Complications in Total Hip Arthroplasties After Acetabulum Fractures: A Comparative Study of Conventional Cups Versus Dual Mobility Cups

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ABSTRACT

Introduction: Degenerative hip disease can develop after an acetabulum fracture. Total Hip Arthroplasty (THA) is a common salvage procedure that generally yields good outcomes but is not without technical difficulties and complications. **Objective:** To analyze the clinical and radiological outcomes and short- and medium-term complications of THA by comparing uncemented, dual-mobility acetabular cups with conventional uncemented cups. **Materials and Methods:** We retrospectively evaluated 37 patients who underwent THA between 2003 and 2022. Clinical and functional outcomes were assessed using the Merle d'Aubigné and Postel scale, while radiographic outcomes were evaluated according to the modified Stauffer criteria and the stability of cementless components based on Engh parameters. **Results:** The final sample included 37 patients (11 women and 26 men) with an average age of 43.78 years. The average follow-up time was 6.6 years. Outcomes were excellent in 54% of cases, good in 32.4%, fair in 8.1%, and poor in 5.5%. Fisher's exact test showed no significant correlation between the type of cup used and the risk of complications. **Conclusions:** Total hip arthroplasty using dual-mobility cups is a highly effective treatment option for the sequelae of acetabular fractures, offering excellent outcomes and a very low complication rate.

Keywords: Acetabulum fractures; dual mobility; total hip replacement; dislocation; revision of total hip arthroplasty; instability.
Level of Evidence: IV

Complicaciones en las artroplastias totales de cadera después de fracturas de acetábulo. Estudio comparativo entre cotilos convencionales y de doble movilidad

RESUMEN

Introducción: La enfermedad degenerativa de la cadera puede desarrollarse después de una fractura de acetábulo. La artroplastia total de cadera es un procedimiento de salvataje muy utilizado que logra buenos resultados, pero que no está libre de dificultades técnicas y complicaciones. **Objetivos:** Analizar los resultados clínicos y radiográficos de la artroplastia total de cadera y sus complicaciones a corto y mediano plazo, comparando componentes acetabulares de doble movilidad no cementados y cotilos convencionales no cementados. **Materiales y Métodos:** Se evaluó retrospectivamente a 37 pacientes sometidos a una artroplastia total de cadera entre 2003 y 2022. Se analizaron los resultados clínicos y funcionales según la escala de Merle D´Aubigné; los resultados radiográficos, según los criterios modificados de Stauffer; y la estabilidad de los componentes no cementados mediante los parámetros de Engh. **Resultados:** La muestra estaba compuesta por 37 pacientes (11 mujeres y 26 hombres), con una media de edad de 43.78 años. El tiempo promedio de seguimiento fue de 6.6 años. Los resultados fueron excelentes (54%), buenos (32,4%), regulares (8,1%) y malos (5,5%). Mediante la prueba exacta de Fisher, se comparó entre el tipo de cotilo empleado y el riesgo de complicaciones, y no se encontró una correlación significativa. **Conclusiones:** La artroplastia total de cadera con cotilos de doble movilidad es una opción muy válida para tratar las secuelas de fracturas acetabulares, logra excelentes resultados y la tasa de complicaciones es muy baja.

Palabras clave: Fracturas de acetábulo; doble movilidad; reemplazo total de cadera; luxación; revisión de artroplastia total de cadera; inestabilidad.
Nivel de Evidencia: IV

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INTRODUCTION

Degenerative hip disease, also known as secondary hip osteoarthritis, may develop after a fracture of the acetabulum due to joint incongruity or the severity of the initial injury. Its incidence ranges from 12% to 57%.[1]

Osteonecrosis of the femoral head is another possible complication of fractures and fracture-dislocations of the acetabulum, occurring with a frequency of 2% to 40%. [2]

When post-traumatic osteoarthritis develops, total hip arthroplasty (THA) is a common and effective salvage procedure, although it is not without challenges and complications. Patients who present with post-traumatic osteoarthritis tend to do so at an earlier age compared to those with primary hip osteoarthritis, yet they exhibit similar symptoms: limited joint range of motion, pain, and functional limitations.

Open reduction and internal fixation of a displaced acetabular fracture may reduce the risk of post-traumatic osteoarthritis. This approach can also optimize acetabular bone stock and minimize pelvic deformity, which could be advantageous if a THA is needed later. However, a history of acetabular osteosynthesis may present technical challenges during joint replacement surgery, as the patient may present with scar tissue, heterotopic ossifications, osteosynthesis material, pseudarthrosis of acetabular fracture lines, cavitary or segmental bone defects, and even hidden infection. Therefore, preoperative planning is crucial to prevent major complications, reduce surgical time, and optimize outcomes.

In selected cases where a displaced acetabular fracture has a low likelihood of a favorable long-term outcome after osteosynthesis, THA during the acute stage may provide an alternative means of achieving a painless, mobile hip.[4,5] Indications for THA within 30 days of fracture (acute stage) include patients over 60 years old, posterior wall comminution or impaction, dome impaction (gull sign),[6] severe osteopenia, severe osteochondral injury to the femoral head, and associated femoral neck fracture. This approach is based on evidence that the short-term conversion rate to THA for acetabular fractures in older adults treated with open reduction and internal fixation is 22% to 54%.[7,8]

Unfortunately, most published studies are short or medium-term and report significant failure rates and many technical problems related to surgery and previous trauma.[9-11] One of the persistent challenges of THA after acetabular fracture is prosthetic dislocation, which is one of the most frequent complications after mechanical aseptic loosening and infection.[12-15] Moreover, patients in this group tend to be younger and more physically active, often seeking to return to the same sports and work activities as before the accident.

OBJECTIVES

The purpose of this study was to analyze the clinical and radiographic outcomes of total hip arthroplasty (THA) performed after the development of post-traumatic osteoarthritis following an acetabular fracture, as well as its short- and medium-term complications. The study compared the outcomes between uncemented dual-mobility acetabular components and conventional uncemented cups.

