Why large-head metal-on-metal hip replacements are painful

THE ANATOMICAL BASIS OF PSOAS IMPINGEMENT ON THE FEMORAL HEAD-NECK JUNCTION

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Large-head metal-on-metal total hip replacement has a failure rate of almost 8% at five years, three times the revision rate of conventional hip replacement. Unexplained pain remains a feature of this type of arthroplasty.

All designs of the femoral component of large-head metal-on-metal total hip replacements share a unique characteristic: a subtended angle of 120° defining the proportion of a sphere that the head represents. Using MRI, we measured the contact area of the iliopsoas tendon on the femoral head in sagittal reconstruction of 20 hips of patients with symptomatic femoroacetabular impingement. We also measured the articular extent of the femoral head on 40 normal hips and ten with cam-type deformities. Finally, we performed virtual hip resurfacing on normal and cam-type hips, avoiding overhang of the metal rim inferomedially.

The articular surface of the femoral head has a subtended angle of 120° anteriorly and posteriorly, but only 100° medially. Virtual surgery in a normally shaped femoral head showed a 20° skirt of metal protruding medially where iliopsoas articulates.

The excessive extent of the large-diameter femoral components may cause iliopsoas impingement independently of the acetabular component. This may be the cause of post-operative pain with these implants.

Large-head metal-on-metal total hip replacements (MoM THRs) have the highest failure rate of any sort of hip arthroplasty in the National Joint Registry, with a failure rate of almost 8% at five years.1 Hip resurfacing arthroplasty (HRA) has the next highest rate, at 6%, three times the revision rate of conventional hip replacement. Reasons suggested for this surprising rate of re-operation include surgeon error in positioning of the acetabular component,2 and the design and manufacture of the acetabular component.3 Unexplained pain remains a feature of this bearing couple,4 and the high failure rate has led to one device being withdrawn from clinical use.5 All designs of the femoral components of HRAs and large-head MoM THRs share a unique design characteristic: a subtended angle of 120° defining the proportion of a sphere that the head represents. This is exactly the same shape as the ball of all contemporary small-ball hip replacements, whose results are substantially superior, even with identical metallurgy.6

The aim of this study was to investigate whether the contour of the large-head femoral component of a large-head MoM THR might be a source of unexplained pain by impinging on the iliopsoas tendon.

Materials and Methods
MRI scans of hips were formatted in sagittal section in order to enable imaging of the relationship between the psoas tendon and the femoral head with the leg in extension (Fig. 1). The area of contact between the femoral head and neck and the psoas tendon were evaluated in a series of 20 hips in patients with symptoms of femoroacetabular impingement.6

The excessive extent of the large-diameter femoral components may cause iliopsoas impingement independently of the acetabular component. This may be the cause of post-operative pain with these implants.

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Figure 1a – set of sagittal T1-weighted MRI sections, showing the lateral border of the acetabulum (left), the midportion of the femoral head (centre) and the lateral extent of the articular surface (right). They show the apposition of the iliopsoas tendon to the femoral head and neck with the patient supine, but without muscle contraction (arrows indicate the contact area). Figure 1b – sagittal T1-weighted MRI scans of three patients, showing the midportion of the femoral head with symptoms of femoroacetabular impingement, with changes in their psoas tendon at the contact area (arrows).

Images showing how a frame of reference was defined using the neck axis and a trochanteric line. A marker was placed on the tip of the greater trochanter (a). The lesser trochanter was modelled as a sphere and the centre of this was taken (b). This was connected to the marker on the tip of the greater trochanter. A trochanteric line was now established. Markers were placed all around the femoral head and it was modelled as a sphere (c, d). The centre of this spherical shape is the centre of the femoral head. The neck was orientated so that it was vertical on the screen and in both the sagittal and coronal orthogonal planes on the orthogonal image (e). The middle of the neck was noted, and a marker was placed above and below in both planes to produce the neck axis independent of the femoral head. The frame of reference was established from the neck axis and the trochanteric line (f).

The femoral head was then measured to demonstrate the following features: the position and size of the femoral head in relation to the femoral neck axis; the limit of the articular surface of the femoral head in normal and cam-type hips; and the limit of the spherical surface of the cam lesion. These measurements were taken principally by one of the authors (AA) under the supervision of the senior author (JPC), with reliability measurements made by another (KD). Bland-Altman analysis showed good inter- and intra-observer reproducibility for all measures, especially for the subtended angles and the femoral head diameter (Table I).

Virtual surgery was then undertaken with 3D templates of a hip resurfacing device (Cormet; Corin, Swindon, United Kingdom; although all resurfacing devices appear to
Table 1. The characteristics of the femoral heads of normal and cam-type hips within a particular cohort

<table>
<thead>
<tr>
<th></th>
<th>Normal hips (mean, SD)</th>
<th>Cam-type hips (mean, SD)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral head-neck bearing (*)</td>
<td>180 (33)</td>
<td>245 (27)</td>
<td>0.0037</td>
</tr>
<tr>
<td>Femoral head-neck offset (mm)</td>
<td>2 (1.0)</td>
<td>3 (1.3)</td>
<td>0.0155</td>
</tr>
<tr>
<td>Femoral head diameter (mm)</td>
<td>46 (4)</td>
<td>53 (4)</td>
<td>0.00007</td>
</tr>
<tr>
<td>RMS* error (head diameter)</td>
<td>0.3 (0.1)</td>
<td>0.4 (0.0)</td>
<td>0.00001</td>
</tr>
</tbody>
</table>

* RMS, root mean squared

Images showing the femoral head-neck offset, the limit of sphericity and the limit of the articular surface. The proximal femur was observed from above with the trochanteric line aligned vertically, giving an axis (a). Markers were placed at the limit of sphericity of the femoral head and the articular margin, in the orthogonal images (b). The subtended angles for a few markers are shown (c). They were placed at the limit of sphericity, and on the articular margin every 10° around the femoral head, obtaining 36 points. The subtended angles were plotted as a function of the ‘clock’ position angles. The lateral aspect of the femoral head is 12 o’clock, the anterior aspect 3 o’clock, etc. The discrepancy between the limit of sphericity and the limit of the articular surface is shown in cam-type deformities (d).

have nearly identical femoral head extent with a subtended angle of 120°), with the aim of positioning the femoral stem in the middle of the neck, and fitting the femoral head of the closest-matched size to that of the normal hip, while correcting the head-neck deformity in the cam hip.

