The use of hydroxyapatite-coated CAD-CAM femoral components in adolescents and young adults with inflammatory polyarthritis

TEN-YEAR RESULTS

Between June 1991 and January 1995, 42 hydroxyapatite-coated CAD-CAM femoral components were inserted in 25 patients with inflammatory polyarthritis, 21 of whom had juvenile idiopathic arthritis. Their mean age was 21 years (11 to 35). All the patients were reviewed clinically and radiologically at one, three and five years. At the final review at a mean of 11.2 years (8 to 13) 37 hips in 23 patients were available for assessment.

A total of four femoral components (9.5%) had failed, of which two were radiologically loose and two were revised. The four failed components were in patients aged 16 years or less at the time of surgery. Hydroxyapatite-coated customised femoral components give excellent medium- to long-term results in skeletally-mature young adults with inflammatory polyarthritis. Patients aged less than 16 years at the time of surgery have a risk of 28.5% of failure of the femoral component at approximately ten years.

Previous studies have demonstrated the initial benefits of cemented total hip replacement (THR) in adolescents and young adults suffering from inflammatory polyarthritis. However, relatively high rates of early aseptic loosening have been reported. The postulated causes for early failure in these patients include severe osteoporosis, the relatively small size of the femur leading to high torsional stresses per unit area and, in adolescents, continuing diaphyseal bone growth and a high level of immune reaction to foreign material.

Revision of cemented femoral components in such patients is almost inevitable and can be particularly challenging. Not only is the femoral anatomy often atypical, increasing the difficulty of extraction of the cement, but there often is osteopenia with poor bone stock.

The use of uncemented femoral components in young patients with an inflammatory polyarthritis means that cement does not have to be extracted at the time of revision. However, their use has previously been limited because of concerns that osteopenia may lead to femoral fracture during insertion and that a possible mis-match between metaphyseal and diaphyseal sizing may compromise initial stability and fixation. Reports describing the follow-up of uncemented THR in this group of patients have been limited.

We have addressed these problems by using Computer Assisted Design – Computer Assisted Manufacture (CAD-CAM) femoral components (Centre for Biomedical Engineering, Royal National Orthopaedic Hospital, Middlesex, United Kingdom). Customised components maximise the ‘fit and fill’ in the proximal femur at the time of implantation and thereby provide stability for the component ab initio. In addition, the strain pattern in the proximal femur using the CAD-CAM has been found to be closer to normal than with other types of prosthesis which preserve bone mass. In most femoral components used in this study a lateral flare was added to fill the space between the component and the bone of the proximal and lateral part of the femoral canal. The bespoke design also allowed the correction of the marked anteverision of the femoral neck which may be found in patients with juvenile idiopathic arthritis (Fig. 1).

The femoral components were coated with hydroxyapatite (HA) over the proximal third to enhance contact and fixation while the distal part of the stem acted to prevent any toggling. High-crystallisation HA was used with a thickness of 75 µm to 100 µm. The acetabular components were uncemented, porous-coated prostheses.

We describe the results at ten years of the use of consecutive HA-coated CAD-CAM femoral components in adolescents and young adult patients with inflammatory polyarthritis.

Patients and Methods
Between June 1991 and January 1995, 25 patients with inflammatory polyarthritis,
of whom 21 had juvenile idiopathic arthritis, underwent 42 consecutive THRs using HA-coated CAD-CAM femoral components of two types of design (both Centre for Biomedical Engineering). All had been manufactured using measurements derived from CT and standardised radiography. In the first 14 hips, straight-stem femoral components were used, while the subsequent 28 implants had the addition of a proximal lateral flare. This change was made during the study with the theoretical aim of increasing the proximal stability of the femoral component and reducing subsidence.

All the femoral components were modular with a 22 mm cobalt-chrome head. The indication for THR in every case was uncontrolled pain.

The mean age of onset of arthritis was 8 years 9 months (2 years to 23 years). Of the 21 patients who had juvenile idiopathic arthritis, 18 were seronegative (11 systemic, four polyarticular and three extended pauciarticular). Two were seropositive, of whom one had ankylosing spondylitis. A further patient had disseminated lupus erythematosus. Of the 25 patients, 18 were female and seven male.

