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Modular Dual Mobility Cup: A Matched Short-Term Study

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Abstract

Purpose: Instability remains one of the main problems after primary complex and revision hip surgery. The introduction of modular Dual Modular Cup (modular DMC) has helped to overcome some of the limitations of standard DMC. The aim of this study was to review the clinical, radiological outcomes and rate of complications with the use of these kind of constructs.

Methods: This is a retrospective series of patients who received different types of modular DMC in a single institution. We analyzed clinically and radiologically 101 patients at one, three and six months for the first year then every year from the date of surgery.

Results: At the most recent follow-up only two patients reported dislocation which were treated conservatively without further problems, one of these two patients subsequently was revised due a periprosthetic joint infection. A third patient was submitted to revision as the consequence of aseptic loosening of the cup associated with mispositioning of the metallic liner.

Conclusion: The use of modular DMC offers several advantages in selected patients, and our results are encouraging in terms of stability and rate of complications rate compared to the international literature. Further studies on a larger number of patients and with longer follow-ups are needed to confirm the safety of the construct.

Keywords: Hip arthroplasty; Revision; Primary; Instability; Dual mobility; Modular cup.

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Introduction

Total Hip Arthroplasty (THA) is one of the most successful procedures in orthopedics as it allows fast recovery, in terms of treats pain, improves function and quality of life in patients affected by both end stage degenerative and post-traumatic hip disease as well as acute femoral neck fractures. Instability, however, remains a persistent problem, and the most common complication in both primary and revision cases [1]. Even if several options have been developed to prevent and treat this complication Dual Mobility Cup (DMC) became an attractive option since its initial elaboration in 1976 by Gilles Bousquet in Saint-Etienne (France) [2]. The implant combined three principles:

1) The "low friction" principle of THA popularized by Charnley [3] thanks to the small diameter of the femoral head (22.2 mm)

2) The Mckee-Farrar concept of using a larger diameter femoral head to enhance implant stability [4].

3) The Christiansen hip notion which allowed mobility of the head [5].

The evolution of Bouquet's design has led to numerous modifications during the last three decades to contrast the issues of the first generation. In fact, the rate of acetabular revisions was not negligible, due to acetabular loosening or intra-prosthetic dislocation (IPD) [6]. The first failures were due to use a non-bioactive coating of alumina on the surface as well as to the presence of lateral horns on the socket impinging on the femoral prosthetic neck. The IPD was extensively studied at the beginning of this century by Lecuire et alt [7] and Philippot et al [8] who identified 81 cases (80 patients) with IPD from among 1960 primary THAs performed between January 1985 and December 1998, with a rate of 4.1%. IPD is mainly related to the wear of retentive rim which leads to failure of the capture mechanism between the mobile polyethylene liner and femoral head. With new generations of DMC and thanks to the studies of Noyer [9] who introduced the concept of third joint let emerging the role of the femoral neck in terms of design, dimensions, and surface finishing, we have assisted to the disappearance of this complication [10]. More recently, some companies in the development of the DM design introduces the concept of modularity (modular DMC). The advantages include the ability to initially use screw fixation for the shell in the challenging cases and to visualize the acetabular floor during impaction. Modular constructs provide subsequent placement of a metal liner between the titanium standard acetabular shell and the polyethylene liner. Therefore, there is an increased thickness of the construct and a reduction of the internal diameter of the cup with a theoretical major risk for dislocation.

The aim of this study was to review the clinical, radiological outcomes with the use of different models of modular DMC in primary and revision cases. We hypothesized that patients undergoing hip surgery modular DMC bearing will have lower dislocation rates and revision rates for instability when compared with reported data of existing literature for patients receiving standard DMC hip articulations. We also investigated whether the modular acetabular components of the DM articulation increase the risk of new complications.

