JB&JS OPEN ACCESS

A Prospective Study of the IlluminOss Photodynamic Nail System for Pelvic Stabilization

Treatment of Impending and Actual Fractures from Metastatic Bone Disease, Multiple Myeloma, and Primary Bone Lymphoma

Santiago A. Lozano-Calderon, MD, PhD, Marcos R. Gonzalez, MD, Joseph O. Werenski, BS, Kayla Quinn, NP, Diana Freiberger, NP, and Kevin A. Raskin, MD

Investigation performed at Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts

Background: The stabilization of metastatic lesions in the periacetabular region can be successfully performed using percutaneous techniques. Photodynamic nails (PDNs) are among the available tools for stabilization. Data on postoperative complications and functional outcomes are, however, scarce.

Methods: Patients undergoing percutaneous stabilization using PDNs (IlluminOss Medical) for impending or actual minimally displaced pathological fractures of the pelvis from metastatic bone disease, multiple myeloma, or primary bone lymphoma were enrolled prospectively. Outcomes were assessed preoperatively and postoperatively at the 2-day, 2-week, 6-week, 3-month, 6-month, and 1-year time points. Functional outcomes assessed included the Patient-Reported Outcomes Measurement Information System (PROMIS) Physical Function, PROMIS Pain Interference, Combined Pain and Ambulatory Function (CPAF), EuroQol-Visual Analogue Scale (EQ-VAS), and Musculoskeletal Tumor Society (MSTS) scores. Pain was assessed using a VAS.

Results: A total of 30 patients treated with PDNs were included. The median VAS pain score dropped from 60 points preoperatively to 30 at 6 weeks postoperatively ($p = 0.004$). The median CPAF score improved from 6 preoperatively to 7 postoperatively at the 6-week mark. The median EQ-VAS score showed significant improvement at 6 weeks (70 versus 50; $p = 0.006$). The median 2-week PROMIS Pain Interference score was significantly lower than preoperatively (64.1 versus 66.9; $p = 0.03$). An improvement in the median PROMIS Physical Function score was seen at 6 weeks following surgery compared with preoperatively (37 versus 30.1; $p = 0.001$). A significant improvement in the MSTS score was seen as soon as 2 days after surgery (77% versus 40%; $p < 0.0001$).

Conclusions: Among patients with pelvic bone metastases, multiple myeloma, or primary bone lymphoma, we found that treatment using PDNs resulted in immediate return to ambulation and rapid functional outcome improvement, with low complication rates. In this population, this technique represents a safe alternative to open surgery.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Bone metastases can substantially impair a patient's physical function, quality of life, and survival[1]. In the U.S., approximately 280,000 cases are diagnosed annually, a number projected to increase as advanced treatments become more accessible[2,3]. With an annual expenditure of $12.6 billion for metastatic bone disease treatment, this trend will continue to financially strain the U.S. health-care system[4].

Lytic lesions in the periacetabular region cause severe pain and increase the risk of pathological fractures. Surgery is typically recommended for patients with symptoms on axial weight-bearing. Traditionally, these lesions were often treated with open surgery following the technique described by Harrington or one of its many iterations[5,6]. However, open surgical approaches carry a high risk of postoperative complications,

Disclosure: Funding provided by IlluminOss, Inc. The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJSOA/A677).

including infection, implant loosening, and hip dislocation, potentially delaying or interrupting systemic treatment and radiation therapy[7-9].

To minimize the risks associated with open surgery, minimally invasive percutaneous techniques have emerged as viable options[10-14]. These procedures involve the use of percutaneous screws and cementoplasty, and potential tumor ablation, for pelvic stabilization. We describe a novel procedure using photodynamic nails (PDNs) for this purpose. PDNs are light-sensitive monomers that conform to patient-specific anatomy and enable optimal radiographic surveillance because of their radiolucent properties. The literature highlights the benefits of PDNs, including shorter operative time, reduced blood loss, and improved physical function compared with open surgery[15]. However, data on postoperative patient-reported outcomes (PROs) remain limited.

The purpose of this prospective study was to describe postoperative complications and functional outcomes of patients treated with PDNs (IlluminOss Medical) for pelvic bone metastases, multiple myeloma, or primary bone lymphoma.

Materials and Methods

Study Design and Setting

Institutional review board approval (2021P000047) preceded this prospective cohort study conducted at a large, tertiary care, academic medical center in the northeastern U.S.

Patients were prospectively enrolled after consent was obtained by the treating surgeon. Preoperative pain questionnaires and surveys regarding function were administered within 2 weeks before surgery, followed by postoperative surveys at various intervals (2 days, 2 weeks, 6 weeks, 3 months, 6 months, and 1 year) during outpatient visits. These surveys were administered by either the treating surgeon or advanced practice providers in our division. In instances in which patients could not come to the office at a specific time point, surveys were mailed to their residential address.

Thirty-two patients were enrolled at our institution between 2021 and 2023 (Fig. 1). Two patients were enrolled but not treated with PDNs. One patient showed notable improvement with systemic treatment and did not require surgery anymore. The second patient underwent open reduction and internal fixation after the surgeon intraoperatively determined that the fracture was unsuitable for PDN stabilization because of substantial comminution.

Participants

Inclusion criteria for the study were the following: (1) a skeletally mature patient ≥21 years of age; (2) impending or actual nondisplaced or minimally displaced pathological fractures of the pelvis secondary to bone metastases, multiple myeloma, or primary bone lymphoma; and (3) a visual analogue scale (VAS) pain score of ≥30 on a 0 to 100 scale. We excluded patients with oligometastatic cancer, specifically those with histologies indicating a favorable prognosis (e.g., renal cell carcinoma, papillary thyroid carcinoma, certain subtypes of breast cancer), as they could benefit from metastasectomy. The definition of

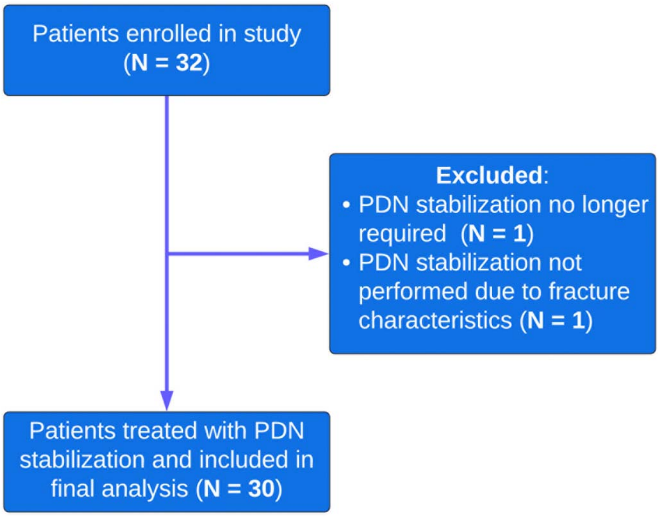

Fig. 1
Flowchart of patient inclusion in the study. PDN = photodynamic nail.

