Clinical and radiographic results of cementless reverse total shoulder arthroplasty: a comparative study with 2 to 5 years of follow-up

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Background: Most studies of reverse total shoulder arthroplasty (RTSA) involve cemented humeral stems. To our knowledge, this is the first study to compare the results of cementless RTSA, using a porous-coated stem designed for uncemented fixation, with cemented RTSA.

Methods: A prospective database of patients undergoing RTSA was retrospectively reviewed for patients with a diagnosis of cuff tear arthropathy or severe rotator cuff deficiency with minimum 2-year follow-up. Of these, 37 patients had cemented RTSA and 64 patients had cementless RTSA. Outcome measures included Constant-Murley scores, American Shoulder and Elbow Surgeons scores, visual analog pain scale scores, range of motion, patient satisfaction, and radiographic evidence of complication.

Results: Compared with preoperative values, both cohorts demonstrated significant improvements (P < .01) in all functional scores, active forward elevation, and active internal rotation. There was no significant difference (P > .05) in comparing the changes in these values after surgery between the cemented and cementless cohorts. On radiographic evaluation, there was no evidence of loosening or humeral components “at risk” of loosening in either group. There was no significant difference (P = 1.0) in the incidence of humeral component radiolucent lines between the cemented and uncemented cohorts. There was no significant difference (P = .30) in the incidence of scapular notching between the cemented (n = 8) and uncemented (n = 10) cohorts.

Conclusion: Cementless fixation of a porous-coated RTSA humeral stem provides clinical and radiographic outcomes equivalent to those of cemented stems at minimum 2-year follow-up. With advantages such as simplified operative technique, no cement-related complications, greater ease of revision, and long-lasting biologic fixation, uncemented fixation may provide several benefits over cemented fixation.

Level of evidence: Level III, Retrospective Cohort Study, Treatment Study.

Keywords: Reverse total shoulder arthroplasty; uncemented fixation; cuff tear arthropathy; rotator cuff deficiency; porous-coated stem

All data were collected and reviewed under approval of the Beaumont Health System Human Investigations Committee, protocol #2006-088.

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Studies have demonstrated both clinical and radiologic success of reverse total shoulder arthroplasty (RTSA) with follow-up approaching 10 years.\(^9\,14\) Despite a few promising long-term outcomes studies, the rate of humeral loosening is thought to be high with RTSA compared with total shoulder arthroplasty.\(^5\) The higher rate of humeral loosening may in part be related to the semiconstrained nature of the RTSA articulation, imparting a greater shear stress at the stem-bone interface.\(^19\) To avoid the risk of loosening, in addition to a lack of commercially available alternatives designed for cementless fixation, many surgeons have in the past used cemented humeral components in RTSA. As such, the bulk of the RTSA literature includes a majority of patients in whom a cemented humeral component was implanted.\(^2\,3\,7\,9\,11\,15\,22\,24\,28\,33\,35\) Although a recent study reported on early radiographic outcomes of uncemented, proximally porous-coated (PPC) RTSAs,\(^1\) the remaining series in the literature involving cementless RTSAs have used implants not designed for bone ingrowth.\(^9\,19\,34\) Also, the clinical and radiographic results of these non–porous-coated stems that have been implanted without cement are somewhat contradictory.\(^19\,34\) Furthermore, in total shoulder arthroplasty, some studies have shown cemented stems to lead to better functional outcomes\(^15\) and a longer survivorship free of revision surgery\(^4\) than with uncemented stems. Nonetheless, cementless fixation using PPC, press-fit humeral implants designed for bone ingrowth holds promise in RTSA, given promising studies in total shoulder arthroplasty\(^32\) and its proven track record in total hip arthroplasty that has shown survivorship approaching 99% at more than 10 years.\(^5\,27\) Currently, the number of commercially available PPC RTSA implants is steadily growing, but despite this increased popularity, there has been no published study examining clinical and radiographic outcomes in PPC, press-fit humeral stems in comparison to more traditional cemented stems. We hypothesized that the clinical and radiographic results of uncemented RTSA using a PPC humeral stem would be similar to those of cemented RTSA stems with follow-up for at least 2 years.

