ISSN 2348-702X

March 2014 Volume 1 Number 1

World Clinics

ORTHOPEDICS

Current Controversies in Joint Replacement

Editors
Matthew S Austin
Gregg R Klein

JAYPEE

Contents

World Clin Orthoped. 2014;1(1):1-15.

Hard-on-hard Bearing Surfaces in Total Hip Arthroplasty: What to Do When It All Goes Wrong

[1]David Fabi MD, *,[2]Brett R Levine MD MS

[1]Orthopedic Associates Medical Group, San Diego, California, USA
[2]Department of Orthopedics, Rush University Medical Center, Chicago, Illinois, USA

ABSTRACT

Total hip arthroplasty (THA) is being performed at increasing rates with excellent results being reported in the vast majority of patients. Despite these encouraging results, long-term follow-up has targeted the bearing surface as the weakest link in the system. Continuous efforts are being put forth to improve upon both performance and survivorship of primary THA; as a result, developments, such as hard-on-hard bearing, were developed to solve the "wear issues". Early enthusiasm for these so-called alternative bearings has been tempered by the development of unique complications and reports of early failure mechanisms. The following article will discuss the background, workup of hard bearing complications, and their treatments when trouble arises.

INTRODUCTION

In the United States, the prevalence of total hip arthroplasties (THAs) being performed continues to increase at a rapid rate with favorable results being reported in the majority of patients.[1] Furthermore, demographic studies have predicted the rate of THAs to increase exponentially over the next two decades, as a greater number of patients are entering the elderly population range.[1] Despite the clinical success of THA, continuous efforts are being set forth to improve the performance and longevity of these implants as indications for primary surgeries have expanded to younger and more active patients. Such endeavors have included

*Corresponding author
Email: brettlevinemd@gmail.com

the advent of "hard-on-hard" bearings to address the potential shortcomings of such standard "soft bearings" like metal-on-polyethylene (MOP) [this includes standard ultrahigh molecular weight polyethylene (UHMWPE)].

The two most commonly utilized "hard-on-hard" articulations include metal-on-metal (MOM) and ceramic-on-ceramic (COC) bearing surfaces[2] (Figures 1 and 2). Moreover, in the search for the ultimate bearing surface, the advent of diamond, ceramicized metal, and ceramic-on-metal bearings are currently being investigated as viable alternatives to enhance the longevity of primary THA components.

Advantages of these bearing surfaces are predicated on decreased wear rates; therefore, potentially culminating in improved survivorship.[3-5] Other attractive features of these bearing surfaces, including greater hip stability with MOM THA, as larger femoral heads, can be utilized to improve the head-to-neck ratio and jump distances. Unfortunately, as short- and mid-term follow-up has demonstrated,

Figure 1: Example of a metal-on-metal total hip arthroplasty.

Figure 2: Example of a ceramic-on-ceramic total hip arthroplasty.

unforeseen and unique complications can arise with these new technologies.[6-9] Understanding these failure mechanisms may lead to future improvements in the next generation of alternative bearing surfaces.

METAL-ON-METAL TOTAL HIP ARTHROPLASTY

Metal-on-metal THA is not a novel concept as early generations of these bearing surfaces were utilized in the past with limited success. These early MOM designs were essentially abandoned secondary to their high failure rates, and the improved results demonstrated with MOP bearings at the time.[6] The major issues with these early generation MOM bearings were poor manufacturing and engineering processes.[2] Recently, MOM bearings experienced a revival as a result of improved metallurgy and fabrication techniques, and a potential to remedy the conundrum of THA instability.[2] Another potential advantage hinges on the favorable wear rates of MOM THA (in simulator modules) as compared to more traditional MOP bearing surfaces, leading to the speculation of greater long-term survivorship.[3-5] Furthermore, hip resurfacing further contributed to the resurgence of these articulations with the proposed advantages of bone preservation, improved stability, greater range of motion, and more natural kinematics (Figure 3). The allure of a greater range of motion, enhanced stability, and low wear rates made MOM bearings a viable alternative, especially in younger and more active patients with osteoarthritis of the hip.

