Arthroplasty Today 5 (2019) 341–347

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Original research

Cementation of a monoblock dual mobility bearing in a newly implanted porous revision acetabular component in patients undergoing revision total hip arthroplasty

Jonathan A. Gabor, BS [a], James E. Feng, MD [a], Shashank Gupta, BE [a], Tyler E. Calkins, BS [b], Craig J. Della Valle, MD [b], Jonathan Vigdorchik, MD [c], Ran Schwarzkopf, MD, MSc [a, *]

[a] *Department of Orthopedic Surgery, NYU Langone Health, New York, NY, USA*
[b] *Department of Orthopedic Surgery, Rush University Medical Center, Chicago, IL, USA*
[c] *Adult Reconstruction and Joint Replacement, Hospital for Special Surgery, New York, NY, USA*

A R T I C L E I N F O

Article history:
Received 26 February 2019
Received in revised form
27 April 2019
Accepted 5 May 2019
Available online 14 June 2019

Keywords:
Revision hip arthroplasty
Dual mobility
Cemented dual mobility
Dislocation
Instability

A B S T R A C T

Background: The most common indications for revision total hip arthroplasty are instability/dislocation and mechanical loosening. Efforts to address this have included the use of dual mobility (DM) articulations. The aim of this study is to report on the use of cemented DM cups in complex acetabular revision total hip arthroplasty cases with a high risk of recurrent instability.
Methods: A multicenter, retrospective study was conducted. Patients who received a novel acetabular construct consisting of a monoblock DM cup cemented into a fully porous metal shell were included. Outcome data included 90-day complications and readmissions, revision for any reason, and Harris Hip Scores.
Results: Thirty-eight hips in 38 patients were included for this study. At a median follow-up of 215.5 days (range 6-783), the Harris Hip Score improved from a mean of 50 ± 12.2 to 78 ± 11.2 ($P < .001$). One (2.6%) patient experienced a dislocation on postoperative day 1, and was closed reduced with no further complications. There was 1 (2.6%) reoperation for periprosthetic joint infection treated with a 2-stage exchange.
Conclusions: In this complex series of patients, cementation of a monoblock DM cup into a newly implanted fully porous revision shell reliably provided solid fixation with a low risk of dislocation at short-term follow-up. Although longer term follow-up is needed, utilization of this novel construct should be considered in patients at high risk for instability.

Introduction

Revision total hip arthroplasty (rTHA) is a technically challenging surgery with a high risk of complications. Currently, the most common indication for rTHA and re-revision THA is instability/dislocation, which has been reported to range from 6.6% to as high as 28% of all rTHA patients [1-11]. Management options include the use of large femoral heads, constrained acetabular liners, and dual mobility (DM) articulations. Utilization of a larger femoral head confers stability by increasing the head-to-neck ratio, range of motion (ROM) prior to impingement, and head-jump distance [12]. However, the effects can become diminished with acetabular defects that result in cup placements which deviate from the ideal hip center of rotation [13]. Additionally, larger femoral heads have been associated with increased volumetric wear even with the presence of highly cross-linked polyethylene liners [14]. Finally, because these larger femoral heads may require the use of a thinner liner, there remains the potential for polyethylene fracture and mechanical failure in some cases [15].

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to https://doi.org/10.1016/j.artd.2019.05.001.

* Corresponding author. 301 E 17th Street, New York, NY 10003, USA. Tel.: +1 212 598 6000.
E-mail address: ran.schwarzkopf@nyulangone.org

https://doi.org/10.1016/j.artd.2019.05.001
2352-3441/

Meanwhile, constrained acetabular liners are designed to lock the femoral head into the inner bearing surface, which leads to higher forces on the acetabular cup. Consequently, constrained liners restrict ROM causing prosthetic impingement that can lead to unacceptably high failure rates [16,17], including early catastrophic failures in freshly implanted revision cups. To address some of these shortcomings, DM bearings have been advocated.

DM articulations feature an unconstrained tripolar design with 2 mobile articulations. The first articulation is between the prosthetic head and the inner surface of the polyethylene outer head, and the second is between the outer surface of the polyethylene head and the monoblock metal acetabular shell or metal acetabular liner. At the extremes of ROM, the stem engages the edge of the polyethylene liner, causing it to articulate with the inner surface of the metal acetabular shell. This design affords the patient a greater impingement-free ROM while enlarging the effective size of the femoral head, conferring the mechanical advantages offered by a larger femoral head-jump distance. The current generation of DM implants has shown remarkably low dislocation rates following primary THA and rTHA [18-26]. A recent meta-analysis by Levin et al. [27] reported a short- to mid-term dislocation rate of 2.2% following rTHA with the use of DM articulations. Early concerns over excessive early wear due to the additional bearing, aseptic loosening, and intraprosthetic dislocation (IPD) have been largely alleviated, with an aseptic survivorship rate of 97.7% and aseptic loosening and IPD rates at 0.3% and 0.7%, respectively [27].