**Patients and methods**

**Patients**

All patients undergoing RTSA by the senior author (J.M.W.) were offered the opportunity to enroll in a prospective outcomes database. Patients were asked to return postoperatively at 2 weeks, 3 months, 6 months, 1 year, and yearly thereafter for radiographic analysis and collection of clinical outcome data. The database was retrospectively reviewed from 2005 through 2008, during which 247 patients underwent RTSA, with 14 staged bilateral procedures, resulting in 261 RTSAs. Inclusion criteria for this study were diagnosis of cuff tear arthropathy or severe rotator cuff deficiency refractory to all other treatments and minimum 2-year clinical and radiographic follow-up. Exclusion criteria were proximal humeral fractures, glenohumeral instability, rheumatoid arthritis, incomplete follow-up, and revision arthroplasty. These criteria were met by 160 patients, not including 2-year follow-up. Of these, 101 patients had minimum 2-year follow-up (66 men, 35 women), 5 of whom received a staged bilateral RTSA. Only one shoulder from the bilateral patients was included in this study to limit any variables affected by systemic conditions.

Thirty-seven shoulders received a cemented implant by either DePuy Orthopaedics (Delta III; Warsaw, IN, USA) or Tornier (Aequalis Reversed Shoulder; Edina, MN, USA). The use of 2 different cemented implants in this series was due to a shift in implant preference of the senior author (J.M.W.); however, both implants are similar in that each is a Grammont-style prosthesis with the center of rotation located at the glenoid (0 mm of offset) and includes a smooth, tapered humeral stem designed for cemented fixation with a 155° neck-shaft angle. In the cemented group, 28 36-mm and 9 42-mm glenospheres were implanted. Sixty-four shoulders received an uncemented stem by Zimmer (Trabecular Metal Reverse Shoulder; Warsaw, IN, USA). This implant includes a lateraledized center of rotation (2.5 mm of offset) and a cylindrical humeral stem with PPC designed for bone ingrowth with a neck-shaft angle of 160°. In the uncemented group, 48 36-mm glenospheres and 16 40-mm glenospheres were implanted. The cemented RTSAs were implanted between 2005 and 2007, and the uncemented RTSAs were implanted between 2007 and 2008 as a result of another change in implant preference of the senior author (J.M.W.). Both cohorts demonstrated comparable demographics with regard to gender, age, follow-up, and diagnosis (Table 1). Representative radiographs of a cemented and a cementless RTSA from 2 study patients are shown in Figure 1.

**Operative technique**

A deltopectoral approach was used in all cases. Soft tissue releases (anterior deltoid insertion, superior pectoralis major tendon insertion, capsule) were performed to facilitate exposure. The long head of the biceps was tenotomized at the level of the superior pectoralis major insertion for later soft tissue tenodesis. The subscapularis, if present, was tenotomized 1 cm medial to the bicipital groove. The humeral neck was cut of 0° to 20° of

<table>
<thead>
<tr>
<th>Table I Cohort demographics</th>
<th>Cemented (n = 37)</th>
<th>Uncemented (n = 64)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, years (range)</strong></td>
<td>71.95 (55-83)</td>
<td>72.47 (48-92)</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>15 (40.5%)</td>
<td>20 (31.3%)</td>
</tr>
<tr>
<td>Female</td>
<td>22 (59.5%)</td>
<td>44 (68.8%)</td>
</tr>
<tr>
<td><strong>Follow-up, months (range)</strong></td>
<td>37.0 (24-77)</td>
<td>32.4 (24-63)</td>
</tr>
<tr>
<td><strong>Diagnosis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cuff tear arthropathy</td>
<td>27 (73%)</td>
<td>34 (53%)</td>
</tr>
<tr>
<td>Irreparable rotator cuff</td>
<td>10 (27%)</td>
<td>29 (47%)</td>
</tr>
<tr>
<td><strong>Implant</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DePuy</td>
<td>10 (27%)</td>
<td>0</td>
</tr>
<tr>
<td>Tornier</td>
<td>27 (73%)</td>
<td>0</td>
</tr>
<tr>
<td>Zimmer</td>
<td>0</td>
<td>64 (100%)</td>
</tr>
</tbody>
</table>
retroversion. Glenoid preparation consisted of a 360° capsular release, excision of the labrum, and reaming to subchondral bone. Baseplates were placed inferiorly on the glenoid with approximately 10° of inferior tilt. The humeral component was then placed in 0° to 20° of retroversion. In cases of cemented fixation, a stem 2 mm smaller than the last reamer was implanted to ensure an adequate, uniform cement mantle. In cases of uncemented fixation, the stems were generally placed with a tight diaphyseal fixation. If tight diaphyseal fixation was not possible (i.e., the canal diameter was in between stem sizes), impaction autografting was then undertaken. The subscapularis tenotomy was repaired with interrupted No. 2 nonabsorbable sutures. Surgical drains were placed deep to the deltoid and in the subcutaneous tissue before closure.

