ORIGINAL PAPER

G. Maccauro · C. Piconi · L. Pilloni · L. Proietti
V. De Santis · E. De Santis

Surface analysis of a femoral stem after failed total hip replacement

Accepted: 29 March 2000

Abstract We analysed the surface of a Ti alloy femoral stem in a cementless total hip replacement with early failure. A specific protocol consisting of non destructive and destructive tests was used in the evaluation of the retrieved stem. The tests confirmed that implant fretting due to bone abrasion constitutes an early phase of loosening.

Résumé Nous avons analysé les modifications de surface de la tige fémorale en alliage de Titane, dans un cas d'échec précoce de prothèse totale non cimentée de la hanche. On a utilisé un protocole spécifique consistant en tests destructifs et non destructifs, confirmant ainsi que l'usure de l'implant est due à l'abrasion par l'os et constitue la phase précoce du descellement.

Introduction

Currently the analysis of mechanisms of implant failure is usually directed towards the effects of biological host response to wear debris. In this brief communication attention is focussed on the corrosion of the alloy and on methods used for the analysis of retrieved implants.

Case report

A 61-year-old woman with osteoarthritis of the hip, without major medical problems or allergies, underwent right cementless total hip replacement. A titanium aluminium vanadium stem and a HA coated polyethylene socket with a ceramic head were used. The immediate postoperative course was unremarkable and weight-bearing with crutches was allowed ten days postoperatively. Seven months later there was clinical and radiological evidence of loos-

ening, and there was fracture of a screw used for acetabular fixation. Radiographs also revealed a radiolucent line in relation to the stem of more than 1 mm and a pedestal beneath the tip (Fig. 1a, b). Eleven months after operation the patient underwent a revision procedure with a cementless socket and a cemented stem (Fig. 1c), with an excellent clinical result at 2-year follow-up.

Results

Implant analysis

The prosthetic components were submitted to non destructive tests (visual and stereomicroscopical analysis). Areas of corrosion on the stem were selected. The implants were divided and the fragments deposited on Scanning electron microscopy (SEM) stubs and gold-palladium sputtered coated, and observed by SEM JSM-IC 848 A (JEOL, Ltd, Tokyo, Japan) in association with energy-dispersive X-ray analysis (EDAX), according to a protocol previously reported [3].

Macroscopic findings of retrieved implant

Visual examination showed corrosion on the surface of the stem, in which the Titanium dioxide coating had lost its typical blue stain (Fig. 2a). Stereomicroscopy demonstrated fretting areas on the surface of the stem. These areas consisted of grooves filled with white Ti corrosion products and were seen on the proximal anterior region of the surface of the stem and particularly on the tip (Fig. 2b). The direction of the fretting scratches indicated the direction of movement of the implant against bone, and were in a mediolateral direction and along the longitudinal axis of the femur, as indicated by the presence of the pedestal.

Scanning electron microscopy

SEM showed typical aspects of fretting corrosion of the titanium, with scratches on the surface, differing in di-

Giulio Maccauro (✉)

Viale Medaglie d'Oro 246, 00136 Rome, Italy
Tel +39 6 35450775, Fax +39 6 3051161

G. Maccauro · L. Proietti · V. De Santis · E. De Santis
Dept. of Orthopaedics, Catholic University of Rome, Italy

C. Piconi · L. Pilloni
ENEA, New Technology Dept., Rome, Italy

Fig. 1 Radiographs before (a, b) and after revision (c)

Fig. 2 a Corrosion on the surface of the stem. Coating has lost its typical blue stain. b Fretting areas near the tip

mension, oriented along the axis of movement of the stem. Granules were sometimes observed near the scratches. EDAX analysis confirmed that these granules were of titanium (Fig. 3a,b).

Discussion

Titanium and its alloys is used for implants, due to its good biological and mechanical properties, and has been

proposed as the material choice for uncemented femoral components [2]. The high resistance to corrosion in a physiological environment is related to the formation of a passive oxide layer on the surface of the implant. Titanium, titanium alloys and titanium dioxide show little toxicity [1,5]: the in vitro toxicity is dependent on several factors, such as size, shape and impurity content [4]. However, Willert et al. [6] reported the models of corrosion which could develop on the surface of Ti loosened cemented stems, which were pitting associated with abrasion of the cement, and crevice corrosion caused by depletion of oxygen at the implant-cement interface, which reduces the formation of the surface layer. Our case demonstrates that fretting is the main cause of cor-

Fig. 3a,b EDAX analysis

rosion of titanium in association with an uncemented femoral component. It consists of scratches of differing orientation, showing the different movements of implant and the possible abrasive role of the surrounding bone. Abrasion also produces titanium granules, which in-

crease wear. Fretting causes disruption of the surface oxide layer and reduces the resistance of the metal to corrosion. The presence of corrosion on the inferior part of the stem and particularly on the tip is typical for titanium. A possible role is played by the pedestal, which increases the abrasion and may create a crevice distal to the stem. In our case the loosening may have been due to an inappropriate size of femoral component allowing movements along various axes within the femur, and increasing the abrasive effects of bone. In conclusion careful analysis of retrieved Orthopaedic implant materials should be performed using a specific simple protocol; but good surgical planning and operative technique are required to maintain the biomechanical properties of the material used, thus obtaining a good result.

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