The ultrastructure of the tissue surrounding the Christiansen total hip

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Tissue samples obtained from 24 consecutive Christiansen total hip revision operations were examined with transmission electron microscopy. An abundance of wear particles of plastic, originating from the polyoxymethylene socket, were found in the periprosthetic tissue, where they induced fibrinoid necrosis and macrophage activation. Phagocytosing cells revealed degenerative signs of varying degrees. It seems probable that this strong tissue reaction results in excessive bone resorption and is associated with the disastrous rate of socket loosening recorded with the Christiansen prosthesis.

The Christiansen total hip had a trunnion bearing and a socket, which are both made of polyoxymethylene (Delrin®; Sundal et al. 1974). This design was introduced in 1970; and during the following decade, more than 8,000 Christiansen prostheses were implanted in Scandinavia (Dumbleton 1981). The medium- and long-term results of this design have been poor, with a high frequency of loosening requiring reoperation (Ahnfelt 1987, Josefsson et al. 1980, Ohlin 1982, Sudmann et al. 1983). Severe socket wear is a common finding in retrieved Christiansen prostheses (Ohlin et al. 1982, Mathiesen et al. 1986, Havelin et al. 1986). The tissues surrounding such loosened prostheses contain fibrinoid necrosis and marked macrophage proliferation (Persson and Ohlin 1986). We report the ultrastructural changes in such tissues.

Patients and methods

Twenty-four exchange operations for aseptic loosening of the Christiansen total hip prosthesis were performed by one of the authors (A.O.) in 1983 and 1984 at the Department of Orthopedics at Jönköping Hospital, Sweden. There were 10 men and 14 women with a mean age of 71 (54–85) years at the time of revision. The time interval between the primary arthroplasty and the revision averaged 7 (3–8) years. The index diagnosis was arthrosis in 20 cases and late complication of nailed femoral neck fracture in 4 cases. No clinical or radiographic signs of infection were observed; in 19 cases multiple, negative bacteriologic cultures (Kam-

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Figure 1. Detail of the outer zone composed of fibrin (F), and collagen from of disintegrated cells (x 13,000).

