Arthroplasty Rounds

METALLIC WEAR DEBRIS IN ACETABULAR OSTEOLYSIS IN A MECHANICALLY STABLE CEMENTLESS TOTAL HIP REPLACEMENT: REPORT OF A CASE

Michael H. Huo, MD*
Foster Betts, PhD†
George P. Bogumill, MD§
Peter I. Kenmore, MD§
Richard J. Hayek, MD§
Thomas J. Martinelli, MD§

Wear debris has evolved as the primary etiology of mechanical loosening of cemented as well as uncemented total hip arthroplasty. Osteolysis results from particle formation, and this has been most commonly reported to be secondary to polyethylene wear debris. This article demonstrates that metallic particle debris will also result in significant osteolysis. The two sources in this case are cobalt-chromium (Co-Cr) particles from the acetabular component and titanium-alloy (Ti) particles from the Morse taper junction and the Ti-alloy femoral head. However, it is likely that polyethylene debris also contributed to the osteolysis, because a titanium head was used and we know this results in increased poly wear.

Arnold T. Berman, MD

Fixation loosening remains the leading long-term concern in patients following total hip replacement (THR). Recent data have suggested that wear and corrosion of prosthetic implants have become increasingly important in contributing to the failure of THR. Petrov, Petrov, and Petrov.1,2 Significant osteolysis has been reported around the femoral component in both loose and well-fixed cemented THR.3,6 Furthermore, it has been recently reported in well-fixed cementless THR.7 Osteolysis around the acetabular component, however, has been infrequently reported in cemented and cementless THR.8,9 All of these cases were associated with prosthetic loosening. We report a case of significant acetabular osteolysis in a mechanically stable cementless THR.

CASE REPORT
A 41-year-old woman with the diagnosis of idiopathic osteonecrosis of the right hip underwent a cementless THR at another institution in November 1985 (Figs 1-2). The acetabulum was reconstructed using a press-fit, Co-Cr porous coated component with fixation spikes (DePuy, Warsaw, Ind.). The femur was reconstructed using a Ti, proximally porous-coated component with a Ti-alloy 32-mm head (Biomet, Warsaw, Ind.).

The patient did well until late 1990, when she started experiencing intermittent pain in the right groin with long distance walks and stair climbing. There was no history of trauma. She had no local or systemic signs of infection. Radiographs taken in January 1991 showed a massive osteolytic lesion in zone 1 of the acetabulum (Fig 3). The dimensions of the

From the *Orthopedic Center for Joint Reconstruction, Waterbury Hospital Health Center, Waterbury, Conn and the Department of Orthopaedics and Rehabilitation, Yale University School of Medicine; †Department of Biomechanics, Metal Analysis Laboratory, The Hospital for Special Surgery, New York, NY; and §Department of Orthopedic Surgery, Georgetown University School of Medicine, Washington, DC.

Reprint requests: Peter I. Kenmore, MD, Dept of Orthopedic Surgery, Georgetown University School of Medicine, 3800 Reservoir Rd NW, Washington, DC 20007.
lesion were 3.0 cm × 2.5 cm measured on the anterior-posterior (AP) radiograph, corrected for a 20% magnification. A comparison to radiographs taken in November 1986 was undertaken. There was no migration of the cup as measured by the criteria described by Yoder et al. The femoral component was well fixed radiographically.

Workup at that time included a bone scan and computerized tomography (CT). Bone scan demonstrated increased uptake in the delayed phase in zone 1 of the acetabulum. Increased uptake was also observed in zones 1, 4, and 7 of the femoral component in the AP projection. CT scan demonstrated significant defect with lateral cortical breakthrough in the dome of the acetabulum (Fig 4).

The patient was referred to our institution in April 1991 for further workup and treatment. A neoplastic process remained a differential diagnosis. The patient was subsequently scheduled for biopsy and possible revision surgery. Frozen sections of the biopsy specimens did not show any neoplastic or infectious process. Revision surgery was attempted during the same anesthetic session.

There was no gross purulence within the joint or in the lytic lesion. There was no gross metallosis within the pseudocapsule or in the osteolytic lesion. On gross examination, burnishing of the head was observed, and there was no wear of the polyethylene. Circumferential black staining at the Morse taper was also evident. There was no osteolytic process in the proximal femur. The femoral component was mechanically stable by manual testing. The
Fig 5: High-power photomicrograph demonstrating intracytoplasmic metallic debris in the histiocytes (Hematoxylin-eosin stain, 250×).

acetabular component was remarkably stable. Multiple attempts were made to displace the cup without success. There was absolutely no motion at the bone-prosthesis interface under direct visual inspection.

