ARTICULAR PENETRATION IS MORE LIKELY IN GARDEN-I FRACTURES OF THE HIP

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Plain radiographs show only two dimensions of a three-dimensional object. On anteroposterior and lateral radiographs an implant may appear to be safely within the head of the femur although surface penetration has occurred.

We have attempted to identify this complication in the treatment of fractures of the femoral neck and have analysed the position of a screw or pin in the femoral head and neck on the basis of orthogonal frontal and lateral radiographs. A retrospective analysis of 60 cases of osteosynthesis of fractures of the femoral neck confirmed the risk of non-recognition of articular penetration or breaking of the cortex of the neck during surgery.

Unrecognised screw penetration of the hip was observed in 8% and of the posterior part of the neck in 10%. The risk differs according to the type of fracture: it is greater in the coxa valga produced by Garden-I fractures of the femoral neck.

The ideal placement for a screw in fractures of the femoral neck has been a subject of controversy. Brown and Court-Brown showed an increased failure rate if the tip of the nail was over 12 mm from the subchondral articular surface, but others have demonstrated that metal devices which do not appear to be outside the head on the anteroposterior, lateral or frog-leg radiographs may still breach the articular surface. The current recommendation is that a screw or nail should not be close to the articular or other surface, but the depth of penetration is difficult to determine accurately by two-plane radiography. Unrecognised penetration remains possible because frontal and lateral radiographs are orthogonal projections of a sphere (Fig. 1).

Another possibility is that of a breach in the cortex of the femoral neck, although this does not appear to have been reported previously (Fig. 2).

We have studied this specific complication of screw fixation in the treatment of fractures of the femoral neck by analysing possible positions of implants.

PATIENTS AND METHODS

We studied 60 consecutive patients with fractures of the femoral neck treated between 1989 and 1992 with dynamic hip screws, to determine the prevalence of metal penetrating the surface of the femoral head or neck. Such penetration may be secondary to complications such as failure of fixation or nonunion, and therefore patients with these complications during follow-up were excluded. We did include patients with evidence of osteonecrosis without nonunion or failure of fixation.

The series included all Garden grades of fracture. The 60 patients had a mean age of 69 years (45 to 80). The operation had been performed as soon as possible subject to...
We calculated the distance from the tip of the implant to the center of the femoral head. Our methods of calculation are precise, but although the femoral head may be considered to be a sphere, the radiological projections are of the subchondral bone and do not include the articular cartilage. The thickness of the articular cartilage on the normal femoral head is reported to be 2.04 ± 0.36 mm by Roberts et al. We therefore recorded any implant protruding from the subchondral bone by more than 2.4 mm as entering the joint space.

**Breaks in the cortex of the femoral neck.** If the femoral neck is considered to be a cylinder, the co-ordinates of a point relative to the central axis of the cylinder may be calculated in a similar manner, and it is possible to determine from two orthogonal radiographs whether any point is inside or outside the cylinder. A section of the femoral neck is actually an ellipse which is narrower in its lower than in its upper portion, so that the safe distance is overestimated when the implant is in the inferior part of the femoral neck. Our method of calculation therefore underestimates the risk of unrecognised breaching of the cortex of the femoral neck.

**RESULTS**

In the 60 fractures of the femoral neck which we studied by these methods we found 15 unsatisfactory results.

In five hips, three with valgus angulation (Garden I), our calculations showed that the upper extremity of the screw could be intra-articular. In four hips, the screw tip was calculated to be in the thickness of the articular cartilage of the femoral head. In six other hips, the osteosynthesis was calculated to have breached the posterior cortex of the femoral neck; four of these six fractures were in valgus angulation (Garden I).

Our review therefore showed probable technical imperfection in 25% of the 60 hips reviewed. The number of errors of placement (Table I) was greater in Garden-I fractures (9/22: 41%) than in other fractures (6/38: 16%). A chi-squared test showed that this difference was significant (p ≤ 0.03).

During postoperative follow-up, most surgeons review radiographs which show very similar frontal and lateral images of the surgical neck; this means that the imperfections which we describe may continue to go unrecognised. In some of our suspected cases, intra-articular penetration or breaching of the femoral neck was confirmed by fluoroscopy with tangential visualisation in one, and at revision operations for total hip arthroplasty in two. (Fig. 3.)

