Excellent results with femoral revision surgery using an extensively hydroxyapatite-coated stem

59 patients followed for 10–16 years

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Background The outcome of femoral component revision with either cemented or proximally coated stems has been disappointing, but revision with extensively coated stems has been promising. We report long- term outcome of a grit-blasted titanium stem entirely plasma sprayed with hydroxyapatite (HA), in femoral revision surgery.

Patients and methods During 1988 to 1993, we performed 66 femoral revisions in 65 patients (49 women) aged mean 58 (28–86) years. 3 patients died before the 10-year follow-up and 4 did not come for the follow-up examination because they had no hip problems, as confirmed by telephone and by a written reply. 1 of these, however, was previously controlled at 10 years. Thus, 59 patients (60 hips) were followed by clinical and radiographic analysis for 10–16 years after femoral stem revision.

Results 1 stem was re-revised due to mechanical failure, and none were revised because of infection. We noticed a low degree of proximal bone loss and a low incidence of distal bone hypertrophy. These observations indicate no significant net transfer of stress proximally to distally, and a somewhat physiological weight distribution from the stem to the femoral bone. The bone changes confirmed a well-fixed femoral component in asymptomatic patients.

Interpretation Our findings indicate good long-term results with a fully HA-coated stem in femoral revision surgery.

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Femoral stem revision in hip arthroplasty is a challenging problem due to loss of proximal bone stock. Furthermore, the bone is frequently sclerotic and smooth, which is not ideal for implant fixation. The results of revision with either cemented or proximally coated stems have been disappointing (Pellicci et al. 1985, Kavanagh et al. 1995, Woolson and Delaney 1995, Malkani et al. 1996, Mulliken et al. 1996, Davis et al. 2003). More successful results have been obtained with extensively coated stems that provide a more distal fixation (Lawrence et al. 1993, Moreland and Bernstein 1995, Krishnamurthy et al. 1997, Paprosky et al. 1999, Moreland and Moreno 2001). There have, however, been concerns about stress shielding and loss of even more bone from the proximal femur.

During the past decades, we have used an extensively hydroxyapatite- (HA-) coated femoral stem in revision surgery. Our hypothesis has been that HA has the potential to improve both proximal and distal bone fixation and to minimize stress shielding. We report our long-term results.

Patients and methods

Patients

In 1988, we started to use an extensively HA-coated femoral component both in primary and revision total hip replacement. The present series consists of 66 consecutive stem revisions in 65 patients (49 women) that were performed during the years

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1988–1993. The mean age at the time of revision was 58 (28–86) years. The diagnoses that had led to the primary total hip prosthesis included developmental dysplasia of the hip (36), osteoarthritis (25), rheumatoid arthritis (1), and there were 4 others (4 patients). The actual revision procedure was the first-time revision in 53 hips, second revision in 11, and third revision in 2. The mean time since the most recent previous operation was 6 (1–16) years.

The diagnoses that led to revision were aseptic loosening (58), secondary stage of infection (Girdlestone hip) (4), pain of unknown origin (3) and periprosthetic femoral fracture (1). The femoral bone stock was classified according to Paprosky and Weeden (2001). Type I femoral defects (7 hips) entail minimal damage to the proximal metaphysis. Type II defects (41 hips) have metadiaphyseal bone damage with an intact diaphysis. Type III defects have significant metadiaphyseal damage, with Type IIIA (11 hips) entailing greater than 4 cm of fit and Type IIIB (6 hips) involving less than 4 cm of fit at the isthmus. Type IV defects (1 hip) are characterized by extensive metadiaphyseal damage with thin cortices and a widened femoral canal.

In 24 hips the revised prosthesis was cemented, and in 42 it was uncemented. 40 hips had revision of both the femoral and acetabular components. In 21 of these, we used a hemispherical HA-coated cup inserted with press-fit, while in 11 hips an HA-coated screw cup was used (Landos Corail, Landanger, Chaumont, France) and in 8 hips we used a hemispherical porous-coated cup inserted with press-fit (HG cup). 26 hips had revision of the stem alone.

Surgery

We used a direct lateral or posterior approach in all patients. In all cases, our policy was to ream the femoral canal to a size that secured primary stability between the stem and the host bone. Gaps between the stem and the host bone were filled with bone chips and morselized bone prior to stem insertion. Autograft bone from the iliac crest was used—either alone (20 cases) or in combination with allograft bank bone (18 cases). We recommended no weight bearing for 3 months postoperatively.

