Treatment of Paprosky Type IIIA-B Acetabular Defects and Pelvic Discontinuity With Custom 3D Implants: Medium-Term Results

Carlos A. Vega,[*,] Favio Moruno,[*] Esteban Garavano,[**] Matías Sued,[**] Ellery Palomino Prado[**]**

[*] *Orthopedics and Traumatology Service, Hospital Zonal General de Agudos "Dr. Carlos Bocalandro", Loma Hermosa, Buenos Aires, Argentina*

[**] *Hip Pathology Unit, Orthopedics and Traumatology Service, Hospital Central de San Isidro "Dr. Melchor A. Posse", Buenos Aires, Argentina*

ABSTRACT

Introduction: Acetabular revision is a particularly challenging surgery when there is loss of bone stock and extensive acetabular defects. 3D implants can make up for these defects and adapt to each circumstance. The objective of this study was to evaluate clinical and radiographic outcomes in patients with severe acetabular defects treated with 3D-printed implants and determine the appropriate cup constraint for each patient. **Materials and Methods:** A retrospective study was carried out on 10 patients with severe acetabular defects classified as Paprosky type IIIA-B and pelvic discontinuity who underwent surgery with a custom 3D-printed acetabular prosthesis, carried out by the same surgery team between 2016 and 2022. **Results:** The average follow-up was 40.5 months. The Harris hip score improved significantly from an average of 24.2 to 63.5 at the last follow-up. No signs of loosening or migration of the 3D cup in terms of inclination and anteversion were observed in any case, at the last control. **Conclusion:** Custom-made acetabular implants represent a valid solution to treat severe acetabular bone defects and pelvic discontinuity.

Keywords: Acetabular defect; 3D cup; custom implant; reconstruction.

Level of Evidence: IV

Tratamiento de defectos acetabulares tipo IIIA-B de Paprosky y discontinuidad pélvica con implantes 3D a medida: resultados a mediano plazo

RESUMEN

Introducción: La revisión acetabular es una cirugía particularmente desafiante cuando hay pérdida de stock óseo y defectos acetabulares extensos. Los implantes 3D pueden suplir estos defectos y adaptarse a cada circunstancia. El objetivo de este estudio fue evaluar los resultados clínicos y radiográficos en pacientes con defectos acetabulares severos tratados con implantes impresos en 3D y determinar el constreñimiento adecuado del cotilo para cada paciente. **Materiales y Métodos:** Se realizó un estudio retrospectivo de 10 pacientes con defectos acetabulares severos clasificados como tipo IIIA-B de Paprosky y discontinuidad pélvica que se sometieron a una cirugía con prótesis acetabular a medida impresa en 3D, a cargo del mismo equipo quirúrgico, entre 2016 y 2022. **Resultados:** El seguimiento medio fue de 40.5 meses. El puntaje de cadera de Harris mejoró significativamente de un promedio de 24,2 a 63,5 en el último control. No se observaron signos de aflojamiento ni migración del cotilo 3D en cuanto a la inclinación y anteversión en ningún caso, en el último control. **Conclusión:** Los implantes acetabulares a medida representan una solución válida para tratar defectos óseos acetabulares severos y la discontinuidad pélvica.

Palabras clave: Defecto acetabular; cotilo 3D; implante a medida; reconstrucción acetabular.

Nivel de Evidencia: IV

Received on May 10th, 2023. Accepted after evaluation on July 3rd, 2023 • Dr. CARLOS A. VEGA • c_vega78@hotmail.com ID https://orcid.org/0000-0002-6104-5099

How to cite this article: Vega CA, Moruno F, Garavano E, Sued M, Palomino Prado E. Treatment of Paprosky Type IIIA-B Acetabular Defects and Pelvic Discontinuity With Custom 3D Implants: Medium-Term Results. *Rev Asoc Argent Ortop Traumatol* 2023;88(5):511-519. https://doi.org/10.15417/issn.1852-7434.2023.88.5.1760

