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The role of dual-mobility in primary total hip arthroplasty

Alberto Momoli[1], Alessio Mulone[2], Maurizio Ulgelmo[2], Enrico Lunardelli[2], Carlo Ambrosini[2], Stefano Giaretta[1]

[1] UOC Orthopedics and Traumatology, San Bortolo Public Ospital, AULSS 8 Berica, Vicenza, Italy; [2] Orthopedic Clinic, University of Verona, Italy

Summary

Total hip arthroplasty (THA) is one of the most successful surgical procedures in orthopedic surgery. However, to date, instability remains one of the main causes of failure of the first implant, leading to a high number of surgical revisions and causing serious discomfort for the patient.

The dual mobility (DM) implant, designed in France by Prof G. Bousquet and Lng A. Rambert in the 1970s, has shown excellent results in reducing the rate of prosthetic dislocations. The first generation of dual mobility, however, was burdened by a series of complications that limited its use in some categories of high-risk patients.

Over the years, the evolution of prosthetic design and the gradual improvement of materials have made it possible to extend the indications of this type of implant to other categories of patients.

In view of the advantages encountered with the use of dual mobility, this could represent a valid strategy to be adopted in hip prosthetic surgery.

Key words: primary total hip arthroplasty, dual mobility, dislocation, hip instability, high-risk patient

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Correspondence
Stefano Giaretta
UOC Orthopedics and Traumatology, San Bortolo Public Ospital, via Rodolfi 37, 36100 Vicenza, Italy
E-mail: stefano.giaretta@gmail.com

Conflict of interest
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Introduction

Total hip arthroplasty (THA) is considered one of the most successful surgeries in orthopedics as it offers a significant improvement in pain and joint function by improving the quality of life of patients [1]. With the increase in life expectancy, it is estimated that the number of patients who will undergo prosthetic replacement surgery will increase exponentially [2-4]. Despite advances in surgical techniques and implant designs, prosthetic instability is one of the main causes of failure of this surgery. The dislocation rates after primary THA range from 2 to 4% [5] and at present represents the first or second most frequent indication for revision surgery involving serious burden for the patient and an increase in healthcare costs [6,7].

In consideration of the progressive increase in the number of annual implants, it is of fundamental importance to reduce or try to prevent this type of complication by adopting systems that are capable of offering greater stability and longevity of the implant.

In recent years, the use of dual mobility implants has gained increasing popularity and interest from the scientific community as a possible strategy for the reduction and prevention of prosthetic instability.

History of dual mobility

The concept of dual mobility (DM) was invented in 1974 by Prof. Gilles Bousquet of the University Hospital of Saint Etienne and Lng. André Rambert [8], and is based on two fundamental principles:

- the Charnley principle which recommends the use of a significant thickness of polyethylene and femoral head of 22.2 mm to reduce wear due to high friction torque (low friction);
- the McKee-Farrar principle which involves the use of a large diameter femoral head to reduce the risk of dislocation and instability of the prosthesis (Fig. 1).

Combining these two, in some ways contrasting ideas, a dual mobility cup (DMC) is composed of a small femoral head (22.2 or 28 mm), a polyethylene mobile dome insert equipped with an internal retentive edge for the head, and a fixed external metal acetabular cup.

In this system, it is therefore possible to recognize two joints:

- the first joint between the head and the polyethylene insert that guarantees 80% of the articular range of motion (ROM);
- the second joint between the insert and the acetabular cup which occurs when the neck of the femoral stem comes into contact with the margin of the insert and ensures greater stability of the implant at the highest degrees of ROM.

Subsequent studies have shown that, at the extreme degrees of ROM, there is contact between the neck of the femoral stem and the retentive edge of the polyethylene. This feature, which generates a further minimal movement, was described by Noyer in 2003 as the third articulation [9] (Fig. 2).

In this way, the head-PE complex theoretically works like a large femoral head, increasing the jumping distance or the distance to overcome to cause dislocation (Fig. 3).

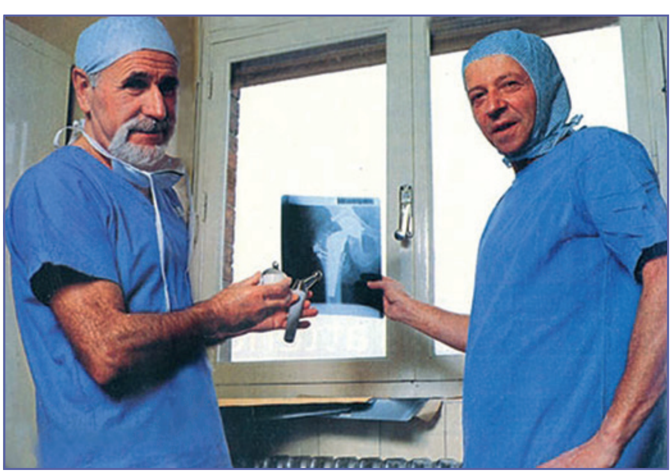

Figure 1. Professor Gilles Bousquet and Engineer Andrè Rambert invented the dual mobility concept.

