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Presence of corrosion products and hypersensitivity-associated reactions in periprosthetic tissue after aseptic loosening of total hip replacements with metal bearing surfaces

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Abstract

Aseptic loosening of articular implants is frequently associated with tissue reactions to wear particles. Some patients, who had received metal-on-metal articulations, present early symptoms including persistent pain and implant failure. These symptoms raise the suspicion about the development of an immunological response. Furthermore, the generation of rare corrosion products in association with metallic implants has been observed. Corrosion products are known to enhance third-body wear and contribute to the loss of the implant.

The purpose of this study was to investigate periprosthetic tissue containing solid corrosion products after aseptic loosening of second-generation metal-on-metal total hip replacements made of low-carbon cobalt–chromium–molybdenum alloy for the presence of immunologically determined tissue changes. Periprosthetic tissue of 11 cases containing uncommon solid deposits was investigated by light microscopy. In order to confirm the presence of corrosion products, additional methods including scanning electron microscopy (SEM) investigation, energy dispersive X-ray (EDX) and Fourier transform infrared microspectroscopy (FTIR) analysis were used.

All investigated cases revealed solid chromium orthophosphate corrosion products as well as metallic wear particles to a various extent. Moreover, various intense tissue reactions characteristic of immune response were observed in all cases. The simultaneous presence of corrosion products and hypersensitivity-associated tissue reaction indicates that a relationship between corrosion development and implant-related hypersensitivity may exist.

Keywords: Corrosion; Metal-induced hypersensitivity; Metal-on-metal; Hip replacement

1. Introduction

In orthopedic surgery total joint arthroplasty has become a routinely performed operation with a high success rate. However, one of the most significant complications is the loosening of articular prosthesis. While septic loosening of implants is morphologically associated with the presence of polymorphonuclear leukocytes in tissue, aseptic loosening is mainly attributed to tissue reactions to wear debris [1–3]. In order to search for alternative bearings, which may reduce wear production in total hip replacements (THRs), different material combinations such metal-on-metal, polyethylene-on-metal or ceramic-on-ceramic have been developed.

Second-generation metal-on-metal THRs with bearing surfaces consisting of cobalt–chromium–molybdenum alloy were introduced in the early 1990s. The main aim was to avoid polyethylene wear production as well as associated complications including osteolysis and implant loosening. Nevertheless, various authors raised concerns

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and reported on complications after the use of metal-on-metal articulations [4,5]. Early aseptic failure of metallic articulations and histological findings associated with immunological determined tissue reactions including fibrinoid necrosis, diffuse and perivascular lymphocytic aggregates, vasculitis as well as osteolytic lesions suggest that metal hypersensitivity was involved in the pathogenesis of aseptic loosening [6–9].

Cobalt and chromium are common metal sensitizers in humans and were considered to be cytotoxic [10,11]. However, the incidence of implant-related hypersensitivity with metal-on-metal articulation is considered low [12,13]. Furthermore, the trigger mechanism eliciting an overaggressive immune response is still unclear. On the one hand, additional factors may be involved in the development of metal-induced hypersensitivity reactions. On the other hand, implant-associated metal hypersensitivity may have been underreported because of diagnostic difficulties [12].

In addition to the release of metal ions into the surrounding environment [14], the occurrence of solid corrosion products was observed [15–20]. Solid corrosion products are considered to enhance third-body wear and may contribute to the loss of the implant by an alteration of the periprosthetic environment.

This study was undertaken to report on histopathological changes in periprosthetic tissue containing solid chromium orthophosphate corrosion products after aseptic loosening of second-generation metal-on-metal THRs consisting of Sikomet® low-carbon cobalt–chromium–molybdenum alloy. A possible relationship between hypersensitivity to cobalt–chromium metal and the generation of solid corrosion products is evaluated.

2. Materials and methods

Between July 2003 and July 2007 periprosthetic tissue of 68 cases was histologically investigated after aseptic loosening of cementless total hip replacement components with second-generation metal-on-metal bearing surfaces made from a single manufacturer. The age of 24 male and 44 female patients ranged between 43 and 85 years. The implantation period ranged between 11 and 144 months.

Out of these cases periprosthetic tissue of 11 cases, which revealed prominent green- to yellow-colored uncommon deposits, was selected for further investigation. The morphological appearance of these particles suspicious of corrosion products has been described previously [18,19]. These 11 cases included patients with ages ranging from 50 to 76 years and implantation periods ranging from 13 to 123 months (mean time 84 months) (Table 1). The initial diagnosis was osteoarthritis (cases 2–10) and osteoarthritis secondary to dysplasia (cases 1 and 11).

The acetabular component of the prostheses consisted of pure titanium threaded cup shells (Ti/Bicon-Plus) (Plus Orthopedics AG, Switzerland). Into the intraosseously placed Ti cup shell the CoCrMo-alloy bearing surface assembled into a polyethylene cup liner is inserted with a snap-fit coupling by the surgeon. The femoral component consisted of titanium-alloy stems (Ti6Al7Nb/SL-Plus) (Plus Orthopedics AG, Switzerland) coupled with femoral ball heads mated with the head–neck conical taper of the stems. Femoral ball heads and acetabular bearing surfaces were made of low-carbon (LC) cobalt–chromium–molybdenum (CoCrMo) alloy (Co28Cr6Mo ASTM (American Society for Testing and Materials) F 799, Sikomet®) (Plus Orthopedics GmbH, Austria) (Fig. 1).

Patients were revised because of increasing pain resulting in stem and/or cup loosening (cases 1–10) and persisting hip pain without evidence of osteolysis (case 11). In case 11 only the bearing surfaces were revised. Periprosthetic tissue was obtained at the time of revision and included pseudocapsule (cases 1–9 and 11), femoral (cases 1–9) and acetabular (cases 3, 4 and 10) bone-implant interface membranes. In case 4, tissue from the proximal part of the femoral bone-implant interface membrane was obtained by curettement. The tissue was fixed in 10% buffered formalin, embedded in paraffin, sectioned to a thickness of two micrometers and stained with hematoxylin and

Table 1
Clinical data of cases containing corrosion products

Case	Gender	Age	Time in situ (months)	Revised components	Corrosion products in periprosthetic tissue		
					Pseudocapsule	Femoral interface	Acetabular interface
1	m	50	13	S	+	+	NO
2	f	68	46	S	–	+	NO
3	f	64	52	S+C	+	+	+
4	f	61	74	C	+	+	+
5	m	67	96	S	–	+	NO
6	m	60	100	S	–	+	NO
7	m	63	101	S	–	+	NO
8	f	65	101	S	–	+	NO
9	m	76	105	S+C	–	+	NO
10	f	66	115	C	NO	NO	+
11	f	52	123	BS	+	NO	NO
			Mean 84				

+, detected; –, not detected; S, stem; C, cup; BS, bearing surfaces; NO, not obtained.