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Original Research

# Augmenting Pathologic Acetabular Bone Loss With Photodynamic Nails to Support Primary Total Hip Arthroplasty

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ABSTRACT

*Background:* Pathologic acetabular defects can undermine the stability and osseointegration of a primary total hip arthroplasty (THA) acetabular component. Our service has used photodynamic nails (PDNs) in a modified Harrington technique to provide space-filling stability to a primary acetabular implant without impeding local osseointegration. Here we describe our experience with PDN-augmented THAs.
*Methods:* An institutional review board-approved retrospective analysis of all patients who underwent PDN-augmented THA in the management of severe (Harrington class II or III) acetabular defects from September 1, 2020 to May 1, 2021 with at least 6 months of follow-up was performed. The primary outcome was implant survivorship. Comparisons between preoperative and 6-week postoperative visual analogue pain scores were made using the Mann-Whitney U test.
*Results:* Six patients were included in this case series, 5 with metastatic cancer and 1 with pelvic discontinuity and avascular necrosis following failed attempted acetabular fixation. The mean follow-up duration was 10.3 ± 4.3 months. The mean age was 75.5 ± 4.7 years, mean body mass index 27.3 ± 5.6, and 5 patients were female. All but 1 patient was American Society of Anesthesiologists (ASA) class III. Two patients required acetabular revisions, one for aseptic loosening and a second for a pathologic fracture secondary to disease progression. One patient passed away 90 days after the procedure. The mean visual analogue pain score significantly improved from 7.8 ± 1.6 to 2.0 ± 1.4 six weeks after surgery ($P = .008$).
*Conclusions:* PDN augmentation of the periacetabular bone of patients with large pelvic defects yields durable pain relief and function in vulnerable hosts. PDN should be considered a part of the reconstructive surgeon's armamentarium.


## Introduction

Poor acetabular bone quality at the implant-bone interface impedes the osseointegration of primary total hip arthroplasty (THA) acetabular implants, particularly in patients with pathologic acetabular defects secondary to metastatic disease or osteoporosis in older and fragile patients [1]. With currently available techniques and tools, these patients are at an increased risk of aseptic loosening that can result in dislocation and mechanical instability [2]. Rowell et al. [3] reported favorable outcomes after cemented acetabular cage reconstruction in patients with Harrington class II and III acetabular defects [4,5], with an 8% revision/reoperation rate unrelated to the loss of acetabular fixation at 2 years postoperatively. However, these constructs required an extensile approach that involved significant blood loss and perioperative morbidity.

Our service's standard of care for treating patients with acetabular compromise due to metastatic disease and osteoporosis has recently migrated to percutaneous augmentation of the compromised bone stock followed, if needed, by primary THA with a modification of the Harrington procedure. There are many techniques that utilize this approach, which traditionally involves the use of cement and/or screws to reinforce a cemented acetabular implant [2,6,7]. While previously published techniques successfully apply Harrington's intent, which was to transfer mechanical loads across the hip to stronger areas of the pelvic bone, current

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percutaneous techniques largely rely on cement and load-replacing constructs that do not permit local osseointegration. As patients with metastatic cancer live longer, thanks to more effective chemotherapies and immunotherapies, the durability of cemented Harrington constructs is unclear [2].

We have previously published a technique that uses photodynamic nails (PDNs) to augment the pelvic and sacral bone stock of patients with symptomatic metastatic disease [8]. PDNs demonstrate impressive resistance to compressive forces [9] and can be delivered via a flexible catheter, permitting anatomic reconstruction of the acetabular columns. PDNs are also radiolucent, which permits effective monitoring for disease progression without a metal artifact. Of particular benefit is the ability to pass screws through the PDN material after curing without the need for a specialized drill bit, thereby permitting the integration of the nail with an endoprosthetic construct without compromising the potential for local osseointegration.

Here, we present our >6-month outcomes following the use of PDNs and primary THA to reconstruct Harrington class II and III acetabular defects in patients with metastatic disease or significant osteoporotic attritional bone loss. We hypothesized that the use of PDNs to augment the acetabular fixation of a primary THA construct would lead to significant pain relief and permit the immediate remobilization of these vulnerable hosts.

