

Does dual mobility cup reduce revision risk in femoral neck fractures compared to conventional THA designs? An international meta-analysis of arthroplasty registries

Running title: Dual mobility versus Conventional THA for Hip Fracture

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JEF, SA, IAH: This study was supported by the Australian Orthopaedic Association Research Foundation. MRW: This study was supported by the NIHR Biomedical Research Centre at University Hospitals Bristol and Weston NHS Foundation Trust and the University of Bristol.

The institution of one or more of the authors (JEF, SA, IAH) has received, during the study period, funding from the Australian Orthopaedic Association Research Foundation. Additionally, the institution of a separate author (MRW) has received, during the study period, funding from the NIHR Biomedical Research Centre at University Hospitals Bristol and Weston NHS Foundation Trust and the University of Bristol

All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research*[®] editors and board members are on file with the publication and can be viewed on request.

1
2 Ethical approval for this study. Each author certifies that his or her institution approved the
3 human protocol for this investigation and that all investigations were conducted in conformity
4 with ethical principles of research. AOANJRR - provided by the Commonwealth of Australia as
5 a federal quality-assurance activity under section 124X of the Health Insurance Act, 1973. NJR –
6 NHS Research Authority (19/YH/0231). SAR (Dnr 2019-06202). LROI - collected as part of
7 usual care and with the intention to improve quality of care. Therefore, ethical approval is not
8 requested. DHR – Danish Protection Agency (20/51164). KP HFR – KP IRB (6375).

This work was performed at the Australian Orthopaedic Association National Joint Replacement Registry, based at the South Australian Health and Medical Research Institute, Adelaide, South Australia.

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9 **Abstract**

10 *Background* Dual mobility cups in THA were designed to reduce prosthesis instability and the
11 subsequent risk of revision surgery in high-risk patients, such as those with hip fractures.

12 However, there are limited data from clinical studies reporting a revision benefit to dual mobility
13 over conventional THA. Collaboration between arthroplasty registries provides an opportunity to
14 describe international practice variations and compare between-country all-cause revision rates
15 for dual mobility and conventional THA.

16 *Questions/purposes* We summarized observational data from multiple arthroplasty registries for
17 patients receiving either a dual mobility or conventional THA to ask: (1) Is dual mobility use
18 associated with a difference in risk of all-cause revision surgery compared to conventional THA?
19 (2) Are there specific patient characteristics associated with dual mobility use in the hip fracture
20 population? (3) Has the use of dual mobility constructs changed over time in patients receiving a
21 THA for hip fracture?

22 *Methods* Six member registries of the International Society of Arthroplasty Registries (from
23 Australia, Denmark, Sweden, the Netherlands, the United Kingdom, and the United States)
24 provided custom aggregate data reports stratified by acetabular cup type (dual mobility or
25 conventional THA) in primary THA for hip fracture between January 1, 2002, and December 31,
26 2019; surgical approach; and patient demographic data (sex, mean age, American Society of
27 Anesthesiologists class, and BMI). The cumulative percent revision and mortality were
28 calculated for each registry. To determine a global hazard ratio of all-cause revision for dual
29 mobility compared to conventional THA designs, we used a pseudo-individual patient data
30 approach to pool Kaplan-Meier prosthesis revision data from each registry and perform a meta-

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31 analysis. The pseudo-IPD approach is a validated technique for meta-analysis of aggregate time-
32 to-event survival data, such as revision surgery, from multiple sources. Data were available for
33 15,024 dual mobility THAs and 97,200 conventional THAs performed for hip fractures during
34 the study period.

35 *Results* The proportion of dual mobility in each registry used to treat hip fractures increased in
36 each registry over time, and constituted 20.5% (2438/11,874) of all THA procedures in 2019. In
37 the majority of registries, a greater proportion of dual mobility THA patients were older, more
38 comorbid, and received a posterior approach compared to conventional THA ($p < 0.001$). After
39 pooling of complete KM survival data from all 6 registries, the cumulative percent revision for
40 conventional THA was 4.3% (95%CI, 4.2-4.5%) and 4.7% (95%CI, 4.3-5.3%) for dual mobility
41 THA at 5 years. After adjusting for between registry differences, we did not demonstrate a lower
42 risk of all-cause revision for patients receiving dual mobility over conventional THA designs for
43 hip fracture in the meta-analysis (hazard ratio 0.95; 95% CI 0.86-1.06). A lower proportion of
44 dual-mobility procedures were revised for dislocation than conventional THAs were (1.1%
45 versus 1.4%) but a higher proportion were revised for infection (1.2% versus 0.8%).

46 *Conclusions* The proportion of dual mobility use in patients with hip fractures increased over
47 time, but there was large variation in use across countries represented here. Dual mobility cups
48 were not associated with a reduction in the overall risk of revision surgery in hip fracture
49 patients. A randomized controlled trial powered to detect the incidence of dislocation and
50 subsequent revision surgery is required to clarify the efficacy of dual mobility cups to treat hip
51 fractures.

52 *Level of Evidence* Level III, therapeutic study

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53 **Introduction**

54 Hip fractures are a substantial source of global morbidity and healthcare expenditure [59].

55 Arthroplasty, which involves either complete or partial replacement of the hip, is recommended

56 over internal fixation for displaced intracapsular hip fractures, and it offers satisfactory hip

57 function and a low risk of revision surgery at long-term follow-up [10]. Hip fracture practice

58 guidelines advocate THA rather than hemiarthroplasty for patients who are independently mobile

59 and have minimal comorbidities before injury [1, 3, 49]. However, dislocation is a risk after

60 THA in the setting of fracture, occurs up to 10 times more commonly than patients undergoing

61 elective THA for osteoarthritis, and represents the most common reason for revision surgery

62 within 5 years for hip fracture patients receiving THA [2, 6, 19, 20, 29, 48, 53, 57].

63 Dual mobility cup total hip arthroplasty has been proposed as an alternative to conventional THA

64 in the hip fracture population to reduce the risk of dislocation, ostensibly garnering the stability

65 benefits of a large-bearing femoral head design that increases the vertical jump distance to

66 dislocation compared to conventional THA [26]. However, these potential benefits come with a

67 higher implant cost compared to conventional THA [7], involve the possibility of increased

68 polyethylene wear [39], as well as intra-prosthetic dislocation [17]. In the absence of randomized

69 controlled trials, observational data supporting the use of dual mobility suggest a moderately

70 reduced risk of revision for dislocation, but only a small reduction in the risk of all-cause

71 revision [11, 36]. Retrospective studies directly comparing dual mobility and conventional THA

72 estimate there is a greater reduction in the risk of revision, but these studies are limited by

73 inadequate follow-up for the outcomes of interest and a moderate-to-high risk of bias [45, 54, 62,

74 63]. Surgical registries are a potent resource for assessing temporal trends in surgical practice,

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75 tracking performance of implants, and demonstrating variations in standards of practice from
76 country to country. Additional benefits include reduced risk of bias in terms of loss to follow-up
77 for important outcomes such as revision surgery, especially in populations with high mortality,
78 such as the hip fracture population.

