Stability of cemented all-polyethylene keeled glenoid components

A RADIOSTEREOMETRIC STUDY WITH A TWO-YEAR FOLLOW-UP

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We studied the stability of cemented all-polyethylene keeled glenoid components by radiostereometric analysis (RSA) in 16 shoulders which had received a total shoulder replacement. There were 14 women (one bilateral) and one man with a mean age of 64 years. The diagnosis was osteoarthritis in eight and rheumatoid arthritis in seven. Two of the shoulders were excluded from the RSA study because of loosening of the tantalum markers.

Three tantalum markers were inserted in the glenoid socket, two in the coracoid process and two in the acromion. The polyethylene keeled glenoid component was marked with three to five tantalum markers. Conventional radiological and RSA examinations were carried out at five to seven days, at four months and at one and two years after operation. Radiolucent lines were found in all except three shoulders. Migration was most pronounced in the distal direction and exceeded 1 mm in four shoulders. In ten shoulders rotation exceeded 2˚ in one or more axes with retroversion/anteversion being most common. No correlation was found between migration and the presence of radiolucent lines on conventional radiographs.

Replacement of the shoulder is a well-accepted surgical procedure for the management of patients with disabling symptoms due to osteoarthritis and rheumatoid arthritis. However, there is still controversy as to whether hemi- or total arthroplasty is superior. This controversy is mainly due to rates of loosening of the glenoid component which may be more than 40%. The definition of loosening has usually been based on the interpretation of conventional radiographs with the presence of a progressive radiolucent line exceeding 2 mm around the entire component or a significant shift in position of the component. A major problem when using radiolucency as an indication of loosening is that limited radiolucent lines are very common and are often seen on the first post-operative radiographs. The presence of radiolucent lines at the cement-bone interface immediately after surgery may reflect imperfect cementing and is arguably of limited value in the diagnosis of aseptic loosening. A further problem with the use of conventional radiographs for the diagnosis of loosening of glenoid components is the considerable liability to error of measurement in assessing the extent and progression of such lines.

Although the rate of re-operation as a result of symptomatic aseptic loosening is relatively low when compared with the high incidence of radiological loosening, the presence of radiolucent lines around the glenoid component in long-term follow-up is a major concern.

Our primary aim therefore was to use radiostereometric analysis (RSA) to study the fixation of a cemented keeled polyethylene glenoid component. Secondly, we wished to correlate the findings of micromovement with the presence of radiolucent lines on conventional radiographs.

Patients and Methods

Between 1998 and 2000 we studied 15 patients who had undergone total shoulder replacement. There were 14 women and one man with a mean age of 64 years (44 to 78). The diagnosis was osteoarthritis in eight and rheumatoid arthritis in seven. All had a competent rotator cuff. One patient had bilateral replacements providing 16 shoulders for study. All had severe disabling pain and radiological signs of arthritis. Two patients (shoulders) were excluded from the RSA because of loosening of tantalum markers, leaving 14 shoulders in 13 patients.

The same surgeon (HR) operated on all patients using the 3M modular prosthesis.
The study was approved by the hospital’s ethical committee. The stem was cemented in seven and uncemented in nine. A standard all-polyethylene keeled glenoid component was inserted using Palacos R cement with gentamicin (Schering-Plough, Malmö, Sweden) in all cases.

During surgery three tantalum spheres with a diameter of 1 mm were inserted into the glenoid socket, two in the coracoid process and two in the acromion. The glenoid components were marked with between three and five tantalum spheres with a diameter of 0.8 mm. These were spaced as widely as possible to optimise the subsequent RSA evaluation which was performed with the patient sitting in front of the film cassettes with the arm beside the trunk. The two x-ray tubes which allowed simultaneous exposure were placed at about 60° to each other in front of the patient with horizontal-beam direction. Exact positioning of the tubes was not critical since the three-dimensional coordinates of each x-ray tube were calculated separately for each examination. The film-to-focus distance was about 100 cm. The first RSA examination (reference examination) was carried out at five to seven days after surgery. The subsequent examinations were done at four months, one year and two years after operation.

The RSA technique allows a three-dimensional high-resolution assessment of movements between segments defined by the tantalum markers. The technique has been described extensively and used by preference for the assessment of migration of hip and knee prostheses.\textsuperscript{5,7}

The RSA measurements were performed using the UmRSA system (RSA Biomedical Innovations, Umeå, Sweden). The movements of the glenoid component in relation to the glenoid socket were assessed using the markers in the glenoid, acromion and coracoid process as the fixed reference segment. The linear movements were expressed as translations along the transverse (x-axis, mediolateral translation), longitudinal (y-axis, proximodistal translation) and sagittal (z-axis, anteroposterior (AP) translation) axes. The angular movements were expressed as rotations about the transverse (x-axis, forward-backward), longitudinal (y-axis, anteversion-retroversion) and sagittal (z-axis, varus-valgus) axes, respectively (Fig. 1).
Table I. The occurrence of radiolucent lines around cemented keeled glenoid components in 16 shoulders followed up for two years (1, superior flange; 2, keel; 3, inferior flange of glenoid component, a, radiolucent line < 1 mm; b, radiolucent line 1 mm to 2 mm; and c, radiolucent line >2 mm)

