Low Rate of Dislocation of Dual-mobility Cups in Primary Total Hip Arthroplasty

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Abstract

Background Dual-mobility (DM) cups were introduced to minimize the risk of THA dislocation. The overall rate of dislocation of DM cups (including both large and small articulations) is controversial and ranges from 0% to 5% in previous studies.

Questions/purposes We therefore recorded (1) the dislocation rate, (2) loosening and osteolysis, and (3) subsequent related revisions with DM cups.

Methods Between 1998 and 2003, 2480 primary THAs with DM cups were undertaken in 2179 patients. The mean age was 69 years (range, 19–94 years). This group underwent specific clinical and radiographic evaluation at a minimum followup of 0.17 years (mean, 7 years; range, 0.17–11 years) to assess dislocation, reoperation, osteolysis, and cup fixation.

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Results There were 22 dislocations (0.88%): 15 dislocations of large articulations (0.6%), with two (0.08%) recurring but only one requiring revision (0.04%), and seven intraprosthetic small articulation dislocations (0.28%), all needing revision surgery. At last followup, mean Harris hip score was 91 (range, 60–100); 2439 cups (98%) showed no signs of loosening; and 141 patients (145 hips) had osteolysis (6%). Osteolysis and cup loosening were more frequent in patients younger than 50 years at the time of surgery. The 10-year survivorship considering revision for any reason was 93% (95% CI, 91%–95%).

Conclusions DM cups had a low dislocation rate in primary THA, with a limited frequency of adverse effects. We recommend DM cups to minimize dislocation in populations at high risk for instability, but they should be avoided in younger, active patients at higher risk for osteolysis.

Each author certifies that his institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

Dislocation of THA was the third leading cause of revision between 1979 and 2000 in the Swedish register [24] and the foremost cause of revision in the United States between 2005 and 2006 at 22% of 51,345 revisions [6]. The cost of a first dislocation represents 20% of that of primary THA at the Mayo Clinic, and the cost of revision due to dislocation is 150% [33]. Considering their cost and frequency, THA dislocations epitomize a public health problem.

Dual-mobility (DM) cups were designed to reduce the risk of THA dislocation based on the large-diameter head concept (Fig. 1). Theoretically, the design should reduce the risk of dislocation according to two principles: (1) the mobile insert should minimize prosthetic neck impingement over the polyethylene component and (2) the large articulation between the insert and the metallic shell should increase ROM before dislocation. The insert is mobile with respect to the metallic shell (large-diameter articulation) and captured and mobile with respect to the femoral head (small articulation with conventional 22.2- or 28-mm diameter) [14, 15, 31, 32, 36]. The design was introduced in 1975 but deployed mainly in the late 1990s [20, 29]. Despite wide dissemination, only a few studies [14, 15, 20, 29, 31, 32, 36] have reported its efficacy in reducing the risk of dislocation and possible adverse effects (namely, osteolysis and cup loosening) that may occur with this specific design in primary THA. Large-articulation dislocation rates are zero in most series of DM cups [14, 15, 21, 31, 32, 36] while other studies have reported a rate of 1.1% [20]. In contrast, the rate of intraprosthetic dislocation (small articulation) is higher, ranging from 0% to 5.2%, but is not considered as an instability event in most series [14, 15, 20, 21, 30–32, 36]. By summing large- and small-articulation dislocations, the rate of instability with DM cups appears to be controversial since only three series have recorded no instability [14, 21, 36] at followup ranging from 3 to 6 years, while other studies with longer followup (6–17 years) have reported 1.8% to 5.2% [15, 20, 31, 32], which is not different from dislocation rates with conventional fixed polyethylene [3, 6, 7]. Similarly, the rate of adverse effects that could be related to DM design (osteolysis, cup loosening) is controversial, ranging from 0% to 12% [14, 20, 31].

We therefore recorded (1) the dislocation rate, (2) osteolysis and loosening, and (3) subsequent related revisions with DM cups in primary arthroplasty in a large population.