Material and methods

Using our institutional database where are collected data to our surgical activity, we reviewed all the patients who were underwent modular DMC implanted from January 2016 to March 2020 for both primary and revision procedures. A total of 101 patients who underwent primary or revision THAs using a modular DMC construct were included in the study. The cohort included 20 Integra cups (Groupe Lepine), 42 Traser (Permedica), 25 Tritanium MDM (Stryker) and 14 to Lima implants Delta TT or Delta Revision. The Devane score, ASA scores and the Charnley classification are presented in Table 1. The cohort comprised 57 men (58 hips) and 44 women (46 hips), aged 60,9 ± 15,8 years (range 19 - 93), with body mass index (BMI) of 24,7 ± 6,7, ASA 1: 6 patients (6%); ASA 2: 31 patients (30%); ASA 3: 52 (51%); ASA 4: 12 patients (12%). Preoperative walking ability was assessed the Charnely classification [11]: it stratifies patients into three categories to quantified walking ability and levels of activity. Patients are assigned to class A if they have single joint arthropathy and no significant medical comorbidity. Class B patients have one other joint in need of an arthroplasty, or an unsuccessful or failing arthroplasty in another joint, while class C patients have multiple joints in need of arthroplasty, multiple failing arthroplasties or significant medical or psychological impairment. The Harris Hip Score [12] was used as the clinical evaluation, this test was applied to all deambulate patients, not femoral neck fractures patients, at the pre-operative outpatient visit and was subsequently used to clinically assess all patients in our practice at the various outpatient check-ups. For practical convenience we have only included the HHS values up to the check-up one year after surgery in the tables below because they are statistically significant.

Eighty-four patients (83%) underwent a primary THA and 17 patients (17%) revision procedures. For primary THA: 23 patients (22%) were fractures, 35 patients (34%) were osteoarthritis, 16 patients (16%) femoral head necrosis and 10 patients (10%) osteosynthesis failures. For the revisions: 6 patients (5%) were treated for periprosthetic infection, 7 patients (6%) were treated for aseptic loosening of prosthetic components and 4 patients (4%) were treated for periprosthetic fractures (Table 2).

Clinical and radiographic follow up was performed at one, three and six months after surgery and then every year. Patients who were unable to return for follow up were mailed a questionnaire and were asked to return radiographic images.

The primary outcome was postoperative dislocation requiring closed reduction, open reduction, or revision THA. Secondary reoperation for any cause, and overall complications where reported. Finally, a clinical and radiological evaluation was performed for each patient.

Radiographic assessment

Plain pelvis X-rays were evaluated at every pre-established follow-up. The measurements were manually performed by one operator (MG), using Carestream Vue Pacs (Rochester, NY). The immediate postoperative standardized anteroposterior and lateral view radiographs were compared to the radiographs taken at the last follow-up. Acetabular inclination was defined as an angle between the line connecting both tear drop and acetabular cup measured on anteroposterior radiographs. Acetabular antever-

sion was calculated according to the method of Woo and Morrey [13] through the cross-table lateral radiograph view. Qualitative evaluation of the acetabular component involved the analysis of the periacetabular zones described by DeLee and Charnley [14], thus recording the presence or absence of linear or focal osteolysis at the bone-cup interface. Criteria for acetabular loosening included continuous radiolucency around the cup in zones 1 to 3 according to DeLee and Charnley a superior migration of greater than 4 mm, severe protrusion, and a progressive tilt of the cup [15]. Gaps, i.e., areas with no initial bone-cup contact in the baseline X-rays, were evaluated. Cup osseointegration was evaluated in the radiographs performed after 1 year according to the criteria described by Moore et al [16].

Most of patients treated are sedentary or carry out light leisure activities, thus classifying them in group 3 and 4 of the Devane score, respectively 24 patients (24%) of group 3 and 66 patients of group 4. 31 patients (30%) were ASA 2 and 52 patients (51%) were ASA 3. 36 patients (35%) had only one hip affected joint and were placed in group A according to Charley's classification, 48 patients (48%) had the contralateral hip affected but not yet surgically treated and were therefore placed in group B1 according to Charley's classification.

The average of first clinical and radiographic follow up was for Lepine cups 34.5 ± 2.66 days; for Permedica was 35.3 ± 4.55 days; for Lima was 33.9 ± 5.87 days and for Stryker was 36.5 ± 3.62 days. The average of second clinical and radiographic follow up was for Lepine cups 101.8 ±7.31 days; for Permedica was 95.3 ± 8.45 days; for Lima was 98.4 ± 8.17 days and for Stryker was 99.7 ± 6.92 days. The average of third clinical and radiographic follow up was for Lepine cups 34.5 ± 2.66 days; for Permedica was 35.3 ± 4.55 days; for Lima was 33.9 ± 5.87 days and for Stryker was 36.5 ± 3.62 days. Next subsequent follow ups were carried out annually.

Statistical analysis: Quantitative data were reported as means !"standard deviation (SD) or medians (range). Differences between the groups were assessed using the One-Way ONAVA including Turkey HSD test for parametric data. The Chi-Square test (APA) was adopted for categorical variables (osseointegration parameters). SPSS software (version 14.0.1; Chicago, IL, USA) was used for the statistical analyses. $p<0.05$ was considered statistically significant.