79 We therefore summarized observational data from multiple arthroplasty registries to ask: (1) Is
80 dual mobility use associated with a difference in risk of revision surgery (all cause or by
81 indication) compared to conventional THA? (2) Are there specific patient characteristics
82 associated with dual mobility use? (3) Has the use of dual mobility constructs changed over time
83 in patients receiving a THA for hip fracture?

84 **Patients and Methods**

85 We performed a systematic review and meta-analysis of arthroplasty and hip fracture registry
86 data, consisting of routinely collected observational data for patients undergoing THA for hip
87 fracture using either a dual mobility or conventional THA prosthesis. A comprehensive list of
88 hip fracture and arthroplasty registries was generated via a PubMed and Embase search using the
89 keywords “hip fracture” AND “national” AND (“registry” OR “database” OR “audit”) including
90 all dates up to December 2019, and via the International Society for Arthroplasty Registries
91 directory. Forty-three registries (29 arthroplasty registries; 14 hip fracture registries) were
92 identified as potential sources of revision surgery data, and an initial query regarding routinely
93 collected revision surgery data was sent. To be eligible to participate, the registry had to be able
94 to provide de-identified aggregate data regarding patient demographics, prosthesis classification
95 and revision surgery according to a custom individual data request. The target population was all
96 patients with hip fractures who received either a dual mobility or conventional THA implant

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97 between January 1, 2002, and December 31, 2019 (Fig. 1). This period was selected to identify
98 all possible dual mobility procedures performed in the hip fracture population, which
99 commenced as early as 2002 in Denmark and as late as 2009 in the United States.

100 Six of the eligible registries agreed to participate: the Australian Orthopaedic Association
101 National Joint Replacement Registry (AOANJRR); the Swedish Hip Arthroplasty Register
102 (SAR); the Dutch Arthroplasty Register (LROI); the Kaiser Permanente Hip Fracture Registry
103 (KP HFR) in the United States; the National Joint Registry (NJR) from England, Wales,
104 Northern Ireland, the Isle of Man, and the States of Guernsey; and the Danish Hip Arthroplasty
105 Registry (DHR). Reasons for exclusion are provided in the Study Flow Diagram (Figure 1). Data
106 were available for 15,024 dual mobility and 97,200 conventional THAs performed from 2002 to
107 2019. To describe the relative frequency of dual mobility use and baseline patient characteristics,
108 each registry provided demographic data, including sex (% male, % female), mean \pm SD age,
109 American Society of Anesthesiologists class, and BMI based on WHO criteria, as well as
110 surgical approach (anterior, lateral or posterior); and the yearly use of primary THA by THA
111 type to describe the proportion of patients with hip fractures who were treated with dual mobility
112 compared with those who were treated with conventional THA.

113 To determine whether the use of dual mobility was associated with a lower risk of all-cause
114 revision compared with conventional THA, each registry provided Kaplan-Meier (KM) survival
115 data for revision for any cause up to 10 years; types of revision by THA type, reported as the
116 absolute number; proportion of primary procedures revised; and proportion of revisions
117 performed for prosthesis dislocation, infection, fracture, and loosening. We evaluated mortality
118 using KM survival data for mortality up to 5 years postoperatively. Complete KM survival data

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119 up to 5 years were available for revision and mortality from all 6 registries. Additional revision
120 data up to 10 years was available from three registries (AOANJRR, NJRR, and DHR). Revision
121 surgery was defined as any second procedure involving removal, exchange, or addition of
122 components. Each registry has greater than 95% completeness of data on arthroplasty
123 procedures, and methods of data collection have been described [12, 18, 25, 33, 37, 58].

124 *Data Access*

125 Each registry provided aggregate-level descriptive statistics in the form of frequencies,
126 proportions, means, and SDs.

127 *Statistical Analysis*

128 To determine within registry differences between dual mobility and conventional THA patients,
129 simple tests of association (independent t test, Chi square) were performed for each registry
130 using summary data. Between registry differences were adjusted for in the meta-analysis for the
131 outcome of interest, all-cause revision surgery.

132 Aggregate KM data were collected to perform survival analyses using revision and mortality as
133 the outcomes of interest, separately for each registry. Although synthesizing individual patient
134 data for meta-analysis is considered the ideal, the regulatory and privacy limitations of sharing
135 patient-level data between registries internationally makes this approach impractical. Hence, we
136 elected to perform a pseudo-individual patient data meta-analysis, whereby the participating
137 arthroplasty registries provided standardized, de-identified aggregate KM survival data for the
138 purposes of meta-analysis in order to approximate the original individual time-to-event data at
139 prespecified time intervals [46].

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140 Revision data, including the number of patients at risk, revision events, and mortality, were
141 pooled using a Cox and Weibull regression in a pseudo-individual patient data approach to
142 determine the HR and 95% CI for revision, comparing dual mobility with conventional THA.
143 Registry (region) was entered as a random effect and fixed effect in the Weibull model to
144 account for differences between registries [27, 60]. The cumulative percent revision (CPR) at a
145 certain time was defined as the complement of the KM survivorship function at that time,
146 multiplied by 100. Sensitivity analyses were performed to determine the effect of excluding
147 individual registries from the meta-analysis. The meta-analysis was conducted using Stata 15.1
148 (StataCorp).

149 *Study Registration*

150 The study was registered prospectively in the PROSPERO database (CRD42020155336) and is
151 reported according to the RECORD Checklist [8].

152 **Results**

153 *(1) Is dual mobility use associated with a difference in risk of revision surgery (all cause or by*
154 *indication) compared to conventional THA?*

155 We did not detect an all-cause revision benefit to dual mobility compared to conventional THA
156 for hip fracture patients in the adjusted meta-analysis.

157 For all-cause revision, all six registries individually reported a lower rate of revision for dual
158 mobility than for conventional THA up to 5 years postoperatively (Fig. 2, full data provided in
159 Supplemental Table 1; supplemental materials are available with the online version of *CORR*[®]).