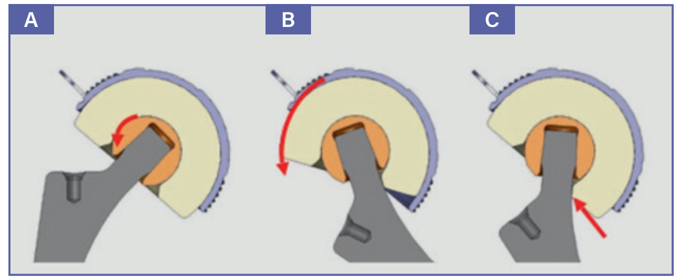

Figure 2. The three articulating surfaces in dual mobility cup: the first articulation (A), the second articulation (B), and the third articulation (C) that act as a large diameter head.

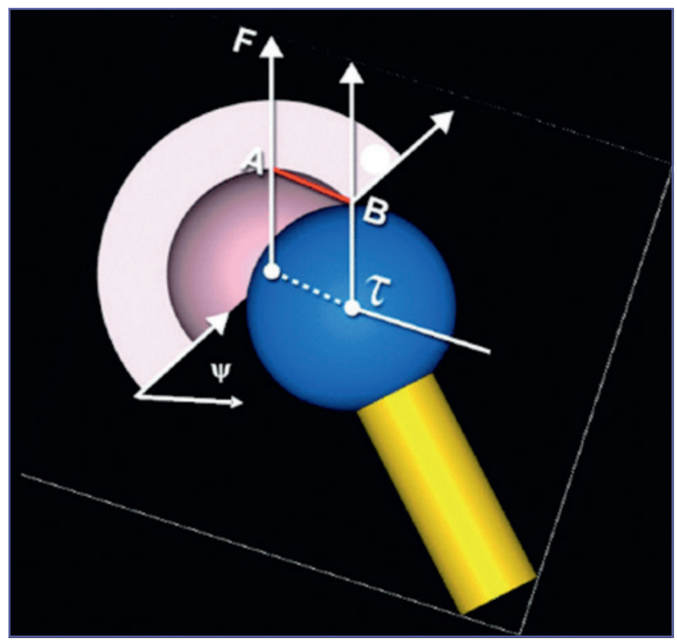

Figure 3. Jumping distance is the degree of lateral translation of the femoral head center required before dislocation occurs.

Originally, the DMC was made up of a 22.2 mm metal head articulated with a linear polyethylene component, articulated in turn with a spherical-shaped acetabular cup in aluminum coated stainless steel (AI203) with a fastening system three-point, with two cone-morse pegs towards the pubic and ischial branches and an iliac bicortical screw, designed to improve the primary stability of the cup (Fig. 4).

Although the first generation of DM had shown promising results, ensuring an increase in implant stability in cases with a high risk of dislocation [10], an exclusive complication of this type of implant was intraprosthetic dislocation (Fig. 5). This complication was due to the degeneration of the retention margin of the

Figure 4. Original design of first generation of dual mobility cup.

Figure 5. A case of intraprosthetic dislocation as a complication of dual mobility implant.

polyethylene insert. The consequent contact between the metal prosthetic head and the cup led to the development of an adverse reaction with the formation of metallosis and rupture of the polyethylene leading to a mechanical failure of the prosthesis. The severity of this potential complication explains why the interest and use of this type of implant was initially limited. Subsequent studies have identified the cause of this problem in contact wear between the rough femoral neck of some types of prosthetic stem and the retentive margin of the insert [9,11,12].

To reduce this wear, changes have been made in subsequent generations of DMC: the retentive edge of the polyethylene insert has been chamfered, the acetabulum cup has been redesigned with a coverage angle greater than 180°, and in some cases polyethylene has been enriched with vitamin E in order to reduce the degradation processes due to oxidation. In addition, the DMC have been associated more with femoral stems with a thinner and polished collar so as to reduce damage to the third joint (Fig. 6). Thanks to these improvements, the intraprosthetic dislocation rate in the new generations of DMC have drastically dropped compared to the past [13,14].