Breakdown of sizes of HA-coated stems used in femoral revision

Size	10	11	12	13	14	15	16	17	18
Primary stems	2	2	7	4	12	8	12	–	1
Revision stems	–	–	4	–	7	–	5	–	2

We used a grit-blasted straight stem made of TiAl6V4 and designed for press-fit insertion (Landos Corail; Landanger, Chaumont, France). The outer surfaces were entirely plasma-sprayed with a 155 ± 35 µm layer of HA. The purity of the HA was reported to be greater than 97%, the density between 1.2 and 1.6 g/mL, the crystallinity greater than 50%, and the porosity less than 10%. The surface roughness of the coating was charcterized by Ra (arithmetical mean roughness value) between 7.5 and 9.5 µm and Rt (maximum profile height) between 50 and 65 µm. The surface roughness of the grit-blasted metal was characterized by Ra between 4 and 6 µm and Rt between 25 and 40 µm. The bonding strength of the coating to the metal was reported to be more than 10 MPa. The technical data were reported by the manufacturer. The stems used are given in the Table. The head was made of stainless steel (Inox) in 57 cases and of Al2O3 (Biolox) in 9. The head diameter was 28 mm in 25 cases and 32 mm in 41.

Follow-up

During follow-up, 3 of the hemispherical HA-coated cups and 1 of the porous-coated cups were revised after 10–13 years due to mechanical failure. 6 patients died (6 hips), but the last follow-up examination for 3 of these patients was between 11 and 13 years after revision; thus, these patients were included. Furthermore, 4 did not attend the follow-up examination because they had no hip problems, as confirmed by telephone and by a written reply. However, 1 of these had been controlled previously at 10 years. Thus, 59 patients (60 hips) were followed for 10–16 years after femoral stem revision. The clinical examination concentrated on thigh pain—graded by the patient on a scale from 1 (worst pain) to 6 (no pain) according to Charnley scores.

Radiographic evaluation included assessment of bone remodeling, osteolysis and fixation of the stem. All radiographs were evaluated by the same radiologist (RBG). Subsidence of the femoral component was determined by the vertical distance from the tip of the trochanter to the lateral shoulder of the prosthesis, considering subsidence of more than 5 mm as being significant. This limit of migration was arbitrarily set, but was based on analysis of manual measurements of migration of hip prostheses (Malchau et al. 1995). Alignment of the femoral component was classified as valgus (the tip of the stem engaged the medial cortex), neutral or varus (the tip of the stem engaged the lateral cortex). Femoral region analysis was performed as described by Gruen et al. (1979). The status of the biological fixation of the stem was assessed by a modification of the criteria described by Engh et al. (1987). Radiographic bony incorporation was defined as extensive intimate bone-implant contact, periprosthetic bone formation and remodeling, and the abscence of migration. Femoral remodeling was assessed as a change in bone density, either as cortical or endosteal bone formation. A decrease in bone density was recorded as atrophy and an increase as hypertrophy. Radiodense lines that roughly paralleled the surface contour of the implant, but were separated from it by a total radiolucent zone (line) of varying thickness, were classified as fibrous ingrowth. Focal area of cortical or trabecular bone loss was considered to be evidence of osteolysis (Zicat et al. 1995).

Results

During surgery, proximal fractures of the femoral bone occurred in 8 hips while inserting the stem in a press-fit situation. All the fractures were stabilized with metallic cerclages. At 3 months after revision, 1 male patient sustained a fall that led to a fracture below the tip of the stem. This was treated by a plate and screws, with uneventful union.

1 stem was revised after 1 year due to mechanical failure. The femoral defect was the one classified as Type IV, and a proximal fracture occurred when inserting the prosthesis. The fracture was stabilized by cerclages, but primary stability of the stem could not be achieved. Postoperative controls revealed increasing subsidence and pain, and at re-revision the stem was loose. No other stems were revised, either because of mechanical loosening or infection.

Stem subsidence exceeding 5 mm was found in 2 hips, the one with ultimate loosening and in another patient with a Type IIIB defect. In this patient, the stem stabilized in the subsided position. Radiolucency adjacent to the stem with a thickness of 1–6 mm was found in 31 hips in Gruen region 1 and in 5 in region 7. Bone atrophy was found in 7 hips in Gruen region 1, in 2 in region 2 and in 9 in region 7. Bone hypertrophy, most often in the form of endosteal condensation around the tip of the stem, was found in 20 hips in Gruen region 4. In 2 hips, bone hypertrophy in region 5 was associated with a varus position of the stem. Osteolysis was found in 5 hips in Gruen region 1 and in 3 in region 7. No patients suffered from significant thigh pain; the pain score was 5 in 7 patients and 6 in the other patients.