"impending fracture" was lesions in the periacetabular area of >50% of the affected column/region (anterior column, posterior column, and sciatic corridor) with or without thinning of the cortex, resulting in a pain score of >8 on a 0 to 10 scale, and the inability to bear weight or the need for assistive devices for weight-bearing. Patients who were uncooperative, incapable of following directions, or deemed unfit for surgery were excluded. PDNs were preferred over alternative percutaneous techniques in patients with extensive pelvic metastatic disease, especially those with lytic lesions creating contained or uncontained defects where flexible monomers potentially provide enhanced bone stabilization, or when additional hardware was necessary. Such hardware was implanted in patients with extensive metastatic involvement of the pelvis, particularly the acetabular area and/or femur.

All patients received standard venous thromboembolism prophylaxis, consisting of 40 mg of low-molecular-weight heparin administered subcutaneously daily. Antibiotic prophylaxis consisted of 2 g of cefazolin administered within 30 minutes of surgery and every 8 hours for 24 hours postoperatively.

Variables and Outcomes of Interest

The following demographic and clinical variables were obtained at the time of surgery: age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) class, primary cancer type, smoking status, other comorbidities according to the Charlson Comorbidity Index (CCI)[16], radiation therapy, chemotherapy, and follow-up duration. Surgical information included the number of PDNs employed, additional hardware used, operative time, estimated blood loss, intraoperative transfusion, ablation use, intensive care unit (ICU) admission and stay, total length of stay, and discharge location. Ablation was performed in cases of radiation therapy- and chemotherapy-resistant tumors for local control. All cases received either radiofrequency ablation or cryoablation. Postoperative complications were prospectively collected and included the following: PDN failure, fracture at the implant site,

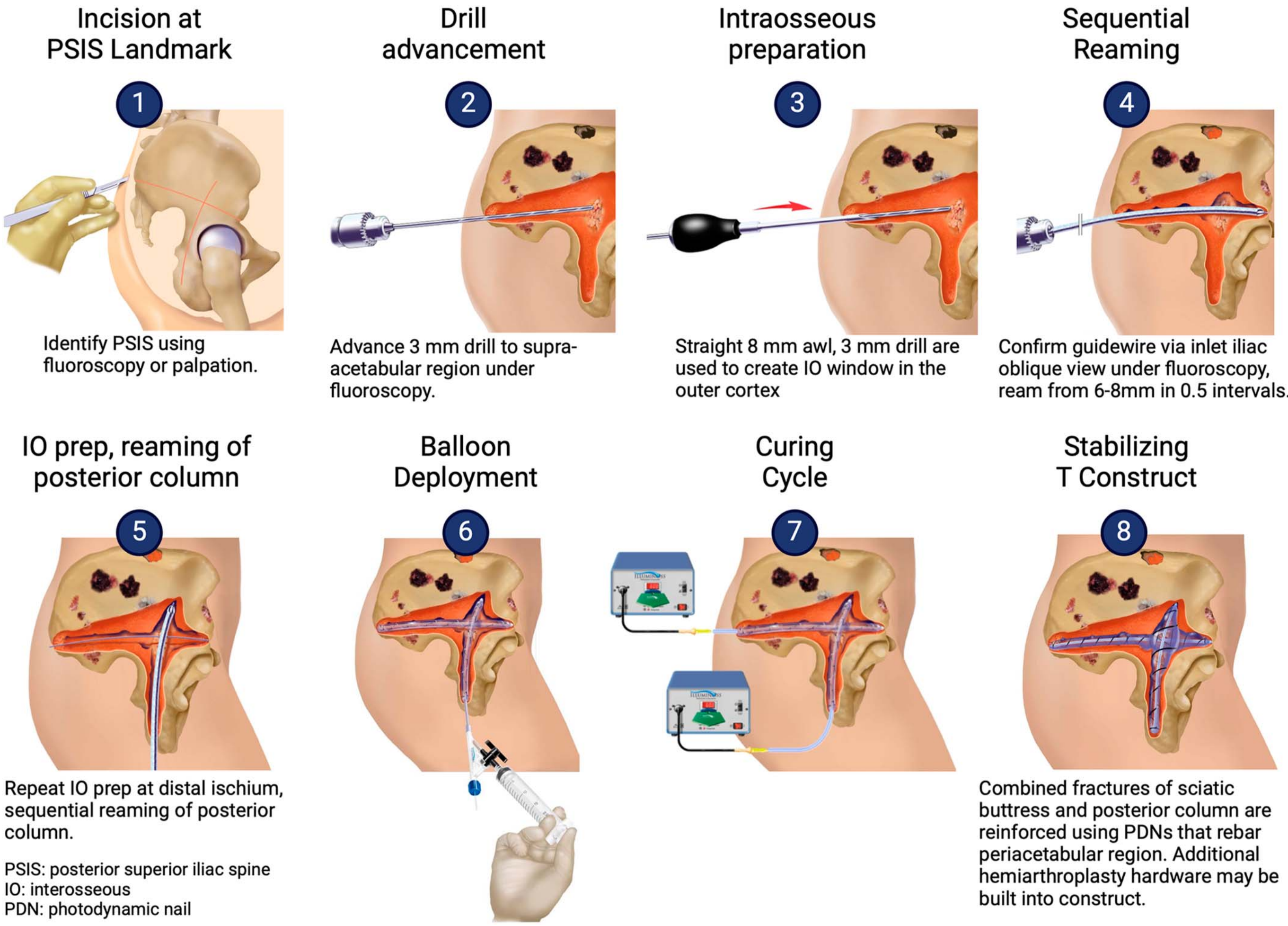

Fig. 2

Illustration of the steps required to use the photodynamic bone stabilization system. PSIS = posterior superior iliac spine, IO =intraosseous, and PDN = photodynamic nail. (Reproduced with permission from: Lozano-Calderon SA, Clunk MJ, Gonzalez MR, Sodhi A, Krueger RK, Gruender AC, Greenberg DD. Assessing Pain and Functional Outcomes of Percutaneous Stabilization of Metastatic Pelvic Lesions via Photodynamic Nails: A Bi-Institutional Investigation of Orthopaedic Outcomes. JBJS Open Access. 2024 Jul 10;9[3]:e23.00148. Copyright © 2024 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 [CC-BY-NC-ND].)

surgical site infection (SSI), tissue disruption, thromboembolic event (TE), reoperation, and 90-day readmission. SSIs were defined using the 2018 Centers for Disease Control and Prevention (CDC) guidelines[17].

