



# Influence of material coupling and assembly condition on the magnitude of micromotion at the stem–neck interface of a modular hip endoprosthesis

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## ABSTRACT

Hip prostheses with a modular neck exhibit, compared to monobloc prostheses, an additional interface which bears the risk of fretting as well as corrosion. Failures at the neck adapter of modular prostheses have been observed for a number of different designs. It has been speculated that micromotions at the stem–neck interface were responsible for these implant failures. The purpose of this study was to investigate the influence of material combinations and assembly conditions on the magnitude of micromotions at the stem–neck interface during cyclic loading.

Modular ( $n=24$ ) and monobloc ( $n=3$ ) hip prostheses of a similar design (Metha, Aesculap AG, Tuttlingen, Germany) were subjected to mechanical testing according to ISO 7206-4 ( $F_{\min}=230$  N,  $F_{\max}=2300$  N,  $f=1$  Hz,  $n=10,000$  cycles). The neck adapters (Ti–6Al–4V or Co–Cr29–Mo alloy) were assembled with a clean or contaminated interface. The micromotion between stem and neck adapter was calculated at five reference points based on the measurements of the three eddy current sensors.

The largest micromotions were observed at the lateral edge of the stem–neck taper connection, which is in accordance with the crack location of clinically failed prostheses. Titanium neck adapters showed significantly larger micromotions than cobalt–chromium neck adapters ( $p=0.005$ ). Contaminated interfaces also exhibited significantly larger micromotions ( $p < 0.001$ ). Since excessive micromotions at the stem–neck interface might be involved in the process of implant failure, special care should be taken to clean the interface prior to assembly and titanium neck adapters with titanium stems should generally be used with caution.

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## 1. Introduction

Hip prostheses with a modular neck adapter have been used in orthopaedic surgery since the end of 1990s (Grupp et al., 2010). Neck modularity of the femoral component of total hip implants is attractive since neck length, anteversion and femur offset can be adjusted intraoperatively after implantation of the prosthesis stem. This allows fitting of the prosthesis to the individual anatomical and implantation condition, reducing wear rate (Traina et al., 2009), enhancing hip stability (D'Angelo et al., 2008; Dennis and Lynch, 2005), increasing range of motion and minimizing the risk of dislocation (Dennis and Lynch, 2005; Garcia-Rey et al., 2008; Widmer and Majewski, 2005). The disadvantage of this flexibility of such systems is an additional interface between the stem and the neck, which bears the risk of micromotions at the interface, resulting in a constant abrasion of the passivation layer and corrosion,

especially for titanium alloys (Duisabeau et al., 2004; Gilbert et al., 1993; Grupp et al., 2010; McKellop et al., 1992). Fretting corrosion can be superposed by crevice corrosion (Hermle, 2007). Crack formation and propagation can ultimately lead to implant failure (Grupp et al., 2010).

In August 2006, the first failure of the titanium alloy (Ti–6Al–4V) neck adapter of a Metha Short Hip Stem Prosthesis (Aesculap AG, Tuttlingen, Germany) occurred (Grupp et al., 2010; Hermle, 2007). Successive failures occurred for the titanium alloy stem in combination with a titanium neck adapter (both Ti–6Al–4V). Neck adapters failed approximately after two years (0.7–4.0 years) of implantation (Grupp et al., 2010). Consequently this implant combination was discontinued in November 2006. The titanium neck adapters were replaced by Co–Cr29–Mo alloy neck adapters, which have not shown any problem in the clinical application until today.

Material coupling has been shown to have an inconsistent influence on fretting and corrosion at the head–neck interface. Corrosion has been consistently reported in mixed metal interfaces (cobalt–chromium and Ti–6Al–4V alloy) (Gilbert et al.,

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