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Original Research

Modular Dual-Mobility Liner Malseating: A Radiographic Analysis

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ABSTRACT

Background: With dislocation as a leading cause for revision after total hip arthroplasty (THA), modular dual-mobility (MDM) constructs are more commonly used at present in an attempt to decrease postoperative instability. With modularity, there is potential for additional complications, including malseating of the liner. The goal of this study was to perform a radiographic analysis on the incidence of MDM liner malseating.

Methods: We retrospectively identified 305 patients (305 THAs) who underwent primary THA with an MDM liner from a single manufacturer inserted by a single surgeon. One hundred fifty-six (51%) patients were male. The mean age was 68 years, and the mean body mass index was 31 kg/m^2. Only patients with both anteroposterior and cross-table lateral radiographs at a minimum of 6 weeks postoperatively were included. Dislocations and reoperations were determined at 1 year after the procedure. All MDM liners were routinely tested intraoperatively with a "4-quadrant test" to assess for proper seating.

Results: Four (4/305, 1.3%) MDM liners were noted to be radiographically malseated at early follow-up with three (3/147, 2.0%) occurring in a thinner two dimentional (2D) ongrowth shell and only one (1/158, 0.6%) observed in a thicker three dimentional (3D) additively manufactured shell. They were inferiorly prominent by a median of 1.2 mm, best seen on the cross-table lateral radiograph. In patients with at least 1-year follow-up, no MDM liners dissociated and no patients sustained a dislocation. Five (1.6%) patients required reoperation unrelated to the acetabular or MDM construct.

Conclusions: Surgeons should be aware that malseating of dual-mobility liners may occur. However, with utilization of a consistent surgical technique to test for seating of the liner, the radiographic incidence of MDM liner malseating was low at 1%. Although there were no short-term clinical implications of liner malseating, long-term follow-up is needed.

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Introduction

Dislocation remains one of the most common complications after primary total hip arthroplasty (THA) and a leading cause of revision THA [1-4]. Although there are a number of risk factors for THA instability [1-4], recent focus of spinopelvic immobility and prior lumbar fusion causing increased risk of THA dislocation has augmented efforts to define overall and patient-specific safe zones for acetabular component positioning in relation to spinopelvic immobility. However, exact acetabular component position that is ideally suited for each patient is unknown and may change over time [5-8]. As such, dual-mobility (DM) articulations, a construct which increases impingement-free range of motion by adding a second articulation and increasing the effective femoral head size and jump distance, have become attractive options for surgeons to mitigate the risk of hip instability [9-15].

Multiple systematic reviews and case series report reduced dislocation rates of DM constructs in high-risk patients undergoing primary and revision THA [10-13]. However, added modularity introduces additional potential complications, including modular liner malseating and/or dissociation and intraprosthetic dislocation (IPD) [16,17]. The notion that a stiff cobalt-chrome liner has a potentially higher risk of malseating because of less-conforming tolerance than that of polyethylene is supported by experiences with incomplete seating of the liner with metal-backed ceramic liners [18,19]. However, there is a paucity of data on modular dual-mobility (MDM) liners incompletely seating, any untoward consequences, and how to minimize and manage the occurrence [20].

As such, the goal of the present study was to radiographically analyze the incidence and outcomes of modular liner malseating in a consecutive series of THAs with MDM constructs and also describe the senior author's technique of routinely testing MDM liners with the "4-quadrant test".

The investigation was performed at the Hospital for Special Surgery, NY.

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Figure 1. Photograph of a modular dual-mobility construct with the acetabular component, cobalt-chrome liner, outer polyethylene bearing, and the inner femoral head.

Patients and methods

We retrospectively identified through an institutional database a consecutive series of patients who underwent a primary THA with an MDM liner (Stryker, Mahwah, NJ) (Fig. 1) by a single surgeon (G.H.W.) from 2012 to 2018. We performed a thorough chart review to assess for operative details and complications. We also performed a radiographic review to measure any asymmetric modular liner prominence within the acetabular component on calibrated radiographs with a magnification marker; asymmetry was measured to the 0.1 mm. The postoperative radiographs (performed between 6 weeks and 3 months postoperatively) were reviewed by two authors independently (J.D. and G.H.W.), and any liners in question were reviewed by an additional author not involved in the surgical procedures (B.P.C.). Liner malseating was defined as any measurable asymmetric prominence on the radiographs. Patients were followed up until revision, reoperation, or final clinical follow-up at a minimum of 1 year. Patients were excluded if they did not have direct cross-table lateral radiographs at follow-up or did not have any radiographic follow-up beyond the immediate postoperative radiograph in the postoperative recovery unit. Institutional review board approval was obtained before study initiation.

