




Review

# Dual-Mobility Cups in Patients Undergoing Primary Total Hip Arthroplasty with Prior Lumbar Spine Fusion: A Systematic Review

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**Abstract:** Spine and hip abnormalities frequently occur together in most of the orthopedic population; therefore, both of these abnormalities impact the outcomes of the modalities that are being used. Few studies have reported reduced dislocation and revision rates with the use of dual-mobility cups (DMCs) in high-risk lumbar spine fusion (LSF) patients undergoing primary total hip arthroplasty (THA). This study aims to clarify the relationship between pre-existing lumbar spinal fusion and the outcomes of THA with dual-mobility constructs. We systematically reviewed the current literature through several online databases following PRISMA protocol and the Cochrane Handbook for Systematic Reviews of Interventions. We used the methodological index for non-randomized studies (MINORS) to evaluate the methodological quality of the included trials. Four studies examined the feasibility and effectiveness of dual-mobility cups in patients undergoing primary THA with prior LSF. Two studies were conducted in the United States, while the other two originated in Finland and France, respectively. The included studies enrolled 284 patients. Most of these patients had instrumented fusions. Seventy-eight percent of patients received one- or two-level fusions. The average age across the studies was 68.22 and the mean body mass index was 28. No cases of postoperative DMC implant dislocations were identified. The incidence of postoperative complications was 6% (10/173), including deep venous thrombosis, periprosthetic loosening, infection, and fracture, greater trochanteric fracture, and superficial wound infections. Most included studies had some methodological limitations, with an average MINORS score of  $10.5 \pm 5.8$ . The use of dual-mobility cups in these high-risk patients undergoing total hip arthroplasty may lead to reduced dislocation rates and postoperative complications. Further long-term follow-up studies are warranted to support these findings.

**Keywords:** total hip arthroplasty; lumbar fusion; dual mobility; dislocation; spinopelvic

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## 1. Introduction

Disorders of the hip and spine commonly occur together, each contributing to a significant burden of pain and morbidity, along with a substantial health-care cost in the United States. An estimated 27 million U.S. adults suffer from osteoarthritis and 59 million suffer from lower back pain [1]. Together, these constitute some of the leading causes of disability around the world. Yet, the diagnosis and treatment of hip–spine-related conditions still pose a significant diagnostic challenge to providers, as the concurrent existence of hip osteoarthritis and spinal disorders is poorly understood. Total hip arthroplasty (THA)

and lumbar spinal fusion (LSF) are both effective procedures for select patients with these combined degenerative pathologies. Nevertheless, patients who have undergone prior LSF are a known high-risk group [2–4]. Patients with concomitant LSF or spinal disease experience higher rates of postoperative complications, poorer postoperative outcomes, and an increased risk of dislocation and revision following primary THA [2–4]. While the appropriate sequence of LSF and THA is still debated, Malkani et al. report that THA dislocation is up to 106% greater among patients who undergo LSF first [3].

Recently, however, some studies have reported reduced dislocation and revision rates with the use of dual-mobility cups (DMCs) in high-risk patients undergoing primary THA [5–8]. Using DMCs in THA reduces instability and dislocation rates for several reasons. DMCs may reduce anteversion and the presumed reason for this improvement is a greater tolerance for articular impingement, along with a higher jump distance and significantly larger femoral head compared to standard cups [9–11]. Therefore, these cups additionally allow for greater range of motion prior to articular impingement. It also ensures a great option for a reduction in dislocation rate after a femur neck fracture, especially when placed under an anterolateral approach [12]. Risk factors for dislocation include a history of instability and abductor apparatus compromise, in which case a constrained cup is considered an alternative or other measures should be taken for compromised abductor apparatus [13]. In addition to this, some articles have reported an increased revision risk for infection after DMC-THAs, but Assi et al. concluded in their meta-analysis that DMCs reduced the risk of postoperative infection in both primary THAs and revision THAs compared to the standard cups [14–16]. Similarly, Prudhon stated that revisions for infections in DMC-THAs were comparable to those of fixed-cup THAs, while fixed-cup THAs were more associated with dislocations compared to DMC-THAs [17]. Additionally, in the patient population younger than 55 years, DMCs have shown improved survival benefits besides reduction in cup loosening and in prosthetic and intra-prosthetic dislocation [18]. Also, there are concerns about fretting, erosion, and long-term survivorship with DMC-THAs, but newer-generation implants have tried to reduce these concerns [19]. The survivorship and clinical/patient satisfaction in THA is also evident from a retrospective study conducted by Harvin et al. which involved 5 years of observation of patients after having prosthetic implants [20]. Rudy et al. concluded that DM systems are considered cost-effective if incremental expenditure stays within approximately USD 1023 of the conventional systems' price, and implant failures or other complications contribute significantly to the economic aspect of these repairs [21]. It was also found that DM systems are cost-saving for revisions in younger patients, but revision cost is affected by the time horizon (cost-effective if beyond 10 years) and patient age greater than 75 years [22]. The available literature so far is based on the utilization of DMCs in patients with THAs, but still, there is a need to focus more on biomechanics/pathomechanics, designs, and complications associated with DMCs' utilization.

