



# Low dislocation rate of Saturne®/Avantage® dual-mobility THA after displaced femoral neck fracture: a cohort study of 966 hips with a minimum 1.6-year follow-up

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## Abstract

**Introduction** Dislocation is a serious and common complication and a great concern with the use of total hip arthroplasty (THA) when treating displaced femoral neck fracture (FNF). Dual-mobility (DM) THA might reduce the dislocation risk. We aim to report the dislocation and revision rate of primary DM THA in patients with displaced FNF.

**Materials and methods** Between 2005 and 2015, 966 consecutive patients (676 women) at mean age 80.5 years (range 42–104) with displaced FNF were operated with DM articulation THA by posterolateral approach (PLA). Patient files and radiographs were evaluated for dislocations, revisions, and other complications until death of the patient or August 1st, 2017. Data were crosschecked with the National Patient Registry. Patient's mental state was tested upon admissions. Surgeon's educational level was noted and post-operative cup position was measured.

**Results** At minimum 1.6-year follow-up, there were 45 (4.7%) dislocations and eight (0.8%) cup revisions. The 30-day mortality was 9.2% and 533 patients (55.2%) were dead at the time of last follow-up. We observed eight intraprosthetic dislocations (IPD); six occurred in relation to closed reduction. Cementless stem fixation was associated with higher dislocation risk ( $p=0.04$ ) and higher rate of stem complications ( $p=0.002$ ). There was no significant association between cognitive impairment and dislocation (OR 2.0, 95% CI 0.96–4.34,  $p=0.06$ ).

**Conclusion** Overall, DM THA inserted via PLA results in an acceptable dislocation risk and low revision rate in fragile, old patients with acute FNF fracture, regardless of mental status. A unique complication in DM THA is IPD, which requires an immediate open reduction surgery.

**Keywords** Femoral neck fracture · Total hip arthroplasty · Dislocation · Dual-mobility cup

## Introduction

Hip arthroplasty has proven superior in terms of lower complication and reoperation rates, and better functional outcome compared to internal fixation (IF) in the treatment of displaced femoral neck fractures (FNF) [1–3]. However, there is no clear consensus if the best treatment choice is total hip arthroplasty (THA) or hemiarthroplasty (HA), and

if the patient age and preoperative ambulatory status and mental status should be considered [4]. Some suggest that THA results in better functional outcome, lower mortality and reduced reoperation risk compared to HA [1, 5, 6]. Dislocation is a serious and common complication, and the greatest concern with use of THA in displaced FNF, and the biggest concern in using THA over HA is the greater dislocation risk associated with THA [7, 8]. Prosthetic joint stability is influenced by several factors including (1) patient-related factors: age, gender, preoperative function and cognitive status, (2) implant factors: design, head size, component fixation, and (3) surgical factors: technique, approach, implant positioning [9]. The theoretical benefit of the original dual-mobility (DM) implant was to increase stability and range to impingement as the large mobile femoral PE head is not constrained inside the cup as in conventional single-mobility (SM) THA [10, 11]. Patients with femoral

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neck fracture (FNF) treated with primary THA do have a higher dislocation rate than patients treated with THA due to osteoarthritis, which can likely be reasoned by higher age, fragility, comorbidity, cognitive impairment and poor ambulation/fall incidents in FNF patients [12, 13].

The aim of this cohort study is to report the rate of dislocation, reoperation and revision for DM THA used as the primary treatment for displaced medial FNF.

## Methods

### Patients

The study design was a retrospective follow-up study of an unselected historic cohort treated with primary DM THA after displaced medial FNF in terms of Garden III, Garden IV, or Garden I–II with  $>20^\circ$  posterior tilt [14, 15]. According to the Danish hip fracture reference program, primary HA or THA is the standard treatment in patients aged  $>70$  years and in younger patients where the fracture cannot be satisfactorily reduced for osteosynthesis [16]. Patients with impaired mental function or poor ambulation were also included and treated with primary DM THA. Patients with secondary DM THA after failed osteosynthesis were not included. In our department, we introduced the DM THA as primary treatment for all displaced medial FNF in 2005 reasoned by a wish to elude conversion from HA to THA due to acetabular erosion, an expected reduction in dislocation rate with DM THA, and evidence of lower mortality and reoperation rate in general in SM THA compared to HA [6, 17–20]. Daily on-call hip surgeons at our institution offer FNF patients treatment with DM THA at highest specialist standards within recommended time limits.

