An evaluation of the radiological changes around the Grammont reverse geometry shoulder arthroplasty after eight to 12 years

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Radiological changes and differences between cemented and uncemented components of Grammont reverse shoulder arthroplasties (DePuy) were analysed at a mean follow-up of 9.6 years (8 to 12). Of 122 reverse shoulder arthroplasties implanted in five shoulder centres between 1993 and 2000, a total of 68 (65 patients) were available for study. The indications for reversed shoulder arthroplasty were cuff tear arthropathy in 48 shoulders, revision of shoulder prostheses of various types in 11 and massive cuff tear in nine. The development of scapular notching, bony scapular spur formation, heterotopic ossification, glenoid and humeral radiolucencies, stem subsidence, radiological signs of stress shielding and resorption of the tuberosities were assessed on standardised true anteroposterior and axillary radiographs.

A scapular notch was observed in 60 shoulders (88%) and was associated with the superolateral approach (p = 0.009). Glenoid radiolucency was present in 11 (16%), bony scapular spur and/or ossifications in 51 (75%), and subsidence of the stem and humeral radiolucency in more than three zones were present in three (8.8%) and in four (11.8%) of 34 cemented components, respectively, and in one (2.9%) and two (5.9%) of 34 uncemented components, respectively. Radiological signs of stress shielding were significantly more frequent with uncemented components (p < 0.001), as was resorption of the greater (p < 0.001) and lesser tuberosities (p = 0.009).

Grammont introduced the reverse shoulder prosthesis in 1985, consisting of a large hemispherical glenoid component without a neck and a congruent polyethylene humeral component implanted with a non-anatomical inclination of 155°. In contrast to previous constrained shoulder prostheses (ball-and-socket or reverse ball-and-socket), the centre of rotation was medialised to lie at the glenoid bone-prosthesis interface, to minimise torque in the glenoid component, increase the moment arm of the deltoid and theoretically protect against glenoid loosening. It also lowers the humerus, which places the deltoid muscle under tension and provides a stable fulcrum for active elevation in the presence of a deficient unbalanced rotator cuff.

Despite good functional results reported with the Grammont reverse shoulder prosthesis (DePuy International Ltd, Leeds, United Kingdom) at short- and mid-term follow-up, complications can occur secondary to the changes in joint biomechanics produced by the design. One such change, the medialisation of the centre of rotation, is responsible for impingement of the medial border of the humeral component on the scapular neck when the arm is adducted. Repetitive contact between polyethylene and bone may result in polyethylene wear debris, chronic inflammation and osteolysis. Although numerous authors have reported their personal experience of this phenomenon, the clinical and radiological evolution of scapular notching is unclear. In some cases it is associated with loosening of the glenoid component, but this is not always the case. Nyffeler, Werner and Gerber reported that the baseplate remained stable even though the inferior half of the glenoid resorbed. Scapular notching has also been associated with the presence of an inferior bone spur and ossifications in the glenohumeral space.

Radiolucency around the Grammont glenoid component has been described less frequently and with a lower rate of loosening than with anatomical total shoulder replacement (TSR). Even though studies have evaluated post-operative changes to the glenoid, such as scapular notching, radiolucent lines (RLLs) and loosening, similar radiological assessment of the humeral side has been reported less frequently. The Grammont prosthesis is a semi-constrained prosthesis where the constraints...
and torsional forces may influence the stability of the humeral component. Few authors\(^{2,17}\) have reported on humeral RLLs, subsidence and resorption of the tuberosities after reversed shoulder replacement. Likewise, general comparison between cemented and uncemented humeral components has rarely been performed.\(^{17}\) Changes on the humeral side,\(^{17}\) such as osteolysis, osteopenia, the development of medial and lateral cortical bone narrowing associated with osteopenia, condensation lines around the tip of the stem, and a spot weld between the cortical bone and the stem, RLLs and loosening, are just as important as changes around the glenoid component in cemented and uncemented reversed shoulder replacements with long follow-up.

The goal of our study was to analyse the radiological changes around the glenoid and humeral components of the Grammont prosthesis at long-term follow-up, and determine whether there were any differences in these changes between cemented and uncemented humeral components.

