Analysis of the retrieved hip after revision with impaction grafting

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Submitted 00-12-28. Accepted 01-04-13

A 77-year-old man with essential hypertension, cardiovascular problems, chronic glomerulonephritis and marked osteoporosis had a cemented primary total arthroplasty of his right hip in 1980 for arthrosis. In 1988, the femoral component was revised with an uncemented stem (Anatomic Medullary Locking (AML); DePuy, Warsaw, IN). In 1992, the hip became painful and osteolytic lesions around the stem in the proximal femur were found. He underwent a new revision with impaction bone grafting (Slooff et al. 1984) (Figure 1). The stem was found to be rotationally unstable. There were no clinical signs of infection; gram stains and intraoperative cultures were negative. It was very difficult to extract the stem. The collar had to be removed with a high-speed burr and the interface between the implant and bone was broken with flexible osteotomes before the stem could be removed. The proximal femur was markedly osteoporotic with massive osteolysis. A comminuted fracture of the proximal femur occurred and was fixed with a reconstruction plate, screws and multiple cerclage wires. The femoral canal was debrided and thoroughly irrigated with jet lavage. Frozen allografts composed of a distal femur with the medial and lateral femoral condyles and a femoral head were morselized and impacted into the femoral canal (Nelissen et al. 1995). The old polyethylene cup was revised to an uncemented press-fit cup supported by two screws. A cemented collarless polished tapered femoral stem (CPT; Zimmer Corp., Warsaw, IN) was then cemented into the impacted bone graft in the femoral canal. After 8 weeks, full weight bearing was allowed. Postoperatively, the patient did well. His hip was painfree with good mobility and no leg length discrepancy. He walked an unlimited distance without support. Routine radiographic examination revealed no measurable subsidence of the femoral compo-

Figure 1. The right hip with the loose AML stem before revision.

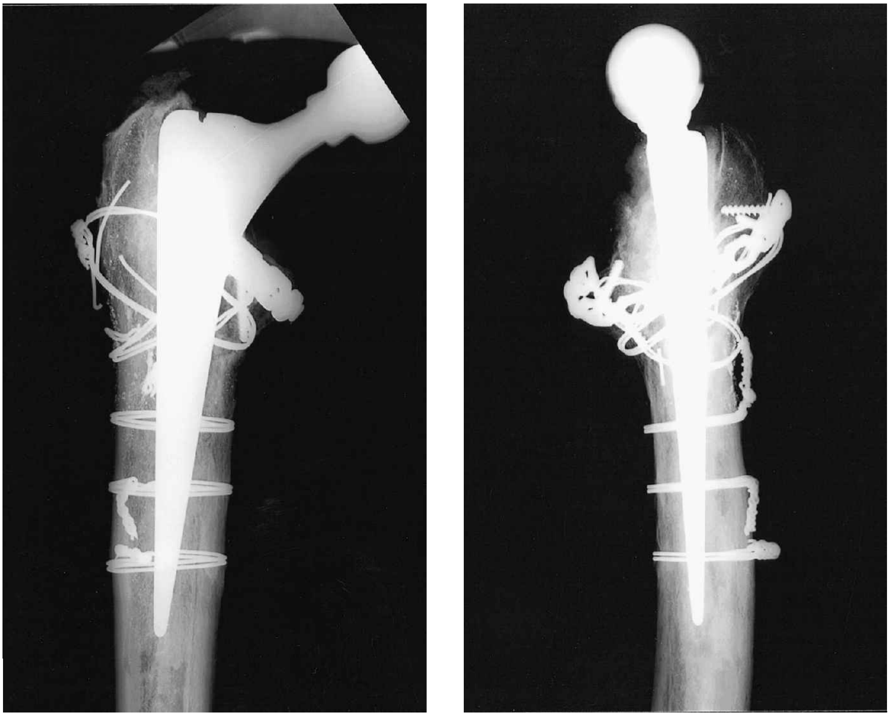

Figure 2. The retrieved femur with the CPT femoral component.