Primary outcomes of interest were the VAS pain score, ambulation status, and functional outcomes. Secondary outcomes included all postoperative complications: implant failure, SSI, TE, and reoperation and readmission rates. Implant failures were defined as those stemming from mechanical disruption of the PDN after curing of the nail. Ambulation and functional outcomes were assessed using both physician-based scores and PROs. The physician-based scores employed were the Eastern Cooperative Oncology Group (ECOG) Performance Status scale and the Musculoskeletal Tumor Society (MSTS) score. We used 2 Patient-Reported Outcomes Measurement Information System (PROMIS)-derived questionnaires: the PROMIS Pain Interference-Short Form 8A and the PROMIS Physical Function-Short Form 10A. Additional PROs assessed were the Combined Pain and Ambulatory Function (CPAF) score and the EuroQol (EQ)-VAS. Preoperative outcomes were available for all included patients. PRO and physician-based scores were available for 26 patients at the 2-day postoperative mark, 22 patients at the 2-week mark, 21 patients at the 6-week mark, 15 patients at the 3-month mark, 11 patients at the 6-month mark, and 2 patients at the 1-year mark.

Surgical Technique

All surgical procedures were performed because of symptomatic metastatic disease of the pelvis, multiple myeloma, or primary bone lymphoma. This technique reinforces the anterior or posterior column, sciatic corridor, and supra-acetabular areas of the pelvis with PDNs (Fig. 2). Posterior-column stabilization involves inserting a balloon up the ischium, while stabilization of the sciatic corridor entails using a balloon advanced from the posterior inferior iliac spine to the anterior inferior iliac spine. If required, the anterior column can be stabilized in a retrograde fashion from the ipsilateral superior pubic ramus. Stabilization of the anterior column can also be achieved in an antegrade fashion through a lateral supra-acetabular incision. In cases needing further stability in the supra-acetabular area or over the root of the superior pubic ramus, multiple balloons can be placed. The procedure may be performed with the patient supine or prone (we prefer the prone position) on a radiolucent table and with chest rolls, as detailed in a previously published report on our technique[15,18]. While the surgery can be carried out with fluoroscopy alone, computed tomography (CT)-guided computer navigation is highly recommended to improve tactile feedback when drilling through the affected pelvic structures. Once cured, PDNs create a stable implant, securing the inner and outer cortices of the hemipelvis. Figure 3 shows preoperative, intraoperative, and postoperative radiographs of a patient who underwent pelvic bone stabilization with PDNs.

Statistical Analysis

Demographic, clinical, and treatment characteristics are reported using descriptive statistics. Because of non-normal distributions, we report the median and interquartile range for continuous variables. Differences between groups were evaluated using the chi-square test, for categorical variables, and the Kruskal-Wallis test, for continuous variables. A post-hoc nonparametric comparison of subgroups was performed using the Dunn test. A p value of <0.05 was considered significant. All statistical analyses were performed using Stata (StataCorp).

Results

The median age of the cohort was 68 years, 14 (47%) of the patients were female, and the median BMI was 25.3 kg/m^2 (Table I). Prostate cancer (27%), multiple myeloma (13%), and breast cancer (13%) were the most prevalent primary cancers. Thirty-seven percent of the patients received radiation therapy to the ipsilateral pelvis, with 17% and 20% receiving it as neoadjuvant or adjuvant treatment, respectively. Neoadjuvant or adjuvant chemotherapy was administered to 80% of the patients. The median follow-up was 6.8 months.

Twenty-six (87%) of the patients had periacetabular lesions (Enneking zone II), while 4 had lesions in non-acetabular areas (Enneking zones I, III, and IV). Of patients with periacetabular lesions, 2 (8%) had Harrington type-1 lesions, 6 (23%) had type-2 lesions, and 18 (69%) had type-3 lesions. Among all patients (n = 30), the majority received either 2 (37%) or 3 (37%) PDNs (Table II). Seven (23%) of the patients required additional hardware, with 5 patients undergoing total hip arthroplasty (THA), 1 receiving a femoral intramedullary nail, and 1 treated with the use of 2 percutaneous screws in the ipsilateral ilium (Table III). The median operative time and estimated blood loss were 199 minutes and 200 mL, respectively. Intraoperative ablation was performed in 8 (27%) of the patients. Cryoablation and radiofrequency ablation were used in 1 (3%) and 7 (23%) of the patients, respectively. The median length of stay was 2.5 days, with 83% discharged to home.

Postoperative Complications

No PDN failures occurred, and only 1 patient experienced a postoperative fracture at the implant site because of disease progression. There was no failure or rupture of the implant itself (Table IV). Postoperative SSIs and TEs occurred in 2 (7%) and 3 (10%) of the patients, respectively. The 3 patients with TEs developed deep venous thrombosis at 9, 10, and 28 days, respectively, after surgery. Debridement was performed for both patients with SSIs, 1 for a superficial infection and the other for a periprosthetic joint infection related to the THA (Table III). In all cases, the PDN remained in place. Three other patients required reoperation: 1 underwent THA because of

