We used roentgen stereophotogrammetric analysis to follow 33 C-stem femoral components for two years after primary total hip arthroplasty. All components migrated distally and posteriorly within the cement mantle. The mean distal migration was 1.35 mm (SD 0.62) at two years and the mean posterior migration was 1.35 mm (SD 0.69) at two years. All the femoral components rotated into retroversion with a mean rotation at two years of 1.9˚ (SD 1.1). For all other directions, the prosthesis was stable up to two years. Compared with other tapered prostheses, the distal migration of the C-stem is the same, but posterior rotation and posterior migration are greater.

The C-stem (DePuy International, Leeds, UK) is a triple-tapered, polished and collarless femoral component made from high nitrogen stainless steel (Ortron) (Fig. 1). These features can facilitate distal migration within the cement mantle, a phenomenon first noticed on radiographs, and later confirmed by roentgen stereophotogrammetric analysis (RSA), for the double-tapered, polished Exeter stem (Stryker Howmedica Orthopaedics, Mahwah, New Jersey). Low revision rates are reported for the Exeter prosthesis and the view that early migration predicts later failure has not been confirmed with double-tapered designs. Whether a triple-tapered stem has any advantages is not known and, to our knowledge, no pre-clinical data have been published. Short-to-mid-term clinical data for up to seven years (mean 3.5) have shown similar radiographic appearances as the Exeter stem and clinical scores have been excellent. We therefore sought to establish the migration and rotation patterns of the C-stem up to two years after implantation, with special emphasis on the interfaces at which these movements occur.

**Patients and Methods**

We studied 36 patients under the age of 75 years with primary osteoarthritis of the hip. None had undergone previous hip surgery. We excluded two patients because of uncertain RSA measurements and one patient, who underwent bilateral simultaneous hip replacements (one hip was included in the study), continued to have pain in both hips and developed increasing bone-cement lucencies in both femora of the same degree. On clinical grounds we suspected septic loosening but the cultures at revision, taken from multiple biopsies, were negative. The remaining 14 men and 19...
The diagnosis was primary osteoarthritis in all hips. Informed consent was obtained from each patient and the study protocol was approved by the ethics committee of the university.

Operative technique. The operations were performed by two surgeons (TvS, AC) (16 and 17 operations, respectively) with the patient in a supine position; a direct lateral approach was used without an osteotomy of the greater trochanter. Pre-chilled Palacos bone cement (Schering-Plough International, Kenilworth, New Jersey) containing gentamicin was used with a modern cementing technique. A hollow distal centraliser for adequate placement within the cement mantle, and a gelatin end-cap to allow subsidence, were used when inserting the femoral components.

An intravenous antibiotic (cloxacillin 2g x 3) was given during the operation and continued for 24 hours and low-molecular-weight heparin (enoxaparin 40 mg) was given for ten days as thromboembolic prophylaxis.

Roentgen stereophotogrammetric analysis. In order to enable RSA follow-up according to the method described by Selvik,\textsuperscript{14,15} 0.8 mm tantalum markers were implanted in the greater and lesser trochanters and 1 mm markers within the cement mantle (Fig. 2). We marked 26 of the femoral components with a 0.8 mm marker mounted on a metallic tower at the shoulder and the tip of the prosthesis, so that rotation could be calculated. For RSA analysis we used UmRSA version 5.0 software (RSA Biomedical, Umeå, Sweden). The initial RSA examination was performed at a median of one day (1 to 2) after surgery. RSA was then performed in 30 patients at three months, in 29 at six months and in 32 at one and two years. For rotation the corresponding number of patients was 22, 21, 22 and 21. As the tantalum markers in the cement mantle were close both to each other and to the femoral component they could be difficult to see. Measurements of the cement mantle could, therefore, only be performed in 23 patients at three months, in 22 at six months, in 24 at one year and in 22 at two years.

The accuracy of the RSA method was calculated by repeat examinations, on the same day, of ten patients for rotation and 16 patients for migration. The movement between these examinations, expected to be zero within pairs, and the standard deviation for each direction of movement, was calculated. Using the Student’s $t$-distribution the 99% confidence intervals for the smallest significant movement in each direction were determined.