While the theoretical benefits of DMCs are clear, limited studies have evaluated these new implants in patients with prior spinal surgery. Moreover, no evidence-based guidelines exist and the benefits are still unclear. Therefore, a systematic review of available evidence is essential for surgeons who treat patients with these combined pathologies. The purpose of this systematic review is to evaluate published outcomes on the relationship between pre-existing lumbar spinal fusion and DMC outcomes in primary THA.

## 2. Methods

### 2.1. Search Protocol

We performed a systematic review in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statement and fulfilled the quality guidelines as reported in the Cochrane Handbook for Systematic Reviews of Intervention [23]. This systematic review is exempt from IRB and ethics approval because we collected and synthesized data in previously published trials in which informed consent had already been obtained by investigators.

We conducted a detailed literature search using PubMed MEDLINE (National Library of Medicine) via Ovid, Web of Science, the Cochrane database, and Science Direct databases on 1 June 2021 using Boolean operations and the following keywords: “total hip”, “dual-mobility”, “double-mobility”, “tripolar”, “arthroplasty”, “fusion”, “spine”, “complications”, and “economic impact”. References of available studies were manually examined, from which we retrieved studies meeting the inclusion criteria to ensure the inclusion of all available, relevant evidence.

## 2.2. Article Selection

Two independent reviewers (MA and EM) examined and analyzed article titles, article abstracts, and full-text documents for eligibility. Articles progressing to full-text review were screened for final eligibility based on prespecified inclusion and exclusion criteria derived from our PICO (Population, Intervention, Comparison, and Outcome) question. Our PICO criteria were as follows:

Population: patients undergoing elective primary THA with prior lumbar spine fusion;  
Intervention: dual-mobility cups;  
Comparison: either other types of cups or no cups;  
Outcome: incidence of postoperative complications.

The inclusion criteria were randomized controlled trials, non-randomized prospective trials, or retrospective observational cohort studies that were published in or translated into English with a full text and that examined the effectiveness of dual-mobility cups in patients undergoing primary THA with prior LSF. Trials not meeting the PICO criteria were excluded. Duplicate articles were removed, as were studies with unavailable data. Disagreements were reconciled after review with consultation from the senior author.

## 2.3. Data Collection and Data Items

Two authors (MA and EM) extracted the data from the included studies independently. Self-designed tables were generated to sort both the qualitative and quantitative data for our analysis. The extracted data variables used were as follows: (1) demographics and study characteristics (author, country of trial, year of publication, type of study, and level of evidence), (2) patient characteristics (number of patients, mean age, sex, body mass index, and follow-up period), (3) surgical characteristics (type of previous LSF and characteristics of THA), and (4) DMC characteristics (size of acetabular shell and cup).

The two reviewers (MA and EM) independently used the methodological index for non-randomized studies (MINORS) framework to evaluate the methodological quality of the included non-randomized trials [24]. This index includes twelve items, and each item is scored as “0” (not reported), “1” (reported but inadequate), or “2” (reported and adequate). The level of evidence was designated for each study based on guidelines previously introduced by the American Volume of the Journal of Bone and Joint Surgery in 2003 [25].