In registry and early clinical data, it was noted that MOM THAs may be associated with several unique concerns not commonly experienced in the past. Multiple reports have since described the occurrence of increased serum cobalt and chromium levels in patients with MOM bearing surfaces.[6,7] The long-term consequences of this phenomenon are currently unknown due to the lack

Figure 3: Birmingham hip resurfacing.

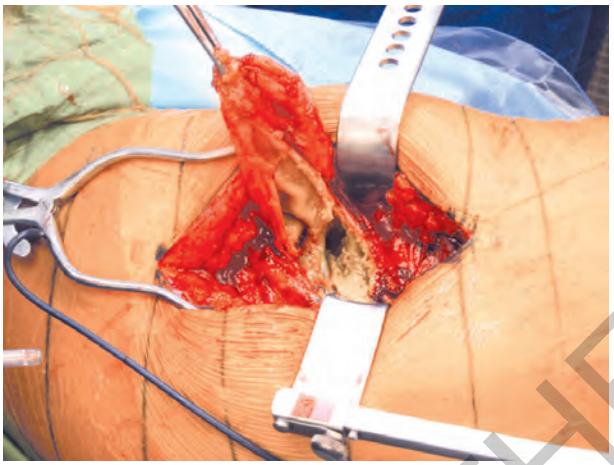


Figure 4: Intraoperative image of a patient with a large pseudotumor.

of long-term data with these newer implants. Fortunately, thus far, a direct relationship between elevated serum ion levels and malignancy or deleterious systemic effects has not been definitively proven. However, there have been case reports of potential systemic issues that have been observed, such as acute renal failure and neurological illnesses seen with elevated ion levels.[10,11] Furthermore, these metal ions do cross the placenta and thus implantation of MOM THAs is not recommended in women of child-bearing age.[12]

Again, true validity and a direct causal relationship of these happenstances are not possible without further investigation and cases demonstrating similar findings. Despite a paucity of reports on systemic issues, there are a plethora of reports in the literature discussing localized effects and morbidity associated with metal sensitivity, metallosis, newly described pseudotumors, and aseptic lymphocytic vasculitis-associated lesions (ALVALs)[6-9,13-18] (Figure 4). As a result, revisions of MOM THAs are being undertaken for reasons rarely if ever encountered before. There is a wide spectrum of presentation of adverse local tissue reactions, many attributing the etiology to be related to component malposition, female gender, and femoral head size.[19,20] Additionally, important consideration must be placed on manufacturer design, recent implant recalls, and the material science associated with components with such unacceptable high early failure rates.[21,22]

CERAMIC-ON-CERAMIC BEARINGS

Like MOM bearings, the impetus behind the development of COC bearings was to improve upon UHMWPE wear and THA survivorship. Similar to MOM

bearings, unforeseen complications surfaced throughout the short- and mid-term follow-up of these implants. With early generation COC bearings, femoral head and/or liner fracture was a serious cause for concern with reported rates as high as 13.4% in ceramic heads manufactured before 1990.[23] This concerning fracture rate was in part due to materials that were manufactured by companies that are no longer in the current market.[23] With later generations of ceramic heads, this occurrence has decreased exponentially to a reported rate of 0.004%.[23] Fortunately, this risk of fracture has been reduced significantly, and newer generation ceramic bearings have demonstrated improvement in performance compared to older generation ceramic femoral heads. The conundrum behind ceramic femoral head fracture lies in the exorbitant amount of ceramic debris encountered at the time of revision surgery as well as determining the best articulation couple for the subsequent revision THA. Often, complete removal of debris is not possible and a substantial risk for third-body wear as well as an adverse local tissue reaction (pseudotumor) remains.

