The femoral head/neck offset and hip resurfacing

Because the femoral head/neck junction is preserved in hip resurfacing, patients may be at greater risk of impingement, leading to abnormal wear patterns and pain. We assessed femoral head/neck offset in 63 hips undergoing metal-on-metal hip resurfacing and in 56 hips presenting with non-arthritic pain secondary to femoroacetabular impingement. Most hips undergoing resurfacing (57%; 36) had an offset ratio ≤ 0.15 pre-operatively and required greater correction of offset at operation than the rest of the group. In the non-arthritic hips the mean offset ratio was 0.137 (0.04 to 0.23), with the offset ratio correlating negatively to an increasing α angle. An offset ratio ≤ 0.15 had a 9.5-fold increased relative risk of having an α angle ≥ 50.5°. Most hips undergoing resurfacing have an abnormal femoral head/neck offset, which is best assessed in the sagittal plane.

The main advantages of resurfacing over a standard total hip replacement are preservation of the proximal femoral bone stock and enhanced stability owing to the larger size of the femoral head.1 With the introduction of metal-on-metal bearings, hip resurfacing has shown excellent short- and medium-term results, with patients returning to high levels of activity.2-5 However, appropriate patient selection and proper positioning of the implant have been shown to influence the outcome.4,6,7 Orientation of the femoral component in the coronal plane has been the focus of particular attention, as a valgus orientation favours survival of the implant but is associated with a decrease in femoral offset.8,9 Both Silva et al10 and Loughead et al11 have shown that femoral offset is reduced with hip resurfacing compared with a stemmed replacement. Although a decreased femoral offset with a stemmed device is associated with increased polyethylene wear12 and instability of the hip,13 the clinical implications of a reduced femoral offset in hip resurfacing have yet to be defined.14 The function of the hip is also influenced by the femoral head/neck offset ratio,15,17 which when insufficient leads to femoroacetabular impingement, causing hip pain and labral tears.15,18,22 Although an insufficient femoral head/neck offset ratio has long been recognised under various descriptions, such as tilt or a pistol grip deformity,23,24 there were no radiological criteria to define this deformity until recently. With the advent of specialised imaging techniques, it is apparent that it is best characterised in the sagittal plane.15,17,21 More importantly, as was postulated by both Murray23 and Stulberg et al,24 and re-emphasised by Harris,25 this deformity is the underlying cause of arthritis of the hip in over 40% of cases. Therefore, because the femoral head/neck junction is preserved with hip resurfacing, patients undergoing this type of procedure might be at risk of impingement, either from malposition of the implant or from lack of correction of the underlying deformity.

We have sought to determine what represents an abnormal femoral head/neck offset ratio, and hypothesise that a majority of patients undergoing hip resurfacing have an abnormal offset ratio consistent with femoroacetabular impingement.

Patients and Methods

The femoral head/neck offset ratio of a consecutive series of patients undergoing hip resurfacing was measured and compared with that of a group of patients with non-arthritic hip pain secondary to femoroacetabular impingement.

A total of 65 hips (60 patients) were treated for osteoarthritis with a hybrid metal-on-metal hip resurfacing procedure (Conserve Plus, Wright Medical Technology, Arlington, Tennessee) as part of an investigational device exemption (IDE) clinical trial approved by our Institutional Review Board. The aetiology was idiopathic osteoarthritis in 48 hips (74%),

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osteonecrosis in six (9.2%), post-traumatic arthritis in four (6.1%), dysplasia in five (7.7%), slipped capital femoral epiphysis in one (1.5%) and Perthes’ disease in one (1.5%).

Of the 60 patients, 39 were Charnley class A and 21 Charnley class B.26 All the operations were performed by the senior author (PEB), using an approach for surgical dislocation originally described by Ganz et al27 and adapted for hip resurfacing.28 A trochanteric slide osteotomy was used, leaving the short external rotators intact and the hip dislocated anteriorly after a Z-shaped capsulotomy. Prior to placing the guide wire into the femoral neck and preparing the femoral head, prominent anterolateral osteophytes were removed using head spherometer gauges (Wright Medical Technology) (Fig. 1a) to optimise the head/neck offset. Care was taken not to damage the retinacular vessels, which are located mainly superolaterally.29 With the neck axis defined, a cylindrical reamer matching the size of the femoral head was used as a guide to introduce the K-wire (Fig. 1b). Further optimisation of the offset could be obtained by translating the femoral component anteriorly. Once the components had been placed, with proper restoration of the femoral head/neck offset (Fig. 1c), the trochanteric fragment was fixed with two or three 4.5 mm cortical screws.