This entailed that while the first generation was mainly used in France, the continuous evolution of these implants and the encouraging results of subsequent generations have favored a global growth of scientific interest in this solution even outside French borders, as demonstrated by the growing number of publications in literature over the course of the last decade [15] (Fig. 7).

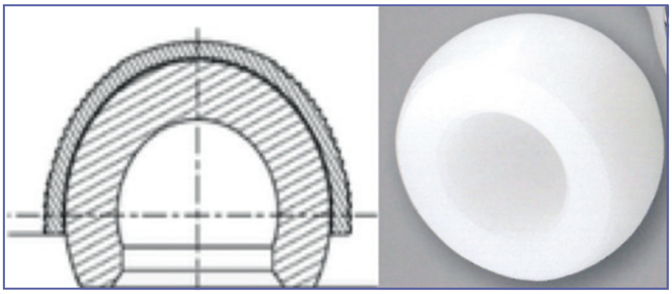

Figure 6. New highly cross-linked polyethylene with chamfered retentive edge.

The excellent results of the DM concept have led over the years to develop other engineering solutions to obtain dual mobility systems using traditional cups. CrCo inserts are installed in the standard cups able to accommodate polyethylene domes so as to combine the potential advantages of standard cups (the use of screws, the coating materials that allow excellent primary and secondary stability) with the concept of dual mobility.

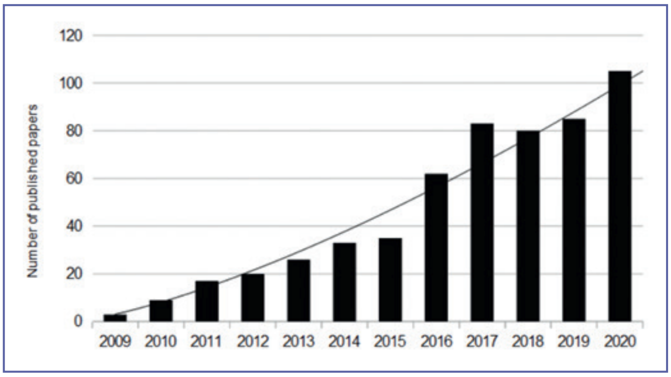

Figure 7. Distribution of published articles on the dual mobility cup according to publication year.

Dual mobility for primary total hip arthroplasty

An analysis of the literature shows that the average percentage of dislocation after primary THA is 2.10% (range 0.12-16.13%) [16]. Instability after primary hip arthroplasty is a multifactorial phenomenon related to non-modifiable patient characteristics such as: anatomical morphologies, abductor muscle deficit, spino-pelvic rigidity, neurological and psychiatric disorders; variables dependent on the surgeon such as the choice of surgical access and type of implant, operator's experience, and positioning of the prosthetic components.

One of the most important modifiable factors is the correct positioning of the acetabulum cup. In 1994, Lewinnek described the so-called "Safe Zone" by observing a reduction in the risk of dislocation for the acetabular cups positioned with an inclination angle of 30°-55° and an anteversion angle of 10°-20°. However, even with the cup positioned within this safety zone, the THA that undergoes dislocation is not negligible [17], representing the reason for 14.5% of hip replacement surgeries in the US in 2019 [6].

To reduce the dislocation rate, one strategy has been to use larger diameter femoral heads (LDH). This was also possible thanks to the improvement in the quality of the polyethylene which allowed the use of increasingly larger heads up to diameters of 36 mm and in addition to the detriment, however, of lower insert thicknesses, creating doubts about the longevity of these implants.

The metal-to-metal hip prosthesis allowed the use of large diameter femoral heads; however, this type of implant was burdened with a high, unacceptable short-to-medium term revision rate. When a femoral stem associated with a large diameter metal prosthetic head was used, the so-called ARMD (Adverse Reaction to Metal Debris) often developed due to the accumulation of metal ions (metallosis from cobalt and chromium) and debris (debris) to level of peri-prosthetic tissues. The metal-metal coupling can therefore be used, with very precise and accurate indications, only with the resurfacing technique.

Dual mobility represents a valid alternative to be able to use large diameter prosthetic heads. This means that, compared to conventional implants, the DM cups have an improved range of motion of 30.5° in flexion, 15.4° in abduction, and 22.4° in external rotation, while maintaining good implant stability.

The increased ROM allows for fewer restrictions on movements and post-operative activities, resulting in better patient satisfaction. This type of implant, in fact, compared with a conventional implant, has shown excellent results in the short-medium term.