From 2005 to 2014, the Saturne<sup>®</sup> DM Acetabular System (Amplitude, Valence, France) was used in combination with a cemented Exeter stem or a cementless Corail stem [15]. Due to a regional tender in July 2014, our department was obliged to change cup system to the Advantage<sup>®</sup> DM acetabular system (Zimmer Biomet, Warsaw, Indiana, USA), while the stem systems stayed unchanged. Cemented or cementless fixation was used according to surgeon's preference, preoperative evaluation of radiographs and intraoperative judgement of bone quality. Gentamycin-loaded Palacos bone cement (Haeremus Medical GmbH, Wehrheim, Germany) was utilized.

The cohort consisted of 966 consecutive hips (31 bilateral hips), including 676 women and 290 men, with a mean age of 80.5 (SD 9.5, range 42–104) years. All patients were admitted and treated in the Department of Orthopedics, Hospital Unit West, Holstebro, Denmark between January 2005 and December 2015.

Patients were operated by consultants highly experienced in hip surgery ( $n=798$ ) and supervised residents ( $n=168$ ). Reflecting every day's real-world acute surgery management, a number of surgeons were involved in operating of the large number of patients during the operation period from 2005 to 2015. All surgeons were either orthopedic consultants ( $n=13$ ) or orthopedic residents ( $n=12$ ) supervised by senior a surgeon. The surgical approach was posterolateral in all cases and the external rotators were resutured in all cases. All received prophylactic antibiotics as 1 g Diclocil<sup>®</sup> (dicloxacillin) administered intravenous preoperatively as well as two times during the first 24 post-operative hours.

All patient files were crosschecked with post-operative radiographs to verify cup type, fixation type (cemented/cementless/hybrid prosthesis), and complications. Pulmonary embolism and deep vein thrombosis were considered to be in relation to THA surgery when occurring within 3 months after the operation.

We further crosschecked the data with The Danish National Patient Register for any missed postoperative complications outside our own department (dislocation, fracture, infection, cup or stem revision). The Danish Patient Register is considered to be largely complete since all activities in public hospitals are included. All diagnoses for every admission are recorded including non-operative procedures, e.g. closed reduction of dislocated THA [21]. This ensures that all complications registered at other hospitals are recorded and were available for evaluation in this study.

Since 2011, as a standard in our department, nurses have completed a Danish version of the abbreviated 0–9 mental status test for admitted FNF patients prior to surgery. A test score between 0 and 5 is considered low cognitive function [22]. Mental status test results were available for 65% of the patients ( $n=634$ ).

All radiographs were taken using a standardized set-up at our radiology department. Postoperative radiographs include a radiograph of the pelvis, and an anteroposterior and lateral view of the hip. Radiographs of the pelvis and the affected hip were taken with the patient in supine position. All radiographs were taken with 15–20 degrees internal rotation of the legs. Lateral view was taken with 90 degrees flexion of the hip and knee of the non-affected side. All radiographs were evaluated by one observer (ST-J). Cup inclination was measured manually on digital postoperative standard anteroposterior (AP) pelvic radiographs, as the angle between the plane through the opening of the cup and the horizontal plane (ischial tuberosity line) [23]. Due to missing postoperative pelvic radiographs, we could only measure inclination in 38 of the 45 patients who suffered hip dislocation. The reason for missing post-operative radiographs was poor physical condition of the patients so that they were not able to get post-operative radiograph. The version of the cup was assessed dichotomously to be either anteverted or retroverted

based on relation to the ischial tuberosity/ischium on the postoperative lateral radiographs as described by Paterno et al. [24].

