Recurrent instability remains a common cause of failure after revision total hip arthroplasty (THA). Dual mobility (DM) cups and designs with constrained acetabular liners (CAL) have both been developed to help overcome this challenge. The aim of this report is to compare safety and efficacy outcomes of both designs based on the literature. A comprehensive literature review including published evidence on the results of DM and CAL in revision THA was performed and summarized. Available literature focusing on overall survival, dislocation, loosening, intra-prosthetic dislocation (IPD), and functional outcomes were analysed. Forty-six reports including an evaluation of 5,617 total hips were evaluated were included in the review. The included studies were divided into two distinct groups based on implantation approach: i) CAL (n=15) and ii) DM (n=31). The DM group had higher overall survival rates (94.7% vs. 81.0%), lower dislocation rates (2.6% vs. 11.0%), and lower acetabular loosening rates (1.0% vs. 2.0%) compared to the CAL group. IPDs were reported in 6 studies (mean rate, 0.6%). No differences in functional outcomes were identified due to incomplete reports. Our observations reveal that designs with CAL have poorer outcomes as compared to DM cups in revision THA. Currently, the use of DM seems more appropriate since they offer lower rates of dislocations, loosening and re-revisions in the short- and mid-term. Concerns regarding the potential of increased wear in a younger, high-demand population require additional data and evaluation by long-term studies for the DM design.

Key Words: Dual mobility, Total hip arthroplasty, Constrained, Dislocation, Revision

INTRODUCTION

Total hip arthroplasty (THA) is regarded as one of the most successful and cost-effective surgical procedures in end-stage hip arthritis. THA effectively reduces pain, improves function, mobility and quality of life. As health care continues to improve and life expectancy increases, the demand for total joint arthroplasty will rise to reflect this more active, aging population. Internationally, the amount of THAs is expected to increase by 170% between now and 2030. In addition, an increasing number of THA require revision; total hip revisions are also projected to increase by 137% by 2030. Complications after THA can be very challenging for both the surgeon and the
Thromboembolic disease, infection, peri-prosthetic fracture, aseptic loosening and dislocation are the most common postoperative complications.

Postoperative dislocation remains a persistent, disabling complication after THA. Recurrent instability after revision THA represents an even greater burden and is the leading indication for re-revision surgery. Dislocation rates range between 0.3% and 10% in primary THA. Depending on the reasons for revision, dislocation rates after revision THA varies from 5.0% to 30.0%. Contributing factors to instability include component malposition, impingement, inadequate soft tissue tension, abductor insufficiency, neuromuscular disorders, cognitive dysfunctions, and non-compliance. In many cases, the etiology is multifactorial. Several prosthetic options and surgical approaches have been tested to both prevent and treat instability (e.g., component reorientation, trochanteric advancement, soft tissue reinforcement, capsulorraphy, large-diameter femoral heads, constrained liners, dual mobility constructs), however, none are without risk.

The purpose of this study is to review literature comparing outcomes of constrained acetabular components with those of dual mobility (DM) cups in revision THA. In view of the increased importance of revision THAs, this study aims to compare the outcomes of both implants including overall survival, dislocation rates, implant migration/loosening, DM implant-specific complications (IPD), and functional outcomes (Harris hip score, HHS). Conversion to a DM design and a constrained liner are both procedures for recurrent instability. In current clinical practice, constrained liners are only used in a salvage procedure; DM cups, on the other hand, are also used in primary THA.

The principle feature of constrained acetabular components is to hold the femoral head captive within the cup by means of a locking ring mechanism. There are two prevailing designs for constrained implants: the constrained tripolar and the locking ring. In this study, constrained tripolar devices are not included. A constrained liner is a device consisting of a polyethylene (PE) liner and a reinforcing ring. As shown in Fig. 1, the metal locking ring fits into a groove on the outer surface of the liner to reinforce the capture of the femoral head within the liner. These constrained components are designed to physically resist dislocation by avoiding re-expansion of the liner. The metal locking ring allows immediate stability, but may be associated with a reduced range of motion (ROM) due to impingement of the neck on the PE liner. The restricted movement of the components may increase the forces at the bone/implant interface, increasing the risk of aseptic loosening and the necessity for re-revision.

Implant failure can be classified to five distinct types: Type I failure is failure at the implant-bone interface. Type II and III failures are respectively disconnection of the PE liner from the cup or locking ring failure. Type IV failure is dislocation of the femoral head from the liner. Type V failure is infection.

