Optimal acetabular orientation for hip resurfacing


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Pseudotumours are a rare complication of hip resurfacing. They are thought to be a response to metal debris which may be caused by edge loading due to poor orientation of the acetabular component. Our aim was to determine the optimal acetabular orientation to minimise the risk of pseudotumour formation.

We matched 31 hip resurfacing revisions for pseudotumour formation with 58 controls who had a satisfactory outcome from this procedure. The radiographic inclination and anteversion angles of the acetabular component were measured on anteroposterior radiographs of the pelvis using Einzel-Bild-Roentgen-Analyse software. The mean inclination angle (47°, 10° to 81°) and anteversion angle (14°, 4° to 34°) of the pseudotumour cases were the same (p = 0.8, p = 0.2) as the controls, 46° (29° to 60°) and 16° (4° to 30°) respectively, but the variation was greater. Assuming an accuracy of implantation of ± 10° about a target position, the optimal radiographic position was found to be approximately 45° of inclination and 20° of anteversion. The incidence of pseudotumours inside the zone was four times lower (p = 0.007) than outside the zone.

In order to minimise the risk of pseudotumour formation we recommend that surgeons implant the acetabular component at an inclination of 45° (± 10) and anteversion of 20° (± 10) on post-operative radiographs. Because of differences between the radiographic and the operative angles, this may be best achieved by aiming for an inclination of 40° and an anteversion of 25°.

The third generation of metal-on-metal hip resurfacing arthroplasty has gained popularity in recent years owing to its perceived advantages over total hip replacement (THR) in the treatment of the younger adult with end-stage hip disease. The results from the surgeon-investor groups and some independent centres have shown that the failure rates in resurfacing compare well with those of THR, particularly in this group of patients. However, data from registries show that the former has a higher revision rate, except in young men. This raises the possibility that many hip resurfacing might be implanted with suboptimal techniques or inappropriate indications. There is therefore a need to define the indications and techniques more clearly.

The causes of failure in hip resurfacing include fracture of the femoral neck, loosening, infection and inflammatory pseudotumour.

In this context the term pseudotumour has been used to include any non-infected mass, which may be either cystic or solid. These lesions are sometimes called other names by different groups, such as: cysts, bursae, aseptic lymphocytic vasculitis-associated lesions (ALVAL), metal sensitivity, metal reactions, unexplained pain or culture-negative infections. The symptoms associated with a pseudotumour are very variable. The outcome of revisions tend to be poor because of the associated soft-tissue destruction. The patient risk factors for pseudotumour have been defined. The most important factor is female gender, others include age <40 and small size and dysplasia. The surgical risk factors have not been clearly defined.

Positioning of the components has been shown to be important in improving function and preventing failure following THR. The orientation of the acetabular component affects stability, range of movement, component migration and polyethylene wear. Lewinnek et al identified from radiological measurements a safe zone position of 40° (± 10°) inclination and 15° (± 10°) anteversion to minimise the risk of dislocation. The positioning of the femoral components in hip resurfacing is important and influences the incidence of fractures and other complications. However, the importance...
of the orientation of the acetabular component in hip resurfacing may have been underestimated because of the very low dislocation rate associated with the large diameter of the femoral component. Pseudotumours are generally thought to be caused by release of metal debris resulting from abnormal functioning of the metallic bearing. Possible problems include impingement on the rim, edge loading, deformation of the acetabular component, poor metallurgy and manufacture, and lack of fluid film lubrication.

Orientation of the acetabular component contributes to many of these processes. Recent studies have identified an association between an angle of inclination > 55° and elevated serum levels of metal ions, presumably due to edge loading. Additionally, elevated serum levels of metal ions are associated with pseudotumour formation but no association has been established between the position of the acetabular component and the development of a pseudotumour.

The orientation of an acetabular component is described by its angles of inclination and anteversion. The measurements of these angles made at operation and on post-operative radiographs are different. The operative inclination angle is similar to the abduction of the component and operative anteversion is similar to flexion, whereas radiographic inclination and anteversion are projected angles. The difference between the angles depends on the orientation of the component. The designers of the devices used in hip resurfacing currently suggest that the angle of inclination should be 40° and that anteversion should be 20°.