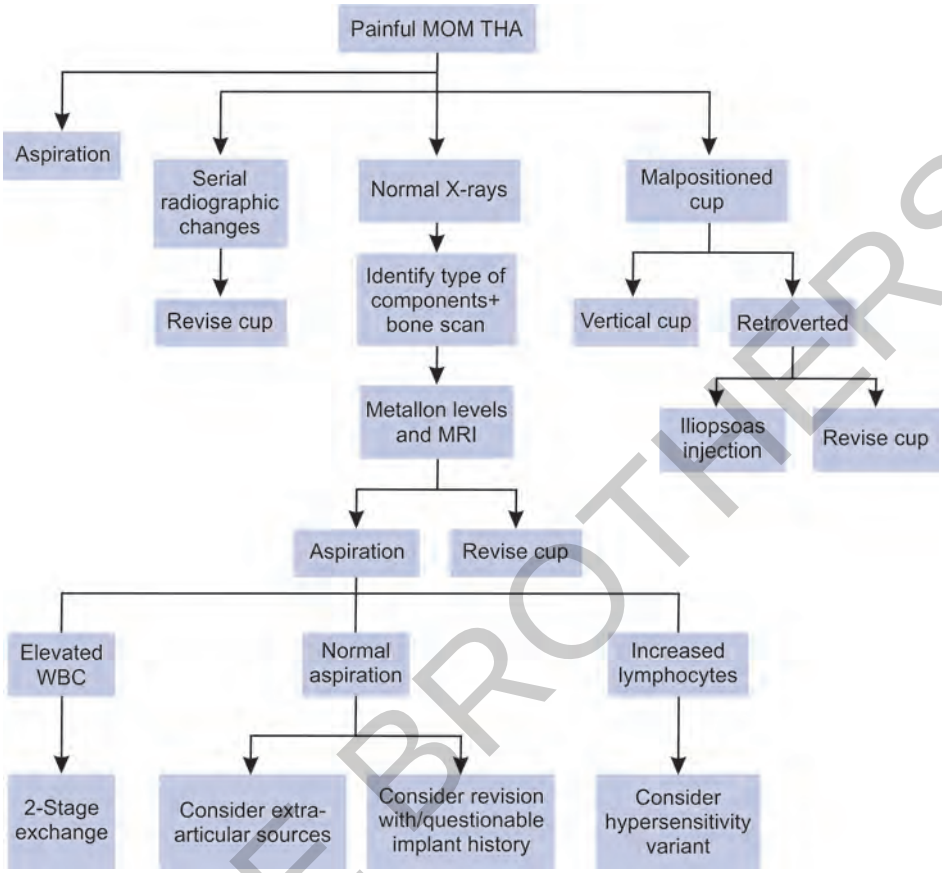
DIAGNOSIS

In terms of establishing a diagnosis for the painful hard-on-hard bearing THA, both COC and MOM must be discussed individually based upon their unique failure mechanisms. First and foremost, as with all painful THAs, infection must be ruled out prior to revision surgery, starting with a laboratory assessment to include a sedimentation rate and C-reactive protein (CRP) as well as hip aspiration and cell count when appropriate. Particularly with adverse tissue reactions, purulent looking material may be associated with necrotic cells and not infection when found during aspiration.

Evaluation of Painful Metal-on-metal Total Hip Arthroplasty

With regards to establishing a diagnosis for painful MOM THA, we have reported on a detailed algorithm to workup this situation (Figure 5). In the past, MOM complications were considered a diagnosis of exclusion once more common reasons for THA failure, such as instability, aseptic, and septic loosening and particulate-induced osteolysis, were thoroughly investigated with standard and advanced imaging modalities when appropriate.

In the setting of negative screening laboratories, routine hip aspiration is not recommended with standard THAs in the past. However, one needs to be aware that distinction between septic failure and MOM-related failures can be quite difficult to differentiate. MOM reactions can mimic infection with elevated inflammatory markers [erythrocyte sedimentation rate (ESR) and CRP], increased synovial white blood cell counts (need a manual count as necrotic debris



MOM, metal-on-metal; THA, total hip arthroplasty; MRI, magnetic resonance imaging; WBC, white blood cell.