## Material and methods

This work was an institutional review board-approved retrospective analysis of consecutive patients who presented with severe (Harrington class II or III) acetabular defects secondary to metastatic disease or osteoporosis who were treated with PDN augmentation followed by endoprosthetic reconstruction with a primary THA by 1 of 2 surgeons at a tertiary referral academic medical center between September 1, 2020 and May 1, 2021. Patients with less than 6 months of follow-up without mortalities and megaprosthetic reconstructions were excluded.

All data were collected from the medical record. The primary outcome was implant survivorship, defined as revision-free survival. Secondary outcomes were unplanned returns to operating room (OR), estimated blood loss (EBL), transfused units of blood, hospital days until discharge, change in visual analogue pain score (VAS) from before to 6 weeks after surgery, and Patient Reported Outcomes Measurement Information System (PROMIS) mental and physical function scores at maximum follow-up. Short-term VAS was selected as these procedures are largely palliative in nature, and while function as measured with PROMIS scores after 6 months of follow-up speaks about the durability of the construct, the immediate goal of this procedure is to improve pain and permit remobilization.

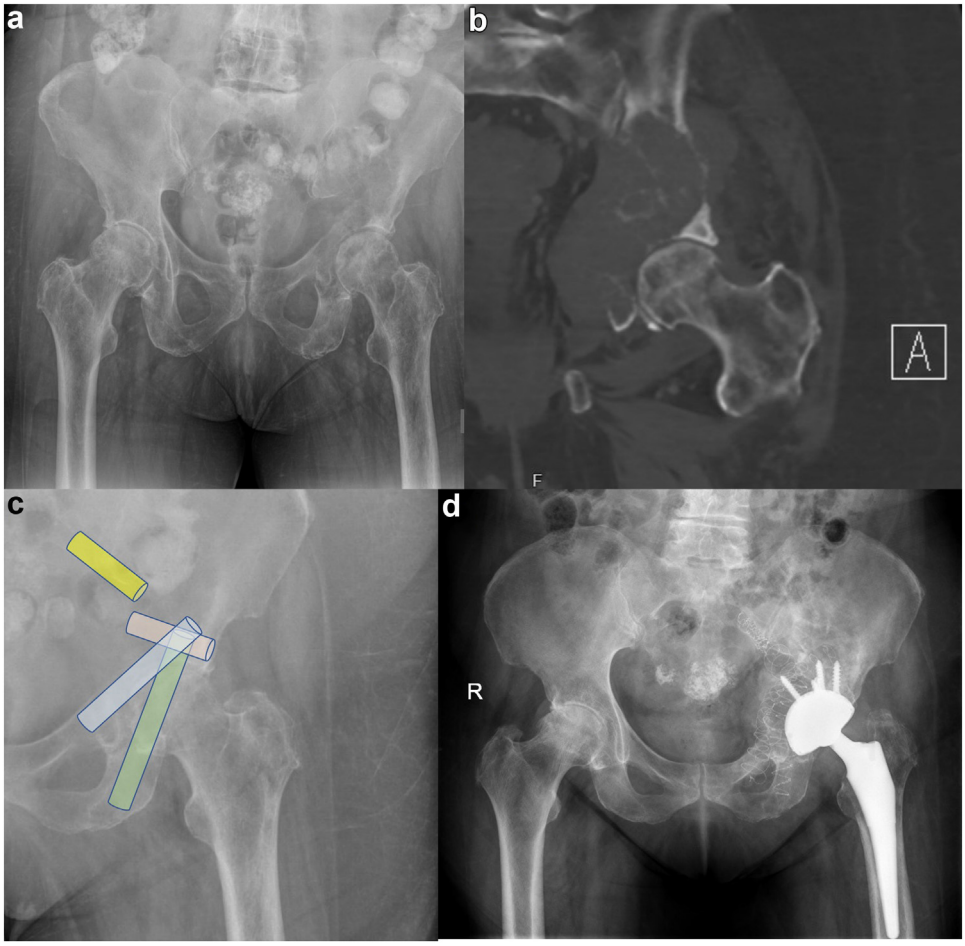


**Figure 1.** A 72-year-old female with B-cell lymphoma presented with severe left hip pain and the inability to ambulate. (a) Radiographs demonstrated periacetabular and sacral lytic lesions, and (b) a computed tomography scan of the hip showed significant destruction of the anterior and posterior columns as well as involvement of the sacroiliac (SI) joint. (c) The patient underwent PDN placement for periacetabular reconstruction, total hip arthroplasty, and SI stabilization with a PDN implant. (d) Six months after surgery, the patient's PDN and primary THA implants are well fixed. She ambulates with a cane and has minimal functional pain.

*Surgical technique*

The use of percutaneous pelvic corridors in the screw fixation of pelvic and acetabular fractures is well known in the orthopaedic trauma literature and has been previously utilized during PDN fixation by our group [8,10]. In brief, the 2 main corridors utilized during PDN fixation are the posterior column, the supraacetabular pathway, and a line connecting the posterior superior iliac spine to the anterior inferior iliac spine. A third balloon recreating the anterior column is used in cases of severe bone attrition (Fig. 1). All PDNs were from the IlluminOss system (IlluminOss, East Providence, RI).

