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Original research

Anatomic dual mobility compared to modular dual mobility in primary total hip arthroplasty: a matched cohort study

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ABSTRACT

Background: Dual mobility (DM) has been used in primary total hip arthroplasty recently for their low dislocation rates, low revision rates, and improved patient functional outcomes. We compared 2 DM systems, anatomic dual mobility (ADM; Stryker, Mahwah, NJ) and modular dual mobility (MDM; Stryker, Mahwah, NJ), to determine differences in dislocation rates, revision rates, and patient outcome scores.
Methods: The study was a single-center matched retrospective review of prospectively collected data of patients who underwent primary total hip arthroplasty surgery with an ADM or MDM system by a single surgeon from 2012 to 2017. Demographics, operative details, postoperative patient-reported outcomes, and clinical outcomes were recorded. A Kaplan-Meier survivorship curve to compare survival time between groups was collected as well.
Results: Five hundred seventy-four patients were included in the study with 287 patients matched in each group with mean 2.86 years of follow-up. The dislocation rate in each cohort was 0%, the acetabular-specific revision rate was 0%, and in each cohort, overall revision rate in each cohort was 1.7%. In general, patient-reported outcomes were similar for each group (Harris Hip Score Pain ($P = .919$), Harris Hip Score Function ($P = .736$), Western Ontario and McMaster Universities Osteoarthritis Index ($P = .139$), Pain Visual Analog Scale ($P = .146$), Veterans RAND 12-Item Health Survey ($P = .99$), University of California, Los Angeles ($P = .417$), and Harris Hip Score Total ($P = .136$). There was a slight clinically insignificant increase in hip flexion between the cohorts favoring the ADM group (98.6 ± 9.8 vs 94.0 ± 9.7, $P < .001$).
Conclusions: Both DM systems had similar patient-reported outcomes that were quite favorable. At 2.86 years of follow-up, neither the ADM nor MDM systems demonstrated dislocation, and both had low acetabular-specific and overall revision rates in this matched cohort study.

Introduction

By 2030, primary total hip arthroplasty (THA) is anticipated to grow 171% for a projected 635,000 procedures annually [1]. Even though THA is considered one of the most successful surgeries performed today, complications may occur. Aseptic loosening, infection, and dislocation present challenges for both the patient and the surgeon. For instance, the cumulative risk of dislocation within the first postoperative month is 1% and within the first year is approximately 2%, and continuously increased to approximately 7% after 25 years [2].

Dual mobility (DM) cups were introduced more than 40 years ago by Bousquet and Rambert. It combined 2 concepts in THA: (1) large diameter mobile component in a highly polished acetabular liner and (2) low friction principle from Sir John Charnley. Together, the system provides increased stability by adding an articulating interface and altering the head-neck ratio. Improved stability can manifest in a reduced risk of dislocation, less impingement, lower friction, and lower wear [3].

Dual mobility (DM) has been used in primary total hip arthroplasty recently for its low dislocation rates, low revision rates, and improved patient functional outcomes. We compared two DM

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systems, anatomic dual mobility (ADM; Stryker, Mahwah, NJ) and modular dual mobility (MDM; Stryker, Mahwah, NJ), to determine differences in dislocation rates, revision rates, and patient outcome scores.

Material and methods

Using our institution's registry of prospectively collected data, our hospital statistician matched the cohorts on the following criteria: 1:1 matching of MDM liner and ADM liner, exact sex, age ±5 years, and body mass index (BMI) ±5 kg/m^2. This included only primary THA performed by a single surgeon at 1 high-volume arthroplasty center. The indications for MDM and ADM liners were: (1) noninflammatory degenerative joint disease, (2) rheumatoid arthritis, (3) correction of functional deformity, (4) treatment of nonunion, femoral neck fractures of proximal femur, and (5) increased dislocation risks. ADM was used instead of MDM for patients with small anatomy to try an avoid a 22 mm metal head (36 and 38 mm liners; Table 1).

