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Dual mobility in primary total hip arthroplasty: current concepts

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- Total hip arthroplasty (THA) is one of the most successful surgical procedures – reducing pain and providing functional improvement. However, THA instability is a disabling condition and remains the most common indication for revision THA. To combat the risk of instability, the concept of dual mobility (DM) was developed. This article provides a comprehensive review of DM in the literature.
- Widespread use of first-generation DM was limited due to concern regarding wear of the polyethylene head and the unique complication of intraprosthetic dislocation (IPD). Implant modifications using highly cross-linked, durable polyethylene and a smooth, cylindrical femoral neck have all but eliminated IPD in contemporary DM.
- In multiple studies, DM demonstrates statistically significant reductions in dislocation rates comparative to standard bearing primary THA. These results have been particular promising in high-risk patient populations and femoral neck fractures – where low dislocation rates and improved functional outcomes are a recurrent theme. From an economic perspective, DM is equally exciting – with lower accrued costs and higher accrued utility comparative to standard bearing THA.
- Longer-term clinical evidence and higher-quality prospective comparative studies are required to strengthen current research. Dual mobility may well represent the future gold standard for THA in high-risk patient populations and femoral neck fractures, but due diligence of long-term performance is needed before recommendations for widespread use can be justified.

Keywords: dislocation; dual mobility; total hip arthroplasty; total hip replacement

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Introduction

Total hip arthroplasty (THA) is one of the most successful surgical procedures – reducing pain and providing functional improvement to enhance patients' quality of life. As healthcare continues to evolve and life expectancy rises, the demand for THA will grow, with the number of THAs performed in the United States projected to increase by 174% by 2030 compared to 2005.[1] However, THA is not without risk. Total hip arthroplasty instability is a disabling condition and remains the most common indication for revision THA in the United States; accounting for 22.5% of revisions.[1] It is particularly prevalent in high-risk cohorts (such as those with neuromuscular disease, obesity or cognitive dysfunction) where revision rates have reached up to 14%.[2] The economic ramifications of this are staggering – with the cost of revision often exceeding 50,000 US dollars prior to consideration of additional costs such as post-acute hospital care.[1]

To combat the risk of instability, Gilles Bousquet and Andrè Rambert introduced the concept of dual mobility (DM) in France in 1974.[3] Incorporating an additional bearing with the interposition of a mobile polyethylene layer between the prosthetic head and the acetabular shell, the dual mobility cup (DMC) combines Charnley's low-friction principle with the McKee–Farrar concept of an increased femoral head-to-neck ratio to maximize stability.[4,5] Despite promising results in reducing instability in France, widespread use of the DMC was limited due to concerns regarding the nature of dual articulation causing accelerated wear of the polythene acetabular liner and the unique complication of intraprosthetic dislocation (IPD).[6–9] However, following the United States Food and Drug Administration's approval of the DM design in 2009, use of DM has undergone a renaissance in recent years.

Fig. 1 Vice clamp to assemble metal head in polyethylene outer head (picture courtesy of LIMA Corporate, Italy).

Fig. 2 Assembled components (picture courtesy of LIMA Corporate, Italy).

This article provides a comprehensive up-to-date review of DM in the literature. We describe first-generation and contemporary DM, analyse the use of DM in primary THA, and discuss the role for DM in femoral neck fractures and fixed spinopelvic alignment. Finally we assess the cost-effectiveness of DM, and explore what the future may hold.

First-generation DM

The first generation of DMC incorporated a hemispherical stainless-steel acetabular socket with an alumina coating and an inner polished surface. This was anchored with two stainless-steel pins pressed into two holes in the socket and a 4.5 mm screw inserted through a clip into the ilium. The mobile outer head was constructed from ultra-high molecular weight polyethylene (PE) and the inner femoral head was metal. Intraoperatively, a vice clamp was used to force the inner femoral head into the outer head and beyond its PE retentive rim (see Figs. 1 and 2).

The inner femoral head is dominant during normal ranges of motion, and the outer PE head is dominant during high ranges of motion – explaining the term 'dual mobility'. Stability is optimized by combining Charnley's low-friction principle with the McKee–Farrar concept of an increased femoral head-to-neck ratio, thereby reducing the risk of dislocation by facilitating an increased range of movement before impingement and maximizing the jump distance needed for the femoral head to separate from the acetabular socket.[4,5]

Short-term results illustrated the effectiveness of first-generation DM in improving stability. In 1986, Bousquet described a dislocation rate of 2.2% in 136 cases of revision THA using DM at a mean 35 months follow-up.[6] This has been corroborated in the longer term, with Boyer et al reporting no dislocations at 22 years follow-up for 240 cases of primary THA with DM.[7]

However, a complication observed exclusively in DM was reported in the literature. 'Intraprosthetic dislocation' (IPD) defines dissociation of the outer PE head from the inner femoral head secondary to degeneration of the PE retentive rim. Subsequently, the femoral head remains in the acetabular socket while the PE head lies adjacent – illustrated by a C-shaped bubble on plain radiographs. Critically, the resultant metal-on-metal articulation between the inner femoral head and the acetabular socket causes rapid wear, release of metal ions and local soft-tissue metallosis. Meanwhile the patient experiences acute limb shortening and pain.