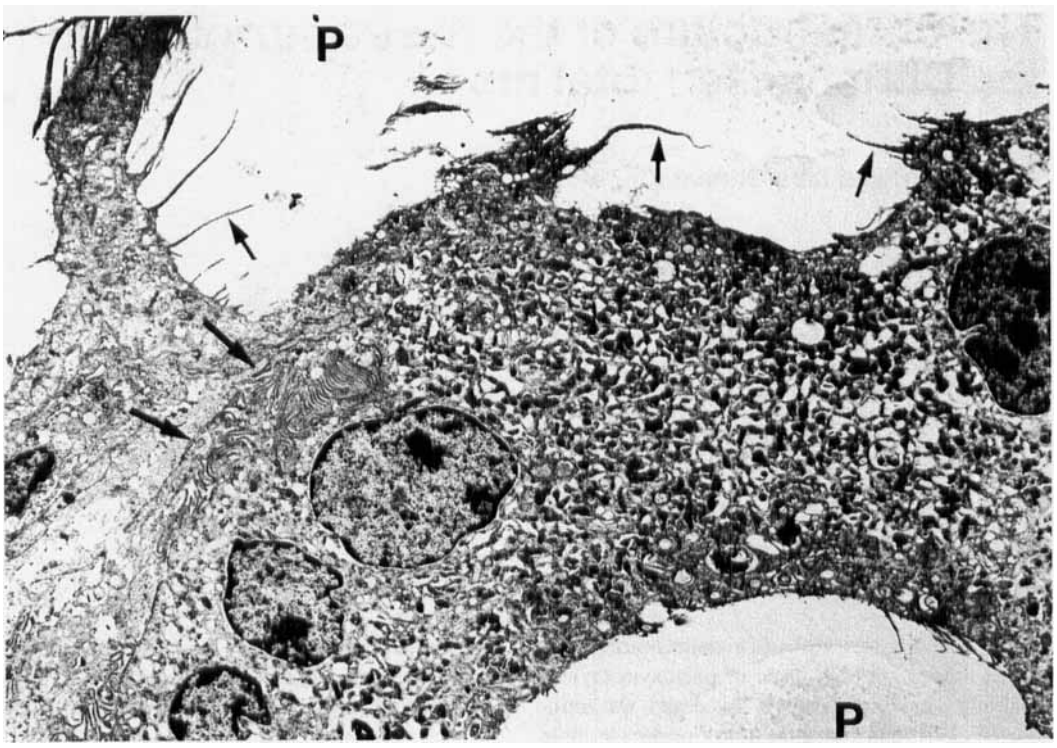

Figure 2

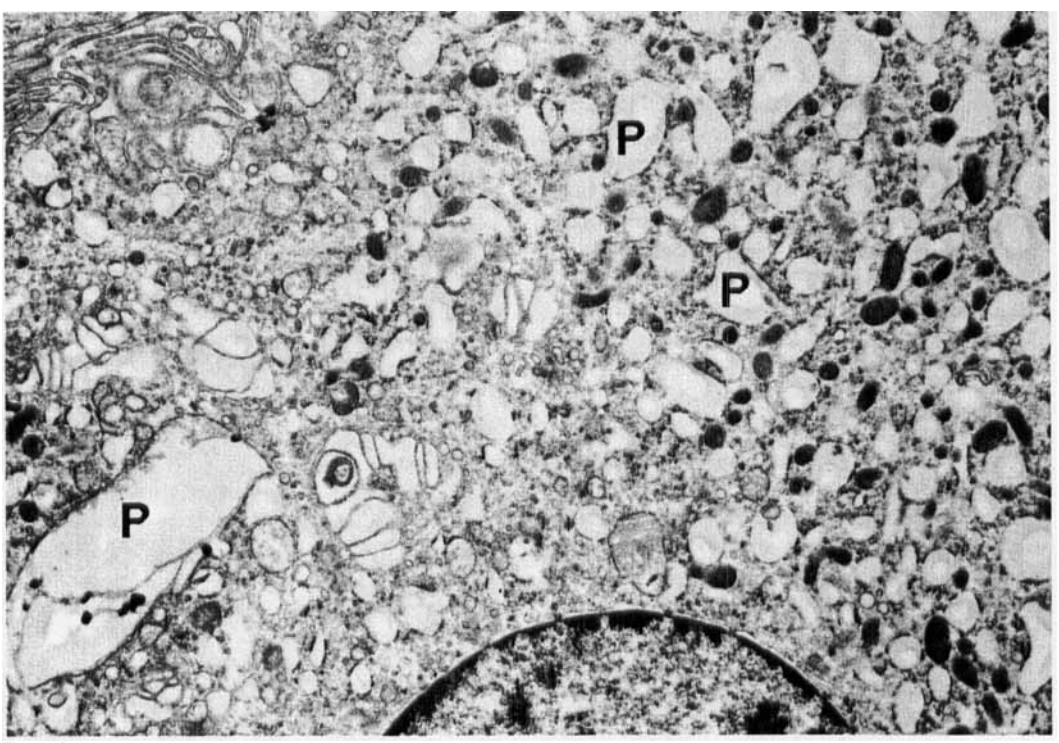

Figure 3

Figure 2. Multinucleated giant cells with osteoclast-like features and a prominent ruffled border (large arrows). The cells surround large plastic particles (P). The plastic material shows narrow crevices, which are filled with delicate cytoplasmic processes (small arrows) (x 3,700).

Figure 3. Detail of a multinucleated macrophage with numerous small plastic particles (P) within the cytoplasm (x 11,000).