MATERIALS AND METHODS

We retrospectively evaluated 49 patients, including their medical records and radiographic files, who had undergone THA as treatment for post-traumatic osteoarthritis following an acetabular fracture, as well as acute-stage THA in selected cases, between 2003 and 2022 (Figures 1 and 2).

The inclusion criteria were as follows: 1) patients admitted to the Hospital Municipal de Urgencias or Clínica Privada Vélez Sarsfield in Córdoba, with an initial diagnosis of acetabular fracture, who underwent THA as definitive treatment with a follow-up of no less than six months; 2) age >15 years; 3) regular attendance at follow-up appointments; and 4) availability of clinical records and complementary studies for clinical and radiographic evaluation.

The exclusion criteria were: 1) pathological fractures; 2) previous rheumatic diseases affecting the joint; and 3) loss to follow-up or death due to other causes.

After applying these criteria, 37 patients were selected.

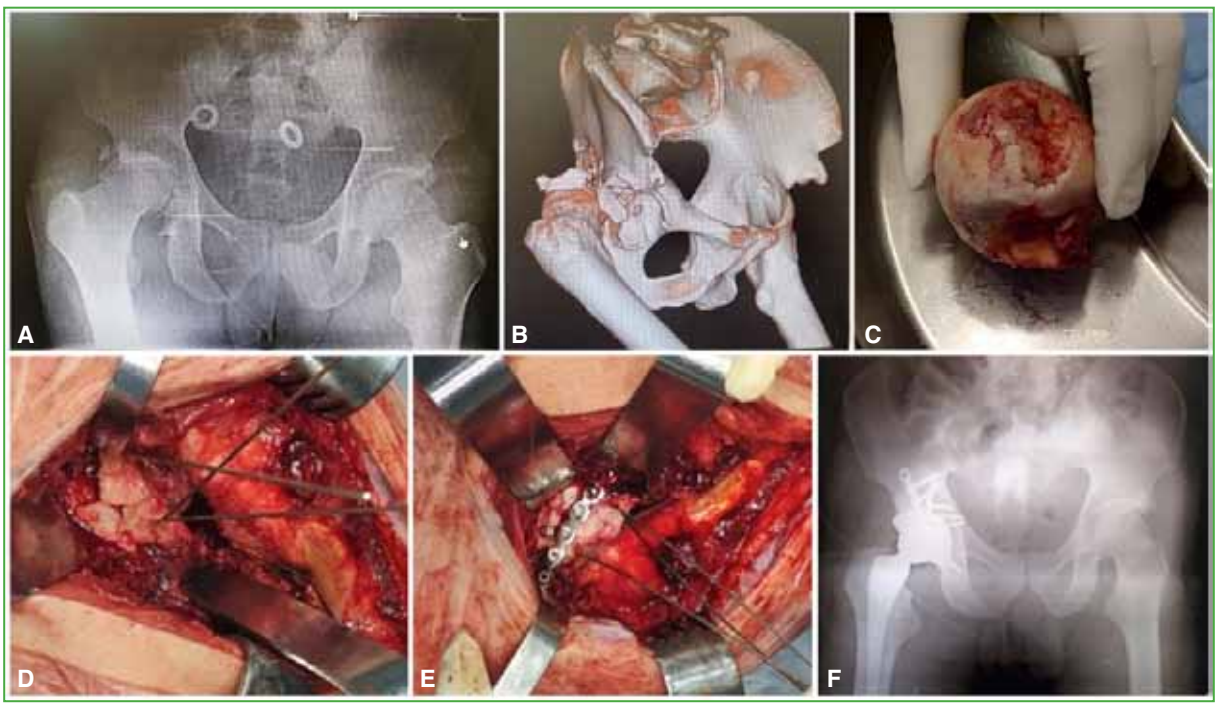

Figure 1. 59-year-old man with acetabular fracture-dislocation due to a traffic accident, with more than 30 days of evolution. **A.** Anteroposterior radiograph of the pelvis. **B.** Tomography with 3D reconstruction showing a fracture-dislocation of the posterior wall and column. **C.** Image showing a severe osteochondral lesion of the femoral head. Osteosynthesis plus total hip arthroplasty is indicated in one stage. **D and E.** Intraoperative images: wall reduction and provisional posterior column fixation with a 3.5 mm reconstruction plate. F. Postoperative anteroposterior pelvis radiograph showing cementless total hip arthroplasty. Excellent outcomes were achieved by the end of the study.

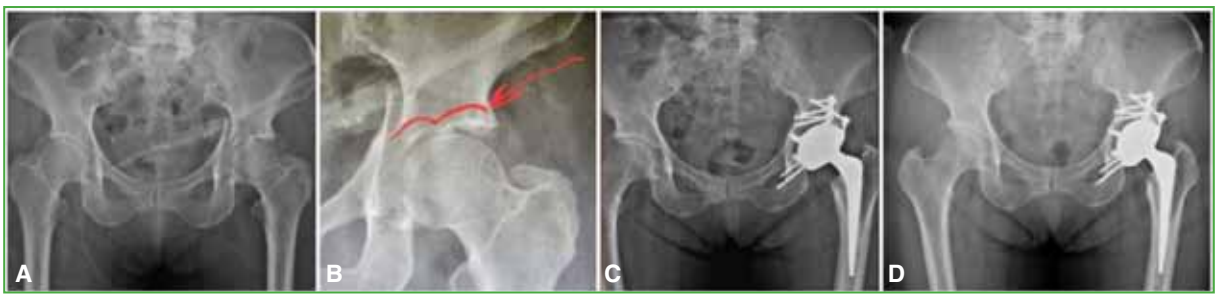

Figure 2. 75-year-old woman with a transverse and posterior wall fracture of the left acetabulum. **A.** Anteroposterior radiograph of the pelvis. **B.** Magnified radiograph showing the "gull sign" due to impaction of the acetabulum bearing zone. **C.** Anteroposterior radiograph of the pelvis in the immediate postoperative period, with osteosynthesis of the posterior wall and column and hybrid total hip arthroplasty with a dual-mobility cup. **D.** Anteroposterior radiograph of the pelvis 3 years after surgery, showing very good clinical and radiographic evolution.

