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Metal-on-Metal Total Hip Revisions: Pearls and Pitfalls

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ABSTRACT

Background: At the turn of the 21st century, there was a re-emergence of metal-on-metal (MoM) articulation with 35% of all total hip arthroplasty implants having MoM articulation. Approximately 10 years after its peak use, MoM articulation began to decrease dramatically as revisions became more apparent because of adverse reaction to metal debris. Today, there are surveillance guidelines and reconstructive clinical pearls a surgeon should recognize.
Methods: This article gives a literature-based overview of clinical pearls and discusses how to avoid pitfalls when performing revision of a metal-on-metal total hip arthroplasty.
Results: Patients with MoM can be risk-stratified based on symptom, implant, and testing variables. Those patients who are symptomatic and/or develop adverse reaction to metal debris with local tissue destruction will require a revision. The revision of MoM can be challenging due to bone and soft tissue destruction. Constraint may be needed in cases of abductor deficiency.
Conclusion: Although MoM implants for THA have declined significantly, surgeons are still faced with the revision burden from a decade of high use. Risk stratification tools are available to aid in revision decision making, and the surgeon should be prepared to address the challenges these revisions present.

Total hip arthroplasty (THA) was first documented in 1891 by Dr. Gluck [1] who performed this surgery with an ivory ball and socket affixed with nickel plated screws [2] and has evolved to become the best surgery of the 21st century [3]. Around the turn of the 21st century, there was a re-emergence of metal-on-metal (MoM) total hip implants with the hope to obtain an implant that will have improved survivorship because of the lack of wear created from traditional polyethylene bearings [4]. The fluid film lubrication theoretically allowed the 2 surfaces to slide past each other with minimal contact thereby significantly reducing wear [5].

This notion of limited wear due to fluid film lubrication was short lived, however, and was disproven in 2013 [6]. Researchers demonstrated during normal walking there were brief periods of time where contact between the metal surfaces was present, thereby exhibiting boundary lubrication instead of fluid film lubrication. The researchers continued to discuss that during more strenuous hip motions such as ascending and descending stairs up to 36% of the gait cycle was under direct contact, or boundary lubrication, thereby increasing frictional stress at the bone implant interface and any modular components [7,8]. This MoM touching is increased in implant malposition thereby causing edge loading and generating a multitude of metal ions released into the serum and synovium [9,10]. Increased metal ion concentrations have been shown to have local and systemic consequences including direct cytotoxic effects, thereby causing abductor deficiency, capsular attenuation, and bony reabsorption leading to implant loosening.

In addition to the improved wear that was theorized, MoM THA implants gained popularity because of the superior head-neck ratio. With a large metal head, hip stability and range of motion were enhanced by allowing for an increase in jump distance and better range of motion before interprosthetic impingement [11,12]. This accumulation of benefits surged thereby making MoM implants 35% of all THA implants used [13].

Approximately 10 years after the peak of its use, MoM hip implant usage decreased dramatically as numerous revisions

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became apparent because of adverse reaction to metal debris (ARMD), infection, and aseptic loosening. ARMD became more widely documented and known and eventually became an umbrella term to encompass a spectrum of reactions involving metal debris including acute lymphocytic vasculitis and pseudotumors [14]. Recently, certain MoM hip designs have shown survivorship as low as 46% in 10 years, demonstrating some hip designs are more troublesome than others [15].

When evaluating a patient with a MoM hip prosthesis, it becomes important to properly review pertinent radiology and lab tests, risk-stratify the patient, and then plan proper surgical intervention. Because of the destructive nature of the ARMD, hip stability, due to capsular and abductor deficiency, and poor bone stock becomes critical to proper reconstructive revisions, and healing environments need to be optimized [16]. Results of MoM revision are varied based on the type of MoM implant used, reason for THA failure, and soft tissue and bony deficits produced through ARMD [17]. The purpose of this study is to give a detailed report regarding how to avoid common pitfalls and evaluate available pearls with revision reconstructive surgery.

