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Clinical Faceoff

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Clinical Faceoff: Instability After THA: The Potential Role of the Bearing Surface

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Instability after THA continues to adversely impact this otherwise-near-perfect operation. While instability has many causes, perhaps the most common relates to malpositioning of the components. The fear of instability may have been the main driver behind the use of metal-on-metal (MoM) bearing surface across the globe. Indeed, at one point in time, nearly one-third of the THAs performed in the United States used MoM bearing surfaces [23]. While it appears that larger femoral heads may reduce the risk of dislocation after THA, the influence of the bearing surface is less-well understood, and it has become a pressing question.

I have asked two world experts, Michael J. Dunbar MD, FRCSC, PhD, Professor of Surgery in the Department of Orthopaedic Surgery at Dalhousie University and Laurent Sedel MD, Emeritus Professor of Orthopaedics at the University of Paris to offer their perspectives on the bearing surface issue as it pertains to instability after THA. These renowned surgeons have invested immense energy to understating post-THA instability, and the influence of bearing surfaces on this problem.

Javad Parvizi MD, FRCS: *Despite our concerted efforts during the last three decades, we still do not seem to have solved the issue of instability after THA. Why might that be?*

Michael J. Dunbar MD, FRCSC, PhD: Post-THA instability has not been solved for several reasons. While larger femoral heads do afford a measure of protection, concerns about corrosion and local soft-tissue reactions, as well as uncertainty regarding whether large femoral heads are part of MoM articulations [25] remain on surgeons' minds. And although surgeons template THAs from plain two-dimensional (2-D) radiographs, THA remains a 3-D operation. Additionally, there is considerable disagreement about what the "safe zone" for acetabular cup placement should be [21], or whether a "safe zone" even exists [1]. Variations in pelvic morphology, such as width-to-height ratio, may also be associated with variation in acetabular orientation and morphology. Cementless stems that are wedged into a position in the femoral canal may further limit a surgeon's options for femoral anteversion compared to what is possible with cemented stems.

Hip dislocations occur when patients are moving, most often when changing positions that involve flexion. Considering this, hip dislocation is essentially a 4-D problem associated with movement of a 3-D object through time and space. There is increasing awareness of this issue in the crossover spine literature [3, 7, 24], where an increased risk of dislocation has been reported in individuals with spinal fusions. Large variability has been reported in the range of individual truncal pelvic motion when changing positions, such as rising from a chair [10]. This variability likely would follow a normal frequency

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distribution as well, with resultant outliers. Yet the surgery is performed with the pelvis bolstered in a static, and often nonanatomical, position with no meaningful consideration of how pelvic position might change dynamically. It is perhaps not surprising why even a sophisticated 3-D approach to safe zones may miss the target in this 4-D problem.

Further complicating matters are patient factors like neuromuscular control, collagen type and strength, and many others; despite these almost certainly making a difference, their individual variability is difficult to assess before surgery or act on intraoperatively.

Laurent Sedel MD: Dr. Dunbar did a good job of addressing dislocation right after surgery. While I agree with what he said, I would also note that many surgeons no longer use bearings with increased head sizes. Increasing the head size with a ceramic-on-ceramic (CoC) bearing, for example, would reduce the liner thickness and potentially lead to a fracture.

Regarding patient evaluation, I use the EOS® imaging system (EOS® Imaging SA, Paris, France), which provides the exact 3-D anatomy of the patient's hip. I also recommend addressing anteversion differently. For example, a patient with developmental dysplasia of the hip anteverted about 40° or more will benefit from a THA procedure, and because their muscles will adapt to anteversion, I recommend a 25° anteversion instead of my usual 15°. This degree of anteversion is difficult to obtain with a cementless stem, but I solved this problem by using a cemented straight stem. Lumbar fusion could change the pelvic position, as well as the type of surgical approach, surgeon experience, and patient-related factors. Still, every solution has the potential to introduce new problems. In France, surgeons use dual-mobility cups because they effectively reduce the risk of early dislocation. But in the long-term, dual-mobility cups are at risk of intraprosthetic dislocation [9].

My main concern is addressing long-term instability and/or dislocation. In my view, long-term instability of the prosthetic hip is related not only to the size and orientation of prosthetic materials, but it might also involve the soft-tissue healing after surgery. This healing process might be altered or modified by foreign body reactions produced by the sliding parts or the bearing surface [29].

In my practice, I found that when I use CoC bearings, a biological response to these tiny ceramic particles create a strong and fibrous tissue around the hip called neocapsules. These neocapsules limit the possibility of late dislocation.