The radiographs were of adequate quality to measure the orientation of the acetabular component were identified (pseudotumour group). The diagnosis of pseudotumour had been made on the basis of clinical, radiological, intra-operative and histological findings, as previously described. The group comprised 24 women with a mean age at primary surgery of 53 years (29 to 67), and six men with a mean age at the initial operation of 54 years (40 to 68). One patient had bilateral revisions for bilateral pseudotumours. Four different resurfacing designs were involved: 14 received the Birmingham Hip Resurfacing (Smith & Nephew, Birmingham, United Kingdom), 14, the Conserve Plus (Wright Medical Technology, Memphis, Tennessee), two, the Cormet (Corin PLC, Cirencester, United Kingdom) and one the ReCap (Biomet, Warsaw, Indiana). The mean time to revision was 3.4 years (0.7 to 8.3). The primary procedures had been performed at seven different centres (Table I).

We attempted to match each hip resurfacing in this group with two asymptomatic hip resurfacings to create a control group from our total cohort in order to increase the statistical power. The controls were matched according to known risk factors for pseudotumour formation, namely gender, age at primary resurfacing, pre-operative diagnosis, duration of follow-up, and the design and size of the component. We were able to obtain 58 control cases (Table I), but these had components from only three designs.

Radiological measurements. These were obtained from digitised supine anteroposterior films of the pelvis, which were taken following our standardised protocol. The Einzel-Bild-Roentgen-Analyse (EBRA, University of Innsbruck, Innsbruck, Austria) software was used to measure the orientation of the acetabular component in terms of anteversion (RCA) and inclination (RCI). EBRA is a validated program that enables the user to calculate the degree of inclination and version of the component from the supine radiograph, and from lateral films it can be determined whether the component is anteverted or retroverted. All of the measurements were performed by two observers (one

Table I. Pseudotumour and control group characteristics; numbers are given on a per-case basis

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>Mean age (yrs) (range)</th>
<th>Diagnosis</th>
<th>Mean survival (yrs) (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pseudotumour</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>31</td>
<td>53.5 (28.7 to 67.9)</td>
<td>27 × OA² x dysplasia</td>
<td>3.4 (0.7 to 8.3)</td>
</tr>
<tr>
<td>M</td>
<td>6</td>
<td>53.8 (40.8 to 67.9)</td>
<td>6 × OA</td>
<td>4.3 (1.1 to 8.3)</td>
</tr>
<tr>
<td>F</td>
<td>25</td>
<td>53.5 (28.7 to 67.1)</td>
<td>21 × OA x dysplasia</td>
<td>3.2 (0.7 to 6.6)</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>58</td>
<td>54.0 (29.9 to 68.1)</td>
<td>50 × OA x dysplasia</td>
<td>-</td>
</tr>
<tr>
<td>M</td>
<td>10</td>
<td>54.0 (40.3 to 68.1)</td>
<td>10 × OA</td>
<td>-</td>
</tr>
<tr>
<td>F</td>
<td>48</td>
<td>54.0 (29.9 to 67.4)</td>
<td>40 × OA x dysplasia</td>
<td>-</td>
</tr>
</tbody>
</table>

* OA, osteoarthritis
author (GG)), with excellent inter-observer reliability. The inter-class correlation co-efficients were 0.97 (95% confidence intervals (CI) 0.964 to 0.986) for anteversion and 0.99 (96% CI 0.985 to 0.994) for inclination. The values used in the study were the mean of the two measurements made by the two observers. For each case, adding the RCA and RCI values gave a combined inclination and anteversion value (CIA). In addition, the neck-shaft angle and the stem-shaft angle were measured from the radiographs, which allowed us to determine the position of the femoral component in the coronal plane.

Analyses. The values of the RCA, RCI and CIA were compared between the groups using the Mann-Whitney U test. The orientation data were plotted on a scatter plot, with RCA on the x-axis and RCI on the y-axis. Two different approaches were used to identify the optimal component orientation.

Method 1: Optimal orientation based on degree space distance. The Euclidean distance in the scatter plot degree space (r) of each acetabular component from any point P, with anteversion PA and inclination PI, can be calculated using the following equation:

\[ r = \sqrt{\text{RCA - PA}^2 + \text{RCI - PI}^2} \]

The mean distances from any given point in the scatter plot from the pseudotumour cases \( r_{PT} \) and the control cases \( r_{CONTROL} \) were calculated separately. The distance ratio, defined as \( r_{PT}/r_{CONTROL} \), was calculated for every combination of each degree increment in RCA and RCI within the pre-determined limits. This was then plotted as a contour plot, with the former on the x-axis and the latter on the y-axis. The larger the value of the distance ratio, the nearer the point is to the controls and the further from the pseudotumours. The optimal orientation, which was at the maximum value of the distance ratio, was then determined.