Although biomechanical studies have validated the use of cementation of a DM cup into a well-fixed metal acetabular shell as a viable alternative to a standard cemented polyethylene liner, clinical reports evaluating outcomes of this construct in patients at high risk for recurrent instability and dislocation have been equivocal [22,28-31]. The goal of this study is to analyze the short-term outcomes, and rates of complications, reoperations, and re-revisions of a DM cup meant for cementation cemented into a newly implanted highly porous revision acetabular shell. Our hypothesis is that this reconstruction construct would decrease the incidence of instability after complex rTHA, without an increase in early construct failure.

Material and methods

A multi-institutional retrospective study was conducted using clinical data of patients who received a novel rTHA construct that utilized a monoblock DM cup that is intended for insertion with cement (cemented POLARCUP; Smith & Nephew, Memphis, TN), cemented into a fully porous revision acetabular component (REDAPT; Smith & Nephew). Two institutions contributed the data of 34 patients and 4 patients, respectively, to this study. The study procedures were reviewed and approved by the university Institutional Review Board (Study #i17-00535).

Data collection

All institutions participating in this study performed a retrospective chart review of a consecutive cohort of patients who underwent rTHA surgery and received the rTHA construct. Baseline demographics (age, gender, race, and insurance type), preoperative status (body mass index, and Charlson Comorbidity Index, radiographic Paprosky classification of the acetabular defects, number of previous revision surgeries, time interval from last hip arthroplasty, surgical indication), surgical factors (extended trochanteric osteotomy performed, allograft used, number of screws used, concomitant acetabular cage usage, intraoperative complications), and quality outcomes (length of stay, inpatient complications, 30-day and 90-day readmissions, all-cause re-revisions) were collected.

Patients

Thirty-eight patients treated by 7 fellowship-trained arthroplasty surgeons between May 2016 and June 2018 were included. All patients who received the POLARCUP cemented into a REDAPT acetabular component over this time period were included in this study. No patients were excluded. The decision was made to use this construct if it was felt by the operating surgeon that the patient would be at a high risk of instability following a complex acetabular reconstruction in which a fully porous acetabular shell was used. Risk was defined by the degree of acetabular bone loss (as defined by the Paprosky classification), as well as the patient history and indication for revision [32].

The mean patient age was 62.7 $\pm$ 9.7 years. There were 18 males (47.4%) and 20 females (52.6%) with a mean body mass index of 29.7 $\pm$ 7.0 kg/m^2. Patients underwent a mean of 1.6 prior reconstructive hip surgeries (range 1-4), including the primary THA. The mean amount of time between the primary THA and the revision surgery of interest was 12.7 $\pm$ 9.2 years. Preoperatively, the majority of patients ambulated with either a rolling walker (13, 34.2%) or cane (16, 42.1%). According to the Paprosky classification, 4 (10.5%) patients were type IIA, 10 (26.3%) patients were type IIB, 6 (15.8%) patients were type IIC, 9 (23.7%) patients were type IIIA, and 9 (23.7%) patients were type IIIB [32]. Additional demographics can be found in Table 1. Specific indications for rTHA included 23 (60.5%) patients for aseptic loosening of the acetabulum, 9 (23.7%) for periprosthetic joint infection, 4 (10.5%) for instability, and 2 (5.3%) for malorientation of the acetabular cup and soft tissue impingement (Table 2).

Surgical technique

Twenty-seven (71.1%) cases were performed using a posterior approach and 11 cases (28.9%) were performed using a modified direct lateral approach. Femoral stems were revised in addition to the acetabular components in 20 (52.6%) cases. Extended trochanteric osteotomies were performed to extract well-fixed femoral components in 7 (20%) cases. Fresh frozen cancellous allograft was used to fill contained defects in 18 (47.4%) cases, and concomitant acetabular cages were used in 11 (28.9%) cases. Mean surgical time was 208.6 $\pm$ 62.9 minutes.

