The Journal of Arthroplasty 28 (2013) 1036–1040

Contents lists available at SciVerse ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

The Influence of Head Size on Corrosion and Fretting Behaviour at the Head-Neck Interface of Artificial Hip Joints

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ARTICLE INFO

Article history:
Received 8 March 2012
Accepted 12 October 2012

Keywords:
corrosion
fretting
head size
modular
hip

ABSTRACT

The primary goal of this study was to determine if head size affects corrosion and fretting behaviour at the head-neck taper interface of modular hip prostheses. Seventy-four implants were retrieved that featured either a 28 mm or a 36 mm head with a metal-on-polyethylene articulation. The bore of the heads and the neck of the stems were divided into eight regions each and graded by three observers for corrosion and fretting damage separately using modified criteria as reported in the literature. The 36 mm head size featured a significant difference in the corrosion head scores ($p = 0.022$) in comparison to the 28 mm heads. This may be attributed to a greater torque acting along the taper interface due to activities of daily living.

Modular hip prostheses are well-known for improving the quality of life for patients who have degenerative hip disorders. Modular hip prostheses have many advantages in comparison to single component hip prostheses. These advantages include the adjustment of the patient's leg length during surgery, a decreased inventory size, reduced costs, simplified revision procedures, and the femoral stem can be implanted prior to the insertion of the acetabular component [1–5].

One significant problem of modular hip prostheses is that metal ions and particles are not only being generated from wear at the articulation site, but they may also be produced at the head-neck taper interface due to corrosion [1,6–12]. Excessive concentrations of cobalt and chromium in the body are known to be harmful as they have been linked to lymphatic reactivity, hypersensitivity, local tissue toxicity, chromosomal damage, impaired renal function, and malignant cellular transformations [12,13]. Additionally, recent reports indicate the possibility of pseudotumours forming in patients due to the presence of increased levels of metal ions from wear and corrosion in hip resurfacing and modular hip prostheses [14–18].

Corrosion of taper surfaces in modular hip prostheses is a critical issue that can get worse over time. Fig. 1 illustrates the progression of a CoCr taper surface that has not been implanted (Fig. 1A) to taper surfaces with mild, moderate, and severe corrosion and fretting damage. Fig. 1B illustrates a taper surface that contains minimal corrosion and fretting damage. The machining grooves along the head are still detectable as indicated with the two arrows; however, there appears to be pitting between the grooves. The taper surface in Fig. 1C contains moderate corrosion and fretting damage. The taper surface displays etching marks as shown by the arrow and the machining grooves are no longer visible. Finally, the taper surface displayed in Fig. 1D features severe corrosion and fretting damage. This image may indicate that not only are the grooves no longer present, but the entire CoCr surface was possibly attacked by the biological fluid within the taper connection.

A retrieval analysis was performed to answer the following questions with respect to corrosion behaviour at the head-neck taper interface of modular hip prostheses. First, does head size influence corrosion or fretting behaviour along the head-neck taper junction? Second, does the head taper display similar corrosion and fretting damage in comparison to the neck taper? Third, does a relationship exist between corrosion and fretting damage? Finally, is there a difference in the corrosion and fretting damage between prostheses manufactured from two different companies?

The Conflict of Interest statement associated with this article can be found at http://dx.doi.org/10.1016/j.arth.2012.10.017.

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0883-5403/2806-0031$36.00/0 – see front matter
http://dx.doi.org/10.1016/j.arth.2012.10.017