Epinette et al. analyzing 143 DM implants *vs* 130 conventional implants in a prospective study with 4 years of follow-up showed 0% dislocation for DM *versus* 5.4% for conventional ones [18].

Caton et al. in a case-control study comparing 105 DM against 215 conventional ones at 10 years of follow-up, reported a dislocation rate of 0.9 *vs* 12.9% and a revision rate of 2.1 *vs* 12.9% [19].

Pituckanotai et al. in a meta-analysis comparing DM and standard THA with large diameter femoral heads found a lower 5-year overall dislocation and revision rate for dual mobility implants [20].

Dual mobility in femoral neck fractures

Replacement arthroplasty is the treatment of choice in displaced femoral neck fractures, as it allows for rapid mobilization and early loading. Although partial hip replacement is associated with shorter operating times and reduced post-operative blood loss compared to total replacement, total hip replacement allows for better functional results with higher Harris Hip Score values [21].

The guidelines of the British National Institute for Health and Excellence in Care (NICE) recommend total hip replacement over hemiarthroplasty in patients without cognitive impairment who are able to walk outdoors even with aids [22].

THA performed for femoral neck fracture treatment is, however, known to be characterized by a high rate of secondary instability due to a combination of muscle failure and propensity for accidental falls [23].

The risk of prosthetic dislocation is in fact up to 3.8 times higher than in total hip replacements on coxarthrosis [24], and is the main cause of revision of THAs on fractures [25].

The use of a dual mobility implant in this type of patient could represent a valid option to prevent postoperative dislocation. Although studies in the literature are often limited by short follow-up times and non-homogeneous populations due to morbidity, the data show favorable functional and clinical results with a low rate of dislocation, especially in patients with other risk factors for instability. On the other hand, no difference was found in the incidence of other complications such as infections or periprosthetic fractures. Darrith et al. in a review of 554 THA with DM cups on femoral neck fracture, found a

survival rate of 97.8% at 16 months and a dislocation rate of 2.3% [13]. This data was also confirmed by a recent meta-analysis analyzing 7189 THA DM on fracture, which showed a dislocation rate of 1.5% and intraprosthetic dislocation of 0.04% after an average follow-up of 30 months [26].
In addition to the treatment of the intracapsular femoral neck fracture, the DM may represent an option for prosthetic conversion following a failure of internal osteosynthesis for extracapsular fractures. The severe bone deficit after removal of the means of synthesis and the advanced cognitive impairment typical of these patients contributes to a high degree of post-operative instability. There is, at present, some data from a French series suggesting that the dual mobility implants could reduce the dislocation rate in this particular indication [27-29].

Dual mobility in neurological and psychiatric disorders

Hip pathology in patients with neuromuscular disorders has always represented a challenge for the orthopedic surgeon. Congenital and acquired pathologies during developmental age such as cerebral palsy, myelomeningocele, or poliomyelitis interfere with normal joint development, resulting in dysplasia with subluxation of the hip [30].
In adult neurological pathologies, such as Parkinson's disease or multiple sclerosis, the problem to be faced is the imbalance of muscle groups on a spastic-contractural basis. In addition, many of these conditions are characterized by impaired balance during walking with an increased risk of falls. For these reasons, there is a particularly high risk of prosthetic dislocation in patients with neurological disorders.
Since the first generation, DM recognizes in this category of patients the most classic of its indications by exploiting its antiluxant potential with fewer problems related to the wear of polyethylene due to the reduced functional demands of patients [31].
Ryu et al. in a prospective study analyzing the use of DM for femoral neck fractures in patients with neuromuscular disorders found no significant differences in the dislocation rate compared to dual mobility in the control group [32].
Lazennec et al. in a retrospective study analyzing 59 patients with Parkinson's disease undergoing total hip replacement with dual mobility for hip osteoarthritis found satisfactory medium-term results consistent with the progression of the underlying disease [33]. In patients with neuromuscular disorders, DM is thus confirmed to be a valid treatment option when hip replacement is indicated.

Dual mobility and spino-pelvic relationships

Recent research has focused on the influence of spinopelvic mobility and the inclination and anteversion of the acetabular component in the hip prosthesis. The movement from standing to sitting is normally accompanied by the posterior tilt of the pelvis, thus allowing the acetabulum to open to release the hip [34,35].
Reduced spinal mobility leads to limited posterior pelvic tilt (APT) when passing from standing to sitting, with a reduction in acetabular anteversion and possible anterior impingement.
A kyphotic spine with spinal imbalance with a PI-LL index > 10 during the standing position is compensated by increasing the posterior pelvic tilt. This leads to an increase in acetabular anteversion in an upright position and therefore to possible posterior impingement. In a consecutive series of 1000 patients, Esposito et al. showed that reduced spino-pelvic mobility is related to a significant rate of prosthetic dislocation [36].
Based on these principles, Stefl et al. determined the position of the acetabular component of 160 THA based on preoperative spinal mobility [37].
However, patients suffering from degenerative pathologies of the spine with an anteversion change of less than 5° between standing and sitting are considered to be at high risk of dislocation even with perfect positioning of the acetabular component. According to Stefl et al., these patients should be candidates for a dual mobility implant [37].

