A. Ebied, D. A. Hoad-Reddick, V. Raut

From Wrightington Hospital, Wigan, England

Medium-term results of the Charnley low-offset femoral stem

A reduced femoral offset in total hip replacement has been thought to be disadvantageous. We reviewed the results of 54 consecutive primary total hip replacements in 49 patients (mean age of 68 years) performed between August 1990 and December 1994, with a mean follow-up of 8.8 years (SD 2.1). The mean pre-operative femoral offset for these hips was 41 mm (SD 7.4). All patients received a low-offset Charnley stem and a polyethylene cup inserted by a single surgeon.

At their latest follow-up, surviving patients had a significant improvement in the performance of their hip. Three had undergone revision, one each for deep infection, recurrent dislocation and late pain with subluxation. No hips had been revised, or were at risk of revision, for aseptic loosening. The mean annual linear rate of wear was 0.2 mm (SD 0.08) for the whole group. There was no correlation between the pre-operative femoral offset and the post-operative rate of wear. Our survivorship estimate was 91% when revision for any reason was taken as an end-point, but 100% if aseptic loosening was considered as the end-point. Our study demonstrates that a low-offset femoral stem can produce good, medium-term results.

The hip acts as a fulcrum between the body-weight and the abductor mechanism, but with their short lever arm when compared with the body-weight, the abductor muscles are considered to be at a mechanical disadvantage. For this reason, femoral offset has received considerable attention and various strategies have been used to reduce the reactive forces across the prosthetic hip. A reduced femoral offset has been associated with weak abductors and a tendency towards a Trendelenburg gait. McGrory et al described a correlation between femoral offset, the range of hip abduction and the strength of the abductor muscles, while offset has also been found to affect the rate of polyethylene wear. In a cadaver model, an extended femoral offset reduced the reactive forces across the articular surface of the hip with no adverse effects on the medial femoral cement mantle.

Although a femoral stem with an extended offset may have some advantages, a precise match of a patient’s own offset is the objective. In certain situations such as when there are soft-tissue contractures in a chronically dislocated or subluxed hip, or if the patient’s own hip has a short offset, the use of a short-offset stem may be needed. We therefore report the medium-term results of the use of a Charnley low-offset stem (DePuy, Leeds, UK), commonly known as the ‘three-quarter-neck stem’.

Patients and Methods

We reviewed a series of 54 consecutive total hip replacements (THRs) in 49 patients, two men and 47 women, with a mean age at the time of surgery of 68 years (29 to 84). The most common primary diagnosis was osteoarthritis (Table I). Six of the hips with a primary diagnosis of OA showed proximal

Table I. Details of the pre-operative diagnoses in the 54 hips

<table>
<thead>
<tr>
<th>Primary diagnosis</th>
<th>OA*</th>
<th>SUFE†</th>
<th>Nonunion of fracture of the neck of the femur</th>
<th>DDH‡</th>
<th>Rheumatoid arthritis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of hips</td>
<td>47</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

* OA, osteoarthritis  † SUFE, slipped upper femoral epiphysis  ‡ DDH, developmental dysplasia of the hip
patient in the supine position. The acetabular components were cemented polyethylene cups; 38 were Wroblewski angle bore (DePuy) and 16 Charnley long posterior wall components (DePuy). The femora were prepared with reamers and bone curettes. Particular attention was paid to clearing the femoral calcar, as advocated by Wroblewski et al.9 The femoral components were cemented using an intramedullary bone block and finger packing of the cement. Thirteen acetabular components were introduced with autologous bone graft. The roofs of four acetabula were reconstructed with a bulk bone graft fixed by two partially-threaded cancellous screws and washers. In nine acetabula the bone graft comprised sliced bone and morsellised chips impacted into the acetabular floor. Acetabular cement pressurisation was performed using Ling’s cement pressuriser (Howmedica, London, UK).

In 23 hips, Palacos cement with gentamicin (Schering-Plough, Welwyn, UK) was used and in 31 hips CMW cement loaded with gentamicin (CMW Laboratories, Blackpool, UK). The greater trochanter was re-attached using the double-spring wiring technique.10

The operations were performed between August 1990 and December 1994 with a mean period of follow-up of 8.8 years (1.6 to 11.3; SD 2.1). The standard follow-up protocol of our unit was followed, comprising clinical and radiological review at three months, one year and every two to four years thereafter. Patients were assessed pre-operatively and at their latest follow-up using Charnley’s modification of the grading of Merle d’Aubigné and Postel.1