The patient was placed in the lateral decubitus position on a radiolucent surgical table. Guidewires for the PDN catheters were placed using computed tomography navigation and/or fluoroscopy. A small incision was made over the target entry, and the bone cortex was opened with a sharp awl. A blunt guidewire was advanced under image-guidance to confirm appropriate anatomic bridging. This procedure was then repeated for any other planned augmentation pathways. Once all guidewires were in place, each corridor was sequentially reamed with flexible cannulated reamers. The expected diameters of each corridor were estimated using the patient's preoperative computed tomography scan. Balloon sheaths 8-9 mm in diameter were generally used. Implant length was based off of guidewire measurement. The balloon catheter with the monomer was prepared and primed, and a white protective tube was cut so that only the desired length of the balloon catheter was inflated with monomer. The guidewire and dilator were removed, and the balloon catheter was inflated. Monomer injection was visualized fluoroscopically by the expansion of spiral radiopaque markers on the outside of the balloon (Fig. 2). Curing was performed using blue light, with curing time based on implant dimensions.

A THA was then performed. Acetabular screws were drilled through a multihole hemispheric nonconstrained acetabular cup through the PDN monomer. While the number of screws used for each implant were variable, in general, we placed as many as possible.

*Statistical analysis*

Statistical analysis was performed using Prism 9.2 (GraphPad, La Jolla, CA). Comparisons between preoperative and 6-week postoperative VAS scores were performed using the Mann-Whitney U test, with $P < .05$ considered significant. Continuous variables were written as mean ± standard deviation (median, 95% confidence interval [CI]). Categorial variables were written as percentages.

## Results

Six patients were included in this case series. Five cases were for a metastatic disease, while a sixth was for pelvic discontinuity and