The outcomes were classified as excellent, good, fair, or poor according to the Merle D'Aubigné functional evaluation scale, which is based on three parameters: pain, range of motion, and gait (Table 1). The final score was the sum of the values obtained for each parameter (Table 2).

Table 1. Merle D'Aubigné functional assessment scale.

Score	Pain	Range of motion	Gait
6	None	90° flexion	Normal
5	Mild	70°-90° flexion	Slight limp after long distances
4	After 30 minutes of walking	50°-70° flexion	Limp after long distances, may require cane or crutches
3	Moderate	30°-50° flexion	Significant limp, requires cane
2	Severe	<30° flexion	Very limited
1	Very severe	Very restricted	Bedridden

Table 2. Merle D'Aubigné total score scale.

Total sum	Scoring
17-18	Excellent
15-16	Good
13-14	Fair
<13	Poor

The collected data were evaluated by comparing conventional uncemented cups with uncemented dual-mobility cups.

As a working hypothesis, we aimed to determine whether the use of dual-mobility cups was statistically significant in reducing the risk of complications such as loosening or prosthetic dislocation. To assess this, we used the chi-squared method with Yates correction, and the results were further compared using Fisher's test.

Preoperative planning

Preoperative evaluation and planning was conducted on anteroposterior radiographs of the pelvis in the Judet views (inlet and outlet) and CT scans. Acetabular fractures were classified according to the Judet and Letournel classification, while residual acetabular defects were categorized using the *American Academy of Orthopaedic Surgeons* (AAOS) scale, which divides them into five types: type I, segmental defects; type II, cavitary defects; type III, combined defects; type IV, pelvic discontinuity; and type V, hip arthrodesis.

The surgical approach most commonly used for THA was the posterolateral approach over the previous scar (Kocher-Langenbeck). In cases without a previous wound, the Gibson posterolateral approach was performed. Trochanteric osteotomy was not performed in any case. Femoral stems were selected based on bone quality or density and the type of femoral canal according to the Dorr classification. The selection of acetabular components depended on the presence of previous defects or a history of acetabular fracture-dislocations, with dual-mobility cups indicated in such cases. Osteosynthesis material was removed, partially or totally, only if it interfered with acetabular reaming (Figure 3). For the treatment of acetabular bone defects, iliac crest bone graft or autologous bone graft from the femoral head was used (Figure 4). Neither cadaveric nor lyophilized donor grafts were used in any case. To restore the anatomy of the acetabular labrum, structural grafts were used for segmental defects, while 4 x 4 mm cancellous bone chips (impregnated with 1 g of vancomycin) were used for cavitary defects. Autologous structural grafts were provisionally fixed with 1.8 mm diameter pins, and once the optimal position was achieved, definitive osteosynthesis was performed with AO reconstruction plates and 3.5 mm cortical screws. No acrylic bone cement (polymethylmethacrylate) or bone substitute was used as a filler for bone defects.

Figure 3. 24-year-old male, referred from another province, with failed osteosynthesis and hip dislocation. Removal of the osteosynthesis and an uncemented total hip arthroplasty with a dual-mobility cup (due to severe osteochondral joint injury) are planned. **A.** Anteroposterior radiograph of the pelvis. **B.** Anteroposterior radiograph of the pelvis after hip reduction, awaiting arthroplasty. **C.** Postoperative anteroposterior radiograph of the pelvis showing very good clinical evolution.

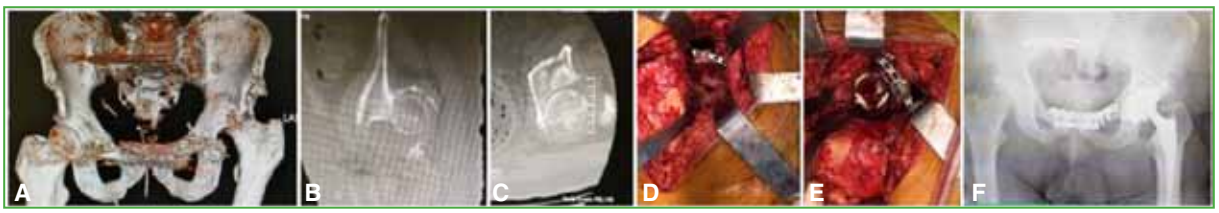

Figure 4. 54-year-old man with a chronic fracture-dislocation of more than 12 months' duration, due to cardiovascular contraindications and a history of pelvis osteosynthesis with a dislocated left hip. **A.** 3D tomography of the pelvis. **B and C.** Computed tomography scans, selected slices, showing chronic left hip dislocation. **D.** Femoral head autograft plus osteosynthesis with a 3.5 mm plate. **E.** Dual-mobility cementless acetabular component implant with ischial, ilial, and pubic anchors. **F.** Postoperative anteroposterior pelvis radiograph of hybrid total hip arthroplasty, showing excellent clinical and radiographic evolution.

In selected cases, THA was indicated within 30 days of the accident (acute stage) based on criteria predicting poor prognosis for acetabular fractures: patients >60 years old, comminution or impaction of the posterior wall, dome impaction, advanced age, severe osteopenia, femoral head impaction, and fractures of the femoral neck and head.

Treatment and postoperative evaluation

Twenty-four hours after surgery, all patients began a plan of passive and active assisted hip movements. Antibiotic prophylaxis was continued with 1 g of cephalothin for 48 hours. Patients who did not require bone grafting were permitted immediate full weight-bearing, while those with structural grafting were instructed to begin partial weight-bearing at 30 days and full weight-bearing at 45 to 60 days. No indomethacin prophylaxis or radiotherapy was administered to reduce the incidence of heterotopic ossifications. Anteroposterior and axial radiographs of the hip were taken at 1, 3, and 6 months after THA, and then annually. Probable or definitive loosening of cemented femoral stems was assessed on radiographs using the modified Stauffer criteria. The stability of uncemented components was evaluated according to Engh criteria. Femoral stems were assessed based on Gruen zones.[18]

Statistical analysis

Categorical variables are expressed as percentages and the number of patients observed. Continuous variables are presented as mean and standard deviation, providing measures of central tendency and data dispersion. Table 3 summarizes the different statistical tests and values of the comparisons performed. Fisher's exact test was used to evaluate whether there was an association between the type of cup used and the risk of complications.

