International Orthopaedics (2018) 42:1241–1246
https://doi.org/10.1007/s00264-018-3767-4

ORIGINAL PAPER

Dual mobility hip arthroplasty provides better outcomes compared to hemiarthroplasty for displaced femoral neck fractures: a retrospective comparative clinical study

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Received: 29 September 2017 / Accepted: 4 January 2018 / Published online: 17 January 2018

Abstract

Purpose Total hip arthroplasty with a dual mobility cup (DMC) is a proposed alternative to the widely performed bipolar hemiarthroplasty (BHA) for treating displaced intracapsular femoral neck fractures (DFNF) in the elderly. However, the comparison between the two modalities has not been extensively conducted thus far.

Methods A retrospective cohort study was conducted with DFNF patients aged over 65 years who were treated either by BHA or DMC. After propensity matching each group comprised 84 patients (168 patients in total) and was analyzed using peri-operative and post-operative parameters.

Results Mean follow-up durations were 22.1 and 21.7 months in the BHA and DMC groups, respectively. The BHA group demonstrated significantly less intra-operative blood loss ($p = 0.001$) and a shorter length of operation ($p < 0.001$). However, there was no difference in one-year mortality ($p = 0.773$). The Harris hip score (HHS) was significantly higher ($p = 0.018$) in the DMC group. The dislocation rate was not different between the two groups ($p = 1.000$).

Conclusion In DFNF patients aged over 65 years, short-term observation showed DMC to be the preferred treatment over BHA with better clinical outcome, without disadvantages in mortality or dislocation rate. Further long-term investigations are recommended to strengthen these results.

Keywords Femoral neck fracture · Hip arthroplasty · Hemiarthroplasty · Dual mobility cup · Dislocation · Harris hip score

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Introduction

In 2000, 1.6 million new hip fractures occurred worldwide [1], and this number is expected to rise to 4.5 million by 2050 [2]. Most hip fractures are treated operatively [3], and, among these, 45% are displaced intracapsular femoral neck fractures (DFNF) for which the most widely performed treatment in the elderly is bipolar hemiarthroplasty (BHA) [4].

Historically, conventional total hip arthroplasty without a dual mobility cup (THA) was reserved for DFNF patients with an underlying acetabular pathology [5]. As the mortality after hip fractures has decreased due to enhancements in peri-operative management and rehabilitation [6, 7], functional performance and the risk that revision surgery will be needed are being taken into account more often. Therefore, THA has been extensively studied as an option for DFNF, regardless of acetabular lesions, with reports of better functional outcome

and less possibility for the need for revision surgery in return for a higher dislocation rate [8, 9]. However, this risk of dislocation has limited the use of THA for DFNF patients and BHA remains the most practiced treatment [4].

Meanwhile, to lessen the dislocation rate associated with THA, the "dual mobility" concept was developed in France by Bousquet [10]. Total hip arthroplasty with a dual mobility cup (DMC) is composed of two articulations, one being the nonconstrained articulation between the acetabular cup and the liner and the other between the constrained liner and the femoral head. The constrained liner acts as an extension of the femoral head, increasing the head-neck ratio and jump distance, which reduces the risk of dislocation [11]. This can be an advantage in DFNF treatment, as hip arthroplasty due to fracture is reported to be more prone to dislocation than other indications for the procedure such as osteoarthritis [12, 13].

Though studies have repeatedly confirmed the lower dislocation rate of DMC compared to THA and its use for revisions in recurrent THA dislocation [14–16], only a few have limited the investigation to DFNF patients. Compared to THA, DMC showed similar functional results [17] with a significantly lower risk of dislocation [17, 18], making it a suitable alternative for DFNF treatment.

However, the outcomes of DMC in relation to BHA for DFNF treatment have not been elucidated. Because the risk of a high dislocation is minimized, DMC may be an ideal alternative to the widely-practiced BHA for providing better functional outcomes without compromising joint stability. However, thus far, there has been only one study in the literature comparing BHA and DMC in terms of dislocation, revision, and mortality [19].

The present study is among the first to compare BHA and DMC for treating DFNF, and is the first to compare postoperative clinical score after these procedures.

Materials and methods

Inclusion and exclusion criteria

With approval of the Institutional Review Board and in accordance with the Declaration of Helsinki of ethical standards, a retrospective cohort study of patients who met the following inclusion criteria was performed: (1) over 65 years old at the time of injury, (2) sustained an acute DFNF (Garden III or IV), (3) subsequently treated with either BHA or DMC, and (4) available follow-up records of at least 12 months post-operatively.