Patients

Three hundred twenty-four patients (324 THAs) who underwent MDM THA were identified. No patients died before 1-year minimum follow-up. Nineteen patients (19 THAs) did not have direct cross-table lateral radiographs at follow-up; because none of them had evidence of liner malseating on an anteroposterior (AP) and frog lateral radiographs at 6-week follow-up, we excluded these patients from the radiographic analysis to obtain the cleanest cohort with true orthogonal radiographs. Therefore, 305 patients (305 THAs) were included in the present study. One hundred fifty-six (51%) patients were male. The mean age was 68 years (range, 31 to 92 years). The mean body mass index was 31 kg/m^2 (range, 17-59 kg/m^2). One hundred sixty-five (55%) patients had clinical follow-up of at least 1 year and were therefore included in analysis of complications. For that subset, the mean follow-up was 2 years (range, 1-5 years) after primary THA.

All patients underwent a primary posterolateral THA performed by a surgeon experienced in primary and complex revision THAs at a single tertiary care academic institution. Before 2016, the surgeon selectively used MDM constructs on high-risk patients; after 2016, the surgeons routinely used MDM constructs in THA with specific implants (modular vs nonmodular) being determined mainly by preoperative templating of the patient size.

Acetabular components implanted in these patients were as follows: 147 (48%) 2D ongrowth Trident I PSL (peripheral self-locking) shells (Stryker, Mahwah, NJ) and 158 (52%) thicker, three-dimensionally (3D) latest generation, additively manufactered, Trident II shells (Stryker, Mahwah, NJ). All MDM constructs were modular, consisting of a cobalt-chrome metal liner, a large polyethylene bearing, and an inner femoral head (Fig. 1). The median acetabular cup size was 52 mm (range, 46-62 mm). The median effective femoral head size (which is also the same as the modular liner size) of the polyethylene bearing was 42 mm (range, 36-52 mm). The femoral head size is dictated by the size of the acetabular component. As the senior surgeon preferentially used a different implant system (Anatomic Dual Mobility®, Stryker) for smaller sized acetabular components (46 mm to 50 mm), which only use a 28-mm head, 300 (98%) femoral heads were 28 mm and only 5 (2%) were 22.2 mm. Of the 300 28-mm femoral heads, 197 (66%) were ceramic (CeramTec, Germany) and 103 (34%) were cobalt-chromium.

Surgical technique

The meticulous surgical technique to test for liner malseating was as follows: after placement of the cementless acetabular component, the entire periphery of the cup was debrided of all soft tissues and bones that may impede impaction of the modular liner. Thorough removal of all peripheral osteophytes and overhanging soft tissue before insertion of the MDM liner is imperative, and a full 360° view of the rim of the acetabular component should be achieved. If screws are used, it is also important to ensure that there is no prominence of any screw head before inserting the MDM liner. The acetabular component should then be irrigated and suctioned. The MDM liner should then be placed from inferior to superior, ensuring it is flush circumferentially and rotated so it is in line with the tabs. A forceful impaction, regardless of the mallet weight, is then used to impact the liner and engage the taper. The authors use a “4-quadrant test” to ensure proper taper engagement and complete liner seating (Fig. 2). Using an impactor, the periphery of the cup was struck at all 4 quadrants (12 o’clock/superior, 6 o’clock/inferior, 3 o’clock/posterior in a left THA, and then 9 o’clock/anterior in a left THA), turning attention to the opposite quadrant to ensure that the liner is not toggling. Once confirmed that the liner is completely seated and not toggling, another final forceful impaction is performed. If during the “4-quadrant test” the liner toggles, the liner should be removed and the process should be repeated; extra attention should be paid to the cup periphery, redebriding, and re-exposing, as necessary, and to any prominent screw head. On postoperative AP and direct cross-table lateral radiographs, the MDM liner should be flush with the acetabular component (Fig. 3). At the senior surgeon’s recommendation, this technique is similar to that outlined by the manufacturer.

Statistical analysis

All data are presented as median or mean values with ranges. Fischer exact square tests were used to compare all dichotomous variables (risk factors for liner incomplete seating). Statistical significance was set at alpha <0.05.