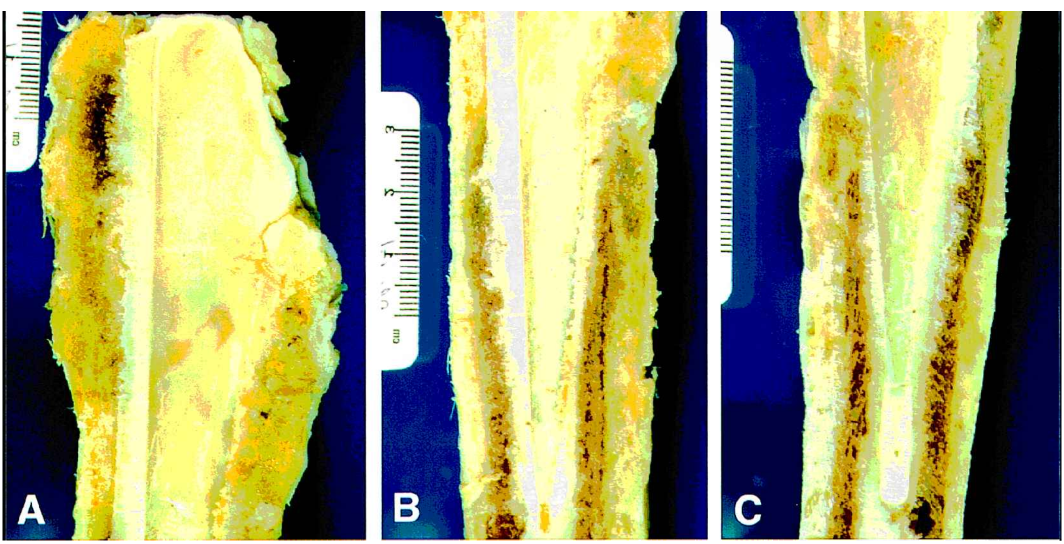

Figure 3. Photograph of the longitudinally-sectioned specimen showing the cortex, the impacted partially remodeled bone graft which in the medial proximal part mostly consisted of fibrous tissue and the cement mantle. A the proximal part, B the middle and C the distal part of the specimen.

nent. 3 years later, he died suddenly of a myocardial infarction. Before his death, the patient's consent had been obtained to retrieve and examine his hip.

After fixation, the femur was radiographed and photographed (Figure 2). The implant was extracted from the femur without difficulty and an endoscope was used to visualize and photograph the

Figure 4. Endoscopic view of the cement mantle showing an intact mantle without cracks.

inner cement mantle. The femur was then bisected longitudinally close to the frontal plane so that the resulting two segments would be oriented similarly to an anteroposterior radiograph. The cement mantle was measured in this plane and the femur was radiographed and photographed (Figure 3). 44 transverse cuts of the two bisected segments of proximal femur were then made, radiographed and representative sections decalcified for routine histology. Adjacent sections were embedded in plastic for un-decalcified processing.

Retrieval analysis

At the time of retrieval, there were no radiographic signs of loosening, and the stem was judged as stable by manual manipulation. The femoral component was removed and did not seem to have been bonded to the cement. Endoscopic evaluation of the proximal femur showed an intact cement mantle without evidence of cracks (Figure 4). The cement mantle measured 163 mm from the proxi-