Criticism of dual mobility

One of the major criticisms of dual mobility implants concerns the longevity of the implant with particular attention to early wear of polyethylene. The degree of resistance of polyethylene was studied using stereometric analysis techniques by a French team which found no differences in the degree of wear of the polyethylene of the dual mobility cups compared to that used in conventional cups [38].
Adam et al. analyzed the degree of wear of 40 dual mobility cup inserts and found no significant differences from the inserts used in metal-polyethylene couplings with 22.2 mm diameter femoral heads of conventional cups [39].
Another aspect to consider is the survival of the implant. Aseptic loosening is one of the most common causes of revisions of dual mobility cups. The excessive ROM characteristic of these implants can lead to impingement phenomena with an impact on the acetabular cup and consequently its early mobilization [40].
In a retrospective study, Cypres et al., analyzing 244 DMC implants with cementless femoral stems, reported excellent functional results with an acetabular cup survival of 95.9% and femoral stem survival of 99.1% at 10-year follow-up [41].
The studies in the literature therefore allow us to state that dual mobility does not mean double wear or lower implant survival.
Another aspect to consider, no less important, is that of the costs associated with this type of implant. Dual mobility has higher costs than conventional systems. However, re-hospitalization for dislocations or for surgical revisions in case of implant instability is associated with significantly higher costs

than with a conventional primary implant. Epinette et al. evaluated the cost-benefit ratio in a probabilistic analysis with a relative risk of prosthetic dislocation of 0.4 in dual mobility implants compared to conventional ones, reporting actual economic savings estimated at tens of millions of euros per year. This data observed in France can obviously be reported internationally [42].

Evolution of indications

Due to the limitations of the first generation, traditionally DM as a first implant was considered only for certain categories of patients at high risk of dislocation [43].

Increasing the survival of the new generations of dual mobility implants [41], their superior ROM [44], and greater stability have recently favored the extension of the dual mobility indication to further categories of previously excluded patients such as young adults. In recent years, the average age of patients who undergo prosthetic surgery has been decreasing. It is estimated that in 2030 52% of primary hip replacements will be implanted in patients under 65 years of age. As a result, the number of prosthetic revisions is expected to increase dramatically [45].

Bayliss et al., in an article published in The Lancet, introduced the concept of 'lifetime risk' or the cumulative probability over a lifetime of undergoing surgical revision after prosthetic surgery. The estimated lifetime risk, in patients over 70 years of age, is around 5% and decreases with advancing age.

For younger patients between the ages of 50 and 54, this risk is estimated to be much higher, reaching up to 29%[46]. In this scenario, the orthopedic surgeon should postpone this type of surgery as long as possible and possibly choose implants that guarantee stability and long survival. Given these assumptions, the use of DM would seem to represent a valid option in this type of patient. Recent studies are showing excellent results in the short to medium term.

Rowan et al., in a retrospective cohort study, reported excellent results in preventing the instability of dual mobility implants compared to conventional ones in a population of patients less than 55 years at 3 years of follow-up.

Assi et al., in a recent study of 60 primary implants in patients under the age of 55 with very high functional demand, reported no episodes of atraumatic dislocations, no aseptic loosening, and no radiographic signs of periprosthetic bone resorption at 70 months [47].

Another category of patients who can benefit from a dual mobility implant are obese patients. Numerous studies in the literature report a dislocation rate in primary implants that is 3.7 times greater than in the normal population in patients with a high BMI. One of the reasons to explain this is that the increase in the circumference of the thigh causes impingement and a potential dislocating force on the prosthesis. In fact, during hip adduction, a lateral force is generated due to thigh-thigh contact, which acts by pushing the head of the femur out of the cup, compromising joint stability [48].

Hernigou et al. in fact, observed a significant decrease in the 7-year dislocation rate in cases where a constrained insert or DM cups were used (2%) compared to traditional THA (9%) [49].

