We revised 24 consecutive hips with loosening of the femoral stem using impaction allograft and a cemented stem with an unpolished proximal surface. Repeated radiostereometric examinations for up to two years showed a slow rate of subsidence with a mean of 0.32 mm (-2.0 to +0.31). Fifteen cases followed for a further year showed the same mean subsidence after three years, indicating stabilisation. A tendency to retroversion of the stems was noted between the operation and the last follow-up. Retroversion was also recorded when displacement of the stem was studied in ten of the patients after two years. Repeated determination of bone mineral density showed an initial loss after six months, followed by recovery to the postoperative level at two years. Defects in the cement mantle and malalignment of the stem were often noted on postoperative radiographs, but did not correlate with the degrees of migration or displacement. After one year, increasing frequency of trabecular remodelling or resorption of the graft was observed in the greater trochanter and distal to the tip of the stem. Cortical repair was noted distally and medially (Gruen regions 3, 5 and 6). Migration of the stems was the lowest reported to date, which we attribute to the improved grafting technique and to the hardness of the graft.


In revising the femoral component of hip arthroplasties, Simon et al.1 and Gie et al.2 reported promising results when using impacted cancellous allograft, with a low incidence of radiolucent lines, early evidence of cortical remodelling and self-limiting subsidence. They used polished femoral stems, which were expected to debond from the cement mantle and subside as the cement crept or deformed.3,4 The association of this with cement fracture has recently been debated.4

In primary arthroplasty, good clinical results have been obtained with femoral stems of varying design, length and finish.5 Less is known about their performance in revision surgery. Our aim was to evaluate the combined use at revision of impacted allograft, cement and a femoral stem with an unpolished proximal surface and collar.

Patients and Methods

Between March 1993 and November 1995, we performed 24 revisions using impacted allografts and cement for fixation of the femoral component. There were ten men and 14 women with a mean age of 65 years (38 to 84). Seven were Charnley group-A, 11 group-B and six group-C. In 18 patients revision was being undertaken for the first time, in five for the second and in one for the third. Preoperative radiographs had shown that five patients had type-I loosening, as defined by Gustilo and Pasternak,6 18 had type-II and one had type-III. After removal of the loose stems, the intraoperative classification was three type-I, 17 type-II and four type-III loosenings. On the Endo-Klinik scale7 one patient had grade-1 loosening, 16 had grade-2 and seven had grade-3.

In all patients we used cobalt-chrome alloy Spectron EF stems (Smith & Nephew, Memphis, Tennessee), 135 mm in length with grit-blasted proximal and bead-blasted distal surfaces (surface roughness = 112 µm and 26 µm, respectively). The stems were supplied with three titanium pegs, each tipped with a tantalum marker for subsequent radiostereometric (RSA) studies (Fig. 1). Further bone markers were inserted into the proximal femur once the femoral canal had been cleaned.

We developed instruments and trial prostheses suitable for use with the Spectron stem. The casts were 2 mm wider and 1 mm longer than the Spectron stems. A cannulated handle attached to the trial stem facilitated proximal impaction.

During surgery we applied prophylactic cerclage wires in 14 patients, usually before the loose stem had been
removed. In six of these, the stainless-steel mesh was attached with more wires to cover defects.

We used the technique of Gie et al\textsuperscript{8} for impaction of morsellised allograft. The surgeon estimated the torsional stability of the trial stem by rotating the handle internally or externally. In later cases, the use of a torque wrench made it easier to reproduce this procedure. When the handle was removed a modular collar and a femoral head of appropriate size were fitted. We left the trial prosthesis in place until immediately before the cement was introduced (Palacos with Gentamicin; Shering Plough, Labo nv, Herst-op-den-Berg, Belgium) by retrograde filling.

Postoperatively, patients were mobilised within one to two days. Depending on the preference of the surgeon, weight-bearing was restricted for three to four months in 18 patients and for five to six months in the remaining six.

There were no fractures during the procedure. Nearly three years after revision one patient sustained a femoral fracture distal to the prosthesis in a fall. Heterotopic bone was excised from another patient 20 months after the operation.