Surgical approach: MDM

All primary THA procedures using the MDM system were performed by one author who has been implementing DM systems for over 10 years, utilizing the posterior approach throughout this period. First, the acetabular component is inserted using a standard press-fit technique. Screws were utilized as needed to augment the fixation, especially in weaker bone. The MDM design has a modular cobalt-chromium liner that fits into the taper of all the existing titanium Stryker acetabular shells (Figs. 1 and 2). A 22-mm femoral head (only manufactured in cobalt-chromium) or a 28-mm femoral head (manufactured in both cobalt-chromium and ceramic) is assembled using an intraoperative press into an all-polyethylene X3 liner. This head/polyethylene liner assembly is then impacted onto the trunnion of the femoral stem and then the hip is reduced. The entire DM construct articulates against the MDM modular liner. The size of the insert corresponds with the acetabular shell diameter that is implanted (Table 1).

Surgical approach: ADM

All primary THA procedures using the ADM system were performed by the same author as the MDM system using the posterior approach exclusively. The design has an anatomic-shaped rim to match the native acetabular socket (Figs. 3 and 4). The design includes an anterior recess in the shell to accommodate the iliopsoas tendon and potentially reduce psoas impingement symptoms. There is also a prominence posteriorly and inferiorly that makes the cup deeper than a hemisphere in this region where the rim extends beyond 180°. This was designed to aid in greater stability in deep flexion. The ADM system is a hydroxyapatite-coated press-fit cobalt-chromium acetabular cup (46-64 mm) that is articulated by a nonconstrained mobile liner (40-58 mm; Figs. 3 and 4) containing a 28-mm femoral head (available in cobalt-chromium or ceramic). The size of the polyethylene insert corresponds with the acetabular shell that is implanted as well (Table 2). The head and liner are again assembled with an intraoperative press and then the head/liner assembly is impacted onto the trunnion of the femoral stem.

Figure 1. Modular dual mobility acetabular system (ADM X3; Stryker Orthopedics, Mahwah, NJ).

Outcome measurements

The primary outcome measurements were dislocation rate and revision rate. The secondary outcome measurements were patient-reported outcome measurements (PROMs), including Veterans RAND 12 Item Health Survey, University of California, Los Angeles activity scale, Pain Visual Analog Scale (Pain VAS), Western Ontario and McMaster Universities Osteoarthritis Index, Harris Hip Score Pain (HHS Pain), Harris Hip Score Function (HHS Function), Harris Hip Score Total (HHS Total), and Range of Motion with hip Flexion (ROM Flexion). Scores were collected at the respective postoperative visits. Head size, liner size, cup size, and head offset were also recorded. We also collected the reason for revision by head size, liner size, and cup size for both groups. A Kaplan-Meier survivorship curve was created to compare the survivorship between groups.

Statistical methods

Normally distributed continuous data were compared using Student's *t*-test data. A *P*-value of <.05 was determined to be statistically significant.

Results

There was a total of 812 total hip replacements performed between 2012 and 2017 by the senior surgeon. Seven hundred thirty-one hips were DM hips and 81 hips were non-DM hips. Four hundred forty were performed using ADM and 291 were performed using MDM. A total of 791 patients underwent primary THA using DM implants by a single surgeon using the posterior approach during this time period. After the 1:1 matching procedure, there were 287 patients in the ADM group and 287 patients in the MDM

Table 1
MDM cobalt-chromium liner, corresponding acetabular shell, poly insert, and poly thickness.