160 KM survival curves were reconstructed for the risk of revision surgery in the dual mobility and
161 conventional THA cohorts using data extracted from the six arthroplasty registries. In the

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162 unadjusted meta-analysis of CPR, the log-rank test did not demonstrate equivalent survivorship
163 between dual mobility and conventional THA ($p = 0.003$). At 5 years, the CPR for conventional
164 THA was 4.3% (95%CI, 4.2-4.5%) and 4.7% (95%CI, 4.3-5.3%) for dual mobility THA using
165 complete KM survival data for all 6 registries. At 10 years, the CPR for conventional THA was
166 6.7% (95%CI, 6.3- 7.1%) and 6.9% (5.8-8.2%) for dual mobility THA. Unadjusted survival
167 curves are provided in Supplemental Fig. 1; supplemental materials are available with the online
168 version of *CORR*[®]). However, when the same data were adjusted to account for between-registry
169 differences, no difference in the risk of revision was observed when treating the registries as a
170 fixed effect (HR 0.96; 95% CI, 0.86-1.06) or random effect (HR 0.96; 95% CI, 0.86-1.07) using
171 a Weibull proportional hazards model. There was agreement between all statistical models (Fig.
172 3).

173 As the relative contributions of dual mobility and conventional THA procedures varied widely
174 between registries, we performed a sensitivity analysis to determine the influence of individual
175 registries on the meta-analysis. For example, 49.1% of dual mobility THAs (7,384 out of 15,024)
176 were recorded by the DHR, while 37.6% of conventional THAs (36,515 out of 97,200) were
177 recorded by the NJR. The sensitivity analysis demonstrated that the results of the meta-analysis
178 were consistent as individual registries were removed from the analysis (Table 1).

179 The number of conventional and dual mobility prostheses revised for the indications of
180 prosthesis dislocation, infection, fracture, and loosening for all registries are presented in Table 2
181 (a breakdown by registry is available in Supplemental Table 2; supplemental materials are
182 available with the online version of *CORR*[®]).

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183 Differences in mortality were explored because they may indicate differences in patient
184 selection. Five of the six registries reported a lower cumulative percent mortality for
185 conventional THA than for dual mobility up to 5 years postoperatively (Fig. 4). The sixth
186 registry (KP HFR) did not have data in order to provide the cumulative percent mortality at 5
187 years for the dual mobility cohort due to the relatively recent use of the prosthesis (<2 years) in
188 their registry. The cumulative percent mortality varied widely between THA types and between
189 registries (Fig. 4, full data provided in Supplemental Table 3; supplemental materials are
190 available with the online version of *CORR*[®]). For mortality, the reconstructed KM curves
191 demonstrated a higher cumulative percent mortality for dual mobility than for conventional THA
192 at 1 year postoperatively, and this difference increased up to 5 years postoperatively
193 (Supplemental Fig. 2; supplemental materials are available with the online version of *CORR*[®]).

194

195 *(2) Are there specific patient characteristics associated with dual mobility use within each*
196 *registry?*

197 The majority of registries reported dual mobility patients to be older and more comorbid, and
198 have received a posterior approach compared to conventional THA patients (Table 3). In 4 of the
199 6 registries studied (AOANJRR, SAR, NJR, DHR), mean age was higher for dual mobility
200 compared to conventional THA patients ($p < 0.001$). Dual mobility was used in similarly aged
201 patients to conventional THA in the LROI and KP HFR ($p > 0.05$). Dual mobility was used in
202 different proportions according to sex in 4 of the 6 registries studied (SAR, LROI, NJR, DHR).
203 Dual mobility was more likely to be used in male patients in the SAR (39%, 959/2481 vs 30%,
204 4992/16,541) ($p < 0.001$), LROI (34%, 391/1135 vs 31%, 3398/10,934) ($p = 0.02$), and NJR

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205 (32%, 586/1857 vs 27%, 9852/36,515) ($p < 0.001$). There were no differences observed in
206 proportions of dual mobility use compared to conventional THA use according to sex in the
207 AOANJRR and KP HFR. For the American Society for Anaesthesiologists (ASA) score, 5 out of
208 the 6 registries studied (AOANJRR, SAR, LROI, NJR, DHR) reported different proportions of
209 comorbidities ($p < 0.001$). Of these, 4 registries (SAR, LROI, NJR, DHR) reported a greater
210 proportion of dual mobility patients to have severe systemic disease (ASA Class III) than
211 conventional THA patients as follows: SAR (50% 1139/2481 vs 27%, 4446/16,541), LROI
212 (38%, 428/1135 vs 23%, 2468/10,934), NJR (39%, 721/1857 vs 27%, 9812/36,515), DHR (47%,
213 1029/7384 vs 28%, 338/10,437). Mean BMI was found to be lower for dual mobility patients
214 than conventional THA patients in 3 out of the 6 registries (AOANJRR, SAR, DHR) ($p < 0.001$).
215 The differences were small and likely to be significant due to the large number of patients (Table
216 3). Finally, 5 out of the 6 registries (AOANJRR, SAR, LROI, NJR, DHR) reported differences in
217 the proportions of surgical approaches ($p < 0.001$). Of these registries, 4 reported a greater
218 proportion of dual mobility procedures being undertaken by the posterior approach compared to
219 conventional THA as follows: (68%, 1333/2457 vs 56%, 4618/21,088), SAR (52%, 1277/2481
220 vs 39%, 6382/16,541), LROI (85%, 967/1135 vs 59%, 6355/10934), NJR (90% 1664/1857 vs
221 58%, 21,052/36,515). Given the within registry differences observed, comparison of the overall
222 differences between registries was not performed as these are adjusted on later analysis of the
223 outcome of interest, all-cause revision surgery.