INTRODUCTION

In recent years, the number of primary arthroplasties has increased exponentially, so the absolute number of revisions will have a directly proportional increase.[1] Acetabular revision is a challenging surgery, particularly when there is loss of bone stock with extensive acetabular defects, poor bone quality, and implant migration. Successful acetabular reconstruction with fixation of prosthetic components requires sufficient primary stability for subsequent secondary osseointegration.[2,3] Reasons for revision are attributable to various causes: dislocation, instability, mechanical loosening, infection, among others.[4]

A wide range of surgical strategies are available for the resolution of this condition, such as acetabular support rings, trabecular metal cups with wedges, etcetera. However, it has not yet been defined which one should be used as a reference. While many contained defects can be managed with the use of standard cups, extensive uncontained defects may require custom-made implants given the complexity of the bone defect.[5] 3D implants can treat acetabular defects and be tailored to each situation by printing images from a preoperative computed tomography (CT) scan, giving the surgeon the option of adding precision metal sockets to the implant based on the hemipelvis defects, as well as fixation adjustments to the remaining bone stock by designing and locating precisely oriented screw holes for the bones: ilium, ischium, and pubis, taking into account the bone quality for optimal fixation and planning the reconstruction of the hip center of rotation.[6,7]

Custom-made implants are costly in terms of both money and time; yet, they are a viable therapeutic alternative for extensive bone defects that cannot be treated with standard implants. Although this method is quite costly compared to the use of standard implants, it can often be the only possible solution for revision total hip arthroplasty (THA). Custom implants were developed to achieve implant stability and restore hip biomechanics when there is significant loss of bone stock.[7]

The aim of this study was to evaluate the clinical and radiological outcomes in patients with severe Paprosky type IIIA-B acetabular defects and pelvic discontinuity after treatment with custom 3D-printed implants using CT for revision surgery and to determine the appropriate cup constraint for each patient based on individual patient needs.

MATERIALS AND METHODS

A retrospective evaluation of patients who underwent surgery with a custom 3D-printed acetabular prosthesis for the treatment of severe Paprosky type IIIA-B acetabular defects and pelvic discontinuity between 2016 and 2022 was performed.

Ten patients (7 females and 3 males) underwent revision THA using a custom 3D-designed acetabular component to reconstruct severe acetabular defects. Patient information, including the indication for initial THA and the number of previous operations or revision procedures, was collected from hospital medical records and entered into an Excel spreadsheet (Table 1).

Acetabular involvement was determined according to the Paprosky classification[8] and the American Academy of Orthopaedic Surgeons classification. At admission and at the final control, the Harris Hip Score (HHS), the Oxford Hip Score (OHS), and the Short Form-36 Health Survey (SF-36) were employed.

All patients were operated on by the same surgical team. Inclusion criteria were: patients with severe Paprosky type IIIA or type IIIB acetabular defects and pelvic discontinuity who had been authorized by the infectious diseases team to undergo the second revision stage. Exclusion criteria were: patients with Paprosky types I and II acetabular defects or minor acetabular defects, and active infection.

Although there were no malnourished or morbidly obese patients, we usually tried to correct the clinical condition by setting a BMI between 18 and 30 by protocol.

Preoperative planning and development of the customized 3D acetabular component

All patients underwent revision THA with a customized 3D acetabular component to reconstruct extensive acetabular defects. Prior to surgery, CT images with a metal artifact reduction algorithm were taken of each patient in the supine position, with the lower limbs aligned in anatomical position and neutral rotation. The tomographic slices were 1 mm over the entire pelvis and the data were saved in standard DICOM format (Digital Imaging and Communications in Medicine).

Table 1. Patient characteristics

Patients	Follow-up (months)	Sex	Age	BMI	Indication for primary THA	Reason for the revision	Paprosky type	Revision surgery
1	28	F	82	25	Rheumatoid arthritis	Septic loosening	IIIB	2
2	63	F	73	23	Osteoarthritis	Recurrent dislocation	IIIA	1
3	60	F	68	18	Osteoarthritis	Aseptic loosening	IIIA	1
4	13	F	70	22	Osteoarthritis	Septic loosening	IIIB	3
5	24	F	81	29	Rheumatoid arthritis	Septic loosening	IIIB	2
6	20	F	79	27	Osteoarthritis	Septic loosening	IIIB	2
7	29	F	63	21	Residual hip dysplasia	Septic loosening	IIIB Discontinuity	5
8	72	M	73	23	Rheumatoid arthritis	Aseptic loosening	IIIB	1
9	31	M	80	27	Osteoarthritis	Aseptic loosening	IIIA	2
10	65	M	68	26	Osteoarthritis	Septic loosening	IIIB	2

BMI = body mass index; THA = total hip arthroplasty.