The revision shell is unique, offering a combination of locking and nonlocking cancellous bone screws. Following final cup insertion, the DM monoblock acetabular cup was then cemented in place, when the cement had reached a doughy consistency (Fig. 1). The metal acetabular cup intended for cementation is manufactured from stainless steel. Its backside design features antirotation fins as well as 0.35-mm equatorial teeth that further enhance primary stability. The monoblock DM shell was a minimum of 11 mm smaller in outer diameter than the revision shell utilized. The median porous metal shell size was 60 mm (range 54-76), the median polyethylene outer head size was 47 mm (range 43-63), and the inner femoral head sizes were 28 mm (in cups $\geq$47 mm) and 22 mm (43 and 45 mm cups), respectively An example of preoperative/postoperative pelvic radiographs is shown in Figure 2.

Results

Thirty-eight patients were available for both clinical and radiographic evaluation at a median follow-up of 215.5 days (range 6-783). There were no intraoperative complications. There were 7 (18.4%) inpatient complications. Two (5.3%) were surgical complications and included an anterior hip dislocation on postoperative day 1 in 1 patient and proximal deep vein thrombosis in another patient. The dislocation was spontaneous and not precipitated by any trauma/falls, and a closed reduction was performed with no

Table 1
Baseline patient demographics (n = 38).

Age (y)	62.7 ± 9.7
Gender	
Male	18 (47.4%)
Female	20 (52.6%)
BMI	29.7 ± 7.0
Race	
African American (Black)	8 (21.1%)
Asian	1 (2.6%)
White	22 (57.9%)
Other	5 (13.2%)
ASA	
1	0 (0.0%)
2	16 (42.1%)
3	20 (52.6%)
4	2 (5.3%)
Charlson Comorbidity Index	2.8 ± 1.6
Smoking status	
Current smoker	5 (13.2%)
Former smoker	17 (44.7%)
Never smoker	16 (42.1%)
Marital status	
Married	11 (28.9%)
Divorced	3 (7.9%)
Single	15 (39.5%)
Other	9 (23.7%)
Insurance type	
Commercial	12 (31.6%)
Medicare	16 (42.1%)
Medicaid	8 (21.1%)
Worker's compensation	2 (5.3%)
Laterality	
Left	17 (44.7%)
Right	21 (55.3%)
Previous reconstructive surgeries	1.6 ± 0.8
Paprosky classification	
IIA	4 (10.5%)
IIB	10 (26.3%)
IIC	6 (15.8%)
IIIA	9 (23.7%)
IIIB	9 (23.7%)
Preoperative ambulatory status	
Rolling walker	13 (34.2%)
Cane	16 (42.1%)
Crutches	2 (5.3%)
Unassisted	5 (13.2%)
Unknown	2 (5.3%)
Mean time from primary to revision (y)	12.7 ± 9.2

ASA, American Society of Anesthesiologists; BMI, body mass index.

complications. At latest follow-up, the patient was doing well with 5/5 abductor strength and had no hip instability since the dislocation. The deep vein thrombosis was treated with heparin and inferior vena cava filter placement; heparin was stopped and the patient resumed aspirin therapy for prophylaxis prior to discharge, with no further complications. Five (13.2%) were medical complications and included supraventricular tachycardia, atrial fibrillation, urinary retention, urinary tract infection, and myocardial infarction in 1 patient each. Four (11.8%) patients had postoperative anemia treated with blood transfusion. Additional surgical information can be found in Table 3.

The majority of patients were discharged home with health services (26, 68.4%), followed by skilled nursing facilities (9, 23.7%), acute rehabilitation facilities (1, 2.6%), and home with self-care (2, 5.3%). Postoperatively, 4 (10.5%) patients experienced complications—3 (7.9%) within 30 days and 1 (2.6%) within 90 days following discharge. One patient experienced a nondisplaced fracture of the greater trochanter, which was treated nonoperatively. Two patients experienced infection—1 was treated with an irrigation and debridement due to continued wound drainage, with no further returns to the operating room; the other underwent a 2-stage exchange for a periprosthetic joint infection 10 months after the index revision surgery. One patient was admitted for dehydration and acute renal failure; this patient expired due to cardiac complications and so had an orthopedic follow-up time of only 6 days.

Table 2
Indication for revision THA of interest (n = 38).

Aseptic loosening	23 (60.5%)
Septic failure	9 (23.7%)
Instability	4 (10.5%)
Malorientation of the acetabular cup	2 (5.3%)

The mean Harris Hip Score at last follow-up was 78 (range 49-95), significantly improved from the mean preoperative score of 50 (range 35-78) ($P < .001$). At latest radiographic follow-up, there were no dissociations at the DM-cement interface. All outcome information is summarized in Table 4.