224

225 *(3) Has the use of dual mobility constructs changed over time in patients receiving a THA for hip*
226 *fracture?*

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227 Dual mobility was used in 15.5% (15024/97,200) of primary THAs performed for hip fractures
228 during the period January 1st 2002 to December 31st 2019. The use of dual mobility varied
229 between registries, in order of descending frequency of 41.4% (7384/17,821, DHR), 15.0%
230 (2481/16,545, SAR), 11.7% (2457/21,088, AOANJRR), 7.2% (815/11,282, LROI), 5.1%
231 (1857/36,515, NJR) and 4.2% (56/1,337, KP HFR). The frequency of dual mobility use for hip
232 fractures increased each year in all six registries (Fig. 5). Full frequency data provided in
233 Supplemental Table 4; supplemental materials are available with the online version of *CORR*[®].
234 In the final study year (January 1st to December 31 2019), dual mobility was used in 20.5%
235 (2438/11,874) of all procedures. By registry, in order of descending frequency, dual mobility
236 was used in 68.0% (679/999, DHR), 34.4% (642/1,866, AOANJRR), 26.7% (357/1,337, SAR),
237 22.5% (303/1,344, LROI), 13.5% (26/193, KP HFR), and 9.0% (431/4,807, NJR) of primary
238 THAs performed for hip fracture in 2019 (Fig. 5).
239
240

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241 **Discussion**

242 Dual mobility THA is used in patient populations that have a high-risk of prosthesis dislocation
243 and premature revision after joint replacement, such as hip fractures. Current observational series
244 supporting the use of dual mobility over conventional THA in hip fractures are small and
245 underpowered to detect important outcomes such as revision surgery, and appropriately powered
246 randomized controlled trials may be unfeasible due to the large numbers of patients required.
247 Therefore, we combined data from one hip fracture registry and five national arthroplasty
248 registries to determine whether a revision surgery benefit exists for dual mobility THA, as well
249 as describe implant usage, indications for revision, and demographics compared to patients
250 receiving conventional THA. The most important finding of this study is that we did not identify
251 a revision surgery benefit to dual mobility over conventional THA for hip fracture patients.

252 *Limitations*

253 Several limitations exist when using registry data. The lack of difference in revision in the
254 pooled analysis may be due to heterogeneity between the registries. Potential sources of
255 heterogeneity include differences in patient selection, surgical technique, implant factors and
256 outcome measurement between registries. These factors, in turn, may have stark influences on
257 the revision surgery and mortality rates, and be driving the large differences in dual mobility
258 THA use between countries. Additionally, the threshold for revision surgery might be different
259 between the dual mobility and conventional THA patient cohorts, especially considering the
260 different baseline characteristics and mortality rates between the groups in all registries. If the
261 dual mobility group consists of frailer individuals, frailty can also interfere with the risk of
262 infection and periprosthetic fractures. We have not reported femoral head size, and there are

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263 likely to be many conventional THA patients with smaller (< 32mm) femoral heads in our
264 cohort, especially during the first decade of the study period (2002-2012). This may bias the risk
265 of revision in favour of dual mobility THA. Revision as an outcome may underestimate the real
266 dislocation problem because patients with hip fractures undergo revision less frequently than
267 healthier patients who undergo THA [35]. Additionally, local legislative and jurisdictional
268 restrictions on arthroplasty registries make the acquisition of true individual patient data
269 impractical for combining observational data from multiple registries to generate a pooled HR
270 for the relative risk of revision for dual mobility and conventional THA in patients with hip
271 fractures. Hence, we elected for a pseudo-individual patient data approach, which has been
272 validated for time-to-event outcomes such as revision surgery [27, 60]. An alternative analysis
273 would be to perform propensity score matching based on common risk factors. However,
274 important unmeasured variables would likely remain (e.g., patient activity levels), and this
275 analysis was not possible using these data as only summary data was provided by each registry.
276 Finally, we received data from 5 of the 29 invited arthroplasty registries, and 1 of the 14 invited
277 hip fracture registries. The reasons for this are myriad; the majority did not respond to our initial
278 query, and many simply do not collect prosthesis revision data. Most hip fracture registries
279 collect data on in-hospital standards of care, such as time to surgery. This may therefore limit the
280 generalizability of our findings. Similar collaborative efforts have yielded participation of up to 8
281 arthroplasty registries [41], but more typically consist of geographically and culturally similar
282 blocks, such as the Nordic Arthroplasty Register Association, which features 4 member registries
283 [42]. As far as we are aware, our work represents the first attempt to define and justify, in a

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284 systematic manner, the number of potential observational data sources that may yield revision
285 surgery data in the hip fracture population.

286 Many higher quality academic journals now limit the publication of meta-analyses (that is, data
287 pooling in the context of a systematic review) when the data sources are retrospective. The main
288 reason for this is to avoid the pooling of data from studies whose designs and populations are
289 incomparable. We believe it is reasonable to meta-analyze registry data in a study like ours
290 because the means of data collection and populations are generally reasonably similar (the data
291 sources represent the widespread surgical practices of large numbers of surgeons and the patients
292 whom they treat, and the longitudinal data capture processes are comparable across the registries
293 we included here). And, of course, doing so allows us to answer questions that would not be
294 answerable with any other study design.

295 *Risk of revision surgery for dual mobility compared with conventional THA in hip fracture*

296 For all-cause revision, all six registries reported a lower risk of revision for dual mobility
297 implants than for conventional THA up to 5 years after surgery. However, when we pooled the
298 data to perform the pseudo-individual patient data meta-analysis, and adjusted for between-
299 registry differences, this benefit was not replicated. For clinicians treating hip fractures with
300 THA, the most important outcomes influencing implant choice, among others, are a reduction in
301 hip dislocation and a subsequent reduction in revision surgery for prosthesis instability. Our
302 study suggests that dual mobility THA may not be reducing the incidence of revision surgery in
303 hip fractures on a global population level. Prior registry studies that were able to adjust for
304 femoral head size may provide some potential reasons for our observations. It may be that dual
305 mobility THA only demonstrates a benefit over smaller (≤ 28 mm) head sizes, and that a

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306 clinically unimportant difference is present for larger head sizes (≥ 32 mm). Bloemheuvel et al.
307 [11], in a multivariable Cox regression analysis of LROI data, demonstrated no overall
308 difference in cup revision between dual mobility and conventional THA, and only a difference
309 between dual mobility and smaller-diameter (22-28 mm) conventional THA heads. Hoskins et al.
310 [31], who examined all 16,692 hip fractures in the AOANJRR treated with THA between 2008
311 and 2018, observed a similar trend, reporting a revision benefit only in conventional THA with a
312 head size of 32 mm, not in conventional THAs with a large femoral head (> 32 mm). These
313 results may reflect residual confounding due to differences between patient groups as more
314 complex analyses have yielded different results. Jobory et al. [36], using data from the Nordic
315 Arthroplasty Registry Association, which included Danish, Norwegian, and Swedish data,
316 identified a 25% reduction in overall revision (HR 0.75; 95% CI, 0.62-0.92) and a 55% reduction
317 in the risk of revision for dislocation (HR 0.45; 95% CI, 0.30-0.68) using propensity score
318 matching of 4,520 dual mobility cups with 4,520 conventional THAs for hip fracture. However,
319 like our study, femoral head size was not included as a covariate, and only a limited number of
320 common variables shared between the registries (age, sex, fixation of cup and stem, and year of
321 surgery) were used to perform patient matching. Finally, data are contradictory as to whether
322 dual mobility confers an additional risk of infection compared with conventional THA. Jobory et
323 al [36], specifically examining the revision risk in a hip fracture cohort, did not detect a
324 difference in the risk of revision for deep infection. However, two large observational studies,
325 one of revision THA procedures [50] and the other of elective THA performed for osteoarthritis
326 [40], estimated a risk of deep infection in dual mobility that was two to three times that of

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327 conventional THA. Similar to our analysis, both studies identified higher levels of patient
328 comorbidities as a confounder in the dual mobility cohort and did not adjust for these covariates.

