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Original Research

Does Perioperative Radiation Affect Implant Survivorship of Primary Total Hip Arthroplasty in the Setting of Metastatic Bone Disease?

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ABSTRACT

Background: Metastatic bone disease (MBD) commonly affects the hip and surgical intervention including total hip arthroplasty (THA) is often indicated to treat the joint and improve function. Patients with metastatic cancer often receive radiotherapy, and orthopaedic oncologists must consider surgical risks with operating on irradiated bone and soft tissue. We evaluated surgical outcomes and implant survival (IS) of titanium acetabular components and femoral components in patients treated for MBD in the setting of perioperative radiation.

Methods: This was a retrospective review of patients who underwent THA for MBD at 3 institutions between 2017 and 2021. Outcomes included rates of reoperation, complications, IS, and overall survival.

Results: Forty-six patients who received primary THA for MBD were included in the study. Twenty patients (43.5%) received perioperative radiation for MBD. Six postoperative complications including one superficial wound infection, 2 dislocations, 2 pathologic fractures, and one aseptic acetabular component loosening led to 5 reoperations. There were no significant differences in postoperative outcomes, reoperation after THA, and IS based on radiotherapy status.

Conclusions: To our knowledge, this is the first paper evaluating primary THA outcomes and IS between patients who receive perioperative radiation for MBD to the hip and those who do not. As surgical management is a crucial part of the treatment in alleviating pain and disability in patients with MBD, we continue to recommend THA for patients who received radiation at the operative site.

Introduction

Metastatic cancer in patients with solid tumors most commonly affects the skeletal system, with incidences of approximately 280,000 cases per year in the United States [1,2]. The incidence of metastatic bone disease (MBD) varies by tumor type and is most common in patients with multiple myeloma, prostate cancer, breast cancer, and lung cancer [3]. The femoral and pelvic bones are common sites for metastases making up 33% and 19% of all metastatic lesions, respectively [4–7]. Bone metastases in the proximal femur and pelvis carry significant morbidity including pain, impaired mobility, and pathologic fracture [6]. Furthermore, these metastatic lesions compromise the stability of the hip leading to mechanical failure, and are associated with an increased risk of mortality [6,8,9].

Management of metastatic lesions about the hip involves complex clinical decision-making. In cases of severely compromised function or risk of pathologic fracture, surgical stabilization is indicated. If there is an impending or complete pathologic fracture of the proximal femur, treatment options include open reduction and internal fixation (ORIF) with plate and screw constructs, intramedullary nailing (IMN), or resection with total hip arthroplasty (THA)/hemiarthroplasty [8,10,11]. If there is evidence of acetabular involvement, THA is the recommended treatment option [10,12]. Studies have reported higher failure in patients

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surgically treated with ORIF or IMN due to lack of load sharing between the fixation device and the bone [13–15]. Therefore, THA is strongly considered in cases in which further progression and destruction will likely lead to hardware failure [11,13].

In contrast to THA in the setting of osteoarthritis, the clinical decision-making process of selecting THA for MBD is complicated by the underlying pathology. Namely, up to 50% of these patients are irradiated in an attempt to treat the underlying malignancy [16]. Radiation can compromise the native bone stock and may affect component rate of mechanical failure [17–20]. In previously irradiated hips, implants such as tantalum cups and porous titanium components containing porous ingrowth surfaces may prove beneficial by promoting osseointegration as early as 5 weeks after implantation [21,22]. Prior studies have demonstrated improved implant survival (IS) of tantalum cups in patients with a history of pelvic radiation for primary cancer [23–26]; however, 2 other studies have more recently demonstrated similar IS of porous titanium components [27,28].

Although the long-term survival of tantalum cups has been studied in patients with a history of pelvic radiation for primary tumors [23–26] and in patients with metastatic disease [29,30], there is a paucity of data reporting the functioning and long-term IS of titanium cups used for THA in patients with a history of radiation to the operative hip for MBD. The purpose of this investigation was to examine the differences in rates of postoperative complications, reoperation, IS, and overall survival (OS) in patients after primary THA with titanium cups for MBD in the setting of perioperative radiation.

Material and methods

A retrospective review of all primary THA patients with histopathological and radiographically diagnosed MBD at the hip between 2017 and 2021 was conducted at 3 institutions. Exclusion criteria included patients undergoing revision THA and no information regarding previous radiotherapy treatments. This study was exempt from institutional review board approval based on institutional guidelines, and the requirement for informed consent was waived.