Conclusions

Given the increase in the number of primary THA implants, the problem of prosthetic instability is destined to assume a growing impact in the coming years. Since its origins, dual mobility has allowed a reduction in the prosthetic dislocation rate compared to conventional implants. For decades, this type of implant has, therefore, represented the gold standard for hip prosthetic surgery in patients at high risk of instability. Improvements in prosthetic design and materials have made it possible to put an end to the problems of the first generation of dual mobility cups. Overcoming the skepticism of the first implants and the intrinsic characteristics of dual mobility, such as increased ROM and excellent stability, has therefore extended its use even beyond the more classic indications. Added to this is the proven economic benefit related to the low revision rate due to the instability of dual mobility systems. The "Dual Mobility for All" option could be considered a good solution to prevent prosthetic instability in the first implant and improve the quality of life of patients. The excellent short to medium term results of dual mobility used in young patients with high functional demands and in other categories of patients, however, are not substantiated by long-term follow-up. Therefore, further studies are necessary to confirm the validity of this type of implant in hip prosthetic surgery.

References

1 Learmonth ID, Young C, Rorabeck C. The operation of the century: total hip replacement. Lancet 2007;370:1508-1519. https://doi.org/10.1016/S0140-6736(07)60457-7

2 Culliford D, Maskell J, Judge A, et al.; COASt Study Group. Future projections of total hip and knee arthroplasty in the UK: results from the UK Clinical Practice Research Datalink. Osteoarthritis Cartilage 2015;23:594-600. https://doi.org/10.1016/j.joca.2014.12.022

3 Nemes S, Gordon M, Rogmark C, et al. Projections of total hip replacement in Sweden from 2013 to 2030. Acta Orthop 2014;85:238-243. https://doi.org/10.3109/17453674.2014.913224

4 Sloan M, Premkumar A, Sheth NP. Projected volume of primary total joint arthroplasty in the U.S., 2014 to 2030. J Bone Joint Surg Am 2018;10:1455-1460. https://doi.org/10.2106/JBJS.17.01617

5 Bozic KJ, Kurtz SM, Lau E, et al. The epidemiology of revision total hip arthroplasty in the United States. J Bone Joint Surg Am 2009;91:128-133. https://doi.org/10.2106/JBJS.H.00155

6 American Academy of Orthopaedic Surgeons (AAOS). American Joint Replacement Registry (AJRR): 2020 Annual Report, 2020.

7 Vanhegan IS, Malik AK, Jayakumar P, et al. A financial analysis of revision hip arthroplasty: the economic burden in relation to the

national tariff. J Bone Joint Surg Br 2012;94:619-623. https://doi.org/10.1302/0301-620X.94B5.27073

8 Noyer D, Caton JH. Once upon a time… dual mobility: history. Int Orthop 2017;41:611-618. https://doi.org/10.1007/s00264-016-3361-6

9 Noyer D, GILES Group collaborators. La troisième articulation des prothèses de hanche à double mobilité. Maitrise orthopedique 2003, p. 121.

10 Bousquet G, Argenson C, Godeneche JL, et al. Reprises après descellement aseptique des arthroplasties totales de hanche cimentées par la prothèse sans ciment de Bousquet. A propos de 136 observations. Rev Chir Orthop Reparatrice Appar Mot 1986;72(Suppl)2:70-74.

11 D'Apuzzo MR, Koch CN, Esposito CI, et al. Assessment of damage on a dual mobility acetabular system. J Arthroplasty 2016;31:1828-1835. https://doi.org/10.1016/j.arth.2016.01.039

12 Neri T, Boyer B, Geringer J, et al. Intraprosthetic dislocation of dual mobility total hip arthroplasty: still occurring?. Int Orthop 2019;43:1097-1105. https://doi.org/10.1007/s00264-018-4054-0

13 Darrith B, Courtney PM, Della Valle CJ. Outcomes of dual mobility components in total hip arthroplasty: a systematic review of the literature. Bone Joint J 2018;100-B:11-19. https://doi.org/10.1302/0301-620X.100B1.BJJ-2017-0462.R1

14 Levin JM, Sultan AA, O'Donnell JA, et al. Modern dual-mobility cups in revision total hip arthroplasty: a systematic review and meta-analysis. J Arthroplasty 2018;33:3793-3800. https://doi.org/10.1016/j.arth.2018.08.013

15 Batailler C, Fary C, Verdier R, et al. The evolution of outcomes and indications for the dual-mobility cup: a systematic review. Int Orthop 2017;41:645-659. https://doi.org/10.1007/s00264-016-3377-y

16 Kununtsor SK, Barrett MC, Beswick AD, et al. Risk factors for dislocation after primary total hip replacement: a systematic review and meta-analysis of 125 studies involving approximately five million hip replacements. Lancet Rheumatol 2019;1:e111-121. https://doi.org/10.1016/S2665-9913(19)30045-1

