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ORIGINAL ARTICLE

Primary shoulder arthroplasty using a custom-made hip-inspired implant for the treatment of advanced glenohumeral arthritis in the presence of severe glenoid bone loss

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Background: Total shoulder arthroplasty for end-stage glenohumeral arthritis with severe glenoid bone loss poses a unique challenge for shoulder surgeons. Current surgical solutions are limited and associated with high complication rates. We hypothesized that a custom-made computer-aided design–computer-aided manufacturing (CAD-CAM) total shoulder replacement (TSR; Stanmore Implants Worldwide, Elstree, UK) resembling a total hip prosthesis could offer a reliable alternative for this challenging subset of patients.
Methods: Thirty-seven patients with rotator cuff–deficient end-stage glenohumeral arthritis and severe glenoid bone loss (assessed as not amenable to treatment with standard anatomic or reverse total shoulder implants) were treated with the CAD-CAM TSR between 2006 and 2013. Clinical data were collected prospectively and analyzed at a mean follow-up of 5 years.
Results: Postoperatively, the pain level with activity decreased from 9.2 ± 1.7 to 2.4 ± 2.9 ($P < .001$). The Oxford Shoulder Score improved from 11 ± 8 points to 27 ± 11 points ($P < .001$), and the Subjective Shoulder Value (on a 0%-100% scale) improved from 23% ± 14% to 60% ± 24% ($P < .001$). Active forward elevation improved from 39° ± 23° to 63° ± 38° ($P < .001$), and external rotation improved from 6° ± 16° to 15° ± 17° ($P = .001$). Component revision was required in 6 of 37 patients (16%) (glenoid loosening in 1, humeral stem loosening in 3, periprosthetic fracture in 1, and prosthesis dislocation in 1).
Conclusion: The CAD-CAM TSR offers a reliable alternative for the treatment of end-stage glenohumeral arthritis with severe glenoid deficiency not amenable to standard anatomic or reverse total shoulder implants, with maintenance of significant pain relief and clinical-functional improvement at 5-year postoperative follow-up.
Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Total shoulder arthroplasty; hip-inspired shoulder replacement; CAD-CAM shoulder; custom shoulder implant; glenoid deficiency; glenoid bone loss; rotator cuff arthropathy

The study was reviewed by the Royal National Orthopaedic Hospital National Health Service Research and Development Management Board on March 27, 2013, under the title "Service evaluation of primary shoulder arthroplasty for cuff-deficient glenoid-deficient shoulders—Medium-term outcomes" (study registration No. SE13.007). On the basis of the National Research Ethics Service "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 Research and Development Office.

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Patients with severe glenoid bone loss who require shoulder arthroplasty for symptomatic glenohumeral arthritis pose a unique surgical challenge for shoulder surgeons. Traditionally, these patients were treated with humeral head replacement avoiding glenoid implantation.[8-10] Evidence of superior outcomes with the use of total shoulder implants over hemiarthroplasty in these cases[6,16,18] led to the development of various techniques aiming at realigning the axis of the glenoid and securing implants in the deficient glenoid vault (eg, eccentric reaming, augmented glenoid components, glenoid reconstruction with bone grafts, and reverse arthroplasty with or without bone augmentation).[1,3,5,12,17] Although suitable for mild to moderate glenoid bone loss, the extent of glenoid deficiency in any plane that can be addressed by these techniques is limited, and none of these techniques provides a reliable solution for the most challenging cases associated with advanced glenoid bone loss[5,23] where more than 2 quadrants of the glenoid vault are absent.

The computer-aided design–computer-aided manufacturing (CAD-CAM) total shoulder replacement (TSR) (Stanmore Implants Worldwide, Elstree, UK), a hip-inspired total shoulder design with a large acetabulum-like glenoid shell, fixed to the scapula around the deficient glenoid rather than to the glenoid itself, may offer an alternative solution for securing a glenoid implant in severely deficient glenoid bone. Our institution has a historical experience with replacement of bone defects in revision arthroplasties and musculoskeletal oncology using massive endoprostheses rather than prosthetic-allograft reconstruction, and it was on this background that the present strategy was formulated. Previous studies conducted at our institution reported the clinical and radiographic outcomes of patients with severe glenoid erosion who underwent revision arthroplasty with the CAD-CAM TSR for failed humeral head replacement[20] and glenoid-side failure of reverse shoulder arthroplasty not amenable to other available implants.[19] At a mean follow-up of 3 years after revision with the CAD-CAM TSR, there was a significant improvement in pain levels and clinical scores and there was no evidence of glenoid loosing.[19,20]

The objectives of this study were to evaluate the clinical and radiographic outcomes after primary shoulder reconstruction with the CAD-CAM TSR in this challenging subset of patients.