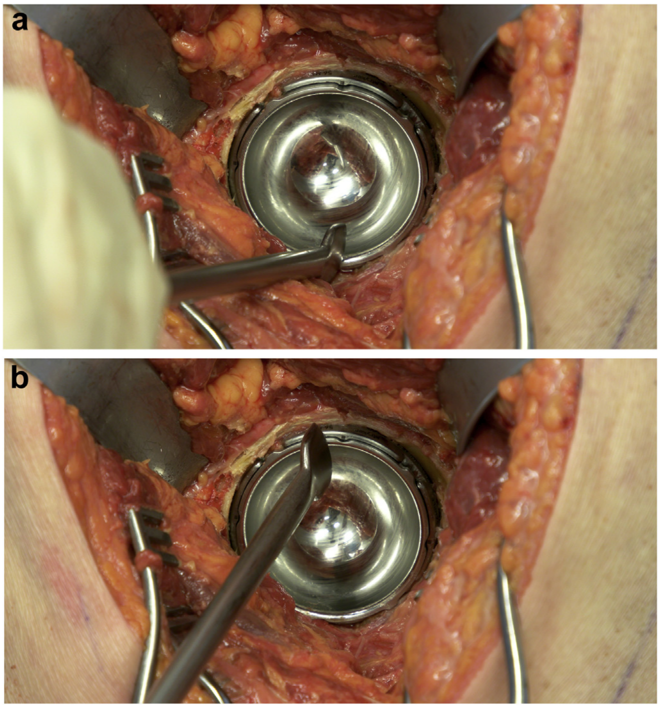

Figure 2. Photographs of the 4-quadrant test performed intraoperatively to assess for any incomplete MDM liner seating. Using a cup rim impactor, the rim was firmly impacted at 6 o'clock (a), 12 o'clock (b), 3 o'clock, and 9 o'clock, watching the opposite quadrant during impaction to ensure that the liner does not toggle.

Results

MDM liner dissociation and malseating

Four (4/305, 1.3%) patients (4 THAs) had radiographic evidence of incomplete liner seating with prominence at the inferior acetabular rim (Fig. 4) at their 6-week radiographic follow-up. The median amount of liner prominence was 1.2 mm (range, 1.0-1.4 mm). Three (3/147, 2.0%) occurred in the thinner 2D Trident I PSL ongrowth shell, and one (1/158, 0.6%) occurred in the thicker 3D additively manufactured Trident II shell ($P = .35$). Two of the acetabular components were 50 mm, and 2 were 52 mm; all hips had a 28-mm ceramic head. None of these patients had pain, had a complication, or underwent revision during the study period. These patients were all followed up for at least 1 year radiographically (mean, 2 years; range, 1-4 years), without any change in the liner seating or dissociation.

Complications

Of the patients with minimum 1-year clinical follow-up, no patients sustained a liner dissociation, dislocation, or IPD during this study period. Five (1.6%) patients underwent reoperation. Indications for reoperation included the following: for acute postoperative prosthetic joint infections in 3 (1%) patients, a symptomatic hematoma in one (0.3%) patient who was aggressively anticoagulated postoperatively, and an isolated femoral revision for a postoperative periprosthetic Vancouver B2 fracture (0.3%). Of those patients with at least 1 year of clinical follow-up, no patients underwent a reoperation for dislocation or the acetabular component bearing surface.

Discussion

DM constructs increase prosthetic hip stability by increasing the effective femoral head size and adding a second articulation, which both increase the range of motion free of impingement and increase the jump distance [5-8,21,22]. As history has taught us of the potential complications of modular junctions in THA [23-27], it is important to analyze the incidence of liner malseating and dissociation at this modular junction. With a meticulous surgical technique, the overall incidence of liner malseating was 1.3% at minimum 6-week follow-up. The amount of malseating (median 1.2 mm of prominence) did not change between 6-week and 1-year radiographic follow-up.

Furthermore, with the newer and thicker 3D additively manufactured cup, the incidence of liner malseating was only 0.6% (1/158). Although there are likely many associated factors, a meticulous surgical technique performed consistently by the senior author in all of these cases potentially contributed to this low rate of malseating. Otherwise, the incidence of the problem may have been higher and corroborating studies are needed in this regard. By comparison, we are aware of one study that demonstrated an incidence of MDM liner malseating of 5.8% in a cohort of patients who underwent THA, in which the surgery was performed by 17 surgeons, where routine liner testing was not performed [18]. Furthermore, it was previously noted by Miller et al. [19] that the incidence of liner malseating was 7.2% in a series of ceramic-on-ceramic THAs. In this study, the modular junction was a titanium-on-titanium taper as the ceramic liner was imbedded in a titanium outer shell and surgeons did not routinely test the modular ceramic liners.

Causes of malseating include soft-tissue or bone interposition, prominent screw heads, impaction in an already malseated position, and potentially plastic deformation of the acetabular component during impaction [19,20,23-29]. This rate of liner malseating is significantly lower than that in reports of similarly hard and inelastic