Fig. 1 The principle of the DM cup is shown. The mobile polyethylene insert is not constrained in the metallic shell constituting the large articulation. It is clipped over the femoral head (22- or 28-mm diameter) constituting the small articulation. Squared arrows indicate rim location, and a sectional image (insert), with the same arrows, reproduces polyethylene rim capture of the femoral head.

Patients and Methods

From 1998 to 2003, 15 centers treated 3070 patients with 3474 primary THAs using DM cups. During the study period, one center exclusively implanted DM cups in a total of 1265 primary THAs (1183 patients). All other centers selected DM cups in hips at risk of dislocation, representing 2209 hips (1887 patients). In these 14 centers, DM cups embodied a mean of 6% (range, 2%–18%) of the primary THAs performed during the study period with the following indications: (1) patients older than 70 years, (2) neurologic disease impairing locomotion (Parkinson's disease, hemiplegia), and (3) cognitive impairment (Alzheimer's disease, dementia, etc). There were 1780 women and 1290 men, with a mean age of 70 ± 10 years (range, 16–95 years) (Table 1). Four hundred four patients underwent bilateral procedures. Mean BMI was 24 (range, 13–46); 392 patients (13%) were obese (BMI > 30 kg/m²). The initial diagnosis was primary osteoarthritis in 2694 hips (77%), femoral head osteonecrosis in 396 hips (11%), arthrosis secondary to childhood disease (dysplasia, Legg-Calvé-Perthes disease, slipped capital femoral epiphysis) in 264 hips (8%), and other conditions (inflammatory arthritis, postinfection, Paget's disease, THA after hip fusion, post-trauma) in 120 hips (3%). One hundred eighty-nine hips (5%) had undergone surgery previously. Two hundred sixty-five patients (9%) had neurologic dysfunction (motor and/or cognitive impairment). The 3070 patients were reviewed retrospectively in 2009. Of the initial group, 398 patients (470 hips) died (at a mean 2.2 years after surgery [range, 17 days to 6 years]) and 493 others (524 hips)

Table 1. Demographic data on total cohort of patients with dual-mobility cup arthroplasties (3070 patients) and those assessed at followup (2179 patients)

Variable	Total cohort	Assessed at followup
Number of patients/hips	3070/3474	2179/2480
Sex (female/male) (number of patients)	1780 (58%)/1290 (42%)	1286 (59%)/893 (41%)
Bilateral procedures (number of patients)	404 (13%)	301 (14%)
Followup (years)*	7 ± 1.6 (0.17–11)	7 ± 1.7 (0.17–11)
Age (years)*	70 ± 10 (16–95)	69 ± 10 (19–94)
BMI*	24 ± 4 (13–46)	26 ± 4 (13–46)
Neurologic disease (number of patients)	265 (9%)	171 (8%)
Number of hips with previous surgery	189 (5%)	135 (5%)

* Values are expressed as means ± SD, with range in parentheses.

were lost to followup (at a mean 2.4 years after surgery [range, 2 months to 4 years]), leaving 2179 patients (2480 hips) available for the current study (Table 1). Minimum followup was 0.17 years (mean, 7 years; median, 6.6 years; range, 0.17–11 years) including revisions performed within 5 years of followup and 5 years (mean, 7 years; range, 5–11 years) excluding revisions (Table 1). All patients were recalled specifically for this study, and 2179 patients (2480 hips) underwent clinical and radiographic assessment in 2009.