### Patients and Methods

Between 1993 and 2000, 122 Grammont Reverse Shoulder Arthroplasties (RSA) (Delta III, DePuy International Ltd, Leeds, United Kingdom) were implanted in 119 patients by five shoulder surgeons (DM, LF, CN, CM, GW) in five centres for shoulder surgery. We reviewed all shoulders with a minimum radiological follow-up of eight years. We excluded 19 patients (19 shoulders) who had died, 26 patients (26 shoulders) who could not be traced or who had incomplete imaging, and nine patients (nine shoulders) who required revision with removal or replacement of a RSA performed during the study period. Six of the nine shoulders which required revision had been revised for infection, one for glenosphere unscrewing and two for glenoid loosening related to a technical error in the positioning of the glenoid with superior tilt. In these cases of glenoid loosening, revision was performed at three months and at three years after implantation, respectively.

This left a study group of 68 RSAs implanted in 65 patients: 20 men and 45 women, with a mean age at operation of 69.4 years (49 to 88). The indications for RSA are listed in Table I, these included seven failed hemiarthroplasties (four with previous implants for proximal humeral fractures with nonunion of the tuberosities, and three with rotator cuff tears), two TSR failures (one glenoid loosening and one due to a cuff tear with pseudoparalysis) and revision of two previous RSA for prosthetic instability.

The surgical approach for implantation of the RSA was superolateral in 35 shoulders, deltopectoral in 30 and transacromial in three. According to surgeon preference, the humeral component was cemented in 34 shoulders (50%). The mean follow-up was 9.6 years (8 to 12) for the cemented and ten years (8 to 12) for the uncemented group. Radiological assessment included a true anteroposterior (AP) view in the plane of the scapula and an axillary view performed under fluoroscopic control. The analysis was performed on radiographs obtained immediately after the operation and at the most recent follow-up. Pre-operative radiographs were also assessed to determine the presence of scapular spurs before RSA. Radiological analysis was performed by one independent, blinded observer (BM) not involved in the original surgery.

The glenoid component was assessed for the presence of a scapular notch according to the Sirveaux-Nerot four-grade classification,\(^{18,19}\) a bony scapular spur (Fig. 1) and ossification (Fig. 2) in the gleno-humeral space. A bony excrescence was defined as a pillar scapular spur if it was absent pre-operatively and if it was in continuity with the bone of the scapular neck post-operatively (Fig. 1). Ossifications were defined as heterotopic bone in the gleno-humeral space if they were not in continuity with the scapular neck (Fig. 2).

Any radiolucent lines around the glenoid screws, around the peg or below the baseplate were classified according to their width (< 2 mm or ≥ 2 mm). Loosening was considered to be present if the glenoid component had migrated, as demonstrated by shift, tilt or subsidence, or if complete radiolucency ≥ 2 mm was present in each zone.

Humeral radiolucent lines were assessed in seven zones according to the classification of Gruen et al\(^{13}\) adapted to the shoulder (Fig. 3) and were classified according to width.
Loosening was defined as displacement of the humeral component between the time of the initial post-operative radiograph and the most recent follow-up, or if radiolucency $\geq 2$ mm were present in more than three zones. Subsidence was measured as the change in the vertical distance between the most superior aspect of the humeral component and the greater tuberosity.

The presence of stress shielding was defined as the development of medial and lateral cortical bone narrowing associated with osteopenia in zones 2 and 6, condensation lines around the tip of the stem, and a spot weld between the cortical bone and the stem (Fig. 4). The relative stem size was calculated as the ratio between the diameter of the stem and the diameter of the diaphysis, as shown in Figure 5. Partial or complete resorption of the tuberosities was determined by comparing radiographs taken at the most recent follow-up (Figs 6 and 7) with the immediate post-operative radiographs. The appearance of the tuberosities and humeral radiolucency in zones 1 and 7 were assessed in only 63 cases (29 cemented and 34 uncemented) because the five cases of revision RSA were excluded as the tuberosities were absent on the immediate post-operative radiograph.