Demographic and clinicopathological information including sex, age, body mass index, smoking history, chronic steroid usage, primary tumor type, pathologic fracture at diagnosis, and chemotherapy and radiotherapy treatments were collected from the medical record (Table 1). Preoperative labs, operative characteristics (Table 2), and postoperative outcomes were also collected from the medical record. Acetabular components utilized included: G7 with plasma spray or OsseoTi (Zimmer Biomet, Warsaw, IN), Pinnacle (DePuy Synthes, Warsaw, IN), Tritanium (Stryker, Mahwah, NJ), POLARCUP (Smith & Nephew, England, UK), Novation Crown Cup (Exactech, Gainesville, FL), and Restoration GAP II (Stryker). Femoral components utilized included primary femoral stems: VerSys LD/Fx Cemented Hip Prostheses (Zimmer Biomet, Warsaw, IN), Omnifit femoral stem (Stryker, Mahwah, NJ), Accolade II (Stryker, Mahwah, NJ), Anthology (Smith & Nephew, England, UK), Synergy (Smith & Nephew, England, UK), Zimmer Trabecular Metal Primary Hip Prosthesis (Zimmer Biomet, Warsaw, IN), Novation Press-Fit (Exactech, Gainesville, FL), DePuy Summit (DePuy Synthes, Warsaw, IN), Biomet Echo (Zimmer Biomet, Warsaw, IN), Biomet Taperloc (Zimmer Biomet, Warsaw, IN), DePuy Actis (DePuy Synthes, Warsaw, IN), and DePuy Endurance (DePuy Synthes, Warsaw, IN) and revision femoral stems: Restoration Modular Hip System (Stryker, Mahwah, NJ) and Echelon (Smith & Nephew, England, UK). Perioperative radiation was defined as a history of radiation to the operative hip or receiving radiation within 6 weeks postoperatively. OS was defined as the time from the date of surgery to the date of last follow-up or death from any cause. IS was calculated from the date of surgery to the date of last follow-up or death from any cause or until revision THA.

Table 1
Patient demographic and clinical characteristics.

Variable	N (%)
Age at diagnosis (years), mean ± SD	60.89 ± 12.94
BMI at diagnosis, median (IQR)	27.92 (24.60-33.23)
Sex	
Male	24 (52.2)
Female	22 (47.8)
Smoking history	17 (37)
Chronic steroid use	2 (4.3)
Primary tumor type	
Breast cancer	14 (30.4)
Lung cancer	8 (17.4)
Prostate cancer	6 (13)
Renal cell carcinoma	4 (8.7)
Unknown primary	3 (6.5)
Multiple myeloma	2 (4.3)
Esophageal cancer	2 (4.3)
Cervical cancer	1 (2.2)
Colon cancer	1 (2.2)
Urothelial carcinoma	1 (2.2)
Melanoma	1 (2.2)
Thyroid cancer	1 (2.2)
Peripheral nerve sheath tumor	1 (2.2)
Gastric cancer	1 (2.2)
Pathologic fracture[a]	14 (30.4)
Femoral head/neck	11
Periacetabular	7
Location of metastatic lesions	
Femoral lesions	29
Periacetabular lesions	14
Femoral and periacetabular lesions	3
Chemotherapy	35 (76.1)
Perioperative radiation	20 (43.5)

IQR, interquartile range; BMI, body mass index; SD, standard deviation.
[a] Some patients had multiple pathologic fracture locations.

Statistical analysis

Continuous variables were described as medians with an interquartile range or means with standard deviation depending on normality, and compared using Mann-Whitney U test or student's t test as appropriate. Categorical variables were described as totals and frequencies and compared using the χ^2 test. Associations

Table 2
Operative characteristics.

Variable	N (%)
Operative duration, minutes, median (IQR)	127 (102-157)
Estimated blood loss, mL, median (IQR)	200 (150-400)
Femoral component	
Cemented	21 (45.7)
Uncemented	25 (54.3)
Primary femoral stem	40
Revision femoral stem	6
Acetabular component	
Porous titanium coating	25 (54.3)
Plasma spray	14 (30.4)
3-D printed porous titanium	5 (10.9)
Cage and cement	2 (4.3)
Intraoperative complication	2 (4.3)
Length of stay, days, median (IQR)	3 (2-7.50)
Discharge disposition	
Home	36 (78.3)
Acute rehab	4 (8.7)
Skilled nursing	6 (13)

SD, standard deviation; IQR, interquartile range; mL, milliliters; 3-D, 3 dimensional.

between perioperative radiotherapy, as well as other clinical factors, with OS and IS were analyzed with Kaplan-Meier curves and log-rank testing. Cox proportional hazards regression was used to determine prognostic factors in univariable and multivariable analyses, expressed as hazard ratios (HRs) and 95% confidence intervals (CIs). Factors that were statistically significant on univariable analysis were included in the multivariable model. All statistical analysis was performed using SPSS statistical software (version 26.0 IBM, Armonk, NY). Significance was determined a priori by an alpha level of 0.05.