Table 1:

	INTEGRA Groupe Lépine	*TRASER Permedica*	*TT or Revision LIMA*	*Tritanium MDM Stryker*	*TOT*	*p-value*
Patients	20	42	14	25	101	
Age	71,5 (±15.1)	62,8 (±15.9)	60,1 (±10,3)	49,8 (±11,6)	60,9 (±!15,8)	0.00003
Side	Dx 7 (35%) Sx 13 (65%)	Dx 20 (47%) Sx 22 (53%)	Dx 9 (64%) Sx 5 (36%)	Dx 16 (56%) Sx 9 (36%)	Dx 52 (51%) Sx 49 (49%)	0.178255
Sex	M 9 (45%) F 11 (55%)	M 22 (53%) F 20 (47%)	M 9 (64%) F 5 (36%)	M 17 (68%) F 8 (32%)	M 57 (56%) F 44 (44%)	0.383155
BMI	25.1 ± (4.8)	25.8 (±3.9)	26.3 (±5.2)	26.2 (±3.5)	25.9 (± (4.1)	0.01313
ASA	ASA2: 1 (5%) ASA3: 13 (65%) ASA4: 6 (30%)	ASA1: 5 (11%) ASA2: 12 (28%) ASA3: 20 (47%) ASA4: 5 (11%)	ASA2: 6 (43%) ASA3: 7 (50%) ASA4: 1 (7%)	ASA1: 1 (4%) ASA2: 12(48%) ASA3: 12(48%)	ASA1: 6 (6%) ASA2:31(30%) ASA3:52(51%) ASA4:12(12%)	0.065057
Charnley classification	A: 6 (32%) B1: 8 (37%) B2: 1 (5%) C: 5 (26%)	A: 10 (23%) B1: 26 (61%) B2: 4 (9%) C: 2 (4%)	A: 3 (21%) B1: 9 (64%) B2: 2 (15%) C: 0	A: 17 (68%) B1: 5 (20%) B2: 3 (12%) C: 0	A: 36 (35%) B1: 48 (48%) B2: 10 (10%) C: 7 (7%)	0.003435
Devane activity score	D2: 0 D3: 5 (25%) D4: 12 (60%) D5: 3 (15%)	D2: 4 (9%) D3: 9 (21%) D4: 26 (61%) D5: 3 (7%)	D2: 0 D3: 2 (14%) D4: 11 (78%) D5: 1 (8%)	D2: 0 D3: 8 (32%) D4: 17 (68%) D5: 0	D2: 4 (4%) D3: 24 (24%) D4: 66 (65%) D5: 7 (7%)	0.887444

Results

We reported only two cases of dislocation during the follow-up period, once was observed in Permedica Traser group and once for Lima implant. The first patient was submitted to closed reduction and no further episodes of dislocation occurred. The second patient, from the Lima group, initially underwent closed reduction of the dislocation but was subsequently complicated by a periprosthetic joint infection in pelvic discontinuity due to failure of the complex acetabular fracture six months after the operation.

Three patients had radiographic evidence of liner mispositioning, of these two cases occurred in the Permedica group and one in the Stryker MDM group. In one of the two patients in the Permedica group the radiological divergence of the shell line indicative of mispositioning, clearly identified on post-operative CT and radiography, disappeared at the one year following follow-up, while in the other patient the radiographic divergence was observed on any subsequent follow-up even if still short term (48 months). Both patients had excellent clinical evaluation (HHS mean at 6th month 89.9 ± 2.3; HHS mean at one year 95.6 ± 1.6). The third patient, from the Tritanium MDM Stryker group, had an unfavorable evolution with progressive increase of the divergence of the shell line associated with a painful noise, therefore the patient underwent revision surgery and after the operation the HHS had a remarkable improvement.

In our case series the mean value of cup abduction and anteversion were 37.3 ± 0.4 and 21.4 ± 2.1 respectively. Sixty four

patients (63%) were in the Lewinnek safety zone. A total of 36 patients (37%) were outside the safe zone for one or both of the parameters of cup abduction and cup anteversion. Specifically, 9 patients (45%) in the Lepine group; 19 patients (44%) in the Permedica group; 2 patients (14%) in the Lima group and 8 patients (32%) in the Stryker group Table 2.