## 2.4. Statistical Analysis

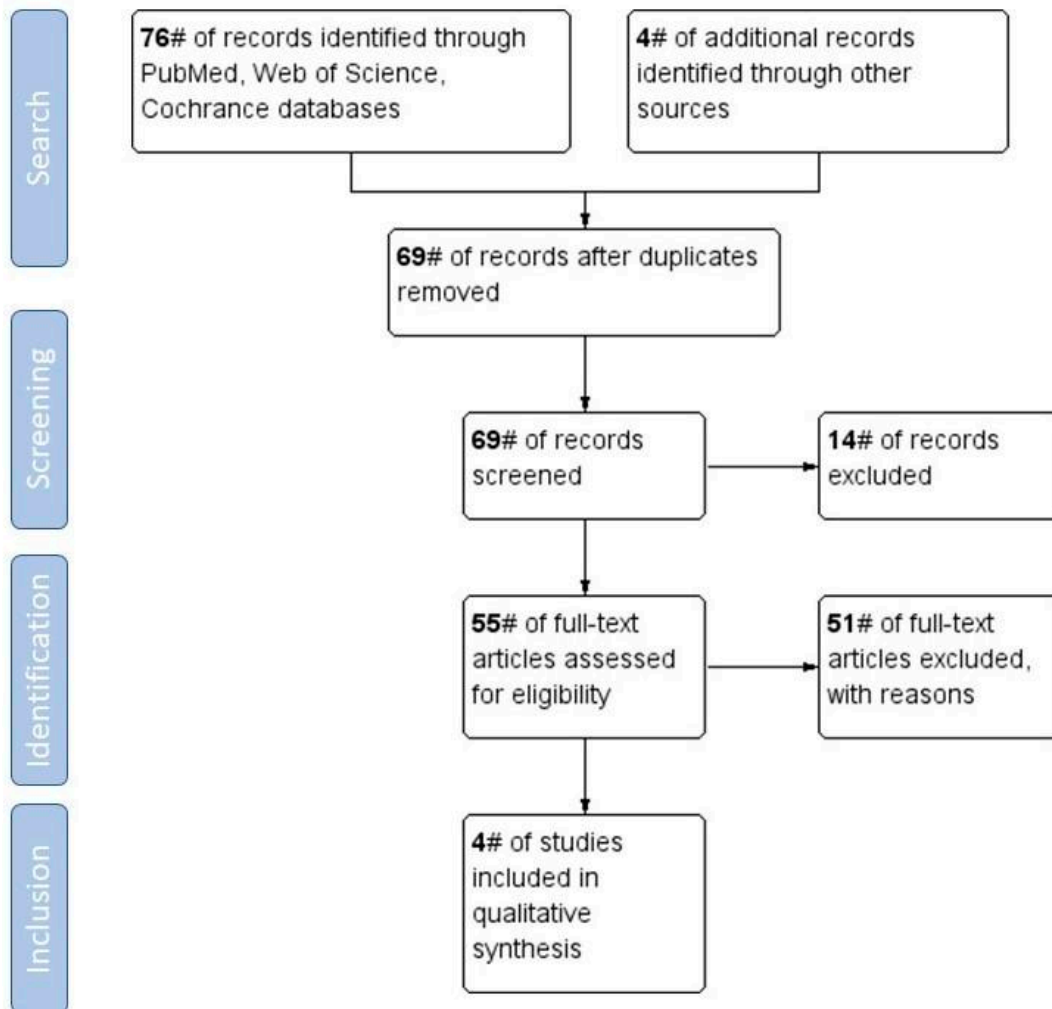
Graph pad prism (version 8.0.0) was used to analyze the data. Mean, standard deviation, range, median, and interquartile range were reported. Continuous variables were presented as mean  $\pm$  standard deviation (SD), while categorical variables were summarized as percentages.

# 3. Results

## 3.1. Search Strategy and Study Selection

Our search strategy identified 76 publications for possible inclusion. The PRISMA diagram for our protocol is displayed in (Figure 1). A manual search through the references of screened publications produced an additional four articles. After duplicates were removed, 69 full-text articles were screened for eligibility according to the inclusion criteria. After screening, 65 studies were excluded due to an irrelevant population, intervention,

comparison, or outcome. After eligibility screening, four studies met the inclusion criteria. Based upon the American Academy of Orthopedic Surgeons Evidence-Based Practice Committee, two out of four studies have level III grade evidence, while the other two are level IV. (Figure 1)



**Figure 1.** Search strategy identification, inclusion, and exclusion flow chart.

### 3.2. Geographical Distribution of the Included Studies

Four studies (284 patients) examined the effectiveness of DMCs in patients undergoing primary THA with prior LSF within the study period between 2019 and 2020. Two of the studies were conducted in the United States, while the other two were conducted in Europe.