Repeated RSA examinations were done in the supine position at five to ten days and at six weeks after operation. In 15 patients there was complete follow-up, including RSA examinations, at three and six months and then annually for three years; seven others were similarly followed up for two years. Two were excluded from statistical evaluation of the RSA data. In one (case 10) postoperative examination did not take place until six weeks after the procedure, and in the other (case 21) poor visualisation of the tantalum markers at two years made reliable evaluation impossible. In a third patient, we could not calculate rotation because of the poor configuration of bone markers. At follow-up after two years, ten patients were examined both standing normally and on the treated leg only, with about 10° of hip flexion.

We evaluated the proximal (+) and distal (-) translations of the gravitational centre of a segment: distal translation of the segment denoted subsidence. The three stem markers and the centre of the femoral head defined the segment.\textsuperscript{9,10} The degree of rotation of the stem was recorded. The accuracy of the RSA measurements was checked by repeat examinations\textsuperscript{10,11} in 18 patients. The 99\% confidence limits (CI) for this error (absolute mean value 2.9 s\textsuperscript{a}) were 0.16 mm for proximal-to-distal translation, 0.30° for rotation around the transverse axis (anterior-posterior tilt), 0.80° for rotation around the longitudinal axis (anteversion-retroversion) and 0.34° for rotation around the sagittal axis (varus-valgus tilt).

When we began our study of changes in bone mineral density (BMD), 11 patients had already undergone operation, leaving 13 available for a two-year study of the relative changes in BMD. Dual-energy X-ray absorptiometry (DEXA) (DPX-L; Lunar Corporation, Madison, Wis-
Wisconsin) was carried out postoperatively and again after 6, 12 and 24 months. During the DEXA examination the foot of the treated leg was placed in a triangular support in 25° of internal rotation. In the seven Gruen regions BMD was determined in grams per cm$^2$. In all examinations the Gruen region 1 was manually expanded proximally to include the tip of the greater trochanter. From the known length of the stem the software defined the proximal to distal lengths of each region. The accuracy of the measurements was verified by repeating the examinations in 12 patients. To reduce error arising from variations in position of the hip, each patient left the scan table for about ten minutes between examinations. The overall mean difference was 3.6% (SD 3.9%). The highest regional variation was noted in region 5 (Table I).

Two years after the operation, two patients had surgery to the opposite hip, at which time bone biopsies 2 mm in diameter were taken laterally at the level of the tip of the lesser trochanter. These tissues were processed by routine light microscopy and immune and enzymic histological analysis. They were fixed in 4% neutral buffered formaldehyde (pH 7.0), then rinsed and dehydrated in increasingly concentrated ethanol. After embedding in methylmethacrylate, sections were cut at approximately 150 µm and ground down to 5 µm to 10 µm. They were stained in 1% Toluidine Blue in 1% borax solution made up 4:1 with 1% pyronin-G. They were also stained for acid phosphatase and alkaline phosphatase to detect osteoclastic and osteoblastic activity, respectively. To identify macrophages sections were stained with CD68.

Conventional radiological examination was undertaken 1, 2 and 3 years after the operation. We recorded the presence of radiolucent lines at the stem-cement, cement-graft and graft-host bone. Deficiency of the cement mantle was assumed to be present if radiolucency of at least 1 mm was seen at the stem-cement interface on AP or lateral views. The presence of allograft around the stem was assessed similarly. We evaluated the remodelling of the graft and the cortical host bone using the method of Gie et al.

We used the Harris hip score to assess the patients clinically. Pain on activity and at rest was evaluated on a visual analogue scale.

