Original article

Results and limitations of humeral head resurfacing: 105 cases at a mean follow-up of 5 years

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ABSTRACT

Background: The objective of this study was to assess clinical and computed-tomography (CT) outcomes at least 2 years after humeral head resurfacing to treat concentric gleno-humeral osteoarthritis. Hypothesis: Humeral head resurfacing provides similar outcomes to those achieved with stemmed humeral head implants.

Materials and methods: This single-centre retrospective study included 40 Copeland® and 65 Aequalis® humeral resurfacing heads implanted between 2004 and 2012. Mean patient age at diagnosis was 64 years. The diagnoses were osteoarthritis with an intact (68%) or torn (21%) rotator cuff, avascular necrosis (5%), osteoarthritis complicating chronic instability (3%), post-traumatic osteoarthritis (2%), and chronic inflammatory joint disease (1%). Validated clinical scores, radiographs, and CT before surgery and at last follow-up were compared.

Results: During the mean follow-up of 56 months, complications occurred in 24 implants. Revision surgery with reverse shoulder replacement was required in 18 cases, after a mean of 43.6 months, to treat glenoid wear or a rotator cuff tear. At last follow-up, for the implants that did not require revision surgery, the mean Constant score was 64/100. The implants had a mean varus of 5° and mean retroversion of −13.3°. The mean increase in glenoid cavity depth was 2.4 mm. Mean increases in medial and lateral humeral offset were 1.9 mm and 2.7 mm, respectively. Pre-operative factors significantly associated with failure were rotator cuff tear (P = 0.017) and glenoid erosion (P = 0.001).

Discussion: We found a high failure rate related to glenoid wear or progressive rotator-cuff impairment, although CT showed no evidence of implant malposition or overstuffing. Previous studies of stemmed humeral head implants showed better outcomes. Given the low medium-term prosthesis survival rate, we now reserve humeral head resurfacing for concentric osteoarthritis without glenoid erosions or rotator cuff damage.

Level of evidence: IV, retrospective study.

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1. Introduction

Concentric osteoarthritis is classically managed by total shoulder arthroplasty or humeral head replacement. The risk of glenoid component loosening [1,2] and technical difficulties raised by removing a stemmed humeral implant have led us to prefer humeral head resurfacing, a method developed by S Copeland in the 1980s [3,4]. Advantages of humeral head resurfacing include replication of native geometry, preservation of bone stock, and greater ease of revision surgery [5].

The objective of this study was to evaluate the clinical and radiological outcomes of humeral head resurfacing. In addition, factors predicting failure were sought. The working hypothesis was that humeral head resurfacing implants produced similar outcomes to cemented or uncemented stemmed humeral head implants.

2. Materials and methods

2.1. Patients

A single-centre multi-surgeon retrospective study was conducted in 100 patients who underwent humeral head resurfacing to treat concentric gleno-humeral osteoarthritis between 2004 and 2012. There were 70 females and 30 males with a mean age of 64
years (range, 39–83 years) at surgery. The procedure was bilateral in 5 patients; of the 105 implants, 57 were on the right and 48 on the left. Table 1 reports the diagnoses.

Exclusion criteria were follow-up less than 2 years after humeral head resurfacing, eccentric gleno-humeral osteoarthritis, glenoid resurfacing, absence of CT at last follow-up, and last evaluation performed over the telephone instead of during a physical visit.

A pre-operative CT scan was available for 96 (90.5%) of the 105 shoulders. Magnetic resonance imaging (MRI) was performed to assess avascular necrosis in 6 patients and unenhanced CT combined with ultrasonography in 3 patients who were allergic to iodinated contrast agents.

The rotator cuff was torn in 25 (23.8%) shoulders, including 3 with avascular necrosis. The tear involved a single tendon was torn in 19 cases and two or more tendons in 6 cases (Table 2). The amount of tendon retraction was classified according to Patte [6].

The mean index of fatty degeneration according to Goutallier [7] was 0.47/4 (range, 0–2.6).

The humeral head resurfacing procedures were performed by 11 senior surgeons, according to the technique described by Deladerrière et al. [8]. The implant was a Copeland Mark III (Biomet Merck, Swindon, UK) in 40 cases and an Aequalis Resurfacing Head (Tornier, Edina, MN, USA) in 65 cases. Central peg length and implant thickness and diameter varied with implant size.

2.2. Assessment methods

The pre-operative assessment included determination of Constant’s score [9]. In addition, two radiographs were obtained, an antero-posterior view in neural rotation and a scapular Y view. The following radiographic parameters were measured (Fig. 1): coro-nal neck inclination, acromio-humeral interval, and glenoid wear according to Rispoli’s criteria [10]. Severity was graded according to Samilson and Prieto for osteoarthritis [11] and to Arlet and Ficat for avascular necrosis [12](Table 1). Pre-operative CT images were used to determine the following: medial humeral offset (MHO) (Fig. 2), lateral gleno-humeral offset (LGHO) (Fig. 3), humeral head size (Fig. 4), antero-posterior humeral head centring according to Badet [13] (Fig. 5), and glenoid cavity depth (Fig. 6). The reproducibility of these CT parameters has been reported previously by Deladerrière et al. [8] (R > 0.9 according to the Fleiss method).