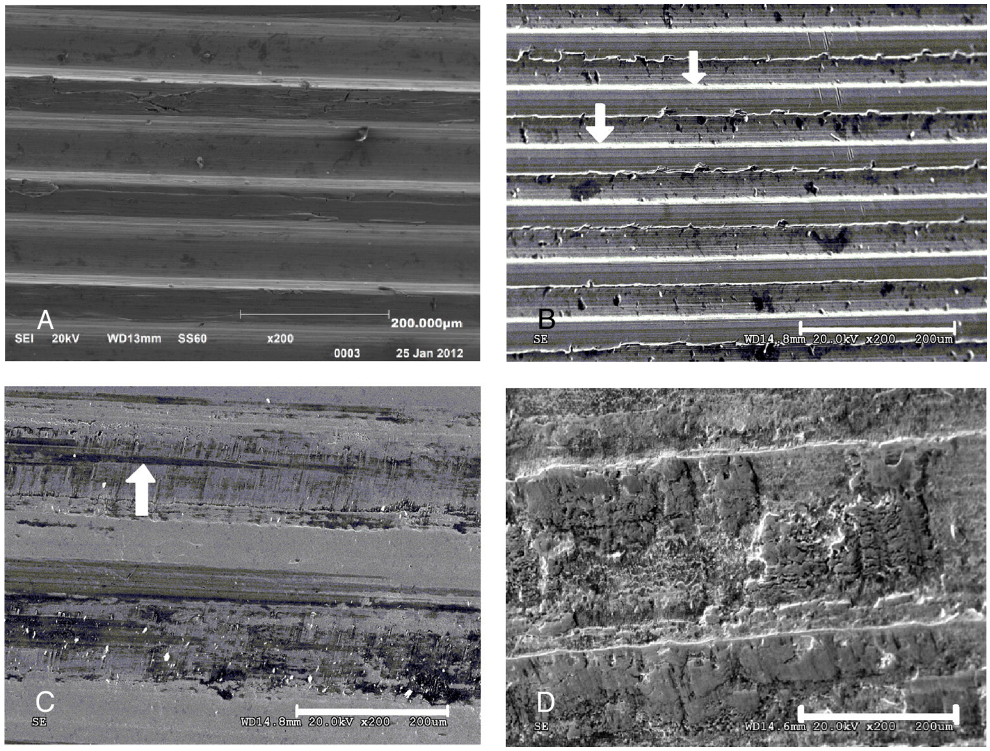

Fig. 1. Scanning electron microscopy (SEM) images of CoCr alloy heads and necks that were not implanted in comparison to implants with little, moderate, and severe corrosion damage. A) SEM of a CoCr alloy neck that has not been implanted. B) Arrows pointing to machining grooves for a CoCr alloy head with little corrosion and fretting damage. C) Arrow pointing to etching marks from fretting for a CoCr alloy head with moderate corrosion and fretting damage. D) Neck of a CoCr alloy stem with significant corrosion and fretting damage.

Methodology

Modular hip prostheses were retrieved in this study that were implanted for at least one month, featured a 12/14 mm taper, heads and stems consisting of CoCr alloy, and a metal-on-polyethylene articulation. The prostheses were separated into two groups based on head size. The first group consisted of modular hip prostheses with 28 mm heads whereas the second group had 36 mm heads. The prostheses were examined for corrosion and fretting damage along the bore taper of the head and the neck taper of the stem.

To assess for corrosion and fretting damage of all of the prostheses, the taper interfaces were examined macroscopically by eye. The neck of the stem and the bore of the head were separated into four quadrants and each quadrant was divided into a superior and inferior region. This technique produced eight regions for the neck and eight regions for the head. To examine the severity of corrosion and fretting damage, each region was scored from zero to three using similar criteria as Goldberg et al. [19] and Kop et al. [20] as shown in Table 2. Each region was also given a score ranging from zero to three to represent the amount of area damaged (Table 2). After assigning severity and area scores for a region, the two scores were multiplied with each other to form a regional score for corrosion or fretting (maximum score of nine). The eight regional scores were summated to reveal separate corrosion and fretting scores for the head and neck. All modular hip prostheses were evaluated independently by three researchers and the scores were averaged. Electronic dispersive spectroscopy was also performed to determine if there was a difference in the chemical composition of the CoCr taper surface when attacked by corrosion and fretting in comparison to a taper surface that has not been implanted.

To determine the statistical intraclass correlation between the researchers for scoring the implants, the statistical software program SPSS version 19.0 (SPSS Inc., Chicago, IL, USA) was used. The Shapiro-Wilk test was performed to determine if the corrosion and fretting scores were normally distributed. In all cases, except for the head corrosion scores for the 36 mm head size group, the corrosion and fretting scores did not display normal distribution. Consequently, the Mann–Whitney *U* test was performed, which is a nonparametric statistical hypothesis test that can be used to determine whether one of two independent sample groups contains significantly larger values. Fisher's Exact test was also conducted, which is a statistical significance test that is used for categorical data when classifying objects in two different ways. Fisher's Exact test and the Mann–Whitney *U* test were performed with an alpha value of 0.05 to determine if there were significant statistical differences ($p<0.05$) between the 28 mm and 36 mm head size groups. When examining for correlations, the Spearman rank correlation coefficient was applied.

Results

This retrieval analysis consisted of 74 modular hip prostheses featuring 59 prostheses with a 28 mm head size and 15 prostheses with a 36 mm head size. The modular hip prostheses were manufactured from two companies (A and B). Of the 74 patients that the prostheses were received from, only 40 stems were retrieved. The rest of the stems were not removed during revision surgery. Details regarding the patients, the prostheses, and the reasons for revision are provided in Table 1.

The intraclass correlation coefficient between the three reviewers for scoring corrosion and fretting were 0.70 and 0.48, respectively. According to Fleiss, this is considered to be a fair correlation between the three reviewers for assessing the corrosion and fretting damage [21].

Fisher's Exact test was conducted to determine if there were significant differences in the ratios for the appearance of corrosion and fretting damage between the two head size groups (Table 3). There were no significant differences in frequency of observed corrosion and