Improving the detection of acetabular osteolysis using oblique radiographs
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Visualisation of periacetabular osteolysis by standard anteroposterior (AP) radiographs underestimates the extent of bone loss around a metal-backed acetabular component. We have assessed the effectiveness of standard radiological views in depicting periacetabular osteolysis, and recommend additional projections which make these lesions more visible. This was accomplished using a computerised simulation of radiological views and a radiological analysis of simulated defects placed at regular intervals around the perimeter of a cadaver acetabulum. The AP view alone showed only 38% of the defects over all of the surface of the cup and failed to depict a 3 mm lesion over 83% of the cup. When combined with the AP view, additional 45° obturator-oblique and iliac-oblique projections increased the depiction, showing 81% of the defects. The addition of the 60° obturator-oblique view further improved the visualisation of posterior defects, increasing the rate of detection to 94%. Based on this analysis, we recommend using at least three radiographic views when assessing the presence and extent of acetabular osteolysis.

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Materials and Methods

We used a computerised simulation of an acetabular cup to evaluate shadowed periprosthetic regions mathematically, and an experimental model to corroborate our findings.

Computer simulation. Using AutoCAD Release 13 (Autodesk, San Rafael, California), a three-dimensional computer modelling program, we modelled the 50 mm diameter hemispherical metal shell of an acetabular component in a typical anatomical orientation of 45° abduction and 20° anteversion. Standard radiological views were simulated to show regions in which acetabular osteolysis would be obscured by the metal shell and remain undetected. The simulation did not take account of magnification or distortion owing to soft-tissue offset.

Four radiological views of these cups were simulated in the CAD model: anteroposterior (AP), 45° and 60° obturator-oblique, and 45° iliac-oblique (Fig. 1). To determine the aggregate amount of interface that could be seen or would be obscured, we analysed seven combinations of these projections (Fig. 2). We then combined the views in order to determine how to achieve maximal visualisation with the least number of radiographs.
Lesions within the bone which is obscured by the metal implant are not visible on plain radiographs. Its volume is termed the radiological ‘shadow’. Figure 3a shows shadows, the boundaries of which are defined by the projection of the acetabular component, directly anterior and posterior to the cup. Figure 3b shows how the volumes created by single radiographs were intersected to simulate the combined shadowed region. The CAD modelling program determined the size and position of these shadowed volumes of periacetabular bone.

By further analysis of the depth of the intersecting volumes, we determined the extent of the surface area of the acetabular component which could be surrounded by bone loss of a given depth. A lucent zone of more than 2 mm has been considered to be evidence of loosening, but we used a more conservative depth of 3 mm. The shadowed volumes were intersected with a 56 mm diameter sphere (Fig. 3c) to simulate shadowed bone extending 3 mm or more into the acetabular wall. We then calculated the surface area of the side touching the modelled implant to obtain the area of the implant which was bordered by shadow at least 3 mm deep. Additionally, we calculated the percentage surface area of the cup which was surrounded by shadowed bone of 3 mm or more in depth.
In vitro radiological examination. Using the fresh-frozen cadaver pelvis (with no pre-existing defects) of a 62-year-old woman, we assessed the depiction of periacetabular bone in a variety of radiological views and related the computer simulation to the clinical setting. We reamed the left acetabulum to accommodate a 50 mm diameter cementless implant (Reflection cup; Smith & Nephew Richards, Memphis, Tennessee). We used lead pellets of alternating diameter (2.8 mm or 3.9 mm) to simulate defects at 16 periacetabular bony sites. Each pellet was press-fitted into a burred hole in the acetabular wall. The holes formed two concentric rings parallel to the face of the implant and 12 mm apart (Fig. 4). The implant was press-fitted after the pellets, and seated in 45° of abduction and 20° of antversion to correspond to the orientation in the computer simulation.

With the pelvis attached to a rotating plate that could be accurately positioned in the desired angular orientation (Fig. 5), we obtained AP, obturator-oblique and iliac-oblique (30°, 45°, 60° and 75°) radiological views. Unless obscured by the radiopaque cup, the pellets were clearly visible. We analysed the number and location of pellets seen in individual views and in combinations of views to determine how effectively each projection depicted the simulated defects.

Additional computer modelling. With additional computer modelling, we ascertained which radiological views left the smallest shadows and therefore showed the greatest number of simulated defects in the examination in vitro. We were then able to calculate by how much the size of the shadow was reduced in each additional radiograph.

Results

Surface area obscuring a 3 mm deep lesion. Figure 2 shows the surface area of the cup in which a lesion of 3 mm or more could remain undetected in seven combinations of the four radiological views. The AP view alone failed to reveal osteolysis 3 mm or more deep over 83% of the cup. With two views, 30% to 50% of the surface of the cup could still be surrounded by obscured osteolysis 3 mm or more in depth. With three views, undetected lesions could surround only 7% to 12% of the surface of the cup. When a fourth view was obtained, only 6% of the surface of the cup was surrounded by shadowed bone 3 mm or more deep.

The most effective combination was the AP, 45° iliac-oblique and 60° obturator-oblique views, in which 7% of the surface area was obscured. Combining the AP view with the 45° iliac-oblique and obturator-oblique views (Judet views) left only 12% of the surface area obscured. When compared with the combination of the AP, 45° iliac-oblique and 60° obturator-oblique views, the addition of the 45° obturator-oblique view decreased the obscured surface area by 1% from 7% to 6%.