Results

Overall demographics

Forty-six patients who underwent THA for MBD of the hip at 3 institutions were included in this study. Twenty patients (43.5%) received perioperative radiation to the operative hip. Two (4.3%) patients sustained intraoperative complications including femoral fracture and intraoperative fracture of the greater trochanter. Of the 46 THA, 21 (45.7%) used cemented femoral components, while 25 (54.3%) utilized uncemented femoral components. Regarding acetabular components, 25 (54.3%) received porous titanium-coated implants, 14 (30.4%) plasma spray-coated implants, 5 (10.9%) 3-D-printed porous titanium implants, and 2 (4%) cages and cement (Table 2). Six (13%) patients sustained postoperative complications. Complications included superficial wound infections (n = 1), dislocations (n = 2), pathologic fractures (n = 2), and aseptic acetabular shell loosening (n = 1). Five (10.9%) patients required reoperation.

Differences by radiotherapy status

Comparison of demographics and procedural characteristics between patients who received perioperative radiation to the operative hip is illustrated in Table 3. The mean Gy dose for patients that received radiation in this time frame was 30.67 Gy ± 6.8. There were no significant differences in age ($P = .633$), sex ($P = .369$), body mass index (BMI) ($P = .188$), smoking history ($P = .708$) or chronic steroid usage ($P = .184$) between both groups. There were significant differences in operative time ($P = .026$) between both groups. No significant difference was seen in postoperative complications ($P = .380$), reoperation after THA ($P = .178$), OS ($P = .921$), or IS ($P = .083$) between both groups (Table 4). Kaplan-Meier curves comparing OS and IS between both groups are illustrated in Figures 1 and 2, respectively.

Overall implant survival

Mean IS, excluding patients with GAP2 cages, was 44.32 months (95% CI 38.97-49.66). IS was 91.8% at 1 year and remained at 86.4% from 2 years to maximum follow-up. Acetabular component coating ($P = .448$) and femoral component cementation ($P = .296$) were not significantly associated with IS. When analyzing IS between femoral metastasis vs acetabular-based metastasis, we found no statistically significant differences ($P = .582$; HR 0.03; 95% CI 0.00-9330.13).

Overall survival

Mean survival was 24.75 months (95% CI 18.12-31.38). OS was 57% at 1 year, 48.2% at 2 years, 42.2% at 3 years, and 31.6% at 4 years

Table 3
Patient demographic and procedural characteristics based on radiotherapy status.

	P-value	Perioperative radiation	No radiation
Total patients		20	26
Primary tumor type	.105		
Prostate cancer		1 (5%)	5 (19.2%)
Breast cancer		3 (15%)	11 (42.3%)
Unknown		2 (10%)	1 (3.8%)
Cervical cancer		1 (5%)	0
Lung cancer		5 (25%)	3 (11.5%)
Renal cell carcinoma		3 (15%)	1 (3.8%)
Colon cancer		1 (5%)	0
Multiple myeloma		2 (10%)	0
Esophageal cancer		0	2 (7.7%)
Urothelial carcinoma		1 (5%)	0
Melanoma		0	1 (3.8%)
Thyroid cancer		1 (5%)	0
Gastric cancer		0	1
Peripheral nerve sheath tumor		0	1 (3.8%)
Chemotherapy	1.00	15 (75%)	20 (76.9%)
Pathologic fracture	.555	7 (35%)	7 (26.9%)
Operative time			
Minutes, median (IQR)	**.026**	135.5 (114.5-206)	119.5 (94.5-139.25)
EBL			
mL, median (IQR)	.060	300 (200-400)	200 (150-337.5)
Platelet count			
Thousand per µL, mean ± SD	.234	244.28 ± 102.62	278.73 ± 85.89
Neutrophil count			
Thousand per µL, mean ± SD	.893	5.89 ± 3.23	5.74 ± 3.53
Intraoperative complications	.667	1 (5%)	1 (3.8%)
Femoral component	.500	12 cemented (60%) 8 cementless (40%)	13 cemented (50%) 13 cementless (50%)
Acetabular component	.293	9 Porous titanium coat (45%) 6 Plasma spray (30%) 3 3-D printed porous titanium (15%) 2 cage and cement (10%)	16 Porous titanium coat (61.5%) 8 Plasma spray (30.8%) 2 3-D printed porous titanium (7.7%)

Statistically significant *P*-values are bolded.
SD, standard deviation; EBL, estimated blood loss; µL, microliter; mL, milliliters; 3D, 3 dimensional.

Table 4
Postoperative outcomes based on radiotherapy status.

	P-value	Perioperative radiation	No radiation
Total patients		20	26
Postoperative complications	.380	4 (20%)	2 (7.7%)
Superficial wound infection		0	1
Dislocation		2	0
Pathologic fracture		1	1
Aseptic acetabular component loosening		1	0
Reoperation after THA	.178	4 (20%)	1 (3.8%)
Overall survival, months			
Mean (95% CI)	.921	25.90 (15.49-36.32)	20.79 (14.39-27.20)
Implant survival, months[a]			
Mean (95% CI)	.083	39.13 (28.15-50.10)	35.91 (32.00-39.82)

THA, total hip arthroplasty; CI, confidence interval.
[a] Of 44 THA excluding GAP2 cages.

postoperatively. Perioperative radiation was an insignificant predictor of OS ($P = .921$). On univariate analysis, OS was significantly associated with preoperative neutrophil lymphocyte ratio ($P = .026$; HR 1.07 [95% CI 1.01-1.13]) and preoperative albumin ($P = .002$; HR 0.34 [95% CI 0.18-0.67]). On multivariate analysis, preoperative albumin remained predictive of improved OS ($P = .007$; HR 0.38 [95% CI 0.19-0.76]) (Table 5).