According to the osseointegration criteria described by Moore we obtained for the Lepine group mainly superolateral buttress and medial stress-shielding for 50 and 64% of the patients; also, for the Permedica and Stryker group we found a prevalence of superolateral buttress and medial stressshielding for 65-85% and 62-58% of the patients respectively; for the Lima group we found a higher prevalence for medial stress-shielding and radial trabeculae for 80-50% of the patients. Radiolucent lines, a radiological sign of mispositioning of the acetabular cup, were found mainly in the Lima group, with 30% of patients, and Lepine with 21% of patients, while less were found in the Permedica group with less than 8% of cases. Despite the presence of radiolucent lines, these were mainly present in zones 1 and 2 as described by DeLee and Charnely, so no alarm for the stability of the prothesis.

Table 2:

	INTEGRA Groupe Lépine	*TRASER Permedica*	*TT or Revision LIMA*	*Tritanium MDM Stryker*	*TOT*	*p-value*
Diagnosis						0.00001
Fractures	3 (15%)	16 (38%)		4 (16%)	23 (22%)	
Osteoarthritis	2 (10%)	14 (33%)	2 (14%)	17 (68%)	35 (34%)	
Necrosis	3 (15%)	8 (19%)	2 (14%)	3 (12%)	16 (16%)	
ORIF failure	3 (15%)	3 (7%)	3 (21%)	1 (4%)	10 (10%)	
Revision	9 (45%)	1 (2%)	7 (50%)		17 (17%)	
Cup position						
Abdution	37.4 ±7.8	37.4 ± 7.1	36.2 ±6.6	38.2 ± 4.6	37.3 ±0.4	0.004535
Anteversion	21.6 ± 7.2	23.8 ± 10.2	17.6 ± 4.4	22.6 ± 7.2	21.4 ± 2.1	0.01574
HHS *1st month* *3rd month* *6th month One year*	70.0 ± 9.0 80.0 ± 9.0 87.6 ± 6.4 93.5 ± 5.2	72.9 ± 4.3 84.1 ± 4.7 92.0 ± 3.9 96.7 ± 2.4	68.2 ± 5.6 79.5 ± 6.2 88.2 ± 6.7 94.9 ± 4.2	72.5 ± 3.5 82.9 ± 3.8 91.8 ± 2.7 97.5 ± 2.0	70.7 ± 1.9 81.5 ± 2.0 89.9 ± 2.3 95.6 ± 1.6	0.99987
Dislocations	0	1 (2,3%)	1 (7%)	0	2 (2%)	
Revisions	0	0	1 (7%)	1 (4%)	2 (2%)	

Table 3:

	INTEGRA Groupe Lépine	*TRASER Permedica*	*TT or Revision LIMA*	*Tritanium MDM Stryker*	*p-value*
Radiolucent lines	3 (21.4%)	3 (8.5%)	3 (30%)	5 (20.8%)	
Superolateral buttress	7 (50%)	23 (65.7%)	1 (10%)	15 (62.5%)	
Medial stressshielding	9 (64.3%)	30 (85.7%)	8 (80%)	14 (58.3%)	
Radial trabeculae	1 (7.1%)	7 (20%)	5 (50%)	3 (12.5%)	
Inferomedial buttress	2 (14.3%)	3 (8.5%)	3 (30%)	5 (20.8%)	
					0.15532

Regarding statical data the distribution of the parametric data of age and BMI is approximately normal, the *f*-ratio value is respectively 8.72469 and 3.68554; the *p*-value is respectively 0.000035 and 0.013137 so the result is significant at $p < 0.05$. For abduction data the *f*-ratio value is 4.41017, the *p*-value is 0.004535 so the result is significant at $p < 0.05$; even for anteversion data the *f*-ratio value is 3.60829, the *p*-value is 0.01574 so the result is significant at $p < 0.05$.

A chi-square test of independence showed that there was no significant association between the osseointegration criteria described by Moore on our analyzed groups, $X^2 = 16.8501$; $p = 0.1553$. We found no statistically significant correlation between the groups examined and the BMI calculated for each patient.

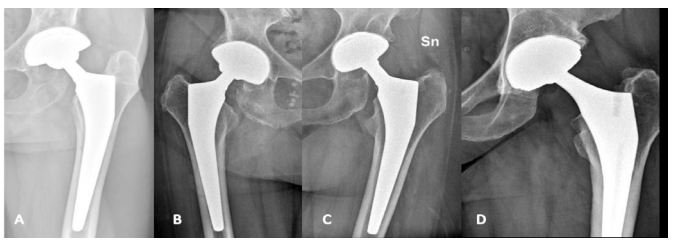

Figure 1: This image shows some examples of cup Osseointegration as described by Moore; Figure A shows an example of radiolucent; Figure B shows an example of superolateral buttressing and medial stress-shielding; Figure C shows radial trabecular; Figure D shows inferomedial buttressing.