DM cups ensure stability using a different biomechanical concept than the constrained locking ring mechanism. While the DM design has been utilized for more than 25 years in Europe, it only became available in North-America in 2009 when FDA approval was achieved. A DM cup is made up of two different articulations, one between the femoral head and the PE liner, and a second between the liner and the acetabular shell. Thus, the first motion arises between the small femoral head and the inner/concave surface of the PE liner, until the neck of the

Fig. 1. Example of constrained acetabular liners with locking ring mechanism. [A] Duraloc constrained system [DePuy Synthes]. [B] Trilogy Acetabular System Constrained Liner [Zimmer].
femoral stem reaches the liner. As shown in Fig. 2, the secondary motion occurs between the outer/convex surface of the PE liner and the acetabular metal cup, when a higher ROM is required. DM is therefore expected to improve the ROM to impingement. The purpose of DM cups is to provide improved head-to-neck ratio, a larger effective head size and a higher jump distance, all of which lead to enhanced stability. Major concerns with DM cups include accelerated PE wear due to an additional bearing surface, aseptic loosening and IPD. IPD is a unique failure mechanism for DM constructs, in which the inner femoral head dislodges from the outer PE liner. The metallic head can then articulate directly with the acetabular socket, causing devastating complications, including rapid wear and severe soft tissue metallosis, that will necessitate re-revision. To prevent the mentioned concerns about accelerated wear on the additional bearing surface, cross-linked ultra-high molecular weight polyethylene (UHMWPE) doped with vitamin-E (an anti-oxidant) have been integrated into DM implants.

**MATERIALS AND METHODS**

PubMed/Medline, Embase, Cochrane Library and Trip Database were searched for articles published up to May 2018. A search was conducted using various combinations of the following search terms: “total hip arthroplasty”, “total hip replacement”, “revision hip arthroplasty”, “revision hip replacement”, “constrained”, “constrained liners”, “constrained acetabular liners”, “constrained components”, “dual mobility”, “dual-mobility”, “bousquet”, “complications”, “outcome”, “failure”, “instability”, “dislocation”, “intra-prosthetic dislocation”, “loosening”, “aseptic loosening”, “acetabular loosening”. There were no set limitations on the year of publication. Only English language papers were evaluated. No limitations were set concerning the category of study (retro-/prospective design), follow-up period or the number of patients enlisted. Inclusion criteria were articles investigating the outcomes of revision THA with constrained acetabular components or a DM design. Patients undergoing primary THA or revision with tripolar constrained devices (Omnifit Osteonics; Trident Stryker, Kalamazoo, MI, USA) were not included in the review. Duplicates, literature reviews, animal studies, *in vitro* investigations, cadaveric studies, technical notes and instructional courses were excluded. Additionally, reference lists of the included papers were manually inspected by the author for missed articles. A flow chart is enclosed according to the PRISMA.
A variety of outcomes were assessed. For each study, we collected data including the number of hips undergoing revision THA, the mean follow-up duration and the mean age of the study population. First, we assessed the overall survival rates. Survival rate or cup survivorship was defined as “1-surgical re-revision due to all causes”. Second, we assessed the incidence rates of the most common complications in revision THA. The first complication evaluated in this study was dislocation rate. Thereafter, we assessed the rate of acetabular loosening, classically described as deterioration of bone implant interface with a measurable migration of the cup. Acetabular loosening is mostly evaluated radiographically according to the DeLee and Charnley classification (Fig. 4).

Finally, the rate of IPD was analysed in all studies involving DM constructs.

Clinical evaluations were assessed using the HHS, a clinician-based outcome scale conducted by a well-qualified, professional health care provider. This standardized outcome measure is a rating scale of 100 points with domains of pain, function, ROM and deformity. Higher scores

![Fig. 3. Literature search/flow chart according to PRISMA guidelines. DM: dual mobility, CAL: constrained acetabular liners.](image)

![Fig. 4. (A) DeLee and Charnley acetabular zones. The acetabulum is divided into three equal zones. Acetabular components are considered loose if they have migrated >3 mm in one zone, or if there is a circumferential peri-acetabular radiolucent line of at least 2 mm in all three zones. (B) Radiolucent zone around acetabular component in zone I and zone II. (C) Acetabular inclination, the angle between the transischial line and a line through the lateral and medial margins of the acetabular cup.](image)
represent better outcomes and less dysfunction. 