Precision of the cup inclination measurements was evaluated as double measurements on 10% of the patients ( $n=81$ ). The average intra-observer inclination difference was  $-0.42$  degrees (SD 1.1) and concordance correlation coefficient was 0.99 implying excellent intra-observer reproducibility.

The protocol for the study was reviewed by The Central Danish Regional Committees on Biomechanical Research Ethics (inquiry 149/2012).

## Statistical methods

The primary endpoint was dislocation. The secondary endpoints were cup/stem revision and periprosthetic fractures with or without needed fracture fixation/component revision. Revision was defined as replacement of either cup or stem component, and all other complications requiring secondary surgery as reoperation.

Non-parametric (Mann–Whitney) statistics was used for continuous data, where data were not normally distributed according to a Shapiro–Wilk test, and parametric (Student's  $t$ -test) statistics where data were normal distributed. Chi-squared test and Fisher's exact test (used for expected cell count of 5 and less) for categorical data and odds ratios for two dichotomous variables were calculated using Woolf approximation. The Kaplan–Meier survival curve for time to first dislocation was made. Statistical significance was set at the 5% level.

## Results

Mean follow-up time was 5.4 (1.6–12.6) years. Of the total 966 patients, 415 (43%) cups and 741 (76.7%) stems were fixed with cemented technique. At the time of last-available follow-up 533 (55.2%) patients were dead. There were more women ( $n=676$ ) than men ( $n=289$ ) in the cohort

( $p<0.001$ ). 30-Day mortality was 9.2% and 1-year mortality was 22.1%.

Demographic data are presented in Table 1.

## Primary fracture augmentation

Eight patients had trochanteric fractures in combination with the FNF, and these were fixed intraoperatively with wire-cables or wires in combination with a trochanteric plate at the primary DM THA surgery.

## Dislocation

There were 45 patients with large-articulation dislocations (4.7%), with a mean time to dislocation of 21 days (median 18, range 1–63) and the number of dislocations was between one and four. Most dislocations  $n=33$  (73%) were treated with closed reduction, but 18 patients underwent operation with either open reduction with/without component replacement, cup revision, or Girdlestone procedure. Age at the time of THA insertion and gender did not jeopardize the risk of dislocation or revision ( $p=0.97$  and  $p=0.24$ , respectively). Neither cup nor stem fixation was associated with higher dislocation risk ( $p=0.4$  and  $p=0.1$ , respectively). Cup inclination was  $3^\circ$  higher in patients with hip dislocation, which was associated with risk of dislocation ( $p=0.04$ ). Cup retroversion was likewise associated with higher dislocation risk ( $p<0.001$ ). The educational level of the primary surgeon was unrelated to the dislocation risk ( $p=0.42$ ). The Saturn<sup>®</sup> and Advantage<sup>®</sup> DM cup systems had similar dislocation risk ( $p=0.84$ ). Of the 65% patients who underwent mental testing, 29% were categorized as cognitive impaired ( $n=185$ ). There was no significant association between cognitive impairment and dislocation (OR=2.0, 95% CI 0.96–4.34,  $p=0.06$ ). Kaplan–Meier survival curves for time to first dislocation according to preoperative assessed mental status are presented in Fig. 1.