Hamadouche et al described a 2% rate of IPD in 51 cases of revision THA using DM at a mean follow-up of 51 months.[8] In a larger prospective study, Philippot et al reported a 4.1% rate of IPD in 1960 primary THA using DM at a mean follow-up of 14 years.[9] Scepticism following recurrent reports of IPD may explain the limited global use of first-generation DM, with the United States Food and Drug Administration's approval of the DM design only being attained in 2009.

Contemporary DM

The contemporary DMC has evolved considerably since Bousquet's first-generation model in 1974. D'Apuzzo et al's retrieval study of PE DM components illustrated that, although motion occurs at both articulations, the motion of the femoral head against the inner aspect of the PE head dominates, producing higher wear.[10] Building upon this, Neri et al's retrieval study of 93 DM implants demonstrates IPD is a wear complication mainly resulting from contact between the femoral neck and the outer side of the retaining PE rim.[11] Consequently, the contemporary DMC has been refined to include a more anatomic cup which reduces anterior overhang, the PE insert has been modified via addition of a retentive chamber to decrease the risk of dislocation, and the femoral neck has become thinner and more polished to reduce liner impingement.[12,13] Further, advancement in biomaterial technology has resulted in the first-generation DMC's alumina coating being replaced by a bilayer of porous titanium and hydroxyapatite, and development of a highly cross-linked, durable PE rim, minimizing wear during contact with the femoral neck.[12,13]

Cemented fixation is not widely used, with cup survivorship varying from 94% to 96% at 5 to 8 years.[8,14,15] Cementless fixation relies on primary stability, leading to osteointegration of host bone onto the implant. Subsequently there is an element of remodelling, which is dependent on transfer of load to the bone from the cup.[16]

Laboratory data illustrate the favourable rate of wear in the contemporary DMC comparative to first-generation implants. Netter et al analysed the wear performance of highly cross-linked PE DM implants in adverse conditions and demonstrated an excellent tolerance for third-body particles and microseparation.[17] Similarly, a research article by the manufacturer (Stryker Orthopaedics) showed a reduction in wear of up to 75% using contemporary highly cross-linked PE DM components comparative to the first-generation DMC inert PE implant.[18]

These findings have been corroborated by clinical data. In Darrith et al's systematic review comprising 54 articles with 10783 DM primary THAs at a mean follow-up of 8.5 years, no cases of IPD were recorded for primary THA undertaken after 2007.[13] Further, the increased incidence of IPD in primary THA using the first-generation DMC was statistically significant, with a 3.3% incidence of IPD in primary THA using first-generation DM with an inner head size of 22 mm.[13] Similarly, Levin et al's analysis of 693 DM revision THAs performed after 2010 illustrated an IPD rate of just 0.2% at 31 months mean follow-up (compared to the 2% rate of IPD in DM revision THA using first-generation DM at 51 months mean follow-up).[19]

DM versus standard bearing in primary THA

The contemporary DMC has demonstrated excellent short and mid-term results compared to standard bearing implants in primary THA. In a prospective cohort study of 143 DM versus 130 standard bearing implants at 4 years follow-up, Epinette established a statistically significant difference in dislocation rate favouring DM (0% versus 5.4%). In all cases the stem was the same, and the acetabular shell was an hydroxyapatite (HA)-coated press-fit cup coupled with a 28 mm head. There were no cases of mechanical cup loosening in either cohort.[20]

Similarly, in a case control study comparing 105 DM and 215 standard bearings with a 22 mm head in primary THA, Caton et al observed a statistically significant difference in both dislocation rate (0.9% versus 12.9% respectively) and revision rate (2.1% versus 12.9% respectively) at 10 years follow-up.[21] Equally reassuringly, when analysing a matched cohort of 231 primary DM revisions and 231 primary standard cup revisions, Prudhon et al demonstrated no significant difference in aseptic loosening, infection or periprosthetic fracture between the two cohorts. Instead, the principle significant difference was the increased rate of revision for dislocation in standard bearing cups (17.7%) comparative to DM (4.7%).[22]

