The Journal of Arthroplasty 31 (2016) 1123–1127

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Basic Science

The Relationship Between Cobalt/Chromium Ratios and the High Prevalence of Head-Stem Junction Corrosion in Metal-on-Metal Total Hip Arthroplasty

Harry S. Hothi, BEng, MSc, PhD *, Reshid Berber, BSc, MBBS, MRCS(Eng), Robert K. Whittaker, BSc, MSc, Gordon W. Blunn, BSc, PhD, John A. Skinner, MBBS, FRCS(Eng), FRCS(Orth), Alister J. Hart, MA, MD, FRCS(Orth)

Institute of Orthopaedics and Musculoskeletal Science, University College London, Royal National Orthopaedic Hospital, Stanmore, United Kingdom

ARTICLE INFO

Article history:
Received 15 January 2015
Received in revised form
3 November 2015
Accepted 5 November 2015
Available online 26 November 2015

Keywords:
taper
corrosion
metal-on-metal
retrieval
cobalt
chromium

ABSTRACT

Background: The size of the clinical impact of corrosion of the taper junction of metal-on-metal total hip arthroplasties (MOM-THAs) is unclear. Examination of a large number of retrieved MOM resurfacings and total hip arthroplasties can help us understand the role of taper corrosion in metal ion release.
Methods: We graded the severity of corrosion at the taper junction of 395 MOM-THAs and compared the prerevision whole blood metal ion levels of these hips with 529 failed MOM hip resurfacings.
Results: Virtually all MOM-THA hips (n = 388) had evidence of corrosion of the head-stem taper junction and graded as severe in 31% (n = 124). The median cobalt/chromium (Co/Cr) ratio was 1.58 (0.01-13.82) and 1.08 (0-4.86) for MOM-THA and MOM hip resurfacing, respectively; this difference was significant ($P < .001$). THA hips with severely corroded tapers had the highest median Co/Cr ratio of 1.86 (0.01-10).
Conclusions: This study demonstrates the high prevalence of severe taper corrosion, which may be related to an elevated Co/Cr ratio before revision.

The size of the clinical impact of metal ions released from the taper junctions of metal-on-metal total hip arthroplasties (MOM-THAs) is unknown. Numerous studies have reported on the wide range of volumetric material loss that has been measured at the surface of the femoral head taper [1–3], and it is largely accepted that the mechanism of material loss may be due to mechanical wear, corrosion, or a combination of both.

The volume of material loss at the taper has been shown to be significantly moderately correlated with a well-published visual scoring scale for the severity of corrosion [4,5]. It was found that virtually all tapers that had evidence of no, mild, or moderate corrosion had volumetric material loss of <5 mm^3; however, tapers that were visually severely corroded (score, 4) revealed a large variation in material loss of between 1 mm^3 and over 25 mm^3.

The black surface deposits associated with severe taper corrosion have been shown to be rich in chromium (Cr) with comparatively fewer cobalt (Co) ions [5]. It is speculated that as the severity of corrosion increases, an increase will also be detected in the whole blood Co/Cr ratio as more Cr will be retained on the taper surface, whereas a greater concentration of Co ions will be released into the blood.

It is proposed therefore that a greater focus on the analysis of severely corroded tapers may be key in understanding the role of the taper junction in implant failure. The magnitude of the clinical frequency of severe taper corrosion however is unclear. Recent studies that have reported on corrosion of failed contemporary hips have examined a relatively low number of components, ranging from 12 to 150 [4–12]. Goldberg et al [5] reported evidence of severe corrosion in 10% of 221 tapers; however, these were of hips explanted over a decade ago. It remains unclear to what extent severe taper corrosion is present in a wider cohort of failed modern MOM hips.

The purpose of this study therefore was to (1) report on the prevalence and severity of corrosion in the largest study of

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to http://dx.doi.org/10.1016/j.arth.2015.11.014.

* Reprint requests: Harry S. Hothi, BEng, MSc, PhD, Institute of Orthopaedics and Musculoskeletal Science, University College London, Royal National Orthopaedic Hospital, Brockley Hill, Stanmore, Middlesex, United Kingdom, HA7 4LP.

http://dx.doi.org/10.1016/j.arth.2015.11.014
0883-5403/

retrieved MOM-THA hips of current designs (n = 395) and (2) determine whether this damage mechanism can be detected before revision by comparing corrosion scores with prerevision blood metal ion levels of the 395 MOM-THAs and a series of 529 failed MOM hip resurfacings.

Methods

This was a retrospective cohort study involving a consecutive series of 395 failed MOM-THA hip implants received at our retrieval center that had an unobstructed female head taper surface which could be visually assessed. Implants were collected from over 38 contributing hospitals during the period July 2009 to April 2014. Prerevision Co and Cr blood metal ion levels were collected, together with patient demographic data relating to gender, age at primary surgery, and time to revision (Table 1). The hip designs consisted of the Adept (27), ASR XL (68), BHR (66), Conserve (10), Cormet (35), Magnum (50), Metasul (42), Mitch (10), Pinnacle (66), Ultima (6), and others (15), with a median head diameter of 45 mm (28-60); these consisted of 19 small heads (<36 mm) and 376 large heads (≥36 mm).