All patients received hemispherical DM cups. Nine types of DM cups were implanted: 1491 NovaeTM (porous coating of bilayer alumina and hydroxyapatite on stainless steel) (Serf, Décines, France), 10 AdvantageTM (porous coating of hydroxyapatite on stainless steel) (Biomet, Valence, France), 119 CollegiaTM (porous coating of hydroxyapatite on cobalt-chromium) (Cremascoli-Wright, Paris, France), 137 EOLTM (porous coating of hydroxyapatite and titanium spray on stainless steel) (Norton-Ceramconcept, Paris, France), 756 GyrosTM (porous coating of hydroxyapatite on stainless steel) (DePuy, St Priest, France), 102 TregorTM (porous coating of hydroxyapatite and titanium spray on cobalt-chromium) (Aston, St Etienne, France), 495 PolarcupTM (porous coating of hydroxyapatite and titanium spray on stainless steel) (Endoplus, Courbevoie, France), 166 SaturneTM (porous coating of hydroxyapatite and titanium spray on stainless steel) (Amplitude, Valence, France), and 198 EvoraTM (porous coating of hydroxyapatite on cobalt-chromium) (Science et Médecine, Créteil, France). All of these implants consisted of a metallic shell (3 mm thick), including a mobile polyethylene insert (articulated with the metallic shell) (Fig. 1). According to the manufacturers, four designs (EOLTM, EvoraTM, PolarcupTM, and TregorTM) have self-centering constructs by moving inside the center of rotation of the small articulation with respect to the center of the large articulation. We were unable to obtain accurate specifications from the manufacturers regarding

these designs (distance between the centers of rotation, variations according to the diameter of the small and large articulations, etc). The polyethylene insert was hemispherical, of ultrahigh molecular weight (not crosslinked), sterilized under vacuum, and variable in thickness but always 6 mm or more (depending on cup and femoral head diameters). The diameter of the small articulation was 22 mm in 1372 hips, 28 mm in 2018 hips, and unknown in 84 hips. The insert was articulated with the femoral head after it was impacted by force over a polyethylene rim designed for retention (Fig. 1). The metallic shell was made of stainless steel (n = 3055, 87%) or cobalt-chromium (n = 419, 13%).

The surgical approach was posterolateral in 2452 hips (70.6%), direct lateral in 1013 hips (29.2%), and lateral with trochanteric osteotomy in nine hips (0.2%). The bearing couples were metal/polyethylene in 1638 hips (47%) and ceramic/polyethylene in 1836 hips (53%). Four types of femoral stems were implanted: 1152 stems (33%) were cemented, 2110 (61%) were cementless with hydroxyapatite coating, 127 (3.6%) were cementless with alumina powder coating, and 85 (2.4%) were rough-blasted cementless titanium stems. Cup fixation was cementless in 3368 (97%) cups, while 106 (3%) cups were cemented because of insufficient primary fixation. Cementless fixation was achieved with porous hydroxyapatite coating in 3368 hips (applied on a titanium plasma layer or alumina layer), with press fit alone in 1011 (30%), additional pins in 1246 (37%), and screws plus pins in 1111 (33%). Bulk autologous bone grafting was undertaken in 292 hips (8.4%) to correct acetabular bone deficiency.

Full weightbearing was permitted the day after surgery in 3421 hips (98%) but not for 53 of 292 hips that had acetabular bone grafting; these hips were allowed full weightbearing 6 weeks after the index procedure.

One observer was selected at each of the 15 study centers to assess patients according to the same criteria; none of the observers participated in surgery, and all of

them were required to evaluate patients in their corresponding center in 2009. The data at followup were compared with a local database including postoperative and intermediate followup, which were different among centers (at least a survey was performed every 2 years). Clinical evaluation was conducted according to the Merle d'Aubigné hip score [27] and the Harris hip score [16]. Level of activity was assessed according to Devane et al. [9]. In addition, because of large-diameter articulations, the observers looked for iliopsoas irritation at followup examination (for each patient reporting pain, it was asked whether it occurred on hip flexion in the supine position). The dislocation rate (with large articulations) was recorded from the medical charts and during the specific evaluation in 2009. The intraprosthetic dislocation rate was recorded in the same manner. Intraprosthetic dislocation is a specific complication of DM cups (Fig. 2). The head extracts from the polyethylene, indicating retention failure between the head and polyethylene in small articulations.