The area of the acetabular bone defect was estimated with a specific image processing program (Mimics, Materialise).

Total radial acetabular bone loss was measured following the method described by Gelaude et al.[9] Bone quality was evaluated by the program in all cases and quantified in Hounsfield units (Figure 1) and, with this information, a precision calculation was made to place the screws in a divergent manner in areas where good bone quality was available so that they would have an optimal grip and, in this way, obtain the maximum possible stability.

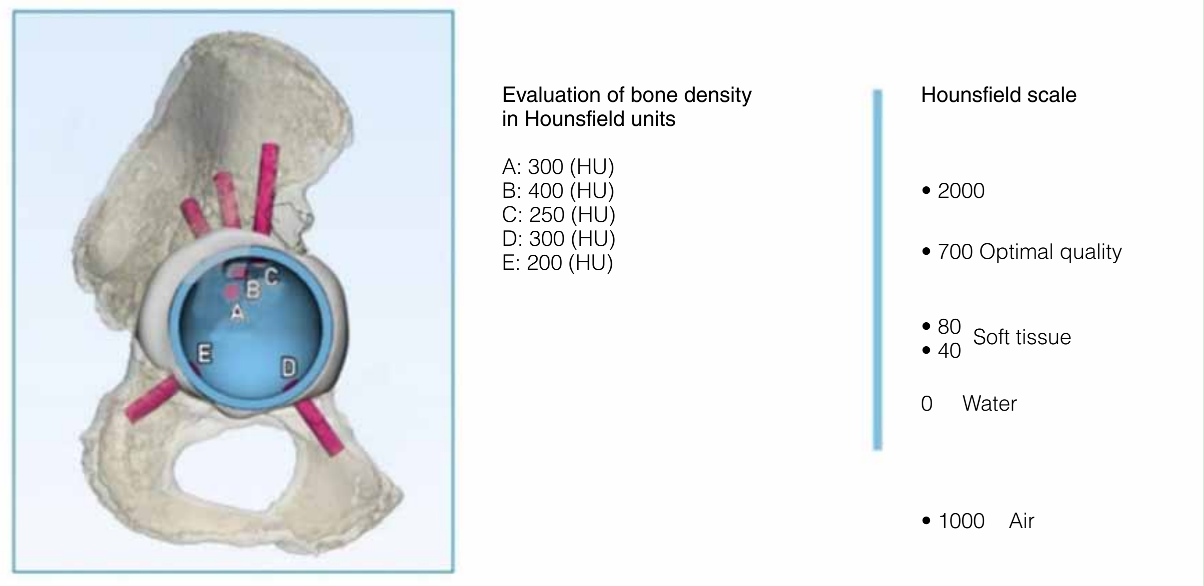

Figure 1. Evaluation of bone density in Hounsfield units (HU).

Prior to the final manufacture of the 3D implant, the technicians and design engineers and the surgeon communicated constantly to optimize the inclination, anteversion and center of rotation of the implant. This communication between the bioengineer and the surgeon is critical for achieving the highest precision in implant development. Thus, two implants are manufactured; first, a plastic prototype of the implant and the affected hemipelvis, which is sterilized and used during surgery to reduce the margin of error. Secondly, the implant is custom made in definitive trabecular titanium.

Selection of the cemented implant

The degree of cup constraint was determined on a patient-by-patient basis. Dual-mobility cups were indicated for patients without comorbidities, increasing the degree of constraint according to the personal risk of dislocation, one of the most common complications of this technique. Patients with extensive abductor mechanism involvement were assessed using MRI, which was requested with a CT scan prior to surgery, to establish their risk of instability.