The comparison group consisted of 51 consecutive patients (56 hips) with hip pain, who had a positive labral tear on magnetic resonance imaging with gadolinium arthrography. The mean duration of their symptoms was 14.5 months (3 to 36). All had signs and symptoms consistent with impingement, with a positive impingement sign as well as pain in the hip on prolonged sitting. Hips with evidence of acetabular dysplasia with a centre edge angle < 25˚ and/or arthritis of a Tonnis grade30 >1 were excluded. Institutional Review Board approval was obtained for this study. Impingement secondary to an insufficient femoral head/neck offset ratio was diagnosed by three-dimensional computed tomography (CT), as reported by Beaulé et al.17 With the contour of the femoral head overlaid with a perfect circle centred over the head, the $\alpha$ angle21 is measured by the angle from the centre-line of the femoral neck to the centre-point of the femoral head, and the anterior edge of the femoral neck where this crosses the radius of the femoral head. A larger angle corresponds to diminished concavity or a lack of offset at that head/neck junction. All measurements were performed by the same observer (EZ).

All patients had a standard anteroposterior (AP) pelvic radiograph as well as a cross-table lateral view. In the patients who underwent hip resurfacing, a radiograph was obtained after the operation. Two hips in the resurfacing group had inadequate radiographs which did not allow measurements, leaving 63 hips (58 patients) available for study. One observer (NH) retrospectively reviewed the radiographs for all 119 hips. All were taken using either traditional techniques or digital imaging printed at 100% magnification.

On the AP pelvic radiographs of the non-arthritic hips the shape of the femoral head was subdivided into two categories. Those with an aspherical and/or a pistol-grip appearance24 had a femoral head with flattening on the
normally concave surface of the lateral femoral neck, or a head with lack of sphericity (Fig. 2). Spherical heads had a concave lateral surface with a round appearance (Fig. 3). In the resurfacing group, the femoral stem-shaft angle and the angle of abduction of the acetabular component were measured on the post-operative radiograph.\(^7\)

On the cross-table lateral radiograph, the femoral head/neck offset was measured by the offset ratio.\(^16\) A line bisecting the longitudinal axis of the femoral neck, not necessarily through the centre of the head, was drawn, followed by a second line parallel to this and a tangent to the anterior part of the neck, and finally a third line parallel to the first two and tangential to the anterior aspect of the head. The offset ratio was then calculated by dividing the distance between the second two lines by the diameter of the head. In the resurfacing group, the offset ratio was also measured after operation (Fig. 4), as was the version of the femoral component defined as the angle between the stem and the femoral shaft. All measurements were made by one observer (NH).

A parametric Student’s \(t\)-test was used to compare the individual measurements on both the plain radiographs and the three-dimensional CT scans. The standard deviations (SD) were also calculated. The association between variables was tested using Pearson’s correlation coefficient after a normal distribution was confirmed. Cox regression and multivariate linear regression analysis was performed to determine any association between offset ratio, the appearance of the head, the \(\alpha\) angle, the diagnosis and patient-related factors. A two-tailed \(p\)-value < 0.05 was considered to be statistically significant.

Results

The patients undergoing hip resurfacing and the comparison group were similar in age and gender, with a mean age of 45.7 years (22 to 60) and 43 years (22 to 55), respectively (\(p = 0.3\)). Of the resurfacing group, 42 of 58 were male and in the control group 31 of 51 were male.

