgery for failed humeral head replacement following shoulder trauma—service evaluation of RNOH cases between January 2005 and June 2011" (study registration No. SE12.024). On the basis of the National Research Ethics Service's "Defining Research" leaflet, it was concluded that the study fits into the category of service evaluation and, as such, does not require approval from the Research Ethics Committee or R&D Office.

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Humeral head replacement (HHR) is an accepted treatment option for complex proximal humeral fractures.[3,9] Despite reliable pain relief, clinical outcomes after HHR performed for proximal humeral fractures are less predictable for shoulder function and vary from satisfactory to poor in different studies.[1,2,12,21] Rotator cuff dysfunction and prosthetic problems such as loosening and misalignment have been associated with poor outcomes and may require revision.[8,15] These factors also lead to eccentric and irregular forces on the glenoid, resulting in glenoid erosion and bone loss, which complicate further surgery.[4,18,22] Eccentric reaming, glenoid reconstruction with bone graft, and the use of augmented glenoid components and custom implants have been suggested as potential techniques of dealing with the deficient glenoid.[30,32,35] However, the clinical outcomes of these techniques are controversial and highlight the need for better solutions to address advanced glenoid bone loss.[13,14,16,28]

A shoulder replacement design resembling a total hip prosthesis may offer an alternative method of addressing the cuff-deficient glenoid-deficient shoulder. Such prosthetic design (Epoca Reco Glenoid; Synthes, Solothurn, Switzerland) has been reported as an alternative to reverse total shoulder arthroplasty (RTSA) for the treatment of cuff tear arthropathy.[19] The computer-assisted design/computer-assisted manufacturing (CAD/CAM) shoulder (Stanmore Implants, Elstree, UK) is a custom-made, total hip–like shoulder implant with a large glenoid shell. It is secured to the scapula around the deficient glenoid (rather than to the deficient glenoid itself) and may facilitate glenoid component fixation in poor glenoid bone stock. Unlike most reverse total shoulder designs, it lateralizes the center of rotation and is expected to improve deltoid function by lateralizing rather than distalizing the arm. In our opinion, this prosthetic design should be considered as an alternative to RTSA only in glenoid-deficient shoulders, when the ability to achieve secure fixation of a glenoid component is questionable. The use of a hip replacement–like prosthesis in revision shoulder arthroplasty for the treatment of advanced glenoid bone loss has not been previously evaluated to our knowledge.

The objective of this study was to evaluate the clinical outcome of our patients who underwent revision shoulder arthroplasty for failed post-traumatic HHR, associated with rotator cuff and glenoid deficiency, with the CAD/CAM shoulder. We hypothesized that the use of this prosthetic design will alleviate pain and improve function in our patients.

Materials and methods

Twenty-four patients underwent revision shoulder arthroplasty for failed HHR (performed previously for the treatment of proximal humeral fracture or fracture sequelae) with the CAD/CAM shoulder prosthesis in our shoulder surgery unit between 2005 and 2010 and were included in this study. All the patients had severe pain and disability because of insufficient rotator cuff and advanced glenoid bone loss, which failed to improve with nonoperative treatment over a period of 6 to 12 months. Three patients were excluded for missing preoperative data, leaving 21 patients available for data analysis. Glenoid bone stock was assessed based on high-quality shoulder radiographs and computed tomography scans (and confirmed intraoperatively) according to the classification described by Walch et al.[34] Type A2 and B2 glenoids with bone loss and erosion medial to the coracoid base and type C glenoids were considered to have advanced glenoid bone loss and were revised with the CAD/CAM shoulder. Patients with glenoid morphology other than the described earlier (ie, glenoid types A1, A2, and B2 with erosion remaining lateral to the coracoid base and type B1) were treated with other prosthetic designs and were not included in this study.

The decision on whether to use a cemented or uncemented humeral stem was made by a shoulder consultant based on the bone quality and patient's characteristics. Specifically, patients with good humeral bone quality—that is, combined medial and lateral cortical thickness of the proximal humeral diaphysis of 4 mm or greater on preoperative anteroposterior radiographs (and confirmed intraoperatively)—and no pre-existing conditions affecting bone healing (eg, diabetes mellitus, heavy smoking, corticosteroids, or anti-inflammatory medication) underwent revision with uncemented humeral stems. Patients with lower humerus bone quality and/or chronic conditions affecting bone healing underwent revision with cemented humeral stems.

The implants were designed and manufactured by Stanmore Implants and were custom-made based on the patient's preoperative shoulder computed tomography scan. The CAD/CAM shoulder prosthesis comprises 5 components. The first component is an uncemented, hydroxyapatite-coated titanium glenoid shell with slots for screw fixation to the scapula. The shell diameter is based on the patient's scapular morphology. The shell wall thickness is fixed at 2 mm. The second component is a high–molecular weight polyethylene liner (cemented into the glenoid shell) with an inner diameter of either 28 or 32 mm. The liner diameter is determined by the inner diameter of the glenoid shell and is designed to allow for a 2-mm cement mantle and the wall thickness of the liner. The liner depth is designed to be 2 mm deeper than the radius of the prosthetic humeral head (available in a 28- or 32-mm size) to contain the head, firmly creating a fixed-fulcrum, inherently stable, linked implant. The third component is a cobalt-chrome tapered humeral stem, cemented or uncemented in variable sizes based on the patient's proximal humerus morphology and condition. Uncemented stems are designed with 6 longitudinal 1-mm fins with hydroxyapatite coating. The fourth component is a cobalt-chrome spherical humeral head available in a 28- or 32-mm size (according to the glenoid shell and liner size). The prosthetic head is inserted on the stem cervix in a press-fit fashion and mated into the liner by direct pressure. The prosthesis maximal range of motion is 60° around its central position (ie, with the stem neck perpendicular to the liner) before impingement of the neck on the liner lip occurs. Finally, the fifth component is 3.5-mm titanium fixation screws with compatible washers (Fig. 1).

Operative technique

All the revisions were performed with the patient in the beach-chair position through a deltopectoral approach, extended