Radiographs. Conventional radiographs were taken post-operatively, and at one and two years after surgery, at the same time as the RSA radiographs. The radiographic evaluation included assessment of stem alignment, cement mantle defects, cement fractures, radiolucent lines, localised endosteal femoral lysis, and cortical hypertrophy. At the time of evaluation no radiographs were missing.

Clinical assessment. The clinical results were evaluated by the Charnley\textsuperscript{13} and the Harris hip scores.\textsuperscript{16}

Statistical analysis. As the RSA data parameters were not normally distributed, we usually used non-parametric methods. The Mann-Whitney U test was used for group comparisons. The Wilcoxon matched pairs test was used for calculating prosthetic movement between measurements and the Spearman’s rank correlation test was used to assess correlations. The statistical calculations were undertaken using Statistica version 6.1 (StatSoft, Inc, Tulsa, Oklahoma) with values for $p < 0.05$ being regarded as significant.

Results

Accuracy. The levels of significant migration and rotation are shown in Table I.
No statistically significant difference for prosthetic migration and rotation in any direction between the two surgeons was detected at two years (p = 0.2 to 0.6).

Cement. The cement mantle was stable within the femur and, by two years, the mean distal migration was 0.09 mm (SD 0.10) and the mean posterior rotation was 0.02° (SD 0.31). We therefore concluded that all migration/rotation took place within the cement mantle.

Migration. All femoral components migrated distally within the femur with most of this migration taking place within the first three months after surgery (Fig. 2). By two years the mean distal migration was 1.35 mm (SD 0.62) (Fig. 3). All components migrated posteriorly to a similar degree as the level of distal migration so that by two years the mean posterior migration was 1.35 mm (SD 0.69) (Fig. 4). The main component of the posterior migration took place within the first six months after surgery.

For both distal and posterior migration there was a statistically significant migration between one and two years (p < 0.001 and p = 0.009, respectively) so the femoral component did not appear to stabilise in these directions for the first two years after surgery.

Of the 33 femoral components, 26 migrated into slight varus (n = 5) or valgus (n = 21) with a mean migration at two years of 0.41 mm (SD 0.23). There was no statistically significant migration between one and two years into varus or valgus (p = 0.26) with the majority of the migration being within the first three months after surgery. The femoral component does, therefore, appear to stabilise within two years in these directions.

There was a tendency for distal and posterior migration to correlate at two years (Spearman’s r = 0.3; p = 0.08).

No correlation was found between the size or offset of the femoral component and migration in any direction at two years (Spearman’s r = 0 to 0.2; p = 0.2 to 0.9).

Rotation. All femoral components rotated towards retroversion (y-axis), most of which occurred during the first three to six months after surgery (Fig. 5). By two years the mean posterior rotation was 1.9° (SD 1.1). There was a significant posterior rotation between one and two years (p = 0.03) so it appeared that the femoral component did not stabilise in this direction for the first two years. A correlation was found between distal migration and retroversion at two years (Spearman’s r = 0.6; p < 0.001), and for posterior migration and retroversion at two years (Spearman’s r = 0.7; p < 0.001).

Eleven of 22 stems tilted backwards (around the x-axis) with a mean tilt at two years of 0.44° (SD 0.47). There was no significant forward or backward tilt between one and
two years \((p = 0.60)\), the major part of this tilt occurring within the first three months after surgery. The femoral component therefore appeared to stabilise within two years in these directions.

Nine of 22 stems rotated into slight varus \((n = 1)\) or valgus \((n = 8)\) (around the z-axis) with a mean rotation at two years of 0.28° \((\text{SD} \ 0.24)\). There was no significant rotation between one and two years into varus or valgus \((p = 0.30)\), the majority of this rotation occurring within the first three months after surgery. The femoral component, therefore, appeared to stabilise within two years in these directions.

No correlation was found between the size or offset of the femoral component and rotation in any direction at two years (Spearman’s \(r = 0.1\) to 0.4; \(p = 0.1\) to 0.5).