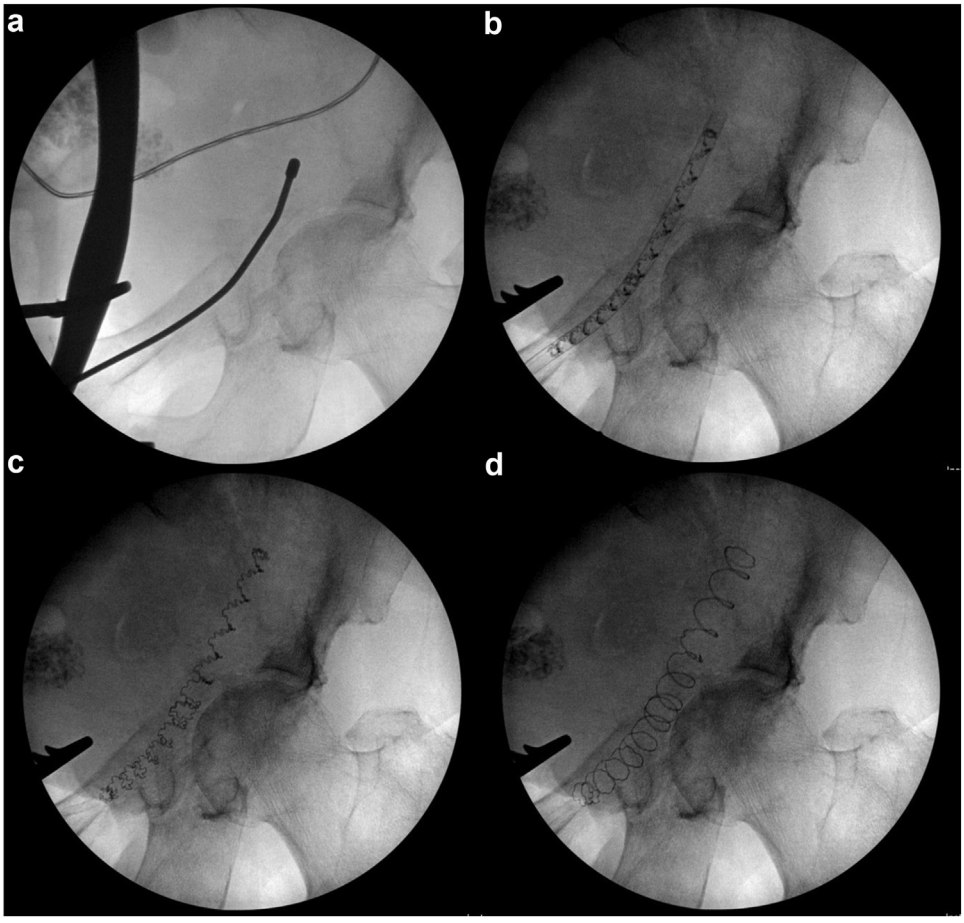


**Figure 2.** Fluoroscopy images of PDN placement. (a) A guidewire is passed along the target acetabular corridor, permitting confirmation of anatomic implant placement. (b) A sheath is passed over the guidewire, which is then removed, thereby permitting placement of the PDN implant. Implant position is denoted by radio-opaque coils. Polymer is then injected into the implant (c), which permits its expansion to its maximum or target size (d). Asymmetric filling is possible, pending anatomic and lesion limitations. Following filling of the implant, light annealing is performed over a time period that varies by implant length and size.

**Table 1**
Patient demographics, comorbidities, and perioperative details and outcomes.

| Patient (age, sex) | BMI | ACCI | ASA | SORG 90-d survival (%) | SORG 1-y survival (%) | Pathology | Harrington classification | Illuminoss balloon sizes | Acetabular implant (make, size, number of screws) |
|---|---|---|---|---|---|---|---|---|---|
| 76 y/o, female | 30.5 | 10 | III | 89 | 38 | Melanoma | III | Posterior column: 90 × 18/22 mm<br>PSIS-AIIS: 80 × 8.0 mm | Smith and Nephew REDAPT shell<br>52-mm OD with dual-mobility liner<br>6 Screws |
| 72 y/o, female | 25.2 | 12 | III | 95 | 68 | B-cell lymphoma | II | Anterior column: 120 × 9.0 mm<br>Posterior column: 160 × 22/13 mm<br>PSIS-AIIS: 90 × 18/22 mm | Smith and Nephew REDAPT shell 52-mm<br>OD with dual mobility liner<br>6 Screws |
| 71 y/o, female | 23.4 | 10 | III | 95 | 73 | NSCLC | III | Anterior column: 90 × 18/22 mm | Smith and Nephew REDAPT shell 54-mm<br>OD with dual mobility liner<br>6 Screws |
| 71 y/o, female | 24.0 | 10 | III | 96 | 70 | Myeloma | II | Posterior column: 160 × 22/13 mm<br>PSIS-AIIS: 160 × 22/13 mm | Stryker Trident II<br>50-mm OD with dual-mobility liner<br>6 Screws |
| 83 y/o, male | 37.2 | 11 | III | 84 | 68 | Plasmacytoma | II | Posterior column: 160 × 22/13 mm | Stryker Trident II 58-mm OD with<br>dual-mobility liner<br>5 Screws |
| 77 y/o, female | 23.4 | 6 | II | N/A | N/A | Failure of fixation transverse acetabulum fracture | III | Posterior column: 130 × 9.0 mm<br>PSIS-AIIS: 130 × 9.0 mm | Stryker Trident II 52-mm OD with<br>dual-mobility liner<br>4 Screws |