Before each surgery, synovial fluid was aspirated by arthrocentesis to rule out prosthesis-related infection. Patients with a diagnosis of periprosthetic infection underwent a two-stage revision and definitive surgery was performed with the authorization of the Infectious Diseases Department after complete targeted antibiotic treatment and a recorded decrease in serological markers.

Surgical technique

Preoperative antibiotic prophylaxis was indicated, in addition to tranexamic acid at the time of anesthetic induction and at wound closure.

All surgeries were performed by the same surgical team. The patient was placed in the lateral decubitus position with conventional preparation. An extended posterolateral hip approach was performed in all cases, which was deepened to the articular plane with subsequent tissue debridement to expose the acetabular defect and achieve adequate exposure of the ilium, ischium, and pubis. Osteophytes were removed as determined by preoperative planning.

During surgery, the surgeon relied on the anatomical plastic prototype of the hemipelvis and the trial implant as a guide to identify the defect calculated in the previous CT scan analysis.

First, the trial implant was placed according to the planned setting and the function and stability were evaluated. Subsequently, the trial prototype was removed and the definitive 3D cup was implanted in the acetabular defect and fixed with screws using the placement guides; three screws were placed in the ilium, one in the pubis and two crossed screws in the ischium, which provides greater stability to the implant. Finally, a cup with a varying degree of constraint was cemented into the custom-made implant, depending on the requirements of each patient. It should be highlighted that the 3D implant offers versatility in the selection of numerous cup choices with varying degrees of constraint that can be cemented into the implant to meet the patient's circumstances and lessen the risk of instability. In addition, it allows to improve the component orientation, if necessary. In other words, the cemented cup selected has an anteversion and inclination that are independent of the 3D implant, resulting in acceptable stability and a lower dislocation rate.

A joint drain was left in all cases (for 48 h) and the wound was closed in layers.

Postoperative protocol

Postoperative analgesia began with ropivacaine wound infiltration during closure and was maintained with intravenous ketorolac combined with oral paracetamol. This multimodal pain management, together with the administration of enoxaparin for 30 days, facilitates physical and rehabilitation therapy, expediting hospital discharge and decreasing the risk of deep vein thrombosis.

Patients were mobilized early, allowing them to stand on the first day following surgery. Partial weight-bearing was indicated for the first three weeks, followed by a progression to full weight-bearing 6 to 8 weeks after surgery.

Serial radiographs of the pelvis (anteroposterior, axial, alar, and obturator views) were taken in the immediate postoperative period, and after one week, one month, and three months, where osseointegration of all implants was observed (Figure 2). Annual control radiographs were then taken. A follow-up CT scan was also requested after three months.

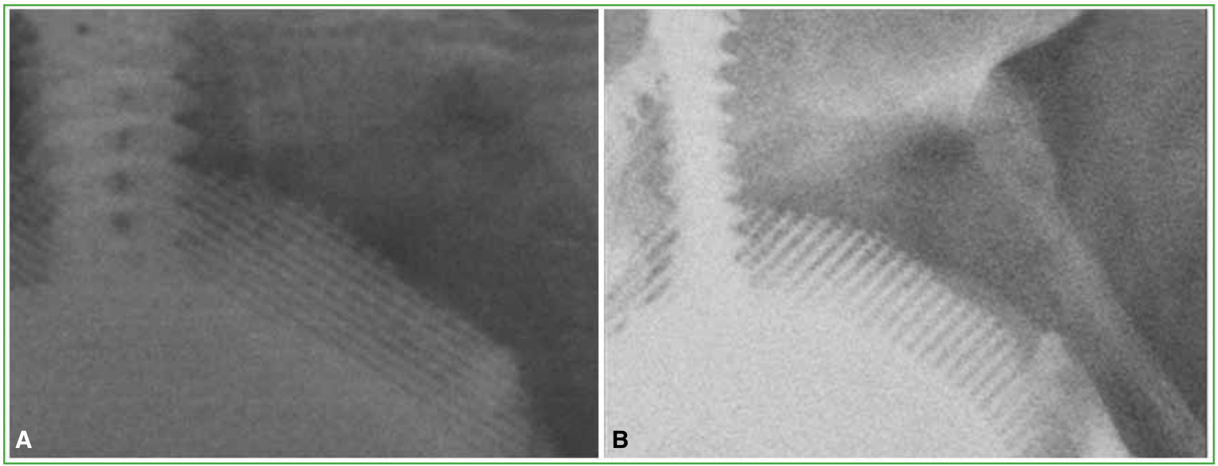

Figure 2. A. Magnified radiograph of the right hip, AP view, in the immediate postoperative period. The trabecular metal of the 3D implant is observed. **B.** Magnified radiograph of the right hip, AP view, 3 months after surgery. Signs of osseointegration are detected around the trabecular metal.