### 3.3. Methodological Index for Non-Randomized Studies (MINORS)

There was no significant correlation between the year of publication and the total MINORS score ( $r^2 = 0.7426$ ). Most included studies had some methodological limitations, with an average MINORS score of 10.5, ranging from 5 to 18 (Table 1). The following parameters were most likely to receive a low score: (1) the inclusion of consecutive patients, (2) prospective collection of data: the vast majority of data were not collected according to an established protocol before beginning the study, (3) unbiased assessment of study endpoints: evaluations were not blinded, and the rationale for non-blinding was not clearly stated, (4) a follow-up period appropriate to the aim of the study, (5) prospective calculation of the study size: a power analysis was not performed prior to starting the study, (6) an adequate control group, (7) contemporary groups: there were some historical comparisons between control and studied groups that were not managed in same time

period, (8) baseline equivalence groups: comparative groups were not similar regarding criteria other than the studied endpoints, and (9) an adequate statistical analysis: some of the included studies did not report confidence intervals nor relative risk. (Table 1).

**Table 1.** Quality assessment for non-randomized studies (MINORS).

Quality Assessment for Non-Randomized Studies (MINORS)	Mean	SD	MIN	MAX
(1) A clearly stated aim	1.75	0.5	1	2
(2) Inclusion of consecutive patients	0.75	0.95	0	2
(3) Prospective collection of data	0	0	0	0
(4) Endpoints appropriate to the aim of the study	1.75	0.5	1	2
(5) Unbiased assessment of the study endpoint	1.25	0.5	1	2
(6) Follow-up period appropriate to the aim of the study	1	1.15	0	2
(7) Loss to follow-up less than 5%	2	0	2	2
(8) Prospective calculation of the study size	0	0	0	0
<b>Total for non-comparative (=16)</b>	<b>8.5</b>	<b>3.10</b>	<b>5</b>	<b>12</b>
(9) An adequate control group	0.5	1	0	2
(10) Contemporary groups	0.5	1	0	2
(11) Baseline equivalence analyses	0.5	1	0	2
(12) Adequate statistical	0.5	1	0	2
<b>Total (=24)</b>	<b>10.5</b>	<b>5.80</b>	<b>5</b>	<b>18</b>

SD, standard deviation; MIN, minimum; MAX, maximum.

### 3.4. Patient Characteristics

The four included studies followed-up 284 patients post-THA to demonstrate the incidence of complications in the setting of dual-mobility cup implantation. The average age across the included studies was  $68.22 \pm 1.89$  years old (a range of 46–87). Sixty-four percent of the included population was female. The average body mass index (BMI) was 28 across the studies. A total of 284 patients were evaluated, and 78% of patients had received prior one- and two-level lumbar spine fusions. The majority of THA implants were modular dual-mobility cups, although this was only reported by two studies [7,8]. (Table 2)

**Table 2.** Study characteristics.

Author	Country	Study Design	Level of Evidence	Patient Number	Sex F/M	Use of Robotic THA	Spinal Surgery	Mean Age (Years)	BMI	Follow-Up (Months)
Nessler 2020	USA	Case series	IV	93	56/47	robotic (65%)	LSF	66	30	32.4
Chalmers 2020	USA	Case series	IV	80	57/23	robotic (33%)	LSF	69	28	36
Dagneaux 2019	France	Case-control	III	82	49/33	N/A	DJD or LSF	70.4	26	N/A
Mononen 2020	Finland	Retrospective	III	29	N/A	N/A	LSF or Discectomy	67.5	N/A	N/A

USA: the United States of America; F: female; M: male; DJD: degenerative joint disease; LSF: lumbar spine fusion; mm: millimeter; NA: not available; BMI: body mass index.