Dr. Parvizi: *What do you think drives the rather-dramatic differences from nation to nation in terms of bearing selection in THA?*

Dr. Dunbar: When different types of bearing utilization rates are compared, we find that bearing selection is not dramatically different among nations—at least not among those that have registries [2, 26, 32]. Generally, nations use crosslinked metal-on-polyethylene (MoP), CoC, ceramic-on-polyethylene, and MoM bearings. The proportional difference in bearing use is what varies among countries. Interestingly, countries with arthroplasty registries report MoP as the bearing used most frequently, followed by ceramics, and then MoM [2, 26, 32]. The proportional differences vary, but the order of use does not. Countries with the longest-standing registries, like Sweden, have the lowest utilization of bearings other than MoP, which are implanted in more than 80% of all patients in that country [32]. It has been postulated that decades of reporting outcomes to surgeons via the registry has resulted in the standardization of bearings [12]. Countries with registries that have been in existence for shorter periods of time like England and Wales, report more variation in bearing choices, but this variation is related to the type of femoral fixation. For example, in the 13th Annual Report of the National Joint Registry for England, Wales, Northern Ireland, and the Isle of Man, 84% of cemented hips received a MoP bearing, while only 57% of hybrid cases and 42% of uncemented cases received MoP [26]. Given that most hips in Sweden are still cemented [16], it appears that at least some of the variation in bearing selection between nations is more related to the type of femoral fixation [10]. Briefly, some countries concentrate on what works and eliminate what does not, while other countries favor quality improvement through innovation. Those that eliminate what they do not use tend to standardize to what they started with. Therefore, countries like Sweden, which started with MoP, report less registry experience with other bearing couples.

Joint registries are ideal to study the question of bearing utilization, but not all countries have them. Subsequently, there is a selection bias in the literature. For example, it is widely believed that the utilization of ceramic bearings is higher in France than other countries, but without a national registry it is difficult to look for cause and effect within the country. It is similarly difficult to compare to other nations as well [9]. This could be related to higher utilization of uncemented femoral fixation and France's early adoption of ceramic bearings.

Finally, and perhaps most importantly, there are differences in bearing choices because of the large standard effect size associated with hip replacement [20]. Standard effect size refers to the magnitude of the effect of the intervention, independent from the sample size. Because THA has such a large standard effect size, it becomes difficult to assess small differences in dislocation risk that may exist among bearing options.

Dr. Sedel: This is an interesting question that requires examining the registry data and/or a country's healthcare policies.

In South Korea, 76% of the bearings used in THA are CoC [34], compared to less than 5% for Scandinavian countries and the US [11]. The Swedish registry proved its efficacy for quality improvement, but at the same time, showed that revision THAs were far more frequent in patients under 55 years, reaching 25% at 10 years [11].

But registries have their limitations. For example, registries do not include materials that could be popular in other countries. The Swedish registry does not include very much about CoC, MoM, nor dual mobility cups, which are frequently used as primary implants in France [5].

The major argument against CoC has been the possibility of bearing fracture. However, those fractures are rare with contemporary materials, and were more common with earlier materials because of low-density and large grain size [15]. While some may feel that fracture is a risk that especially applies to young and active patients, my own observation from many years of using this bearing couple is that these fractures generally do not occur during strenuous activities [14].

In the United States, the fear of fracture is high due to concerns about litigation and rising insurance fees, which in my view, helps explain why CoCs are rarely used there. In France, our healthcare system is nationalized; the cost to the system for a CoC THA is twice that of a THA with a MoP bearing. Despite the price difference, surgeons in France still choose CoC bearings if they best correspond to the patient profile. I assume that with time and scientific data, it might be possible to arrive at a consensus on the correct material for each patient, but we are not there yet.

Dr. Parvizi: *On what basis do you believe that for a given head size a bearing material in general, and ceramic bearing in particular, may reduce the risk of late dislocation after THA?*

Dr. Sedel: Revision for hip dislocation/instability in the Medicare population represents 22.5% of all revisions (the most common cause) followed by mechanical loosening, infection, and all other causes [6]. Nearly all of these patients had at least one component made of polyethylene. Recent registry data from Australia, New Zealand, and the UK found low rates of dislocation, instability, and infection burden [2, 26-28]. In these young patients, the incidence of instability for CoC bearings was low (2% to 3%) [13], which is even more impressive considering the majority of these patients engaged in strenuous physical activities.

Dr. Dunbar: There is insufficient evidence to support the premise that bearing type reduces the risk of dislocation. Dislocations occur infrequently, and subsequently, large numbers of patients need to be followed to determine the factors that reduce the risk of this uncommon event. This makes randomized control trials difficult and impractical. Further, randomized control trials introduce their own inherent biases since they are usually performed by expert surgeons on a select group of patients within academic institutions. National joint replacement registries can study larger numbers of patients and avoid many of the pitfalls of randomized control trials. However, registries also have limitations; it is often difficult to account for other variables that are not controlled at the time of surgery. There may be selection biases in the use of ceramic bearings regarding patient age and activity levels as well as surgeon experience, provider/site surgical volume, surgical approach, head size, BMI, and frailty. Unless these variables are accounted for in a multivariate regression model, it is possible that differences seen in survival curves between bearing types in fact represents selection biases. For example, if ceramic bearings are used more commonly by more experienced surgeons, or if they are used more commonly in younger patients, then any reported differences in outcome may be more related to these factors as opposed to material ones. When the relevant variables are all imputed into a multivariate model, power often suffers making statistically valid observations problematic.