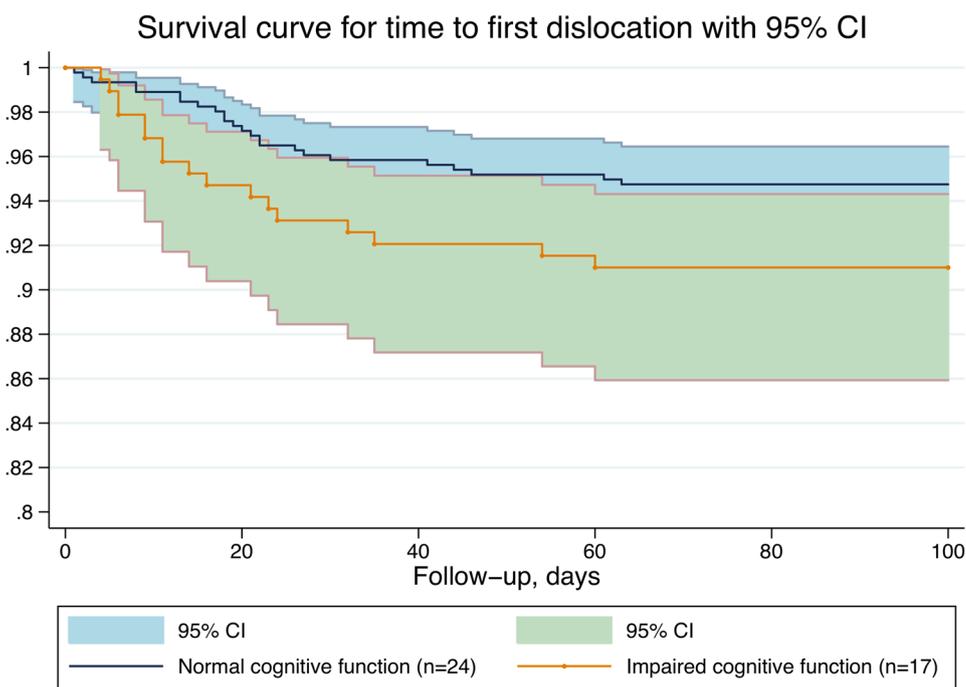
Eight patients (0.8%) experienced intraprosthetic dislocation (IPD). Six IPD occurred during an attempt of closed reduction, and two IPDs occurred in relation to a fall (9 days

**Table 1** Patient demographics by cup fixation

Variables	Cemented DM, $n=415$	Cementless DM, $n=551$
Age at operation, years (SD; range)	81.6 (8.9; 42–104)	79.6 (10; 47.3–103.2)
Gender M, F	M 116, F 299	M 174, F 377
Follow-up years (SD; range)	6.4 (2.4; 1.6–12.6)	4.7 (2.3; 1.6–12.6)
Cup inclination (SD; range)	43.8 (7.3; 24.4–68)	42 (9.1; 15.3–69.4)
Cup version, (anteversion/retroversion)	389/9	506/30
DM implant		
Saturne	395	389
Avantage	20	162

DM dual mobility

**Fig. 1** Kaplan–Meier curves for time to first dislocation according to preoperative normal or impaired cognitive status. Follow-up is 100 days since all first time dislocations occurred within the first 63 days after index surgery



and 5 years after surgery). Mean days to IPD for seven of the eight IPD was 37.6 days (range 6–97). All IPD required open surgery with femoral head and liner replacement. IPD was not related to DM system type ( $p=0.66$ ).

Dislocation data are presented in Table 2.

### Cup revision

Eight (0.8%) of the 966 DM cups were revised (exchange of cup, femoral head and liner). Four revisions were due to aseptic loosening, three were due to repeated dislocations due to either retroverted cup ( $n=2$ ) or very steep inclination ( $n=1$ ), and one was due to septic loosening. Revision of the DM cup was not associated with the fixation type of cup

( $p=0.75$ ) or stem ( $p=0.91$ ). All aseptic or septic DM cup loosening sum up to 0.9% ( $n=9$ ) in this cohort.

### Reoperation, cup and stem

In total there were 2.7% ( $n=26$ ) hip related reoperations. Two DM cups were revised to Girdlestone due to aseptic cup loosening. Three patients sustained a fall-related acetabular fracture around the inserted DM cup post-operatively and were treated conservatively; one of these also had an IPD. Within all DM cup revisions and reoperations (IPD, infections, Girdlestone, dislocations), cup fixation was not associated with higher risk ( $p=0.32$ ), but cementless stem fixation was ( $p=0.018$ ). We observed post-operative deep infection in 1% ( $n=10$ ), and these