### 3.5. Patient Outcomes with DMCs

Radiographic outcome measurements of the DMC implants were reported by three studies (Table 3). Chalmers et al. specifically reported that mean acetabular cup inclination was  $44^\circ$  (ranging from  $30^\circ$  to  $57^\circ$ ) and anteversion was  $24^\circ$  (ranging from  $12^\circ$  to  $40^\circ$ ). A total of 78 (90%) and 48 (55%) of acetabular cups were within the Lewinnek safe zone for inclination and anteversion, respectively [7]. Dagneaux et al. reported that mean anteversion

and inclination among DMC acetabular components were 13° and 46°, respectively [6]. Moreover, 90% and 64% of acetabular components were within Lewinnek's safe zone for anteversion and inclination measurements, respectively. Nessler et al. did not report individual measurements but noted that all acetabular components were implanted with approximately 20° of anteversion and 45° of inclination [8].

**Table 3.** Study Evaluated for Outcomes.

Author	Acetabular Shell	Acetabular Cup	Type of Dual-Mobility Cup	Acetabular Anteversion	Acetabular Inclination	Dislocation Rate
Nessler 2020	44–62 mm	36–48 mm	14% ADM 86% MDM	~20°	~45°	0%
Chalmers 2020	52 (44–62) mm	42 (36–52) mm	35% ADM 65% MDM	24°	44°	0%
Dagneaux 2019	N/A	N/A	N/A	N/A	N/A	N/A
Mononen 2020	N/A	32 mm	N/A	13°	46°	0%

ADM: anatomic dual mobility; MDM: modular dual mobility; mm: millimeter; NA: not available.

Two out of the four trials reported dislocation rates among their DMC cohort specifically [7,8]. No patients in Chalmer et al.'s cohort of 80 patients (86 THA) undergoing DMC implant following previous LSF experienced implant dislocation over a mean follow-up of 3 years [7]. Moreover, the radiographic review demonstrated no liner dissociation in any patients. In Nessler et al.'s retrospective review of 93 patients receiving DMCs, they also identified no cases of implant instability or dislocation over an average follow-up of 2.7 years [8]. While Mononen et al. evaluated 29 patients with DMCs implanted following prior spinal surgery, they did not report the dislocation rate among this cohort. Rather, they found that larger femoral head components reduced dislocation rates in general [5]. Only Chalmers et al. reported patient-reported outcomes. They reported that DMCs were associated with significant postoperative improvement in HOOS Jr, VR-12 physical, and VR-12 mental (all  $p < 0.001$ ) [7]. In patients receiving dual-mobility cup implants, the overall incidence of postoperative complications in the patient population was 10% (10/173) [7,8]. Complications included deep venous thrombosis, periprosthetic loosening, infection, and greater trochanteric fracture. (Table 3)

#### 4. Discussion

Dislocation remains one of the most common complications after THA and a leading cause of revision, which is further exacerbated in the setting of prior lumbar surgery [4,26–32]. One consequence of spinal fusion is an alteration in normal spinopelvic biomechanisms. The orientation of the pelvis determines the sagittal position of the sacral plate in relation to the femoral heads [30]. Forward motion (anteversion) of the pelvis decreases the pelvic tilt (PT), while retroversion increases the PT, forcing the hips to extend with an anterior imbalance when walking, in turn moving the acetabulum vertically [31]. Therefore, when going from standing to sitting, lumbar lordosis decreases, tilting the pelvis posteriorly [32]. A posterior PT increases acetabular anteversion to accommodate femoral flexion.

In fusion procedures that render a spine immobile, a change in position from standing to sitting does not allow for the compensatory increase in acetabular anteversion or PT adjustment, leading to a greater risk of anterior dislocation and impingement with an anatomically positioned THA [33]. Lewinnek et al. defined a 'safe zone', an important factor for maintaining THA stability, for the acetabular cup within the anatomical measurements of 5–25 degrees of anteversion and 30–50 degrees of inclination [34]. However, the exact acetabular component position suited for each patient is unknown, especially for those with prior LSF. This suggests that cup placement should be individualized based on the type of spinal deformity [8,35].