Discussion

Recurrent instability is the most common cause of failure requiring repeat revision following rTHA. A number of surgical treatment modalities have been proposed to decrease the incidence of hip instability in high-risk patients, including the use of DM bearings [16]. The unconstrained tripolar design of the DM implant enhances stability by effectively increasing the femoral head size while increasing the ROM to impingement and jump distance needed for dislocation. The long-term survivorship as well as rates of dislocation following rTHA with DM has been excellent [27,33]. However, a fraction of high-risk patients will continue to experience dislocation despite these enhanced implant designs. In these patients, novel constructs may be of unique benefit. In this report, we describe a low risk of dislocation among a complex cohort of patients where a novel construct was utilized, including the use of a monoblock DM cup specifically intended for insertion with cement, cemented into a cementless revision acetabular component. Although biomechanical studies have suggested that this type of construct is sound and, in fact, stronger than cemented polyethylene liners which have been commonly used in clinical practice, there have been little clinical data to support the use of this construct [28,34,35].

In many rTHA cases, a well-fixed acetabular shell can be retained; however, all of the cases included in the present study required an acetabular shell revision. Due to the extent of the bone loss and bony defects, it was felt by the operating surgeons that a fully porous revision shell rather than a modular acetabular cup was needed to achieve adequate fixation and reconstruction of the acetabulum. The advantage of using a newly implanted fully porous shell, aside from the location and number of screw holes and shell porosity, is having the ability to place the acetabular shell in the best reconstruction position possible. However, as this may not be the best position for hip stability, a liner is cemented within the shell in a better "safe-zone" position. The use of cement is necessary as these shells have no locking mechanism. In order to impart greater stability to the construct, the decision was made to use a DM shell rather than a polyethylene liner in these cases. An example of this is shown in Figure 3; the revision shell is placed in over 55° of abduction and in a more neutral version in order to achieve good construct fixation, and the DM cup is placed in a more stable fixation around 40° of abduction and 15° of anteversion.

To our knowledge, this is the largest US study to date reporting on the clinical outcomes of a cemented DM cup in a newly implanted fully porous acetabular shell. Our results show that cementation of a DM cup designed for cemented use into a newly implanted highly porous, revision acetabular shell can lead to

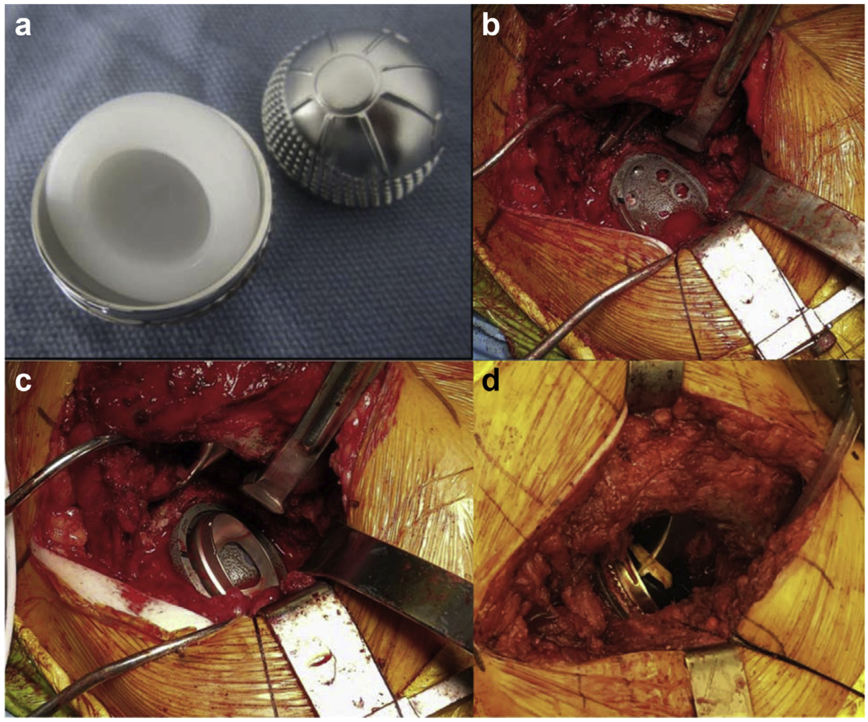

Figure 1. (a) POLARCUP intended for cementation prior to implantation. (b) REDAPT fully porous shell impacted in place following acetabular preparation. (c) Trial placement of DM monoblock cup. (d) DM cup cemented into revision acetabular shell.

enhanced hip stability in the early postoperative period with a low risk of early dislocation or mechanical failure. One (2.6%) patient experienced a spontaneous dislocation on postoperative day 1, which was closed reduced later that day with no further recurrence of instability. In our cohort, there were no IPDs or failures at the DM-cement interface, nor were there any instances of re-revision for early aseptic loosening. Only 1 (2.6%) patient required a re-revision with removal of hardware, which was due to a periprosthetic joint infection. However, at the time of explant, all the components were noted to be well-fixed. Evidence of functional improvements in this cohort was demonstrated by significant improvements in hip ROM, as well as a significant improvement in Harris Hip Scores.