Discussion

Common locations of metastasis in the skeletal system include the proximal femur and acetabulum [1,2,4–7]. As the proximal femur and acetabulum constitute a significant weight-bearing joint, pain and pathologic fracture of the hip joint cause significant morbidity in this patient population [6,8]. In the event of severely compromised function or risk of pathologic fracture, surgical stabilization is often indicated. Investigations into surgical management of MBD to the hip have demonstrated THA to have lower implant failure rates and fewer complications compared to IMN and ORIF; however, THA in patients with a history of radiation has different risk factors to consider [8,10–15]. Radiation can compromise wound healing, bone health, and the implant's ability to integrate into the bone [17–20]. While few studies have investigated the IS of tantalum cups in patients with MBD, no study has compared postoperative outcomes or IS of modern implants in this cohort receiving perioperative radiation [29,30].

Patients with metastatic cancer have increased rates of postoperative complications, reoperations, and mortality following primary THA compared to patients without metastatic cancer [9,31]. In addition, patients with a history of pelvic radiation have increased rates of reoperation following THA [32]. In our cohort, 13% of patients experienced postoperative complications, which is comparable to the 8.9% rate reported by Schneiderbauer et al [33] in 306 hip arthroplasties for MBD and 10.4% rate reported by Sorenson et al [34] in 105 hip arthroplasties for MBD. One patient experienced a superficial surgical site infection near the incision site. Another patient experienced aseptic acetabular component loosening. This patient received radiation 1 month after surgery. Novikov et al [32] reported 10% aseptic acetabular component loosening in patients after THA with a history of pelvic radiation, which is consistent with our cohort. Furthermore, 2 patients (4.3%) in our cohort experienced dislocations. One patient received radiation 1 month prior to their THA and the other patient received radiation 2 months prior. Houdek et al [29] and Lavignac et al [35] reported a 3% dislocation rate after THA for patients with metastatic disease; however, in patients with a history of pelvic radiation, there have been various rates of dislocation ranging from zero percent to 16% dependent on the acetabular component utilized (23-27). The final 2 complications in our cohort were 2 pathologic

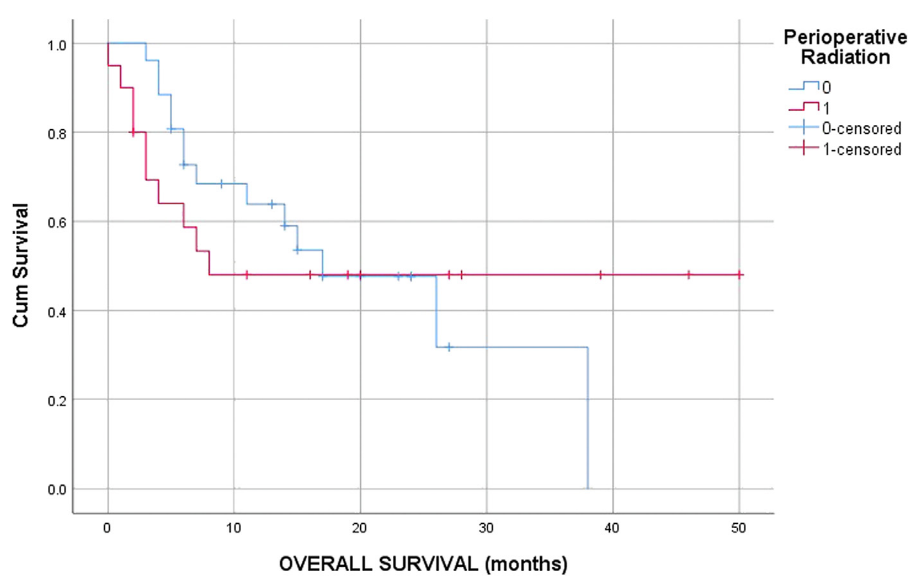

Figure 1. Kaplan-Meier curve comparing overall survival between both groups.