Radiographs (AP pelvis) were taken at followup and assessed by the single observer conducting the clinical examination. We compared immediate postoperative radiographs with intermediate radiographs and radiographs at last followup to evaluate cup fixation according to Massin et al. [25] (cup loosening was diagnosed if cup migration exceeded 5 mm or 5° in any direction) and to look for osteolysis, defined as a new or expanding darkened

area in which no trabeculae were visible adjacent to the cup or the stem. When identified, periprosthetic osteolytic lesions were described according to DeLee and Charnley [8] for the acetabulum and Gruen et al. [13] for the femur. We did not perform a complementary study to measure interobserver variability in assessing cup fixation and osteolysis. To limit errors in defining loosening, we considered signs of definitive cup migration [25], avoiding those with low reliability, such as radiolucencies and their progression. We are aware that detection of osteolysis is greatly variable on plain radiographs (kappa agreement ranging from 0.28 to 0.44) but is improved when using consecutive series of radiographs as in the current study (kappa agreement ranging from 0.39 to 0.63) [10]. The cup inclination angle was measured with respect to the horizontal line joining the teardrops on AP views [17], which is the most accurate method on plain radiographs [17, 25].

Categorical variables (sex, dislocation, osteolysis, cup fixation, reoperation, indication of THA, Devane activity score, previous hip surgery, neurologic dysfunction, diameter of the small articulation) were expressed as frequency and percentage, and numerical variables (age, BMI, cup inclination, functional score) as mean $\pm$ SD and range. Several variables had missing values, namely, osteolysis (103 missing, 4%), BMI (433 missing, 17%), cup inclination (468 missing, 19%), diameter of the small articulation (40 missing, 2%) and Devane activity score (71 missing, 3%). We did not use a specific method to handle missing data. That was decided because the missing values did not affect major variables except for osteolysis (which had a limited number of missing data) and because we did not perform multivariable analyses. We measured differences in dislocation, osteolysis, and cup loosening rates according to sex, indication of THA, former hip surgery, surgical approach, diameter of the small articulation, and neurologic dysfunction using the chi-square test or Fisher's exact test. Likewise, differences in dislocation, osteolysis, and cup loosening rates relating to age, BMI, and cup inclination were assessed using the unpaired Wilcoxon test. Regarding age at DM cups insertion, the cohort was divided into three subgroups (< 50 years, $\geq$ 50 and < 70 years, and $\geq$ 70 years), and the relationships between this categorical variable and the occurrence of osteolysis and cup loosening were investigated using the chi-square test or Fisher's exact test. In addition, we compared the followup of patients with osteolysis versus those without osteolysis and age at surgery according to indication of THA using the unpaired Wilcoxon test. The evolution of functional scores from preoperative to followup was analyzed using the paired Wilcoxon test. Survival functions (with 95% CIs) were estimated using the Kaplan-Meier method with three types of end points: (1) cup revision for any reason, (2) dislocation of the large or small articulations, and

Fig. 2 Intraprosthetic dislocation occurred at 4 years of followup in the small articulation, requiring revision involving polyethylene insert exchange.

(3) cup revision for loosening. We performed statistical analysis with SAS[®] Version 9.2 (SAS Institute, Inc, Cary, NC, USA).

Results

There were 22 dislocations among 2480 hips (0.88%): 15 dislocations of the large articulation (0.6%) and seven intraprosthetic dislocations of the small articulation (0.28%). Among the 15 large-articulation dislocations (0.6%), only one was revised for recurrent dislocation (0.04%). Twelve large-articulation dislocations (0.48%) occurred within 3 months after the index procedure and did not recur. Three large-articulation dislocations occurred beyond 3 months after insertion: two (0.08%) recurred (one hip had one recurrence, and one hip had two recurrences, leading to the previously mentioned revision to correct cup malposition with a new DM cup and without recurrence) and the third one occurred at 6 years after insertion without recurrence. The large-articulation dislocation rate was not different according to the variables tested, except in cases of previous hip surgery ($p = 0.01$) (Table 2). Furthermore, the large-articulation dislocation rate was not different if the surgery was performed through a posterolateral versus a direct lateral approach ($p = 0.08$) (Table 2). Seven intraprosthetic dislocations (0.28%) (Fig. 2) occurred after a mean of 84 months (range, 32–138 months) in five women and two men, with a mean age of 60 years (range, 44–80 years). The small-articulation dislocation rate was not different according to the variables tested, with the exception of age, as patients who had intraprosthetic dislocation were younger ($p = 0.005$) and when the small articulation diameter was 22 mm ($p = 0.01$) (Table 3). Intraprosthetic dislocations were revised with polyethylene insert exchange in four hips (four emergency revisions) and cup revision in three remaining hips presenting damage to the articular surface of the metallic shell because of prolonged contact with the femoral head. In summary, eight hips (0.32%) were reoperated on due to dislocation, combining large and small articulations.