Evaluation of the MoM Patient

As with all THA implants, there is a variety of reasons for persistent pain, and this multifactorial etiology can primarily be from intrinsic or extrinsic hip pathology or a combination of both [18]. A careful examination of the spine and detailed account of the onset of hip pain should be evaluated and accounted for before discussing revision hip arthroplasty. If there is a history of poor wound healing or pain after a dental/gastrointestinal procedure, particularly pain at rest, the surgeon should consider infection and evaluate this possibility with the appropriate testing [19]. Mechanical symptoms should be assessed both via history and clinically as well as an evaluation of the patient's gait to check for muscle weakness and limping.

Surgeons should carefully scrutinize the patient radiographs to evaluate for component position, signs of edge loading or impingement, signs of osteolysis, or implant loosening. The surgeon should assess for high cup inclination [9] and large femoral head size as these 2 factors have been shown to increase metal ion production secondary to edge loading [10], and particular attention should be paid to the retroacetabular, ischial, and pubic regions on patient radiographs.

When evaluating laboratory tests, the surgeon should take caution at interpreting the results as these are different than what most surgeons are accustomed to. For example, with conventional metal-on-polyethylene evaluation, elevated erythrocyte sedimentation rate and c-reactive protein levels have specificity levels as high as 0.93 [20], and synovial cell counts greater than 3000 with 80% polymorphonuclear cells have been shown to be most accurate [21] at diagnosing infection; however, this is not always the case with MoM THAs. For patients with MoM articulation, erythrocyte sedimentation rate and c-reactive protein levels have been reported to be elevated in soft tissue ARMD [22] despite not having an infection. Furthermore, synovial cell counts may be elevated greater than 3000 with up to 95% polymorphonuclear cells in ARMD [19]. Soft tissue suspension in synovial cell count evaluation makes automated cell count inaccurate [19] and manual differentiation necessary so that currently there is no absolute cell count quantity that is specific for infection.

The next laboratory finding that should be assessed is serum metal ion levels. Metal ions are released from articular and modular surfaces of the implant into the serum via mechanically assisted crevice corrosion [23]. Metal ion levels can be influenced by the implant type, implant materials and design, diameter of the bearings, and positioning of the implant [19]. Recently, both foreign and domestic government agencies [24–26] have recommended advanced cross-sectional imaging on all MoM patients with chromium or cobalt levels above 7 parts per billion (ppb), giving a sensitivity and specificity of 52% and 89%, respectively [27]. Next, there is not a well-understood correlation between cobalt/chromium levels in the serum, synovium, or blood and the extent of adverse local soft tissue reactions seen at time of revision surgery.

Imaging around an implant has always been tricky and no consensus exists regarding proper advanced imaging [28]. Ultrasound techniques have been shown to be effective in detecting a soft tissue mass adjacent to the implant [29] and are not affected by the presence of metal [30]. This modality can differentiate between solid and cystic lesions and aid in biopsy and aspirations but is operator dependent with a large learning curve [19] and can be difficult in large patients [31]. Metal artifact reduction sequence (MARS) MRI allows for imaging around the peri-implant area by decreasing image distortion created by the ferromagnetic property of the cobalt chrome implant [30]. MARS MRI becomes an important advanced imaging modality that allows for the evaluation of fluid collection boundaries and solid masses as well as the

Table 1
Risk Stratification of Patients.