RESULTS

The literature search resulted in a total of 46 references. We divided the studies that met the inclusion criteria into two distinct groups. The first group included 15 studies reporting use of constrained acetabular liners (CAL) components in revision THA. Of the 15 includes articles, 14 had a retrospective design. Studies were published starting from 1994, the latest in 2017. A total of 1,924 hips were analysed in this group. The mean follow-up period ranged from 19 months to 120 months. The average age at the time of the procedure was 69.0±7.0 years. The mean dislocation rate was 11.0% (range, 0-29.0%; standard deviation [SD], 8.7) and average survival rate was 81.0% (range, 54.7-97.2%; SD, 10.9). Evaluating all cases of acetabular loosening revealed a mean rate of 2.0% (range, 0-8.3%; SD, 2.8).

The second group included 31 studies dealing with DM devices in the setting of revision THA; of these, 23 were retrospective. Analysis of the 31 reports included 3,693 hips. The first reports included in this review were published in 2009, at the time when FDA approval for DM devices was obtained in the United States. The average follow-up time ranged from 16 to 87 months. Mean age at surgery of the overall study population was 68.8±6.2 years. Dislocation rates vary from 0-10.4% with a mean dislocation rate of 2.6±2.5%. Overall survival ranged between 88.9% and 100%, with a mean rate of 94.7±3.5%. Analysis of acetabular loosening revealed a rate of 1.0% (range, 0-6.4%; SD, 1.5). Of the 31 studies, 6 report one or more cases of IPD (range, 0-4.0%). The average rate of IPD was 0.6±1.2%. These data reconfirm that this unique complication encountered with DM cups is extremely rare.

Table 2-4 summarize the extracted data. The results of this study led to the development of some general considerations about both designs.

DISCUSSION

As seen from the aforementioned results, our main finding was that DM cups seem preferable to constrained cups. This literature review revealed higher survival rates for the DM designs compared to the CAL designs (94.7% vs. 81.0%). Overall dislocation rates and loosening
rates using DM in revision THA are lower than those reported in revision THA with a constrained implant (2.6% vs. 11.0% and 1.0% vs. 2.0%, respectively). We emphasize that the success of these implants are reported with great variation. It is important to bear in mind that any type of prosthesis (including DM constructs or CAL constructs) cannot compensate for poor surgical technique or technical errors, such as incorrect implant orientation or inadequate restoration of soft-tissue tension. Surgeons must consider all the involved parameters including implant features, patient characteristics, positioning and soft tissues conditions. Risk factors for re-revision were described as younger age (50-59 yr) at the time of index surgery, revision for recurrent dislocation, revision following deep infection and the number of previous revision surgeries at the same joint. We report that most studies assess an elderly population (>65 yr), with few data on younger more active patients. It is necessary to exercise caution when using DM or constrained implants in this high-demand population, in whom increased wear could be problematic.

Our results are in line with previous reviews. The general limitations of constrained designs are the decreased ROM to impingement, risk of breakage of the liner or retaining ring, increased component loosening due to high interfacial stress and excessive volumetric PE wear. Considering the high failure rates revealed in this review, we suggest that clinicians maintain the use of constrained liners limited to salvage scenarios in selected patients in whom other operative options are not practical or have not been successful. The most documented indications for use of a CAL design nowadays are senile, low-activity patients, including those with neuromuscular disorders, cognitive impairment, idiopathic instability, abductor insufficiency, or insufficient soft tissue tension.

As mentioned above, DM devices provide a greater effective head size and improve the head-to-neck ratio of the implant. Therefore, DM is expected to increase the arc of motion of the hip joint contrary to constrained devices. However, the additional bearing surface in DM cups raises major concerns about accelerated wear and loosening as well as the newly encountered failure method IPD. Our findings demonstrate that IPD is exceedingly rare and the favorable low rates of loosening indicate
that DM cups do not result in high stresses at the bone-implant interface\(^7\).