Figure 5: A proposed algorithm to investigate painful metal-on-metal total hip arthroplasty.[9]

often leads to inaccurate results) and large joint effusions that grossly resemble purulent material (Figure 6).[10] There are published case reports discussing these findings in significant detail.[10]

In the workup of a painful MOM THA, we highly recommend preoperative hip synovial fluid aspiration despite the results of the screening lab tests. Analysis of the synovial fluid white blood cell count and cell differential was initially thought to be a vital element of the workup. Unfortunately, cell counts and differential are often equivocal, and culture results take several days to finalize. With experience, the fluid color and soft tissue appearance intraoperatively will portray the underlying diagnosis of an adverse local tissue reaction (Figures 4 and 6). The preoperative cell count and culture results can ultimately be used to guide perioperative antibiotic

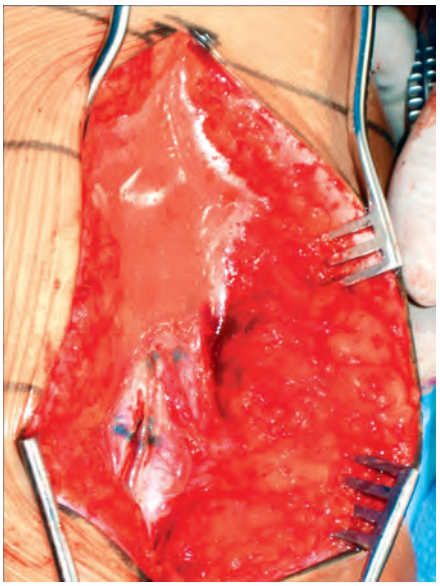


Figure 6: Intraoperative image demonstrating the gross appearance of a metal sensitivity/metallosis effusion and how it mimics the gross appearance of purulence. This effusion ultimately was aseptic in nature.

treatment after the revision THA. In addition, intraoperative cultures are necessary to address the possibility of a false-negative preoperative culture.

As with other THA components, scrutiny of serial radiographs with a particular focus on acetabular cup position, identification of component manufacturer, and signs of loosening is essential to elucidate the cause of failure. When loosening is ruled out either with stable serial radiographs and/or a negative triple phase bone scan, serum metal ion level analysis should be drawn. In reality, in the absence of gross component migration or overt septic arthritis, it is suggested to obtain metal ion levels in all painful MOM THAs. This is advisable in order to achieve a baseline level such that return to normal standards can be followed. Elevated serum metal ion levels in the setting of a painful and well-fixed acetabular cup suggest the presence of a local soft tissue reaction that can range from a painful effusion to severe soft tissue necrosis or pseudotumor. In the setting of a malpositioned well-fixed acetabular cup (particularly vertical and/or retroverted position), this diagnosis should be entertained as edge loading and high contact stresses can be expected *in vivo*. In this scenario, preoperative imaging with ultrasonography, magnetic resonance imaging (MRI), or computed tomography (CT) is recommended. If a localized fluid collection is identified, an intra-articular aspiration is recommended with lab analysis to inspect the presence of metal debris/ions. Additionally, physical examination should look for the presence of a soft tissue mass. If present or suspected, there should be a low threshold to obtain the aforementioned advanced imaging studies.

Figure 7: Radiograph of a patient with a retroverted high profile metal-on-metal articulation. Physical examination and intra-operative findings demonstrated iliopsoas impingement. The patient's pain improved after revision total hip arthroplasty.

In actuality, obtaining a CT, MRI, or ultrasound in the setting of elevated metal ion levels and pain to investigate for the presence of an intra-articular effusion or pseudotumor is commonly performed despite the suggestion to follow an algorithmic approach. The confirmation of such soft tissue findings provide further indication for revision THA as well as prepare the surgeon for what will be encountered at the time of revision THA. The soft tissue destruction may be mild or involve a greater area leading to difficulties with a large dead space or abductor compromise during the revision THA.

Other important examination findings include pain with resisted hip flexion, which potentially indicates the diagnosis of iliopsoas impingement, especially in the setting of a retroverted acetabular cup or high-profile cup and articulation. Iliopsoas impingement can be confirmed with an interventional radiology-guided iliopsoas injection (Figure 7). As previously mentioned, component types, when necessary, should be identified by radiograph, previous operative report, or implant stickers. This is essential, as there are now well-known problematic acetabular cups with significantly high early failure rates related to aseptic loosening and joint seizing.[21,22]

Evaluation of a Painful Ceramic-on-ceramic Total Hip Arthroplasty

Unique to COC, THA is the incidence of clinically audible "squeaking". This phenomenon has a reported incidence range of 0.7–20.9%.[24] Causes of this