Osteolysis was identified on sequential radiographs in 145 hips (6%): acetabular osteolysis in 91 hips (3.8%), femoral osteolysis in 78 hips (3.2%), and combined femoral and acetabular osteolysis in 24 hips (1%) (Table 4). The osteolysis rate was not different according to the tested variables except when DM cups were inserted in younger patients, particularly those younger than 50 years (13%) ($p < 0.001$) (Fig. 3), and in cases of arthrosis secondary to childhood disease (14%) ($p < 0.001$) (Table 5). Mean followup after surgery was comparable, whether osteolysis occurred (6.8 ± 1.7 years; range, 0.2–11 years) or not (6.9 ± 1.9 years; range, 0.17–11 years) ($p = 0.8$). On

radiographs, 2439 cups (98%) appeared to be well fixed. Thirty-one cups were revised due to loosening after a mean followup of 6 ± 2 years (range, 1.5–10 years). The cup loosening rate was not different according to the variables tested except when DM cups were inserted in patients younger than 50 years (5%) ($p = 0.005$) and in cases of arthrosis secondary to childhood disease (5%) ($p < 0.001$) (Table 5).

The 10-year survival rates were 93% (95% CI, 91%–95%) with revision for any reason, 98% (95% CI, 97%–99%) with dislocation of the large or small articulations, and 97% (95% CI, 94%–98%) with revision due to cup loosening as end points (Fig. 4). The mean Harris hip score increased ($p < 0.001$) from 39 ± 15 (range, 0–85) preoperatively to 91 ± 11 (range, 60–100) at latest followup. The mean Merle d'Aubigné functional score rose ($p < 0.001$) from 10 ± 2 (range, 0–17) to 17 ± 2 (range, 4–18). At latest followup, 2314 hips (93%) had no pain or rare and mild pain. Fifty-three hips (2%) had isolated anterior pain on hip flexion in the supine position, which suggested clinical iliopsoas irritation. Among these 53 hips, 30 hips had Harris hip scores of 40 points, 16 hips 30 points, and seven hips 20 points, indicating no hips had severe pain. Five revisions were performed with cup exchange for anterior pain. According to the Devane score, patients were moderately active, with nine (0.4%) rated as Grade V, 81 (3.6%) as Grade IV, 451 (21%) as Grade III, 1233 (57%) as Grade II, and 405 (18%) as Grade I.

Discussion

DM cups of mobile polyethylene were introduced in 1975 to reduce the risk of THA dislocation. Most series of DM cups encountered no large-articulation dislocation [14, 15, 21, 31, 32, 36], while others report about 1% [20] (Table 6). Most of these series comprised a limited number of patients, which may underestimate the occurrence of dislocation, a very rare event with DM cups [29, 31, 32]. Furthermore, all of these series did not consider intraprosthetic dislocations as accidents of instability, although they were more frequent, ranging from 0% to 5.2% [14, 30, 32]. When summing instability of the small and large articulations, the rate of dislocation of DM cups in primary THA appears to be controversial, ranging from 0% to 5.2%, close to the rate in conventional THA with fixed polyethylene [3, 6, 7]. In addition, there is no clear identification of the factors favoring instability (large and small articulations) [22, 30]. DM cups are suspected to produce higher rates of loosening and osteolysis relating to constrained-mobile polyethylene, but their frequencies are not well established [20, 32]. To address these controversies, we recorded (1) the dislocation rate, (2) osteolysis and