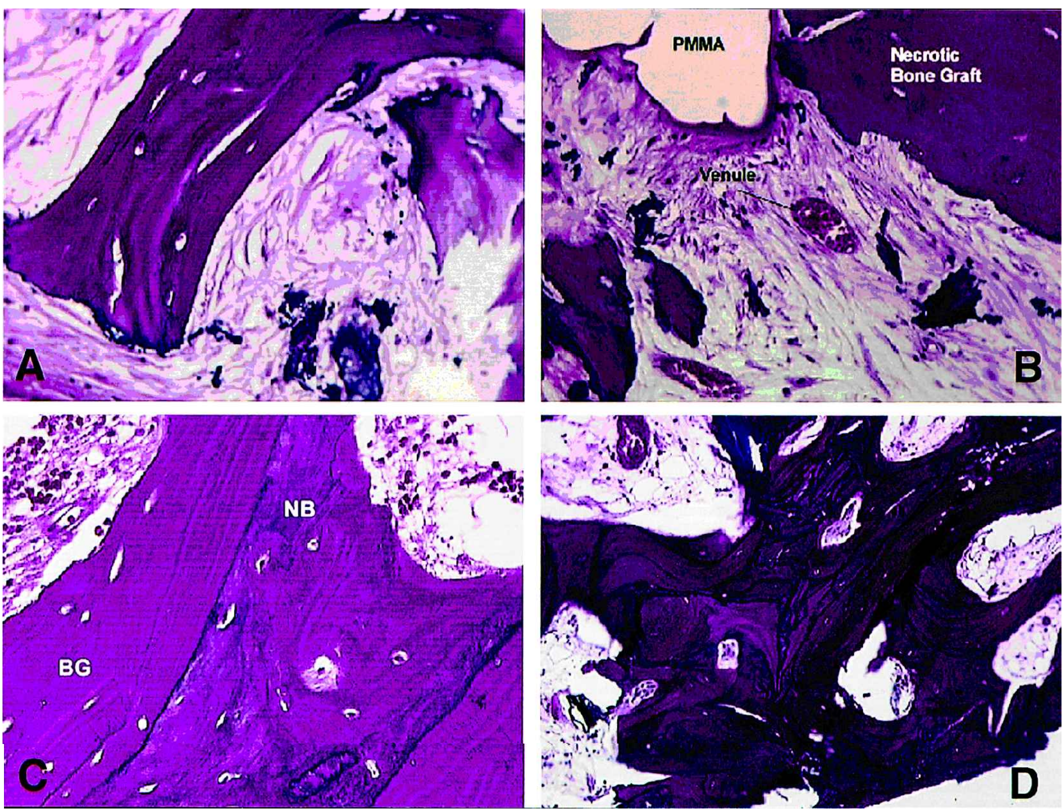

Figure 5. High magnification photomicrograph of
A. Zone I. Necrotic bone graft and fibrosis
B. The inner zone consisting of bone cement (PMMA), blood vessels, fibrous tissue and necrotic bone graft.
C. Zone II. Necrotic bone graft undergoing creeping substitution. BG bone graft. NB new bone.
D. Zone II. Revascularized necrotic bone graft undergoing creeping substitution.

mal-lateral part of the implant to the tip of the centralizer. The thickness of the cement mantle was measured in 10 mm increments. It was especially thin at the proximal medial site (1 mm), and varied between 2 and 6 mm in thickness, with the thickest part located on the distal-lateral side of the stem. Adjacent to the cement was an inner zone of mostly necrotic trabecular graft bone, blood vessels and cement. This zone was surrounded by a zone of organizing bone graft often showing areas of creeping substitution consistent with gradual graft incorporation. Vascularized fibrous tissue was present around some of the incorporating bone graft fragments, but no continuous fibrous membrane was found (Figure 5). A linear band of condensation was present similar to the "neo-cortex" previously described around conventionally-cemented stems marking the periphery of the impacted graft (Jasty et al. 1990, Nelissen et al. 1995, Mikhail et al. 1999). Peripherally to this "neo-cortex" was a zone of histologically viable trabecular bone and cortex. These zones were not circumferential, but could still be seen in the proximal, mid, and distal sections of the specimen. The bone graft had not remodeled consistently. Much of the graft distally appeared to have remodeled while the proximal medial wall, especially the area under the reconstruction plate, consisted of fibrous tissue and fragments of necrotic bone without incorporation (Figure 6).

Specimen radiographs showed metal beads in the cortex, suggesting that debris from previous implants had not been completely removed. Within the cortex we found macrophages containing small particles of metal debris probably from the previous implants. There were areas of transmural defects suggesting that the fracture had not healed completely. In these defects, macrophages were present as well as small particles of implant wear debris. Macrophages apparently had migrated through the cortical defect and were seen beneath the periostium superior and inferior to the defect. In the impacted bone graft, pieces of nonvascularized fibrous tissue and pieces of cartilage without evidence of remodeling or incorporation were also found.