The mean pre-operative offset ratio for the resurfacing group was 0.15 (0.07 to 0.30) and not significantly different between the different diagnostic groups (\(p = 0.11\)) (Table I). The mean offset ratio for the resurfacing group was not significantly greater than in the comparison group: 0.150 (0.07 to 0.30) vs 0.137 (0.04 to 0.23) (\(p = 0.326\)). Of the resurfaced hips 36 of 63 (57%) had an offset ratio \(\leq 0.15\). The mean post-operative offset ratio of 0.20 (0.13 to 0.34) was significantly greater than in both the pre-operative and the comparison groups (\(p < 0.0001\)). The mean correction of the offset ratio was significantly greater for the hips that presented with an offset ratio \(\leq 0.15\) preoperatively (36 hips), 0.066 (0.07 to 0.14) vs 0.027 (0.15 to 0.30), respectively (\(p = 0.003\)). The mean size of the femoral component was 47.6 mm (40 to 54). The mean angle of

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**Fig. 2**

Anteroposterior radiograph of the pelvis of a 45-year-old man with pain in the left hip associated with a pistol-grip deformity. The insets show the associated anterior labral tear as well as the cross-table lateral radiograph with an offset ratio of 0.15. The \(\alpha\) angle was measured at 90.0°.
The abduction of the acetabular component was 44.4˚ (35˚ to 60˚). The mean femoral stem-shaft angle on the AP and cross-table lateral views was 139.8˚ (125˚ to 150˚) and 21.0˚ (10˚ to 35˚), respectively. There were no correlations between correction of offset and the size of the femoral head/neck offset ratio (r = -0.012) or the stem-shaft angle on the cross-table lateral view (r = -0.127).

In the comparison group, the mean α angle as measured by three-dimensional CT was 69.2˚ (41.5˚ to 100˚). A total of 11 hips had an α angle < 50.5˚. Of the 56 hips, 30 had an aspherical and/or pistol-grip appearance, the remainder being spherical. The former had a significantly larger mean α angle than the spherical (75.6˚ (42.1˚ to 100˚) vs 61.9˚ (41.8˚ to 100˚), respectively; p = 0.003). The mean femoral head/neck offset ratio was 0.137 (0.04 to 0.23, SD 0.05). The offset ratio was significantly negatively correlated with the α angle (r = -0.40, p = 0.002). The mean offset ratio was not significantly smaller for the abnormally shaped femoral heads than for the spherical (0.125 (0.04 to 0.224) vs 0.149 (0.05 to 0.229); p = 0.118). The offset ratio did not correlate with age (p = 0.32) or gender (p = 0.20). To determine the value of an offset ratio which was consistent with femoroacetabular impingement, we chose an α angle ≥ 50.5˚ as diagnostic.7,21 In 45 of 56 hips with an α angle ≥ 50.5˚, the mean offset ratio was significantly smaller than those with an α angle < 50.5˚ (0.13 (0.04 to 0.22) vs 0.18

Table I. Offset ratio before and after operation subdivided by the aetiology

<table>
<thead>
<tr>
<th>Aetiology (n)</th>
<th>Average offset ratio</th>
<th>Pre-operative (range)</th>
<th>Post-operative (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dysplasia (5)</td>
<td>0.17 (0.14 to 0.21)</td>
<td>0.19 (0.17 to 0.21)</td>
<td></td>
</tr>
<tr>
<td>Osteoarthritis (47)</td>
<td>0.14 (0.07 to 0.30)</td>
<td>0.19 (0.13 to 0.31)</td>
<td></td>
</tr>
<tr>
<td>Osteonecrosis (5)</td>
<td>0.14 (0.10 to 0.19)</td>
<td>0.19 (0.14 to 0.25)</td>
<td></td>
</tr>
<tr>
<td>Post-traumatic arthritis (4)</td>
<td>0.16 (0.13 to 0.20)</td>
<td>0.22 (0.16 to 0.34)</td>
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</tbody>
</table>

In Fig. 3, the anteroposterior radiograph of the pelvis of a 30-year-old man with pain in the left hip associated with a spherical femoral head. The inset is of the cross-table lateral radiograph with an offset ratio measured at 0.08. The α angle was measured at 100˚.
Based on logistic regression, an offset ratio of $\leq 0.15$ has a 9.5-fold increase in relative risk of having an $\alpha$ angle $\geq 50.5^\circ$ ($p = 0.007$). Consequently, the mean $\alpha$ angle was significantly larger with an offset $\leq 0.15$.  