Liner diameter (mm)	36	38	42	46	48	52	54	58
Shell diameter (mm)	48	50-52	54-56	58-60	62-64	66-68	70-72	74-80
Head diameter (mm)	22.2	22.2	28	28	28	28	28	28
Poly thickness (mm)	6.7	7.7	6.8	8.8	9.8	11.8	12.8	14.8

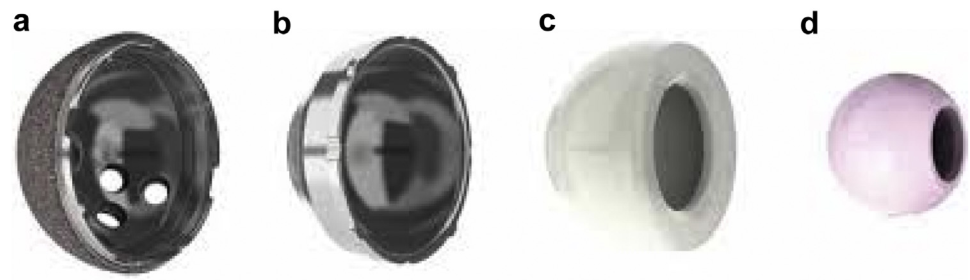

Figure 2. Modular dual mobility acetabular system (MDM X3; Stryker Orthopedics).

group or a total of 574 patients in this study. The average age of the ADM group was 67.8 ± 9.9 years and the average age of the MDM group was 67.9 ± 10.2 years ($P = 0.924$). The average BMI in the ADM group was 29.1 ± 5.1 kg/m^2 and the average BMI in the MDM group was 29.3 ± 5.3 kg/m^2 ($P = 0.607$). The male to female ratio in the ADM group was 148:139 and the male to female ratio in the MDM group was 148:139 ($P = 0.99$). The average follow-up was 2.86 years in both the ADM (1-8.3 years) and MDM (1.0-6.7 years) groups. Eleven (3.8%) were lost to follow-up in the ADM group and 19 (6.6%) were lost to follow-up in the MDM group. The comparison of head size between the ADM and MDM cohorts is indicated in Table 3, and the comparison of cup size between cohorts is noted in Table 4. In addition, the comparison between head offset in ADM and MDM cohorts is noted in Table 5.

We found no dislocations in the ADM group (0/287, 0%) and the MDM group (0/287, 0%). The acetabular-specific revision rate in both groups was 0%. The overall revision rate in the ADM group was 5/287 (1.7%) and in the MDM group was 5/287 (1.7%). In the ADM group, 3/287 (1.0%) was due to periprosthetic fracture of the femur and 2/287 (0.70%) was due to an adverse local tissue reaction from a recalled modular neck stem. In the MDM group, 1/287 (0.35%) was due to periprosthetic fracture of the femur and 4/287 (1.4%) were due to infection. We included the reason for revision by head size, liner size, and cup size (Table 6).

The results showed similar PROMs between the ADM and MDM groups with only a slight increase in hip flexion favoring the ADM group (98.6° ± 9.8° vs 94.0° ± 9.7°, $P < 0.001$). There was no difference in several PROMs between the groups at a follow-up of 2.86 years in both groups: HHS Pain (35.2 ± 11.4 vs 35.1 ± 11.1, $P = .919$), HHS Function (36.3 ± 9.7 vs 36.6 ± 8.8, $P = .736$), Western Ontario and McMaster Universities Osteoarthritis Index (80.6 ± 18.5 vs 77.4 ± 19.5, $P = .139$), Pain VAS (19.2 ± 25.0 vs 16.1 ± 21.7, $P = .146$), Veterans RAND 12 Item Health Survey (41.1 ± 11.4 vs 41.1 ± 10.6, $P = .99$), University of California, Los Angeles activity scale (4.8 ± 2.0 vs 4.6 ± 2.1, $P = .417$), and HHS Total (80.8 ± 18.6 vs 77.1 ± 18.7, $P = .136$), at the respective follow-up visits were not statistically significant, respectively. We also found a statistically significant difference in head size ($P = .024$; Table 3) and cup size ($P < .0001$; Table 4). The Kaplan-Meier survivorship curve showed a similar survivorship in the ADM group and the MDM group ($P = 0.55$; Fig. 5). The ADM survivorship at 36 months was 0.92 and the MDM survivorship at 36 months was 0.98. Also, there was no difference in time until revision by reason for revision between the groups (Table 7).