Figure 6. Radiograph of a transverse section of the specimen at the level of the calcar showing host bone cortex, impacted partially remodeled graft and vascularized fibrous tissue in the calcar region.

Discussion

Although some investigators have shown excellent clinical results with the use of impaction grafting for revision arthroplasty (Slooff et al. 1984, Gie et al. 1993, Ling et al. 1993), others have reported less consistent results (Jazrawi et al. 1999). Controversies associated with impaction allografting for revision femoral arthroplasty include the presence or absence of "bonding" of the stem to the cement, the most appropriate thickness of the mantles of cement and bone graft, the optimal size of morselized graft particles and the optimal compressive force applied during bone graft impaction. Moreover, some authors have questioned whether impacted bone graft can ever achieve the revascularization ultimately necessary for new bone formation.

8 proximal femora retrieval samples that had undergone revision arthroplasty with impaction grafting have been reported (Ling et al. 1993, Ullmark and Linder 1998, Linder 2000). Ling and co-workers (1993) analyzed the proximal femur retrieved from a patient who died 3.5 years after cemented revision arthroplasty with impaction grafting. They described three zones: "regenerated cortical bone", "interface zone", and "deep layer". The layer closest to the implant contained necrotic bone enveloped in cement, while the intermediate zone showed direct contact between methyl methacrylate and osteoid with scattered foreign body type giant cells. No direct contact between viable mineralized bone and cement was visualized. The outer zone contained histologically normal cortex and fatty bone marrow with a few islands of dead bone. Ullmark and Linder (1998) described a proximal femur retrieved 6 months after a cemented revision arthroplasty, using a standard Charnley stem and impaction grafting. They found that almost all of the graft had been revascularized, with pieces of dead bone graft embedded in fibrous stroma. Bone remodeling with new bone formation had proceeded from the periphery to less than 0.5 mm from the cement. Linder (2000) reported his observations on 6 autopsy femurs and 8 biopsies. His findings were very similar to ours. Besides the above 8 autopsy retrievals, we previously reported the evaluation of proximal femur biopsies that had been obtained at the time of removal of trochanteric wires from 4 patients, 11–27 months after revision arthroplasty with impaction grafting (Nelissen et al. 1995, Mikhail et al. 1999). These cases also documented histologically viable bone with evidence of graft remodeling.

Histologic evaluation of the present, clinically satisfactory revision arthroplasty specimen showed variable bone graft incorporation 3 years after insertion. In some regions, especially distal, we identified three ill-defined histologic zones: 1) an inner zone consisting of bone cement, vascularized fibrous tissue, and fragments of necrotic bone graft, some of which showed evidence of "creeping substitution", partially necrotic trabeculae, 2) a middle zone containing mostly viable trabecular bone and an incomplete peripheral "neo-cortex", and 3) an outer zone composed of viable cortex. The bone graft had not remodeled consistently. This finding was similar to results reported by Ullmark and Linder (1998), who detected more graft incorporation distally than proximally, although they found a faster rate of graft incorporation than seen in our case. Many factors probably influence the pattern and rate of allograft incorporation, including the immunologic compatibility of the allograft, the size and porosity of impacted graft particles, the thickness and tightness of the graft, the direction and magnitude of mechanical load applied to the graft, the vascularity of the host bed, and the overall capacity of the host to form new bone (Stevenson et al. 1996, Bauer and Muschler 2000, Tägil 2000). During revision, it seems desirable to remove as much of the inflammatory membrane as possible. We also noted in this femur the presence of several pieces of hyaline cartilage, undoubtedly of bone graft origin. These fragments showed no evidence of associated bone formation and emphasize the importance of removing cartilage from the allograft as completely as possible. We also have clear evidence of revascularization of the impacted allograft even in areas where there was minimal new bone formation.

The issue of bonding between the implant and the cement has been considered important to obtain and maintain stable fixation (Harris 1992, Verdonschot and Huiskes 1996). The good clinical result in this case suggests that neither complete bone graft incorporation, nor a thick cement mantle are required, so long as the construct achieves satisfactory stability.

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