Clinical evaluation

A trained, independent clinical research nurse examined patients preoperatively and at each time point postoperatively. Functional outcomes were evaluated by the Constant-Murley score, American Shoulder and Elbow Surgeons (ASES) score (including the ASES activities of daily living component score), and Subjective Shoulder Value. Patients were asked to rate their pain on a visual analog scale of 0 (none) to 10 (maximal). Range of motion was measured with a goniometer, including active external rotation (aER) and active forward elevation (aFE). Active internal rotation (aIR) was measured as the highest spinal level that the patient’s thumb could reach.

Radiographic evaluation

Anteroposterior and lateral radiographs were obtained at each postoperative visit. A board-certified, musculoskeletal radiologist who was blinded to clinical outcome reviewed the early postoperative radiograph and each subsequent radiograph for any evidence of complication including change in humeral component position (subsidence or tilt), osteolysis (circular or oval areas of distinct bone loss), humeral component radiolucent lines (RLLs; any lucency of more than 1 mm at the implant-bone or cement-bone interface), Gruen zones where the RLLs were located, humeral stress shielding (a relative decrease in cortical thickness surrounding the implant on successive radiographs or relatively thinner cortices surrounding the implant compared with the native humerus distal to the stem), humeral spot welds (bridging trabeculae from the endosteal surface of the humerus to the PPC of the implant), component failure, and scapular notching. Humeral component subsidence was evaluated by measuring the distance from the tip of the greater tuberosity to the most superior aspect of the humeral component. Humeral component tilt was measured as the angular difference between the axis of the humeral component and the axis of the humeral shaft. A humeral component was considered loose if there was a change in implant position (subsidence or tilt) on successive radiographs. A humeral component was considered “at risk” of loosening if there were RLLs ≥2 mm in 3 or more Gruen zones. Scapular notching was graded according to the system of Sirveaux.

Chart review

Medical records were reviewed to determine the length of surgery, humeral implant size, and any postoperative complications. Major complications were recorded and defined as requiring prolonged hospital stay or reoperation. All other complications were considered minor.

Statistical analysis

An independent, institutional biostatistician conducted the statistical analysis. Normality of variables was assessed by a Shapiro-Wilks test. Each cohort was examined separately for the significance in improvement from preoperative to most recent follow-up of all outcomes measures. Continuous, normal variables were compared by a paired t test, and non-normal variables were compared by a Wilcoxon rank sum test. Noncontinuous variables were compared between cohorts with a test of marginal homogeneity. The degree of improvement and radiographic parameters were then compared between cohorts. Continuous, normal variables were compared by an independent t test, and non-normal variables were compared by a Mann-Whitney U test. Noncontinuous variables were compared between cohorts with a Fisher test or Kruskal-Wallis test as appropriate. Significance was set at $P < .05$. 

Figure 1 Anteroposterior radiographs of a cemented (A) and cementless (B) RTSA taken at 2-year follow-up.
Results

Clinical evaluation

Compared with preoperative values, both cohorts demonstrated significant improvements at most recent follow-up in Constant-Murley score, ASES total and the activities of daily living component scores, Subjective Shoulder Value, visual analog scale for pain, and aFE ($P < .001$) as well as aIR (cemented, $P < .001$; uncemented, $P = .008$) (Figs. 2 and 3; Table II). The cemented cohort showed a significant improvement in aER ($P = .002$), but the cementless cohort did not ($P = .157$). There was no significant difference in comparing the degree of improvement in any of these values between the cemented and cementless cohorts ($P > .05$) (Table II). There was also no significant difference in patient satisfaction ($P = 1$), with 93.8% satisfaction in the cementless group and 94.4% satisfaction in the cemented group.