The consequences of intra-articular penetration or breakage of the cortex of the femoral neck require discussion. We saw evidence of chondrolysis in two of the hips with the screw in the thickness of the articular cartilage. This was diagnosed only when the joint space was narrowed to one half of the normal contralateral joint space.

We diagnosed avascular necrosis in 14 hips, and 11 of these were shown to have a technical imperfection. Table II shows the incidence of necrosis according to the type of

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**Tip of the screw in relation to the centre of the femoral head.** We calculated the distance from the tip of the implant to the center of the femoral head (OM). The radius of the head (R) may be determined from the frontal and lateral images, and it was therefore possible to discover whether the distance OM was greater or less than this radius, and hence whether the tip was inside or outside the sphere of the femoral head. For all measurements we corrected the potential radiological magnification of one image compared with another, on the basis of the known size of the implant.

The Euclidean co-ordinates of a point in space may be determined from measurements in two planes and related to the centre of the femoral head. Thus, three simple measurements on each film can reveal the distance between the tip of the implant and the centre of the head of that film. A graph derived from the general calculation can then be used to reveal whether the tip is inside or outside the sphere. Details of the calculation and the graph may be obtained directly from the senior author.

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Fig. 2

The femoral neck can be considered as a cylinder, and by the same argument as that for a sphere, a point outside the neck may be projected frontally and laterally as being within the neck. The ‘blind’ volumes are those between the cylinder and a rectangular box, such as in direction R.
fracture, articular penetration, breach of the posterior cortex of the femoral neck and the depth of the screw. All the hips with a fracture angulation into valgus and evidence of osteonecrosis had a technical imperfection.

**DISCUSSION**

We have confirmed the observation made by Noordeen et al.\(^3\) that unrecognised joint penetration may occur in the treatment of fractures of the femoral neck. We have also shown a similar phenomenon for a breach of the femoral neck. This secondary risk may be explained by the morphology of the greater trochanter, the elliptical section of the femoral neck, and its anatomical torsion around its own axis.\(^8\) The length of the femoral neck has also been reported to be frequently above normal in patients with cervical fractures of the femoral neck.\(^9\)

For impacted fractures in a valgus position (Garden type-I), the risk of intra-articular penetration was higher than that for other types of fracture. This may be because in a Garden type-I fracture, the tip of the screw is not usually in the equatorial plane of the femoral head. The reason is that head displacement, both into valgus and posteriorly, is deliberately not reduced to avoid fracture disengagement.\(^10\) As a result, the tip of the screw is placed in the anterior portion of the head, projecting above the equatorial plane of the centre of the head on the lateral radiograph (Fig. 4). This must increase the risk of penetration.\(^3\)

In such coxa valga fractures, the theoretical risk of a breach in the posterior cortex of the femoral neck is also undoubtedly higher. During osteosynthesis, the screw is usually directed towards the centre of the head. In Garden type-I fractures, coxa valga is usually associated with retroversion of the head, and therefore the screw will probably break the posterior cortex of the neck unless the trochanteric entry site is placed more anteriorly (Fig. 4). Joint penetration or breaking of the posterior cortex of the femoral neck may help to explain the abnormally high

<table>
<thead>
<tr>
<th>Garden type</th>
<th>Total Number</th>
<th>Intra-articular penetration</th>
<th>Femoral neck breaching</th>
<th>In articular cartilage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 5)</td>
<td>With necrosis</td>
<td>Without necrosis</td>
<td>With necrosis</td>
</tr>
<tr>
<td>I</td>
<td>22</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>II</td>
<td>3</td>
<td>1</td>
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</tr>
<tr>
<td>III</td>
<td>23</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>IV</td>
<td>12</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Fig. 3a Fig. 3b Fig. 3c

Analysis of these radiographs (a,b) showed that the posterior cortex of the femoral neck had been breached to implant the screw. The patient developed osteonecrosis, and the defect in the neck caused by the screw was confirmed at a subsequent THR (c).
rate of avascular necrosis observed for Garden type-I fractures treated by osteosynthesis. Apart from the consequences of intra-articular implantation for degenerative change, the effect of simple intra-articular drilling during osteosynthesis is uncertain. The role of pin protrusion in the aetiology of chondrolysis was not clearly shown in a rabbit series, irrespective of the type of osteosynthesis, show a markedly higher incidence of avascular necrosis than that observed in the natural course of conservatively-treated Garden type-I fractures (Table III). This difference has produced a preference for conservative treatment without osteosynthesis by some authors, despite the risk of secondary displacement.

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