Volumes shadowed by metal acetabular cup. Since the obscured surface area was greatly reduced when combinations of three or four radiological views were obtained, we further analysed the volume and location of the shadowed regions in these combinations. We identified six distinct sites. Of the six, three covered less than 5% of the surface area of the cup. The main shadowed regions were in the mid-portion of the anterior and posterior columns. Figure 6 shows the volumes of these shadows for each of the three combinations of radiological views of a 50 mm cup. While the addition of a fourth view only marginally increased the amount of surface area that could be seen, it markedly reduced the volume of the shadow in the anterior and posterior columns.

In-vitro radiological analysis. Analysis of the radiological views of the radiopaque metal shell and lead pellets in the cadaver pelvis gave findings similar to those derived from

Fig. 4
Diagram showing the orientation of the pellets inserted into the acetabulum for the radiological examination.

Fig. 5
Diagram of the device used to position the cadaver pelvis in the correct angular orientation for the various radiological views.
the computer simulation (Figs 7 and 8). The combination of the AP, 45° iliac-oblique and 45° obturator-oblique views failed to show three of the pellets (19%). The combination of the AP, 45° iliac-oblique and 60° obturator-oblique views failed to depict only two pellets (12%). In the four-view combination, only one pellet (6%) was not visible. The undetected pellets were located in the same anterior and posterior shadowed volumes which the computer simulation had identified.

Discussion

Accurate identification of periacetabular osteolysis is critical to the management of revision THA. Early surgical intervention has been associated with improved clinical outcome and greater cost-effectiveness. Although osteolysis may be linked to changes in serum markers such as cytokine levels, radiographs are still the only way of assessing the presence and extent of osteolysis. Radiographs allow the surgeon to ascertain the degree of the fixation of the acetabular cup to the underlying bone. Knowledge of whether a specific area of osteolysis is rapidly progressing or quiescent is helpful in planning a revision procedure. A major portion of the three-dimensional surface of the cup can be obscured by the radiopaque metal backing, particularly when only one radiological view (usually AP) is used (Fig. 9).

The results of our computer simulation and cadaver study demonstrate that a minimum of three radiographs is
needed for maximal visualisation of the surface of the cup and the periacetabular bone. The optimal three views are the AP, 45° iliac-oblique and 60° obturator-oblique.

For linear-shaped lesions, these three radiological views showed 93% of bone around the cup, and the addition of the 45° obturator-oblique view increased the amount visible by only 1%. Figure 6 shows that in the assessment of cystic lesions, the combination of four radiographs (AP, 45° iliac-oblique, 45° and 60° obturator-oblique views) reduced the volumes of the anterior shadow by 75% and the posterior shadow by 25%, when compared with the combination of AP, 45° iliac-oblique and 60° obturator-oblique views.

The differences in visualisation of linear and cavitary defects relate to the location of the shadowed interface. For linear defects, good visualisation of the surface area of the cup is important. For cavitary defects, it is important to have a good image of the bone beyond the surface of the cup. Although they leave a relatively small footprint on the cup’s surface, cavitary defects may extend deep into the pelvic bone and therefore jeopardise both the stability of the cup and the fixation of a revision prosthesis.

The reason that the 60° obturator-oblique view produced a clearer image of the surface of the cup than the 45° obturator-oblique view is related to the anteversion. The 60° obturator-oblique projection provided a more tangential view in which a greater region of the surface of the anteverted cup could be seen.

In acetabular revision, bony defects are most commonly seen in the superolateral and posterolateral regions or in regions located both superiorly and posteriorly. When there is an intact rim which allows firm
fixation of the implant, central cavitary defects are less difficult to revise. Since AP radiographs do not show the superolateral region of the acetabulum sufficiently well, additional views which improve visualisation of the posterior shadow, not seen in the AP view, are helpful in determining the extent of bone loss in this region. In combination with the AP and 45° iliac-oblique view, the 45° obturator-oblique view reduced the volume of this shadow by approximately one half. The combination of AP, 45° iliac-oblique and 60° obturator-oblique views reduced the posterior volume of the shadow by an additional 30%. To improve visualisation of the posterior shadow it is important that at least the 60° obturator-oblique view be obtained. The addition of the 45° obturator-oblique view further added to the volume visualised, but to a less extent. If the anterior shadow is to be visualised, the four-radiograph combination of AP, 45° iliac-oblique, and 45° and 60° obturator-oblique views should be obtained.

Obtaining the recommended radiographs may present a challenge for the radiographer. It may be difficult to position the patient accurately for separate 45° and 60° obturator-oblique views. A useful hint for obtaining the 60° obturator-oblique view is to place the patient at a greater angle than is customary for the standard 45° obturator-oblique view.

Improved visualisation of bony defects surrounding acetabular components will not necessarily lead to an increase in the rate of revision surgery. Suggestions that the radiological appearance of acetabular osteolysis necessitates revision of the implant may not apply to cases in which the osteolysis can be seen better. Improved visualisation will help the surgeon to assess the rate of progression of known bony lesions and to plan appropriate treatment. Ultimately, both better preoperative management and more timely and effective operations will improve the treatment in revision THA.

Single AP radiographs are insufficient for visualising bony defects around metal-backed acetabular cups. The view of the periacetabular bone adjacent to the implant surface, as required in investigation of a linear defect, is most clear in a combination of AP, 45° iliac-oblique and 60° obturator-oblique views. The best view of the periacetabular bone beyond the metal-backed component, as required for assessment of a cystic defect, is obtained from the four-radiograph combination of AP, 45° iliac-oblique, and 45° and 60° obturator-oblique views. Follow-up studies which rely solely on AP radiographs may under-represent the degree of bone resorption.

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