329 *Patient Characteristics Associated with dual mobility THA*

330 Patients receiving dual mobility implants were more likely to be older and less healthy than
331 patients receiving conventional THA. Our data suggest there is confounding by indication as
332 well as patient selection bias, which makes it difficult to compare dual mobility with
333 conventional THA based on registry data alone. The higher mortality in the dual mobility cohort
334 is further evidence of a patient selection bias. It is also not clear whether the surgical approach
335 influences the efficacy of dual mobility. The posterior approach is a major risk factor for
336 instability after arthroplasty for hip fracture [28]. Of the registries we studied, in the SAR, no
337 quantitative differences in CPR were demonstrated at 1 or 5 years, in contrast to the five other
338 registries. This may be due to the far greater proportion of procedures undertaken via the lateral
339 approach in the SAR, which provides protection against dislocation. Despite this, the SAR did
340 not have the lowest percentage of patients who underwent revision for prosthesis dislocation,
341 suggesting other factors may also be important.

342 *Dual Mobility THA Use in Patients with Hip Fractures*

343 The use of dual mobility constructs in patients undergoing THA for hip fractures increased
344 steadily over time. This increase occurred in all included registries. We also observed substantial
345 international practice variation in dual mobility THA use as a proportion of procedures, ranging
346 from 68% (679 of 999) in the DHR to 9% (431 of 4807) in the NJR in the final study year. The
347 reasons for this phenomenon are unclear. Current evidence examining the use of dual mobility in
348 patients with hip fractures consists of two tiers of data: first, adjusted analyses of observational

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349 data published by national arthroplasty registries [11, 28, 31, 36], and second, smaller
350 uncontrolled cohort or case-control studies. A total of 140 patients with dual mobility and 132
351 with conventional THA were reported in the three retrospective, comparative studies that
352 provided a direct comparison [23, 45, 54]. These studies were judged to be at a high risk of bias
353 in a recent systematic review [62] and do not provide statistical power for any meaningful
354 analyses. The remainder of the non-registry-derived studies consist of case series without a
355 comparison with conventional THA [4, 5, 15, 24, 32, 43, 47, 52], or comparison with
356 conventional THA for osteoarthritis in an elective setting [13, 30, 51]. Other published studies
357 compared dual mobility cups with bipolar hemiarthroplasty [9, 14, 21, 34, 38, 44, 55]. These
358 studies have been cited in systematic reviews [16, 17, 62], and may give a biased estimate of the
359 treatment benefit of dual mobility THA in the absence of randomized controlled trials comparing
360 dual mobility and conventional THA for hip fractures. Three trials are actively recruiting, with
361 results not expected for 3 to 5 years [22, 56, 61].

362

363 *Conclusion*

364 Dual mobility for the treatment of hip fractures did not result in a difference in all-cause revision
365 compared with conventional THA. A higher proportion of procedures revised for infection may
366 offset the observed benefit of a lower proportion of revisions for dislocation in this global cohort
367 of patients in whom dual mobility THA was used. Wide variations in revision and mortality rates
368 internationally make comparative analyses challenging. We believe a high-quality randomized
369 controlled trial comparing dual mobility with the best available comparator, a large-head
370 conventional THA implant, is required to clarify whether dual mobility cups result in a lower

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371 incidence of dislocation. Such a trial should be registry-nested, such that subsequent revision
372 surgery in hip fracture patients can be causally associated with bearing choice.

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References

- 375 1. Adam P, Philippe R, Ehlinger M, et al. Dual mobility cups hip arthroplasty as a treatment
376 for displaced fracture of the femoral neck in the elderly. A prospective, systematic,
377 multicenter study with specific focus on postoperative dislocation. *Orthop Traumatol*
378 *Surg Research*. 2012;98:296-300.
- 379 1. (AAOS) AAOS. *Management of Hip Fractures in the Elderly Evidence-Based Clinical*
380 *Practice Guideline*.
- 381 2. AOA. *Hip, Knee & Shoulder Arthroplasty: 2020 Annual Report*. Adelaide, AOA, 1-474,
382 2020.
- 383 3. (NICE) NifHaCE. *Hip fracture: management (Clinical guideline CG124)*.
- 384 4. Adam P, Philippe R, Ehlinger M, Roche O, Bonnomet F, Mole D, Fessy MH. Dual mobility
385 cups hip arthroplasty as a treatment for displaced fracture of the femoral neck in the
386 elderly. A prospective, systematic, multicenter study with specific focus on
387 postoperative dislocation. *Orthopaedics & traumatology, surgery & research : OTSR*.
388 2012;98:296-300.
- 389 5. Assi CC, Barakat HB, Caton JH, Najjar EN, Samaha CT, Yammine KF. Mortality Rate and
390 Mid-Term Outcomes of Total Hip Arthroplasty Using Dual Mobility Cups for the
391 Treatment of Femoral Neck Fractures in a Middle Eastern Population. *The Journal of*
392 *arthroplasty*. 2019;34:333-337.
- 393 6. Baker RP, Squires B, Gargan MF, Bannister GC. Total hip arthroplasty and
394 hemiarthroplasty in mobile, independent patients with a displaced intracapsular
395 fracture of the femoral neck. A randomized, controlled trial. *The Journal of bone and*
396 *joint surgery. American volume*. 2006;88:2583-2589.
- 397 7. Barlow BT, McLawhorn AS, Westrich GH. The Cost-Effectiveness of Dual Mobility
398 Implants for Primary Total Hip Arthroplasty: A Computer-Based Cost-Utility Model. *The*
399 *Journal of bone and joint surgery. American volume*. 2017;99:768-777.
- 400 8. Benchimol EI, Smeeth L, Guttman A, Harron K, Moher D, Petersen I, Sørensen HT, von
401 Elm E, Langan SM. The REporting of studies Conducted using Observational Routinely-
402 collected health Data (RECORD) statement. *PLoS Med*. 2015;12:e1001885.
- 403 9. Bensen AS, Jakobsen T, Krarup N. Dual mobility cup reduces dislocation and re-
404 operation when used to treat displaced femoral neck fractures. *International*
405 *orthopaedics*. 2014;38:1241-1245.
- 406 10. Bhandari M, Swiontkowski M. Management of Acute Hip Fracture. *N Engl J Med*.
407 2017;377:2053-2062.
- 408 11. Bloemheuvel EM, Van Steenberghe LN, Swierstra BA. Low revision rate of dual mobility
409 cups after arthroplasty for acute hip fractures: report of 11,857 hip fractures in the
410 Dutch Arthroplasty Register (2007-2019). *Acta Orthop*. 2021;92:36-39.
- 411 12. *National Joint Registry 17th Annual Report 2020*, 2020.
- 412 13. Bouche PA, Corsia S, Boukebous B, Boutroux P, Zahi R, Guillon P. Is the position of dual-
413 mobility cup in THA for femoral neck fractures optimal? A retrospective study. *Eur J*
414 *Orthop Surg Traumatol*. 2020;30:275-280.