Results

MRI scans. In all the cases studied the psoas tendon articulated with the femoral head-neck junction when the patient was lying supine. The zone of contact extended across the entire anterior head neck junction (Fig. 1).

Models generated from CT scans. The articular margin of the normal femoral head was not circular but sinusoidal. It comprised a flexion facet anteriorly which extended to a subtended angle of 120° (SD 8) and a smaller extension facet posteriorly which extended to a subtended angle of 116° (SD 6). At the medial and lateral extents these articular margins were reduced to around 100° (SD 6). Cam hips had
similar articular margins medially and laterally, but extended further beyond 120°, between 50° and 120° (Fig. 3).

In normal hips the centre of the femoral head was displaced by a mean of 1.7 mm (0.3 to 4.2) medially from the axis of the neck at a bearing of 180° (141° to 259°). This was significantly different from the femoral head centre in cam-type hips, which was displaced a mean 2.8 mm (1.2 to 30) and at a bearing of 245° (204° to 292°) (Fig. 5 and Table I). The femoral head was also substantially and significantly larger in cam-type hips, with a mean diameter of 53 mm (48 to 59) compared with 46.4 mm in normal hips (39 to 50) (Table II). The root mean squared error in modelling the femoral head as a sphere was also significantly higher in cam-type hips, signifying that they were less spherical (Table II). Age did not correlate with any of the variables, but normal male femoral heads (mean 52 mm) were larger than normal female heads (mean 45 mm) (p < 0.001).

Virtual surgery on the normal femoral heads aligning the femoral stem in the middle of the neck showed that resurfacing the normal hip left a prominent skirt of metal anteromedially and posterolaterally (Fig. 4). Virtual surgery on the cam hips confirmed that the psoas impingement zone could be avoided by reducing the size of the femoral component and translating it superiorly, while keeping the stem in the middle of the femoral neck (Fig. 5).

**Discussion**

This was a small image-based study describing the anatomy and pathoanatomy of the femoral head and neck, specifically with regard to the design of large head MoM THR. The MRI scans showed the area of the femoral head and neck that acts as a fulcrum for the iliopectineus tendon when the hip is extended. On the basis of these static and unloaded images it looks as though the entire anterior articular rim is involved.

The CT scans document the shape, size and articular extent of the normal and cam-type femoral heads. When the femoral component of a large head MoM THR is then superimposed onto the femoral head, a rim of metal as much as 20° wide remains prominent anteromedially. In normal femoral heads it may be difficult to bury this rim. Cam-type femoral heads, in contrast, are larger than normal, with excessive bone anteromedially. In our series of 20 cam hips it was always possible to resurface them and keep the metal skirt within the bony contour by reducing the size of the femoral component, translating the head centre anterosuperiorly and anteverting the stem (Fig. 5).

Although there are several possible explanations, we suggest that one plausible cause of ‘unexplained’ pain following large head MoM THR may be psoas tendon irritation from the oversized apron of the metal head that extends well beyond the limit of the normal femoral head. The MRI data indicate that this extension may be into an area that is
used as a fulcrum by the tendon of iliopsoas in full extension. The data we present offer a theoretical explanation but do not conclusively prove this to be the case. However, the fact that identical bearings of smaller dimensions have excellent outcomes, and that most unexplained pain following HRA is seen in women with small femoral heads, who rarely have cam-type hips, does make a compelling association. The outstanding results of hip resurfacing seen in men, particularly those with cam-type hips, also supports this hypothesis, while the poorer results reported in women by the registries may be supported by the findings of virtual surgery (Fig. 6) which shows clearly the extent of the overhang in a slightly dysplastic female femoral head.

The practical implications of this information are threefold: first, HRA for patients with cam-type impingement remains sensible, as is borne out by the registry data from both England and Wales and Australia, but when sizing and positioning the femoral head, care should be taken to ensure that its anteromedial rim is within the bony margin. Secondly, when resurfacing for other reasons, the data we present suggest that it may be worth ensuring that the anteromedial part of the femoral head is ‘tucked in’, to prevent the rim impinging on the psoas tendon. Thirdly, large-head MoM THR appears to run the risk of psoas tendon impingement. The size of the femoral head, the position of its centre and the extent of the margin should all be considered in relation to the lesser trochanter, even if there is no femoral neck. If the centre of the acetabulum is moved forward, or the size of the head is increased, it appears to be impossible to avoid psoas impingement. A smaller bearing couple, which stops the femoral head from pressing on the psoas tendon in extension, may reduce the risk of postoperative pain from impingement tendonitis. This is a small image-based study, which seeks to draw conclusions from the differing morphologies that predispose to osteoarthritis and the shape of the current generation of resurfacing and large head metal-on-metal bearings. We have been unable to image the phenomenon it sets out to describe, owing to the limitations in imaging techniques available today which are unable to produce MRI sequences of soft tissue in direct juxtaposition to cobalt-chromium alloy. As such, no firm conclusions should be drawn, but the observations may provide one explanation of the masses found in iliopsoas associated with these bearings.

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References