From March 2007 to May 2013, all consecutive patients over the age of 65 years who sustained a DFNF were treated with BHA. Due to the occasional complaints of hip pain and loss of function in follow-up patients, from June 2013 to August 2016, DMC was performed for the same indication. Therefore, there was no bias in patient selection, as the treatment option was dependent only on the date of surgery.

Exclusion criteria were as follows: (1) severe cognitive dysfunction which may have hindered post-operative rehabilitation, (2) history of previous hip surgery on either side, (3) pathologic fracture, (4) concomitant fractures of other areas, (5) absence of independent walking capability prior to trauma, (6) implants and/or surgical approach other than those specified in this study.

The total number of patients after applying the exclusions was 214 in the BHA group and 84 in the DMC group.

Surgical intervention

All surgeries in both groups were performed from a posterolateral approach by a single senior surgeon specialized in hip and trauma surgery, familiar in both hemiarthroplasty and total hip arthroplasty.

The 214 patients in the BHA group received hemiarthroplasty with a beta titanium alloy Accolade TMZF femoral stem, a 28 mm Biolox Delta Ceramic V40 femoral head, and a UHR Universal Head Bipolar System (all from Stryker, Mahwah, NJ, USA).

The 84 patients in the DMC group underwent total hip arthroplasty with the same femoral component as the BHA group. However, for the acetabular side a dual mobility MDMX3 system composed of a pure titanium Trident PSL shell, Co-Cr MDM liner, and a UHMWPE X3 bearing (all from Stryker, Mahwah, NJ, USA) was implanted.

Noncemented press-fit fixation without screws was performed for all prostheses with femoral stem anteversion of 15°, and acetabular component anteversion of 15° with an inclination of 40°. Proper fit and the position of the components were confirmed by fluoroscopy. Stability was tested at 90° of flexion. Internal rotation was first tested at 60° followed by 30° adduction with neutral rotation. The tagged short external rotator tendons and the posterior capsule were reattached to the greater trochanter with multiple transosseous nonabsorbable sutures.

Intravenous cefazolin were administrated 60 minutes before skin incision and were discontinued 24 hours post-operatively. Immediate mobilization with full weight bearing with aids if necessary was encouraged. Deep vein thrombosis prophylaxis pumps and abduction pillows were applied at all times during bed rest before discharge.

In the case of a dislocation, closed reduction was performed with application of an abductor brace for eight weeks. If open reduction or revision took place, the brace was worn for 12 weeks.

Data collection

The following data were collected from medical records. Demographic data at the time of surgery including age,

gender, and body mass index (BMI); peri-operative parameters including the American Society of Anesthesiologists (ASA) physical status classification [20], intra-operative blood loss (in milliliters; calculated by adding the two volumes A: added weight of used swabs multiplied by 1.05 for blood density, and B: subtracting the volume of lavage fluid from suction containers), length of operation (in minutes; from skin incision to closure); post-operative data comprising follow-up duration (in months), most recent documentation of the Harris hip score (HHS, maximum 100 points) and its subdomain pain (maximum 44 points) [21]. Dislocations and the interval (in days) from surgery were recorded. When applicable, death and its cause were also documented.

Statistical analysis

To minimize selection bias, propensity score matching was done prior to analysis. The maximum difference in propensity score of any matched pair was set to 0.1 for the variables of age, gender, BMI, ASA physical status classification, and the duration of follow-up. As the number of patients ($n = 214$) in the traditional BHA group far exceeds that of the more recent DMC group ($n = 84$), all patients of the DMC group were included in the final analysis each with a matching patient from the BHA group (From this point on, the BHA group refers to the 84 patients after the propensity matching.).

With the same number of matched patients (n = 84) in each group, further statistical analyses were done. For numerical data, independent t-tests were used to compare results expressed as mean ± standard deviation (SD) and range. Pearson Chi-square and Fisher's exact tests were employed for categorical data to derive odds ratios (OR) and 95% confidence intervals (CI). Statistical significance was set to *p*-values below 0.05. IBM SPSS Statistics for Windows, version 24 (IBM Corp., Armonk, NY, USA) was used in all statistical analyses of this study.

Results

As both groups went through propensity matching, age, BMI, gender, and ASA classification showed no significant differences (Table 1).

Mean duration of follow-up in the BHA and DMC groups showed no significant difference ($p = 0.829$). The length of operation was significantly shorter ($p < 0.001$), and intra-operative blood loss was significantly less ($p = 0.001$) in the BHA group. However, the BHA group also demonstrated a significantly lower ($p = 0.018$) HHS at the last follow-up. The mean difference in the HHS was 4.16 (95% CI, 0.74–7.57). BHA group scored significantly less in the subdomain pain in the HHS ($p < 0.001$), with the mean difference of 2.99 (95% CI, 1.89–4.09) (Table 2).