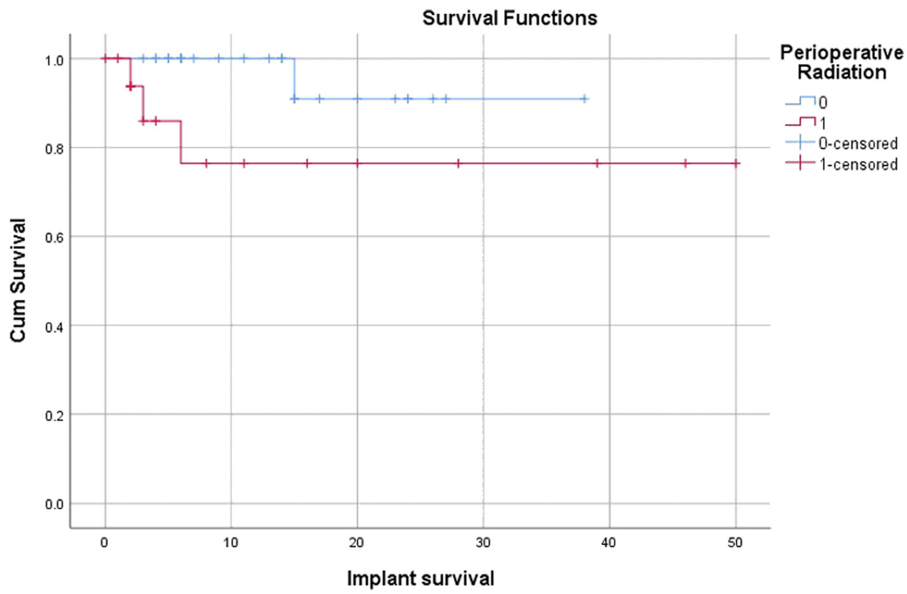

Figure 2. Kaplan-Meier curve comparing implant survival between both groups (excluding GAP2 cages).

femoral fractures occurring 6 months after THA in a patient with perioperative radiation and 15 months after THA in a patient with no perioperative radiation. Of these 6 complications, 5 led to reoperation in our cohort with 4 (20%) patients in the perioperative radiation cohort and one patient (3.8%) who did not receive perioperative radiation. Novikov et al [32] reported a 12% revision rate following THA for MBD in patients with pelvic radiation, while Sorenson et al [34] reported a 3.8% revision rate following THA for MBD. Although we found no significant difference comparing reoperation in both groups, this may be a result of the small number of reoperations.

Overall IS of titanium acetabular components in our cohort, excluding GAP2 cages, had a mean of 44.32 months with 86.4% overall IS at maximum follow-up. Our implant survivorship was comparable to previous studies reporting on tantalum survivorship following THA for metastatic disease [29]. Houdek et al [29] reported 92% IS of tantalum components at 4 years of follow-up and Thein et al [36] reported 100% IS of porous titanium components at a mean of 18.6 months after THA in patients with MBD to the hip. Comparison of IS times, excluding GAP2 cages, between patients that had received perioperative radiation and those that did not yielded no significant differences ($P = .083$). Radiation has dose-dependent effects on bone, and previous studies have demonstrated significant alterations to the bone structure starting after 3000-4000 cGy [17,18]. In our cohort of 18 patients who received perioperative radiation, excluding patients who received GAP2 cages, the mean Gy was 30.67 Gy. Similar IS findings were reported by Rose et al [23] and Wellings et al [27] in patients with a mean of 58-63 Gy.

Prior studies have reported tantalum acetabular components to be superior to nontantalum acetabular components in patients after THA with a history of non-MBD pelvic radiation [20,23–26,28]. Rose et al [23] reported a 100% implant survivorship rate at a mean of 31 months follow-up after THA with tantalum acetabular components in patients with a history of pelvic radiation for prostate, gynecologic, and colorectal cancer. Similar IS of tantalum components has been reported by Joglekar et al [26] and De Paolis et al [24] in patients who received non-MBD pelvic radiation. However, 2 studies have demonstrated comparable IS rates of porous titanium implants [27,28]. Wellings et al [27] reported 89% IS of porous titanium implants at 10-year follow-up after 38 THA in patients with a history of pelvic radiation for majority of primary tumors including prostate, gynecologic, and colorectal cancer. Kim et al [28] reported a 95% IS of porous titanium at 2-year follow-up after 58 THA in patients with pelvic radiation for prostate cancer. These new titanium components are manufactured in several methods

Table 5
Overall survival and implant survival.

	Univariate analysis	Multivariate analysis
Overall survival		
Mean, months (95% CI)	24.75 (18.12-31.38)	
Chemotherapy	$P = .428$; HR 1.48 (95% CI 0.55-3.99)	
Perioperative radiation	$P = .921$; HR 1.04 (95% CI 0.46-2.38)	
NLR	$\boldsymbol{P} = \mathbf{.026}$; HR 1.07 (95% CI 1.01-1.13)	$P = .250$; HR 1.04 (95% CI 0.98-1.10)
Albumin	$\boldsymbol{P} = \mathbf{.002}$; HR 0.34 (95% CI 0.18-0.67)	$\boldsymbol{P} = \mathbf{.007}$; HR 0.38 (95% CI 0.19-0.76)
Implant survival[a]		
Mean, months (95% CI)	44.32 (38.97-49.66)	
Chronic steroids	$P = .843$; HR 1.53 (95% CI 0.02-98.54)	
Perioperative radiation	$P = .210$; HR 10.45 (95% CI 0.27-409.42)	
Acetabular component (porous titanium vs plasma spray)	$P = .448$; HR 0.22 (95% CI 0.01-11.10)	
Femoral component (cemented vs cementless)	$P = .296$; HR 7.66 (95% CI 0.17-348.08)	