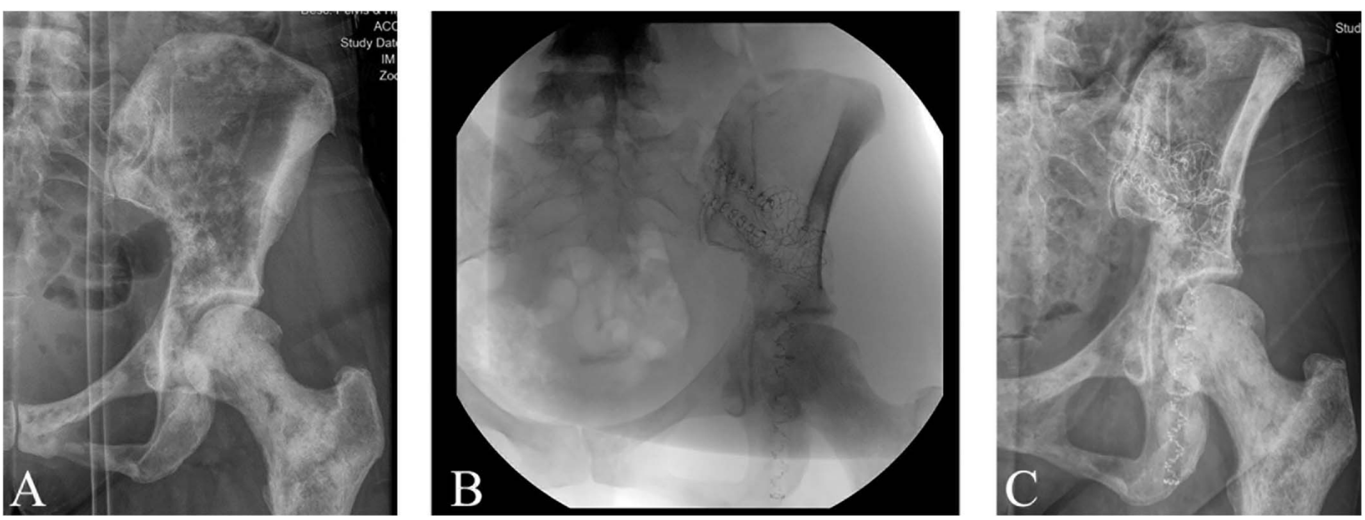

Fig. 3

Fig. 3-A Preoperative radiograph of a 48-year-old female patient with metastatic breast cancer displaying multifocal osseous metastases. **Figs. 3-B and 3-C** Intraoperative (**Fig. 3-B**) and postoperative (**Fig. 3-C**) radiographs displaying the photodynamic nail in place.

TABLE I Demographics of Included Patients (N = 30)*

Age† *(yr)*	68 (57-73)
Female sex	14 (47%)
BMI† *(kg/m²)*	25.3 (21.8-28.5)
ASA class	
2	2 (7%)
3	27 (90%)
4	1 (3%)
Primary cancer	
Prostate	8 (27%)
Multiple myeloma	4 (13%)
Breast	4 (13%)
Lung	3 (10%)
Thyroid	2 (7%)
Gastrointestinal	2 (7%)
Lymphoma	1 (3%)
Hepatocellular	1 (3%)
Other	5 (17%)
Smoker	8 (27%)
Other comorbidities (CCI)	8 (27%)
Radiation therapy	11 (37%)
Neoadjuvant	5 (17%)
Adjuvant	6 (20%)
Chemotherapy	24 (80%)
Follow-up† *(mo)*	6.8 (3.7-10.2)

*The values are given as the number, with the percentage in parentheses, except where otherwise noted. ASA = American Society of Anesthesiologists, BMI = body mass index, CCI = Charlson Comorbidity Index. †The values are given as the median, with the interquartile range in parentheses.

femoral head collapse, while the other 2 received additional PDNs because of balloon extrusion from disease progression or new symptomatic pelvic lesions. The overall reoperation and readmission rates were 17% and 10%, respectively.

ECOG Performance Status

Preoperatively, 75% of the patients had ECOG scores of between 1 and 3, and 25% were designated as ECOG 0 (Fig. 4). Over time, there was an increase in the percentage of patients classified as having ECOG 1 status coupled with a decrease in those with an ECOG 3 status.

Pain, Ambulation, and Functional Outcomes

At 6 weeks postoperatively, the median VAS pain score was lower than the score before surgery (30 versus 60; $p = 0.004$) (Fig. 5). After the 6-week mark, lower VAS pain scores compared with preoperatively were seen at all time points.

The median CPAF score improved from a preoperative score of 6 to a postoperative score of 7 at the 6-week mark (Fig. 6-A). Likewise, an improvement in the median EQ-VAS score was seen at 6 weeks (70 versus 50; $p = 0.006$) (Fig. 6-B), with sustained improvement at all subsequent time points compared with preoperatively. Early ambulation was evident for most patients, with 89.3% bearing weight as tolerated 2 days after surgery (Fig. 6-C).

The median 2-week PROMIS Pain Interference score was significantly lower than the preoperative score (64.1 versus 66.9; $p = 0.03$) (Fig. 7-A). An improvement in the median PROMIS Physical Function score was seen at 6 weeks after surgery compared with preoperatively (37 versus 30.1; $p = 0.001$) (Fig. 7-B). Both PROs showed sustained improvement over time, and scores were significantly better than preoperative values at all time points from 6 weeks to 1 year. The median MSTS score significantly improved as early as 2 days postoperatively (77% versus 40%; $p < 0.0001$) (Fig. 7-C), with a significantly better score at 2 weeks compared with preoperatively and higher scores at all subsequent time points. One year after surgery, the median MSTS reached 100% (n = 2).

A subanalysis of patients treated with PDN and ablation demonstrated significant improvement in all PROs. The median VAS, EQ-VAS, PROMIS Pain Interference, PROMIS Physical

TABLE II Surgical Details and Postoperative Course (N = 30)*

No. of PDNs	
1	4 (13%)
2	11 (37%)
3	11 (37%)
4	3 (10%)
5	0 (0%)
6	1 (3%)
Additional hardware	7 (23%)
Femoral IMN	1 (3%)
THA	5 (17%)
Percutaneous screws	1 (3%)
Operative time† *(min)*	199 (145-284)
Estimated blood loss† *(mL)*	200 (50-300)
pRBC units transfused	3 (10%)
Ablation	8 (27%)
ICU admission	2 (7%)
ICU stay† *(days)*	5 (4-6)
Total length of stay† *(days)*	2.5 (1-5)
Discharge location	
Home	25 (83%)
Rehabilitation facility	3 (10%)
Hospital/comfort measures only	2 (7%)

*The values are given as the number, with the percentage in parentheses, except where otherwise noted. ICU = intensive care unit, IMN = intramedullary nail, PDN = photodynamic nail, pRBC = packed red blood cell, and THA = total hip arthroplasty. †The values are given as the median, with the interquartile range in parentheses.

TABLE III Data on Patients with Additional Hardware Implanted*

Case	Age *(yr)*	Sex	Primary Tumor	Ablation	Additional Hardware	Operative Time *(min)*	EBL *(mL)*	Reoperation	Follow-up *(mo)*	Final status
1	75	Male	Prostate	—	Femoral IMN	248	300	Yes, for balloon extrusion	3	Died
2	51	Female	Breast	—	THA	520	2,000	—	11.8	Alive
3	57	Male	Prostate	Yes	THA	480	200	Yes, for superficial infection	10.4	Alive
4	87	Male	Prostate	—	THA	315	200	Yes, for periprosthetic joint infection	8.9	Alive
5	73	Male	Prostate	—	THA	336	500	—	8.5	Alive
6	71	Male	Lymphoma	—	THA	386	400	—	6.5	Alive
7	51	Female	Breast	—	Percutaneous screws (2)	267	200	—	4.1	Alive

*EBL = estimated blood loss, IMN = intramedullary nail, and THA = total hip arthroplasty.