Studies on the clinical performance of cemented DM cups have been generally limited, but have been more common in Europe where the use of DM is more widespread. Hamadouche et al [36]

Figure 2. Preoperative (left) and postoperative (right) anteroposterior hip radiographs.

Table 3
Surgical information (n = 38).

Anesthesia type		
General	30 (68.4%)	
Regional (spinal/epidural)	8 (21.1%)	
Surgeon		
Surgeon 1	1 (2.6%)	
Surgeon 2	1 (2.6%)	
Surgeon 3	11 (28.9%)	
Surgeon 4	14 (36.8%)	
Surgeon 5	2 (5.3%)	
Surgeon 6	5 (13.2%)	
Surgical time (min)	208.6 ± 62.9	
Median porous metal shell size (mm)	62 (54-76)	
Median number of screws	5 (3-14)	
Median dual-mobility outer cup size (mm)	48 (43-63)	
Median femoral head size (mm)	28 (22-28)	
Femoral stem revised	20 (52.6%)	
Bone allograft used		
Yes	18 (47.4%)	
No	18 (47.4%)	
Unknown	2 (5.3%)	
Extended trochanteric osteotomy		
Yes	7 (18.4%)	
No	31 (81.6%)	
Acetabular cage construct used		
Yes	11 (28.9%)	
No	27 (71.1%)	
Intraoperative complications	0 (0.0%)	
Inpatient complications	7 (18.4%)	
Medical	5 (13.2%)	Patient 5: supraventricular tachycardia Patient 22: UTI Patient 28: atrial fibrillation Patient 34: urinary retention Patient 36: myocardial infarction
Surgical	2 (5.3%)	Patient 13: DVT Patient 37: anterior hip dislocation on POD1
Postoperative anemia requiring blood transfusion	4 (10.5%)	
Length of stay (d)	4.7 ± 2.9	

DVT, deep vein thrombosis; POD, postoperative day; UTI, urinary tract infection.

reviewed 47 patients treated with cemented DM cups for recurrent dislocation following primary or revision THA. After a minimum follow-up of 2 years, 2 patients (4.3%) had further episodes of dislocation, which occurred between the polyethylene outer head and the metal shell in 1 hip, and the femoral inner head and the outer polyethylene head (IPD) in the other. The authors suspected that improper placement of the acetabular shell in excessive abduction was responsible for the former, and wear and fatigue deformation due to excessive activity was responsible for the latter. A later follow-up study reporting on the 5- to 13-year results of this cohort was performed [37]. Three patients (5.6%) experienced recurrent dislocation, 2 of which were intraprosthetic. The cumulative survival rate at 10 years was 86.1% using redislocation as the end point, and the authors concluded that DM represents the best reconstructive option for the treatment of recurrent hip instability after THA. Schneider et al explored the outcomes of 96 rTHAs with cemented DM constructs intended for cement use (Novae Stick; SERF, Décines, France) and acetabular cages. Despite the majority of patients having severe acetabular bone loss, they found a high dislocation rate of 10.4% and an aseptic survivorship rate of 99.3% at 8 years [29]. Haen et al [38] found that when there is a moderate deficiency in bone stock, rates of mechanical loosening are comparable regardless of whether an acetabular reinforcement device is used in conjunction with a cemented DM cup.

Plummer et al [22] were the first US group to report on the clinical performance of a construct that was similar to the one used in this series. Nine of the 36 revised hips in their series received DM components cemented into well-fixed or new acetabular shells. Of these, 2 required re-revision due to failure at the DM-cement interface within the first 90 postoperative days. Importantly, these cases utilized a technique that involved roughening the backside of a modular DM liner (modular dual mobility; Stryker, Mahwah, NJ) with a high-speed burr and then cementing it into a shell [22]. The authors, currently, strongly recommend against the use of this technique. At a minimum follow-up of 2 years, no failures had been observed with the other cemented DM cups in their study. Chalmers et al [30] reviewed the results of 18 patients who had undergone rTHA with a monoblock DM construct cemented into a well-fixed or new acetabular component. At mean follow-up of 3 years, 3 patients (17%) experienced postoperative dislocations, and no cups failed at the DM-cement interface. The dislocations occurred at a mean of 4 months postoperatively. Two were treated with open reduction and 1 with revision to a cemented constrained liner. Evangelista et al [31] assessed the outcomes of 18 patients who underwent cementation of a DM monoblock cup, designed for cementation, into a well-fixed or new revision acetabular cup. At a mean follow-up of 36 months, there were no cases of hip dislocation nor any dissociation at the DM-cement interface.