Table 3. Results of statistical tests.

Variable	Comparison	Statistical test	p	Significant (p <0.05)
Age	Study patients' gender	Mann-Whitney U	0.64	No
Merle D'Aubigné's score	Types of cups used	Mann-Whitney U	0.38	No
Complications	Risks and complications with the prosthesis type	Fisher's Exact	0.25	No

RESULTS

Out of the 49 patients evaluated, 12 were excluded due to loss to follow-up, including three who died of causes unrelated to the condition under study. Therefore, the final sample included 37 patients (11 women and 26 men). All cases were unilateral. The mean age was 43.78 years (range 23-75) (Figure 5).

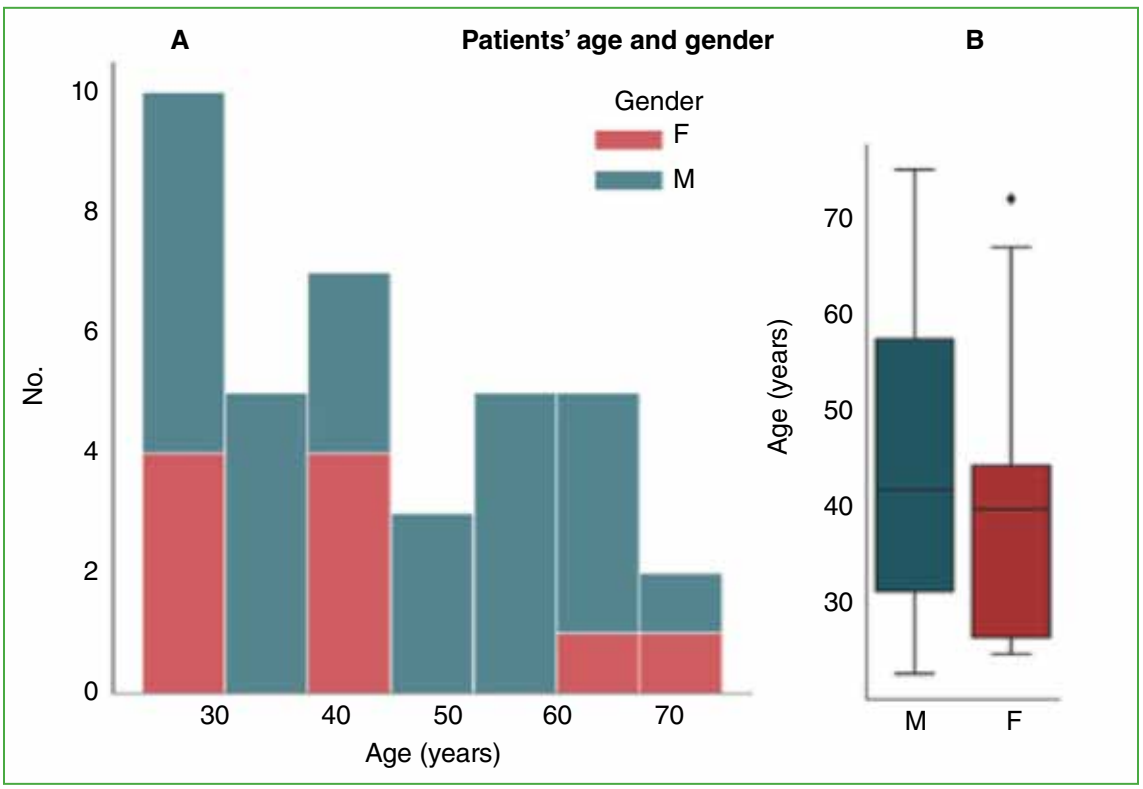

Figure 5. Age and gender of the patients included in the study. **A.** Age distribution. **B.** Percentage according to gender.

The mean follow-up time after THA was 6.6 years (min. 6 months; max. 16 years).

Cemented stems were used in 32.4% of the patients, primarily in those with Dorr C femur, generally due to osteopenia resulting from post-fracture dysfunction of the acetabulum. Cementless stems were used in 67.6% of the cases, with excellent outcomes and no loosening observed by the end of the study (Figure 6).

As for the acetabular component, the fixation system was always cementless. Jumbo cups were not used. In 14 patients, cementless dual-mobility cups were implanted, which were coated in hydroxyapatite of French origin, with additional anchorages to ilium, ischium and pubis with corresponding liners and a captive cobalt-chromium head of 28 mm diameter. One patient (case 48) received a custom-made, porous, uncemented cup of national origin, into which a dual-mobility cup was cemented, with good clinical outcomes to date. In the rest of the sample (23 cases), conventional uncemented cups were used (from the Mercosur and imported) with porous titanium coating and additional fixation with 1 to 3 screws of 6.5 mm diameter, as needed (Figure 6). Of these, 18 hips were fitted with 28 mm diameter heads, and five with 32 mm diameter heads. This variation depended on the provision by the Ministry of Health, as most patients were public hospital patients without insurance.