RESULTS

In the final analysis, 10 patients were included (Table 1), the mean follow-up was 40.5 months (range 13-72). Seven patients were female and three were male, with a mean age of 73.7 years (range 63-82). The mean body mass index was 24.1 kg/m^2 (range 18-29). Indications for primary THA were diagnoses of hip dysplasia (n = 1), rheumatoid arthritis (n = 3) and osteoarthritis (n = 6).

Patients had undergone an average of 2.1 revision surgeries (range 1-5).

All had a poor functional score prior to surgery. HHS improved from 24.2 (range 10-40) at admission to 63.5 (range 35-92) in the last control. The mean OHS was 34.5 (range 15-46) and the mean SF-36 was 68.8 (range 58-95) (Table 2). In the final control, the patient's range of motion, pain relief, and independence improved after surgery when compared to pre-surgical values, as evidenced by the aforementioned functional scores.

Table 2. Comparison of preoperative and postoperative functional scores.

Patients		Preoperative evaluation			Postoperative evaluation	
	HHS	OHS	SF-36	HHS	OHS	SF-36
1	40	18	48	65	40	70
2	25	15	32	70	36	72
3	38	18	42	92	46	95
4	10	16	20	35	35	40
5	21	19	35	82	39	80
6	24	17	36	60	36	69
7	15	21	25	58	32	65
8	20	18	29	50	24	58
9	28	10	35	52	15	58
10	21	19	32	71	42	81
Average	24,2	17,1	33,4	63,5	34,5	68,8

HHS = Hip Harris Score; OHS = Oxford Hip Score; SF-36 = Short Form-36 Health Survey.

Anteroposterior radiographs of the pelvis, and alar and obturator radiographs of the affected hip were taken one week, one month, and three months after surgery and then annually. Following Manaster's criteria,[10] no signs of loosening or migration of the 3D cup in terms of inclination and anteversion were observed in any case in the last control (Figure 3), so that the medium-term implant survival, according to the Kaplan-Meier method, is 100% (Table 3). A control CT scan was performed three months after surgery where the osseointegration of all implants was confirmed.

Figure 3. Anteroposterior radiographs of the left hip. Radiographic control of inclination and anteversion. **A.** Immediate postoperative period. **B.** 29 months after surgery.

Regarding the degree of constraint of the cemented cup within the 3D implant, dual-mobility cups were indicated to seven patients who had a sufficient abductor mechanism and appropriate stability. In the remaining three patients, given the loss of continuity of the abductor mechanism and the intraoperative maneuvers with a significant risk of dislocation, it was decided to increase the constraint and cement a tripolar cup. It should be noted that, in these last three patients, acetabular reconstruction was combined with a non-conventional femoral prosthesis, due to the loss of bone stock in the proximal femur. From the above, it is clear that the implant constraint was chosen specifically for each patient based on his or her requirements.

Table 3. Implant survival according to the Kaplan-Meier method.

Patient	Months	Survival %
1	13	100
2	20	100
3	24	100
4	28	100
5	29	100
6	31	100
7	60	100
8	63	100
9	65	100
10	72	100

Complications

Four of the 10 patients suffered complications, resulting in a 40% complication rate. A recurrent dislocation occurred during the first six weeks of surgery; this complication was treated by increasing the degree of constraint by removing a dual-mobility cup and replacing it with a more constrained cup cemented into the 3D implant. One patient suffered from sciatic nerve neuropraxia, which resolved in the third month following surgery. Two patients required mechanical-surgical debridement due to persistent secretion through the wound within the first three postoperative weeks, the evolution was good and no further interventions were necessary.