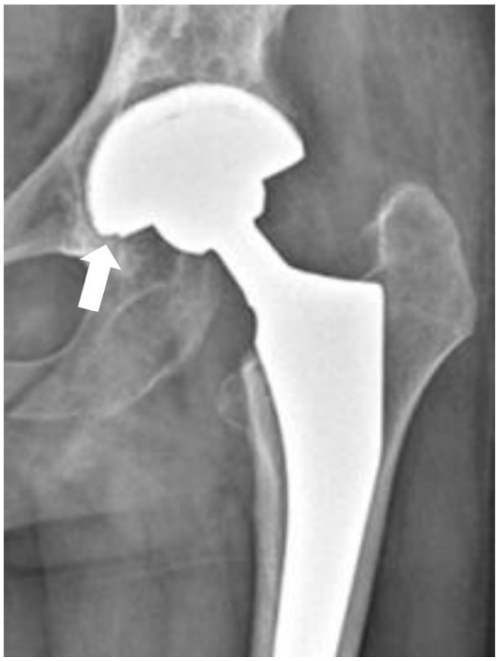

Figure 2: This image arrow shows an example of mispositioning.

Discussion

To our knowledge this is the second paper over the use of different models of modular DMC in primary or revision procedures. If we exclude the paper of Addona et al [17] which determine the incidence of early IPD in primary, revision, and conversion THA using two different DMC modular implants the others published studies focused on only one implant [18]. The present study, on the contrary, evaluate the early results of four modular DMC constructs implanted in a single institution. It is a consecutive series of patients submitted to primary, revision or conversion THA procedures. Specifically, first at all we aimed to investigate the incidence of dislocation in this heterogeneous population as well as the incidence of other complications.

We reported only 2 cases of dislocation for all groups. The first one was a patients affected by psychiatric disorders and additive behaviors with correct range of acetabular inclination 32° and slide increment in anteversion 29° regarding the Lewinnek safe zone. The second patient was surgically treated for posterior acetabular wall fracture and posterior hip dislocation with plate and screws, after femoral head necrosis he was treated with total hip prosthesis, the acetabular cup abduction was 40° and the anteversion was 25°. Both patients were submitted to closed reduction with no further episode of dislocation at a two years follow-up. No case of revision for dislocation were reported.

In our study we have reported only two cases of revision surgery. The first case, belonging to the Permedica group, after a first dislocation treated with close reduction went into periprosthetic infection and was therefore treated surgically for prosthetic revision. The second case, belonging to the Stryker group, showed radiological signs of aseptic loosening of the cup associated with mispositioning of the metallic liner in one of the serial controls and was therefore treated surgically for revision.

Use of a modular DMC in THA in high-risk patients surgical submitted to primary, revision or conversion THA resulted in a low implant dislocation rate. Particularly, we reported only two cases (1.9%) of dislocation for all groups. The data we obtained are in line with the data reported in the literature and confirm the reduction of the dislocation rate of primary and revision arthroplasties [20]. Through this study we can confirm our hypothesis that even the modular DMC can have a safe effect in reducing instability.

The first important finding to consider is the after THA, hips with less Jump-Distance (JD) are theoretically more susceptible to dislocate than hips with more JD. The characteristic of modular DMC, which adds one more modular cobalt-chromium liner to isolate the inner surface let necessarily to a reduction of the internal diameter of the cup and consequently the JD. Taking as reference the modular DMC implant which has a reduction of 6 mm of the outer diameter of the liner independently to the size of the implant, in case of modular MDC this reduction is always greater and can reach up to less 14 mm for some companies. In the light of these observations, it is plausible to hypothesize that in relation to conventional prostheses that the interposition of a mobile insert itself allows to increase the effective diameter of the head and optimize the head / neck ratio [19]. However, in a recent multicenter study on modular DM cups for revision a major risk of dislocation was associated smaller outer diameter of the polyethylene ball particularly in case of 38 mm or less [21].

According to Sariali [22] others, factors can influence the JD in association to a reduction of the inner surface. These Authors pointed out as the theoretical increase in stability obtained by using femoral heads above 36 mm could be compromise in cases of vertical positioning of the cup. At the same time any increase in offset of the femoral head substantially reduces the jumping distance and it should therefore be avoided.