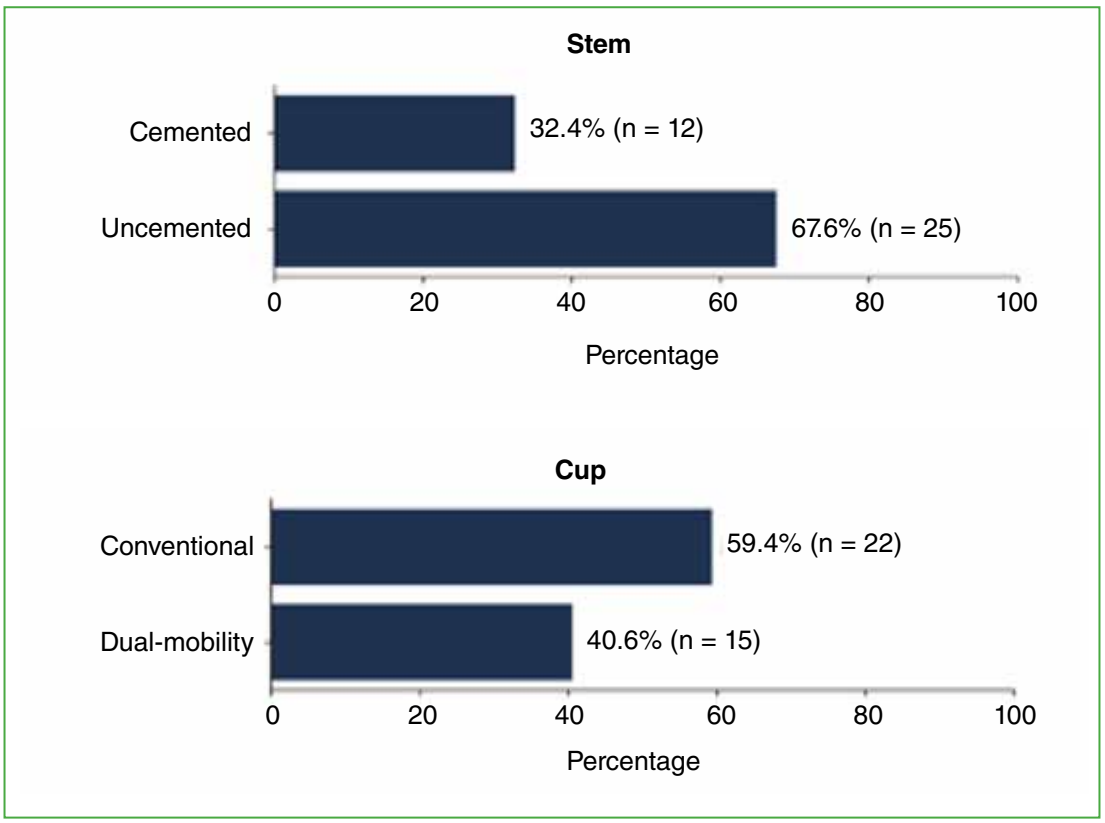

Figure 6. Proportion of stem and cup types used in hip arthroplasty surgeries.

During THA, some technical difficulties arose related to the approach for acetabular fracture fixation in hips that had been previously operated on, due to the existing scar, some asymptomatic heterotopic calcifications (Brooker grade I), and the presence of osteosynthesis materials. In only four cases was it necessary to remove the osteosynthesis material; in two of these, only the screws that interfered with acetabular reaming were removed. After dislocation of the hip and osteotomy of the femoral neck, acetabular defects were re-evaluated and classified under direct vision. The resulting acetabular defects, according to the AAOS scale, are shown in Figure 7. In three cases, the initial treatment of the fracture was conservative due to economic problems, and the condition progressed to early post-traumatic osteoarthritis. In five cases, THA was the initial treatment. Two of these patients were lost to follow-up and excluded from the study. The remaining three patients (cases 7, 40, and 49) had good outcomes until the end of the study. In four other cases (with AAOS type III defects), acetabular reconstruc-

tion with structural and ground bone autograft, osteosynthesis with a 3.5 mm plate and screws, and THA was performed, all with excellent outcomes by the end of the study. The mean time between the accident causing the acetabular fracture and THA was 26.9 months (range 1-144). The most frequent types of fractures that progressed to post-traumatic osteoarthritis were: posterior wall with posterior hip dislocation (43%), spine and posterior wall (16.2%), transverse plus posterior wall (16.2%), and isolated transverse (8.1%). In the latter, rapid erosion of the femoral head occurred due to joint incongruity (Figure 8).

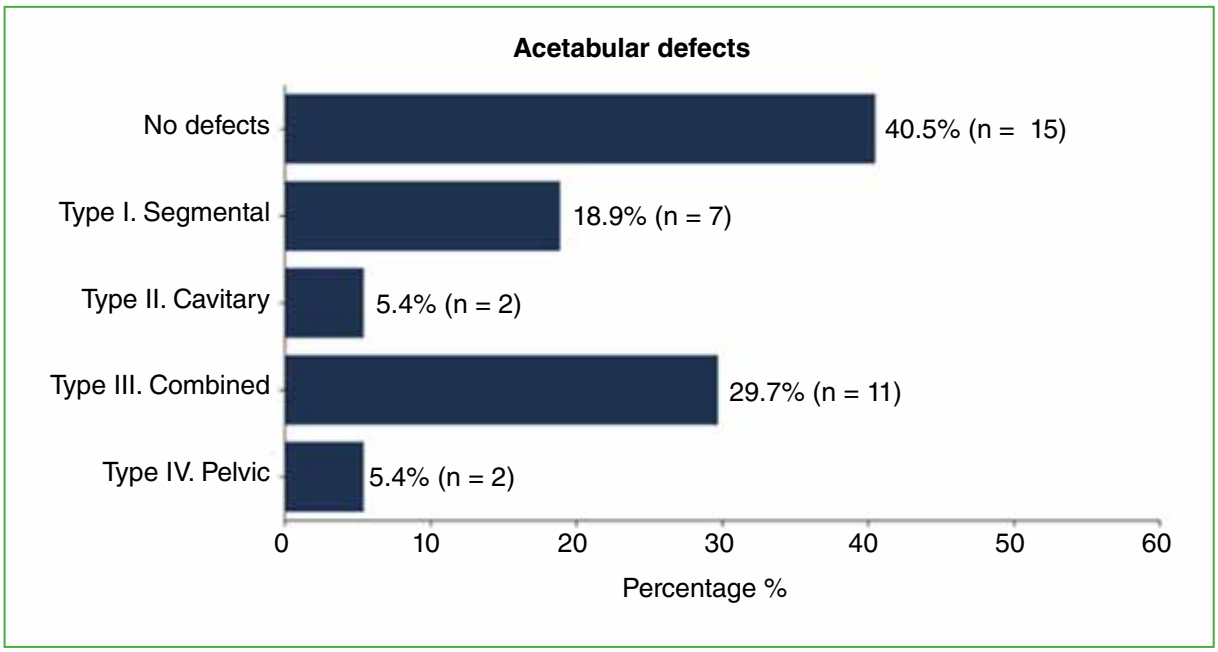

Figure 7. Percentage and number of patients according to the different types of acetabular defects according to the AAOS scale.