ASA, American Society of Anesthesiologists classification; ACCI, age-adjusted Charlson Comorbidity Index; BMI, body mass index; EBL, estimated blood loss; NSCLC, non-small cell lung cancer; OD, outer diameter; PRBC, packed red blood cells; PSIS-AIIS, a line connecting posterior superior iliac spine to the anterior inferior iliac spine; SORG, Spine Oncology Research Group; VAS, visual analogue pain score.

avascular necrosis following failed attempted fixation of a transverse acetabular fracture. A seventh patient who underwent an augmented THA for chronic protrusion of a prior hemiarthroplasty was excluded from this series due to <6 months of follow-up.

Table 1 summarizes case details, pathologies, and outcomes including implant specifics. The mean age was 75.5 ± 4.7 (median 74.5, 95% CI 70.6 to 80.5) years, mean BMI 27.3 ± 5.6 (median 24.6, 95% CI 21.4 to 31.2), and 5 (5/6, 83.3%) were female. The mean age-adjusted Charlson comorbidity index was 8.5 ± 2.8 (median 10.0, 95% CI 5.6 to 11.5), and all but 1 patient were of American Society of Anesthesiologists (ASA) class III. Of those patients with cancer, 2 had multiple myeloma, 1 had lung cancer, 1 had B-cell lymphoma, and 1 had melanoma. No patient had prior radiotherapy, and 3 had prior chemotherapy. Two patients would receive 20-Gy adjuvant radiation postoperatively.

The mean EBL was 858.3 ± 583.8 (median 850.0, 95% CI 583.8 to 1133.0) cc, and a mean 1.5 ± 1.4 (median 1.5, 95% CI 0.05 to 2.9) units of packed red blood cells were transfused throughout the patient's hospital stay. The mean time until clearance for discharge from the date of surgery was 4.5 ± 1.5 (median 4.5, 95% CI 2.9 to 6.1) days. Two patients were discharged home, 3 were sent to an acute rehab facility, and 1 was sent to a skilled nursing facility.

The mean follow-up duration was 15.0 ± 5.4 (median 14.2, 95% CI 8.3 to 21.8) months. One patient required a 90-day return to the OR for an aseptic wound revision for a superficial dehiscence without the need for implant revision or modular component exchange. This patient did not receive adjuvant radiation. There were no infections or thromboembolic complications, nor were there any other medically indicated readmissions. One patient had a 90-day mortality secondary to his malignancy. Two patients required acetabular revisions, 1 for aseptic loosening at 3 months postoperatively and a second for a pathologic fracture secondary to disease progression 12 months after surgery. The aseptic loosening was treated with a larger primary acetabular implant without additional augmentation and has done well for 9 months after this procedure. The second was managed with a tantalum augment and an 8-hole pelvic recon plate. The mean VAS significantly improved from 7.8 ± 1.6 preoperatively to 2.0 ± 1.4 six weeks after surgery ($P = .008$). The PDN was left in place in the first patient and used as an adjunct for screw fixation of the revision cup. In the second patient, the PDN had become loose due to disease progression, so was removed. This PDN was supporting the anterior column. The mean PROMIS physical and mental function subscores 6 months after surgery were 41.2 ± 5.1 (median 42.3, 95% CI 34.9 to 47.5) and 50.9 ± 7.2 (median 53.3, 95% CI 41.9 to 59.9), respectively.