The range of movement, the Constant score$^{20}$ and the level of patients satisfaction (very satisfied, satisfied, uncertain and disappointed) were used to assess clinical outcome at the most recent follow-up.

**Statistical analysis.** The relationships between qualitative and categorical variables were tested using Pearson’s chi-squared test, the G-test or Fisher’s Exact test in accordance with their limits. Wilcoxon’s two-sample test was used for the quantitative variables. Statistical significance was set at a $p$-value $< 0.05$.

The Institutional Review Board and the ethical committee approved this research project.

**Results**

**Scapular notch.** A scapular notch was observed in 60 shoulders (88%). Figure 8 shows the severity of notching based on the Sirveaux-Nerot classification. Grade 4 notching was noted most frequently and it was present significantly more often following the use of the superolateral approach (23 of 35, 66%) than in the deltopectoral approach (nine of 30, 30%) (chi-squared test, $p = 0.009$).

**Bony scapular spur and ossifications in the glenohumeral space.** A scapular spur and/or ossifications in the glenohumeral space were observed in 51 cases (75%). A scapular spur was more frequent after the superolateral approach (23 of 35, 66%) than after the deltopectoral approach (12 of 30, 40%) (chi-squared test, $p = 0.06$). Ossifications in the glenohumeral space were more frequent in those with cemented components (chi-squared test, $p = 0.09$). Spurs and ossifications were more frequent in the presence of notching, but they also occurred in the absence of inferior notching.

**Glenoid radiolucency.** A radiolucent line around the glenoid component was present in 11 of 68 shoulders (16%), more often in the presence of grade 4 notching (9 of 11) shoulders (G Log-likelihood ratio $t$-test, $p = 0.01$). Radiolucent lines were incomplete in eight shoulders (extending around the baseplate in six, around the baseplate and screws in one, and around the baseplate and central peg in one) and complete in three (around baseplate, screws and central peg). No cases of radiolucent lines $\geq 2$ mm in all zones were observed. Radiolucent lines $\geq 2$ mm were present in one or two zones in nine shoulders. Unscrewing of the glenosphere was observed in the three shoulders with complete radiolucent lines ($< 2$ mm). No tilt or migration of the component was observed.

**Humeral radiolucency.** Humeral radiolucencies were present in 39 shoulders (57%). In 36 of these (92%) the radiolucencies were $\geq 2$ mm wide, whereas in the other three
(8%) they were < 2 mm wide. Humeral radiolucent lines in zones 1, 2, 3, 4 and 6 were more frequent with cemented components (Table II). However, radiolucent lines in zone 7 were significantly more frequent in uncemented RSAs (chi-squared test, \( p = 0.004 \)). The frequency of radiolucent lines in zone 5 was the same in the two groups. Radiolucent lines \( \geq 2 \) mm in width in more than three zones were noted more frequently in cemented RSAs (4 of 34, 11.8%) than in uncemented (2 of 34, 5.9%), and occurred more often in the proximal zones. Subsidence of the stem was observed in two of these six shoulders. Radiolucent lines in zones 6 and 7 were related to the development of a notch (chi-squared test, \( p = 0.044 \) and \( p = 0.002 \), respectively).

Subsidence of the humeral component. Subsidence or a tilt of the humeral component was present in three of 34 (8.8%) cemented and one of 34 (2.9%) uncemented components (G Log-likelihood ratio test, \( p = 0.292 \)).

Stress shielding (one or more signs of bone narrowing with osteopenia, condensation line around the stem, and spot weld). Cortical bone narrowing with osteopenia was observed in zones 2 and 6 (Fig. 4) in two of 34 (5.9%) cemented and 16 of 34 (47%) uncemented RSAs.
Condensation lines around the stem were present exclusively in uncemented RSAs. We observed a condensation line around the stem, typically in zone 4 in 25 of 34 shoulders (73.5%) and a spot weld between cortical bone and the stem in zones 3 and 5 in 17 of 34 (50%) (Fig. 4). Bone narrowing with osteopenia was associated with a condensation line in zone 4 in 13 of 18 (72%) (chi-squared test, p < 0.001) and with a spot weld in 11 of 18 (61%) (chi-squared test, p < 0.001).