AU: Please do not delete query boxes or remove line numbers; ensure you address each query in the query box. You may modify text within selected text or outside the selected text (as appropriate) without deleting the query.

- 415 14. Boukebous B, Boutroux P, Zahi R, Azmy C, Guillon P. Comparison of dual mobility total
416 hip arthroplasty and bipolar arthroplasty for femoral neck fractures: A retrospective
417 case-control study of 199 hips. *Orthopaedics & traumatology, surgery & research : OTSR.*
418 2018;104:369-375.
- 419 15. Canton G, Moghnie A, Cleva M, Kostoris FM, Murena L. Dual mobility total hip
420 arthroplasty in the treatment of femoral neck fractures: a retrospective evaluation at
421 mid-term follow-up. *Acta Biomed.* 2019;90:98-103.
- 422 16. Cha YH, Yoo JI, Kim JT, Park CH, Ahn YS, Choy WS, Ha YC, Koo KH. Dual mobility total hip
423 arthroplasty in the treatment of femoral neck fractures. *The bone & joint journal.*
424 2020;102-b:1457-1466.
- 425 17. Darrith B, Courtney PM, Della Valle CJ. Outcomes of dual mobility components in total
426 hip arthroplasty: a systematic review of the literature. *The bone & joint journal.*
427 2018;100-b:11-19.
- 428 18. de Steiger RN, Graves SE. Orthopaedic registries: the Australian experience. *EFORT Open*
429 *Rev.* 2019;4:409-415.
- 430 19. Ekhtiari S, Gormley J, Axelrod DE, Devji T, Bhandari M, Guyatt GH. Total Hip Arthroplasty
431 Versus Hemiarthroplasty for Displaced Femoral Neck Fracture: A Systematic Review and
432 Meta-Analysis of Randomized Controlled Trials. *The Journal of bone and joint surgery.*
433 *American volume.* 2020;102:1638-1645.
- 434 20. Enocson A, Hedbeck CJ, Tidermark J, Pettersson H, Ponzer S, Lapidus LJ. Dislocation of
435 total hip replacement in patients with fractures of the femoral neck. *Acta Orthop.*
436 2009;80:184-189.
- 437 21. Fahad S, Nawaz Khan MZ, Aqueel T, Hashmi P. Comparison of bipolar hemiarthroplasty
438 and total hip arthroplasty with dual mobility cup in the treatment of old active patients
439 with displaced neck of femur fracture: A retrospective cohort study. *Ann Med Surg*
440 *(Lond).* 2019;45:62-65.
- 441 22. Farey JEH, T.; Adie S.; Harris I.A.; the DISTINCT Group. DISTINCT: Dual Mobility Versus
442 Standard Total Hip Arthroplasty In Femoral Neck Fractures, A Registry-Nested, Cluster-
443 Randomised Trial. *ACTRN12621000069853.* Australian New Zealand Clinical Trials
444 Registry (ANZCTR); 2021.
- 445 23. G. ZMMKDSTAGAN. Dual mobility cups reduce dislocation rate in total hip arthroplasty
446 for displaced femoral neck fractures. *J of IMAB.* 2018;24:2077-2081.
- 447 24. Graversen AE, Jakobsen SS, Kristensen PK, Thillemann TM. No dislocations after primary
448 hip arthroplasty with the dual mobility cup in displaced femoral neck fracture in patients
449 with dementia. A one-year follow-up in 20 patients. *Sicot j.* 2017;3:9.
- 450 25. Gundtoft PH, Varnum C, Pedersen AB, Overgaard S. The Danish Hip Arthroplasty
451 Register. *Clin Epidemiol.* 2016;8:509-514.
- 452 26. Guyen O. Constrained liners, dual mobility or large diameter heads to avoid dislocation
453 in THA. *EFORT Open Rev.* 2016;1:197-204.

AU: Please do not delete query boxes or remove line numbers; ensure you address each query in the query box. You may modify text within selected text or outside the selected text (as appropriate) without deleting the query.