## Results

### RSA studies of migration

For up to two years after operation, subsidence took place at a diminishing rate (year 1 v year 2: Wilcoxon signed-rank test, $p = 0.03$, $n = 22$). The stems seemed to have stabilised after two years (year 2 v year 3: Wilcoxon signed-rank test, $p = 0.54$, $n = 15$) (Fig. 2). At two years, nine of the stems had subsided by -1.97 to -0.24 mm. A further nine displayed slight proximal-to-distal displacement of -0.15 mm to 0.07 mm and three proximal displacement of 0.20 mm to 0.31 mm. After three years there were ten cases of subsidence, four of proximal-to-distal displacement, and one of proximal displacement. In the two cases with incomplete data there was subsidence of -0.36 and -0.35 mm after one and three years, respectively. In the patient with

### Table II. Rotation (degrees) of the stems evaluated by RSA

<table>
<thead>
<tr>
<th>Migration</th>
<th>Number</th>
<th>Mean</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
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<tr>
<td>0 to 2 years</td>
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<td>0.8</td>
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<tr>
<td>0 to 3 years</td>
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<td>-0.3</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>0 to 2 years</td>
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<td>1.0</td>
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<td>5.3</td>
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<tr>
<td>0 to 3 years</td>
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<td>1.1</td>
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<tr>
<td>0 to 2 years</td>
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<td>0.0</td>
<td>-1.3</td>
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<td>0 to 3 years</td>
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<td>10</td>
<td>0.0</td>
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</table>
the femoral fracture the stem showed minor (0.04 mm) proximal-to-distal displacement after two years. At three years, when the fractures had healed after open reduction and plate fixation, the stem had subsided minimally (-0.22 mm). With increasing retroversion, the stems tended to rotate around the longitudinal axis of the femur. Retroversion was greatest (5.3°) in the patient who had the most pronounced subsidence, amounting to -2.0 mm at the two-year follow-up. As Table II shows, this stem also showed the most distinct varus drift (-1.3°).

**RSA studies of inducible displacements.** The mean proximal-to-distal displacement was close to zero (Fig. 2). Generally, there was increased retroversion of the stem when the patients were standing, either on both legs or only on the treated leg (Table II). When the patients moved from lying supine to standing normally on both legs, no stems showed significant subsidence (>0.16 mm), but there was distal displacement in two stems when patients stood only on the one leg (-0.24 mm and -0.84 mm). The maximum individual inducible rotation was 1.9°. When patients stood only on the treated leg, proximal-to-distal displacement correlated closely with the type of migration at the two-year follow-up (non-parametric correlation, \( r = 0.78, p = 0.0007 \)).

**Bone mineral density.** As shown in Figure 3, the BMD decreased by 8% to 10% in Gruen regions 1, 2 and 7 (Wilcoxon signed-rank test, \( p = 0.003 \) to 0.02) between the postoperative and six-month evaluations. Six months after surgery the BMD increased in most regions (6 months \( v \) 2 years: zones 1, 2, 4 to 6, \( p = 0.0009 \) to 0.03), and at two years values equal or close to those recorded postoperatively were noted in all regions (postoperatively \( v \) 2 years: \( p > 0.05 \)). There was no relationship between the change in BMD at two years and the migration values (non-parametric correlation).

**Trochanteric biopsies.** Figure 6 shows that there was a clear border between the cortical bone and the grafted region, which comprised mainly live cancellous and some dead bone. Under polarised light some immature woven bone could be seen next to dead bone. Osteoblastic activity was observed in small areas only. The presence of numerous acid phosphatase-staining macrophages indicated osteoclastic activity.

**Conventional radiography.** We labelled AP views as Gruen regions 1 to 7 and lateral views as regions 8 to 14 (Fig. 4). Postoperative radiographs showed that 11 stems had complete cement mantles. In five cases, there were defects in one or two of the 14 Gruen regions and in three or more regions in eight patients. The most common defect, seen in ten cases, was that the cement did not reach the tip of the stem. Fifteen of the stems had varus or valgus alignment of 0±2°, eight had varus of 3° to 6° and one valgus of 3°. In 12 cases allograft completely surrounded...
the stems. The allograft was imperfect in one or two regions in five cases, and in seven cases no graft material was visible in three to six of 14 regions. At no stage of follow-up did we find any relationship between the recorded migration (proximal-to-distal translation and rotation) and the state of either the mantle of cement or allograft, or the position of the stem (Mann-Whitney U test, non-parametric correlation).