The mean age at THR was 21 years (11 to 35). Seven patients (14 hips) were aged 16 years or less at the time of the initial THR. Of the 25 patients, eight had unilateral and 17 bilateral THR, making a total of 42 replacements available for the study.

The hips were scored clinically pre-operatively and at one, three, five and approximately ten years after operation using the Hospital for Special Surgery (HSS) system. This allows a maximum of ten points each for pain, range of movement, mobility and function, giving a maximum composite score of 40 points.

### Radiological Assessment
Anteroposterior and lateral plain radiographs of the hip were obtained immediately after operation. Further anteroposterior radiographs were taken at approximately six months and at one, three, five and ten years. They were examined for progressive radiolucencies in each of the Gruen zones, subsidence or migration, formation of heterotopic new bone and stress shielding as shown by resorption of the calcar.

Comparison of the radiographs at three, five and ten years was made with those obtained at one year after operation. Peri-prosthetic radiolucencies were considered to be significant if they were greater than 2 mm. Subsidence was considered to be significant if it was greater than 1 cm. Although this value seems to be rather high, it has been shown to correlate well with clinical outcome.

Heterotopic ossification was assessed according to the classification proposed by Brooker et al. Stress shielding was considered to be present if there had been selective resorption of bone from the medial femoral neck at the calcar.

### Survivorship Analysis
Kaplan-Meier curves were constructed for each femoral component and for each THR. The components were deemed to have failed if revision was required for any reason or if at review the components were radiologically loose.

### Results

**Clinical**
All the 42 hips were reviewed at six months, and at one, three and five years. At the final follow-up, 37 hips in 23 patients had been reviewed at a mean of 11.2 years (8 to 13). One patient (one hip) could not be traced and one patient (two hips) had died. Two femoral components had been revised, one at eight years and one at ten years.
The hip scores were evaluated and the difference in value at each review was compared with the pre-operative score (Fig. 2).

Clinically and radiologically, there was no difference between femoral components with straight stems and those with an additional proximal lateral flare.

**Complications.** There were two per-operative fractures of the calcar that required wiring. A further calcar split was noted but was not considered to be severe enough to require wiring. There was subsidence of one femoral component during the first few post-operative weeks, splitting the proximal femur. At exploration the prosthesis had stabilised. Nevertheless, the proximal femur was reinforced using cerclage wires. The prosthesis remained satisfactory throughout the period of review. Only one hip dislocated at six months, but has been stable subsequently. Two acetabular components were revised for aseptic loosening and three further components were noted to be loose at the final radiological review. One patient remains symptomatic and is scheduled for revision surgery. A total of four hips underwent replacement of the high-density polyethylene acetabular liners, one on two occasions.

**Radiological.** Complete sets of radiographs were available, with the loss of only three. The ten-year films were not available for one patient with bilateral replacements who had died and for one with a unilateral replacement who had been lost to follow-up. The radiological results are based on 39 hips. There was evidence of subsidence of the femoral stem and/or loosening in four hips (10.2%) in three patients (7.6%). These three patients were the youngest at the time of the arthroplasty, aged 11, 12 and 13 years. Of the loose femoral components, two were revised, and two in one patient are asymptomatic. A further patient with a loose femoral component has had a peri-prosthetic fracture which has been plated. Stress shielding was seen in nine hips (23%). Formation of heterotopic new bone was present in approximately half of the hips, but most changes were only Brooker class 1 or 2.

The Kaplan-Meier curves for the femoral component and the THR are shown in Figure 3. The annual percentage success for the femoral component was 83% at between 13 and 14 years and for THR was 71.4% at between 12 and 13 years.

**Age at total hip replacement.** Seven patients (14 hips) were aged 16 years or less at the time of the initial THR (mean 13.7 years; 11 to 16) and were not skeletally mature. The mean follow-up for this group was 10.75 years (9.5 to 13). Four femoral components in three patients had failed, two of which were revised.
A total of 16 patients (25 hips) had the initial operation at a mean age of 24 years (17 to 38). The mean follow-up was 10.9 years (8 to 13). In this group there were no failures of the femoral component.