Method 2: Optimal orientation based on lowest incidence of pseudotumour. As suggested by Lewinnek et al., it was assumed that a surgeon can implant an acetabular component within ± 10° of a target. In order to obtain an optimal ± 10° zone, for every combination of RCA and RCI a \( 2 \times 2 \) contingency table was constructed. This consisted of the numbers of pseudotumour cases within and outside a zone defined by ± 10° about the considered location on the scatter plot, as well as the number of control cases within and outside this zone. Fisher’s exact test was then applied to the contingency table. This was repeated for every combination of each degree increment in RCA and RCI within the pre-determined limits. A contour plot of the resulting probability values allowed the location of the optimal zone to be established.

Both sets of analyses were performed using custom routines written with Matlab version R2009a software (The MathWorks Inc., Natick, Massachusetts). In addition, the distances \( r \) for each group (pseudotumour and control) and contingency tables were constructed for Lewinnek’s zone, a zone defined by ± 10° about the designer-stated placement target of 40°/20° (termed the designer zone) and the above-defined optimal zone. The values of \( r \) for each zone were then compared between the two groups using the Mann-Whitney U test. For each of contingency tables Fisher’s exact test was performed.

Statistical analysis. Statistical significance was defined as \( p \leq 0.05 \). Statistical analyses were performed using SPSS v 15.0 (SPSS Inc., Chicago, Illinois) and the Matlab Statistics Toolbox (v 7.1) (The MathWorks Inc).

Results

The values of inclination and anteversion for both groups are shown in Figure 1. For the entire set of measurements (89 hips) the mean RCA was 15.1° (4.1° to 33.6°, SD 7.6°) and the mean RCI was 46.6° (10.1° to 80.6°, SD 10.2°). The mean acetabular anteversion in the pseudotumour group was 14.1° (4.1° to 33.6°, SD 8.4°) and in the control group was 15.6° (4.3° to 32.9°, SD 7.2°). These were not statistically different (Mann-Whitney, \( p = 0.21 \)). The mean acetabular inclination in the pseudotumour group was 47.5° (10.1° to 80.6°, SD 14.5°) and in the control group was 46.1° (28.7° to 59.8°, SD 7.1°). These were not statistically different (Mann-Whitney, \( p = 0.84 \)). The mean combined radiographic orientation for the pseudotumour group was 61.6° (19.5° to 95.2°, SD 17.8°) and for the control group was 61.7° (40.3° to 90.0°, SD 10.2°). These were also not statistically different (Mann-Whitney, \( p = 0.72 \)).
The location on the scatter plot with the maximum value of the distance ratio was an anteversion of 19° and an inclination of 45° (Fig. 2). The maximum value of the distance ratio was 1.6. The optimal zone with the lowest risk of incidence of pseudotumour was centred at an anteversion of 21° and an inclination of 43°. This was the centre of the contour corresponding to a p-value of 0.0015 (Mann-Whitney) (Fig. 3). This was also the zone with the lowest risk ratio, with risk of pseudotumour being 3.1 times higher outside this zone than that inside. As these two methods gave similar orientations, they were rounded to the nearest 5°, giving the optimal zone to be a ± 10° zone centred on 45°/20°.

For Lewinnek’s zone there was no significant difference (Mann-Whitney, p = 0.055) in the distance, r, from the centre of the zone between the pseudotumour and control groups. However, r was significantly larger for the pseudotumour group for both the designer zone (Mann-Whitney, p = 0.003) and the optimal zone (Mann-Whitney, p = 0.001, Table II).

In all, 13 pseudotumour cases had acetabular components positioned within Lewinnek’s zone versus 18 outside this. There were 35 controls inside Lewinnek’s zone and 23 outside. There was no difference in the probability of pseudotumour formation for components positioned within Lewinnek’s zone compared to those positioned outside (Mann-Whitney, p = 0.12). However, there was a significantly (Mann-Whitney, p = 0.012) lower probability of pseudotumour within the designer zone. There were six pseudotumour cases inside the designer zone versus 25 outside; 27 controls were in the designer zone versus 31 outside. For the optimal zone, the risk of pseudotumour was significantly (Mann-Whitney, p = 0.007) lower inside the zone than outside. There were eight pseudotumours found inside the zone versus 23 outside, and there were 33 controls inside the optimal zone versus 25 outside. Although the pseudotumours occurring with optimal position tended to be in women with small components, there was no real difference in the incidence of these risk factors (Fisher’s exact test, p = .31 for gender, and p = 0.6 for size) in optimally and non-optimally positioned pseudotumour patients.