Function, and MSTS scores improved by 6 weeks, while CPAF scores improved by 1 year. Similarly, patients treated with PDN and THA (n = 5) had significant improvement in all PROs except the CPAF score between the preoperative assessment and the 6-month mark (Table V).

Discussion

Periacetabular bone metastases are associated with substantial pain, severely limiting patients' mobility and quality of life. Treatment of these lesions mainly focuses on palliating the pain, restoring ambulation, and providing pelvic structural stability[12,19]. Traditionally, periacetabular stabilization was achieved through methods like the Harrington technique or its variations, which carry a high complication rate and often require prolonged interruption of systemic treatment and/or radiation therapy to allow for wound healing[5,6]. Minimally invasive techniques offer a viable alternative, with studies noting shorter operative times, decreased blood loss, and shorter hospital stays[10-14].

TABLE IV Postoperative Complications (N = 30)

PDN failure	0 (0%)
Postoperative fracture at the implant site	1 (3%)
Surgical site infection*	
Superficial	1 (3%)
Deep	1 (3%)
Tissue disruption*	1 (3%)
Dehiscence	1 (3%)
Thromboembolic event*	3 (10%)
Reoperation	5 (17%)
Readmission	3 (10%)

*Within 90 days following surgery.

The percutaneous stabilization of bone lesions with PDNs combines the intrinsic benefits of percutaneous techniques with the advantages of a flexible, radiolucent monomer[15,20]. Because of their radiolucent properties, PDNs enable optimal visualization of radiation therapy response, critical in radiosensitive tumors such as multiple myeloma. They also provide the potential advantage of the earlier resumption of systemic treatment and postoperative radiation therapy compared with open techniques, which often entail substantial delays[21]. This expedited resumption of chemoradiation is attributed to smaller incisions, shorter healing time, and PDN location away from the radiation field.

Our study demonstrated the feasibility and low complication rate of PDNs in treating pelvic bone metastases, multiple myeloma, or primary bone lymphoma with rapid improvement in functional outcomes. One of the limitations in the literature regarding the percutaneous management of pelvic metastases is the lack of PROs. Unlike previous studies that relied on physician-based assessments, such as the MSTS score[10,13,14] and ECOG scale[11,12], or only evaluated the pain VAS[14] and CPAF[10], our study utilized a wider range of both physician-based and PRO questionnaires. Within 6 weeks postoperatively, we observed a significant improvement across all measures. For the MSTS and PROMIS Pain Interference scores, however, patients showed improvement at the 2-day and 2-week mark, respectively. To our knowledge, this is the only prospective study, with the largest prospective cohort, describing the use of PDNs to treat pelvic bone metastases.

Regarding complications, we report a 7% SSI rate and a 17% reoperation rate, primarily related to failure of additional hardware rather than PDN failure. Notably, none of the reoperations performed were because of catastrophic implant failure but rather because of disease progression or new symptomatic lesions. Nonetheless, surgeons should remain vigilant to potential failure modes for PDNs during or after the procedure. These include balloon rupture during inflation, extravasation of

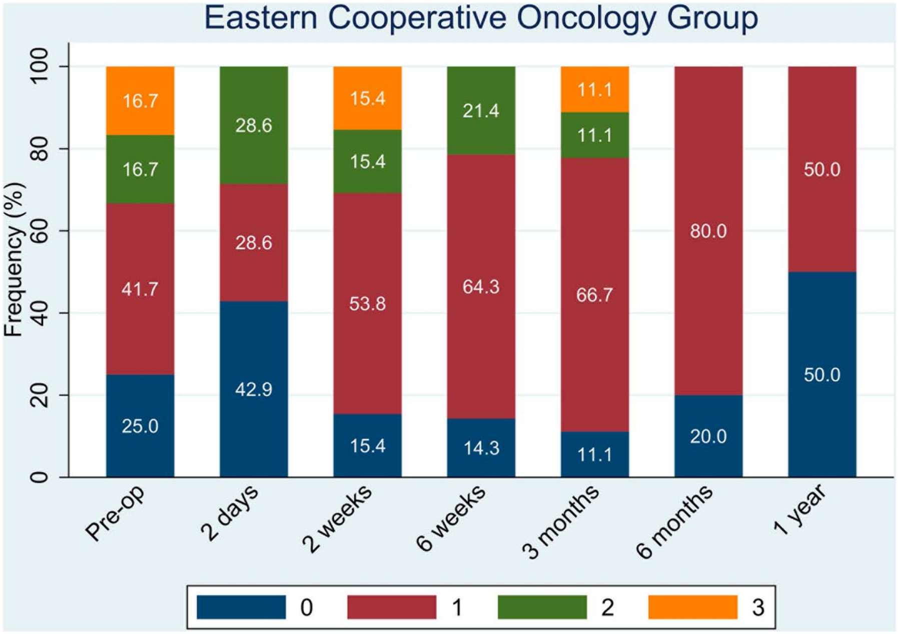

Fig. 4
Distribution of scores on the Eastern Cooperative Oncology Group (ECOG) Performance Status Scale.

the polymer from the balloon before curing, fracture displacement, and balloon extrusion or migration before and/or after curing.

Our findings align with prior research on the percutaneous stabilization of pelvic lesions[10,11,13]. English et al. reported a 16% reintervention rate in 38 patients treated with minimally invasive osteoplasty and screw fixation, with 8% experiencing cement extrusion and subsequent weight-bearing restrictions[13]. In comparison, only 1 patient in our series required surgical reintervention because of balloon extrusion from disease progression. This lower rate underscores a key advantage of PDNs, which is their in situ customizability. Available in diverse lengths and diameters, these implants can be tailored to each patient's pelvic anatomy to maximize defect filling[22]. Overall, postoperative