*Fig. 4*  
Cross-table lateral radiograph of a 46-year-old man before and after resurfacing of the hip. The offset ratios were 0.07 and 0.16, respectively.
(76.8° (46.5° to 100°) vs 62.8° (41.8° to 94.3°)), if the offset ratio is ≥ 0.15 (p = 0.0004). Multivariate regression analysis showed that lack of sphericity of the head on an AP view (p = 0.01) and a decreasing offset ratio (p = 0.05) were significantly correlated to an α angle ≥ 50.5°.

Discussion

Hip resurfacing presents a number of technical challenges in terms of the position and size of the femoral implant.6 Although significant emphasis has been placed on the orientation of the femoral component in the coronal plane and its impact on biomechanical reconstruction,8,10,11 little is known about its placement in the sagittal plane and how this relates to the femoral head/neck offset.28,31,32 However, we do know that with stemmed hip replacements an appropriate head/neck offset is important to minimise the risk of impingement,33,34 as this relates to the functional range of movement,9,36 the stability of the hip17 and wear of the bearing surface.18,39 In our study, 57% of hips treated by resurfacing had an abnormal head/neck offset ratio preoperatively. Correction of this deformity becomes important, as the experience with metal-on-metal total hip replacements showed early failures due to poor design of the femoral stem, with an inappropriate head/neck offset leading to component loosening and abnormal patterns of wear.28,40-42 A recent paper by Howie et al38 noted that a third of retrieved McKee-Farrar prostheses had evidence of impingement between the acetabular and the femoral components. This was associated with evidence of fatigue wear in the retrieved components, leading to increased production of cobalt-chrome particles and fragments, increasing the potential for third-body wear.43,45 In 109 retrieved Wagner metal-on-polyethylene resurfacing components, Wiadrowski et al45 found evidence of eccentric wear at the rim of the acetabular component secondary to impingement of the femoral neck or residual cement at the edge of the femoral component in 84% of cases.

In our comparison group, which we used to determine what offset ratio leads to impingement, the results must be viewed in the context of certain limitations, including the number of patients, one radiological observer, and the technical limitations of obtaining the correct projection of the impinging femoral head/neck area with the cross-table lateral radiograph. Despite this, and because of its simplicity in the clinical setting, the cross-table lateral radiograph should be part of the surgical planning, with an offset ratio ≤ 0.15 representing a significant risk for femoroacetabular impingement. The main limitation of this study in terms of determining the risk of impingement is that only the bony aspect was studied, whereas impingement after hip replacement is multifactorial and includes factors such as the soft tissue and the orientation of the acetabular component.33,37 D’Lima et al33 demonstrated that there is a complex interaction between abduction of the acetabular component, its anteversion and the anteversion of the femoral component in determining the maximum range of movement available. With hip resurfacing, the lack of modularity on the femoral side requires the use of other means to optimise the femoral head/neck offset. Optimum positioning of the femoral component and correction of any underlying abnormality to maximise the femoral head/neck offset ratio will minimise the risk of impingement and maximise the functional range of movement.35,37 Because the femoral head overlaps the cortex of the neck and projects most prominently posteriorly,46 it is necessary to identify the neck axis or else there will be a tendency to place the femoral component more posteriorly on the neck. This will add to the deficient anterior offset already present, which, if left uncorrected, can result in persistent pain secondary to impingement.47 Although the larger diameter of the femoral head with hip resurfacing may provide a greater functional range of movement,48 Chandler et al35 compared the range of movement of normal and prosthetic hips and demonstrated that bony contact eventually becomes the limiting parameter, so that an increase in the diameter of the head no longer contributes to increased movement.

The importance of an appropriate head/neck offset ratio has long been recognised in total hip replacement.34,35,49 We believe that this may influence the development of arthritis in the hip5,32-34 and its treatment by resurfacing. Recognition of the lack of femoral head/neck offset permits its correction, which will affect the functional end-point of a stable range of movement. We have shown that osteoarthritic hips removal of the anterior osteophytes enables correction of the deficient femoral head/neck offset ratio without putting the neck at increased risk of fracture after hip resurfacing.50

Supplementary Material

A further opinion by Mr Richard Field is available with the electronic version of this article on our website at www.jbjs.org.uk

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References