Table 2. Comparison of characteristics of 2480 hips in 2179 patients who did or did not have large-articulation dislocations

Variable	Dislocation (n = 15)	No dislocation (n = 2465)	p Value
Sex (female/male) (number of hips)	7 (47%)/8 (53%)	1316 (53%)/1149 (47%)	0.89
Age (years)*	69 ± 16 (42–89)	69 ± 10 (19–94)	0.62
BMI*	28 ± 3 (13–46)	26 ± 4 (13–46)	0.12
Etiology (number of hips)			0.10
Primary arthrosis	10 (66%)	1944 (79%)	
Arthrosis secondary to childhood disease	1 (7%)	195 (8%)	
Femoral head necrosis	4 (27%)	236 (10%)	
Miscellaneous	0	90 (3%)	
Neurologic impairment (number of hips)	1 (7%)	170 (7%)	0.61
Previous surgery (number of hips)	3 (20%)	132 (5%)	0.01
Surgical approach (posterolateral/lateral) (number of hips)	14 (93%)/1 (7%)	1744 (70%)/721 (30%)	0.08
Diameter of the small articulation (22 mm/28 mm) [†]	5 (0.5%)/10 (0.7%)	951 (99.5%)/1474 (99.3%)	0.79

* Values are expressed as means ± SD, with range in parentheses; [†]diameter of the small articulation was unknown in 40 hips.

Table 3. Comparison of the characteristics of 2480 hips in 2179 patients who did or did not have intraprosthetic small-articulation dislocations

Variable	Dislocation (n = 7)	No dislocation (n = 2473)	p Value
Sex (female/male) (number of hips)	5 (71%)/2(19%)	1317 (53%)/1156 (47%)	0.2
Age (years)*	56 ± 11 (44–73)	69 ± 10 (19–94)	0.005
BMI*	31 ± 5 (25–37)	26 ± 4 (13–46)	0.07
Etiology (number of hips)			0.6
Primary arthrosis	6 (86%)	1948 (79%)	
Arthrosis secondary to childhood disease	0	196 (8%)	
Femoral head necrosis	1 (14%)	239 (10%)	
Miscellaneous	0	90 (4%)	
Neurologic impairment (number of hips)	0	171	1
Previous surgery (number of hips)	1 (14%)	134 (5%)	0.4
Surgical approach (posterolateral/lateral) (number of hips)	6 (86%)/1 (14%)	1752 (71%)/721 (29%)	0.6
Diameter of the small articulation (22 mm/28 mm) [†]	6 (0.6%)/1 (0.1%)	950 (99.4%)/1483 (99.9%)	0.01

* Values are expressed as means ± SD, with range in parentheses; [†]diameter of the small articulation was unknown in 40 hips.

loosening, and (3) subsequent related revisions with DM cups in primary arthroplasty in a large population similar to those currently reported in national registers.

Our study had several limitations. First, owing to the retrospective design, some variables had missing values. However, due to the recall assessment of all patients in 2009, there were few missing values and none of the major ones was affected (except osteolysis with 4% missing values from 2480 hips). Second, the indications for DM cups were not homogeneous between centers. However, the center nonselectively implanting DM cups had the opportunity to obtain a large cohort, while the 14 others centers using these cups in hips at higher risk of dislocation highlighted the effect of DM cups to minimize instability. Third, in relation to the multicenter design, different approaches were taken by different surgeons, and

DM cup designs were different. While we could not obtain accurate specifications from the manufacturers regarding the variations in self-centering mechanisms with four of the designs (EOL™, Evora™, Polarcup™, and Tregor™), we do not believe the self-centering design had an influence on whether a dislocation occurred at the small or large articulations. This issue does not jeopardize our conclusions since the study was designed to reflect the effect of DM cups in average clinical practice and not merely to assess expert surgeons in high-volume centers. Moreover, regarding the heterogeneity of DM cup design, the main goal was to measure the dislocation rate, and from that point of view, only one design (ie, the DM cup) was evaluated. Fourth, we had no control group of patients treated with alternative implants. However, we had a large population of THAs (including patients at risk of