Statistically significant P-values are bolded.
CI, confidence interval; NLR, neutrophil lymphocyte ratio.
[a] Of 44 THA excluding GAP2 cages.

including porous titanium coating, 3-D printed porous titanium, and plasma sprayed. On univariate analysis, we found no significant difference in IS of these various designs ($P = .448$) consistent with Bondarenko et al's [37] biomechanical study demonstrating similar osseointegration among various titanium components.

Regarding cementation of the femoral component, studies have reported excellent implant survivorship of cemented and cementless femoral components in patients after THA for MBD [35,36,38]. Jacofsky et al [38] reported a 10% implant failure in 5 years in cemented THA and bipolar hemiarthroplasties. Thein et al [36] reported no implant failures at the last follow-up of 18.6 months in 60 uncemented THAs for MBD to the hip. In our study, we found a 10.9% overall implant failure rate with 4 failures in cemented THA and one implant failure in uncemented THA. There was no significant difference ($P = .296$) in IS of femoral components, excluding patients who received GAP2 cages, in patients with MBD after THA. Previous studies have demonstrated high failure rates of cemented and cementless components in patients with a history of pelvic radiation [19,20,25]. However, more recent studies with porous titanium and tantalum components have shown improved outcomes in both cemented and cementless THA following pelvic radiation [23,24,26–28]. In our study, we found no significant difference in IS following cemented or uncemented THA in patients based on radiotherapy status.

OS in patients who receive hip arthroplasty for metastatic disease is typically poor [30,33,34]. Sorenson et al [34] reported 39% survival after 1 year of joint arthroplasty in upper and lower extremity MBD, while Schneiderbauer et al [33] reported 41% survival after 1 year following THA and hemiarthroplasty for MBD. In our cohort, the mean survival was 24.75 months, and 57% of patients survived 1 year postoperatively. Although we reported a higher OS, this may be due to modern improvements in systemic and targeted treatments. On univariate and multivariate analyses, preoperative albumin was an independent predictor of improved OS. In patients undergoing THA, low preoperative albumin levels have been demonstrated to be a significant predictor of mortality, which is consistent with our findings [39]. Further studies into the prognostic abilities of preoperative albumin in patients undergoing THA for MBD need to be conducted to determine the significance of this finding.

Management of patients with MBD to the hip requires a multidisciplinary effort involving medical oncology, radiotherapy, as well as surgical management. For surgical management of MBD, orthopaedic oncologists must determine potential risks with surgery in patients with a history of pelvic radiation. Radiation has been shown to affect bone structure and its healing ability; however, new porous titanium implants and alternative primary-style implants have demonstrated excellent IS and low rates of reoperation in patients after THA in irradiated bone [27,28]. This is the first study comparing postoperative outcomes after primary THA in patients who received perioperative radiation to the hip for MBD compared to those who did not, and we found no significant differences. As surgical management is a crucial part of the treatment for alleviating pain and disability in patients with MBD, we continue to recommend THA for patients who received radiation at the operative site.

This study has several limitations. Although this study recruited patients from less than 10 surgeons at 3 institutions, the sample size and short follow-up may limit the external validity of our results. The short follow-up in our study as well as the loss of some patients in our cohort to follow-up may have underestimated the true implant failure rate. The heterogeneity of primary tumor types in patients with perioperative radiation compared to those without perioperative radiation is an additional limitation. Additionally, the numerous primary tumor types included in our study preclude any conclusions from being drawn for any of the tumor subtypes. Furthermore, this was a retrospective study and is subject to the biases inherent in retrospective analysis. Regarding radiotherapy treatments, 5 of the 20 subjects who received perioperative radiation had no documentation of the Gy units administered, biasing our mean Gy calculated for this cohort.

Conclusions

Although radiotherapy can compromise wound healing, bone health, as well as the implant's ability to incorporate into the bone, modern implants have demonstrated excellent survivorship in the setting of radiation. In patients with MBD of the hip requiring THA, we report no significant difference in outcomes in those treated with perioperative radiation compared to those who received no radiation.