Patients were re-evaluated by an independent observer, who determined Constant’s score, the Simple Shoulder Test (SST) score [14], and the DASH score [15]. Patients were asked whether they were very satisfied, satisfied, or dissatisfied with the procedure. In all the included patients, the radiographic and CT evaluation performed pre-operatively was repeated at last follow-up. The images were examined for a radiolucent line around the implant or secondary implant displacement. Cup version (Fig. 7) was assessed only at last follow-up.

In patients who required revision surgery, a comprehensive clinical and radiographic evaluation was conducted before the repeat procedure. This allowed us to include their outcomes at the time of revision surgery into the study analysis.

2.3. Statistical analysis

Quantitative variables were analysed by applying Student’s t test for paired data and the chi-square test when sample size was greater than 30. Fisher’s test was used for qualitative variables. Continuous variables were compared using Wilcoxon’s test. Between-group comparisons were with the Mann–Whitney test. Values of P < 0.05 were considered statistically significant.

Implant survival was assessed using the Kaplan–Meier method, with revision by reverse shoulder arthroplasty as the endpoint.

Table 1

<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Gleno-humeral osteoarthritis with an intact rotator cuff</td>
<td>71</td>
<td>15 grade 2</td>
<td>6 grade 3</td>
</tr>
<tr>
<td>Gleno-humeral osteoarthritis with a torn rotator cuff</td>
<td>22</td>
<td>30 grade 4</td>
<td></td>
</tr>
<tr>
<td>Avascular necrosis</td>
<td>6</td>
<td>13 grade 4</td>
<td></td>
</tr>
<tr>
<td>Gleno-humeral osteoarthritis due to shoulder instability</td>
<td>3</td>
<td>2 grade 3</td>
<td></td>
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<tr>
<td>Post-traumatic glenohumeral osteoarthritis</td>
<td>2</td>
<td>1 grade 3</td>
<td></td>
</tr>
<tr>
<td>Inflammatory joint disease</td>
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<td>1 grade 4</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>105</td>
<td></td>
<td></td>
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</table>

Table 2

<table>
<thead>
<tr>
<th>Tear</th>
<th>Supra-spinatus (SS) only</th>
<th>Infra-spinatus (IS) only</th>
<th>Sub-scapularis (SS) only</th>
<th>SE+IS</th>
<th>SE+SS</th>
</tr>
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<tbody>
<tr>
<td>Partial thickness</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Full-thickness without retraction, type 1 according to Patte [6]</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Full-thickness with retraction, type 2 according to Patte [6]</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
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</tbody>
</table>
3. Results

3.1. Complications and failures

After a mean follow-up of 56 months (range, 24–120 months), complications had occurred for 24 (22.8%) patients. In 1 patient, a tear in the reattached subscapularis 1 month post-operatively required repeat suturing, which produced a satisfactory outcome. Another patient experienced superficial surgical-site infection, which resolved after appropriate antibiotic therapy. In four cases, prolonged physical therapy was required to treat adhesive capsulitis.

Failure requiring implant removal occurred in 18 (17%) cases. Causes of failure were glenoid wear in 10 cases and isolated rotator cuff tears in 8 cases (present before the resurfacing procedure in 70% of cases). Mean time to revision surgery was 43.6 months (range, 14–62 months).

3.2. Clinical outcomes

Of the 100 included patients (105 shoulders), 79 (83 shoulders) were re-evaluated during a physician visit. Of the remaining 21 patients, 8 had died, 11 were re-evaluated during a telephone call, and 2 were lost to follow-up.

The total Constant’s score improved significantly, from 36/100 (range, 14–61) pre-operatively to 64/100 (range, 23–100) at last follow-up ($P<0.001$).

Outcomes were best in the group with avascular necrosis, followed by the group with concentric osteoarthritis and an intact rotator cuff and by the group with chronic shoulder instability ($P<0.001$) (Table 3).

At last follow-up, the mean DASH score was 62.8/100 (range, 24–110) and the mean SST score was 6.2/12 (range, 0–12). Of the 100 patients, 65 were satisfied or very satisfied with the resurfacing procedure.

Fig. 2. Medial humeral offset (MHO) is defined as the distance from the centre of the humeral head (C) and the axis of the humeral diaphysis (D).