Discussion

Successful femoral reconstruction with an uncemented stem requires immediate axial and rotational stability, and the prosthesis must be in intimate contact with the host bone to promote osseointegration for permanent stability. Our results indicate that we obtained stability and osseointegration by the use of a cementless HA-coated stem. The tapered nature of the stem allows it to gain axial and rotational stability, but with the risk of fracturing weakened bone stock. However, cerclage of the fractures ensured reliable adaptation between the host bone and implant.

In 18 of 66 femoral revisions we used a stem designed for primary insertion. In Paprosky type I and type II femurs, such a stem provides reliable initial fixation. In patients with substantial femoral bone loss (Paprosky type III and type IV), a longer revision stem for better diaphyseal fit increases the surface area of fresh bone in contact with the stem for osseointegration. During recent years, we have used a long stem designed for very distal fixation in Paprosky type IV defects. With only a few cases followed for less than 10 years, the results are promising.

Poor bone stock is a risk factor in femoral revision, and requires bone grafting. Bone grafts mainly serve two functions: osteogenesis and mechanical support, which are essential in uncemented solutions. We reconstructed cavitary or contained defects using morselized bone. In type I revisions, bone grafting was hardly needed. In type II revisions, autograft was used for filling cavitary defects. In most type III and type IV revisions, additional use of strut grafts and allografts was required for reconstruction of segmental bone loss.

The results of cemented revision of femoral stems have in general been poor, but with the use of modern cementing techniques the results have been improved. Still, the rate of femoral loosening is reported to range from 6% to 36% at about 10 years (Rubash and Harris 1988, Katz et al. 1995, Mulroy and Harris 1996, Hultmark et al. 2000, Haydon et al. 2004). A likely explanation for the high rate of mechanical failure in cemented femoral revision is that it is difficult to obtain good cement interdigitation with sclerotic bone.

Femoral impaction allografting with cement has the potential to restore bone stock (Leopold et al. 2000). Although differences in inclusion criteria, surgical technique and clinical assessment make analysis of published results somewhat difficult, the short-term to intermediate-term results with this technique are promising. In series with severe bone deficiency, impaction allografting has femoral failure rates from 9% to 12% at 2- to 4-year minimum follow-up (Meding et al. 1997, Leopold et al. 1999). The failure rate has been lower in series that excluded some of the more severe cases of bone loss (Gie et al. 1993, Mahoney et al. 2005). In a series of 207 patients (226 hips), survivorship at 10–11 years with aseptic femoral loosening as the endpoint was 99% (Halliday et al. 2003). However, in another 10 patients a further surgical procedure had to be carried out for femoral fracture. Impaction allografting is demanding and time consuming, and major complications such as intraoperative and postoperative femoral fractures and prosthetic dislocations occur (Leopold et al 2000). Furthermore, the importance of stem subsidence remains a controversial issue. Some investigators have hypothesized that subsidence is necessary or beneficial for graft incorporation (Gie et al. 1993, Elting et al. 1995), while others have implicated it as the cause of complications—including thigh pain, cement mantle fracture and hip dislocation (Eldridge et al. 1997, Meding et al. 1997). At the present time, then, substantial questions remain regarding the durability of impaction allografting and the rather high rate of complications as compared with cementless revision with extensively porous-coated stems that have shown excellent durability, relatively few complications and good long-term results (Leopold et al. 2000). Instability in only 2–7% of cases has been reported after 7–13 years (Lawrence et al. 1993, Moreland and Bernstein 1995, Krishnamurthy et al. 1997, Paprosky et al. 1999, Moreland and Moreno 2001). However, concerns regarding proximal stress shielding with extensively coated stems still exist (Paprosky et al. 1999, Moreland and Moreno 2001).

Postmortem analyses have reported an early and extensive bone deposition over HA coating (Bauer et al. 1991, Hardy et al. 1991, Søballe et al. 1991 Furlong 1993, Kärrholm et al. 1994, Coathrup et al. 2001) as compared to porous and grit-blasted coatings. Although none of these studies have specifically addressed femoral component revision, they support the notion that HA coating has the potential to increase bony ingrowths and minimize stress shielding. In a recent clinical report, Crawford et al. (2004) found an overall failure rate of 2% with an extensively HA-coated stem in revision surgery. No evidence of stress shielding was seen in 78% of the patients. However, the follow-up time was only 2–5 years.