Although DM implants may present a promising solution for preventing hip instability, a potential disadvantage is their increased cost relative to traditional THA implants [39-41].

Table 4
Outcomes (n = 38).

Median follow-up (d)	215.5 (range 6-783)	
Discharge disposition		
Home or self-care	2 (5.3%)	
Home with health services	26 (68.4%)	
Skilled nursing facility	9 (23.7%)	
Acute rehabilitation facility	1 (2.6%)	
Inpatient complications	7 (18.4%)	
30-day complications	3 (7.9%)	Patient 11: hip pain, radiograph showed avulsion fracture of the greater trochanter
Readmissions	2 (5.3%)	Patient 32: hip pain/drainage, treated with irrigation and debridement[a] Patient 36: dehydration and acute renal failure[a]
90-day complications	1 (2.6%)	Patient 24: irrigation and debridement of hip wound[a]
Readmissions	1 (2.6%)	
Re-revisions	1 (2.6%)	Patient 28: removal of hardware
Deep infection	1 (2.6%)	
Dislocation	0 (0.0%)	
Aseptic loosening	0 (0.0%)	
Ambulatory status at latest follow-up		
Rolling walker	11 (28.9%)	
Cane	13 (34.2%)	
Crutches	1 (2.6%)	
Unassisted	12 (31.6%)	
Unknown	1 (2.6%)	

[a] Resulted in hospital readmission.

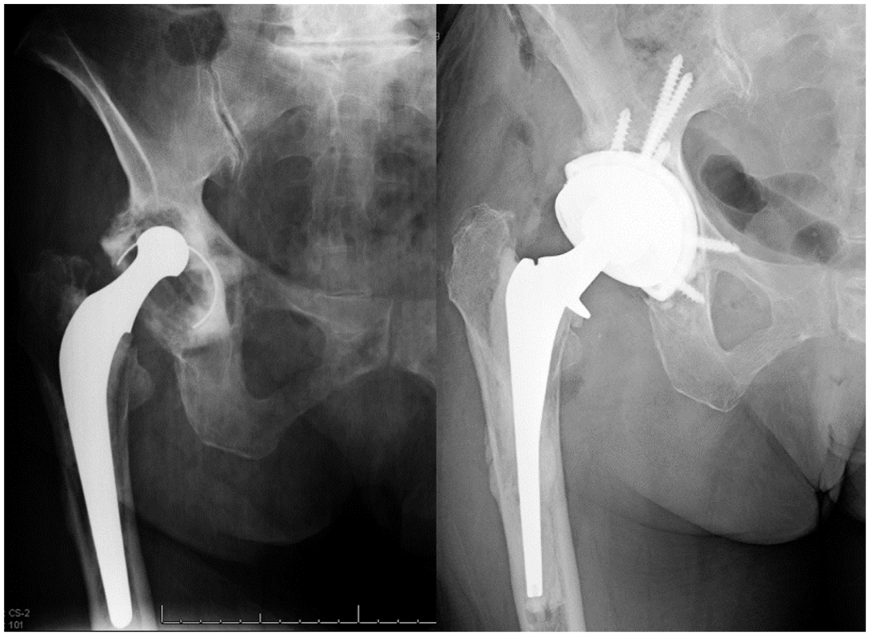

Figure 3. Representative example of a fully porous acetabular shell implanted in a position for maximum bony coverage but less than ideal stability (abduction >55°, anteversion <10°), with the DM cup cemented within in a better position for hip stability.

However, given the economic burden posed by rTHA procedures, which can exceed $50,000 in hospital charges alone, the use of DM implants may actually be more cost-effective from a societal perspective, especially in complex rTHA with an increased risk of instability [1].

Our study has several limitations that must be taken into consideration. Only 1 type of fully porous acetabular shell and DM cup was used in this study, and therefore the results may not be generalizable to other designs and constructs. The cohort of patients in this study was relatively small and the follow-up time was limited. Despite this, the incidence rates of dislocation in both primary and revision THA are highest in the immediate postoperative period and remain elevated throughout the first 3 postoperative months, which is adequately covered in the present study [42]. Still, further follow-up will be required to ensure long-term durability of this construct. Future studies may be needed to directly compare outcomes among cemented DM cups, constrained liners, and large femoral heads utilized in complex THA revision cases.