There was no difference (Mann-Whitney, p = 0.29) in the mean neck-shaft angle between the pseudotumour group of 134° (126° to 144°), and the control group of 133° (120° to 146°). Similarly, there was no difference (Mann-Whitney, p = 0.579) in the mean stem-shaft angle between the two groups, with the pseudotumour group having a mean of 137° (121° to 152°) and the controls having a mean of 138° (126° to 157°).

**Discussion**

In this study we found that the mean acetabular inclination and anteversion were the same for those with pseudotumours and the controls. The mean combined inclination and anteversion was also the same. This suggests that a simple analysis of component orientation does not help explain why pseudotumours develop. We did, however, observe that the variability of the inclination and the
anteversion was larger in the patients with pseudotumour than in the controls. This suggests that there may be an optimal orientation for the acetabular component, and that the outliers may be more likely to develop a pseudotumour. Based on this suggestion, and an assumption that a surgeon could at best implant an acetabular component within SD 10° of anteversion and inclination of a desired target, we reanalysed the data to determine the optimal position for a surgeon to aim for to minimise the risk of pseudotumour. The optimal position was found to be 21° of anteversion and 43° of inclination. For simplicity, we therefore recommend that, when implanting resurfacing acetabular components, surgeons should aim to achieve 20° of radiographic anteversion and 45° of inclination. A separate analysis based on the distance of the pseudotumour and control cases from any given orientation confirmed that this was the optimal position.

The incidence of pseudotumour occurring when the acetabular component was optimally positioned (20° ± 10° anteversion and 45° ± 10° inclination) was approximately four times lower, and this was significantly lower (Fisher’s exact, p = 0.007) than when it was not so placed. Unfortunately, this position does not represent a safe zone, as eight pseudotumours occurred despite optimal placement of the acetabulum. Hence, it would appear that although orientation of the acetabular component is important, other factors also contribute to the development of pseudotumour. Although pseudotumours occurring with optimal position tended to be in females with small components, there was no real difference in the incidence of these risk factors (Fisher’s exact, p = 0.31 for gender and p = 0.60 for size) in optimally and non-optimally positioned pseudotumour patients, suggesting that there is no direct linkage with these risk factors.

Although it is generally accepted that appropriate positioning of the acetabular component is essential for the long-term success of THR, there have been relatively few studies to determine the most appropriate orientation. Lewinnek et al.24 is the most quoted and they defined a safe zone of 15° (± 10°) anteversion and 40° (± 10°) inclination. We found that the incidence of pseudotumour was the same inside and outside Lewinnek’s zone, and so cannot recommend this for resurfacing. When resurfacing was repopularised it was generally perceived that orientation of the acetabular component was not as important as for conventional THR, because the large head virtually eliminated the risk of dislocation. Greater emphasis was placed on positioning of the femoral component. However, it has become apparent that acetabular orientation is more critical with resurfacing than with conventional THR because of the consequence of metal debris released as a result of impingement or edge loading. The main focus has been on inclination, with a number of studies30,31 showing that steeply inclined acetabular components are associated with high ion levels. We are not aware of any previous study that has defined an optimal zone for resurfacing acetabular orientation. Our optimal zone was selected to minimise the risk of developing a pseudotumour.

The manufacturers currently recommend that the hip resurfacing acetabular components should be positioned in 40° inclination and 20° anteversion. However, we have not been able to find any evidence in the literature to justify this. Implantation of an acetabular component within a ± 10° zone around 40°/20° does significantly reduce the risk of pseudotumour formation, but the decrease was not as marked as it was by placing it in our optimal zone.

In this study, although the majority of patients had either Birmingham Hip Resurfacings (38 of 89) or Conserve Plus (45 of 89) components, four different designs of implants had been used. In this study there was no difference in incidence of pseudotumours with the different devices. Reports in the literature have highlighted the importance of the acetabular component coverage angle in the process of edge loading, and have shown that different designs vary in the amount of cover they provide. The functional inclination will therefore have a slightly different relationship to radiographic inclination for each design.