Radiographs were inspected for demarcation, gaps at the cement-bone or cement-stem interfaces and endosteal cavitation. For analysis, the acetabula were divided into the three zones of DeLee and Charnley.11 The orientation and position of the acetabular component in the horizontal plane were assessed by calculating the acetabular angle and by defining the position in relation to the original floor and rim. Loosening or risk of loosening was assessed using the criteria of Hodgkinson, Shelley and Wroblewski.12

On the femoral side the position of the stem was defined. If the long axis of a stem deviated from the axis of the medullary canal by more than 5˚, it was considered to be either in varus or valgus depending on the direction. The cement-stem and the cement-bone interfaces were divided into the seven zones described by Gruen, McNeice and Amstutz,13 and the radiographs were inspected for lines of demarcation and/or osteolysis. Bone changes at the level of the calcar and at the tip of the stem were also noted. The linear rate of wear was calculated as the degree of penetration of the cup in millimetres.14

Statistical analysis. Using Pearson’s method, we assessed the correlation between age, height, weight and the pre-operative femoral offset with the annual rate of wear. Confidence limits were constructed using Fisher’s Z-transformation. For survivorship analysis, a Kaplan-Meier estimate was used, with a 95% confidence interval (CI). Revision for any reason was taken as the end-point and those patients
who died whilst awaiting surgery were included as censored.\textsuperscript{15} Values for $p < 0.05$ were regarded as significant.

**Results**

Of the 49 patients, 14 died from conditions unrelated to their arthroplasty, one was lost to follow-up and another was unable to attend for review. However, a telephone consultation was arranged and recent radiographs were inspected. Clinically, all patients had a significant improvement ($p < 0.05$) in their modified Merle d’Aubigné and Postel score, which was maintained at their latest follow-up (Fig. 2).

Radiological evaluation showed that all the cups were within the boundaries of the original acetabulum or were covered by the bone-graft augmentation. The mean acetabular inclination was 37° (30 to 45; SD 4). Evaluation of the acetabular cement mantle one year after surgery showed demarcation lines $\leq 1$ mm in 14 cups. There were eight lines in zone I, three in zone II and six in zone III. Acetabula which had received impaction grafts showed similar demarcations in zones II and III. One zone was affected in 11 cups and two in three. No cup had all three zones involved. At the latest review no demarcation line had progressed, although 24 cups showed lines $\leq 1$ mm in one (17 cups) or two (seven cups) zones. No cup was either loose or appeared to be at risk of loosening. The demarcation lines were not progressive and there was no osteolysis or evidence of cavitation. All stems were in a neutral position with an intact cement mantle in all zones; none was loose and there was no evidence of endosteal cavitation. Lines of demarcation at the cement-bone interface were noted in 14 hips. Most were in zones I (six) and VII (six hips) although lines were also found in zones II (one), III (four), V (two) and VI (five). No lines were seen in zone IV. One zone was affected in eight hips, two in five, three in one and four in two. There was evidence of cortical hypertrophy at the level of the tip of the stem in two hips. The position of the stem had not changed in any patient.

**Survivorship.** Taking revision for any reason as an endpoint, our survivorship estimate was 91% at 12 years (Fig. 3). However, with aseptic loosening as the endpoint the survivorship was 100%, since no patient had radiological evidence of loosening or had been revised for this reason.

**Linear wear rate.** The annual rate of linear wear of the polyethylene defined by the magnitude of penetration of the cup was calculated as previously described.\textsuperscript{16} The mean annual rate of wear for the series was 0.2 mm (0.08 to 0.4; SD 0.08). When the mean annual rate of wear of the hips in group A (0.2 mm SD 0.1) was compared with that of group B (0.2 mm SD 0.06) no difference was found ($p = 0.9$). No correlation was found between the mean annual rate of linear wear and either the pre-operative offset or any other variable.

**Revision surgery.** At the latest follow-up, three hips had been revised; two were early, one for deep infection and one for recurrent dislocation. The third revision was performed for late recurrent subluxation and pain. The patient with early, recurrent dislocation had nonunion of the greater trochanter but with well-fixed components in acceptable positions. An acetabular augment was used in this patient to lengthen the posterior wall of the cup. No further dislocations occurred. The revision for late subluxation and pain was performed seven years after the primary procedure. At revision the components were stable and in a good position. The cup was worn, with penetration of the head into the cup leading to medial displacement and impingement of the neck. The femoral component was revised to a stem of larger offset (Fig. 4).

**Correlations.** The null hypothesis that $r = 0$ (i.e. no correlation) was tested using a modified $t$-test.\textsuperscript{15,17} No significant correlation was found between the pre-operative offset and the annual rate of wear (Fig. 5). A statistically significant correlation was found between weight and the pre-operative offset ($p = 0.001$).