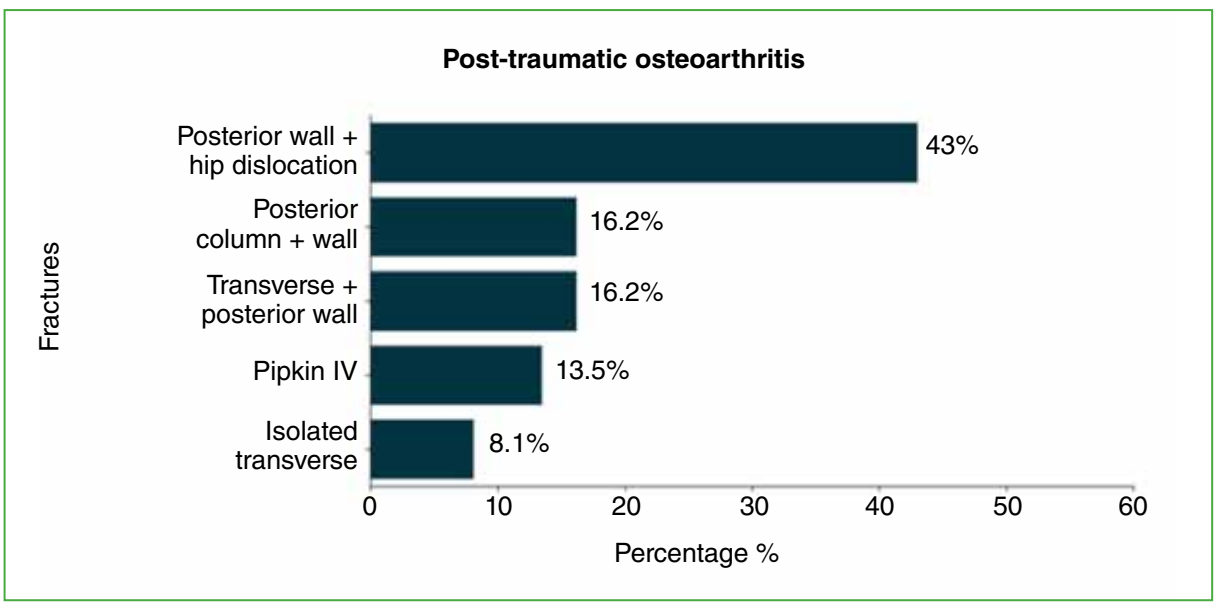

Figure 8. Percentage of the different types of fractures in patients who developed post-traumatic osteoarthritis.

In addition, there were five cases of femoral head and acetabulum fractures classified as Pipkin type IV (13.5%), one of which was excluded due to loss to follow-up. The remaining four cases rapidly progressed to necrosis and post-traumatic osteoarthritis due to the severity of the initial osteochondral lesion. Three patients received conventional cementless prostheses, and one received a cementless dual-mobility cup. All had good to excellent functional and radiographic outcomes by the end of the evaluation.

Clinical and radiographic findings

According to the Merle D'Aubigné scale, the outcomes were classified as excellent (54%), good (32.4%), and fair (8.1%). Of these, Case 3 underwent revision at 6 years due to septic loosening, and Case 10 (with cementless THA) experienced two episodes of posterior prosthetic dislocation, which were resolved with closed reduction, and has not had any new episodes. In 5.5% of the cases, the results were fair or poor. One of these patients is awaiting revision due to acetabular loosening (conventional cementless) and resorption of the structural bone graft. By the end of the study, there had been no septic or aseptic loosening of any of the implanted dual-mobility components, nor were there significant signs of acetabular radiolucency. In Case 45, a possible proximal debonding of an uncemented hydroxyapatite-coated stem was noted in Gruen zones 1 and 7. In one of the mirror-polished Charnley cemented stems (Case 3), femoral hypertrophy was detected around the tip of the stem (Gruen zones 3, 4, and 5), indicating load concentration.