Radiolucency adjacent to prostheses has been correlated histologically with a fibrous layer between the bone and the prosthesis (Engh et al. 1987, Pidhorz et al. 1993). We found radiolucent lines adjacent to the stem in 36 hips, all located proximally and mostly limited to the lateral region of the stem. The central and distal regions of the prostheses were otherwise well osseointegrated.

Thigh pain has been a considerable problem in both proximally and fully coated uncemented stems, which is thought to indicate distal stress transfer to cortical bone. Cortical hypertrophy around the distal part of an uncemented press-fit stem has been reported in two thirds of the hips by Amstutz et al. (1989). In our study, no patient had significant thigh pain, and the absence of radiolucent lines in the diaphysis suggests a comprehensive diaphyseal bonding. Furthermore, new bone formation adjacent to the prosthesis was associated with only a moderate degree of bone remodeling. The low degree of proximal bone loss that we found in our study and a very low incidence of distal cortical hypertrophy indicate that there was no significant net transfer of stress proximally to distally, and a somewhat physiological weight distribution from the stem to the femoral bone.

Author contributions

OR: clinical analysis. RBG: radiographic analysis.

No competing interests declared.

Amstutz H C, Nasser S, More R C, Kabo J M. The anthropometric total hip femoral prosthesis; preliminary clinical and roentgenographic findings of exactfit cementless application. Clin Orthop 1989; (242): 104-19.

Bauer T W, Geesink R C T, Zimmerman R, McMahon J T. Hydroxyapatite-coated femoral stems. Histological analysis of components retrieved at autopsy. J Bone Joint Surg (Am) 1991; 73: 1439-52.

Coathup M J, Blunn G W, Flynn N, Williams C, Thomas N P. A comparison of bone remodeling around hydroxyapatite-coated, porous-coated and grit-blasted hip replacements retrieved at post-mortem. J Bone Joint Surg (Br) 2001; 83: 118-23.

Crawford C H, Malkani A L, Incavo S J, Morris H B, Krupp R J, Baker D. Femoral component revision using an extensively hydroxyapatite-coated stem. J Arthroplasty 2004; 19: 8-13.

Davis C M, Berry D J, Harmsen W S. Cemented revision of failed uncemented femoral components of total hip arthroplasty. J Bone Joint Surg (Am) 2003; 85: 1264-9.

Eldridge J D, Smith E J, Hubble M J, Whitehouse S L, Learmont I D. Massive early subsidence following femoral impaction grafting. J Arthroplasty 1997; 12: 535-40.

Elting J J, Mikhail W E, Zicat B E. Preliminary report of impaction grafting for exchange femoral arthroplasty. Clin Orthop 1995; (319): 167-9.

Engh C A, Bobyn J D, Glassman A H. Porous-coated hip replacement; the factors governing bone in-growth, stress shielding and clinical results. J Bone Joint Surg (Br) 1987; 69: 45-55.

Furlong R J. Six years use of the unmodified furlong hydroxyapatite ceramic coated total hip replacement. Acta Orthop Belg 1993; 59: 323-9.

Gie G A, Linder L, Ring R S. Impacted cancellous allografts and cement for revision total hip arthroplasty. J Bone Joint Surg (Br) 1993; 75: 14-21.

Gruen T A, McNeice G M, Amstutz H C. ”Modes of failure” of cemented stem-type femoral components: a radiographic analysis of loosening. Clin Orthop 1979; (141): 17-27.

Halliday B R, English H W, Timperley A J, Gie G A, Ling R S. Femoral impaction grafting with cement in revision total hip replacement. Evolution of the technique and results. J Bone Joint Surg (Br) 2003; 85: 809-17.

Hardy D C, Frayssinet P, Guilhem A, Lafontaine M A, Delince P E. Bonding of hydroxyapatite-coated femoral prostheses: histopathology of specimens from four cases. J Bone Joint Surg (Br) 1991; 73: 732-40.

Haydon C M, Mehin R, Burnett S, Rorabeck C H, Bourne R B, McCalden R W, MacDonald S J. Revision total hip arthroplasty with use of a cemented femoral component. Results at a mean of ten years. J Bone Joint Surg (Am) 2004; 86: 1179-85.

Hultmark P, Kärrholm J, Strömberg C, Herberts P, Mose C H, Malchau H. Cemented first-time revisions of the femoral component: prospective 7 to 13 years' follow-up using second-generation and third-generation technique. J Arthroplasty 2000; 15: 551-61.