The relative stem diameter was significantly larger in the uncemented (0.31) than in the cemented (0.26) group (Student’s t-test, p < 0.001). An increasing ratio correlated significantly with a condensation line (Student’s t-test, p = 0.004) and a spot weld (Student’s t-test, p = 0.01), but not with bone narrowing (Student’s t-test, p = 0.1).

Appearance of tuberosities (n = 63 shoulders). Partial or complete resorption of the greater tuberosity (Fig. 6) was present in 20 of 29 (69%) cemented and 34 of 34 (100%) uncemented RSAs (chi-squared test, p < 0.001). Partial or complete resorption of the lesser tuberosity (Fig. 7) was present in 13 of 29 (45%) cemented and 26 of 34 (76%) uncemented RSAs (chi-squared test, p = 0.009).

Clinical outcome. At radiological follow-up clinical data were available for 58 shoulders (85%). The mean total Constant score was slightly higher in the cemented than in the uncemented group, but this was not significant (Wilcoxon two-sample test, p = 0.5) (Table III). The same was true of active anterior elevation (Wilcoxon two-sample test, p = 0.9), external rotation with the arm at the side (Wilcoxon two-sample test, p = 0.4), and at 90° of abduction Wilcoxon two-sample test (p = 0.9). Internal rotation was significantly better in the uncemented group (Wilcoxon two-sample test, p = 0.01).

In all, 28 patients (48.3%) were very satisfied, 21 (36.2%) were satisfied, six were (10.3%) uncertain and three (5.2%) were disappointed.

Complications were observed in seven shoulders. In four of these prosthetic instability occurred in the first month after surgery, requiring closed reduction in two and open reduction with the insertion of a thicker polyethylene component or of an additional metallic spacer in the remainder. In the other three patients the complications did not require additional surgical treatment: a traumatic humeral shaft fracture occurred in two patients at one and nine years respectively after surgery, and an acromial fracture occurred in one patient two years after surgery.

Discussion
In this study of 68 Grammont RSAs with a minimum follow-up of eight years we found scapular notching developed in 60 of 68 (88%) of shoulders. Elsewhere the incidence of scapular notching ranged from 50.7% to 63.6%.
with follow-up between 3.7 and 6.5 years.\textsuperscript{5,8,12,19} Our longer follow-up shows that the incidence of notching increases with time. A higher proportion of notching was observed following the superolateral surgical approach. It has been noted previously that there is a tendency to place the baseplate with superior tilt and higher on the glenoid when the RSA is implanted using the superolateral rather than the deltopectoral approach.\textsuperscript{8} The precision with which the glenoid implant is positioned may reduce inferior scapular notching.\textsuperscript{9-11} This point could not be proven in our study, where most of the prostheses assessed were part of the initial experience of each surgeon, when the baseplate was not implanted as low as possible on the glenoid. Nevertheless, at a mean follow-up of about ten years we did not observe the evolution of glenoid loosening in association with scapular notching.

In agreement with Nyffeler et al\textsuperscript{7} we believe that the stability of the glenoid component depends mainly on the central peg. Revision for notching or for loosening secondary to notching is unreported in our experience. The two cases of revision for glenoid loosening that we excluded from the study were performed early after the implantation, and loosening was related to a technical error in the positioning of the glenosphere was a cause of late failure.

Bone spurs and ossifications were frequent radiological findings, and were observed independently of the presence of a scapular notch. Like notches, spurs were found more frequently following the superolateral approach. This finding supports the hypothesis that the inferior scapular bone spur could be a traction osteophyte resulting from an incomplete release of the triceps,\textsuperscript{10} which is more difficult to perform via the superolateral approach. Ossifications were observed more frequently with cemented devices. Their presence could be the result of a chronic foreign-body reaction of the capsule, as described by others.\textsuperscript{9}