Conclusions

Cementation of a DM monoblock cup into a newly implanted fully porous revision shell was associated with a low risk of surgical complications and re-revision at short-term follow-up. This technique allows for placement of the porous cup such that bony purchase is maximized, and allows for improved placement of the DM cup with regards to abduction, and anteversion, and the hip's natural center of rotation. Considerations for this construct should be made in patients at high risk of dislocation in order to provide durable fixation and improved stability.

References

[1] Bozic KJ, Kurtz SM, Lau E, et al. The epidemiology of revision total hip arthroplasty in the United States. J Bone Joint Surg Am 2009;91:128.
[2] Gwam CU, Mistry JB, Mohamed NS, et al. Current epidemiology of revision total hip arthroplasty in the United States: National Inpatient sample 2009 to 2013. J Arthroplasty 2017;32:2088.
[3] Parvizi J, Picinic E, Sharkey PF. Revision total hip arthroplasty for instability: surgical techniques and principles. J Bone Joint Surg Am 2008;90:1134.
[4] Wetters NG, Murray TG, Moric M, et al. Risk factors for dislocation after revision total hip arthroplasty. Clin Orthop Relat Res 2013;471:410.
[5] Berend KR, Sporer SM, Sierra RJ, Glassman AH, Morris MJ. Achieving stability and lower-limb length in total hip arthroplasty. J Bone Joint Surg Am 2010;92:2737.
[6] Alberton GM, High WA, Morrey BF. Dislocation after revision total hip arthroplasty: an analysis of risk factors and treatment options. J Bone Joint Surg Am 2002;84-A:1788.
[7] Carter AH, Sheehan EC, Mortazavi SMJ, et al. Revision for recurrent instability. J Arthroplasty 2011;26:46.
[8] Khatod M, Barber T, Paxton E, Namba R, Fithian D. An analysis of the risk of hip dislocation with a contemporary total joint registry. Clin Orthop Relat Res 2006;447:19.
[9] Mahomed NN, Barrett JA, Katz JN, et al. Rates and outcomes of primary and revision total hip replacement in the United States Medicare population. J Bone Joint Surg Am 2003;85-A:27.
[10] Weiss RJ, Beckman MO, Enocson A, Schmalholz A, Stark A. Minimum 5-year follow-up of a cementless, modular, tapered stem in hip revision arthroplasty. J Arthroplasty 2011;26:16.
[11] Springer BD, Fehring TK, Griffin WL, Odum SM, Masonis JL. Why revision total hip arthroplasty fails. Clin Orthop Relat Res 2009;467:166.
[12] Garbuz DS, Masri BA, Duncan CP, et al. The Frank Stinchfield Award: dislocation in revision THA: do large heads (36 and 40 mm) result in reduced dislocation rates in a randomized clinical trial? Clin Orthop Relat Res 2012;470:351.
[13] Halley D, Glassman A, Crowninshield RD. Recurrent dislocation after revision total hip replacement with a large prosthetic femoral head. A case report. J Bone Joint Surg Am 2004;86-A:827.
[14] Lachiewicz PF, Soileau ES, Martell JM. Wear and osteolysis of highly cross-linked polyethylene at 10 to 14 years: the effect of femoral head size. Clin Orthop Relat Res 2016;474:365.
[15] Tower SS, Currier JH, Currier BH, et al. Rim cracking of the cross-linked longevity polyethylene acetabular liner after total hip arthroplasty. J Bone Joint Surg Am 2007;89:2212.
[16] Guyen O. Constrained liners, dual mobility or large diameter heads to avoid dislocation in THA. EFORT Open Rev 2016;1:197.
[17] Berend KR, Lombardi AV, Mallory TH, et al. The long-term outcome of 755 consecutive constrained acetabular components in total hip arthroplasty: examining the successes and failures. J Arthroplasty 2005;20:93.
[18] Dangin A, Boulat S, Farizon F, Philippot R. Prevention of dislocation risk during hip revision surgery with the dual mobility concept; study of a new generation of dual mobility cups. Surg Technol Int 2016;29:314.
[19] Harwin SF, Sultan AA, Khlopas A, et al. Mid-term outcomes of dual mobility acetabular cups for revision total hip arthroplasty. J Arthroplasty 2018;33:1494.
[20] Jauregui JJ, Pierce TP, Elmallah RK, et al. Dual mobility cups: an effective prosthesis in revision total hip arthroplasties for preventing dislocations. Hip Int 2016;26:57.