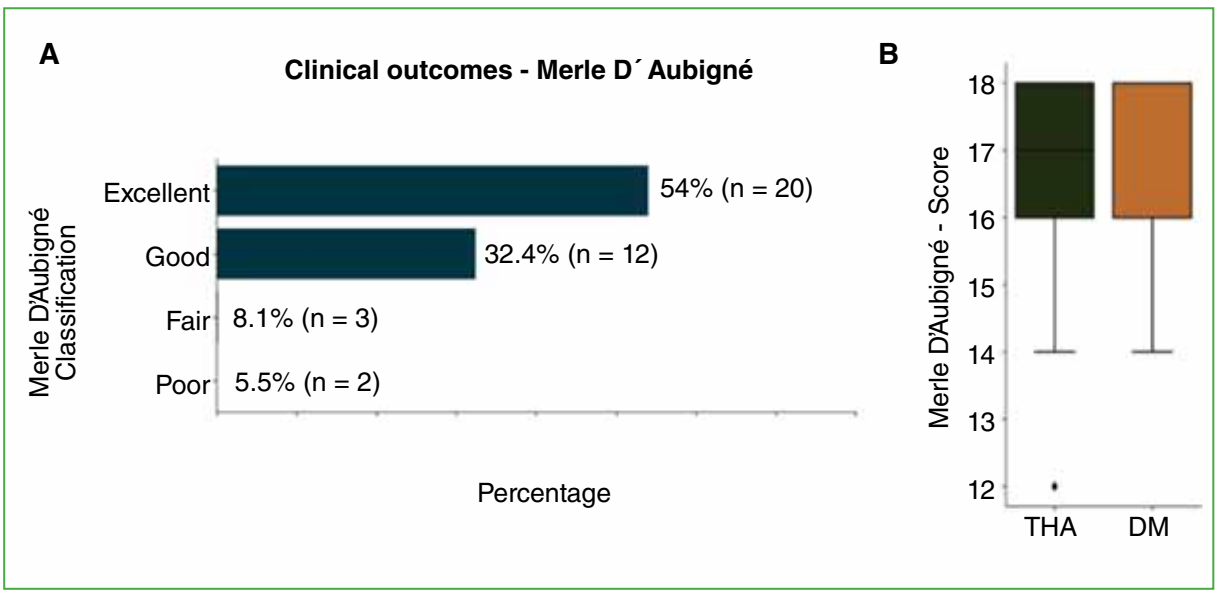

Figure 9. A. Percentage and number of patients classified according to the Merle D'Aubigné scale. **B.** Box plot of the scores obtained according to this same scale, for conventional cups (total hip arthroplasty, THA) and dual-mobility (DM) cups.

The dislocation rate in THAs with conventional cups was 8.1% (Cases 2, 10, and 13), all of which involved a previous Kocher-Langenbeck posterior approach and 28 mm diameter heads. In contrast, there were no prosthetic or intraprosthetic dislocations with dual-mobility cups.

No significant correlation was found between the type of cup used (conventional vs. dual-mobility) and the risk of complications ($p = 0.25$).

DISCUSSION

The main complication of THA following acetabular fractures is prosthetic dislocation, which prompted this study. Matta and Ferguson[1] reported a dislocation rate of 8% with conventional cups in 57 patients. In this series, the rate was the same, but it was possible to reduce it to zero with the use of dual-mobility cups.

Like other authors,[19,20] it was confirmed that THA after acetabular fracture is more difficult than routine primary arthroplasty due to previous scarring, heterotopic ossifications, remaining osteosynthesis material, and residual acetabular defects. Additionally, acetabular reconstruction was more challenging and technically laborious in patients who had not undergone prior surgery (open reduction and acetabular internal fixation). Some of these conservatively treated cases had severe medial defects with intrapelvic protrusion, complicating the procedure.

Several authors have reported that aseptic loosening is more frequent in patients with type III acetabular deficiencies (AAOS classification).[21] According to several studies, better outcomes are obtained with uncemented acetabular components compared to cemented cups if acetabular deficiencies are present. In this series, the short- and medium-term results with biologically fixed acetabular components were very good. This was likely because the acetabular components were implanted with a bone remnant of at least 60% of the patient's own bone. Additionally, structural grafts demonstrated excellent osseointegration, mainly due to the initial stability provided by the corresponding osteosynthesis.Patients who progressed more rapidly to post-traumatic osteoarthritis or avascular necrosis and required immediate THA were those who sustained fractures of the posterior wall or column with joint impaction, associated with chondral lesions from dislocation at the time of the initial trauma. The average time elapsed between the accident causing the acetabular fracture and THA was 26.9 months. Several publications[22,23] note that patients over 60 years old with acetabular fractures treated with reduction and internal fixation have a conversion rate to THA exceeding 30%. In Kreder et al.'s study,[24] 54% of 128 patients with a history of posterior acetabular wall fracture underwent THA within less than two years. In another study of 46 cases, O'Toole et al. reported a 34% conversion rate. These data suggest a favorable balance toward THA in the acute stage when making decisions for older patients. According to various French authors, after 15 years of follow-up with new technologies applied to dual-mobility cups, the survival rate improved from 81.4% to 96.3%, and the dislocation rate improved from 0% to 1%. The intraprosthetic dislocation rate ranged from 0% to 5.2%. Causes of cup failure included aseptic loosening (1.8-3.4%), excessive wear of the polyethylene insert (1-2%), and screw fracture (1%). Guyen et al.,[25] Leclercq et al.,[26] and Vielpeau et al.,[27] in published series of 167, 200 and 231 patients with primary THAs using current dual-mobility designs, with a follow-up time of 3-6 years, reported a dislocation rate of 0%.

CONCLUSIONS

Based on the above, THA with dual-mobility cups is a highly effective option for treating acetabular fracture sequelae, yielding excellent clinical and radiographic outcomes with a very low complication rate. However, conventional cementless cups with 32 or 36 mm diameter prosthetic femoral heads remain the gold standard. In selected cases with combined acetabular defects, porous titanium 3D custom cups should be considered, as they are cost-effective and have thus far shown promising results. Although no statistically significant correlation was found between the type of cup used (conventional vs. dual-mobility) and the risk of complications, and no prosthetic dislocations were observed with dual-mobility cups, it is important to continue with long-term follow-up, include more cases, and obtain more reliable results.

Conflict of interest: The author declares no conflicts of interest.