A recent meta-analysis by An et al. demonstrated that previous LSF increases the relative risk of THA dislocation and revision two- to three-fold [2]. Bedard et al., in an institutional study, demonstrated that the THA dislocation rate among THA patients with

concurrent spinopelvic fusion was 20% [26]. Barry et al. demonstrated that patients with pre-existing LSF experienced worse early outcomes after primary THA including higher rates of complications (31%) and reoperation (14%) [4]. Patient-reported outcomes were also poorer in patients with prior LSF compared to those without [2]. Pre-existing lumbar disease alone has been associated with poorer patient-reported outcome measures post-THA [36]. However, the invention of DMCs has opened the door to decreasing the risk of dislocation, particularly in those with prior spinal fusion surgery.

This article provides a review of the current literature to reach a consensus as to the potential benefits of DMCs in primary THA with prior lumbar fusion. The main finding of this paper is that DMC utilization in primary THA in the setting of prior lumbar fusion may be more effective in the prevention of dislocation compared to standard cups. As seen in two included retrospective studies, dislocation rates were 0% among the study cohorts comprising 93 and 80 patients, respectively [7,8]. Additionally, the rate of postoperative complications, such as deep venous thrombosis, periprosthetic loosening, infection, and greater trochanteric fracture, was 6%. These findings are consistent with reported outcomes in current studies of patients with DMC THA [9].

The finding that the acetabular component of DMCs does not contribute to added instability suggests the benefit of the increased range of motion with DMC versus traditional implants. DMCs have two interfaces: the convex surface of the polyethylene liner with the acetabular shell that is engaged when exceeding normal range of motion, and the femoral head and the polyethylene liner that is engaged during normal range of motion [9]. As the polyethylene liner articulates, the range of motion is increased until the femoral neck impinges against the rim of the shell [10]. The head liner functions as a large femoral head, allowing for a greater range of motion, head-to-neck ratio, and jump distance before dislocation [10]. To prevent impingement, the distance between the femur and acetabulum must be increased, which is producible with DMCs [11]. Given the traditional risks associated with a history of prior lumbar fusion, these early studies demonstrating the likely benefits of DMCs in reducing THA dislocation rates indicate that further, high-quality prospective investigations are needed. It will also be important to compare DMCs to alternative implant options such as the use of high-walled polyethylene liners or constrained acetabular components.

It is important to note that not all included studies specified dislocation rates. Although most dislocations occur within 1 year after THA, late dislocations (i.e., after 5 years) were not reported in any of the included studies; thus, conclusive findings cannot be drawn and extended follow-up is needed in future studies [37]. Additionally, the period between fusion and THA varied greatly between groups. It is difficult to conclude if the time between the two procedures could influence dislocation rates and complications. One other limitation is the surgical approach. THAs in the included studies were performed via either direct anterior, posterior, superior, or posterolateral approaches, with each group having a relatively small population size for comparison. As such, we are unable to comment on the associations between the type of surgical technique and complications; moreover, there is no current study specifying the appropriate approach to be taken by surgeons when treating patients who have undergone spinal fusion. Additional limitations may be due to detectable biases in the included studies. Only studies published in English were included, although there is no evidence of systematic biases due to language restrictions in medical meta-analyses [38,39]. The inclusion of non-randomized trials in our systematic review may cause limitations in data quality. However, the Cochrane Handbook considers the inclusion of non-randomized studies in data synthesis acceptable given that the authors carefully consider the likely extent of heterogeneity between included studies when deciding whether to quantitatively pool findings [40].

## 5. Conclusions

Dual-mobility cups are a viable alternative to standard cups for patients with prior lumbar spine fusion who present a higher risk of THA instability. By using dual-mobility

cup implants, the greater femoral head size and jump distance both provide a reduced rate of THA dislocation and instability. Furthermore, this reduces postoperative complications and may have significant health system benefits by reducing the THA revision burden. Although these data are encouraging, future high-quality, prospective, studies are needed to determine of the efficacy of DMC THAs in patients with prior spine fusion and to demonstrate the long-term stability of these implants. Special considerations should be given to the revision infection, economic burden, and prosthetic and intra-prosthetic dislocation.

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## Abbreviations

Dual-mobility cups (DMC); lumbar spine fusion (LSF); total hip arthroplasty (THA); methodological index for non-randomized studies (MINORS); standard deviation (SD).

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