17 Abdel MP, von Roth P, Jennings MT, et al. What safe zone? The vast majority of dislocated THAs are within the Lewinnek safe zone for acetabular component position. Clin Orthop Relat Res 2016;474:386-391. https://doi.org/10.1007/s11999-015-4432-5

18 Epinette JA. Clinical outcomes, survivorship and adverse events with mobile-bearings versus fixed-bearings in hip arthroplasty-a prospective comparative cohort study of 143 ADM versus 130 trident cups at 2 to 6-year follow-up. J Arthroplasty 2015;30:241-248. https://doi.org/10.1016/j.arth.2014.09.022

19 Caton JH, Prudhon JL, Ferreira A, et al. A comparative and retrospective study of three hundred and twenty primary Charnley type hip replacements with a minimum follow up of ten years to assess whether a dual mobility cup has a decreased dislocation risk. Int Orthop 2014;38:1125-1129. https://doi.org/10.1007/s00264-014-2313-2

20 Pituckanotai K, Arirachakaran A, Tuchinda H, et al. Risk of revision and dislocation in single, dual mobility and large femoral head total hip arthroplasty: systematic review and network meta-analysis. Eur J Orthop Surg Traumatol 2018;28:445-455. https://doi.org/10.1007/s00590-017-2073-y

21 Kim YT, Yoo JH, Kim MK, et al. Dual mobility hip arthroplasty provides better outcomes compared to hemiarthroplasty for displaced femoral neck fractures: a retrospective comparative clinical study. Int Orthop 2018;42:1241-1246. https://doi.org/10.1007/s00264-018-3767-4

22 National Institute for Health and Care Excellence (NICE). Clinical guideline on hip fracture management, 2017 update.

23 Meek RM, Allan DB, McPhillips G, et al. Epidemiology of dislocation after total hip arthroplasty. Clin Orthop Relat Res 2006;447:9-18. https://doi.org/10.1097/01.blo.0000218754.12311.4a

24 Hailer NP, Weiss RJ, Stark A, et al. The risk of revision due to dislocation after total hip arthroplasty depends on surgical approach, femoral head size, sex, and primary diagnosis. An analysis of 78,098 operations in the Swedish Hip Arthroplasty Register. Acta Orthop 2012;83:442-448. https://doi.org/10.3109/17453674.2012.733919

25 HEALTH Investigators, Bhandari M, Einhorn TA, Guyatt G, et al. Total hip arthroplasty or hemiarthroplasty for hip fracture. N Engl J Med 2019;381:2199-2208. https://doi.org/10.1056/NEJMoa1906190

26 You D, Sepehri A, Kooner S, et al. Outcomes of total hip arthroplasty using dual mobility components in patients with a femoral neck fracture. Bone Joint J 2020;102-B:811-821. https://doi.org/10.1302/0301-620X.102B7.BJJ-2019-1486.R1

27 Morice A, Ducellier F, Bizot P; Orthopaedics and Traumatology Society of Western France (SOO). Total hip arthroplasty after failed fixation of a proximal femur fracture: analysis of 59 cases of intra- and extra-capsular fractures. Orthop Traumatol Surg Res 2018;104: https://doi.org/10.1016/j.otsr.2018.04.015

28 Boulat S, Neri T, Boyer B, et al. Dual mobility cups in total hip arthroplasty after failed internal fixation of proximal femoral fractures. Orthop Traumatol Surg Res 2019;105:681-686. https://doi.org/10.1016/j.otsr.2019.01.014

29 Favreau H, Ehlinger M, Adam P, et al. Total hip arthroplasty with exclusive use of dual-mobility cup after failure of internal fixation in trochanteric fracture. Orthop Traumatol Surg Res 2020;106:645-649. https://doi.org/10.1016/j.otsr.2020.02.011

30 Hermanson M, Hägglund G, Riad J, et al. Prediction of hip displacement in children with cerebral palsy: development of the CPUP hip score. Bone Joint J 2015;97-B:1441-1444. https://doi.org/10.1302/0301-620X.97B10.35978

31 Raphael BS, Dines JS, Akerman M, et al. Long-term follow-up of total hip arthroplasty in patients with cerebral palsy. Clin Orthop Relat Res 2010;468:1845-1854. https://doi.org/10.1007/s11999-009-1167-1

32 Ryu HG, Roh YJ, Oh KJ, et al. Dual mobility articulation total hip arthroplasty for displaced neck fracture in elderly with neuromuscular disorder. Injury 2021. https://doi.org/10.1016/j.injury.2021.01.005 [Epub ahead of print]