Radiographic evaluation

On radiographic evaluation, there was no evidence of humeral component loosening or subsidence, osteolysis, or component failure observed in either cohort at any time point. One cemented shoulder developed RLLs located in Gruen zone 1. Two cementless shoulders developed RLLs: one located in Gruen zones 1 and 7 and the other in Gruen zones 4 and 5. There was no significant difference ($P = 1.0$) in the incidence of humeral component RLLs between the cohorts. Stress shielding was observed in 5 cementless shoulders and 0 cemented shoulders; however, this was not significantly different ($P = .15$). In each case of stress shielding, bone resorption was consistently seen laterally at the metadiaphyseal junction (Gruen zones 1 and 2). There were 10 shoulders in the cementless cohort that showed evidence of spot welding. There was no significant difference ($P = .30$) in the incidence of scapular notching between the cemented ($n = 8$) and cementless ($n = 10$) cohorts overall; however, the cementless patients exhibited grade 1 and 2 scapular notching, whereas the cemented patients exhibited grade 2 and 3 notching (Table III). There were no cases of baseplate loosening in either group.

Chart review

The average operative time for the cemented group (199 ± 25 minutes) was significantly greater ($P < .001$) than that for the cementless group (151 ± 27 minutes). The average stem diameters were greater in the uncemented group ($P < .001$). There were 5 major complications and 1 minor complication in the cemented group: 3 systemic complications (myocardial infarction, deep venous thrombosis, pulmonary embolism), 1 case of prosthetic instability (dislocation) 2 weeks postoperatively requiring revision, 1 periprosthetic infection requiring revision, and 1 acromial stress fracture that was treated nonoperatively. There were 5 major complications in the cementless group: 2 systemic complications (myocardial infarction, deep venous thrombosis) and 3 cases of late prosthetic instability requiring revision surgery. One case of revision for instability was performed 3 years postoperatively because of a history of...
multiple dislocations of unclear predisposing etiology; the other 2 revisions were in the same patient: once at 2 months because of dislocation after a fall and again at 5 months because of recurrent instability. All revision surgeries for instability consisted of replacing unconstrained liners with a thicker constrained liner. The second revision in the uncemented patient consisted of exchange of the baseplate, glenosphere, and polyethylene as well as placement of a modular, metallic humeral spacer.

Table II  Clinical outcomes for the cemented and uncemented cohorts

<table>
<thead>
<tr>
<th></th>
<th>Cemented</th>
<th></th>
<th></th>
<th>Uncemented</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative</td>
<td>Postoperative</td>
<td></td>
<td>Preoperative</td>
<td>Postoperative</td>
<td></td>
</tr>
<tr>
<td>ASES</td>
<td>32.0 ± 16.2</td>
<td>84.9 ± 18.9</td>
<td>&lt;.001</td>
<td>36.1 ± 17.0</td>
<td>77.1 ± 18.3</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>CMS</td>
<td>23.6 ± 10.1</td>
<td>63.5 ± 14.8</td>
<td>&lt;.001</td>
<td>29.2 ± 12.8</td>
<td>64.1 ± 14.4</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>SSV</td>
<td>21.5 ± 16.7</td>
<td>76.7 ± 21.9</td>
<td>&lt;.001</td>
<td>24.5 ± 23.7</td>
<td>80.1 ± 19.2</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Pain</td>
<td>6.0 ± 2.3</td>
<td>1.4 ± 2.1</td>
<td>&lt;.001</td>
<td>6.0 ± 2.8</td>
<td>1.3 ± 2.2</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>aFE</td>
<td>52.4 ± 25.1</td>
<td>119.3 ± 22.0</td>
<td>&lt;.001</td>
<td>73.3 ± 33.2</td>
<td>131.0 ± 18.5</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>aER</td>
<td>7.30 ± 21.3</td>
<td>19.7 ± 19.3</td>
<td>.002</td>
<td>22.1 ± 23.5</td>
<td>26.5 ± 21.0</td>
<td>.157</td>
</tr>
</tbody>
</table>

ASES, American Shoulder and Elbow Surgeons score; CMS, Constant-Murley score; SSV, Subjective Shoulder Value; aFE, active forward elevation; aER, active external rotation.

