

Metal-on-metal total hip arthroplasty: is there still a role in 2016?

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Abstract The use of metal-on-metal (MoM) bearings in total hip arthroplasty (THA) was popularized due to its enhanced wear profile and the ability to use large femoral heads to reduce post-operative instability. However, enthusiasm for the bearing declined following serious complications encountered at the primary articulation. This review discusses the development of MoM and the subsequent unexpected downstream challenges, most notably elevated serum metal ion levels, aseptic lymphocyte-dominated vasculitis-associated lesions (ALVAL), pseudotumor formation, and subsequent soft tissue and bone destruction. Both patient centered risk factors as well as component design led to high early failure rates resulting in product recalls and an overall decline in the use of MoM. In 2016, there is not a role for large-head MoM bearing in THA. Alternatively, the bearing has shown promise in hip resurfacing procedures for carefully selected patients.

Keywords Metal-on-metal · Total hip arthroplasty · Alternative bearings

Introduction

Total hip arthroplasty (THA) is one of the most successful procedures performed annually in the USA. As the population ages, the number of primary arthroplasty procedures performed each year is rising in conjunction with an increasing revision burden. As patients live longer and place higher demands on their prosthesis, the choice of bearing surface is critical to the longevity of the implant.

One of the common technologies utilized to optimize implant longevity has been the use of alternative bearings to decrease wear at the primary articulation. Many bearing options are available, each with different associated advantages and disadvantages. One bearing choice, which has become controversial, is large-head metal-on-metal (MoM) THA. This report briefly describes the rise and fall of the MoM bearing in THA. The bearing wear properties, early/mid-term failure (due to ALVAL, pseudotumor, metallosis, etc.), and associated elevated serum metal ion levels have led us to conclude that in 2016, there is no role for the use of large-head MoM in primary total hip arthroplasty.

Bearing options in total hip arthroplasty

Early success in THA was seen with the use of a cobalt-chromium metal head in conjunction with a conventional polyethylene bearing. The bearing provided excellent early results, but led to eventual polyethylene wear and aseptic acetabular component loosening. Polyethylene wear became an important concern for achieving favorable clinical outcomes as wear can lead to instability, osteolysis, and possible component loosening requiring component revision. Wear and osteolysis associated with conventional polyethylene led to enthusiasm for the use of alternative bearings.

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In an effort to improve the wear profile of conventional polyethylene, the material was treated with gamma irradiation to achieve cross-linking. This dramatically improved the wear characteristics of the polyethylene, albeit at the expense of the mechanical properties such as fracture toughness and resistance to crack propagation due to generation of free radicals through the irradiation process. Additional processing was conducted with either heat annealing or remelting in order to quench the free radicals and decrease the propensity for polyethylene oxidation.

This brought about further excitement for additional alternative bearing choices. Hybrid alternative bearing options such as the use of ceramic femoral heads in conjunction with a highly cross-linked polyethylene acetabular liner have become the current mainstay in primary THA. However, hard-on-hard bearings are an attractive option when focusing on trying to optimize wear reduction. The combination of boundary and elasto-hydrodynamic lubrication significantly reduces wear, compared to boundary lubrication alone in hard on soft bearings (e.g., metal on polyethylene). These mechanical properties are seen with both MoM and ceramic-on-ceramic bearings (CoC). CoC bearings have had mixed results throughout the literature, with early generations experiencing issues with ceramic fracture and squeaking [1]. The newest generation of ceramics exhibit an exceedingly low fracture risk [2, 3], yet the squeaking hip continues to be an issue [4]. Ranawat et al. reported 10.7 % of patients with CoC hips complained of audible squeaking [5].

Metal-on-metal

MoM hips were popularized in recognition of the low volumetric wear rate and increased stability using large heads [6]. The concept of large-head MoM bearing has been used in conjunction with both hip resurfacing and total hip arthroplasty. Advantages unique to hip resurfacing include the ability to preserve bone stock in young patients, improved gait and proprioception, and easy conversion to THA. Additionally, Bedigrew et al. have suggested that it is safe to return to high impact activity following a resurfacing procedure [7].

Wear, pseudotumor, and metal ions

Over the last 30 years, much has been learned about MoM bearings in THA and in resurfacing. The volumetric wear of the bearing in vitro is extremely low compared with metal or ceramic on polyethylene. However, the particles generated by the MoM bearing are significantly smaller (average size of

42 nm) than a metal-on-poly bearing (average size of 0.21 μm) [8, 9]. Although the particle size is smaller, the number of particles generated is 13–500 times greater [8] and they have been found to be more biologically active.

The generated particles cause both a local soft tissue response and a systemic increase in cobalt and chromium ion levels. Periarticular tissues have been shown to develop a nonspecific lymphocytic inflammatory response known as aseptic lymphocyte-dominated vasculitis-associated lesion (ALVAL) [10]. In addition to the ALVAL reaction, MoM hips have been found to have an increased rate of pseudotumor formation and has been documented as being present in as many as 35 % of patients [11]. Pseudotumors can present variably as fluid collections or granulomatous reactions, but often are associated with pain, mimic infection, can be destructive to host bone and soft tissue, and may require revision surgery for treatment.

Engh et al. prospectively randomized patients to 28-mm and 36-mm MoM and 28-mm metal on polyethylene bearings for total hip arthroplasty. They found cobalt levels were highest in the 36-mm MoM group in erythrocytes, serum, and whole blood at 5 years following surgery. Ion levels were lowest in the metal on polyethylene group which revealed metal ion levels unchanged from pre-operative levels [12••].

