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Fatigue Fracture in Dual Modular Revision Total Hip Arthroplasty Stems Failure Analysis and Computed Tomography Diagnostics in Two Cases

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ABSTRACT

We report on two patients with fracture of a modular, tapered and distally fixed, uncemented titanium revision hip stem, not previously described. A failure analysis revealed that the cause of the fractures was the development of fatigue cracks in the mid-stem cobalt–chromium modular junction ending in corrosion-fatigue failure. No material defects or stress risers were found in any of the implants. The diameter of the mid-stem modular junction might be undersized for use in heavy and active patients. We also report a new way of detecting an undisplaced fracture at the modular junction, using the scout image from a computed tomography (CT) scan; a technique that can be used when plain radiographs are inconclusive.

Fracture of the femoral stem is a well known, but infrequent complication of Total Hip Arthroplasty (THA). A consistently low fracture incidence (0.23%–0.27%) has been found over the years [1,2], and many improvements, including the use of cobalt–chromium–molybdenum (CoCrMo) or titanium alloys, have helped reduce the incidence of prosthetic fracture in modern stem designs [3–5].

In revision THA, modular femoral stems are increasingly popular, and stems with more than one modular junction are frequently used. Modularity makes it easier for the surgeon to restore the patient's anatomy by optimizing leg length, version and offset intraoperatively [6–10]. There have also been reports of improvement in the quality of life for patients who receive modular revision stems in comparison with non-modular ones [9,11].

There are however reports indicating that modularity increases the complication rate and might make the implants susceptible to corrosion, fretting and fatigue fracture at the modular junctions [8–10,12,13]. In 2010, a large study of hip prostheses with modular neck adapters reported a failure rate of 1.4% [12]. Recently concern has been raised regarding high blood levels of cobalt due to metal ion release from corrosion at the metal-on-metal taper connections in patients with dual modular cobalt–chrome hip prostheses [14]. In the light of this, the safety in using modular prostheses has become a subject for discussion.

Revitan (Zimmer GmbH, Winterthur, Switzerland) is a dual modular, tapered and distally fixed, uncemented femoral stem manufactured from titanium niobium alloy (TiAl6Nb7). It has a mid-stem modular junction in which the proximal and distal components are joined together by a dual tapered cylinder, made of a cobalt alloy (CoCrMo) to offer high mechanical resistance. Revitan is a development of the PFM-R stem (Zimmer GmbH, Winterthur, Switzerland) which has been successfully used for almost 20 years. To this date, there are very few publications available about Revitan prostheses, but one study from 2009 shows good results after a minimum of 24 months of follow-up of the Revitan curved stems [15]. Fractures of other dual modular, cementless stems have been reported in the literature [6,8,11,16,17], but to our knowledge no fracture of the Revitan stem has been reported.

We are here reporting the fractures of two Revitan straight prostheses. The objectives of this study are to describe our experience with fracture in this stem design and to analyze the underlying cause by metallurgical examination and comparing our findings with the literature. We also report a new way to detect an undisplaced fracture at the modular junction of a femoral component, which is not obvious on plain radiographs.

Materials and Methods

Within one year, two patients presented at our department with fracture at the modular junction of a Revitan stem. The first patient was a still hard working 69 year old farmer, who had had the implant for 36 months at the time of fracture. The revision had been performed for late prosthetic infection in an already revised cemented

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Table 1
Patient Data.

Patient	Age[a] (Years)	Gender	Weight[a] (kg)	BMI[a] (kg/m^2)	Reason for Previous Revision	Number of Revisions[b]	ETO[c] Used During Last Revision	Proximal Component	Distal Component	Time to fracture (months)
1	69	Male	117	31.4	Prosthetic Infection	2	Yes	Cylindrical (55 mm)	Straight (200 mm)	36
2	70	Male	95	29.0	Aseptic Loosening	1	Yes	Cylindrical (65 mm)	Straight (140 mm)	89

[a] At the time of fracture.
[b] Total number of revisions prior to the prosthetic fracture.
[c] Extended Trochanteric Osteotomy.

THA. Despite a rather long recovery period, the patient seemed to heal well, and he was completely asymptomatic for two years prior to the stem fracture. The second patient was a 70 year old, still very active building inspector who had functioned well with the implant for 89 months at the time of fracture. The revision had been performed for aseptic loosening of a cemented THA. Clinical data on the patients are presented in Table 1.