Dr. Parvizi: *What is the reason for the reduction of late hip instability with CoC bearings that Dr. Sedel posits?*

Dr. Sedel: After insertion of CoC material, a dense fibrous tissue will form around the hip [4]. But it is only recently that some investigators suspected this fibrous material plays an important clinical role. I believe it will work as a new capsule. This strong and rigid material might develop into a supportive neoligamentous or neocapsular structure by an adapting process called mechanotransduction [18]. This neocapsule has been observed during THA revision in the setting of a CoC bearing, and some of my colleagues and I retrieved and histologically analyzed the material. A large amount of clean, dense, regular fibrous tissue full of Type-1 collagen, were described [4].

Although some controversy remains about whether CoC bearings are associated with a reduced risk of dislocation, I believe the finding is real. The question, then, is why might this be? I speculate that the risk reduction involves the differences in the size, number, and biological response to the wear particles that inevitably are generated in a bearing couple [19]. Additionally, the particles generated at a MoP interface result in osteolysis, and a biological reaction to these particles increases the risk of late dislocation because of joint effusion. A thin and compliant neocapsule has also been observed in MoP bearings [30, 34], and I believe that the mechanical properties of this thin neocapsule makes them further susceptible to late dislocation. I speculate that these problems not only contribute to late dislocation, but also are absent (or nearly absent) in CoC THAs [13, 17, 27].

Dr. Dunbar: In the spirit of the debate, let's assume that the dislocation rate may be lower late-term for ceramic heads, given a specific head size. Why might this be? Considering Prof. Sedel's response, Occam's Razor comes to mind. Is it more likely that an unusual and ill-defined biological response is established with ceramic bearings that leads to a secondary biomechanical effect on stability via a cellular response in the joint capsule, or is it more likely that the highly mechanical event of dislocation is related to head size and polyethylene wear? I would argue for the latter. Given a specific patient, it is more likely that a CoC bearing would have a larger femoral head compared to a MoP bearing given the concerns for wear. As discussed above, this is a biasing factor that would favor dislocation rates in ceramic bearings. Much of the data used to compare late rates of dislocation between bearing types is, by definition, historic. Therefore, much of the polyethylene used in the comparative cohorts is noncrosslinked and susceptible to polyethylene wear. This leads to a reduction in containment of the femoral head, subsequently increasing the risk of dislocation.

A further argument against this hypothesis is that osteolysis has not been eliminated with the use of ceramic bearings. In fact, osteolysis has been reported [36], suggesting that biologically active particles are still present. This is further supported by the fact that osteolysis remains the leading cause for revision in hips with ceramic bearings in the Australian Orthopaedic Association National Joint Replacement Registry [2]. The negative experience of MoM bearings has focused our interest on biological responses around the hip to wear particles. To be fair, such an experience forces an open mind to the potential for a biological mechanism via the joint capsule for reduced late instability with ceramic bearings, and this response likely is different from aseptic, lymphocyte-dominated vasculitis-associated lesion, unless the proposed effect would be far more obvious than it is.

The other lesson learned is that there is a patient-specific variable response to metal debris, offering a reason to suspect that this same variability would be present in a proposed biological response profile to ceramic debris, or lack thereof. This represents yet another confounding variable that should ultimately be considered for future research.

Bearing in mind all of the variables that could influence late dislocation rate such as age, gender, BMI, frailty, surgical approach, head size and patient-specific biological responses, and considering the generally low dislocation rate and the long-term loss to followup, it is unlikely that this question will be definitively answered anytime soon.

Dr. Parvizi: *Most of the choices we make in arthroplasty entail tradeoffs. What risks might be associated with broader use of CoC bearings in the general practice community of hip surgeons?*

Dr. Sedel: The surgeon must get a good exposure, clean the cone, and gently implant the liner in the shell in order to avoid fracture, chipping, or dissociation of the liner. But in terms of advantages, after 6 months, the patient can enjoy an active lifestyle, and younger patients with CoC bearings have less risk of infection, instability, or revision for late dislocation [17, 19].

The surgeon should also inform the patient about the possibility of squeaking, although as far as we know, this does not diminish the durability of the procedure [8]. Although the patient can reduce their risk of dislocation, surgeons must inform patients about the risk of bone fracture at implant insertion, material fracture, material dissociation, infection, and/or trunnionosis.

Dr. Dunbar: Most of the risks associated with the broader use of CoC bearings would be borne by the patient. CoC bearings have a known fracture risk ranging as high as 2% [33].

And a fractured ceramic bearing is a serious event, since it results in more surgery, and it can diminish the durability of future revisions in that hip [31]. Clinically important squeaking has also been reported widely with the use of ceramic bearings. This can be very bothersome for patients, sometimes resulting in revision. Squeaking occurs in as many as 21% CoC THAs [22].

The Australian Orthopaedic Association National Joint Replacement Registry data did not show an advantage for CoC bearings in terms of survivorship [2]. As a result, in my estimation, CoC bearings represent a lower-value approach for society.

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