**Table 2** DM cup dislocation by various possible risk factors

Variables	Dislocation	No dislocation	<i>p</i> -value
Number of patients (range, dislocations)	45 (1–4)	918	
Time to dislocation, mean days (SD, range)	21 (16.3; 1–63)		
Age, mean (SD, range)	80.4 (10.8; 49–98)	80.5 (9.5; 42–104)	0.97
Gender (M/F)	10/35	280/641	0.24
Cognitive status (impaired/normal)	13/16	172/433	0.06
Stem fixation (cemented/cementless)	30/15	711/210	0.10
Cup fixation (cemented/cementless)	17/28	398/523	0.47
Inclination, degrees (SD, range)	45.6 (9.1; 31.7–67.2)	42.6 (8.4; 15.3–69.4)	0.04
Version (anteversion/retroversion)	35/10	860/29	<0.001
Surgeon (resident/consultant)	10/35	158/763	0.37
Cup revision	3	5	<0.001

patients were reoperated with either cup revision, cup reoperation or Girdlestone procedure. All THA-related complications are presented in Fig. 2.

In total there were 3.1% ( $n = 30$ ) stem-related stem reoperations. All stem fracture complications after primary DM THA were related to new fall events, and 24 periprosthetic stem fractures were operated with plate and wire-cable fixation. Six patients with stem loosening, of which five were aseptic and one septic, were all revised with a new stem. Nine patients were treated conservatively for post-operative stem complications. These were six trochanteric fractures, two periprosthetic stem fractures, and one stem subsidence. Cementless stem fixation was associated with a higher risk of conservative- and operative-treated stem complications ( $p = 0.002$ ).

### Other complications

We observed six pulmonary embolisms within the first 3 months after surgery. All occurred in patients with cemented cup and cemented stem fixation. Cemented cup fixation was associated with higher risk of pulmonary embolism ( $p = 0.03$ ), whereas cemented stem fixation was not ( $p = 0.18$ ). We observed one deep vein thrombosis, which was not associated with cup or stem fixation (respectively,  $p = 0.4$ ,  $p = 0.6$ ).

### Discussion

To our knowledge, this is the largest consecutive single cohort study to report dislocations and complications of DM in the treatment of FNF. We observed dislocations in 4.7% of DM cups (large articulation) at mean 5.4-year follow-up. Cognitive impairment showed a two times higher insignificant tendency toward higher dislocation risk compared to patients with no cognitive impairment.

A case-control series of 172 hips found significantly lower dislocation rate in DM THA (4.6%) compared to bipolar HA (14.6%) at mean follow-up of 25.3 months [25]. A study of 83 FNFs in patients older than 75 years treated with a DM cup (Avantage, Zimmer Biomet) reported dislocation rate of 4.4% at mean follow-up of 24 months. Of the 83 patients 50 (60%) suffered from at least one severe medical conditions such as Alzheimer's disease, dementia or chronic heart failure [26]. Tarasevicius compared two consecutive groups of FNF patients operated via posterior approach, 42 DM THA and 56 SM THA at mean age 75 and 74 years, respectively, and reported no dislocations at 1 year post-operatively in the DM THA group but eight dislocations in the SM THA group [27]. We show similar dislocation rate with DM THA, but at longer follow-up, and in an unselected cohort of FNF patients—that is mental status was not an exclusion criteria and HA was not used at all in our institution. Furthermore, the mean age at time of surgery is at least 5 years older in our study compared to Bensen