Despite greater blood loss in the DMC group, the transfusion rate was not significantly high ($p = 0.420$). One-year mortality showed no significant difference ($p = 0.773$) in both groups. Causes of death in a total of 13 patients were pneumonia ($n = 7$), cardiac arrest ($n = 4$), and sepsis from sores and urinary tract infection ($n = 2$). None suffered any dislocation prior to death. No significant difference ($p = 1.000$) in dislocation rates was seen between the BHA and DMC groups (Table 3).

All dislocations, five in total, were posterior dislocations and took place within the first five weeks with a mean of 21 days (range, 7–35 days). For all three dislocations in the BHA group, closed reduction was done successfully without any anesthesia necessary. Two patients were treated uneventfully with abduction braces worn for eight weeks, while one patient suffered two more recurrent dislocations after the initial reduction (Fig. 1). Closed reduction after the third dislocation resulted in a dissociation of the bipolar cup from the femoral head, which consequently required revision. As there was no DMC option available in the institution at the period, the treatment was completed with a component exchange of the slightly overstuffed bipolar cup for a smaller component in addition to a longer neck. A thorough transosseous reattachment of the posterior soft

Table 1 Demographic data

	BHA ($n = 84$)	DMC (n = 84)	p-value
Age (years)	72.9 ± 7.8 (65–92)	73.1 ± 6.0 (65–90)	0.783
BMI (kg/m^2)	21.9 ± 3.2 (15.9–29.6)	22.1 ± 3.2 (15.6–30.1)	0.722
Male: female	27: 57	26: 58	1.000
ASA classification	2.1 ± 0.6	2.1 ± 0.6	0.799

Numerical data expressed as mean ± SD (range)

BHA; bipolar hemiarthroplasty, DMC; total hip arthroplasty with a dual mobility cup, BMI; body mass index, ASA; American Society of Anesthesiologists

Table 2 Duration of follow-up, length of operation, intra-operative blood loss, Harris hip score, and subdomain pain

	BHA (n = 84)	DMC (n = 84)	p-value
Duration of follow-up (months)	22.1 ± 9.6 (12–48)	21.7 ± 10.4 (12–46)	0.829
Length of operation (minutes)	64.2 ± 22.4 (32–140)	77.3 ± 23.1 (45–143)	<0.001
Intra-operative blood loss (milliliters)	489.3 ± 189.7 (255–1010)	634.2 ± 337.2 (305–2050)	0.001
Harris hip score	79.3 ± 10.9 (35–99)	83.4 ± 11.5 (54–99)	0.018
Harris hip score subdomain pain	36.7 ± 4.7 (10–44)	39.7 ± 3.6 (20–44)	<0.001

Numerical data expressed as mean ± SD (range)

capsule and tendons was performed followed by use of an abduction brace for 12 weeks.

For the two dislocations in the DMC group, closed reduction was successful in all patients and no further dislocations took place after 5 weeks' application of abduction braces (Fig. 2).

Discussion

In this study, BHA showed the merits of a shorter operative time and less intra-operative blood loss, while DMC demonstrated a higher mean HHS. Both options revealed no significant differences in the transfusion and dislocation rates, and one-year mortality.

The shorter operative time and reduced intra-operative blood loss compared to THA have been repeatedly confirmed in other studies [22, 23]. However, BHA is a simpler procedure involving only the femoral side of the hip joint; longer operative time and more intra-operative blood loss due to acetabular procedures are inherent in every THA or DMC. Therefore, it is only logical to see if these differences affect more meaningful outcomes, such as transfusion rate or mortality. The present study demonstrated that, despite the difference in the amount of blood loss, the transfusion rate was not significantly different between the BHA and DMC groups. Furthermore, no significant difference was seen in one-year mortality as well. A meta-analysis [8] of six randomized controlled trials confirms no difference in the mortality between BHA and THA. Only one study [19] so far has compared BHA and DMC in terms of three-month and one-year mortality, and again showed no difference. The present study adds more strength to this finding.