Fig. 3. Lateral gleno-humeral offset is the distance from the centre of the foot of the coracoid process (C) to the lateral border of the greater tuberosity.
Of the 52 (52/105, 49.5%) shoulders with a total Constant’s score lower than 70/100 at last follow-up, 18 (18/52, 35%) required reverse shoulder arthroplasty.

3.3. Radiological outcomes

No shoulders had peri-prosthetic radio-lucent lines or implant displacement visible by radiography or CT.

Compared to the pre-operative values, coronal cup varus changed by a mean of 5 (range, −42° to 31°) (P < 0.001). The acromio-humeral interval diminished by a mean of 0.8 mm (range, −8 to 10 mm) (P < 0.0001). Glenoid wear was present pre-operatively in 43% of cases and at last follow-up in 52.5% of patients (P < 0.001). Thus, glenoid cavity depth was increased by 2.3 mm at last follow-up (−4 to 10 mm) (P < 0.001). Mean MHO increased by 1.9 mm (range, −4.5 to 10.5 mm) (P < 0.001) and mean LGHO by 2.8 mm (range, −18 to 50 mm) (P = 0.02). Mean humeral head size increased by 0.43 mm (range, −8 to 10 mm) (P = 0.1).

Mean cup retroversion at last follow-up was −13.3° (range, −48° to 36°). Retroversion of the native humeral head was not measured pre-operatively.

Antero-posterior decentring of the humeral head according to Badet showed no significant change at last follow-up (P = 0.14).

3.4. Factors predictive of failure

Pre-operative rotator cuff tear was significantly associated with failure of humeral head resurfacing (P < 0.001). Thus, revision surgery for reverse shoulder arthroplasty was required in 37.5% of

<table>
<thead>
<tr>
<th>Table 3: Constant's score at last follow-up by diagnosis.</th>
<th>Number</th>
<th>Constant's score</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gleno-humeral osteoarthritis with an intact rotator cuff</td>
<td>53</td>
<td>69.5 (23–100)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Gleno-humeral osteoarthritis with a torn rotator cuff</td>
<td>20</td>
<td>64.5 (29–81)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Avascular necrosis</td>
<td>6</td>
<td>84 (72–100)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Gleno-humeral osteoarthritis due to shoulder instability</td>
<td>3</td>
<td>73 (65–82)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Inflammatory joint disease</td>
<td>1</td>
<td>42 (39–45)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
shoulders with, vs. only 12% without, a pre-operative rotator cuff tear.

Pre-operative glenoid erosion was another predictor of failure. Revision surgery for reverse shoulder arthroplasty was required in 36% of patients with, vs. only 5% of patients without, pre-operative glenoid erosion ($P < 0.0001$).

In contrast, humeral head decentring in the antero-posterior direction was not a risk factor for failure of humeral head resurfacing ($P = 0.5$).

Variables describing implant position such as varus or overstuffing were not significantly associated with clinical outcomes.

3.5. Comparison of the Copeland\textsuperscript{TM} and Aequalis Resurfacing Head\textsuperscript{TM} implants

Revision surgery was required for 2/40 (5%) Copeland\textsuperscript{TM} implants and 16/65 (24.6%) Aequalis Resurfacing Head\textsuperscript{TM} implants ($P = 0.001$). In the Copeland\textsuperscript{TM} group, cumulative survival after a mean follow-up of 74 months (range, 34–120 months) was 92%; after the shorter mean follow-up of 45.8 months (range, 24–72 months) in the Aequalis Resurfacing Head\textsuperscript{TM} group, cumulative survival was 54% (Fig. 8).

The proportion of shoulders with pre-operative glenoid cavity erosions was 30% in the Copeland\textsuperscript{TM} group and 51% in the Aequalis Resurfacing Head\textsuperscript{TM} group ($P = 0.036$).

At last follow-up, mean MHO was 7.2 mm in the Copeland\textsuperscript{TM} group and 5.3 mm in the Aequalis Resurfacing Head\textsuperscript{TM} group ($P = 0.001$). The mean size difference between the native head and resurfaced head was −0.5 mm in the Copeland\textsuperscript{TM} group and +1.1 mm in the Aequalis Resurfacing Head\textsuperscript{TM} group ($P = 0.02$).

The two groups were comparable for all other variables recorded pre-operatively and at last follow-up.

4. Discussion

Humeral head resurfacing has the advantage of replicating the patient’s anatomy [5]. In addition, the preservation of bone stock facilitates subsequent revision surgery. Finally, the absence of a glenoid component eliminates the risk of loosening.

The limitations of our study are related to the retrospective design and absence of anatomic evaluation of the rotator cuff, which was evaluated indirectly based on the radiographic acromiohumeral interval. The number of patients with each diagnosis was too small for an evaluation of potential associations between diagnosis and implant survival. The large number of surgeons may have affected the reproducibility of the resurfacing procedure.