DISCUSSION

Acetabular bone loss remains a major surgical challenge in revision THA. With custom implants, acceptable outcomes were achieved with a significant improvement in function. In this study, all patients had at least one Paprosky type III acetabular defect and one had pelvic discontinuity.

The optimal surgical strategy for these patients has not yet been defined. The multiple procedures described, such as the use of large-sized cups, structural grafts or reconstruction cages, among others, did not achieve favorable outcomes in the medium and long term. As reported in the study by Sembrano and Cheng,[11] acetabular reconstruction with reconstruction cages had a 5-year survival rate of 87.8% and and a radiological loosening rate of 80.7%. Similarly, Amenabar et al. found that reconstruction cages and structural grafting resulted in an 85% survival rate after 10 years.[12]

In this study, functional and radiographic outcomes were evaluated after custom implant placement in patients with severe acetabular bone defects. This technique is particularly useful in older patients in whom the aim is to resolve the condition and restore function quickly, rather than prioritizing the supply of bone stock. In general, satisfactory clinical and radiographic outcomes were observed. Our results are comparable with those of recent research.

In the study by Wind et al., 19 patients were evaluated after placement of custom-made implants during an average follow-up of 31 months. The HHS improved significantly from 38 to 63.[13]

Similarly, Taunton et al. studied pelvic discontinuity in 57 patients, at an average of 65 months after the use of custom implants, and reported a final HHS of 74.8.[14] In the study with the longest follow-up (average 10 years), HHS improved from 41 to 80.[15]

A systematic review published by Chiarlone et al. investigated custom-made acetabular implants for severe acetabular bone defects and obtained satisfactory medium-term clinical and radiographic outcomes. The survival rate of the acetabular component ranged from 86.5% to 100%, but the reoperation rate was 24.5%.[16] Only one patient in our study experienced a hip dislocation following 3D cup implantation and underwent revision surgery, which included the implantation of a cup with greater constraint and an improvement in anteversion and tilt, allowing us to intervene in the likely reasons. In this situation, the use of cups with different degrees of constraint will reduce the risk of prosthesis dislocation, one of the main complications described. We believe that the determination of preoperative cup constraint is essential to reduce the risk of dislocations.

In the review by De Martino et al., only 1.7% had aseptic loosening of custom-made implants. However, the overall complication rate was 30%.[17] In our study, the complication rate was 40%. However, none of the implants had to be removed due to postoperative complications.

One of the strengths of the study is that both the surgical interventions and the follow-up of the patients were performed by the same team. Likewise, no patient was lost during the follow-up, so we have a complete record of them and their evolution over time.

This study has several limitations. The main ones are the small sample size and the lack of a control group, as well as its retrospective design. Only retrospective trials investigating custom-made hip implants for severe acetabular defects are available. However, a prospective trial would be beneficial and should be conducted in the future.

CONCLUSIONS

Custom-made acetabular implants represent a valid solution for treating severe acetabular bone defects and Paprosky type IIIA-B pelvic discontinuity. This strategy enables the implant to be adjusted to the residual receptor bone, thereby avoiding bone deficiency and restoring hip biomechanics, as well as to cement inside a cup with an independent orientation to the 3D implant, with satisfactory clinical and radiographic outcomes in the medium-term follow-up. However, long-term results still need to be evaluated.

Conflict of interest: The authors declare no conflicts of interest.

F. Moruno ORCID ID: https://orcid.org/0000-0002-9522-4079
E. Garavano ORCID ID: https://orcid.org/0000-0002-6216-4356
M. Sued ORCID ID: https://orcid.org/0000-0002-1901-8302
E. Palomino Prado ORCID ID: https://orcid.org/0009-0001-5659-0375