Discussion

Due to the novelty of comparing PROMs between DM systems, the literature contains (1) comparisons of DM vs fixed-bearing (FB) outcomes and (2) DM outcomes without a control group. One study showed similar mHHS (mean Harris Hip Score) between DM (both MDM and ADM) and FB in a matched analysis of 136 THAs at 3.2 and 3.4 years, respectively [4]. Another study found an improvement in HHS using an ADM cup from 41 to 86 ($P < .001$) and a decrease in VAS pain score from 5.9 to 0.7 at a minimum 2-year follow-up. Both studies solidify the efficacy of DM PROMs, which gives our study the impetus to have larger patient numbers and include more outcomes [5].

Figure 3. Anatomic dual mobility (ADM X3; Stryker Orthopedics).

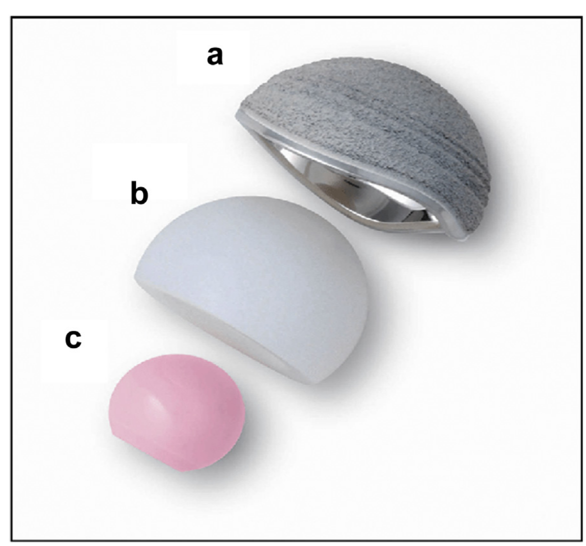

Figure 4. ADM X3 components: (a) acetabular shell; (b) poly insert; and (c) femoral head.

Table 2
ADM cup, insert, thickness, and head diameter.

ADM cup diameter (mm)	ADM insert diameter (mm)	Insert thickness (mm)	Head diameter (mm)
46	40	5.9	28
48	42	6.9	28
50	44	7.9	28
52	46	8.9	28
54	48	9.9	28
56	50	10.9	28
58	52	11.9	28
60	54	12.9	28
62	56	13.9	28
64	58	14.9	28

Table 4
Cup size comparison between ADM and MDM.

Head Diameter (mm)	ADM	MDM	*P*-value
38	0 (0%)	2 (0.7%)	
44	0 (0%)	1 (0.3%)	
46	27 (9.4%)	1 (0.3%)	
48	35 (12.2%)	1 (0.3%)	
50	60 (20.9%)	54 (18.8%)	
52	49 (17.1%)	110 (38.3%)	
54	49 (17.1%)	49 (17.1%)	
56	28 (9.8%)	39 (13.6%)	
58	15 (5.2%)	17 (5.9%)	
60	5 (1.7%)	8 (2.8%)	
62	2 (0.7%)	0 (0%)	
			<.0001

Our hypothesis supports our current findings regarding similar PROMs and low dislocation and revision rates (acetabular-specific and overall) in both groups. Similar findings regarding the efficacy of DM systems in primary THA, in both clinical outcomes and low complications exist throughout the literature. De Martino et al. [6] revealed the low rate of postoperative implant instability in several studies using the first-generation Bousquet cups. Darrith et al. [7] reviewed 24 studies at a weighted follow-up of 8.5 years involving the use of DM cups in primary THA and found a weighted total dislocation rate of 0.46%, a weighted total revision rate of 2.02%, and a weighted survivorship rate of 98.0%, which is consistent with our findings of 0%, 1.7%, and 95% for dislocation rate, revision rate, and survivorship, respectively. Both Epinette et al. and Vigdorchik et al. found a dislocation rate of 0% for the ADM implant at 2-6 years and 2-4 years, respectively. They also found higher survivorship at 99.5% and 99.6%, which is higher than our 92% survivorship [5,8]. We suggest the difference is due to losing some of the patients to follow-up. Chughtai et al. [9] also found a dislocation rate of 0% for the MDM implant at 3-year follow-up and a survivorship of 99.3%, which is consistent without 98%. All 3 studies had a 0% revision rate due to mechanical revisions, which is consistent with our revision rates of 0% in the ADM group and 0% in the MDM group due to acetabular-specific revisions.