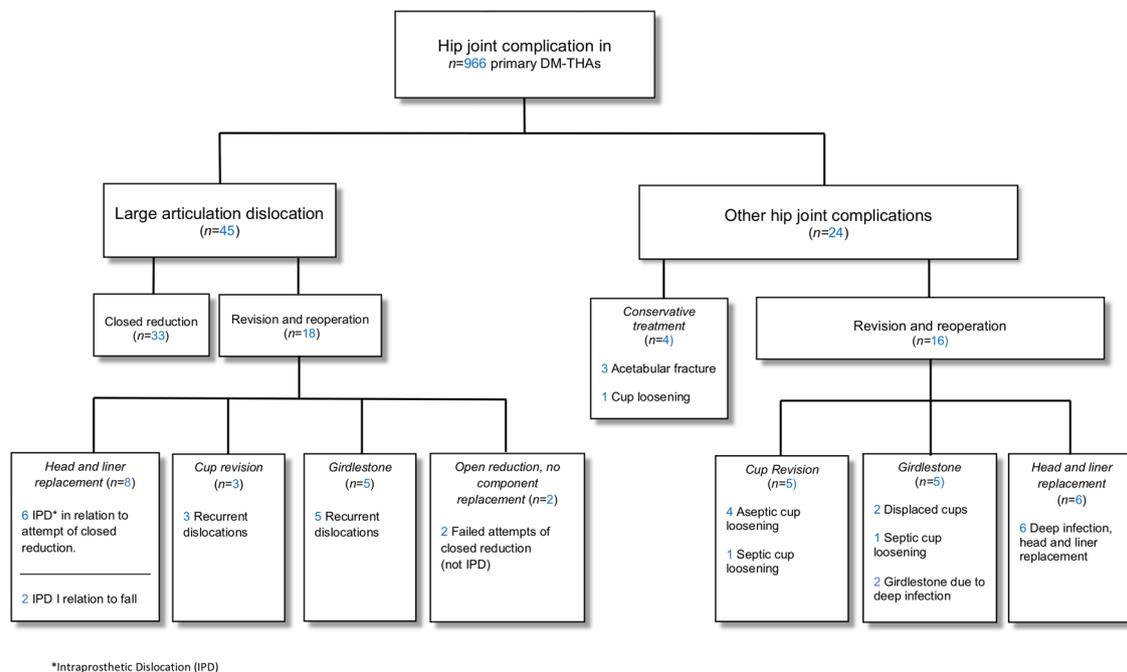


Fig. 2 All DM THA-related complications

et al. and Tarasevicius et al. [25, 27]. Anterior or direct lateral approach has lower reported dislocation rate in THA compared to the posterolateral approach [28, 29]. We only used the posterolateral approach, which is used in 96% of primary THA in Denmark, while others report a dislocation rate for a mix of surgical approaches with THA [30, 31]. Direct comparisons may, therefore, be troublesome. Furthermore, approximately 20% of the DM THAs in our series were inserted by supervised residents, but we found no association between surgeon's experience level and risk of dislocation.

The dislocation rates in FNF patients treated with conventional SM THA vary between 2–18% [8, 32–34], which on average is higher than in all reports of dislocations in DM THA. The reason is most likely that the DM THA design is forgiving on cup positioning and patient factors predisposing to dislocation. This is supported by the fact that we only found a modest average 3° higher inclination in the dislocation group, which is hardly of clinical significance. Although the mean of both our dislocation group (45°) and non-dislocation group (42°) was within the safe zones of cup position defined by Lewinnek et al., both groups had extreme cup inclination outliers between 32°–67° and 15°–69°, respectively.

However, the small inclination difference supports common findings that higher cup inclination increases dislocation risk [35]. We also found that retroversion of the cup was associated with higher dislocation risk, which is in line with a study that showed anteversion of less than 10° or even retroversion of the cup to result in higher risk of posterior dislocation [36]. However, the literature on cup placement is not definite, and the commonly referenced Lewinnek safe zones have been disproven in a recent (2017) systematic review on non-fracture SM THA [37]. Most likely, the dislocation safe zone for cup positioning in DM THA is more liberal than outlined by Lewinnek et al [38].

IPD is a consequence of failure of the retentive rim-locking abilities where the femoral head is linked in the small articulation in the liner. IPD may occur with excessive retentive rim (small articulation) and PE wear or in attempts of closed reduction of dislocation in the large DM articulation. IPD is a unique complication for the DM cup design and rates are reported to be between 0 and 5% of total DM procedures [39, 40]. In our cohort, we observed six IPD, 13.5% of the total number of dislocations, which mainly occurred in relation to closed reduction due to the “bottle-opener” effect described by De Martino et al. [40]. This early complication occurs iatrogenic when the outer PE liner engages the rim of the metal cup or pelvic bone prominence subsequently causing dissociation of the femoral head from the small articulation during a closed reduction maneuver. Focus and attention should be given when attempting to reduce a DM cup large-articulation dislocation, and appropriate sedation and muscle

relaxation or even neuroaxial anaesthesia had been advised when reducing large-articulation DM dislocations [40].