Table 4. Radiographic results at followup in 2179 patients (2480 hips)

Variable	Number of hips
Cup fixation	
Well-fixed cups	2439 (98%)
Revised	31 (1.3%)
Not revised	10 (0.4%)
Osteolysis	145 (5.8%)
Periacetabular	91 (3.7%)
	22 (0.9%) in 3 zones
	20 (0.8%) in 2 zones
	49 (2%) in 1 zone
Femoral	78 (3.1%)
	51 (2%) in 1 zone
	(49 in Zone 1 or 7)
	14 (0.6%) in 2 zones
	(10 in Zones 1 and 7)
	10 (0.4%) in 3 zones
	3 (0.1%) in 4 or more zones
Periacetabular + femoral	24 (1%)

Fig. 3 Occurrence of osteolysis (acetabular and femoral [n =145]) was related to age at surgery: younger patients had a higher osteolysis rate.

dislocation, such as older patients, obese patients, and patients with neuromuscular impairment). Fifth, we lost 15% of the patients to followup. Nevertheless, most lost patients had at least 2-year followup, which should have allowed detection of most dislocations since most (12 of 15 in this series) occurred within 3 months after the index procedure. Furthermore, we knew the status of 84% of patients in a large series, and 95% CI of survival analysis gave us the opportunity to forecast the worst-case

scenario with the lowest interval. Sixth, osteolysis was detected by plain radiographs with possible underestimation. However, all patients underwent sequential radiographs after the index procedures, which allowed better recognition of osteolytic lesions [10]. Finally, as our mean followup did not reach 10 years, we may underestimate the long-term adverse effects of DM cups. However, several series of DM cups with followup of more than 10 or 15 years [20, 29, 31, 32] have not reported an increase in late dislocation or mechanical complications, such as loosening or osteolysis.

The main result of this large cohort was a low large-articulation dislocation rate (0.6%) (0.88% summing both articulations) that was below the rates reported with conventional THA with fixed polyethylene (ranging from 1.8% to 2.9% at 5 to 10 years' followup) [3, 18, 26, 33]. Compared to other series of DM cups, our larger population indicated the actual large-articulation dislocation previously considered to be zero [14, 15, 21, 31, 36]. Moreover, our series underlined that large-articulation dislocations were more frequent in cases of previous surgery, which should alert surgeons implanting DM cups in this situation. Intraprosthetic dislocation is a specific complication of DM cups [15, 22, 32], with incidences ranging from 0% to 5.2% [15, 32], which are supposed to decrease with modern designs [30]. Intraprosthetic dislocations occur after wear, and failure of small-articulation retention over the femoral head should be prevented with smooth head-neck junctions [15, 22, 30]. Our series reporting 0.28% was in line with the literature but reached a higher frequency when DM cups were implanted in younger patients and when using 22 mm as bearing diameter of the small articulation, underlining that this design should be considered with caution in young and active patients. Finally, this large series confirmed DM cups were efficient in reducing THA dislocations in patients at risk since the instability rate was not different in case of obesity or neurologic or cognitive impairment.

We observed osteolysis in 7% and cup loosening in 1.7% at a mean followup of 7 years, which was consistent with rates obtained with THA using fixed noncrosslinked polyethylene inserts [7, 8, 11]. Some series of DM cups recorded osteolysis rates of 9% to 38% [15, 20, 29, 32] but usually limited to the calcar. Likewise, based on a large population, our study confirmed a cup-loosening rate in line with the literature reporting rates of 0% to 12% in DM cup series [20, 31, 32, 36]. In contrast to these DM cup series, we found a higher rate of osteolysis and cup loosening in younger patients and in cases of childhood disease sequelae. These issues were suspected previously [20], but our study confirmed the data and brings to the orthopaedic knowledge two major limits to the use of DM cups. Osteolysis is mainly related to polyethylene wear,