The lytic lesion was completely curetted to bleeding cancellous bone. The cavity involved approximately 20% of the outer surface of the acetabular component. There was no gross evidence of bead shedding or burning of the outer surface of the acetabular component. Due to the mechanical stability of the component, the attending surgeon elected to fill the cavity with methylmethacrylate. The cup was not a modular design; therefore, the polyethylene could not be exchanged. A new Co-Cr head was placed onto the Morse taper.

The patient had an uneventful postoperative course. She was ambulating without pain 2 years after surgery. All cultures were negative for aerobic, anaerobic, fungal, and tuberculosis organisms. Histology of the lytic lesion demonstrated abundant histiocytes with intracytoplasmic metallic debris (Fig 5). Histology of the pseudocapsule showed less intense histiocytic infiltrate; however, metallic debris were also present. Careful review of all the specimen slides using polarized microscopy did not demonstrate any polyethylene fragments. Trace element analysis was performed by atomic absorption spectrophotometry using a Zeeman 5000 graphite furnace (Perkin-Elmer, Norwalk, Conn). The methodology has been described previously.11 Data for trace element analysis are presented in the Table.

**Table**

| METAL ANALYSIS OF TISSUES FROM THE OSTEOLYSIS AND PSEUDOCAPSULE (μg/gm OF DRY TISSUE) |
|-----------------------------------------------|-----------------|-----------------|-----------------|
|                                               | Co              | Cr              | Mo              | Ti              |
| Pseudocapsule                                 | 0.8             | 4.1             | 0.05            | 210             |
| Osteolysis                                    | 605             | 302             | 58.2            | 33              |

implants with fiber-wire pads. Those authors estimated an incidence of 2.9% in their series. No acetabular osteolysis was described among the 16 cases included for that study.

Santavirta et al8 reported osteolysis in six patients with Co-Cr cementless THRs.8 Five of the six cases showed osteolysis in the acetabulum. Location and dimension of the lesions were not specified. Mean interval between primary cementless THR and the onset of osteolysis was 3.2 years. All five cups were loose and revised. Histology showed abundant histiocytes with polyethylene fragments. There was no evidence of metallic debris.

Harris et al described a case of significant acetabular osteolysis in zone 1 in a cemented surface replacement 9 years following the index surgery.9 The cup was mechanically stable but the femoral component was loose on gross examination. Histology demonstrated histiocytic infiltrate with polyethylene debris, but no evidence of metallic debris.

The etiology of osteolysis in THR remains unclear. Many authors attribute this phenomenon principally to foreign body reaction to particulate wear debris. Recently, Schmalzried et al13 reported on the initiating event in the failure mechanism of cemented acetabular components. They concluded that there was a circumferential bone-resorbing membrane formation between bone and cement, extending from the cup periphery toward the dome. Biologically active histiocytes were abundant in this membrane. There were no cement or metallic debris observed on histologic examination. Polyethylene debris were present. The authors, therefore, attributed articulating surface wear and debris generation to be the most important factor in acetabular component failure.

To our knowledge, the only way to assess polyethylene wear debris is by histology. The accuracy of this analysis depends on tissue sampling, preparation, and interpretation. Although we did not observe any evidence of polyethylene debris in our specimens, it is impossible to conclude that polyethylene wear was not a contributing factor in the pathogenesis

**DISCUSSION**

Significant femoral osteolysis in cemented THRs was first observed by Charnley et al.12 It was subsequently characterized by Harris and colleagues.3 It has been reported to occur in 4.6% to 24% of aseptic revisions of cemented THRs.4,6 This entity has been observed by Maloney et al7 in cementless THRs, with both Co-Cr implants with beads, and with Ti-alloy
of this large acetabular osteolytic lesion.

Trace element analysis has been used to quantitate cement and metallic debris in THRs. Two of the authors have also reported metallic debris and trace element analysis in femoral osteolysis in failed cemented THRs. The high Ti level measured in the pseudocapsule in our case was consistent with burningish of the Ti-alloy articulating surface seen on gross examination. Significant controversy still exists in documenting the wear characteristics of Ti-alloy articulating surface in joint prostheses. Although the most severe wear of Ti-alloy implants has been associated with prosthetic loosening, Black et al. reported a case of significant metallosis in a well-fixed cemented Ti-alloy total hip prosthesis. We did not observe any loose beads or bony spicules embedded within the articulating surface on gross examination. However, imperfections within the polyethylene may have initiated the abrasive wear and burningish of the Ti-alloy head in our case. Furthermore, there was metallosis around the Morse taper, which may represent crevice corrosion or fretting. This can also be a source of the metallic debris, as proposed by Collier et al.