The advent of DM systems allows the head-liner complex to function as a large femoral head, increasing the head-neck ratio and jump distance [10]. With the low dislocation and revision rates in this study, little can be said about the effect of head size and cup size differences on dislocations. Generally, cup size ≥56 mm and smaller head size (22.2 mm vs 28 mm) have been noted to be risk factors for recurrent dislocation [11]. Our groups use primarily cups <56 mm and head sizes of 28 mm. While we found a clinically insignificant difference in hip flexion, our study can support the concept that larger heads increase ROM, noting that studies have shown no additional benefit to ROM when increasing femoral head size >38 mm [12,13]. There is not enough evidence to account for the influence of cup size on ROM, which supports a study that found no difference in ROM between a 50-mm and 56-mm cup [14].

The ADM system was designed with left and right anatomical cup shapes that incorporate a psoas cutout to allow for relief between the acetabular shell rim and the iliopsoas tendon [15]. One study found an association between ROM prior to impingement due to the cutout, but did not compare it to the modular design using a matched comparison [16]. In addition, as per Tables 1, 2, we can observe a difference in insert thickness for the same cup size. This is relevant after the finding that the motion of the femoral head against the inner polyethylene bearing dominates in terms of in vivo surface damage [17]. Although we did not examine wear between the 2 systems, we found stability in maintaining an acetabular-specific revision rate of 0% in both groups and an additional study supports the high resistance to wear in both systems. The stability of the ADM system is supported throughout the literature in greater posterior horizontal dislocation distances (PHDD), greater impingement-free ROM, lack of dislocations, and low revision rates [18,19].

Another system, MDM, provides surgeons a choice of fixation surfaces and screw hole configuration for primary or revision THA. This enabled orientation control during component insertion and the ability to control full implant seating. The design was also found to be protective against fretting and corrosion, which has occurred at modular junctions in other devices due to the metal-on-metal taper between the acetabular cup and metal insert [20]. The MDM system offers smaller cup sizes (Table 1), which are designed for patients with smaller anatomies. However, the matching process enabled us to control for differences between groups in regards to age, BMI, and gender. In a similar

Table 3
Head size comparison between ADM and MDM.

Head Diameter (mm)	ADM	MDM	*P*-value
22.2	0 (0%)	5 (1.7%)	
28	287 (100%)	273 (95.1%)	
			.024

Table 5
Head offset comparison between ADM and MDM.

Head Diameter (mm)	ADM	MDM	*P*-value
22 + 0 (V40 or C Taper-Metal)	0 (0%)	5 (1.7%)	
28 − 4.0 (V40 Taper-Metal or Ceramic)	0 (0%)	1 (0.3%)	
28 − 3.0 (C Taper-Metal)	4 (1.4%)	0 (0%)	
28 − 2.5 (C Taper-Ceramic)	1 (0.3%)	0 (0%)	
28 + 0 (V40 or C Taper-Metal or Ceramic)	205 (71.4%)	196 (68.3%)	
28 + 2.5 (C Taper-Metal or Ceramic)	7 (2.4%)	1 (0.3%)	
28 + 4 (V40-Metal or Ceramic)	50 (17.4%)	80 (27.9%)	
28 + 5 (C Taper-Metal or Ceramic)	19 (6.6%)	4 (1.4%)	
28 + 8 (V40 Taper-Metal)	1 (0.3%)	0 (0%)	
			0.0002

Table 6
Reason for revision by head, liner, and cup size.