Materials and methods

This was a retrospective analysis of prospectively collected data. Forty-three patients underwent primary total shoulder arthroplasty with the CAD-CAM TSR in our shoulder surgery unit between 2006 and 2013 and were included in this study. The indication for surgery was unremitting quality of life–limiting pain and disability, due to rotator cuff–insufficient glenohumeral arthritis with advanced glenoid bone loss, not relieved through multiagency nonoperative management (pain management, occupational therapy and physiotherapy, and social service support) over a period of at least 12 months. Glenoid bone stock was assessed by high-quality shoulder radiographs (anteroposterior, axillary, and lateral trans-scapular views) and computed tomography scans and was confirmed intraoperatively according to the classification described by Walch et al.[3,21] Walch type B2 glenoid erosion but with additional bone loss medial to the coracoid base and Walch type C glenoids were considered un-reconstructable with a standard or modified/augmented glenoid implant and were treated with the CAD-CAM TSR.

Six patients were excluded (4 had missing preoperative data and 2 were lost to follow-up), leaving 37 patients (30 female patients) aged 57 ± 21 years (range, 16-85 years) available for data analysis at a mean postoperative follow-up of 60 ± 25 months (range, 24-108 months). The etiology for glenoid deficiency was (1) degenerative bone erosion in 22 patients (related to cuff tear arthropathy in 10 patients and rheumatoid arthritis in 12); (2) congenital glenoid dysplasia in 9 patients (the outcome of this group of patients was recently reported in another paper from our institution, which focused on the surgical management of end-stage glenohumeral arthritis in patients with obstetric brachial plexus palsy[14]); and (3) post-traumatic bone erosion in 6 patients.

All patients underwent fine-cut 2-dimensional computed tomography scans from which the CAD-CAM TSR prosthesis was designed. The humeral component was available in uncemented (23 cases) and cemented (14 cases) versions. The fixation method was determined by the patient's bone quality, that is, patients with a combined proximal humerus medial and lateral cortical thickness of 4 mm or greater and no pre-existing conditions affecting bone healing or likely to lead to progressive deterioration in bone quality (diabetes mellitus, heavy smoking, corticosteroids or anti-inflammatory medication, and so on) were treated with uncemented humeral components. The characteristics of the CAD-CAM TSR components (Stanmore Implants Worldwide) have been detailed in previous publications.[19,20]

Operative technique

All procedures were performed with the patient in the reclining position on a shoulder operating table under general anesthesia with an interscalene block. The arm was draped free, permitting access to the whole scapula. The deltopectoral approach was used in all cases. The attachment of the pectoralis major was left intact. The conjoint tendon was retracted medially with partial detachment from the lateral border of the coracoid to facilitate exposure of the anterior wall of the glenoid when present. In the congenital dysplastic glenoid group, the elongated vertical coracoid (typical of obstetric brachial plexus palsy) was shortened by intraperiosteal dissection and ostectomy, retaining the base to receive the coracoid fixation screw of the glenoid shell. The subscapularis tendon, when present, was released medial to its humeral insertion, and if possible, it was repaired at the end of the procedure. The axillary nerve was carefully explored and protected under nerve stimulator guidance. Releases of the subscapularis tendon, inferior capsule, and long head of the triceps insertion were carried out with nerve stimulator guidance. The humeral head was cut from the medial articular margin to a level approximately 1 cm below the lateral prominence of the greater tuberosity when present. The entire periphery of the proximal humerus was then mobilized, preserving the attachment of the teres minor when present. The resected bone was used for bone graft behind the glenoid shell.

An "acetabulum" for the uncemented titanium glenoid shell was created by concentric reaming of the lateral scapular angle with the aim of realigning the center of rotation of the eventual articulation to the scapular axis. The aim was to permit the shell to abut the