The levels of Co and Cr measured in the acetabular osteolysis tissue were among the highest ever recorded in our laboratory for tissues retrieved from Co-Cr total hip implants. The nominal ratio for molybdenum (Mo) to Co for Co-Cr prostheses is 0.1. Our specimen had a ratio of 0.097. The nominal ratio for Cr to Co is 0.45. Our specimen had a ratio of 0.49. Accounting for measurement variability, we are confident that the metallic debris observed within the acetabular osteolysis was due to the Co-Cr acetabular component. Although the acetabular component was mechanically stable, fretting the outer surface against bone in situ could have been possible. The high levels recorded in our case may be due to the porous coating, which greatly increases the surface area. Previous studies conducted in our laboratory were with tissues retrieved from cemented THRs. These high levels of trace elements may explain, in part, the massive osteolysis seen in this case.

Howie and Vernon-Roberts reported rapid proliferation of macrophages when Co-Cr particles were injected into rat knee joints. Santavirta et al. later characterized the cell population within femoral osteolysis to be of monocyte-macrophage cell line using sophisticated immunostaining techniques. Our hypothesis is that metallic debris were generated with micromotion and possibly from corrosion. This was confirmed by histology and trace element analysis in this case. Metallic debris initiated the activation and proliferation of macrophages. The macrophages generated bioactive cytokines, which led to progressive bone resorption. A similar mechanism was postulated for femoral osteolysis in cemented THRs. We also believe, as others do, that polyethylene debris invariably contribute to the pathogenesis of osteolysis in both the acetabulum and the femur. We were, however, unable to document that in this particular case.

The exact biologic response of the host to acrylic, metal, or polyethylene wear debris remains to be fully characterized. Further research must be continued, especially in light of this phenomenon being observed in mechanically stable THRs. It is only logical to postulate that even higher levels of debris will be present in situations involving loose components.

Our patient has done well at 2-year follow up. Long-term stability of the acetabular component, now with cement filling the defect in zone 1, remains to be determined with continued follow up. Although we exchanged the head for a Co-Cr one, corrosion at the taper may continue, especially since now there are dissimilar metals at the taper. Polyethylene wear debris can be generated when the head articulates against the old polyethylene liner of the cup. All of these processes can lead to further osteolysis in the acetabulum and the femur, challenging long-term fixation.

REFERENCES

10. Yoder SA, Brand RA, Pedersen DR, O'Gorman TW.


EDITORIAL DISCUSSION

ORTHOPEDICS: Could the authors explain why the large defect in the innominate bone was treated by filling it with cement rather than with bone graft?

Huo et al: The initial working diagnosis was either neoplasia or infection in this patient. We, therefore, planned to proceed with a two-stage reconstruction: stage 1—biopsy, followed by stage 2—definitive reconstruction. When the intraoperative histopathology showed neither neoplasia nor infection, the senior surgeon decided to proceed with definitive reconstruction, to minimize the potential added morbidity of another anesthetic session. Our institution did not routinely stock frozen or freeze-dried allograft bone. Autograft from the ipsilateral iliac crest remained an option; however, it could be a source of potential morbidity.

The large defect in the superior dome (zone 1) of the acetabulum should be classified as a superior cavitary defect according to the classification system developed by the American Academy of Orthopaedic Surgeons Committee on the Hip. It is acceptable to supplement such defects with solid or morselized bone graft, or with bone cement during reconstructive hip surgery. It was, therefore, decided by the senior surgeon to proceed with bone cement in this particular case.

Furthermore, the stability of the component was absolutely solid. We had hoped to exchange the component entirely; however, we were unable to remove the cup. Although bone grafting may have been more appropriate, we believe long-term fixation stability of this cup was not compromised by filling with cement.

ORTHOPEDICS: Could the authors explain why they exchanged a titanium for a cobalt chrome alloy rather than, for example, using ceramic to avoid continued metallic corrosion?

Huo et al: Fretting and wear of titanium-alloy articulating surface has been well-documented in the literature, and was present in our case. Corrosion between similar and dissimilar metals at the Morse taper junction has been observed and reported. Corrosion and potential wear at the Morse taper can occur both in the head and at the neck of the femoral component. Substituting with a ceramic component may minimize metallic corrosion and wear in the head; however, it might not prevent similar problems at the neck.

No ceramic component was made available to us at the time of surgery. The best option we had was to replace the worn femoral head with a Co-Cr head by the same manufacturer to ensure maximal fit and stability at the Morse taper. We hope this new articulating surface will allow for minimal polyethylene wear of the cup.

REFERENCES


Section Editor: Arnold T. Berman