[21] Lange JK, Spiro SK, Westrich GH. Utilizing dual mobility components for first-time revision total hip arthroplasty for instability. J Arthroplasty 2018;33:505.
[22] Plummer DR, Christy JM, Sporer SM, Paprosky WG, Della Valle CJ. Dual-mobility articulations for patients at high risk for dislocation. J Arthroplasty 2016;31:131.
[23] Prudhon JL, Steffann F, Ferreira A, et al. Cementless dual-mobility cup in total hip arthroplasty revision. Int Orthop 2014;38:2463.
[24] Snir N, Park BK, Garofolo G, Marwin SE. Revision of failed hip resurfacing and large metal-on-metal total hip arthroplasty using dual-mobility components. Orthopedics 2015;38:369.
[25] Stucinskas J, Kalvaitis T, Smailys A, Robertsson O, Tarasevicius S. Comparison of dual mobility cup and other surgical constructs used for three hundred and sixty two first time hip revisions due to recurrent dislocations: five year results from Lithuanian arthroplasty register. Int Orthop 2018;42:1015.
[26] Sutter EG, McClellan TR, Attarian DE, et al. Outcomes of modular dual mobility acetabular components in revision total hip arthroplasty. J Arthroplasty 2017;32:S220.
[27] Levin JM, Sultan AA, O'Donnell JA, et al. Modern dual-mobility cups in revision total hip arthroplasty: a systematic review and meta-analysis. J Arthroplasty 2018;33:3793.
[28] Wegrzyn J, Thoreson AR, Guyen O, Lewallen DG, An K-N. Cementation of a dual-mobility acetabular component into a well-fixed metal shell during revision total hip arthroplasty: a biomechanical validation. J Orthop Res 2013;31:991.
[29] Schneider L, Philippot R, Boyer B, Farizon F. Revision total hip arthroplasty using a reconstruction cage device and a cemented dual mobility cup. Orthop Traumatol Surg Res 2011;97:807.
[30] Chalmers BP, Ledford CK, Taunton MJ, et al. Cementation of a dual mobility construct in recurrently dislocating and high risk patients undergoing revision total arthroplasty. J Arthroplasty 2018;33:1501.
[31] Evangelista P, Okroj K, Plummer D, Della Valle C, Schwarzkopf R. Do cemented dual-mobility cups confer stability for patients at high risk of dislocation in revision total hip arthroplasty? J Hip Surg 2018;101:577.
[32] Paprosky WG, Perona PG, Lawrence JM. Acetabular defect classification and surgical reconstruction in revision arthroplasty: a 6-year follow-up evaluation. J Arthroplasty 1994;9:33.
[33] Bauchu P, Bonnard O, Cyprès A, et al. The dual-mobility POLARCUP: first results from a multicenter study. Orthopedics 2008;31.
[34] Beaulé PE, Ebramzadeh E, Le Duff M, Prasad R, Amstutz HC. Cementing a liner into a stable cementless acetabular shell: the double-socket technique. J Bone Joint Surg Am 2004;86-A:929.
[35] Callaghan JJ, Parvizi J, Novak CC, et al. A constrained liner cemented into a secure cementless acetabular shell. J Bone Joint Surg Am 2004;86-A:2206.
[36] Hamadouche M, Biau DJ, Huten D, Musset T, Gaucher F. The use of a cemented dual mobility socket to treat recurrent dislocation. Clin Orthop Relat Res 2010;468:3248.
[37] Hamadouche M, Ropars M, Rodaix C, et al. Five to thirteen year results of a cemented dual mobility socket to treat recurrent dislocation. Int Orthop 2017;41:513.
[38] Haen TX, Lonjon G, Vandenbussche E. Can cemented dual-mobility cups be used without a reinforcement device in cases of mild acetabular bone stock alteration in total hip arthroplasty? Orthop Traumatol Surg Res 2015;101:923.
[39] Orthopedic Network News. Hip and knee implant review 2015. https://www.orthopedicnetworknews.com/archives/onn263s1.pdf; 2015. [Accessed 14 March 2019].
[40] Barlow BT, McLawhorn AS, Westrich GH. The cost-effectiveness of dual mobility implants for primary total hip arthroplasty. J Bone Joint Surg Am 2017;99:768.
[41] Rudy HL, Padilla JA, Gabor JA, et al. Cost-effectiveness of dual mobility and a value-based algorithm of utilization. Orthop Clin North Am 2019;50:151.
[42] Phillips CB, Barrett JA, Losina E, et al. Incidence rates of dislocation, pulmonary embolism, and deep infection during the first six months after elective total hip replacement. J Bone Joint Surg Am 2003;85-A:20.