Post-operative erosion of the acetabulum is a major concern in BHA, inducing progressive pain and loss of motion with higher rates of revision surgery after long-term use [9, 24]. In the literature, there has been extensive research comparing clinical scores of BHA versus THA. Multiple studies with DFNF patients confirmed significantly higher post-operative clinical scores in the THA groups than the BHA groups [8, 22]. Meanwhile, Tarasevicius et al. [17] conducted the only study in the literature that compares the clinical outcomes of THA and DMC after DFNF and did not show a significant difference. Until now, it could only be inferred from the above studies that the difference in the clinical scores between the BHA and DMC groups may be similar to that of BHA and THA groups. The current study is the only research done so far to directly compare the clinical outcome between BHA and DMC in terms of the HHS. The resulting mean differences in the HHS and its subdomain pain were 4.16 (95% CI, 0.74–7.57) and 2.99 (95% CI, 1.89–4.09) respectively, favouring DMC over BHA.

Dislocation is a devastating complication in hip arthroplasty. Blewitt et al. [25] even reported a sixfold higher mortality rate of 65% within six months after BHA dislocation compared to a 10% mortality rate during the same period for those without dislocation. Compared to other aetiologies such as osteoarthritis, fracture proved to be a more significant risk factor for post-operative dislocation in hip arthroplasty [12, 13]; BHA still stands as the mainstay of treatment for DFNF [4, 26] due to its lower risk of dislocation compared to THA. On the other hand, DMC was also shown to have a lower risk of dislocation than THA [17].

Thus far only Bensen et al. [19] directly compared the dislocation rates of BHA and DMC for DFNF; BHA proved to be significantly more prone to dislocation then DMC. Though the current study did not show a significant

Table 3 Transfusion rate, one-year mortality, and dislocations

	BHA (n = 84)	DMC (n = 84)	OR (95% CI)	p-value
Transfusions	13 (15.5%)	17 (20.2%)	0.72 (0.33–1.60)	0.420
Deaths within one year	6 (7.1%)	7 (8.3%)	0.85 (0.27–2.63)	0.773
Dislocations	3 (3.6%)	2 (2.4%)	1.52 (0.25–9.33)	1.000

OR; odds ratio, CI; confidence interval

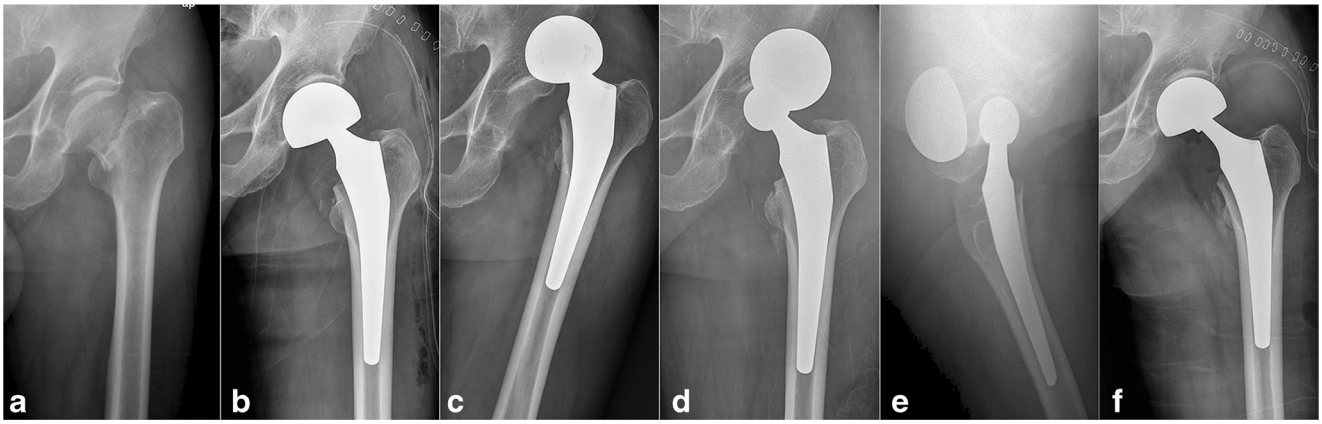

Fig. 1 Recurrent dislocation after a bipolar hemiarthroplasty for displaced femoral neck fracture resulting in an intraprosthetic dissociation after multiple closed reductions. **a** A completely displaced Garden IV intracapsular femoral neck fracture sustained by a 72-year-old man after a fall from standing height. **b** Post-operative radiograph after the initial bipolar hemiarthroplasty. Though not presented in figures, on postoperative day (POD) 18 and 19, while getting up from bed, two posterior dislocations occurred. Closed reduction was performed followed by application of an abductor brace. **c** A third posterior dislocation occurred on POD 23 while standing up from a chair. Closed reduction was attempted. **d**–**e** After an attempt at closed reduction, intraprosthetic dissociation between the bipolar cup and the femoral head occurred, necessitating open surgery. **f** After revision. The slightly overstuffed bipolar cup was exchanged for a cup that was one size smaller and the neck was changed to a longer component. Abduction brace was worn for 12 weeks. No further dislocations occurred

difference, BHA did show a slightly higher dislocation rate. In addition, while one of the BHA dislocations recurred twice, necessitating open revision, all DMC dislocations in our series were successfully treated with closed reduction.