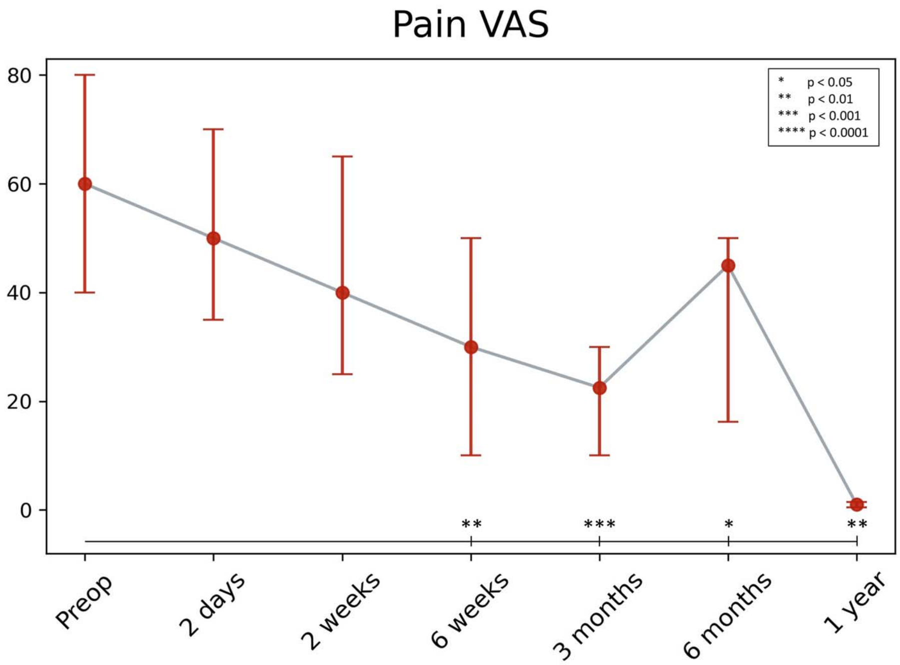

Fig. 5
Visual analogue scale (VAS) pain scores across time. Values shown are the median and interquartile range (bars).

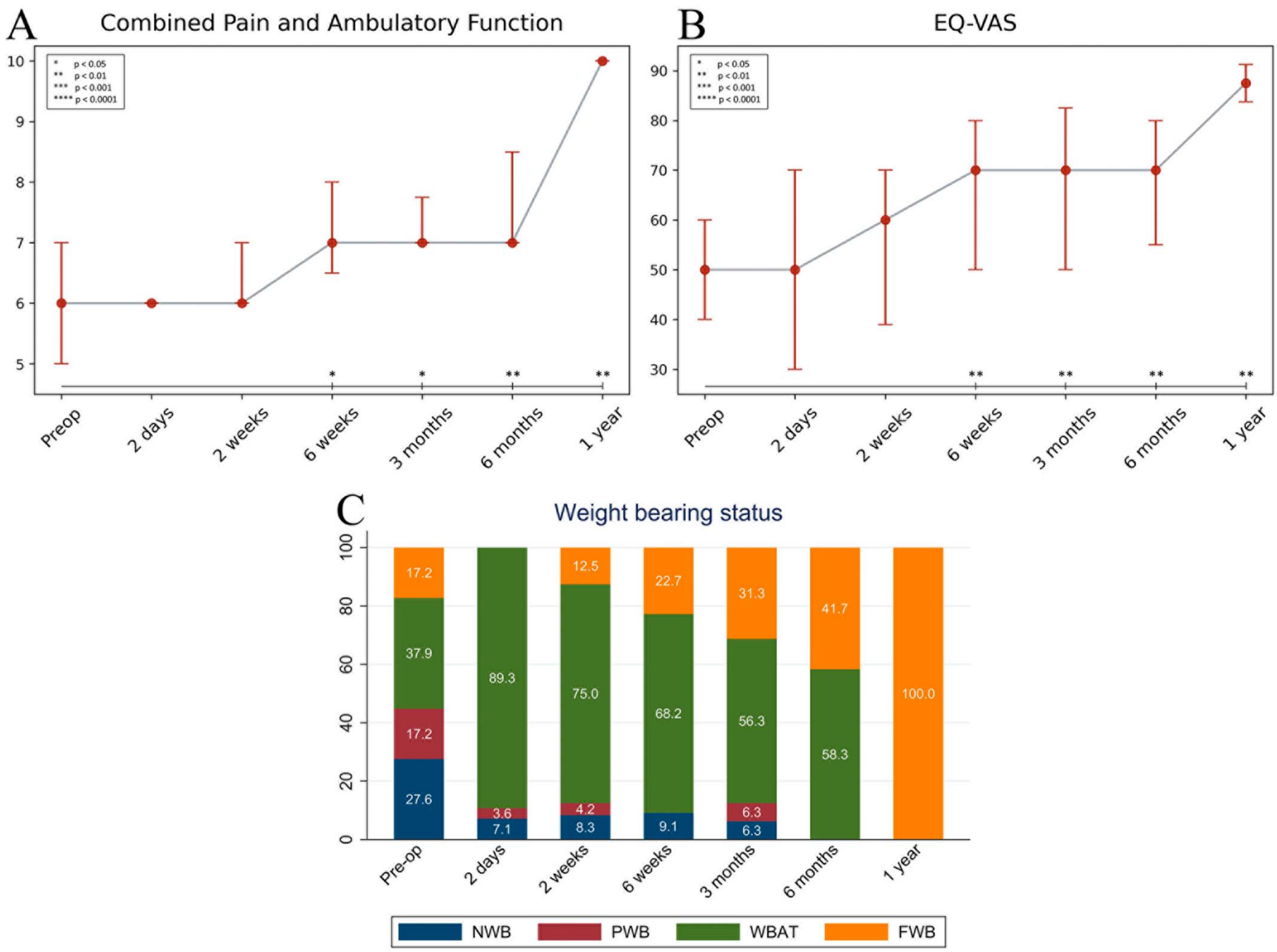

Fig. 6

Combined Pain and Ambulatory Function scores (**Fig. 6-A**), EuroQol-Visual Analogue Scale (EQ-VAS) scores (**Fig. 6-B**), and the weight-bearing status (**Fig. 6-C**) of included patients across time. Values shown in Figs. 6-A and 6-B are the median and interquartile range (bars). NWB = non-weight-bearing, PWB = partial weight-bearing, WBAT = weight-bearing as tolerated, and FWB = full weight-bearing.

complications in our cohort were much lower than the 31% to 36% rate reported for open surgery[8,23]. Minimizing complications in this population is crucial, as they can lead to delays in restarting systemic treatment or radiation therapy. In our study, PDNs demonstrated excellent postoperative outcomes when used for the appropriate indications. However, the primary contraindication for this procedure is oligometastatic cancer with favorable prognosis, where metastasectomy may offer superior oncological outcomes. Additionally, near-complete bone loss in the periacetabular area is a relative contraindication, due to inadequate bone support for balloon placement.

Our study had several limitations. First, this was a prospective study with a limited number of patients and a relatively short follow-up duration. The median follow-up of 6.8 months may not capture all complications and failure events associated with PDNs. Despite the low number of patients assessed, the prospective design of our study ensured that all patients completed the surveys at pre-established time points. Second, there was substantial heterogeneity in terms of primary tumor types, and in the number and anatomic placement of PDNs. Third, only 11 and 2 patients were assessed at the 6-month and 1-year postoperative marks, respectively, limiting the generalizability of results at these time points. Lastly, long-term outcomes for this procedure may be biased toward patients with tumors that respond well to systemic treatment or radiation therapy. This could potentially introduce selection bias, where patients with specific primary tumor types are disproportionately represented in the overall sample.