## Discussion

Large pathologic acetabular bone defects, such as those seen in patients with osteoporosis or metastatic cancer, can be a source of severe pain and dysfunction. Current reconstructive strategies [11–13] rely on an extensile approach or large metal augments that can increase intraoperative morbidity and distort radiographic disease follow-up. Here we used PDNs to augment the peri-acetabular bone of patients with Harrington class II and III acetabular defects, permitting the use of a primary acetabular implant for THA. Patients tolerated their surgery well, 1 non-pathologic loosening was treated with a larger primary cup, and all surviving patients are ambulatory at maximum follow-up. We believe that PDN augmentation is a viable alternative to metal augments or recon endoprostheses in select vulnerable hosts and should be considered a part of the reconstructive surgeon's armamentarium.

Our technique represents a modification of the traditional Harrington procedure, which uses long threaded screws directed through the ischium and pubis through a cemented acetabular implant augmented with cement and steel mesh [2,14,15]. Prior proposed modifications have included a tripod technique [16] and

| EBL | PRBCs (units) | Hospital days until discharge clearance | Complications | VAS pain score preop | VAS pain score 6-wks postop | 6-Mo PROMIS physical sub-score | 6-Mo PROMIS mental sub-score | Max follow-up (mo) |
|---|---|---|---|---|---|---|---|---|
| 1300 | 3 | 7 | Return to OR 3 mo postop for acetabular component loosening Revision REDAPT 62-mm With dual-mobility liner 6 Screws | 8 | 3 | 34.9 | 41.1 | 21.4 |
| 750 | 1 | 5 | 90-D return to OR for aseptic superficial wound dehiscence | 9 | 3 | 43.5 | 58.3 | 7.59 |
| 900 | 2 | 3 | Return to OR 12 mo postop for revision of acetabular component due to disease progression/pathologic fracture 8-Hole pelvic recon small frag plate, 15 × 56-mm tantalum augment, 56-mm multihole Stryker cup 5 Screws | 9 | 1 | 42.3 | 53.3 | 19.1 |
| 900 | 3 | 5 | None | 8 | 0 | 47.7 | 45.8 | 14.2 |
| 800 | 1 | 4 | None | – | – | N/A | N/A | 90-D mortality |
| 500 | 1 | 3 | None | 5 | 3 | 37.4 | 56 | 12.8 |

an “outside-in” threaded pinning through the ilium [17]. Similar to the present work, most studies using a Harrington technique are small case series with limited follow-up. Tillman et al. [18] in a longer-term study reported return to OR and acetabular loosening rates of 10% and 4%, respectively, at a mean 3.2 years after surgery. Harrington procedures permit a hip reconstruction that is immediately stable, with improved pain and unrestricted weight-bearing [2]. However, the efficacy of the Harrington procedure is technique-dependent and questionable in the setting of metastatic disease, with reported loosening/dislocation rates of 3%-29% [19].

Tantalum augments and acetabular implants have been proposed as an alternative to the Harrington procedure due to their ability to provide mechanical stability to the compromised hip and permit eventual osseointegration. In their single-institution analysis of 58 patients who underwent THA with porous tantalum acetabular implants for periacetabular metastatic or attritional bone disease, Houdek et al. [20] reported no cases of mechanical failure or radiographic loosening at mean 2 years of follow-up. The authors’ subsequent comparison of 78 patients who underwent a Harrington procedure with 37 who underwent tantalum acetabular reconstruction showed a 9.6% rate of loosening after the Harrington procedure vs 0% after tantalum reconstruction, which trended towards significance and permitted the authors to ascribe superiority to tantalum reconstructions [2]. The notable difference between these techniques lies in the long-term intended mechanics of the reconstructions. While the Harrington procedure relies on the transmission of applied forces through the hip to the proximal and medial pelvis through an implant-cement interface, the porous tantalum implants allow for bony ingrowth. As patients with a metastatic disease live longer, the durability of a reconstruction that relies purely on mechanical advantage is less likely to persist than one that permits osseointegration. It is therefore key that any proposed reconstructive technique impart short-term mechanical benefits while allowing for long-term biology. It should, however, be noted that tantalum cages are unable to be used in the setting of pathologic sacropelvic discontinuity or in the presence of metastatic disease at the sacropelvic junction. The present work represents case examples where PDNs were used both as potential substrates for periacetabular stability and elsewhere in the pelvis to treat pathologic sacroiliac defects. While the durability of our technique cannot be confirmed by the present work given its modest sample size and short follow-up, we do believe that the mechanical and biologic potential of this strategy lends itself to long-term stability.