Head Diameter (mm), liner ID (mm), cup (mm)	ADM	MDM
28, 28, 48	2 (0.70%): ALTR	NA
28, 28, 50	1 (0.35%): periprosthetic femur fracture	1 (0.35%): infection
28, 28, 52	2 (0.70%): ALTR	2 (0.70%): infection
28, 28, 56	NA	1 (0.35%): periprosthetic fracture
28, 28, 58	NA	1 (0.35%): infection

ALTR, adverse local tissue reaction; NA, not applicable.

way, the MDM system shows stability with low dislocation, revision rates, and improved PROMs compared to the traditional FB hip implant [4,21].

Although we observed slightly greater hip flexion in the ADM group (98.6° vs 94.0°, $P < .0001$), we felt it lacked clinical significance. One of the few studies that compares MDM and ADM showed no difference between the ADM and MDM designs, in regards to impingement-free ROM flexion using a custom hip ROM simulator software that provides a 3-dimensional model of the skeletal system containing the anatomic coordinate systems for the femur and pelvis for the user. However, it did find that the ADM design provided significantly greater PHDD compared to the MDM design [22]. Another study showed that head offset was the most important parameter in influencing PHDD, which positively correlates with ROM flexion [23]. Our study shows a significant difference in head offset as well as an increased flexion in the ADM group at a follow-up of 2.86 years.

We acknowledge some limitations in this study, including the short follow-up period and retrospective nature of the study. We also accounted for the loss to follow-up in the Kaplan-Meier survivorship. We maintained uniformity in this study by use of a single surgeon with a posterior approach, which has been associated with increased rates of dislocation in primary THA. To reduce variability, we matched the cohorts, which allowed for a novel comparison between two types of DM systems that are normally compared to FB instead, contributing to the growing literature of the protective nature of DM systems. Durability in the implant was confirmed by plotting a Kaplan-Meier survivorship curve. We found a difference in hip flexion, although not clinically

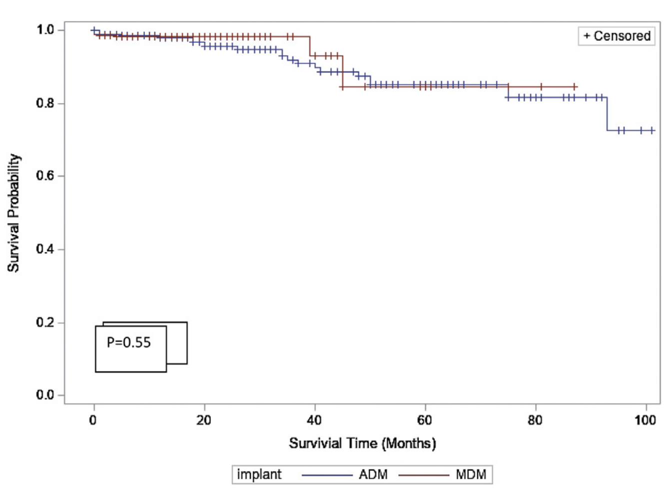

Figure 5. Kaplan-Meier survivorship curve comparison between ADM and MDM.

Table 7
Average time until revision by reason for revision (y).

	ADM	MDM
Periprosthetic fracture	0.07	0.06
ALTR from recalled modular neck stem	0.74	NA
Infection	NA	0.115

ALTR, adverse local tissue reaction; NA, not applicable.

significant. We hope to compare the two systems with a longer follow-up although we anticipate low dislocation rates and revision rates will remain.

Conclusions

In a matched cohort study at 2.86 years of follow-up, both MDM and ADM systems were found to have impressive PROMs, no dislocation, no acetabular-specific revision, and low overall revision rates. Similar survivorship curves were revealed in our analysis as well. Newer DM systems remain a favorable option in primary total hip replacement.

Acknowledgments

The authors were independently responsible for the study design and collection, analysis, and interpretation of the data, as well as the final approval to submit the manuscript. G.W. is a consultant for Stryker, the company that manufactures the implants studied.

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