Conflicts of interest

A. Blank is a paid consultant for Onkos Surgical; Bone Support—Cerament; receives stock options from Exparel/Pacira; receives research support from Swim Across America Cancer Research Grant; is an editorial board member of Rush Orthopedic Journal; Rare Tumors; formal reviewer for Arthroplasty Today; an ad hoc reviewer for CORR, JOP, JSO, and Lancet Oncology; and is a board/committee member of Musculoskeletal Tumor Society. R. Yoon is a speaker bureau of Horizon Therapeutics; is a paid consultant for Arthrex, Depuy, LifeNet Health, OrthoGrid, ORTHOXEL, SI-BONE, Stryker, Synthes, Use-Lab; is an unpaid consultant for BuiltLean; receives research support from Organogenesis, Center of Orthopaedic Trauma Advancement, OMeGA, NIH, Biocomposites, WrightTornier, Biomet, LifeNet Health, Synthes; receives royalties from Springer; is a board/committee member of American Association of Hip and Knee Surgeons, Foundation for Physician Advancement, Foundation of Orthopaedic Trauma, Orthopaedic Trauma Association. All other authors declare no potential conflicts of interest.

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Author contributions

Kyle Sweeney contributed to conceptualization, supervision, writing – review and editing. Alan T. Blank contributed to conceptualization, supervision, writing – review and editing. Dylan Vance contributed to data curation, investigation, writing – original draft, writing – review and editing. Richard S. Yoon contributed to conceptualization, supervision, writing – review and editing. Gayathri Vijayakumar contributed to data curation, formal analysis, investigation, writing – original draft, writing – review and editing. Alex Tang contributed to data curation, investigation, writing – review and editing.