Unlike scapular notching, radiolucent lines around the glenoid component were rare. We observed a radiolucent line around the glenoid in 16% of cases without migration of the implant. Our series confirmed the finding of Cazeneuve and Cristofari\textsuperscript{12} that glenoid radiolucrecy is less frequently observed following RSA than after anatomical TSR.\textsuperscript{15,16}

Like Sirveaux et al\textsuperscript{17} we observed subsidence and humeral radiolucent lines more frequently after cemented than uncemented RSAs. Nevertheless, the global rate of subsidence and tilt (6%) reported in our series remains acceptable. We also found a significant relationship between humeral radiolucent lines in zones 7 and 6 and scapular notching. A large inferior notch and wear of the polyethylene have not been reported to be associated with instability of the humeral component.\textsuperscript{7} The exact effect of polyethylene wear debris on humeral peri-prosthetic changes remains to be elucidated.\textsuperscript{21} Radiolucent lines, especially in cemented humeral components, were located in the proximal zones and did not appear to progress towards loosening of the component at ten years of follow-up.

Radiological changes indicating stress shielding were observed especially with uncemented components without affecting the stability of the stem, and were more obvious with increasing relative stem diameter, which in turn was greater in the uncemented than in the cemented group. This probably explains the more frequent stress shielding observed in uncemented components, and is in line with a previous study on stress shielding and bone resorption in the humerus.\textsuperscript{22}

<p>| Table III. Mean Constant score and mean active range of movement observed in cemented and uncemented groups |
|---------------------------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th></th>
<th>Cemented group</th>
<th>Uncemented group</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Constant score (range)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>60 (32 to 79)</td>
<td>53 (14 to 82)</td>
<td>0.5</td>
</tr>
<tr>
<td>Pain</td>
<td>11 (5 to 15)</td>
<td>10 (0 to 15)</td>
<td>0.6</td>
</tr>
<tr>
<td>Activity</td>
<td>15 (7 to 20)</td>
<td>14 (4 to 20)</td>
<td>0.6</td>
</tr>
<tr>
<td>Mobility</td>
<td>28 (14 to 38)</td>
<td>22 (4 to 38)</td>
<td>0.02</td>
</tr>
<tr>
<td>Strength</td>
<td>7 (1 to 12)</td>
<td>6 (0 to 16)</td>
<td>0.4</td>
</tr>
<tr>
<td>Range of movement (°) (range)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active elevation</td>
<td>132 (90 to 170)</td>
<td>123 (40 to 170)</td>
<td>0.9</td>
</tr>
<tr>
<td>Active external rotation at 0° of abduction</td>
<td>11 (20 to 60)</td>
<td>7 (40 to 60)</td>
<td>0.4</td>
</tr>
<tr>
<td>Active external rotation at 90° of abduction</td>
<td>37 (0 to 90)</td>
<td>35 (0 to 80)</td>
<td>0.9</td>
</tr>
<tr>
<td>Active internal rotation</td>
<td>25 (0 to 60)</td>
<td>40 (0 to 90)</td>
<td>0.01</td>
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* Wilcoxon two-sample test

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of the glenoid implant. The reverse prosthesis does have congruent joint surfaces making it a semi-constrained prosthesis which explains these mechanical complications. We observed eight cases of humeral loosening (including subsidence of the stem and radiolucency ≥ 2 mm in more than three zones) and no cases of glenoid loosening. Our results confirm that the rate of humeral loosening is much higher than after inserting an anatomical prosthesis, and much greater than glenoid loosening after RSA. However, with cemented as well as uncemented components, resorption of the tuberosities and stress shielding had no effect on the stability of the implants, and the radiological signs observed have not led to revision.

The limitations of this study include its retrospective design. However, it is a large series (n = 68) with a mean follow-up of 9.6 years, which enabled us to assess and compare the radiological behaviour of both cemented and uncemented prostheses.

With regard to clinical outcome, the total Constant score was slightly higher in the cemented than in the uncemented group, but this was not significant. (Wilcoxon two-sample test, p = 0.5) The range of movement in terms of active anterior elevation and external rotation was not significantly different between the two groups. However, internal rotation was significantly better in the uncemented group. Future studies will more critically assess the significance of each radiological finding on clinical outcome.

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References