A complex interaction exists between the inclination and anteversion of the acetabular component, the anteversion and inclination of the femoral neck, the orientation and offset of the femoral head, the head-neck ratio, bony anatomy and the range of movement. The reduced head-neck ratio of metal-on-metal resurfacings relative to conventional THRs, coupled with a younger patient with a

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**Table II. Results of analysis for each zone, based on distance and 2 x 2 contingency tables**

<table>
<thead>
<tr>
<th>Zone</th>
<th>Group</th>
<th>Distance r (mean, range)</th>
<th>p-value, Mann-Whitney</th>
<th>Number inside zone</th>
<th>Number outside zone</th>
<th>p-value, Fisher’s exact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lewinnek et al.24</td>
<td>PT</td>
<td>15.3 (1.9 to 40.6)</td>
<td>0.055</td>
<td>13</td>
<td>18</td>
<td>0.120</td>
</tr>
<tr>
<td>40°/15°</td>
<td>Control</td>
<td>10.9 (3.3 to 24.7)</td>
<td></td>
<td>35</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Designers33,36</td>
<td>PT</td>
<td>16.8 (0.5 to 41.1)</td>
<td>0.003</td>
<td>6</td>
<td>25</td>
<td>0.012</td>
</tr>
<tr>
<td>40°/20°</td>
<td>Control</td>
<td>11.3 (0.9 to 21.6)</td>
<td></td>
<td>27</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Optimal</td>
<td>PT</td>
<td>15.6 (3.7 to 36.5)</td>
<td>0.001</td>
<td>8</td>
<td>23</td>
<td>0.007</td>
</tr>
<tr>
<td>45°/20°</td>
<td>Control</td>
<td>9.8 (0.6 to 18.4)</td>
<td></td>
<td>33</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

* PT, pseudotumour
greater range of movement during normal activities, renders the position of the acetabular component of great importance in order to avoid impingement and edge loading with resultant release of debris from metal wear. Too much inclination leads to superior edge loading and too little leads to superior impingement and medial edge loading. Too little anteverision leads to anterior impingement and posterior edge loading in flexion, and too much anteverision leads to posterior impingement or anterior edge loading during extension.

In our series there was a wide range in orientation of the acetabular components in both the pseudotumour and the control groups. Similar findings have been observed in other studies from different centres. We believe that this variation is due to many factors. In three of the pseudotumour cases with extreme malposition we have radiographic evidence that the acetabular component had migrated from a position that was initially satisfactory. Early in our experience there was no consensus as to the optimal orientation of the acetabular component. It was, for example, not clear if it should have the same or a different orientation from that used on a conventional THR or whether a different orientation was needed with different approaches, or if the orientation should be different with different degrees of the femoral neck or head valgus or anteverision. In addition, before we appreciated how critical acetabular orientation was, in cases of acetabular dysplasia we would accept a certain amount of increased inclination and anteverision so as to gain good fixation. A further problem is that with resurfacing it is difficult to implant a component precisely. The reasons for this difficulty include the fact that acetabular visualisation may be compromised, heavy retraction may tilt the pelvis, bone or soft tissue may force an introducer out of place, and the introducers often did not have adequate mechanical alignment guides. When a patient has a post-operative radiograph the pelvis is likely to be in a different orientation from that during the operation so the component orientation will be different. Based on previously defined relationships, in order to achieve an optimal radiographic orientation of 45°/20°, a surgeon should aim for an operative inclination about 3° less, at 42° and an operative anteverision about 7° more, at 27°, than the required radiographic anteverision. Therefore, for simplicity we recommend an operative inclination/anteverision of 40°/25°.

This study has identified malpositioning of the acetabular component as a contributing factor to the development of a pseudotumour. In addition, we have determined the optimal radiographic orientation of the acetabular component (45° (± 10°) inclination and 20° (± 10°) anteverision) that surgeons should aim for in order to reduce the risk of the development of a pseudotumour. Owing to different measurements on radiographs and at operation, this may be best achieved by aiming for an inclination of 40° and an anteverision of 25°.

Supplementary material
An appendix showing the details of the diagnostic investigations performed on patients with pseudotumour can be found with the online version of this article on our website at www.bjjs.org.uk

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References