Recently Tigani et al [23], have calculate how the Jump-Distance (JD) and the increment femoral head offset change, using an analytical 3D-modelling simulation, in conventional DM cup, DMC and standard cup. They matched the same cup size, of a single company, according to cup abduction, anteversion angles, head diameters and femoral head offset. The resulting JD with DM linearly increased as size increasing, whereas for the modular implant JD with slightly increased up to 56 mm cup size, then remained approximately constant. These Authors highlights that JD depends not only on femoral head size and cup positioning, specifically abduction angle than anteversion angle [23], but also from the femoral offset. In our series cup abduction was 37.3 ± 0.4 and anteversion was 21.4 ± 2.1. This contributed to obtaining positive results in terms of stability.

To date, despite the unfavorable theoretical observations previously expressed, the use of DMC provided excellent results in terms of dislocation incidence. A large matched cohort single-center study comparing DMC and standard DM reported for both groups 0% of dislocation after primary THA at a mean follow-up of 2.8 years [24]. A retrospective case-series study of DMC used in revision THA found a dislocation prevalence of 3.1% after 3-year average follow-up [25]. Another recent multicenter retrospective study reported a similar dislocation rate (2.9%) after revision THA in a large cohort of patients treated with DMC [26].

The second important finding of our study was focused on the incidence of possible complication related to this implant con-

struct. We reported only two cases of revision due to infection in a case and liner mispositioning in the other one. The use of DMC involves more potential complications than conventional DM. DMC is a prosthetic construct which adds one more modular cobalt-chromium liner. The possibility of fretting corrosion at the non-articulating metal-on-metal interface between the modular liner and the titanium socket could cause metal release [27,28]. In literature several studies reported uniformly low blood metal ions concentrations in patients undergone modular DMC primary or revision THA, which were found to be acceptable for the safety of patients [29,30]. However, all these studies reported short follow-ups and it is unknown to date the possible adverse biological effects of metal release in the long-term. Recently Chalmers et al reported that no patient with a modular dual-mobility construct and ceramic femoral head had elevated Co levels. That series included also patients revised specifically for adverse local tissue reactions to metal. Three patients had radiographic evidence of incomplete seating of the liner. Two cases occurred in the group of Permedica and one in the Stryker series. Only the last one needed to be submitted to revision. The notion that a stiff cobalt-chrome liner has a potentially higher risk of malseating because of lessconforming tolerance than that of polyethylene has been supported by experiences with incomplete seating of the liner with metal-backed ceramic liners [31]. This complication could be caused by interposition of soft tissue or bone and plastic deformation of acetabular shell during impaction. Cadaveric studies, using the press fit technique with Trident acetabular shells, actually have showed constant compression deformation preventing complete seating of the liner [32]. Two papers [33,34] at our knowledge reported of incomplete seating using MDM Stryker modular dual mobility cups. The incidence was respectively of 5.8% and 1.3% lower than that reported in similarly hard and inelastic metal-backed ceramic liners and significantly higher in low-volume MDM surgeons than high-volume MDM surgeons [33]. Another paper recently has reported an incidence of liner mispositioning of 5.0% with both Stryker and Zimmer Biomet constructs [35]. According to this study component size of 50 mm or smaller was identified as a risk factor for mispositioning.

Limits of our study

Our study has several limitations. First, it is a retrospective review with a relatively small number of patients. Secondly it is a heterogeneous study that includes primary and revision and conversion THAs. Finally, any of our cases was studied for serum ions evaluation. Nevertheless, is the only report where four different modular MDC implants have been studied in a population of high risk patients in a single institution.

Conclusions

The modular DMC are a clear evolution of the simple and standard DMC because they allow the placement of screws on the acetabular cup in order to achieve greater stabilisation of the construct, they allow intraoperative visualization of whether the cup is perfectly adhered to the acetabular base without the use of intraoperative fluoroscopies and finally, thanks to the latest developments and updates which have led to the thinning of the acetabular construct and the metal liner, there is an increase in the JD and therefore an increase in stability compared to standard hip prostheses.

Modular DMC also have disadvantages, such as intraoperative dislocation and mispositioning of the modular components. For the reasons listed above, our study suggests that, in high-risk patients with a previous surgical history of hip instability, the modular DMC component offers a low risk of dislocation and good overall construct survival.

Longer follow-up is obviously needed to determine the prevalence of late complications and the limitations of these components in patients with a high risk of dislocation and revisions for recurrent dislocation.

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