Figure 8: Photograph depicting ceramic head fracture. *From* D'Antonio JA, Sutton K. Ceramic materials as bearing surfaces for total hip arthroplasty. *J Am Acad Orthop Surg.* 2009;17:63-8, *with permission.*

occurrence are currently unknown; however, proposed etiologies include edge-loading, stripe-wear, component malposition, and altered fluid mechanics of the bearing surface.[25-27] Diagnosis of this clinical scenario is often straightforward as patients present with noticeable and very audible squeaking. Scrutiny of serial radiographs is essential as malpositioned components can potentially clue you into this problem. Revision in this scenario is an option as squeaking can be very disheartening, embarrassing, and disruptive to the patient. Squeaking can also indicate a more severe issue with the bearing as a large amount of ceramic wear can occur with or without underlying metal wear as complete ceramic surface delamination can be seen. Thus, this can result in serious local soft tissue involvement and alteration.

Another distinct issue with COC bearings is the incidence of liner and/or femoral head fracture (Figure 8). Earlier generation COC bearings and ceramic heads alone had a high incidence of fracture with bearing produced before 1990 demonstrating a rate of 13.4% as states preciously.[23] Newer generation ceramic heads and liners have fortunately improved upon this complication and now have an extremely low incidence of fracture with a reported incidence of 0.004%.[23] Diagnosis of head and liner fracture is relatively straightforward as this is often noticeable on plain roentgenograms (Figure 9). Revision in this situation must be performed urgently to prevent further soft tissue and component damage.

TREATMENT

Once the diagnosis and reason for failure is elucidated, revision THA should take place. The details of each specific scenario and cause of failure dictate the

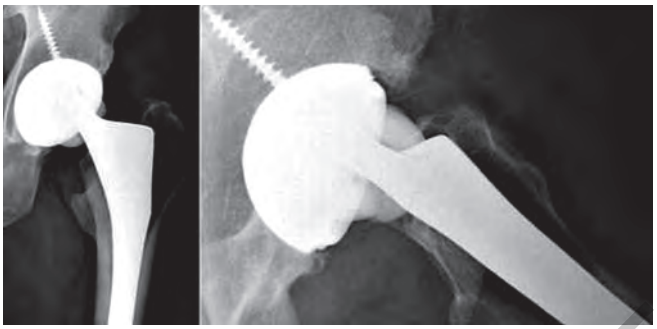


Figure 9: Radiographs depicting ceramic head fracture. *From* Rhoads DP, Baker KC, Israel R, Greene PW. Fracture of an alumina femoral head used in ceramic-on-ceramic total hip arthroplasty. *J Arthroplasty*. 2008;23(8):1239.e25-30, *with permission*.

necessary treatment. Utilizing an algorithmic approach to diagnosis can help with having the correct preoperative studies in acquiring the appropriate intraoperative equipment required for a successful revision surgery.

With a loose acetabular component, cup revision should be performed with a conversion of the hard-on-hard bearing surface to a hard-on-soft articulation [i.e., MOP or ceramic-on-polyethylene (COP)]. Bearing choice can be dictated by patient age and surgeon preference. In the setting of a hard-on-hard articulation failure, we do not recommend revision with a MOM or COC bearing surface. In the following sections, we will discuss treatment options for MOM THA and COC THA troubles separately.

Metal-on-metal Total Hip Arthroplasty

With a stable ingrown cup that is malpositioned and with associated elevated metal ion levels, acetabular cup revision should be considered particularly with a vertical component as this can predict an increase in the risk of polyethylene liner edge-loading and ultimately early failure either via liner fracture or early liner wear from edge-loading. In an ingrown, retroverted cup revision is recommended to avoid further iliopsoas irritation as well as difficulties with hip stability. The risks of cup revision involve addressing bone loss after cup extraction and obtaining stable fixation; however, with current explant osteotomes, bone loss is typically kept to a minimum. The other option in treating iliopsoas impingement requires maintaining the cup and performing an iliopsoas release; however, the potential pitfalls of this are hip flexion weakness with the advantages of not having to address issues associated with acetabular cup revision. Use of a MOP or COP articulation can be utilized when revision for iliopsoas impingement is performed.