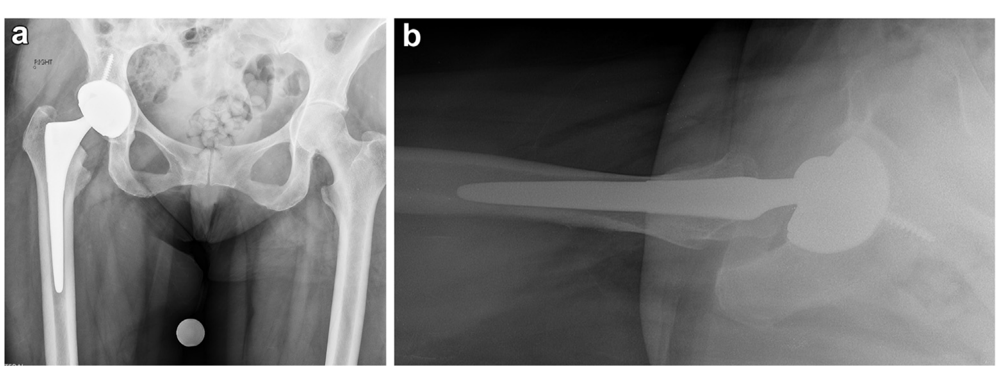

Figure 3. Postoperative AP (a) and direct, cross-table lateral (b) radiographs of a primary THA with a well-seated modular DM construct and MDM liner.

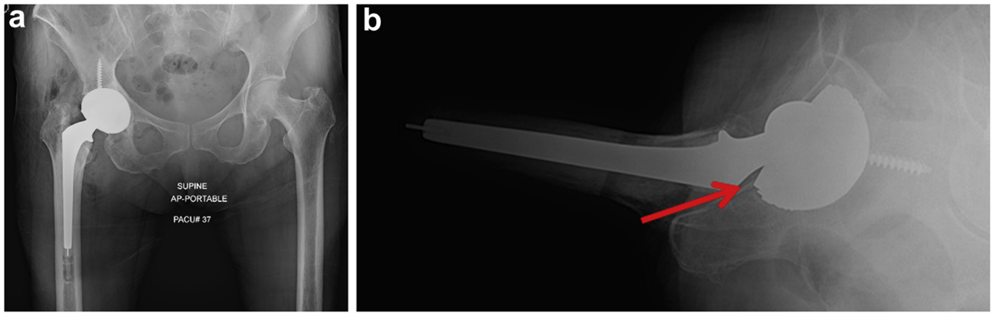

Figure 4. Postoperative AP (a) and direct, cross-table lateral (b) radiographs of a primary THA with an incompletely seating MDM liner. Note the prominence inferiorly and asymmetry indicated by the red arrow in the cross-table lateral radiograph.

metal-backed ceramic liners [19,20]. Langdown et al. [20] reported a 16.4% rate of incomplete liner seating in 117 primary THAs with metal-backed ceramic liners. Miller et al. [19] reported a 7.2% incidence of incomplete liner seating in a series of 694 primary ceramic-on-ceramic THAs using the same acetabular component, the Trident I, as some of the implants in this study. One theory is that there can be plastic deformation of the acetabular component, especially in the hard bone that makes malseating of an inelastic, cobalt-chrome liner more common [19]. Three (2.0%) of the liner malseating occurred in the thinner 2D Trident I PSL ongrowth cup compared with just one (0.6%) in the thicker 3D additively manufactured Trident II cup. Furthermore, Miller et al. [19] found more liner malseating in male patients with excellent bone quality than in females, supporting this theory. Similar to the aforementioned study [19], all of the liners were incompletely engaged inferiorly, which is the most challenging location for the surgeon to visualize intraoperatively. We theorize that the surgical technique, including the “4-quadrant test,” not only mechanically verifies seating but also forces surgeons to thoroughly inspect the liner circumferentially.

We acknowledge several limitations to the present study. First, it is a retrospective review with a relatively small number of patients. The study also includes only primary THAs with MDM constructs performed by a single surgeon at a single institution with extensive experience using MDM liners, potentially limiting its generalizability. Furthermore, this study includes only one specific implant type and may not be generalizable across implant types with other manufacturers. Although no patients with MDM liner malseating had catastrophic implant failures and all patients were asymptomatic at a minimum of 1 year of follow-up, we did not test metal-ion levels (specifically cobalt and chromium levels) to assess for any risk for corrosion secondary to this malseating.

Conclusions

The authors report an overall incidence of MDM liner incomplete seating during primary THA of 1.3% in a single-surgeon study with only 0.6% occurring with a newer and thicker 3D additively manufactered shell. There were no catastrophic sequelae of the liner malseating, IPDs, or extraprosthetic dislocations at short-term follow-up in this series. Continued follow-up of these patients, especially of the malseated liners, is necessary to ensure the implants' safety and durability. In conclusion, the authors recommend that all MDM liners are routinely tested with the "4-quadrant test" to ensure proper seating.

Conflict of interests

G. Westrich receives royalties from Exactech and Stryker Orthopaedics, is a member of the speakers bureau/a part of paid presentations for Stryker Orthopaedics, Exactech, and Mallinckrodt Pharmaceuticals, is a paid consultant for Stryker Orthopaedics and Exactech, receives research support from Stryker Orthopaedics and Exactech, and is a board member/a part of committee appointments for the Eastern Orthopaedic Association; all other authors declare no potential conflicts of interest.

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