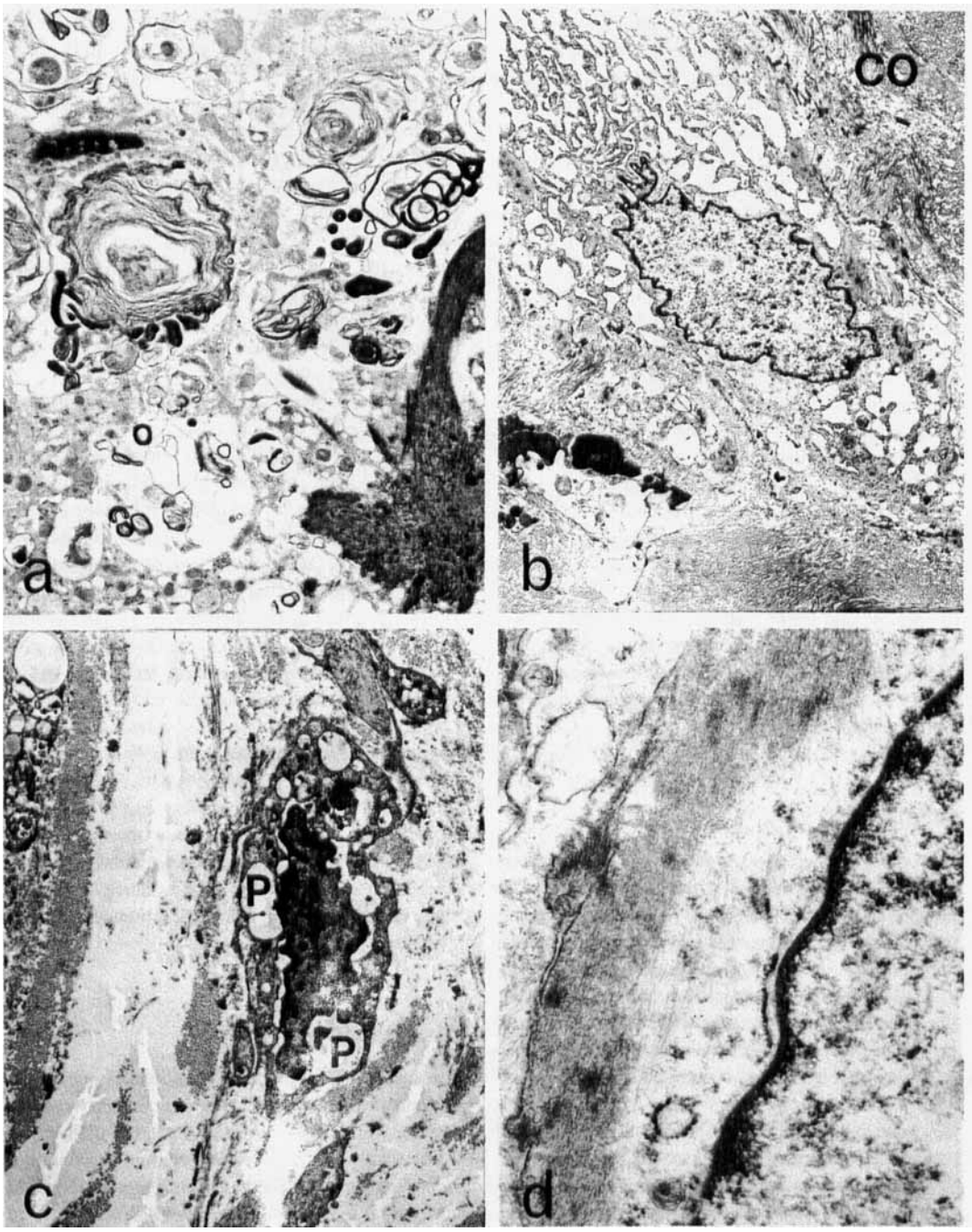

Figure 4

A. Detail of a macrophage with a cytoplasm dominated by lysosomal structures and large phagosomes (x 7,000).
B. Deep portion of the granulation tissue with an active fibroblast with abundant dilated RER and remnants of a necrotic cell surrounded by collagen (co) (x 4,200).
C. Same areas as B showing fibroblasts with plastic particles (P) within the cytoplasm (x 5,300).
D. Detail of a myofibroblast-like cell showing condensed bundles of thin filaments of actin type along the cytoplasmic border. Some elongated densities are seen (x 24,500).

me and Lindberg 1981) were obtained. There were only socket loosening in 17 cases, combined socket and stem loosening in 5, and only stem loosening in 2 cases.