Much of the literature on DM is based in France where its use is more commonplace. Comparatively, global national registry data for DM is limited. However, this is likely to change, with the American Joint Replacement Registry reporting use of DMC in 9.7% of all primary hip arthroplasties in 2017.[23] Further, encouraging early results have emerged in some European national joint registries: comparing 620 DMC with 2170 cemented Exeter cups with a 28 mm head in the Lithuanian Arthroplasty Register, the cumulative revision rate at 5 years was 3.9% in the DM group and 5.2% in the cemented Exeter group.[24] Moreover, in the Dutch Arthroplasty Register, analysis of 3038 DMC and 212,915 standard bearing cups established 0.2% of DMC underwent revision for dislocation at 5 years follow-up compared to 0.5% in the standard bearing group.[25]

Promising results have also been demonstrated when comparing larger femoral head sizes. In a retrospective study of 501 primary THAs in Chicago, Haughom et al illustrated a statistically significant reduction in dislocation rates (0.5% versus 4.5%) using anatomic head sizes comparative to standard bearings with a 36 mm head.[26] Similarly, a meta-analysis of single bearing, DM and large femoral head primary THA established DM to be the implant of choice at 5 years follow-up, with the lowest rates of revision and dislocation (with large femoral head THA exhibiting a relative risk of revision or dislocation of 1.07 comparative to DM).[27]

The results of the contemporary DMC have been even more exciting in high-risk patient populations. Hernigou et al compared the rate of dislocation in obese (defined as a BMI exceeding 30 kg/m^2) patients undergoing primary THA with either DM (or constrained liner) or standard cup. At 7 years follow-up, a statistically significant reduction in dislocation was observed in obese patients who had used DM or constrained liners (2%) rather than the standard bearing cup (9%). Further, use of DM was more effective in reducing dislocation rates than undergoing bariatric surgery prior to THA (14% dislocation rate at 7 years follow-up).[28]

Patients with cerebral palsy or other neurologic diseases are also at high risk of instability following THA. This is likely to be secondary to persistent coxa valga, increased femoral anteversion and associated imbalanced forces generated by the adductor, internal rotator and hip flexor muscles. Raphael et al's review of the use of standard bearing THA in patients with cerebral palsy demonstrated a 14% dislocation rate at a mean follow-up of 9.7 years.[2] Subsequently, DM has been utilized with promising short-term results: Sanders et al report no dislocations in 11 DM THA for patients with cerebral palsy at a mean follow-up of 39 months.[29] Similarly, Morin et al describe no aseptic loosening or dislocations in 40 DM THA performed for patients with cerebral palsy at a mean follow-up of 5 years.[30]

DM in neck of femur fractures (NOFs)

Replacement arthroplasty is the treatment of choice for displaced fragility neck of femur fractures (NOFs), facilitating early mobilization and full weight bearing. Hemiarthroplasty (HA) is associated with shorter operative times and reduced perioperative blood loss comparative to THA; however, THA results in improved Harris Hip Scores and increased walking distance.[31] Consequently, the National Institute for Health and Care Excellence (NICE) guidelines currently advise THA rather than hemiarthroplasty (HA) in cognitively unimpaired patients able to independently mobilize outdoors with no more than the use of a stick.[32]

THA in NOFs are often at high risk of instability secondary to a combination of muscular insufficiency and propensity for recurrent falls. Repeat dislocations in this patient demographic represent a life-threatening complication. Consequently, several centres report using DM THA for NOF with excellent early results. In a population of 105 patients, Tarasevicius et al described a statistically significant reduction in dislocation rate for THA using DM (0%) compared to standard cups (10.4%) during the first postoperative year.[33] Similarly, in a prospective multi-centre study of 214 NOFs treated with DM THA, Adam et al reported a dislocation rate of just 1.4% at 9 months follow-up with 70% of patients returning home with no increase in dependency.[34]

DM THA has also performed favourably compared to HA. Bensen et al retrospectively compared 171 bipolar HA with 175 DM THA performed for patients with displaced NOF. A statistically significant difference in the rate of dislocation was observed – with dislocation occurring in 14.6 % of bipolar HA compared to 4.6% of DM THA.[35] Patient outcome studies are also promising: in Tabori-Jensen et al's cross-sectional study of 124 patients with DM THA following NOF, 89% of patients were satisfied with their operative outcome, with health-related quality of life questionnaires comparable to the population norm at a mean 2.8 year follow-up.[36] Likewise, Kim et al reported a statistically significant improvement in Harris Hip Scores in 168 NOF patients treated with DM THA comparative to HA at 22 months follow-up.[37]

Darrith's systematic review of 554 DM THA performed in NOF patients demonstrates a survival rate of 97.8% at 1.3 years mean follow-up. Aseptic loosening and IPD were reported in only one patient (0.18%) with dislocation occurring in just 2.3%.[13] Although longer-term follow-up is required, excellent functional outcomes coupled with a rate of revision approximately one-fifth of that reported in standard THA for NOFs is exceptionally promising.