After one year, AP views showed bone remodelling and the formation of trabecular bone or cortical repair in at least one Gruen region in five of the original 24 cases. After two years, 20 out of 24 cases had these features, and at three years the AP views of 16 cases showed that they were present in all. These features were less often observed on lateral views (Fig. 4). In regions 1 and 4 there was extensive trabecular remodelling, and resorption was also noted. Cortical repair was observed in regions 3, 5 and 6, particularly medially (Fig. 5). There was no difference in the proximal-to-distal migration between cases with or without signs of cortical repair (with signs of cortical repair: median = -0.22 mm, range -0.85 to -0.31; without signs of cortical repair: median = -0.39 mm, range -2.00 to -0.23, Mann-Whitney U test, p=0.75).

In four patients there were radiolucent lines in at least one of the three interfaces. In cases 8 and 17 radiolucency between the cement and the stem suggested subsidence within the mantle. These cases had subsidence of -1.3 and -2 mm, respectively (Fig. 1) and were the only cases in which subsidence exceeded 1 mm at two years. In case 17 radiolucency developed between the graft and the mantle in regions 7, 8 and 14. Two other patients had partial and non-progressive radiolucency between the graft and the host.

**Clinical results.** The Harris hip scores improved between operation and follow-up at one year (Wilcoxon signed-rank test, p < 0.0005) and no notable changes were recorded later (Table III). The pain score was 30 in the two cases with stem subsidence of 1 to 2 mm. Pain on activity decreased at one year (Wilcoxon signed-rank test, p < 0.0005) and did not change markedly (Table III). There was little or no change in pain at rest (p = 0.046 to 0.17). There was no statistical relationship between pain and proximal-to-distal translations of the stem (non-parametric correlation, Mann-Whitney U test).

**Discussion**

Early subsidence of femoral stems may be due to post-operative compaction of graft material, resorption of graft or host bone, subsidence or combinations of these. Gie et al.² using polished Exeter stems, reported subsidence of 5 to 10 mm in 11 of 56 patients. This occurred mainly inside the cement mantle. In only one case was there subsidence between the mantle and the bone. In their study, the subsidence did not seem to affect the clinical results during
In our patients, the worst subsidence (cases 8 and 9) occurred within the mantle. Although it could not be verified statistically, the fact that both had pain indicates a causal relationship between stem fixation and symptoms. Elting et al. noted a mean subsidence of 2.8 mm in about half of their 56 patients. They concluded that since there was no aseptic loosening after two to five years, some subsidence may be acceptable. Eldridge et al., in a study of 79 patients, reported nine with ‘massive’ (>10 mm) subsidence after impaction grafting of the femur. These hips were symptomatic from the outset and eight required a second revision. The high failure rate was ascribed to varus positioning of the stem. Meding et al. found a mean subsidence of 3.9 mm in 34 hips, 13 of which had a mean subsidence of 10.1 mm. In their series, four patients sustained intraoperative and two postoperative fractures. Two patients required further revisions after two and three years because of aseptic loosening. Ornstein et al. noted that, at follow-up after 18 months, 11 of 16 patients had subsidence of 1 to 4 mm and about half seemed to have stabilised after 12 months. In view of the debate about the use of polished stems in revision surgery, it is interesting that Franzén et al. using unpolished stems both with and without collars (Scan or Optima; Mitab, Sweden), recorded subsidence of 0.4 to 3.9 mm after one year. The mean value (about 1.8 mm) was similar to that reported by Ornstein et al.