REFERENCES

1. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am* 2007;89:780-5. https://doi.org/10.2106/JBJS.F.00222
2. Khanduja V. Total hip arthroplasty in 2017—current concepts and recent advances. *Indian J Orthop* 2017;51:357-8. https://doi.org/10.4103/ortho.IJOrtho_367_17
3. Baauw M, van Hooff ML, Spruit M. Current construct options for revision of large acetabular defects: a systematic review. *JBJS Rev* 2016;4(11):e2. https://doi.org/10.2106/JBJS.RVW.15.00119
4. Friedrich MJ, Schmolders J, Michel RD, Randau TM, Wimmer MD, Kohlhof H, et al. Management of severe periacetabular bone loss combined with pelvic discontinuity in revision hip arthroplasty. *Int Orthop* 2017;38:2455-61. https://doi.org/10.1007/s00264-014-2443-6
5. Berasi CC, Berend KR, Adams JB, Ruh EL, Lombardi AV. Are custom trifange acetabular components effective for reconstruction of catastrophic bone loss? *Clin Orthop Relat Res* 2015;473:528-35. https://doi.org/10.1007/s11999-014-3969-z
6. Hirschmann MT, Konala P, Amsler F, Iranpour F, Friederich NF, Cobb JP. The position and orientation of total knee replacement components: a comparison of conventional radiographs, transverse 2D-CT slices and 3D-CT reconstruction. *J Bone Joint Surg Br* 2011;93:629-33. https://doi.org/10.1302/0301-620X.93B5.25893

7. Kalteis T, Handel M, Herold T, Perlick L, Paetzel C, Grifka J. Position of the acetabular cup – accuracy of radiographic calculation compared to CT-based measurement. *Eur J Radiol* 2006;58:294-300. https://doi.org/10.1016/j.ejrad.2005.10.003
8. Paprosky WG, Perona PG, Lawrence JM. Acetabular defect classification and surgical reconstruction in revision arthroplasty. A 6-year follow-up evaluation. *J Arthroplasty* 1994;9:33-44. https://doi.org/10.1016/0883-5403(94)90135-x
9. Gelaude F, Clijmans T, Delport J. Quantitative computerized assessment of the degree of acetabular bone deficiency: total radial acetabular bone loss (TrABL). *Adv Orthop* 2011:494382. https://doi.org/10.4061/2011/494382
10. Manaster BJ. From the RSNA refresher courses: total hip arthroplasty—radiographic evaluation. *RadioGraphics* 1996;16:645-60. https://doi.org/10.1148/radiographics.16.3.8897629
11. Sembrano JN, Cheng EY. Acetabular cage survival and analysis of factors related to failure. *Clin Orthop Relat Res* 2008;466:1657-65. https://doi.org/10.1007/s1 1999-008-0183-x
12. Amenabar T, Rahman WA, Hetaimish BM, Kuzyk PR, Safir OA, Gross AE. Promising mid-term results with a cup-cage construct for large acetabular defects and pelvic discontinuity. *Clin Orthop Relat Res* 2016;474:408-14. https://doi.org/10.1007/s11999-015-4210-4
13. Wind MA, Swank ML, Sorger JI. Short-term results of a custom trifange acetabular component for massive acetabular bone loss in revision THA. *Orthopedics* 2013;36:e260-e265. https://doi.org/10.3928/01477447-20130222-11
14. Taunton MJ, Fehring TK, Edwards P, Bernasek T, Holt GE, Christie MJ. Pelvic discontinuity treated with custom trifange component: a reliable option. *Clin Orthop Relat Res* 2012;470:428-34. https://doi.org/10.1007/s11999-011-2126-1
15. DeBoer DK, Brinson MR, Morrison IC. Revision total hip arthroplasty for pelvic discontinuity. *J Bone Joint Surg Am* 2007;89:835-40. https://doi.org/10.2106/JBJS.F.00313
16. Chiarlone F, Zanirato A, Cavagnaro L, Alessio-Mazzola M, Felli L, Burastero G. Acetabular custom-made implants for severe acetabular bone defect in revision total hip arthroplasty: a systematic review of the literature. *Arch Orthop Trauma Surg* 2020;140:415-24. https://doi.org/10.1007/s00402-020-03334-5
17. De Martino I, Strigelli V, Cacciola G, Gu A, Bostrom MP, Sculco PK. Survivorship and clinical outcomes of custom trifange acetabular components in revision total hip arthroplasty: a systematic review. *J Arthroplasty* 2019;34:2511-8. https://doi.org/10.1016/j.arth.2019.05.032