Component design, component position, metal hypersensitivity, and female sex are risk factors for elevated metal ion levels [13]. De Haan et al. demonstrated higher metal ion levels in patients with cups positioned at greater abduction angles ($>55^\circ$) due to edge loading, and they also noted the influence of component design [14, 15]. Many monoblock MoM acetabular components were designed with less than 180° coverage. Since these components were designed to be less than a full hemisphere, cups placed with an abduction angle of 45° would behave as if they were in a more vertical position, leading to increased edge loading, wear, and circulating metal ion levels. Additionally, early components with narrow clearance on the perimeter can be deformed with impaction causing failure of fluid film lubrication and increased wear [16–18].

Bayley et al. evaluated 258 hips with mean 4-year follow-up treated with MoM THA with head sizes 42 to 60 mm. Twenty percent of patients were found to have a pseudotumor on ultrasound; however, there was no significant association with any of the risk factors tested. Elevated metal ion levels were associated with smaller head size, bilateral MoM THA, and female sex [13].

Metal ion downstream effects

Patients with MoM hip bearings have been shown to have increased metal ion levels at long-term follow-up [12••].

Metal ions are not metabolized and predominantly renally excreted. Marker et al. found there to be no statistically significant change in renal function attributable to MoM THA in 98 patients over 10 years of follow-up [19].

A 1967 report suggested a link between cobalt levels and cardiomyopathy due to elevated levels of cobalt in a Canadian beer [20]. Fatal cardiomyopathy has also been demonstrated in orthopedic patients with extremely high cobalt levels [21]. Others have reported fatigue, weakness, hypothyroidism, polycythemia, cognitive dysfunction, and neuropathy [21–23]. The safety threshold for cobalt and chromium ions has yet to be defined.

Metal ions are known to be genotoxic. In vitro analysis has shown the potential for cobalt and chromium ions to induce DNA damage directly through disruption at the level of the nucleus and indirectly through the formation of reactive oxygen species [24••]. The Finnish Registry reviewed 10,000 MoM hips and did not find an increase in the overall cancer risk in patients with MoM hips (mean follow-up of 4.6 years) [25]. Further long-term investigation is necessary in order to confirm this short-term data.

Implant recall and implications

In 2010, Depuy issued a recall of its articular surface replacement (ASR) MoM arthroplasty system due to a high rate of revision in registry data. DeSteiger et al. demonstrated a 10.9 % revision rate at 5 years for the ASR hip system in the Australian Registry [26]. The ASR acetabular component was vulnerable to failure for two major reasons. First, the ASR has a sub-hemispherical design (144–165 °), which leads to increased edge loading for a given cup abduction angle. Additionally, the low clearance did not account for cup deformation upon impaction, which could disrupt the intended fluid film lubrication [27].

Since the recall, the use of large-head MoM in THA has sharply fallen from 20 % in 2005 to <1% in 2012 [28]. Surgeons began using more large heads in metal-on-polyethylene bearings in an attempt to avoid the metal debris, but maintain the stability afforded by a large head. This practice has led to the discovery of a relatively new phenomenon, trunnionosis. The use of larger heads place undue stress at the trunnion which can lead to fretting corrosion and subsequently metal wear debris, especially as the design of the trunnion and neck is shorter/smaller for some femoral implants. The maximum stress at the trunnion doubles from size 28- to 40-mm heads [29]. Trunnionosis presents clinically with similar issues as the MoM bearing [30].

In fact, wear at the taper junction has also been noted in large-head MoM THA. Langton et al. showed a 50 % rate of

failure due to taper corrosion in MoM THA with heads larger than 55 mm [31]. Although the failure of large-head MoM THA was mostly attributed to the bearing surface, the taper junction may have played an important role.

Conclusion: is there a role for metal-on-metal total hip arthroplasty?

Based on the current body of literature and experience in the USA, there is not a role for large-head MoM THA in 2016. There are many factors still unknown about the MoM bearing, but the risks do not outweigh the benefits of the use of this bearing option for total hip arthroplasty. The favorable clinical results of metal and ceramic on highly cross-linked ultra-high molecular weight polyethylene and ceramic-on-ceramic bearings provide adequate solutions to counter wear, the reason for the initial enthusiasm for use of MoM. Additionally, in the current medicolegal environment, the surgeon puts him or herself at risk for litigation with any adverse clinical outcomes associated with MoM. Finally, soft tissue and bony destruction seen in some cases associated with MoM have created extremely challenging clinical problems without a definitive solution.

Metal-on-metal hip resurfacing

Although there does not seem to be a role for MoM THA, there are still unique advantages for MoM hip resurfacing, and certain centers are still implanting a large number of these devices in patients that are properly indicated for the procedure. The theoretical advantages of hip resurfacing include maintenance of bone stock, low dislocation rates, improved proprioception, and technically easy revision to THA [32].

Resurfacing is a technically demanding procedure and is associated with a steep learning curve. Early series have had increased rates of femoral neck fracture and loosening with varus placement of the femoral prosthesis [32]. Resurfacing has exhibited the best results with young male patients with adequate residual bone stock, using head sizes larger than 50 mm [32]. With experience and strict patient selection criteria, there is still a role for MoM hip resurfacing arthroplasty in 2016.

Compliance with ethical standards

Conflict of interest Edward J. Silverman, Blair Ashley, and Neil P. Sheth declare that they have no conflict of interest.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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