Table III  Incidence of scapular notching

<table>
<thead>
<tr>
<th>Grade</th>
<th>Cemented</th>
<th>Uncemented</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Stress shielding is a reported phenomenon in cementless anatomic shoulder arthroplasty and has been shown to be inversely proportional to the diameter of the stem. The increased stiffness of the larger diameter press-fit implants leads to more stress shielding and increased proximal bone resorption around the implant. The long-term clinical significance of stress shielding in RTSA is uncertain. Spot welds, although reassuring to the surgeon that bone ingrowth to the prosthesis has occurred, were seen in only 16% of the cementless cases. The long-term clinical significance of spot welding is also unknown; examining this was not in the scope of this study. The greater incidence of more advanced stages of scapular notching as seen in the cemented group is not surprising and is likely related to differences in implant design and the slightly longer follow-up in the cemented group.

Despite the similar clinical and radiographic outcomes between cemented and cementless prostheses, uncemented stems may offer several advantages. First, the operative time is shorter. The average difference seen in this study was 48 minutes. Second, the risk of intraoperative embolism associated with cementing is avoided. To our knowledge, the incidence of intraoperative embolic events during cemented shoulder arthroplasty has not been reported; however, in total hip arthroplasty, with use of conventional cementing techniques, it has been shown to be as high as 93%. In this study, the rate of systemic complications was similar between the groups and in no case was a complication thought to be directly attributable to cementation. Other potential advantages of cementless RTSA include long-lasting biologic fixation of the humerus to the prosthesis and potentially less complicated future revision surgeries.

The reports of cementless RTSA stems in the literature are limited. In the one series involving PPC, uncemented RTSA implants, Bogle et al. reported that in 93 patients, 10.5% had evidence of RLLs; however, none existed in more than one Gruen zone or was more than 2 mm at a minimum follow-up of 2 years. In that study, the overall rate of scapular notching was 43% with 34.2% grade 1, 5.3% grade 2, and 2.6% grade 3. Although this study did not examine any clinical outcomes, the investigators...
similarly found no cases of radiographic loosening or stems at risk of loosening. The additional reports of cementless RTSAs in the literature involve the use of stems not designed for bone ingrowth. Werner et al.,34 in a series of 45 cemented and 13 cementless DePuy Grammont-style RTSAs, reported radiolucencies in both groups; however, there was only one case of stem loosening that occurred in the cementless group. The authors of that study therefore recommended cementation. Melis et al.,19 in a series of 34 cemented and 34 cementless DePuy Grammont-style prostheses observed radiographically for 9.6 years (range, 8 to 12), found superior outcomes in the cementless group. In the uncemented group, subsidence occurred in 1 shoulder (2.9%), and radiolucency of more than 3 Gruen zones was seen in 2 shoulders (5.9%). In the cemented component group, stem subsidence occurred in 3 shoulders (8.8%), and radiolucency of more than 3 Gruen zones was seen in 4 shoulders (11.8%). In this study, stress shielding was also a characteristic of the cementless RTSAs.

To our knowledge, this study is the first of its kind to examine clinical and radiographic outcomes in cementless RTSA using components designed for bone ingrowth. In this study, there were minimal differences in clinical and radiographic outcomes between the groups. However, the results of this study should be viewed in light of certain limitations. First, this study has the shortcomings inherent in a nonrandomized, retrospective study. Second, the cementless RTSAs were performed in the latter half of the study period. There were likely unstudied differences in surgical technique based on surgeon experience that may have had an impact on the outcome. Third, we did not assess the preoperative status of the rotator cuff, which could introduce variability in outcomes. Last, this study has a relatively low sample size and short-term follow-up, and differences between the two studied groups might become apparent with more patients and longer follow-up.

Conclusion
Cementless fixation of a porous-coated RTSA humeral stem provides clinical and radiographic outcomes equivalent to those of traditional cemented stems at 2- to 5-year follow-up. With advantages such as decreased operative time, no risk of cement-related complications, and ease of revision, cementless fixation may provide several benefits over cemented fixation. Longer term studies comparing outcomes of cemented versus cementless RTSA are needed.

Disclaimer
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References