33 Lazennec JY, Kim Y, Pour AE. Total hip arthroplasty in patients with Parkinson disease: improved outcomes with dual mobility implants and cementless fixation. J Arthroplasty 2018;33:1455-1461. https://doi.org/10.1016/j.arth.2017.11.062

34 Wiznia DH, Buchalter DB, Kirby DJ, et al. Applying the hip-spine relationship in total hip arthroplasty. Hip Int 2021;31:144-153. https://doi.org/10.1177/1120700020949837

35 Lum ZC, Giordani M, Meehan JP. Total hip instability and the spinopelvic link. Curr Rev Musculoskelet Med 2020;13:425-434. https://doi.org/10.1007/s12178-020-09648-6

36 Esposito CI, Carroll KM, Sculco PK, et al. Total hip arthroplasty patients with fixed spinopelvic alignment are at higher risk of

hip dislocation. J Arthroplasty 2018;33:1449-1454. https://doi.org/10.1016/j.arth.2017.12.005

37 Stefl M, Lundergan W, Heckmann N, et al. Spinopelvic mobility and acetabular component position for total hip arthroplasty. Bone Joint J 2017;99-B:37-45. https://doi.org/10.1302/0301-620X.99B1.BJJ-2016-0415.R1

38 Pineau V, Lebel B, Gouzy S, et al. Dual mobility hip arthroplasty wear measurement: Experimental accuracy assessment using radiostereometric analysis (RSA). Orthop Traumatol Surg Res 2010;96:609-615. https://doi.org/10.1016/j.otsr.2010.04.007

39 Adam P, Farizon F, Fessy MH. Dual mobility retentive acetabular liners and wear: surface analysis of 40 retrieved polyethylene implants. Orthop Traumatol Surg Res 2014;100:85-91. https://doi.org/10.1016/j.otsr.2013.12.011

40 Hernigou P, Dubory A, Potage D, et al. Dual-mobility arthroplasty failure: a rationale review of causes and technical considerations for revision. Int Orthop 2017;41:481-490. https://doi.org/10.1007/s00264-016-3328-7

41 Cypres A, Fiquet A, Girardin P, et al. Long-term outcomes of a dual-mobility cup and cementless triple-taper femoral stem combination in total hip replacement: a multicenter retrospective analysis. J Orthop Surg Res 2019;14:376. https://doi.org/10.1186/s13018-019-1436-y

42 Epinette JA, Lafuma A, Robert J, et al. Cost-effectiveness model comparing dual-mobility to fixed-bearing designs for total hip replacement in France. Orthop Traumatol Surg Res 2016;102:143-148. https://doi.org/10.1016/j.otsr.2015.12.008

43 Assi C, Barakat H, Mansour J, et al. Primary total hip arthroplasty: mid-term outcomes of dual-mobility cups in patients at high risk of dislocation. HIP Int 2019;Dec 26. https://doi.org/10.1177/1120700019889031 [Epub ahead of print]

44 Ko LM, Hozack WJ. The dual mobility cup: what problems does it solve? Bone Joint J 2016;98-B:60-63. https://doi.org/10.1302/0301-620X.98B1.36332

45 Schreurs BW, Hannink G. Total joint arthroplasty in younger patients: heading for trouble? Lancet 2017;389:1374-1375. https://doi.org/10.1016/S0140-6736(17)30190-3

46 Bayliss LE, Culliford D, Monk AP, et al. he effect of patient age at intervention on risk of implant revision after total replacement of the hip or knee: a population-based cohort study. Lancet 2017;389:1424-1430. https://doi.org/10.1016/S0140-6736(17)30059-4

47 Assi CC, Barakat HB, Caton JH, et al. Mortality rate and mid-term outcomes of total hip arthroplasty using dual mobility cups for the treatment of femoral neck fractures in a Middle Eastern population. J Arthroplasty 2019;34:333-337. https://doi.org/10.1016/j.arth.2018.10.030

48 Elkins JM, Daniel M, Pedersen DR, et al. Morbid obesity may increase dislocation in total hip patients: a biomechanical analysis. Clin Orthop Relat Res 2013;471:971-980. https://doi.org/10.1007/s11999-012-2512-3

49 Hernigou P, Trousselier M, Roubineau F, et al. Dual-mobility or constrained liners are more effective than preoperative bariatric surgery in prevention of THA dislocation. Clin Orthop Relat Res 2016;474:2202-2210. https://doi.org/10.1007/s11999-016-4859-3