**Complications.** Within the first year one hip developed a deep infection and was revised. One patient developed a
deep-vein thrombosis and another survived a pulmonary embolism. Nonunion of the greater trochanter occurred in seven hips (13%); three of these were initially symptomatic and one required early revision for recurrent dislocation. The remaining three had pain which settled completely within a year of surgery without the need for any further surgical intervention. Heterotopic ossification developed in nine hips with Brooker grade I in eight and grade II in one.

Discussion
Femoral offset is an important feature which should be carefully considered in THR. Many reports have supported the restoration of leg length and femoral offset.\textsuperscript{3,4,7,19-22} Davey et al\textsuperscript{7} performed a cadaver study, using prostheses with differing offsets to investigate the loads produced at the femoral head and medial cement mantle. They demonstrated a reduction of the reactive forces across the articular surface of the hip with the use of greater offset. Loading of the medial cement mantle did not seem to be seriously affected.\textsuperscript{7}

Pre-operative planning and the use of templates can help in determining the required size and offset of the prosthesis. The surgeon is usually aided in his final decision by various intra-operative manoeuvres to assess stability. The hip is usually tested for impingement and stability at 90° of flexion (with internal rotation) and extension (with external rotation).\textsuperscript{3} However, it is not always possible to match leg lengths or to reproduce exactly the patient's own femoral offset. Developmental dysplasia, protrusio, acetabular deficiency or collapse of the femoral head are particular instances in which the soft tissues may limit the ability for further correction and may dictate the use of a low-offset stem. Moreover, some patients have a particularly small offset in which case it would be logical to duplicate this.

In our series, the low-offset Charnley stem has given good medium-term survival. No hip had been revised or considered to be at risk of revision because of aseptic loosening. Sakalkale et al\textsuperscript{6} reviewed 17 patients who underwent a staged bilateral THR with a mean follow-up of 5.7 years (2 to 10). In their patients the only side-to-side variation was in the femoral offset. A standard offset stem length was used for one side and an extended offset for the other. They found a significant increase in the rate of linear and volumetric wear when a standard offset was used compared with the extended form.\textsuperscript{6} Using linear regression analysis, a significant correlation was drawn between reduced offset and an increased rate of linear wear.

In our series we found no difference in the annual rate of wear between those patients who had an offset < 40 mm before surgery (group A) and those who had an offset ≥ 40 mm (group B). The mean annual acetabular rate of wear of 0.2 mm (SD 0.08) seen in the whole series was higher than had been previously reported from our unit.\textsuperscript{23} Wroblewski, Fleming and Siney\textsuperscript{24} described the long-term results for patients who had a Charnley THR. The mean age of the

![Radiographs showing a) a satisfactorily aligned low offset-stem complicated at seven years by subluxation and pain and b) revision to a larger-offset component.](image)
patients was 43 years (17 to 68), their mean weight was 63 kg and they were followed up for a mean of 22 years. The mean rate of penetration of the polyethylene was 0.08 mm (0.01 to 0.3). A positive correlation was found between the depth of penetration and the incidence of migration of the cup. In another series of Charnley THRs, components revised for aseptic loosening were found to have a mean rate of wear of 0.19 mm/year compared with 0.09 mm/year for the surviving hips. Although we report no increased incidence of aseptic loosening our observed rate of acetabular penetration raises concern about the future of this group of hips. Aseptic loosening is a multifactorial process and a longer follow-up is needed before a final conclusion can be drawn.

Ranawat et al. drew a correlation between early failure of the cup and the presence of a radiolucency on the immediate post-operative radiographs. Schmalzried et al. considered that biological rather than mechanical factors influenced the process of aseptic loosening, while others attributed failure of the cup to poor initial fixation, positioning, metal backing and sepsis. In our study, lines of demarcation have been observed in 14 cups at one year. These have not progressed throughout the follow-up period. This may suggest that the radiological findings reflected the presence of sclerotic acetabular edges rather than a technical fault in the cementing technique. On the femoral side, lines of demarcation were concentrated in zones I and VII and none was progressive. This suggests stability and a satisfactory cementing technique. Our rate of trochanteric nonunion (13%) is higher than has previously been published from our unit. This may be attributable to the increased abductor forces required with a reduced femoral offset or is, perhaps, a reflection of the surgeon’s learning curve.

Our policy at THR is to reproduce the patient’s own femoral offset when possible. If soft-tissue constraints prevent this, priority is given to soft-tissue balance and stability of the joint. The use of a low-offset stem can give good medium-term results. Long-term results for this group of patients are required before the survival of this stem can be confirmed and the significance of the observed increase in acetabular polyethylene wear can be defined.

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References