Conclusions

In this prospective study, we found that treatment using PDNs resulted in immediate return to ambulation and rapid functional outcome improvement, with low complication rates, in patients with pelvic bone metastases multiple myeloma, or

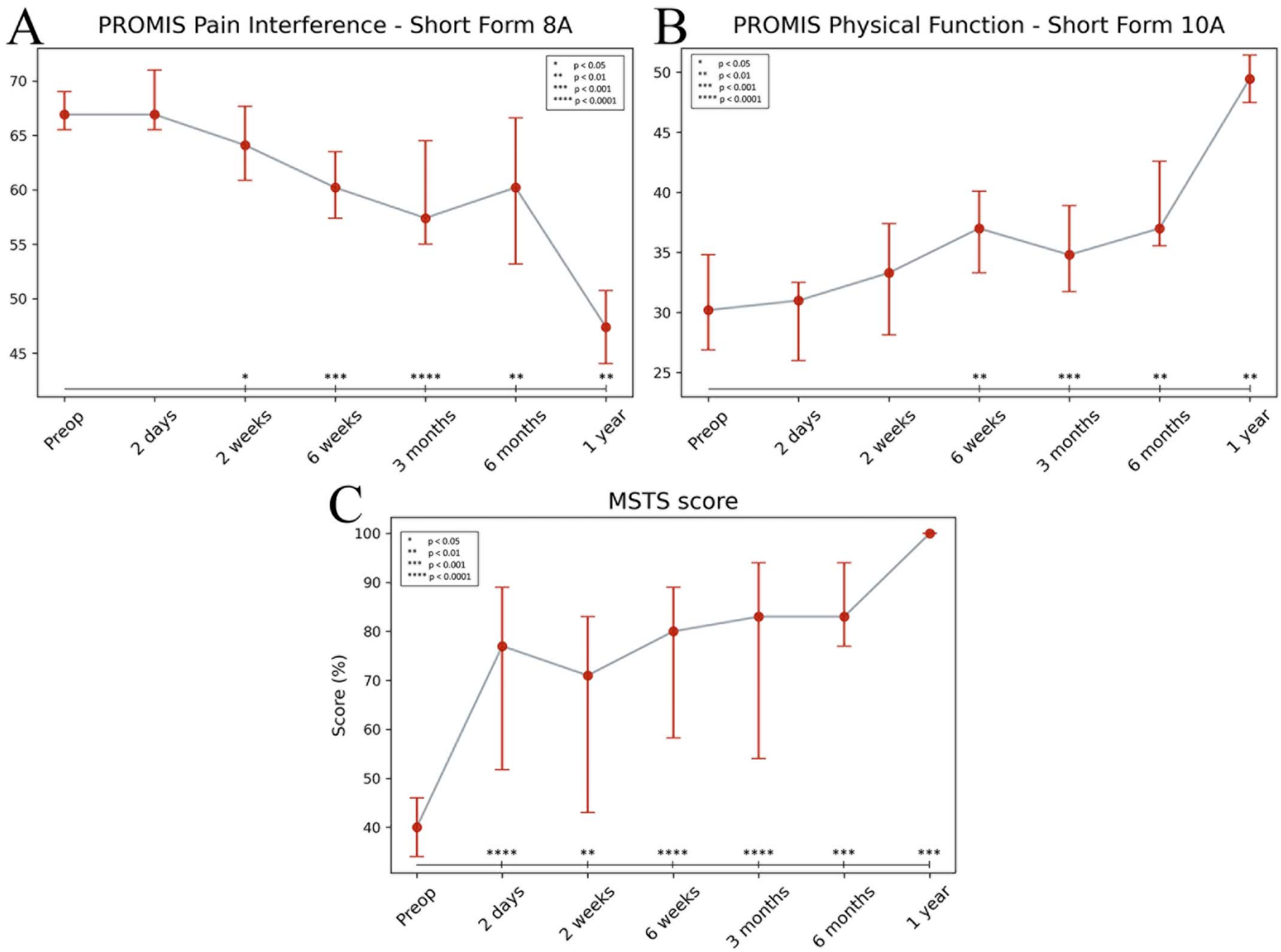

Fig. 7

Patient-Reported Outcomes Measurement Information System (PROMIS) Pain Interference-Short Form 8A (**Fig. 7-A**), PROMIS Physical Function-Short Form 10A (**Fig. 7-B**), and Musculoskeletal Tumor Society (MSTS) (**Fig. 7-C**) scores at different time points. Values shown are the median and interquartile range (bars).

TABLE V Changes in Patient-Reported Outcome Scores Across Time for Patients with Combined Photodynamic Bone Stabilization and Total Hip Arthroplasty (N = 5)*

		Postoperative†				
Questionnaire	Preoperative†	2 Days	2 Wk	6 Wk	3 Mo	6 Mo
Pain VAS	70 (40-80)	55 (40-70)	40 (35-70)	30 (25-50)‡	20 (5-25)§	30 (20-40)‡
CPAF	6 (5-6)	6 (5-6)	6 (6-7)	6 (6-7)	7 (6-9)	7.5 (6-9)
EQ-VAS	65 (60-70)	60 (60-70)	60 (45-70)	80 (75-80)	85 (70-90)‡	77.5 (75-80)‡
PROMIS Pain Interference	66.2 (65.5-66.9)	69.85 (65.85-73.5)	61.5 (61.5-64.1)	62.1 (59.5-68.4)	62.8 (55-72.1)	56.7 (53.2-60.2)‡
PROMIS Physical Function	28.6 (26-35.5)	26.45 (25.5-31.95)	30.2 (28.6-31.8)	33.3 (28.6-40.1)	34.8 (29.4-41.7)	39.8 (37-42.6)‡
MSTS	43 (40-46)	69 (51-71)‡	49 (43-54)	54 (49-71)	69 (49-89)	94.5 (89-100)§

*CPAF = Combined Pain and Ambulatory Function, EQ-VAS = EuroQol-Visual Analogue Scale, MSTS = Musculoskeletal Tumor Society, PROMIS = Patient-Reported Outcomes Measurement Information System, and VAS = visual analogue scale. †The values are given as the median score, with the interquartile range in parentheses. ‡P < 0.05 compared with preoperatively. §P < 0.01 compared with preoperatively.

primary bone lymphoma. Therefore, we conclude that the photodynamic stabilization system represents a safe, attractive alternative to open surgery with the added benefits of customizability and radiolucency. ■

Santiago A. Lozano-Calderon, MD, PhD[1]
Marcos R. Gonzalez, MD[1]
Joseph O. Werenski, BS[1]
Kayla Quinn, NP[1]
Diana Freiberger, NP[1]
Kevin A. Raskin, MD[1]

[1]Division of Orthopaedic Oncology, Department of Orthopaedic Surgery, Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts

Email for corresponding author: slozanocalderon@mgh.harvard.edu

References

1. D'Oronzo S, Coleman R, Brown J, Silvestris F. Metastatic bone disease: Pathogenesis and therapeutic options: Up-date on bone metastasis management. J Bone Oncol. 2018 Nov 6:15:004-4.