Studies of primary hip arthroplasties indicate that the

| Table III. Mean (range) Harris hip and pain scores showing recorded values and the difference between preoperative and follow-up evaluations |
|---------------------------------|----------------|----------------|----------------|----------------|
|                                | Harris score | Pain - VAS     |                |                |
|                                | Number       | Pain Observed  | Difference     | Observed       | Difference     |
|                                |              | 20 (0 to 40)   | -              | 46 (22 to 95)  | -              |
|                                |              | 20 (-10 to +44) | 74 (40 to 100) | 25 (-2 to +55) | 0 (0 to 100)  | -              |
|                                |              | 15 (4 to 44)   | 76 (40 to 100) | 28 (-4 to +55) | 0 (0 to 80)   | -              |
|                                |              | 20 (0 to 34)   | 83 (54 to 100) | 27 (5 to 50)   | 0 (0 to 31)   | 0 (-90 to +21) |

Fig. 5a Fig. 5b

Radiographs of the proximal femur of a 57-year-old man revised because of low-grade infection with *Staphylococcus albus* (a). After two years, the stem had subsided -0.12 mm and there is marked cortical repair medially (b). By this time, the C-reactive protein level and the ESR were normal.
Spectron EF stem, despite its unpolished proximal surface, may slip distally inside the cement mantle.\(^9\) This suggests that while an unpolished surface may have a role in reducing subsidence, the effect of the surface is minor.

Conventional radiographs showed that the state of the cement mantle and the position of the stem were less than optimal in many of our cases. Our low mean subsidence, which on average was about six times smaller than in some of the previous studies, could not therefore be ascribed to these factors.

We know of no other studies of BMD in revision surgery. The decrease in BMD noted at six months could be due to resorption of bone because of inactivity and restricted weight-bearing. Some resorption could have taken place very early on and not been detectable radiologically until a year or two later. In the middle and distal regions, later increases in BMD were compatible with radiological findings. Resorption of the intramedullary graft material was often seen, but the mean BMD at two years was largely unchanged. The cortex may have become wider and perhaps more dense. In region 1, DEXA scans at two years showed little or no change, but in many cases there was radiological evidence of graft resorption. We concluded that there was no association between the restoration of BMD, radiological restitution of bone or proximal-to-distal migration. The two biopsies also showed that some graft had been incorporated. Ectopic calcification around the greater trochanter, however, may have influenced the results.

Eldridge et al\(^15\) and Masterson et al\(^20\) expressed concern about a number of cases in which rapid subsidence coincided with fracture and/or fragmentation of the cement mantle. An analysis of about 200 cases, in which three different implants had been used, showed defective cement mantles in 18% to 50%. The failure rate was highest when the Exeter stem was used. It was felt that one cause of failure was that the trial stems were shorter than the definitive stems. In our study, a comparatively high number of patients with defective mantles also had stems positioned in varus. This could be ascribed partially to the use of a cementing gun nozzle which was too wide to reach the most distal part of the canal. In our later cases we were able to improve our technique by using a thinner nozzle on the cementing gun. Another possible cause could be a tendency to rely on the central guide wire, which can deviate medially in wide or eroded canals. In revision surgery, the partial destruction of anatomical landmarks makes it more difficult to introduce the stem correctly, and the use of a short stem compounds the problem. Again, our technique improved with experience. Despite our initial inadequacies, we did not find that stem positioning and/or the quality of the cement mantle had any influence on early fixation.

The lack of correlation between these factors could indicate that the low level of subsidence in our cases is attributable mainly to techniques of graft-handling and impaction. We believe that it is the hardness of the impacted graft that is of primary importance.

In a study of non-cemented Lubinus stems with impacted allograft, Nivbrant and Kärholm\(^11\) reported subsidence after two years similar to that in our study. In their patients, as in ours, the milled bone was washed in saline at 37°C to increase the relative amount of bone per unit volume and to prevent inflammatory reactions. The results of subsequent studies in our laboratory (unpublished observations) indicate that this process reduces implant migration in an in vitro model.

Graft material which is partially porous gives rise to the risk that particles and joint fluid may come into contact with the interfaces. We tried to seal the interface with cement at operation, but do not know whether this was effective.

Although stem positioning and the quality of the cement mantle are important in revision surgery we believe that the critical success factor may be the allograft.

Financial support was obtained from Ingabritt and Arne Lundberg’s and Felix Neubergh’s Research Foundations, the Swedish Medical Research Council MFR B96-17x-07941-10A, MFR B96-17x-10856-03A and Smith & Nephew, USA.

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