Furthermore, DMC may represent an excellent option in salvage THA for failed fixation of intertrochanteric fractures. In such patients, salvage THA often represents a technical challenge, and is associated with higher rates of postoperative instability.[38,39] Many factors are likely to contribute to this including structural damage post removal of internal fixation, loss of bony landmarks due to trochanteric displacement and patient demographic-related characteristics such as poor bone quality and cognitive dysfunction.[38,39] Therefore, the reduced dislocation rates exhibited by DMC suggest it may represent a useful option.[33–35] Limited literature investigates this: Laffosse et al report use of DM THA in four patients with failed intertrochanteric fracture fixation with no dislocations observed at 20 months follow-up.[40] Larger scale clinical studies are required.

DM in fixed spinopelvic alignment

Recent research has focussed on the influence of spinopelvic mobility and the acetabular component inclination and anteversion for THA.[41,42] Movement from standing to sitting is accompanied by posterior tilt of the pelvis, thus enabling the acetabulum to open for clearance of the hip. In a consecutive series of 1000 patients, Esposito et al demonstrated fixed spinopelvic alignment from standing to sitting causes a statistically significant increase in dislocation post THA, with 92% of dislocators suffering lumbar multi-level degenerative disc disease or surgical spine fusion.[41] Therefore such patients may benefit from DM THA to reduce the risk of dislocation. Building upon this further, Stefl et al used preoperative spinal mobility to determine intraoperative acetabular component position in 160 patients undergoing THA. Although most cases of spinal imbalance could be corrected with appropriate intraoperative acetabular component inclination and anteversion, a cohort of patients with a change in ante-inclination of less than 5° between sitting and standing were identified to be at pathological risk for dislocation even with perfect acetabular component positioning. Stefl et al concluded that this cohort should be considered candidates for DM THA.[42]

Cost-effectiveness of DM

The economic ramifications of THA complications are staggering – with the cost of revision often exceeding 50,000 US dollars prior to consideration of additional costs such as post-acute hospital care.[1] Furthermore, the mean cost for revision surgery in the UK for aseptic cases is £11,897, the full costs of which are often not fully reimbursed by current National Health Service (NHS) hospital tariffs.[43] The significantly reduced revision rates exhibited by contemporary DMC suggest DM may represent a far more cost-effective modality comparative to standard THA bearings.

In France, using Markov modelling with determination of the incremental cost-effectiveness ratio (ICER), the direct healthcare costs of 80,405 patients who had undergone THA were analysed over 4 years. Using a conservative relative risk of dislocation of 0.4 for DM THA versus standard bearing THA, when considering the costs resulting from readmission and rehabilitation, the authors determined DM THA could be expected to save 283 Euros per patient. This result translates into a major economic impact, with an estimated cost-saving of nearly 39.62 million Euros if DM THA was performed for all 140,000 primary THAs carried out in France annually.[44]

Moreover, in Barlow et al's Markov analysis of the lifetime cost-effectiveness of differing arthroplasty modalities, DM THA demonstrated absolute dominance over standard bearing THA – with lower accrued costs (US$39,008 versus US$40,031) and higher accrued utility (13.18 versus 13.13 quality-adjusted life years).[45] Likewise, in patients with spinal deformity, Elbuluk et al illustrated that DM was cost-effective when dislocation rates were reduced to 0.9%, without including longer-term economic implications associated with dislocation such as revision surgery or loss of income.[46] Therefore, although longer-term financial analysis is required, early results suggest DM represents a cost-effective modality for primary THA.

Conclusion

Total hip arthroplasty is one of the most successful surgical procedures – reducing pain and providing functional improvement to enhance patients' quality of life. However, it is not without risk. Total hip arthroplasty instability is a disabling condition and may remain the most common indication for revision THA. The DMC has always exhibited excellent results in reducing THA instability.[6,7] Scepticism regarding first-generation DM centred on complications unique to the DMC such as IPD.[8,9] Implant modifications including use of highly cross-linked, durable PE and a smooth, cylindrical femoral neck have all but eliminated IPD in the contemporary DMC.[12,13]

In multiple short-term studies, DM THA demonstrates a statistically significant reduction in dislocation rates comparative to standard bearing primary THA.[20–22] These results have been particularly promising in high-risk patient populations and femoral neck fractures – where low dislocation rates and improved functional outcomes are a recurrent theme.[33–35] From an economic perspective, DM is equally exciting – with research demonstrating lower accrued costs and higher accrued utility comparative to standard bearing THA.[43–45] Despite this, longer-term clinical evidence and higher-quality prospective comparative studies are required to strengthen current research. DM may well represent the future gold standard for THA in high-risk patient populations and femoral neck fractures, but due diligence on their long-term performance is needed before recommendations for their widespread use can be justified.

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