Radiography

The first patient presented with sudden onset of pain and inability to put weight on his leg. The fracture was obvious on plain radiographs as it was displaced, and this case did not present a diagnostic challenge. The second patient however had an atypical presentation with slowly increasing pain and walking difficulties over a period of a few weeks, until he had to use two crutches. Prosthetic fracture did not seem the most likely cause. Plain radiographs showed no obvious fracture, signs of loosening or other complication (Fig 1). Computed tomography (CT) was performed with 1 mm slices, with and without metal artefact reduction technique.

Failure Analysis

The fractured stems from both patients were analyzed at the Division of Materials Engineering at Lund University, Sweden. The proximal part of the fractured connection was removed and cleaned ultrasonically in ethanol. The cleaned proximal fracture surfaces were examined and photographed in a stereo microscope (Leica Model DFC 320, Leica, Wetzlar, Germany) and an environmental scanning electron microscope (Philips Model XL-30 ESEM, Philips/FEI, Eindhoven, The Netherlands). Energy dispersive spectroscopy and X-ray mapping (EDAX Phoenix System, EDAX, Tilburg, The Netherlands) were performed on the fracture surfaces for qualitative and quantitative information on the chemical components of the material.

The distal parts of the fractured connections were removed and sectioned vertically, to acquire cross sections perpendicular to the fracture surfaces. The exterior, rounded surfaces of the samples were polished so that the sample had two parallel flat surfaces. Knoop Microhardness tests were performed on the samples with a rhombic-based diamond pyramid indenter. The procedure recommended in the ASTM standard E384 was followed. A load of ten grams and a dwell time of ten seconds were used for the measurement.

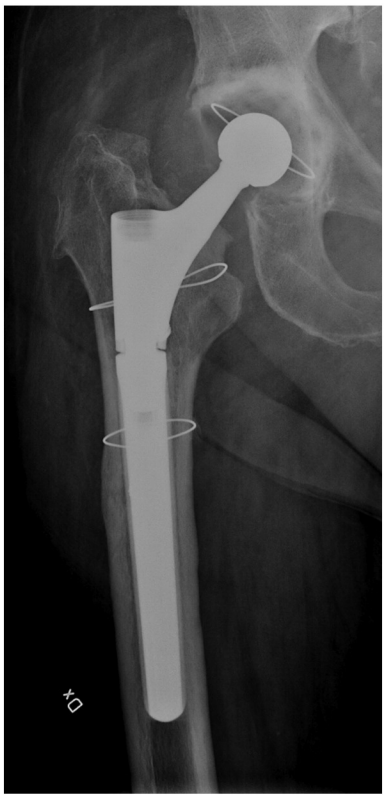

Fig. 1. Anteroposterior radiograph in case 2, initially described as showing no signs of prosthetic fracture.

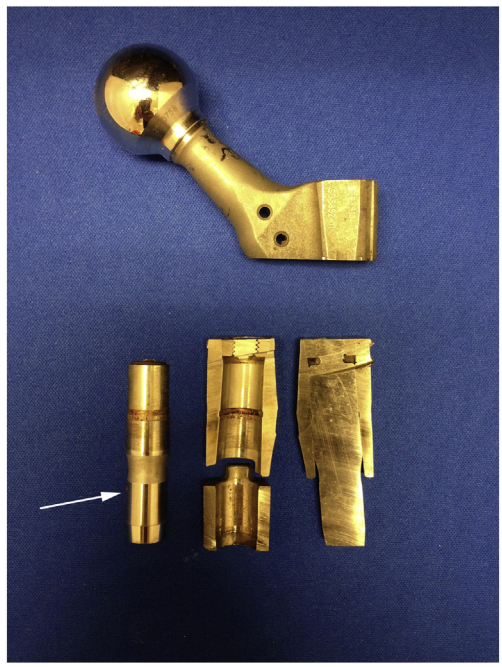

Fig. 2. The mid-stem modular junction of the reference, unfractured Revitan prosthesis after vertical sectioning. On the left is the CoCrMo cylinder connecting the proximal and distal components. In the middle, the surrounding proximal and distal components (with the CoCrMo cylinder removed). The distal component is fixed to the CoCrMo cylinder during the manufacturing, while the proximal component is attached intraoperatively. The arrow shows the level at which the fractures occurred in both cases.