The strength of this study is that much effort was taken to set the type of arthroplasty as the only variable. The two groups were operated by the same surgeon through the same approach, and even share the same femoral component, setting the acetabular procedure as the sole independent variable. Both groups were propensity matched in demographic data and the ASA classification to strengthen the analysis.

However, the limitations must also be considered. Despite propensity matching, this is still a retrospective study with a relatively short observation period. As acetabular erosion is a time-dependent process [24], prospective studies with a longer follow-up should be conducted to evaluate the long-term effects of acetabular erosion and its consequences. Though this study demonstrated a significantly higher HHS and its subdomain pain in the DMC group, the differences are 4.16 and 2.99 within a 100- and 44-point scale, respectively. A possible increase in these differences will have to be investigated with a longer period of follow-up, to strengthen its clinical significance. In addition, the differences in dislocation, need of revision surgery, and mortality will also have to be evaluated in a long-term scale. Better long-term outcome will strengthen the rationale for choosing DMC as the optimal treatment for DFNF, especially for active patients with a longer life expectancy.

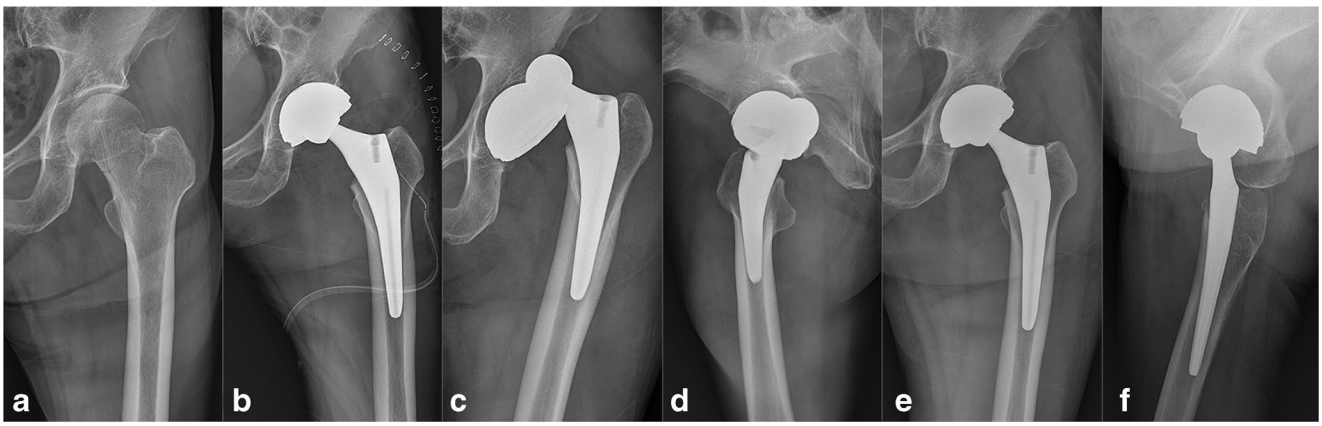

Fig. 2 Dislocation of total hip arthroplasty with a dual mobility cup treated by closed reduction. **a** A partially displaced Garden III intracapsular femoral neck fracture with a complete fracture extending to the medial cortex of the femoral neck, sustained by a 75-year old woman after a fall from standing height. **b** Postoperative radiograph after the initial dual mobility total hip arthroplasty. **c**–**d** On POD 14, posterior dislocation occurred while changing position in bed. **e**–**f** Under procedural sedation with propofol, closed reduction was successful. Abduction brace was used for a further 8 weeks with no recurrent dislocation

Conclusion

As a treatment option for DFNF in patients over 65 years, 22 months' follow-up after BHA and DMC showed no significant difference in the dislocation rate and one-year mortality. However, the HHS was significantly higher after DMC. With higher post-operative performance scores without sacrificing mortality or dislocation rates, DMC showed better short-term outcome. Further evaluation with a longer follow-up is recommended to strengthen these findings.

Compliance with ethical standards This research did not receive any support or grant from funding agencies in the public, commercial, or not-for-profit sectors. All authors declare that they have no conflict of interest. Institutional Review Board approval was obtained, and the study was in compliance with the Declaration of Helsinki.

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