In scenarios of potential adverse local tissue reactions, especially coupled with elevated serum metal ion levels, the surgeon must always be aware that the soft tissue envelope around the hip may be significantly affected. These soft tissue ramifications range from minimal to severe. Presentations can be seemingly insignificant, such as scarring or an effusion, and can expand further to catastrophic necrosis of the abductors (Figure 10). We have devised a classification scheme describing modes of failure and the range of soft tissue involvement seen in MOM THA revisions (Tables 1 and 2).

Figure 10: Intraoperative photograph of patient with complete abductor necrosis from a failed metal-on-metal total hip arthroplasty during one of the authors' cases.

Table 1: Fabi-Levine Mode of Failure Classification[9]

Type	Description	Treatment
1	Metal sensitivity—stable, well aligned acatabular component, elevated metal ions, and pain	Revise bearing only to metal-poly (m-poly) or ceramic-poly (c-poly), if cup modular; if cup monoblock revise cup with m-poly or c-poly, bearing
2	Malpositioned cup—stable malaligned acetabular component, elevated metal ions, and pain	Revise cup with m-poly or c-poly bearing
3	Loose cup	Revise cup with m-poly or c-poly bearing
4	Early failure cups—acetabular components with known high early failure rates	Revise cup with m-poly or c-poly bearing
5	Iliopsoas impingement—ion levels within normal limits, cup retroverted	Iliopsoas release or revise cup to optimal position with m-poly or c-poly bearing

Table 2: Fabi-Levine Metal-on-metal Total Hip Arthroplasty Soft Tissue Complication Classification[9]

Type	Description	Treatment
1	Intracapsular effusion, capsule intact	Revise bearing and/or cup if needed, stability less of an issue
2	Extracapsular effusion, capsule affected, abductors intact	Revise bearing and/or cup if needed, stability more of an issue
3	Capsule affected, abductors affected	Revise bearing and/or cup if needed, stability severely compromised, consider constrained liner, other salvage options

As with all revision THA, postoperative dislocation is a concern, but cannot be underestimated in the setting of failed MOM THA (large femoral head will decrease and abductors may be compromised). At the time of revision surgery, we recommend having multiple component options, such as large femoral heads, tripolar articulations, elevated liners, and constrained liners available to address potential instability issues. Further, it is advisable to use the least constraint possible during revision THA and maintain adequate polyethylene thickness for better long-term survival. Elevated rim liners are utilized when standard ones require minor supplementation to achieve optimal stability. If this is not successful with trialing, then attempts with "tripolar" articulations should be undertaken either with standard or elevated polyethylene liners with bipolar heads, or possibly with newer dual-mobility articulations (i.e., anatomic dual mobility or modular dual mobility. If stability is affected by a malpositioned cup, then revision of the cup should be performed to optimize component position and enhance stability. Finally, if stability still cannot be obtained with a well-positioned cup and the options above, then the use of a constrained liner is warranted. We recommend against the use of constrained liners in conjunction with concomitant cup revision as this can lead to failure of cup ingrowth and/or early cup loosening. However, if an excellent press-fit is obtained with concomitant fixation using multiple screws, constrained liners can be placed with the understanding that early failure and altered ingrowth are possible. Another option is to place a constrained liner in a staged fashion after cup ingrowth has occurred (minimum of 6 weeks) in the setting of repeated early dislocations of an unconstrained articulation. Overall, we do not recommend the use of a constrained liner unless absolutely necessary and all other options have been exhausted.

When adverse metal reaction, metallosis, pseudotumor, and metal sensitivity are diagnosed, revision to a MOP or COP articulation should be performed. We will typically utilize a titanium sleeve over the femoral trunnion in cases with significant Morse taper corrosion.

Available at all medical book stores
or buy directly from Jaypee Brothers through online shopping
at www.jaypeebrothers.com

JAYPEE BROTHERS
Medical Publishers (P) Ltd.
www.jaypeebrothers.com

ISBN 978-93-5152-003-0
9 789351 520030