The assessment of CT parameters in the medium-term after humeral head resurfacing is an original feature of our study. We were thus able to conduct a detailed and accurate analysis of morphology and implant position, which were assessed using validated criteria shown to be reproducible by Deladerrière et al. [8].

In our study, the medium-term failure rate of humeral head resurfacing was 17%. The failures were ascribable to a pre-operative rotator cuff tear or glenoid wear. In previously published studies, the failure rate of stemmed humeral head replacement to treat glenoid wear and rotator cuff tears was only 5–6% [16,17], although the diagnoses and follow-up duration were similar to those in our study. In addition, the proportion of patients who were satisfied or very satisfied was 86.4% after stemmed humeral head replacement [16] compared to only 65% in our study. Thus, in our experience, humeral head resurfacing failed to provide similar outcomes to those of stemmed humeral head replacement in patients with concentric gleno-humeral osteoarthritis.

The clinical outcomes of humeral head resurfacing vary across previous studies. In a study of 56 Copeland Mark III\textsuperscript{TM} implants evaluated after 2.8 years, Thomas et al. found a 1.7% failure rate [18]. Similarly, with 21 Aequalis Resurfacing Head\textsuperscript{TM} implants, Raghavan et al. [19] reported 4.7% of failures due to glenoid wear after a mean follow-up of 3 years. In contrast, Alizadehkhaiyat et al. [20] reported a 17% failure rate 4 years after Copeland Mark IV\textsuperscript{TM} implantation in 100 shoulders. With 64 Global CAP\textsuperscript{TM} (DePuy) implants, Mansat et al. [21] obtained an 8% failure rate after a mean of 3 years.

The designers of the Copeland\textsuperscript{TM} implant reported better outcomes after a longer follow-up [22]. However, the glenoid was resurfaced in 70% of cases and microfractured in 30%, precluding a comparison with our results. In sum, the failure rates seem higher in the more recent studies. Our study supports previously published data.

Levy and Copeland reported the 7-year radiographic outcomes of 340 procedures [23,24]. A radio-lucent line was visible in 6% of cases with the Copeland Mark II\textsuperscript{TM} implant versus no cases with the hydroxyapatite-coated Copeland Mark III\textsuperscript{TM} implant. In our experience, poor implant integration was not a source of failure. The revision procedures showed strong implant fixation with bony regrowth at the underside of the cup and around the central peg.

The greater accuracy of CT compared to radiographs explains the greater glenoid cavity depth in our study (7.8 mm) compared to the study by Mansat et al. (4.9 mm) [21]. The increase in offset contributed to cause glenoid wear. Thus, mean LGHO measured by CT had increased by 2.8 mm at last follow-up. Given the 2.3 mm of glenoid wear, LGHO was increased by 5.1 mm immediately after resurfacing. LGHO was measured using an original method based on two landmarks independent from the patient (centre of the foot of the coracoïd process and lateral border of the greater tuberosity). This method is not affected by the lack of reproducibility of radiographic measurements [25,26].

Merolla et al. [27] reported that using an undersized resurfacing implant improved outcomes by minimising the humeral offset responsible for glenoid wear and secondary rotator cuff damage. The MHO increase in our study was smaller than in previously reported work [4,15] (1.9 mm versus 3.1–3.47 mm). However, the size difference between the native humeral head and the implant at last follow-up was not significant (+0.48 mm), indicating that no overstuffing occurred. This discrepancy is probably ascribable to the greater humeral reaming in our study, leading to a smaller MHO.

The mean humeral retroversion of −13.3° in our study is in keeping with previously published anatomic data [28]. The implants were positioned in slight varus (5°) compared to the pre-operative inclination of the head ($P < 0.0001$) to minimise the risk of superior...
cuff damage during reaming. Similarly, in earlier studies [21,25,29], coronal inclination at last follow-up ranged from 122° to 129.8°.

The failure rate was higher with the Aequalis Resurfacing Head™ implant than with the Copeland™ implant. The only factor explaining this difference was the greater severity of glenoid wear in the Aequalis Resurfacing Head™ group, which reflected a broadening of our surgical indications. The greater humeral head reaming in the Aequalis Resurfacing Head™ group was not sufficient to counteract the adverse effect of the greater pre-operative glenoid wear.

5. Conclusion

The low medium-term survival rate of humeral head resurfacing implants in our study was ascribable to pre-operative glenoid wear and to rotator cuff tears. In our opinion, despite the scrupulous operative technique and implant positioning, the resurfacing implant caused excessive lateral humeral offset responsible for rotator cuff stress and glenoid wear. The major adverse effect of pre-operative glenoid wear explains the difference in outcomes between the two implant models and illustrates the limitations of humeral head resurfacing.

Based on this experience, we now reserve humeral head resurfacing for concentric gleno-humeral osteoarthritus without pre-operative rotator cuff tears or glenoid wear.

Disclosure of interest

The authors declare that they have no competing interest.

References