Variable	Low Risk	Moderate Risk	High Risk
Patient factors	Low activity	Dysplasia Moderate activity	Female with dysplasia High activity
Symptoms	Asymptomatic	Mild hip symptoms Mechanical symptoms No systemic symptoms	Severe hip symptoms Mechanical symptoms Systemic symptoms
Clinical examination	No swelling/gait disturbances	Change in gait No abductor weakness	Change in gait/limp Abductor weakness
Implant type	Small diameter head <36 mm	Large diameter head >36 mm Modular neck Recalled MoM implant	Large diameter head >36 mm Modular neck Recalled MoM implant
Radiographs (2 views ± serial high risk if available)	Acceptable cup orientation No osteolysis	Acceptable cup orientation No osteolysis	Suboptimal cup orientation Implant osteolysis/loosening
Metal ion level test	Low <3 ppb	Moderate (3-10 ppb)	High >10 ppb
Advanced imaging (cross-sectional imaging)	Within normal limits	Abnormal tissue reaction without involvement of surrounding muscle/bone Simple/small cystic lesions without thickened wall	Abnormal tissue reaction with involvement of surrounding muscle/bone Solid lesions Cysts with thickened wall
Treatment recommendation	Annual follow-up	F/U 6 months Consider revision if symptoms worsen, imaging worsens, or ion levels increase	Revision surgery

Adapted From Kwon et al 2014.

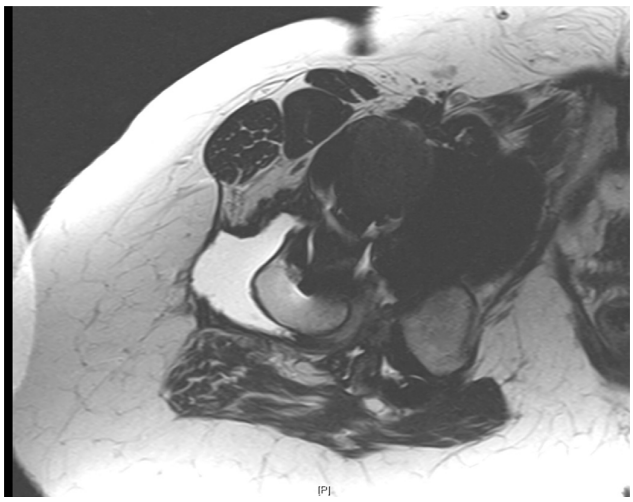

Fig. 1. Axial MRI image demonstrating large fluid collection lateral to the greater trochanter and abductor deficiency noted.

involvement of juxtaposed neurovascular structures. This MRI also allows for evaluation of the soft tissue envelope including hip abductor and gluteal musculature [32]. Using this information, the surgeon is then able to assess the amount of damage to the surrounding soft tissue and make a better assessment of what is needed during the reconstructive process.

Risk Stratification

After carefully evaluating a MoM THA patient and using the information presented previously, the surgeon is able to properly risk-stratify the patient (Table 1). High-risk patients are those who have a high level of activity and more likely to be female with etiology for THA being hip dysplasia. These high-risk patients may experience systemic symptoms, have mechanical clicking, a limp, and even express a Trendelenburg sign because of gluteal weakness. Patients with recalled THAs or large diameter femoral heads (greater than 36 mm) and may have modular or nonmodular THAs are considered high risk.

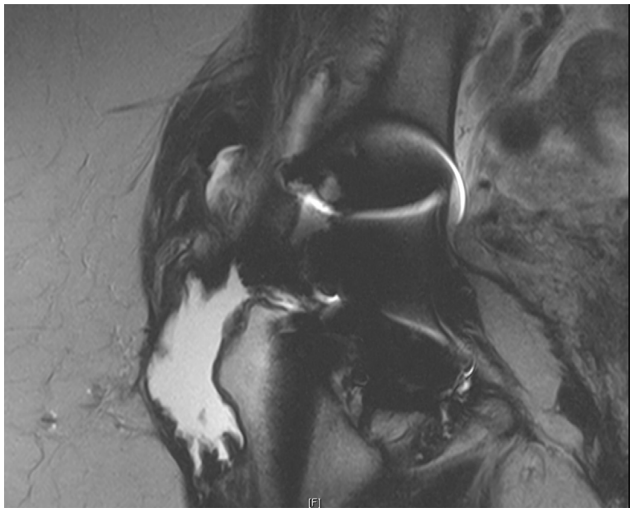

Fig. 2. Sagittal MRI image demonstrating a large fluid collection noted lateral to the greater trochanter with abductor deficiency noted.