At the revision, 5 x 5 x 5-mm tissue samples were collected from the synovial membrane adjacent to the socket. After extraction of the socket, a thick membrane covering the bottom of the acetabulum was found in all the cases, also in the 2 cases with only stem loosening. With a Cloward trephine drill with an inner diameter of 5 mm, a cylindric tissue sample including this membrane and underlying bone was taken out en bloc. After extraction of the femoral stem, a similar biopsy, but from the outside, was taken from the proximal anterior part of the femur beneath the collar. The tissue samples were immediately fixed in 2.5 percent glutaraldehyde in 0.1 M cacodylate buffer at pH 7.2 for 4 h at 4 °C, washed in cold buffer, postfixed with 1 percent OsO_4 for 1 h, dehydrated in ethanol, embedded in Agar resin, and cut on an LKB Ultrotome III. Then, 1-µm-thick sections were stained with toluidine blue, and ultrathin sections were contrast stained with uranyl acetate and lead citrate prior to examination in a Philips 400 electron microscope. In the light microscopic examination of the 1-µm sections, areas for ultrathin sectioning and electron microscopic analysis were selected.

Results

The newly formed capsule-like tissue and the tissue from the bone cement interface had mostly similar morphologic features. Generally, three distinct zones were seen: an outer zone of fibrinoid necrosis, a middle zone composed mainly of macrophages, and a deep collagen-rich zone with a predominance of fibroblast-like cells. The outer zone was composed of a dense fibrillar material of fibrin appearance, irregularly distributed and mingling with some collagen fibers and fragments of necrotic cells (Figure 1). In some areas this zone was very thin or completely absent, with macrophages reaching the surface. In the outer portion of the middle zone, multinucleated giant cells dominated, while mononuclear macrophages dominated the deeper portion. The multinucleated giant cells often had features of osteoclasts, having multiple vesicular nuclei with one or more prominent nucleoli and a cytoplasm dominated by mitochondria and systems of vesicles and vacuoles (Figure 2). The cytoplasmic membrane was extremely ruffled. Single or groups of such cells enclosed large particles of plastic material. Narrow crevices of this material were filled with delicate cytoplasmic processes (Figure 2). Within the cytoplasm of such cells, there were small particles, the smallest still recognizable was less than 0.01 µm in diameter (Figure 3). These plastic particles lacked a surrounding membrane structure, but were often bordered by a condensed cytoplasmic zone packed with free ribosomes. The deeper part of the middle zone was dominated by mononuclear macrophages that, apart from similar small intracytoplasmic particles, were dominated by lysosomal structures and large phagosomes filled with granular material, multilayered membranes, and lipids (Figure 4). Many such cells, as well as the giant cells of the outer portion, showed various stages of cell degeneration to necrosis and complete cell disintegration (Figure 4).

The deep zone had the appearance of granulation tissue composed of fibroblast- and myofibroblast-like cells, collagen, and capillaries. Some of the fibroblasts had very abundant systems of dilated rough endoplasmic reticulum and well-developed Golgi zones, and revealed nuclei with evenly distributed chromatin. Other such cells revealed various degrees of degenerative change, a few containing plastic particles that on occasion were ≤3 µm in diameter (Figure 4). The myofibroblast-like cells differed from the fibroblasts by a less conspicuous rough endoplasmic reticulum and an abundance of thin cytoplasmic filaments arranged parallel along the long axis of the cells. Frequently, elongated densities were seen in these filament bundles. The collagen matrix appeared normal. The capillaries were lined with large protruding endothelial cells. Within the granulation-tissue zone, there were scattered mast cells and a few lymphocytes and granulocytes. Mostly this granulation zone bordered directly onto the underlying bone, interrupted, however, in areas by rows of osteoblasts.