### Radiographic analysis

Thirty femoral stems were aligned neutrally, two were in varus and one in valgus. Their cementation was graded as A in 28 hips and B in 5 hips.\(^{17}\) A radiolucent line \(< 1 \text{ mm}\) between the shoulder of the component and the cement was a common finding and, by two years, was seen in 32 of 33 hips. No cases of osteolysis were seen.

### Clinical evaluation

No post-operative complications were recorded. Pre-operatively the mean Charnley score for pain was 3.0 \((\text{SD} \ 0.7)\), function 2.8 \((\text{SD} \ 0.8)\) and range of movement 3.8 \((\text{SD} \ 1.1)\). By two years the mean score for pain was 5.8 \((\text{SD} \ 0.6)\), function 5.7 \((\text{SD} \ 0.9)\) and range of movement 5.6 \((\text{SD} \ 0.5)\). Corresponding figures for the Harris hip score were 47 \((\text{SD} \ 10)\) and 90 \((\text{SD} \ 10)\).

### Discussion

We found similar levels of distal migration of the C-stem femoral component as those reported for the Exeter femoral component by Alfaro-Adrian et al\(^3\) and Stefandsdottir et al.\(^7\) In the latter study, the bone cement and the cementing and RSA techniques were the same as ours. In the study by Alfaro-Adrian et al,\(^3\) Simplex bone cement was used and the RSA technique differed in that rotation was based upon a geometric model of the implant and not on markers fixed to it. In our study the levels of posterior migration and retroversion were higher than reported for both tapered femoral components and other designs investigated in earlier RSA studies into cemented primary hip arthroplasties.\(^3,5,15,18,19\) The degree to which a femoral component can migrate distally, or rotate without failing, remains unknown.

When comparing the performance of different types of femoral component, migration and rotation are just two features; other important aspects are shape and surface finish.\(^2,20\) It has been suggested that the distal migration of the tapered Exeter stem is beneficial because radial compressive forces are created in the adjacent bone cement and transferred to the bone as hoop stresses.\(^21\) The stem-cement interface is thereby sealed off, preventing access of fluid from the joint space.\(^7\) Similar mechanisms have been suggested for the C-stem where, in 20% of 500 cases, there was a subjective radiological improvement of the bone-cement interface in the proximal femur.\(^10\) Comparing the radiographic appearance in patients receiving C-stem and Exeter femoral components, Ek and Choong\(^12\) found no differences up to five years.

The mean retroversion at two years was higher than the mean 1.12° retroversion reported by Alfaro-Adrian et al\(^3\) at two years or the median 1.2° from Stefandsdottir et al\(^7\) at two years. Both these studies reported on the Exeter femoral component. The changes in retroversion in our study occurred during the initial three-month phase, although the rate of on-going rotation into retroversion thereafter was very similar to the series reported by Stefandsdottir et al\(^7\) for the Exeter component. In their study, the retroversion stabilised after two years. At present we have no knowledge of what might happen with posterior rotation of the C-stem after the first two years. For those prostheses which were not designed to subside, the Charnley-Elite femoral component (DePuy) showed a mean retroversion of 1.29° at two years\(^3\) and the Lubinus SPII (Waldemar LINK GmBH & Co., Hamburg, Germany) a median retroversion of 0.2° at two years.\(^19\) The Exeter femoral component appears to stabilise as it migrates distally, but the C-stem does not show this pattern up to two years and does not, therefore, appear to be more stable than the Exeter femoral component, suggesting that the triple-tapered design has no advantages at this stage of follow-up. However, it may be that this design can tolerate such a migration pattern without risk of subsequent loosening.

We have described the migration pattern of the C-stem femoral component up to two years after surgery. We have found the distal migration inside the cement mantle to be similar to that for the tapered Exeter femoral component, but larger than for other types of cemented implants which are not designed to subside. The posterior rotation and migration were higher than previously reported for cemented prostheses. It is not clear from our early results whether these findings are compatible with a durable, long-term clinical performance. We will continue to follow-up our patients and will report on them in due course.

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### References