REFERENCES

1. Matta JM, Ferguson T. Total hip replacement after acetabular fracture. *Orthopaedics* 2005;28:959-62. https://doi.org/10.3928/0147-7447-20050901-23
2. Lugones MA, Díaz Gallardo P, Bidolegui F, Vindver G, Allende BL. Artroplastia total de cadera con copa no cementada en secuela de fractura de acetábulo. *Rev Asoc Argent Ortop Traumatol* 2012;77(3):185-91. https://doi.org/10.15417/128
3. Brooker AF, Bowerman JW, Robinson RA, Riley LH. Ectopic ossification following total hip replacement. Incidence and method of classification. *J Bone Joint Surg* 1973;55:1629. PMID: 4217797
4. Larson C. Fracture dislocation of the hip. *Clin Orthop Relat Res* 1973;92:147-54. https://doi.org/10.1097/00003086-197305000-00013
5. Mears DC, Velyvis JH. Acute total hip arthroplasty for selected displaced acetabular fractures. Two to twelve-year results. *J Bone Joint Surg Am* 2002;84:1-9. https://doi.org/10.2106/00004623-200201000-00001
6. Anglen JO, Burd TA, Hendricks KJ, Harrison P. The "gull sign". A harbinger of failure for internal fixation of geriatric acetabular fractures. *J Orthop Trauma* 2003;17(9):625-34. https://doi.org/10.1097/00005131-200310000-00005
7. O'Toole RV, Hui E, Chandra A, Nascone JW. How often does open reduction and internal fixation of geriatric acetabular fractures lead to hip arthroplasty? *J Orthop Trauma* 2014;28(3):148-53. https://doi.org/10.1097/bot.0b013e31829c739a
8. Daurka JS, Pastides PS, Lewis A, Rickman M, Bircher MD. Acetabular fractures in patients aged >55 years: a systematic review of the literature. *Bone Joint J* 2014;96-B(2):157-63. https://doi.org/10.1302/0301-620x.96b2.32979
9. Sermon A, Broos P, Vanderschot P. Total hip replacement for acetabular fractures. Results in 121 patients operated between 1983 and 2003. *Injury* 2008;39(8):91421. https://doi.org/10.1016/j.injury.2007.12.004
10. Ranawat A, Zelken J, Helfet D, Buly R. Total hip arthroplasty for posttraumatic arthritis after acetabular fracture. *J Arthroplasty* 2009;24(5):759-67. https://doi.org/10.1016/j.arth.2008.04.004
11. Romness DW, Lewallen DG. Total hip arthroplasty after fracture of the acetabulum. Long-term results. *J Bone Joint Surg Br* 1990;72(5):761-4. https://doi.org/10.1302/0301-620x.72b5.2211750
12. Lachiewicz PF, Watters TS. The use of dual-mobility components in total hip arthroplasty. *J Am Acad Orthop Surg* 2012;20:481-6. https://doi.org/10.5435/jaaos-20-08-481
13. Schairer WW, Sing DC, Vail TP, Bozic KJ. Causes and frequency of unplanned hospital readmission after total hip arthroplasty. *Clin Orthop Relat Res* 2014;472:464-70. https://doi.org/10.1007/s11999-013-3121-5
14. Combes A, Migaud H, Girard J, Duhamel A, Fessy MH. Low rate of dislocation of dual-mobility cups in primary total hip arthroplasty. *Clin Orthop Relat Res* 2013;471:3891-900. https://doi.org/10.1007/s11999-013-2929-3
15. Philippot R, Farizon F, Camilleri JP, Boyer B, Derhi G, Bonnan J, et al. Survival of cementless dual mobility socket with a mean 17 years follow-up. *Rev Chir Orthop Reparatrice Appar Mot* 2008;94:e23-e27. https://doi.org/10.1016/j.rco.2007.10.013
16. Stauffer RN. Ten-year follow-up study of total hip replacement. With particular reference to roentgenographic loosening of the components. *J Bone Joint Surg Am* 1982;64:983-90. PMID: 7118986
17. Engh CA, Bobyn JD, Glassman AH. Porous-coated hip replacement. The factors governing bone ingrowth, stress shielding, and clinical results. *J Bone Joint Surg Br* 1987;69(1):45-55. https://doi.org/10.1302/0301-620x.69b1.3818732
18. Gruen TA, McNeice GM, Amstutz HC. "Modes of failure" of cemented stem-type femoral components: a radiographic analysis of loosening. *Clin Orthop Relat Res* 1979;141:17. PMID: 477100
19. Giannoudis PV, Grotz MRW, Papakostidis C, Dinopoulos H. Operative treatment of displaced fractures of the acetabulum. A meta-analysis. *J Bone Joint Surg Br* 2005;87(1):2-9. PMID: 15686228
20. Judet R, Judet J, Letournel E. Fractures of the acetabulum: classification and surgical approaches for open reduction. Preliminary report. *J Bone Joint Surg Am* 1964;46:1615-46. PMID: 14239854
21. Pritchett JW, Bortel DT. Total hip replacement after central fracture dislocation of the acetabulum. *Orthop Rev* 1991;20:607-10. PMID: 1945506
22. Waddell JP, Morton J. Total hip arthroplasty following acetabular fracture. Annual Meeting of the Orthopaedic Trauma Association, Los Angeles, California, Sept. 23, 1994.
23. Weber M, Berry DJ, Harmsen SH. Total hip arthroplasty after operative treatment of an acetabular fracture. *J Bone Joint Surg* 1998;80(9):1295-305. https://doi.org/10.2106/00004623-199809000-00008

24. Kreder HJ, Rozen N, Borkhoff CM, Laflamme YG, McKee MD, Schemitsch EH, et al. Determinants of functional outcome after simple and complex acetabular fractures involving the posterior wall. *J Bone Joint Surg Br* 2006;88(6):776-82. https://doi.org/10.1302/0301-620x.88b6.17342
25. Guyen O, Chen QS, Bejui-Hugues J, Berry DJ, An KN. Unconstrained tripolar hip implants: effect on hip stability. *Clin Orthop Relat Res* 2007;455:202-8. https://doi.org/10.1097/01.blo.0000238796.59596.1f
26. Leclercq S, Benoit JY, de Rosa JP, Euvrard P, Leteurtre C, Girardin P. Results of the Evora dual-mobility socket after a minimum follow-up of five years. *Rev Chir Orthop Reparatrice Appar Mot* 2008;94(8):e17-e22. https://doi.org/10.1016/j.rco.2007.10.015
27. Vielpeau C, Lebel B, Ardouin L, Burdin G, Lautridou C. The dual mobility socket concept: experience with 668 cases. *Int Orthop* 2011;35(2):225-30. https://doi.org/10.1007/s00264-010-1156-8