The difference in the number of failures of the femoral component was compared between the two groups using Fisher's exact test\(^5\) and was found to be highly significant \((p = 0.009)\). The Kaplan-Meier survival estimates for both groups are shown in Figure 4.

**Discussion**

All the patients in our study had chronic inflammatory polyarthropathy. During the period of review, eight underwent major lower-limb surgery. In addition, one is presently scheduled for a total knee replacement and one for a bilateral hind-foot surgery. These patients therefore have disabilities attributable to the musculoskeletal system in addition to the replaced hip. This is reflected in the total scores for pain, range of movement, mobility and function, as shown in Figure 2, despite a successful THR since the patients still have disability in relation to mobility and function.

A review of comparable series of cemented THRs in young adults with inflammatory polyarthropathy shows a high level of loosening of the femoral component.\(^5,6,8,9\) Witt et al\(^6\) reviewed 96 hips with a mean age of 16.7 years at surgery and a mean follow-up of 11.5 years. Of the femoral components 25% were radiologically loose or had been revised. Chmell et al\(^8\) reviewed 66 hips with a mean age of 19.9 years at operation, and a mean follow-up of 12.8 years. Of the femoral components 18% had been revised and 5% of the remaining 35 components were radiologically loose. Maric and Haynes\(^9\) reviewed 13 hips with a mean age of 18 years at surgery, and a mean follow-up of 9.3 years. Of the femoral components, five (38.5%) were radiologically loose, but functioning well. Learmonth et al\(^5\) reviewed 14 hips with a mean age of 16 years at surgery, and a mean follow-up of 8.5 years. Five femoral components (35.7%) were loose.

In these series there are a total of 189 THRs operated on at a mean age of 17.7 years with a mean follow-up of 10.5 years and a rate of failure of 30%, with an end-point of either loosening or revision. Our study of 42 hips with a mean age of 21 years (11 to 35) at surgery, and a mean follow-up of 11.2 years (8 to 13), identified four failures of the femoral component. This represented a rate of failure of 9.5%. Customised femoral components are therefore superior to the cemented femoral components used in the above series. Our own historical short-term series\(^7\) using cemented femoral components in this group of patients identified a failure rate of 11.5% (loose femoral components) in 57 hips, with a mean follow-up of only 4.7 years (1.6 to 9).

Lehtimaki et al\(^26\) reviewed 186 hips in patients with juvenile idiopathic arthritis and found that the survival of the femoral component was 95.6% at ten years and 91.9% at 15 years. However, they used surgical revision as the end-point rather than including cases of radiological loosening as well. These authors noted that their long-term results were better than those of many other series and attributed this to the low number of adolescents in their series. Their mean age at operation was 31 years.

We have tried to analyse if age at the time of surgery, and thereby skeletal maturity, are important factors in the long-term survival of the implant. From our results it is evident that age clearly plays a role in long-term survival since the rate of failure in the group of patients aged under 16 years was 28.5% compared with none in those aged over 16 years.

Learmonth et al\(^5\) noted that although the epiphysis is closed at the time of surgery, growth does still occur, both at the epiphysis by endocartilaginous ossification and at the diaphysis by radial expansion. The bone grows by deposition of new layers of periosteal bone on the outer surface with simultaneous osteoclastic resorption of the endosteal surface. There is thus an increase in both the outer and inner diameters of the shaft. This could be one explanation for the high incidence of loosening in the younger adolescents.

Learmonth et al\(^5\) also postulated that the relatively high immunocompetence at puberty may mediate increased osteoclastic activity in response to the presence of foreign material, thereby leading to failure.

Clearly, these adolescents do suffer considerable pain. If, possible a THR should be delayed until they have achieved skeletal maturity. Soft-tissue release to correct deformity and synovectomy of the hip to reduce pain can perhaps delay the inevitable need for THR for several years.\(^27\)

For patients with inflammatory polyarthropathy over 16 years of age at the time of surgery, HA-coated, uncemented
CAD-CAM femoral components are long-lasting and function well. The results are superior when compared with cemented femoral components.

Supplementary Material

A table showing radiological appearances at follow-up is available with the electronic version of this paper on our website at www.jbjs.org.uk

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References