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References

[1] Hernandez RK, Wade SW, Reich A, Pirolli M, Liede A, Lyman GH. Incidence of bone metastases in patients with solid tumors: analysis of oncology electronic medical records in the United States. BMC Cancer 2018;18:44.
[2] Tsukamoto S, Kido A, Tanaka Y, Facchini G, Peta G, Rossi G, et al. Current overview of treatment for metastatic bone disease. Curr Oncol 2021;28:3347–72.
[3] Coleman RE. Metastatic bone disease: clinical features, pathophysiology and treatment strategies. Cancer Treat Rev 2001;27:165–76.
[4] Toma CD, Dominkus M, Nedelcu T, Abdolvahab F, Assadian O, Krepler P, et al. Metastatic bone disease: a 36-year single centre trend-analysis of patients admitted to a tertiary orthopaedic surgical department. J Surg Oncol 2007;96:404–10.
[5] Coleman RE. Clinical features of metastatic bone disease and risk of skeletal morbidity. Clin Cancer Res 2006;12(20 Pt 2):6243s–9s.
[6] Hage WD, Aboulafia AJ, Aboulafia DM. Incidence, location, and diagnostic evaluation of metastatic bone disease. Orthop Clin North Am 2000;31:515–28.
[7] Picci P, Manfrini M, Fabbri N, Gambarotti M, Vanel D. Atlas of musculoskeletal tumors and tumorlike lesions: the Rizzoli case archive. Berlin, Germany: Springer Science & Business Media; 2014.
[8] Jacofsky DJ, Haidukewych GJ. Management of pathologic fractures of the proximal femur: state of the art. J Orthop Trauma 2004;18:459–69.
[9] Rhee C, Lethbridge L, Richardson G, Dunbar M. Risk factors for infection, revision, death, blood transfusion and longer hospital stay 3 months and 1 year after primary total hip or knee arthroplasty. Can J Surg J Can Chir 2018;61:165–76.
[10] Harrington KD. Orthopedic surgical management of skeletal complications of malignancy. Cancer 1997;80:1614–27.
[11] Issack PS, Barker J, Baker M, Kotwal SY, Lane JM. Surgical management of metastatic disease of the proximal part of the femur. J Bone Joint Surg Am 2014;96:2091–8.
[12] Issack PS, Kotwal SY, Lane JM. Management of metastatic bone disease of the acetabulum. J Am Acad Orthop Surg 2013;21:685–95.
[13] Steensma M, Boland PJ, Morris CD, Athanasian E, Healey JH. Endoprosthetic treatment is more durable for pathologic proximal femur fractures. Clin Orthop Relat Res 2012;470:920–6.
[14] Yazawa Y, Frassica FJ, Chao EY, Pritchard DJ, Sim FH, Shives TC. Metastatic bone disease. A study of the surgical treatment of 166 pathologic humeral and femoral fractures. Clin Orthop Relat Res 1990:213–9.
[15] Harvey N, Ahlmann ER, Allison DC, Wang L, Menendez LR. Endoprostheses last longer than intramedullary devices in proximal femur metastases. Clin Orthop Relat Res 2012;470:684–91.
[16] Baskar R, Lee KA, Yeo R, Yeoh KW. Cancer and radiation therapy: current advances and future directions. Int J Med Sci 2012;9:193–9.
[17] Bluemke DA, Fishman EK, Scott WW. Skeletal complications of radiation therapy. Radiographics 1994;14:111–21.
[18] Howland WJ, Loeffler RK, Starchman DE, Johnson RG. Postirradiation atrophic changes of bone and related complications. Radiology 1975;117(3 Pt 1):677–85.
[19] Massin P, Duparc J. Total hip replacement in irradiated hips. A retrospective study of 71 cases. J Bone Joint Surg Br 1995;77:847–52.
[20] Jacobs JJ, Kull LR, Frey GA, Gitelis S, Sheinkop MB, Kramer TS, et al. Early failure of acetabular components inserted without cement after previous pelvic irradiation. J Bone Joint Surg Am 1995;77:1829–35.
[21] Bobyn JD, Toh KK, Hacking SA, Tanzer M, Krygier JJ. Tissue response to porous tantalum acetabular cups: a canine model. J Arthroplasty 1999;14:347–54.
[22] Bandyopadhyay A, Mitra I, Shivaram A, Dasgupta N, Bose S. Direct comparison of additively manufactured porous titanium and tantalum implants towards in vivo osseointegration. Addit Manuf 2019;28:259–66.
[23] Rose PS, Halasy M, Trousdale RT, Hanssen AD, Sim FH, Berry DJ, et al. Preliminary results of tantalum acetabular components for THA after pelvic radiation. Clin Orthop Relat Res 2006;453:195–8.
[24] De Paolis M, Zucchini R, Romagnoli C, Romantini M, Mariotti F, Donati DM. Middle term results of tantalum acetabular cups in total hip arthroplasty following pelvic irradiation. Acta Orthop Traumatol Turc 2019;53:165–9.
[25] Cho MR, Kwun KW, Lee DH, Kim SY, Kim JD. Latent period best predicts acetabular cup failure after total hip arthroplasties in radiated hips. Clin Orthop Relat Res 2005;438:165–70.
[26] Joglekar SB, Rose PS, Lewallen DG, Sim FH. Tantalum acetabular cups provide secure fixation in THA after pelvic irradiation at minimum 5-year followup. Clin Orthop Relat Res 2012;470:3041–7.
[27] Wellings EP, Couch CG, Taunton MJ, Pagnano MW, Berry DJ, Abdel MP. Contemporary porous titanium acetabular components for total hip arthroplasty after pelvic radiation. J Arthroplasty 2021;36:1714–8.
[28] Kim KI, Klein GR, Sleeper J, Dicker AP, Rothman RH, Parvizi J. Uncemented total hip arthroplasty in patients with a history of pelvic irradiation for prostate cancer. J Bone Joint Surg Am 2007;89:798–805.
[29] Houdek MT, Ferguson PC, Abdel MP, Griffin AM, Hevesi M, Perry KI, et al. Comparison of porous tantalum acetabular implants and Harrington reconstruction for metastatic disease of the acetabulum. J Bone Joint Surg Am 2020;102:1239–47.
[30] Houdek MT, Abdel MP, Perry KI, Salduz A, Rose PS, Sim FH, et al. Outcome of patients treated with porous tantalum acetabular implants for neoplastic periacetabular lesions. J Am Acad Orthop Surg 2020;28:256–62.
[31] Sloan M, Lee GC. Mortality and complications in patients with metastatic disease after primary total hip and total knee arthroplasty. J Arthroplasty 2020;35:3512–6.
[32] Novikov D, Cohen D, Swanson D, Vojdani S, Khan F. A meta-analysis of outcomes in total hip arthroplasty recipients following pelvic irradiation. J Arthroplasty 2019;34:1546–52.
[33] Schneiderbauer MM, von Knoch M, Schleck CD, Harmsen WS, Sim FH, Scully SP. Patient survival after hip arthroplasty for metastatic disease of the hip. J Bone Joint Surg Am 2004;86:1684–9.
[34] Sørensen MS, Gregersen KG, Grum-Schwensen T, Hovgaard D, Petersen MM. Patient and implant survival following joint replacement because of metastatic bone disease. Acta Orthop 2013;84:301–6.
[35] Lavignac P, Prieur J, Fabre T, Descamps J, Niglis L, Carlier C, et al. Surgical treatment of peri-acetabular metastatic disease: retrospective, multicentre study of 91 THA cases. Orthop Traumatol Surg Res OTSR 2020;106:1025–32.
[36] Thein R, Herman A, Chechik A, Liberman B. Uncemented arthroplasty for metastatic disease of the hip: preliminary clinical experience. J Arthroplasty 2012;27:1658–62.
[37] Bondarenko S, Dedukh N, Filipenko V, Akonjom M, Badnaoui AA, Schwarzkopf R. Comparative analysis of osseointegration in various types of acetabular implant materials. Hip Int 2018;28:622–8.
[38] Jacofsky DJ, Haidukewych GJ, Zhang H, Sim FH. Complications and results of arthroplasty for salvage of failed treatment of malignant pathologic fractures of the hip. Clin Orthop Relat Res 2004:52–6.
[39] Walls JD, Abraham D, Nelson CL, Kamath AF, Elkassabany NM, Liu J. Hypoalbuminemia more than morbid Obesity is an independent predictor of complications after total hip arthroplasty. J Arthroplasty 2015;30:2290–5.