- 454 27. Guyot P, Ades AE, Ouwens MJ, Welton NJ. Enhanced secondary analysis of survival data:
455 reconstructing the data from published Kaplan-Meier survival curves. *BMC Med Res*
456 *Methodol.* 2012;12:9.
- 457 28. Hailer NP, Weiss RJ, Stark A, Kärrholm J. The risk of revision due to dislocation after total
458 hip arthroplasty depends on surgical approach, femoral head size, sex, and primary
459 diagnosis. An analysis of 78,098 operations in the Swedish Hip Arthroplasty Register.
460 *Acta Orthop.* 2012;83:442-448.
- 461 29. Hermansen LL, Viberg B, Hansen L, Overgaard S. "True" Cumulative Incidence of and Risk
462 Factors for Hip Dislocation within 2 Years After Primary Total Hip Arthroplasty Due to
463 Osteoarthritis: A Nationwide Population-Based Study from the Danish Hip Arthroplasty
464 Register. *The Journal of bone and joint surgery. American volume.* 2021;103:295-302.
- 465 30. Homma Y, Baba T, Ozaki Y, Watari T, Kobayashi H, Ochi H, Matsumoto M, Kaneko K. In
466 total hip arthroplasty via the direct anterior approach, a dual-mobility cup prevents
467 dislocation as effectively in hip fracture as in osteoarthritis. *International orthopaedics.*
468 2017;41:491-497.
- 469 31. Hoskins W, Griffin X, Hatton A, de Steiger RN, Bingham R. THA for a Fractured Femoral
470 Neck: Comparing the Revision and Dislocation Rates of Standard-head, Large-head,
471 Dual-mobility, and Constrained Liners. *Clin Orthop Relat Res.* 2021;479:72-81.
- 472 32. Hwang JH, Kim SM, Oh KJ, Kim Y. Dislocations after use of dual-mobility cups in
473 cementless primary total hip arthroplasty: prospective multicentre series. *International*
474 *orthopaedics.* 2018;42:761-767.
- 475 33. Inacio MC, Weiss JM, Miric A, Hunt JJ, Zohman GL, Paxton EW. A Community-Based Hip
476 Fracture Registry: Population, Methods, and Outcomes. *Perm J.* 2015;19:29-36.
- 477 34. Iorio R, Iannotti F, Mazza D, Speranza A, Massafra C, Guzzini M, D'Arrigo C, Ferretti A. Is
478 dual cup mobility better than hemiarthroplasty in patients with dementia and femoral
479 neck fracture? A randomized controlled trial. *Sicot j.* 2019;5:38.
- 480 35. Jobory A, Kärrholm J, Hansson S, Åkesson K, Rogmark C. Dislocation of hemiarthroplasty
481 after hip fracture is common and the risk is increased with posterior approach: result
482 from a national cohort of 25,678 individuals in the Swedish Hip Arthroplasty Register.
483 *Acta Orthop.* 2021;92:413-418.
- 484 36. Jobory A, Kärrholm J, Overgaard S, Becic Pedersen A, Hallan G, Gjertsen JE, Makela K,
485 Rogmark C. Reduced Revision Risk for Dual-Mobility Cup in Total Hip Replacement Due
486 to Hip Fracture: A Matched-Pair Analysis of 9,040 Cases from the Nordic Arthroplasty
487 Register Association (NARA). *The Journal of bone and joint surgery. American volume.*
488 2019;101:1278-1285.
- 489 37. *Swedish Hip Arthroplasty Register. Annual report 2019.*, 2019.
- 490 38. Kim YT, Yoo JH, Kim MK, Kim S, Hwang J. Dual mobility hip arthroplasty provides better
491 outcomes compared to hemiarthroplasty for displaced femoral neck fractures: a
492 retrospective comparative clinical study. *International orthopaedics.* 2018;42:1241-
493 1246.

AU: Please do not delete query boxes or remove line numbers; ensure you address each query in the query box. You may modify text within selected text or outside the selected text (as appropriate) without deleting the query.

- 494 39. Ko LM, Hozack WJ. The dual mobility cup: what problems does it solve? *The bone & joint*
495 *journal*. 2016;98-b:60-63.
- 496 40. Kreipke R, Rogmark C, Pedersen AB, Kärrholm J, Hallan G, Havelin LI, Mäkelä K,
497 Overgaard S. Dual Mobility Cups: Effect on Risk of Revision of Primary Total Hip
498 Arthroplasty Due to Osteoarthritis: A Matched Population-Based Study Using the Nordic
499 Arthroplasty Register Association Database. *The Journal of bone and joint surgery.*
500 *American volume*. 2019;101:169-176.
- 501 41. Lewis PL, Tudor F, Lorimer M, McKie J, Bohm E, Robertsson O, Makela KT, Haapakoski J,
502 Furnes O, Bartz-Johannessen C, Nelissen R, Van Steenberghe LN, Fithian DC, Prentice
503 HA. Short-term Revision Risk of Patellofemoral Arthroplasty Is High: An Analysis from
504 Eight Large Arthroplasty Registries. *Clin Orthop Relat Res*. 2020;478:1222-1231.
- 505 42. Mäkelä KT, Furnes O, Hallan G, Fenstad AM, Rolfson O, Kärrholm J, Rogmark C, Pedersen
506 AB, Robertsson O, A WD, Eskelinen A, Schröder HM, Äärimala V, Rasmussen JV,
507 Salomonsson B, Hole R, Overgaard S. The benefits of collaboration: the Nordic
508 Arthroplasty Register Association. *EFORT Open Rev*. 2019;4:391-400.
- 509 43. Nich C, Vandebussche E, Augereau B, Sadaka J. Do Dual-Mobility Cups Reduce the Risk
510 of Dislocation in Total Hip Arthroplasty for Fractured Neck of Femur in Patients Aged
511 Older Than 75 Years? *The Journal of arthroplasty*. 2016;31:1256-1260.
- 512 44. Nonne D, Sanna F, Bardelli A, Milano P, Rivera F. Use of a Dual mobility cup to prevent
513 hip early arthroplasty dislocation in patients at high falls risk. *Injury*. 2019;50 Suppl
514 4:S26-s29.
- 515 45. Ochi H, Baba T, Homma Y, Matsumoto M, Watari T, Ozaki Y, Kobayashi H, Kaneko K.
516 Total hip arthroplasty via the direct anterior approach with a dual mobility cup for
517 displaced femoral neck fracture in patients with a high risk of dislocation. *Sicot j*.
518 2017;3:56.
- 519 46. Paxton EW, Mohaddes M, Laaksonen I, Lorimer M, Graves SE, Malchau H, Namba RS,
520 Kärrholm J, Rolfson O, Cafri G. Meta-analysis of individual registry results enhances
521 international registry collaboration. *Acta Orthop*. 2018;89:369-373.
- 522 47. Rashed RA, Sevenoaks H, Shabaan AM, Choudry QA, Hammad AS, Kasem MS, El
523 Khadrawe TA, El Dakhkhny MM. Functional outcome and health related quality of life
524 after dual mobility cup total hip replacement for displaced femoral neck fractures in
525 middle aged Egyptian patients. *Injury*. 2018;49:667-672.
- 526 48. Ravikumar KJ, Marsh G. Internal fixation versus hemiarthroplasty versus total hip
527 arthroplasty for displaced subcapital fractures of femur--13 year results of a prospective
528 randomised study. *Injury*. 2000;31:793-797.
- 529 49. Registry ANZHF. *Australian and New Zealand Guidelines for Hip Fracture Care Improving*
530 *Outcomes in Hip Fracture Management of Adults*.
- 531 50. Reina N, Delaunay C, Chiron P, Ramdane N, Hamadouche M. Infection as a cause of
532 primary total hip arthroplasty revision and its predictive factors. *Orthopaedics &*
533 *traumatology, surgery & research : OTSR*. 2013;99:555-561.