Table 5. Osteolysis and cup fixation related to the indication of hip arthroplasty in 2179 patients (2480 hips)

Variable	Primary osteoarthritis (n = 1954)	Necrosis of the femoral head (n = 240)	Arthrosis secondary to childhood disease (n = 196)	Other diagnosis (n = 90)	p Value
Osteolysis (n = 145) (number of hips)	102 (5%)	10 (4%)	27 (14%) [†]	6 (7%)	< 0.001
Acetabular osteolysis (n = 91) (number of hips)	63 (3%)	6 (2%)	18 (9%) [†]	4 (4%)	0.005
Well-fixed cup (n = 2439) (number of hips)	1930 (99%)	235 (98%)	186 (95%) [†]	88 (98%)	< 0.001
Cup loosening (n = 41) (number of hips)	24 (1%)	5 (2%)	10 (5%) [†]	2 (2%)	
Age at surgery (years)*	71 ± 8 (37–94)	62 ± 15 ^{†,‡} (19–94)	60 ± 12 ^{†,‡} (24–80)	65 ± 14 (21–88)	< 0.001

* Values are expressed as means ± SD, with range in parentheses; [†]group with significant difference; [‡]no significant difference between these two groups.

Fig. 4 A graph shows the survival distribution function (95% CI) for the DM cups. The 10-year survival rate, considering dislocation of the large or small articulations, was 98% (95% CI, 97%–99%).

which is comparable for DM cups and cups with fixed noncrosslinked polyethylene [1, 34]. Our study is limited to conventional polyethylene, and to our knowledge, no clinical data on crosslinked polyethylene in DM cups are available, although it is supposed to decrease wear and osteolysis [28] and allows use of large-diameter heads to decrease instability [12].

Ten-year survival was 93% with all revisions included and 96% considering cup revision for mechanical failure or polyethylene exchange as the end point. These results are comparable to those recorded in registries using conventionally fixed polyethylene (ranging from 87% to 93% [24, 35]) and to previous series of DM cups (ranging from 88 to 100% at 6 to 16 years' followup [20, 21]). Our functional results are comparable with those of conventionally fixed,

cementless polyethylene components [23, 24]. Considering DM cups behave like large-diameter head THAs, groin pain could be a possible adverse effect [2, 19, 21]. In fact, our rate was 2%, far below the rates with large-diameter heads and hip resurfacing [4, 5].

Based on our findings, we recommend DM cups to reduce the frequency of dislocation, particularly in patients at high risk. We do not believe they should be used in active patients younger than 50 years, owing to the long-term risk of osteolysis, loosening, and intraprosthetic dislocation. In contrast, DM cups may be advocated in patients younger than 50 years with neuromuscular impairment (Parkinson's disease, dementia, palsy), who are at high risk of dislocation but usually have a low activity level and low risk of osteolysis.

Table 6. Reports of series related to dual-mobility cups in primary THA

Study	Number of hips	Mean followup (years)	Dislocation (large articulations) (%)	Intraprosthetic dislocation (small articulations) (%)	Overall dislocation rate (small + large articulations) (%)	Cup loosening (%)	Survival (%)
Guyen et al. [14]	167	3	0	0	0	0	
Hamadouche et al. [15]	168	6	0	2.4	2.4	0	94.2
Lautridou et al. [20]	437	16.5	1.1	0.7	1.8	12	88.4
Leclercq et al. [21]	175	6	0	0	0	0	100
Philippot et al. [29]	106	10	0	1.9	1.9	1.9	94.6
Philippot et al. [30]	1960	9*		4.1	4.1		
Philippot et al. [31]	384	15.3	0	3.6	3.6	3.3	94.6
Philippot et al. [32]	438	17	0	5.2	5.2	3	89.2
Vielpeau et al. [36]	231	5.2	0	0	0	9	
Current study	2480	7	0.6	0.28	0.88	1.7	95.8

* Mean followup of intraprosthetic dislocation.

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