The first DM cup generation was associated with aseptic loosening and the original design by Bousquet had to be redesigned because of unacceptable revision rates due to acetabular component loosening [12, 39]. The newer DM cup designs have shown more reliability and are comparable to the survival of other well-documented THA systems [41, 42]. Although we did not assess cup migration, radiolucencies and osteolysis systematically in this study, we observed only eight symptomatic cup loosening (0.8%) that led to revision.

Studies have shown that cemented stem fixation is preferable in FNF patients compared to cementless fixation because of the lower incidence of complications such as periprosthetic fractures and superiority in terms of pain relief [43–45]. We view our findings of a strong association of stem complications in cementless stem fixation as supportive for the use of cemented stem fixation technique. A disadvantage of the cemented technique is the risk of cardiovascular complications during pressurized stem cementation [46]. Even though no fatal incidences occurred, all six perioperative embolic events in this study were exclusively associated with cemented stems.

In Denmark, the National Guideline for Hip Fracture Treatment aims at a mortality rate below 10% at 30 days after hip fracture in general (all types of fractures including FNF, intertrochanteric fractures, and subtrochanteric fractures) [47]. The mortality rate in the current study of only displaced FNF treated with DM THA was 9.2% at 30-day and 22.1% at 1-year follow-up. We find these rates comparable to international studies on mortality of all types of hip fractures where the 30-day mortality rates range between 7.3 and 13.3% [47].

One limitation of our study is the lack of a control group, i.e. a control group treated with HA. Several studies have reported good survival, lower mortality, lower reoperation rates and superior functional outcome when treating FNF patients with THA compared to HA [1, 6, 8]. The great concern is higher dislocation rates of THA compared to HA [7, 8]. In this study, we report low DM cup dislocation and revision rates, even lower compared to conventional SM THA when treating FNF patients and the authors believe that the DM cup design is warranted as a standard in the treatment of displaced FNFs.

In a short-term follow-up study, we reported function, health status and satisfaction in a subgroup investigation of 124 patients treated with DM THA for FNF between 2005 and 2011. Oxford Hip Score in the FNF patients was comparable to age- and gender-matched osteoarthritis patients operated at our institution with SM THA. Further, we found no difference in EQ-5D when FNF patients were age and gender matched to a large general population group.

Although we only had patient-reported outcome measures (PROM) and clinical follow-up of patients at sufficient health for an outpatient clinic follow-up, our findings suggest good functional results and quality of life in addition to high satisfaction in patients treated with DM THA [48].

The generalizability of the results from this consecutive unselected large cohort DM cup study in the general context of FNF management is probably very high, but multiple factors unrelated to the cup design, surgical approach and position also pose a risk for THA dislocation including patient factors such as cognitive and ambulatory abilities. We saw a two times of higher dislocation risk, although not statistically significant, in patients with cognitive impairment at the time of surgery—but the majority of patients with cognitive impairment had no hip dislocations. We observed several IPDs in relation to closed reduction of DM THA dislocations, which is a specific and severe complication related to the DM cup design that may lead to immediate open surgery intervention.

Although we believe that the DM THA concept is warranted in the treatment of FNF, future treatment plans might need to include more than one all-inclusive arthroplasty treatment arm. One possible solution could be a combination of THA and HA where patients that are either bedridden have low walking abilities or severe impaired cognitive function and are treated with a cemented HA, and all other patients with displaced FNF are treated with THA [4]. However, this may challenge the local organization as well as trauma surgeons who may have no experience with the technically more demanding THA procedure. Future high-quality prospective studies investigating several treatment arms are needed to evaluate arthroplasty treatment in the heterogenous FNF patient population.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** For this type of study formal consent is not required.

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