2. Christ AB, Piple AS, Gettleman BS, Duong A, Chen M, Wang JC, Heckmann ND, Menendez L. Prevalence of primary malignant tumours, rates of pathological fracture, and mortality in the setting of metastatic bone disease. Bone Joint Open. 2023 Jun 5;4(6):424-31.

3. Li S, Peng Y, Weinhandl ED, Blaes AH, Cetin K, Chia VM, Stryker S, Pinzone JJ, Acquavella JF, Arneson TJ. Estimated number of prevalent cases of metastatic bone disease in the US adult population. Clin Epidemiol. 2012;4:87-93.

4. Schulman KL, Kohles J. Economic burden of metastatic bone disease in the U.S. Cancer. 2007 Jun 1;109(11):2334-42.

5. Harrington KD. The management of acetabular insufficiency secondary to metastatic malignant disease. J Bone Joint Surg Am. 1981 Apr;63(4):653-64.

6. Kask G, Nieminen J, van Iterson V, Naboistsikov M, Pakarinen TK, Laitinen MK. Modified Harrington's procedure for periacetabular metastases in 89 cases: a reliable method for cancer patients with good functional outcome, especially with long expected survival. Acta Orthop. 2020 Jun;91(3):341-6.

7. Rowell P, Lowe M, Sommerville S, Dickinson I. Is an acetabular cage and cement fixation sufficiently durable for the treatment of destructive acetabular metastases? Clin Orthop Relat Res. 2019 Jun;477(6):1459-65.

8. Ho L, Ahlmann ER, Menendez LR. Modified Harrington reconstruction for advanced periacetabular metastatic disease. J Surg Oncol. 2010 Feb 1;101(2):170-4.

9. Marco RA, Sheth DS, Boland PJ, Wunder JS, Siegel JA, Healey JH. Functional and oncological outcome of acetabular reconstruction for the treatment of metastatic disease. J Bone Joint Surg Am. 2000 May;82(5):642-51.

10. Lee FY, Latich I, Toombs C, Mungur A, Conway D, Alder K, Ibe I, Lindskog D, Friedlaender G. Minimally Invasive Image-Guided Ablation, Osteoplasty, Reinforcement, and Internal Fixation (AORIF) for Osteolytic Lesions in the Pelvis and Periarticular Regions of Weight-Bearing Bones. J Vasc Interv Radiol. 2020 Apr;31(4):649-658.e1.

11. Yang R, Goch A, Murphy D, Wang J, Charubhumi V, Fox J, Sen M, Hoang B, Geller D. A Novel Tripod Percutaneous Reconstruction Technique in Periacetabular Lesions Caused by Metastatic Cancer. J Bone Joint Surg Am. 2020 Apr 1;102(7):592-9.

12. Yang R, Singh S, Falk A, Wang J, Thornhill B, Fox J, Sen M, Hoang B, Geller DS. Percutaneous Screw Stabilization of Non-Periacetabular Pelvic Lesions Caused by Metastatic Cancer and Multiple Myeloma. J Bone Joint Surg Am. 2022 Apr 6;104(7):577-85.

13. English DI, Lea WB, King DM, Tutton SM, Neilson JC. Minimally Invasive Stabilization with or without Ablation for Metastatic Periacetabular Tumors. J Bone Joint Surg Am. 2021 Jul 7;103(13):1184-92.

14. Hartung MP, Tutton SM, Hohenwalter EJ, King DM, Neilson JC. Safety and Efficacy of Minimally Invasive Acetabular Stabilization for Periacetabular Metastatic Disease with Thermal Ablation and Augmented Screw Fixation. J Vasc Interv Radiol. 2016 May;27(5):682-688.e1.

15. Fourman MS, Ramsey DC, Newman ET, Raskin KA, Tobert DG, Lozano-Calderon S. How I do it: Percutaneous stabilization of symptomatic sacral and periacetabular metastatic lesions with photodynamic nails. J Surg Oncol. 2021 Dec;124(7):1192-9.

16. Charlson M, Szatrowski TP, Peterson J, Gold J. Validation of a combined comorbidity index. J Clin Epidemiol. 1994 Nov;47(11):1245-51.

17. Borchardt RA, Tzizik D. Update on surgical site infections: The new CDC guidelines. JAAPA. 2018 Apr;31(4):52-4.

18. Lozano-Calderon SA, Clunk MJ, Gonzalez MR, Sodhi A, Krueger RK, Gruender AC, Greenberg DD. Assessing Pain and Functional Outcomes of Percutaneous Stabilization of Metastatic Pelvic Lesions via Photodynamic Nails: A Bi-Institutional Investigation of Orthopaedic Outcomes. JBJS Open Access. 2024 Jul 10;9(3):e23.00148.

19. Al-Hardan W, Garbrecht E, Huntley K, Pretell-Mazzini J. Surgical Management Update in Metastatic Disease of the Pelvis Operative Techniques in Orthopaedics. Oper Tech Orthop. 2021;31(3):100897.

20. Oikonomidis S, Alabsi A, Ashqar G, Graf M, Sobottke R. Intramedullary Stabilization of Pubic Ramus Fractures in Elderly Patients With a Photodynamic Bone Stabilization System (IlluminOss). Geriatr Orthop Surg Rehabil. 2019 Apr 25;10:2151459318824904.

21. Scoccianti G, Rigacci L, Puccini B, Campanacci DA, Simontacchi G, Bosi A, Capanna R. Primary lymphoma of bone: outcome and role of surgery. Int Orthop. 2013 Dec;37(12):2437-42.

22. Gausepohl T, Hoffmann F, Koebke J. Stabilizing of a Metastatic Pelvis Fracture Using a Photodynamic POLYMER Stabilizing System (ILLUMINOSS™). Anatomical Study and First Case Report. Journal of Case Reports in Medicine. 2021;10(2):28-31.

23. Clayer M. The survivorship of protrusio cages for metastatic disease involving the acetabulum. Clin Orthop Relat Res. 2010 Nov;468(11):2980-4.