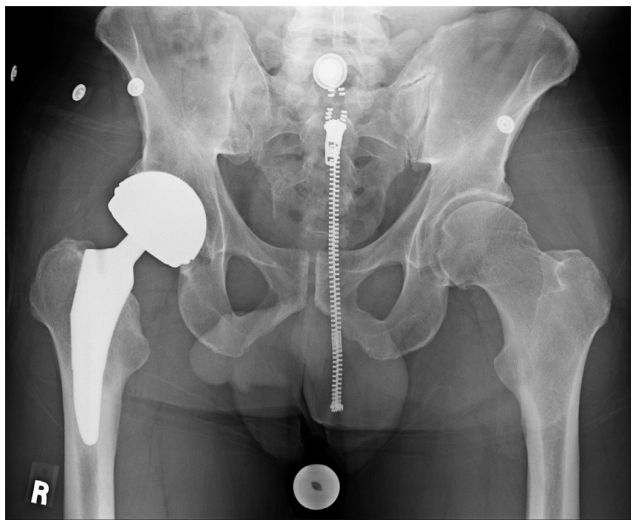

Fig. 3. Anteroposterior radiograph of a 65-year-old male 2 years from cementless metal-on-metal total hip arthroplasty.

As stated earlier, patient imaging should be scrutinized for suboptimal implant positioning or signs of implant loosening. Imaging should start with standard radiographs, and in symptomatic patients, should progress to advanced imaging modalities such as ultrasound or MARS MRI. Metal ion testing greater than 10 ppb with the presence of abnormal thickened tissues surrounding muscle/bone is also noted to be of high risk in patients.

Reconstructive Considerations

When considering revision MoM THA, it is important to realize this is a heterogenic population and not all revision reconstructions are the same. Patients with well-fixed and well-positioned implants may be treated with exchange of modular components and limited revision [33], whereas malpositioned implants and large soft tissue defects require more extensive revision reconstruction [34]. After evaluating the MoM patient and determining the patient to need revision hip arthroplasty, the orthopedic surgeon should be aware of several reconstructive issues. First, the reconstructive surgeon should have a high index of suspicion for infection [35]. Some studies have noted a correlation of increased infection related to MoM hip prosthesis [36] with the thought that increased cobalt and chrome products hamper the immune system, possibly accelerating bacterial growth and increasing antibiotic resistance [35].

Another concern the reconstructive surgeon should be aware of is the metal particles released from the MoM articulations; modular junctions may cause fretting corrosion, elevating metal particle debris within local tissues [37]. This process can produce local adverse tissue effects, causing inflammation and even cytotoxic effects including direct soft tissue damage and periprosthetic osteolysis and loosening [37]. Risk factors for poor outcomes in MoM THA revisions include prerevision radiographic peri-implant loosening, solid lesions ± abductor deficiency seen on MRI, and high-grade intraoperative tissue damage associated at revision surgery. Risk factors for re-revisions were highest in patients with revision etiology for infection or dislocation [38]. Higher morbidity was noted in MoM THA revisions with 14% complication rate and 7% re-revision rate seen at 30 months [39]. Owing to the cytotoxic nature of the metal ions, there is usually extensive abductor musculature noted at the time of surgery [16].