<table>
<thead>
<tr>
<th>Case</th>
<th>Post-operative radioluency</th>
<th>Radioluency at one year</th>
<th>Radioluency at two years</th>
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<tbody>
<tr>
<td>1*</td>
<td>-</td>
<td>1a, 2a, 3a</td>
<td>1a, 2a, 3c</td>
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<tr>
<td>2</td>
<td>-</td>
<td>-</td>
<td>1a, 2a, 3a</td>
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<td>3</td>
<td>-</td>
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<td>3a</td>
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<tr>
<td>4</td>
<td>3a</td>
<td>1a, 2a, 3c</td>
<td>3c</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6*</td>
<td>1a</td>
<td>1a</td>
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<td>7</td>
<td>1a</td>
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<td>1b, 2a, 3a</td>
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<td>8</td>
<td>-</td>
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<td>9</td>
<td>-</td>
<td>3a</td>
<td>1a, 3a</td>
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<td>14</td>
<td>-</td>
<td>-</td>
<td>3a</td>
</tr>
<tr>
<td>15</td>
<td>-</td>
<td>1a, 2a, 3a</td>
<td>3b</td>
</tr>
<tr>
<td>16</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* excluded from RSA because of loosening of tantalum markers

At four months a double examination was carried out in all patients to evaluate the precision of the method. Thus, the critical levels for significant (p < 0.05) translations were >0.11 mm (transverse axis), >0.14 mm (longitudinal axis), and >0.21 mm (sagittal axis), respectively. The corresponding critical levels for significant rotations were >1.02˚ (transverse axis), >1.27˚ (longitudinal axis) and >1.25˚ (sagittal axis).

Conventional AP and lateral radiographs were taken post-operatively and at one and two years. The first AP post-operative radiograph was compared with those obtained with respect to radiolucenties at follow-up at one and two years by an experienced radiologist. The cement-bone interface was divided into three zones, the inferior flange, the keel and the superior flange. A progressive radiolucent zone of 2 mm or more around the entire component or a detectable shift in position was regarded as indicating definitive loosening.

The clinical results were assessed using the score of Constant and Murley before operation and at one and two years after operation although without the variable strength. Since the Constant-Murley scoring system includes assessment of strength at 90˚ of elevation in the scapular plane this variable had to be excluded as none of the rheumatoid patients was able to elevate their shoulder to 90˚. The maximum score with the reduced Constant-Murley score as applied in our study was therefore 75.

Results
Clinical findings. All patients were satisfied with their shoulder replacement. The reduced Constant-Murley score improved significantly (paired t-test, p < 0.01) from a mean of 16 (9 to 43) before surgery to 39 (18 to 64) at follow-up at two years.

Radiological assessment. Radiolucent lines were seen around the cement-bone interface in 13 of the 16 shoulders. Most of the lines were non-progressive and <1 mm in width. Radiolucencies of >2 mm width were only seen at the inferior part of the glenoid in two patients. No component was radiologically loose according to our criteria (Table I).

Radiostereometry. The pattern of translation and rotation of the glenoid component in relation to the scapula are shown in Figure 2. Translation was most pronounced in the distal direction and was >1 mm in four shoulders. Rotation of > 2˚ around one or more axis occurred in ten shoulders. Most components rotated in retroversion or anteversion while rotation forward or backward was small. We found no correlation between the presence of radioluencies on plain radiographs and the pattern of migration on RSA.

Discussion
RSA has been widely used to evaluate hip and knee implants and their fixation. To our knowledge there has been only one earlier report on the study of fixation of the glenoid component by RSA. This showed that the rate of early loosening was underestimated when traditional radiographs were used and therefore recommended the use of RSA. Nagels et al also recommended that future RSA studies should include at least three tantalum markers in the glenoid component. In this study we have used three to five markers allowing us not only to analyse translation, but also rotation of the component.

In previous studies radiolucent lines around the glenoid component have been the most common method for detecting its loosening. However, the relationship between radiolucent lines and loosening is not clear. In an in vitro radiological study Havig et al showed that inaccurate positioning of the patient and anatomical variation of glenoid version strongly influenced the possibility of detecting radioluencies. This is underlined by the fact that we found radiolucent lines in two patients (cases 4 and 15) at follow-up at one year which could not be detected at follow-up at two years. Furthermore, radiolucent lines can often be seen on the first post-operative radiograph. The clinical relevance of radiolucent lines is unclear.

RSA is probably the only available method which can be used in vivo to detect micromovement between an implant and the skeleton. Investigations of knee implants have been performed with an accuracy of movement of about 0.2 mm and 0.3˚ for translations and rotations, respectively.

In our study we found that most translation occurred in the distal direction. In six patients the migration of the glenoid component was ≥0.5 mm distally and in four it was >1 mm. This pattern of migration was also seen in three of
Graphs showing a) mediolateral, b) AP, c) proximodistal translation and d) forward/backward e) retroversion/anteversion and f) varus/valgus rotation of the glenoid component with respect to the scapula during follow-up for two years. The symbols indicate the individual patients according to Table I (2, •; 3, ●; 4, ▲; 5, ○; 7, △; 8, ⊙; 9, △; 10, ○; 11, α; 12, β; 13, ⊗; 14, δ; 15, ; 16, ×).
five patients in the study by Nagels et al.\textsuperscript{2} Another interesting finding was that, despite the fact that radiolucenties were seen in 11 of 16 patients at the inferior pole, angulation in varus/valgus was much less pronounced than that around the longitudinal axis in retroversion or anteversion. This means that our RSA results do not support the idea of a ‘rocking-horse’ mechanism\textsuperscript{2,13,14} which has been described as a possible cause for loosening of glenoid components. We hypothesise that congruent matching between the subchondral plate and the back of the component is mandatory\textsuperscript{4,15} for fixation of the glenoid component but this cannot be proved by this study.

There was no relation between radiolucenties and migration in this series. The short follow-up and the small number of patients make it difficult to assess the significance of this finding. RSA is a precise method which allows assessment of migration of an implant using a small number of patients and has advantages over conventional radiological methods of assessment.

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No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References