PDNs have been previously utilized in multiple weight-bearing applications, including as femoral stabilization of pathologic bone [9] and as subchondral support for the native acetabulum in patients with a metastatic disease [8]. PDNs are longitudinally strong and rotationally stable implants that do not require screw stabilization [21]. The strength of a PDN is closer to that of organic bone compared with metal implants, permitting mechanical resistance to be evenly dispersed throughout the entire PDN and reducing the attritional effects of stress shielding [21]. The directional nature of PDNs also eliminates single-point loading, which is a common cause of implant failure [21]. Another significant benefit of PDNs in pelvic reconstruction is that the monomer is cured only upon exposure to the light source. This yields improved conformation and alignment of the implant compared with cement, which does not harden immediately and is incapable of being as stringently controlled by the surgeon [21]. PDNs are radiolucent, which permits improved monitoring of the local bone using advanced imaging techniques [21]. This is particularly beneficial for cancer patients, in whom the diagnosis of disease progression may be obscured by metal artifacts [21].

There are several limitations to this technique and this case series beyond those intrinsic to retrospective studies. First, PDN is still an emerging technology with a short track record. While the material properties of PDNs are designed to mimic those of organic bone, bony ingrowth through the implant will be limited by its encasement inside a polyethylene balloon catheter. However, the lack of cement or some other space/pore-filling substrate may permit a greater degree of osseointegration than traditional Harrington constructs. This contrast is particularly important at the implant-bone interface of the noncemented acetabular implant placed during our technique. However, a larger sample size, longer follow-up, and functional outcome measures are needed to confirm the viability of this technique. It should also be noted that it was not possible to quantify the actual additive stability provided by the PDN, and therefore, while we were able to radiographically confirm screw penetration through the implant, its actual added benefit is unclear. This can be better established through retrieval or cadaveric studies. Second, a larger sample size, longer follow-up, and better functional outcome measures are necessary to confirm the viability of our technique as an alternative to metal augments or

traditional Harrington constructs. While we can advocate for consideration of PDN in suitable vulnerable patients with large periacetabular bone defects, we cannot ascribe superiority to any single technique. Third, reporting minimal clinically important differences in the health outcomes of cancer patients following what is proposed as a salvage surgery for metastatic disease is a challenge, as even at short follow-up, these patients often have prolonged disability due to systemic therapy and disease progression. Two of our 6 patients died during their follow-up period, 1 within 90 days of surgery and the other 19 months after surgery, highlighting the significant frailty of these hosts. While our final patient demonstrates the versatility of this technique in noncancer patients, we believe that maintained ambulatory status and prolonged pain relief are more important in these patients than minimal clinically important differences. Finally, the clinical potential of PDNs should be supported by retrieval and biomechanical studies. These can help us understand the directional strength imparted by PDNs and the long-term integrity and osseointegration around these implants.

## Conclusions

Management of the compromised hip joints of patients with large acetabular defects is a challenge. Here we described our early experience using PDNs to augment a primary THA in patients with osteoporosis or metastatic disease, with satisfactory outcomes and implant survival in a small series. Findings support the continued use of this technique although intermediate and long-term outcomes are necessary to confirm its viability.

## Conflicts of interest

Santiago A. Lozano Calderón is a paid consultant for Illuminoss and ONKOS and a paid speaker for Carbofix and Daichii Sankyo. Marilyn Heng is a paid consultant for Zimmer-Biomet and an unpaid consultant for the Epic Adult Orthopaedic Steering Board. She is a board member of the New England Orthopaedic Society. All other authors declare no potential conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2022.08.022.

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