Discussion

The influence of plastic and metallic wear particles on the periprosthetic tissues has been a subject of great interest. Several light-microscopic studies on the newly formed capsule and on the bone-cement interface have been performed (Mittelmeier and Singer 1956, Heilmann et al. 1975, Willert and Semlitsch 1975, Wroblewski 1979, Webb et al. 1980, Mirra et al. 1982, Forest et al. 1985, Johansson et al. 1986). Our understanding of the underlying mechanism of periprosthetic bone resorption is incomplete. However, several reports suggest wear debris as an important factor in the chain of events leading to osteolysis (Heilmann et al. 1975, Willert and Semlitsch 1975, Revell et al. 1978, Wroblewski 1979, Webb et al. 1980, Eiken et al. 1985, Forest et al. 1985, Johansson et al. 1986).

The objective of the Christiansen prosthesis design was to reduce friction and wear. The major articulation was intended to occur in the trunnion joint and not between the ball and socket (Sundal et al. 1974). However, a high socket wear rate is most often found both on the radiographs and on the retrieved prostheses from exchange operations (Ohlin 1982, Havelin et al. 1986, Mathiesen et al. 1986). About one quarter of the Christiansen total hip replacements implanted in Sweden during the 1970s have been revised because of loosening (Ahnfelt 1987). A light-microscopic study showed intense macrophage proliferation and activation together with fibrinoid necrosis of the tissues at the bone-cement interface and the newly formed pseudocapsule surrounding the prosthesis (Persson and Ohlin 1986). The few hitherto published transmission electron microscopic studies in this field deal only with prostheses with metal articulating with polyester or polyethylene (Heilmann et al 1975, Pazzaglia et al. 1985). The present study clearly shows that an abundance of polyoxymethylene particles of highly variable size are disintegrated and that such particles are, to a large extent, phagocytized by macrophages. The extensive exposure to such particles in the outer zone of the granulation tissue may have induced the fibrin deposition and cell necrosis. Deeper in the granulation tissue, the largest extracellular particles had activated the macrophages. The smaller particles were phagocytized and almost completely filled some macrophages, which showed varying degrees of degenerative change. Not only the macrophages, but also some of the fibroblastic and myofibroblastic cells contained plastic particles, and some of these cells also showed degenerative changes. It seems likely that the strong collagen production and the fibroblast, myofibroblast, and capillary proliferation seen in the deeper zone of the granulation tissue is a tissue response induced by the degenerative changes in the outer zone.

This investigation shows that large numbers of plastic particles of variable size are deposited in the periprosthetic tissues, where they induced fibrinoid cell necrosis on the surface, with proliferation and activation of macrophages in the middle zone and formation of a deep collagen- and capillary-rich granulation tissue with fibroblasts and myofibroblasts.

An excess of wear particles may initiate bone resorption in the bone-cement interface adjacent to the joint and a subsequent progressive resorption of bone around the cemented implant may take place. A recently published experiment strongly supports such a mechanism in the sequence of events leading to loosening of wear-prone prostheses (Howie et al. 1988). Activated macrophages are probably related to the severe osteolysis often observed in patients operated on with the Christiansen total hip (Alho et al. 1984). Mathiesen et al. (1986) suggested that an increased frictional torque was the most probable mechanism of loosening of the Christiansen socket. The dynamic frictional torques they recorded were certainly higher with the Christiansen than with a conventional prosthesis with a polyethylene socket. However, the torques were not of the magnitude required to loosen an acetabular cup under normal conditions (Anderson et al. 1972, Volz et al. 1977). The cellular reactions reported here might be associated with the high rate of Christiansen socket loosening.

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