**DISLOCATION**

Our findings demonstrate great variation between the dislocation rate in DM and CAL designs. DM devices seem to lower the risk of dislocation in revision THA to 0.0\%-10.4\% (mean, 2.6\%) compared to standard designs (5.0\%-30.0\%)\(^2\),\(^4\),\(^5\),\(^9\)-\(^12\),\(^74\). Constrained designs have been reported with moderate success revealing dislocation rates up to 29.0\% (mean, 11.0\%). These results suggest that DM cups are effective in minimizing the risk of dislocation after revision THA and are probably going to become the gold standard in treating THA dislocations\(^1\),\(^17\),\(^71\),\(^75\).

**FOLLOW-UP TIME**

Another issue to be considered is the fact that all but two studies involving the CAL design, have a short or medium follow-up time (<10 yr)\(^4\),\(^4\). In the DM cup reports specifically, there are limited medium-term and no longer-term studies, likely because DM was unavailable in the United States until FDA approval in 2009. Since DM implants are utilized with increasing frequency in North America, further and longer-term follow-up will be needed to confirm the medium-term results.

**INFECTION**

Surprisingly, few studies evaluate postoperative infectious complications (e.g., superficial soft tissue colonization, deep peri-implant infection). Currently there is no scientific evidence suggesting that one of the discussed designs leads to significantly higher infection rates.

**SURGICAL APPROACH**

An additional factor that may influence the outcome of revision THA, in particular the dislocation rate, is the surgical approach. Multiple reports demonstrated that the posterior approach to the hip joint, requiring detachment of the posterior capsule and short external rotators, is correlated with an increased dislocation rate compared to the anterior, anterolateral, and lateral.
approaches\textsuperscript{6,76-78}. We were unable to draw significant conclusions here due to incomplete reports and substantial differences in indications for revision THA in the included studies.

**FUNCTIONAL OUTCOMES**

Another finding of this study is the lack of functional results in accordance with a clinical scale\textsuperscript{28}. Few reports (<50%) include clinician- and/or patient-reported functional outcomes in their results. The HHS is most commonly used, however, many studies report incomplete functional results without comparative preoperative scores. Scores established only at clinical follow-up but not at baseline are insufficient to allow for conclusions related to the potential impact of the treatment on quality of life\textsuperscript{73}. In a limited number of French studies, the Postel-Merle d’Aubigné score was used. Additionally, few patient-reported outcome measures are described (e.g., Oxford hip score, WOMAC score). We therefore suggest using universal clinical measurement instruments (clinician- and patient-reported) with comparative preoperative and follow-up postoperative results to provide information about the functional performance of the two implants\textsuperscript{28}.

**LIMITATIONS**

This review has several limitations\textsuperscript{1,70,72}. The main limitation is the inconsistent quality of the included studies. First, most papers included in this review have a retrospective design. Second, the majority of the studies are not randomized and lack a control group. Thirdly, many included reports have a small cohort size with an often heterogeneous patient population\textsuperscript{80}. Indications for revision THA are not taken into account individually and there is great variability among the patient population regarding demographics and diagnosis. Furthermore, various modifications and improvements have been made over the years to the mechanics, metallurgy and materials of the original DM or CAL designs\textsuperscript{2}. Subsequent generations of the DM constructs with highly cross-linked UHMWPE and vitamin-E impregnated PE, dual hydroxyapatite and titanium coating instead of alumina, modular shells for screw fixation, cemented designs have all been introduced to improve cup fixation and decrease complications such as PE wear, dislocation, IPD and psoas irritation\textsuperscript{23,26}. For this reason it may be recommended to assess and compare the outcomes of different DM and CAL implant designs mutually in the future. No meta-analysis was performed. Finally, we should mention selection bias as a weakness of the present study as specific data was selectively extracted from the articles\textsuperscript{13}. These limitations confine the level of evidence of this paper.

**CONCLUSION**

In conclusion, this comparative literature review revealed that designs with constrained acetabular components have poorer outcomes as compared to DM cups in revision THA. The use of DM seems more appropriate at the current time since they impose lower rates of dislocations, loosening and re-revisions in the short- and mid-term. While IPD is a new failure mechanism related to DM designs, it is extremely uncommon\textsuperscript{26,71}. Additional data will be needed to assess long-term survivorship of DM cups and concerns regarding increased wear in a younger, high-demand patient population. Constrained designs are still an alternative option but only as salvage procedure for selected, low-demand patients in case of failure of previous treatments\textsuperscript{12}.

**CONFLICT OF INTEREST**

The authors declare that there is no potential conflict of interest relevant to this article.

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