Kärrholm, J, Malchau, H, Snorrason F, Herberts P. Micromotion of femoral stems in total hip arthroplasty: a randomized study of cemented, hydroxyapatite-coated and porous-coated stems with roentgen stereophotogrammetric analysis. J Bone Joint Surg (Am) 1994; 76: 1692-705.

Katz R P, Callaghan J J, Sullivan P M, Johnston R C. Results of cemented femoral revision total hip arthroplasty using improved cementing techniques. Clin Orthop 1995; (319): 178-83.

Kavanagh B F, Ilstrup D M, Fitzgerald R H Jr. Revision total hip arthroplasty. J Bone Joint Surg (Am) 1995; 67: 517-26.

Krishnamurthy A B, MacDonald S J, Paprosky W G. 5- to 13-year follow-up study on cementless femoral components in revision surgery. J Arthroplasty 1997; 12: 839-47.

Lawrence J M, Engh C A, Macalino G E. Revision total hip arthroplasty: long-term results without cement. Orthop Clin North Am 1993; 24: 635-44.

Leopold S S, Berger R A, Rosenber A G. Impaction allografting with cement for femoral component revision: minimum four-year follow-up using a precoated femoral stem. J Bone Joint Surg (Am) 1999; 81: 1080-92.

Leopold S, Jacobs J J, Rosenberg, Stevenson S, Gorss A. Cancellous allograft in revision total hip arthroplasty: a clinical review. Clin Orthop 2000; (337): 86-97.

Mahoney C R, Fehringer E, Kopjar B, Garvin K L. Femoral revuision with impaction grafting and a collarless, polished tapered stem Clin Orthop 2005; (432): 181-7.

Malchau H, Kärrholm J, Xing Wang Y, Herberts P. Accuracy of migration analysis in hip arthroplasty. Acta Orthop Scand 1995; 66: 418-24.

Malkani A L, Lewallen D G, Cabanela M E, Wallrichs S L. Femoral component revision using an uncemented, proximally coated, long stem prosthesis. J Arthroplasty 1996; 11: 411-8.

Meding J B, Ritter M A, Keating E M, Faris P M. Impaction bone grafting before insertion of a femoral stem with cement in revision total hip arthroplasty: a minimum two-year follow-up study. J Bone Joint Surg (Am) 1997; 79: 1834-41.

Moreland A J R, Bernstein M L. Femoral revision hip arthroplasty with uncemented, porous-coated stems. Clin Orthop 1995; (319): 141-50.

Moreland J R, Moreno M A. Cementless femoral revision arthroplasty of the hip: minimum 5 years followup. Clin Orthop 2001; (393): 194-201.

Mulliken B D, Rorabeck C H, Bourne R B. Uncemented revision total hip arthroplasty: a 4- to-6 year review. Clin Orthop 1996; (325): 156-62.

Mulroy W F, Harris W H. Revision total hip arthroplasty with use of so-called second-generation cementing techniques for aseptic loosening of the femoral component. A fifteen-year-average follow-up study. J Bone Joint Surg (Am) 1996; 78: 325-30.

Paprosky W G, Weeden S H. Extensively porous-coated stems in femoral revision arthroplasty. Orthopedics 2001; 24: 871-2.

Paprosky W G, Greidanus N V, Antoniou J. Minimum 10-year-results of extensively porous-coated stems in revision arthroplasty. Clin Orthop 1999; (369): 230-42.

Pellicci P M, Wilson P D Jr, Sledge C B, Salvati E A, Ranawat C S, Poss R, Callaghan J J. Long-term results of revision total hip replacement. A follow-up report. J Bone Joint Surg (Am) 1985; 67: 513-6.

Pidhorz L E, Urban R M, Jacobs J J, Sumner D R, Galante J O. A quantitative study of bone and soft tissues in cementless porous-coated acetabular components retrieved at autopsy. J Arthroplasty 1993; 8: 213-25.

Rubash H E, Harris W H. Revision of nonseptic, loose, cemented femoral components using modern cementing techniques. J Arthroplasty 1988; 3: 241-8.

Søballe K, Gotfredsen K, Brockstedt-Rasmussen H, Nielsen P T, Recknagel K. Histologic analysis of a retrieved hydroxyapatite coated femoral prosthesis. Clin Orthop 1991; (272): 255-8.

Woolson S T, Delaney T J. Failure of proximally porous-coated femoral prosthesis in revision total hip arthroplasty. J Arthroplasty 1995; 10: S22-28.

Zicat B, Engh C A, Gokcen E. Patterns of osteolysis around total hip component inserted with and without cement. J Bone Joint Surg (Am) 1995; 77: 432-9.