The implants were retrieved from 162 male and 233 female patients with a median age of 61 (23-83) years and a median time to revision of 50 (7-200) months. Median whole blood Co and Cr levels prerevision were 7.02 (0.47-212.4) and 3.93 (0.2-111) ppb, respectively. The Co/Cr ratio was calculated individually for each patient; the median ratio was 1.58 (0.01-13.82).

To assess the clinical significance of corrosion at the modular junctions of the MOM-THAs, we also considered in this study prerevision whole blood metal ion levels of a series of 529 retrieved MOM resurfacing hips previously collected at our center (Table 1). Median Co and Cr levels were 5.83 (0-273.8) and 5.92 (0.3-343) ppb, respectively; the median Co/Cr ratio was 1.08 (0-4.86). These implants had been retrieved from 216 male and 313 female patients with a median age of 55 (16-74) years and a median time to revision of 59 (8-178) months. The median head diameter was 46 (38-58) mm.

Table 1
Patient and Implant Data for the Metal-on-Metal (MoM) Total Hip arthroplasties (THAs) and MOM Resurfacings.

Parameter	Number	THA Median (Range)	Resurfacing Median (Range)	*P* Value
Gender (male:female)		162:233	216:313	
Age at primary surgery (y)	—	61 (23-83)	55 (16-74)	<.01
Time to revision (mo)	—	50 (7-200)	59 (8-178)	<.01
Femoral head diameter (mm)	—	45 (28-60)	46 (38-58)	.184
Whole blood cobalt (ppb)	—	7.02 (0.47-212.4)	5.83 (0-273.8)	.144
Whole blood chromium (ppb)	—	3.93 (0.2-111)	5.92 (0.3-343)	<.01
Cobalt/chromium ratio	—	1.58 (0.01-13.82)	1.08 (0-4.86)	<.01
THA bearing design				
Biomet Magnum	50	—	—	—
Corin Cormet	35	—	—	—
DePuy ASR XL	68	—	—	—
DePuy Pinnacle	66	—	—	—
Finsbury Adept	27	—	—	—
S&N BHR	66	—	—	—
Stryker Mitch	10	—	—	—
Wright Conserve	10	—	—	—
Zimmer Metasul	42	—	—	—
Others	21	—	—	—
Resurfacing bearing design				
Corin Cormet	98	—	—	—
DePuy ASR	35	—	—	—
Finsbury Adept	29	—	—	—
S&N BHR	304	—	—	—
Stryker Mitch	12	—	—	—
Wright Conserve	10	—	—	—
Zimmer Durom	17	—	—	—
Others	24	—	—	—

Corrosion Assessment

Each head taper surface was inspected macroscopically and with the aid of a Leica M50 light microscope (Leica Microsystems, Germany) at up to ×40 magnification. A well-published corrosion classification method [5] was used to grade each surface with a score of 1 (no corrosion), 2 (mild corrosion), 3 (moderate corrosion), or 4 (severe corrosion), with increasing evidence of black debris, pitting, and etching indicating greater corrosion. This method has previously been demonstrated as being both repeatable and reproducible [4]. The statistical significance of any differences between the corrosion scores in relation to (1) time to revision, (2) head size, (3) Co and Cr blood metal ion levels, (4) age at primary surgery was examined. After this, the statistical significance of any differences in the Co/Cr ratios between (1) all resurfacing hips, (2) all THAs, and (3) THA hips in each of the four corrosion score categories was investigated. We also tested to see whether there was a significant association between time to revision and Co/Cr ratios for both the resurfacing and total hips.

The Shapiro-Wilk test for normality revealed that all the parameters under investigation were not normally distributed. Therefore, Kruskal-Wallis nonparametric analysis of variance tests were initially performed to detect the presence of significant differences, and post hoc analysis using Mann-Whitney testing was used to identify which specific differences were significant.

Results

We found that 98% (n = 388) of retrieved head tapers showed evidence of corrosion and 31% (n = 124) of tapers were severely corroded (Fig. 1).

There was a significant difference in the time to revision (months) between the corrosion scores ($P < .001$). Post hoc analysis confirmed that the time to revision for hips with corrosion score 3 was significantly greater than score 2 ($P < .05$), and the time to revision for score 4 was significantly greater than scores 2 and 3 ($P < .05$). There was no association between head size and corrosion scores ($P = .141$), and there was no statistically significant difference between the corrosion scores of small (<36 mm) and large (≥36 mm) diameter heads ($P = .685$). We also examined the effect of

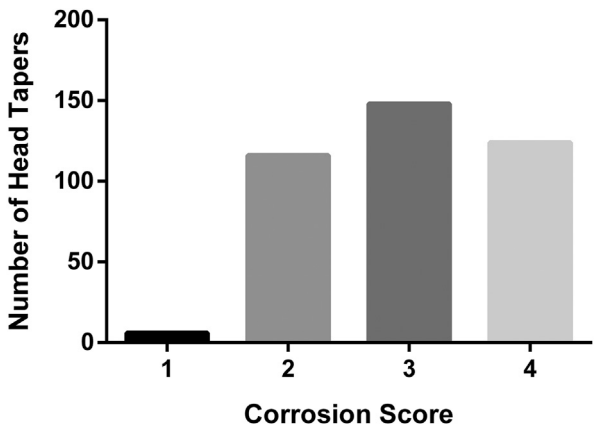

Fig. 1. Distribution of corrosion scores of the total hip arthroplasties head tapers.