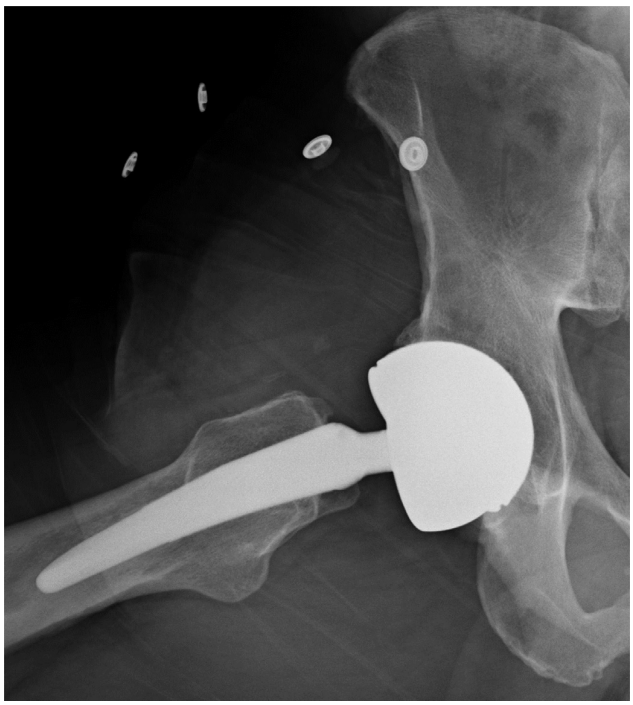

Fig. 4. Frog leg lateral radiograph of a 65-year-old male 2 years from cementless metal-on-metal total hip arthroplasty.

Surgeons should be prepared to address an abductor deficiency (Figs. 1 and 2) with the use of a constrained liner or dual mobility [34]. In patients with a well-positioned acetabular cup and functional gluteus medius musculature, one attractive option is the use of a dual mobility articular bearing [40]. This allows the surgeon to perform a balanced revision debridement, thereby removing damaged tissue but preserving the acetabular cup and large femoral head stability (Figs. 3–5). In cases of severe abductor damage, the surgeon may consider a gluteus maximus muscle transfer described by Leo Whiteside [41].

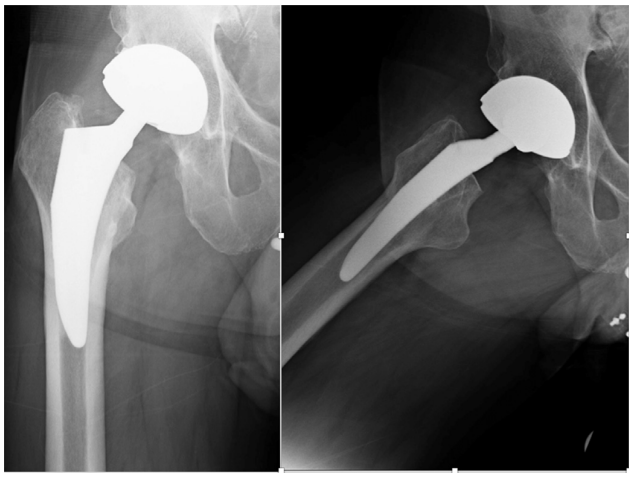

Fig. 5. Postoperative radiograph of the same patient after THA revision. Implants were noted to be well fixed and in good position at time of surgery, and limited revision using dual mobility was elected.

The main complications related to MoM THA hip revisions involve dislocation, failure of ingrowth of new acetabular cup, loss of bone stock, increased morbidity, increased blood loss, and increased operative times [42]. Re-revision surgery after MoM THA revision was most often due to infection, dislocation, or failure of ingrowth [34]. Infection rates are noted to be lower in ceramic on polyethylene articulations [43], and midterm studies have shown ultraporous cups [44] to have low rates of aseptic loosening to combat this problem [45]. Dislocation is noted up to 28% after MoM THA revision via a posterior approach [17].

Conclusions

Despite the multitude theoretical advantages for MoM THA, high complication rates have been demonstrated and in situ results have been less favorable compared with in vitro testing. It has been estimated that over 1 million MoM THAs have been implanted [37], and even with this increased rate of MoM THA revisions, 80% of MoM THAs remain in situ today [33]. Initial outcomes of MoM THA revisions were poor but have improved recently because of improved and regular patient surveillance, lower thresholds for performing revision, and increased surgeon experience with ARMD.

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