AU: Please do not delete query boxes or remove line numbers; ensure you address each query in the query box. You may modify text within selected text or outside the selected text (as appropriate) without deleting the query.

- 534 51. Tabori-Jensen S, Hansen TB, Bøvling S, Aalund P, Homilius M, Stilling M. Good function
535 and high patient satisfaction at mean 2.8 years after dual mobility THA following
536 femoral neck fracture: a cross-sectional study of 124 patients. *Clin Interv Aging*.
537 2018;13:615-621.
- 538 52. Tabori-Jensen S, Hansen TB, Stilling M. Low dislocation rate of Saturne(®)/Avantage(®)
539 dual-mobility THA after displaced femoral neck fracture: a cohort study of 966 hips with
540 a minimum 1.6-year follow-up. *Arch Orthop Trauma Surg*. 2019;139:605-612.
- 541 53. Tarasevicius S, Busevicius M, Robertsson O, Wingstrand H. Dual mobility cup reduces
542 dislocation rate after arthroplasty for femoral neck fracture. *BMC Musculoskelet Disord*.
543 2010;11:175.
- 544 54. Tarasevicius S, Robertsson O, Dobožinskas P, Wingstrand H. A comparison of outcomes
545 and dislocation rates using dual articulation cups and THA for intracapsular femoral neck
546 fractures. *Hip international : the journal of clinical and experimental research on hip
547 pathology and therapy*. 2013;23:22-26.
- 548 55. Ukaj S, Zhuri O, Ukaj F, Podvorica V, Grezda K, Caton J, Prudhon JL, Krasniqi S. Dual
549 Mobility Acetabular Cup Versus Hemiarthroplasty in Treatment of Displaced Femoral
550 Neck Fractures in Elderly Patients: Comparative Study and Results at Minimum 3-Year
551 Follow-up. *Geriatr Orthop Surg Rehabil*. 2019;10:2151459319848610.
- 552 56. Van Beers L, Van Der Wal BCH, Van Loon TG, Moojen DJF, Van Wier MF, Klaassen AD,
553 Willigenburg NW, Poolman RW. Study protocol: Effectiveness of dual-mobility cups
554 compared with uni-polar cups for preventing dislocation after primary total hip
555 arthroplasty in elderly patients - design of a randomized controlled trial nested in the
556 Dutch Arthroplasty Registry. *Acta Orthop*. 2020;91:514-519.
- 557 57. van den Bekerom MP, Hilverdink EF, Sierevelt IN, Reuling EM, Schnater JM, Bonke H,
558 Goslings JC, van Dijk CN, Raaymakers EL. A comparison of hemiarthroplasty with total
559 hip replacement for displaced intracapsular fracture of the femoral neck: a randomised
560 controlled multicentre trial in patients aged 70 years and over. *J Bone Joint Surg Br*.
561 2010;92:1422-1428.
- 562 58. van Steenbergen LN, Denissen GA, Spooren A, van Rooden SM, van Oosterhout FJ,
563 Morrenhof JW, Nelissen RG. More than 95% completeness of reported procedures in
564 the population-based Dutch Arthroplasty Register. *Acta Orthop*. 2015;86:498-505.
- 565 59. Veronese N, Maggi S. Epidemiology and social costs of hip fracture. *Injury*.
566 2018;49:1458-1460.
- 567 60. Wei Y, Royston P. Reconstructing time-to-event data from published Kaplan-Meier
568 curves. *Stata J*. 2017;17:786-802.
- 569 61. Wolf O, Mukka S, Notini M, Möller M, Hailer NP. Study protocol: The DUALITY trial-a
570 register-based, randomized controlled trial to investigate dual mobility cups in hip
571 fracture patients. *Acta Orthop*. 2020;91:506-513.
- 572 62. You D, Sepehri A, Kooner S, Krzyżaniak H, Johal H, Duffy P, Schneider P, Powell J.
573 Outcomes of total hip arthroplasty using dual mobility components in patients with a
574 femoral neck fracture. *The bone & joint journal*. 2020;102-b:811-821.

AU: Please do not delete query boxes or remove line numbers; ensure you address each query in the query box. You may modify text within selected text or outside the selected text (as appropriate) without deleting the query.

- 575 63. Zagorov M, Mihov, K, Dobrilov, S, Tabakov, A, Gospodinov, A, Nenova, G. . Dual mobility
576 cups reduce dislocation rate in total hip arthroplasty for displaced femoral neck
577 fractures. *J of IMAB*. 2018;24:2077-2081.

AU: Please do not delete query boxes or remove line numbers; ensure you address each query in the query box. You may modify text within selected text or outside the selected text (as appropriate) without deleting the query.

Legends

Fig. 1 This flow diagram shows the studies that were included in our review.

Fig. 2 This forest plot shows the Cumulative Percent Revision for dual mobility and conventional THA by registry. DM = dual mobility THA. cTHA = conventional THA. Full data available in Supplemental Table 1.

Fig. 3 This forest plot represents the Cox and Weibull proportional hazards pseudo-IPD meta-analysis of all-cause revision for dual mobility versus conventional THA in patients with hip fractures.

Fig. 4 This forest plot shows the Cumulative Percent Mortality for dual mobility and conventional THA by registry. DM = dual mobility THA. cTHA = conventional THA. Full data available in Supplemental Table 3.

Fig. 5 This graph shows the yearly proportion of hip fractures treated with dual mobility THA by registry.

Supplemental Figures

Supplemental Fig. 1 This graph shows an unadjusted Kaplan-Meier curve for the risk of revision for any cause up to 10 years postoperatively using pooled data from the six arthroplasty registries. Purple line = dual mobility. Blue line = conventional THA.

Supplemental Fig. 2 This Kaplan-Meier curve represents the risk of mortality up to 5 years postoperatively using pooled data from the six arthroplasty registries. Purple line = dual mobility. Blue line = conventional THA.

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Supplemental Tables

Supplemental Table 1. This table shows the full Cumulative Percent Revision data with 95% confidence intervals used to generate Fig. 2.

Supplemental Table 2. Types of revision by bearing, percentage of primaries revised and percentage of revisions for the categories of prosthesis dislocation, infection, fracture and loosening.

Supplemental Table 3. This table shows the full Cumulative Percent Mortality data with 95% confidence intervals used to generate Fig. 4.

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