



Research Paper

Extra-articular resection of the hip joint for pelvic sarcomas: Are there any oncological and functional risks compared with intra-articular resection?



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ABSTRACT

Background: While extra-articular resection (EAR) of the knee and shoulder joint is associated with poorer clinical outcomes, the oncological and functional risks of EAR of the hip joint are unknown. We aimed to compare these risks between EAR of the hip joint and intra-articular resection (IAR).

Methods: We conducted a comparative study of 75 patients who underwent *en-bloc* tumour resection and limb-salvage reconstruction for bone sarcomas of the *peri*-acetabulum between 1996 and 2016. We divided patients into two groups for analyses; EAR (n = 21) and IAR (n = 54).

Results: There was no statistical difference in oncological outcomes; the 5-year cumulative incidence of disease-specific death was 34% and 35% in the EAR and IAR groups, respectively ($p = 0.943$), and the 5-year cumulative incidence of LR was 26% and 34%, respectively ($p = 0.482$). The most common complications were dislocation (28%) and deep infection (28%); there was equally no difference between the groups. The mean Musculoskeletal Tumour Society score was 66% and 65% in the EAR and IAR groups, respectively ($p = 0.795$), and were significantly lower in patients with deep infection (52% vs. 69%; $p = 0.013$). In a sub-analysis on the outcomes in patients who underwent PI-uninvolved PII-resection for chondrosarcoma, no major differences in oncological and functional outcomes were confirmed.

Conclusion: Patients undergoing EAR and limb-salvage reconstructions of the hip joint have undistinguishable oncological, clinical and functional outcomes compared to those undergoing IAR and reconstructions. If preoperative imaging suggests articular tumour involvement, there appears to be no detrimental effect of undertaking EAR to optimise local control.

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1. Introduction

Although most tumours around the hip joint can be treated by intra-articular resection (IAR), extra-articular resection (EAR) is required in rare occasions where bone tumours infiltrate into the joint. In such cases, *en-bloc* resection without opening the joint capsule is indicated. Obtaining an adequate margin and optimising function following resection of pelvic tumours are amongst the biggest orthopaedic oncology challenges, and the EAR may pose an additional risk for worse outcomes, as reported in the knee joint [1,2]. The literature regarding EAR of the hip has been limited to the several case series [3–6]. The largest series to date was a retrospective study of seven patients with pelvic bone tumour with no

control group [6]. There remains a paucity of data on comparisons of the outcomes of EAR and IAR for primary bone tumours of the pelvis.

This study aimed to compare the oncological, clinical, and functional outcomes between EAR of *peri*-acetabular tumours and limb-salvage reconstructions of the hip joint, and those of IAR and reconstructions.

2. Patients and Methods

We conducted a retrospective study of patients who underwent resection for bone sarcomas involving the acetabulum between 1996 and 2016. EAR was considered for patients with clinical signs and obvious tumour involvement within the joint on the immediate preoperative magnetic resonance (MR) images or patients whose hip joint was contaminated by a pathological fracture, inappropriate biopsy or other procedures. We included only patients

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who had limb-salvage reconstruction and, thus, we excluded those who were treated by primary hindquarter amputation or without structural reconstructions (i.e. hip transposition procedure or simple excision). We excluded surviving patients who were lost to follow-up after less than two years.

For a better evaluation of the oncologic and functional outcomes, we divided patients into two groups; the EAR group and IAR group. We classified pelvic resections according to the classification system of Enneking and Dunham [7,8]; iliac (PI), acetabular (PII), pubis or ischium (PIII), and sacral (PIV). Surgically resected specimens were examined for involvement of the margins based on the Enneking system [9]. The resection margins were considered clear when no tumour cells were observed microscopically at the resection margins, and intralesional when tumour cells were observed at the resection margins. Clear margins were further classified as marginal margins (dissection through the pseudocapsule or reactive zone) or wide margins (dissection entirely through the surrounding normal tissue). To minimise bias, we excluded patients who were treated with the re-implantation of the extracorporeally irradiated autografts from the analysis, as none underwent EAR in this group. We assessed function at the final follow-up using the Musculoskeletal Tumour Society (MSTS) evaluation system [10]. Complications were classified according to Henderson *et al.*; type 1, soft-tissue failure; type 2, aseptic loosening; type 3, structural failure; type 4, infection; and type 5, tumour progression. The institutional review board approved this study, and all data was collected from the clinical records and imaging systems as part of routine patient follow-up.

All patients were positioned in the lateral position on the operating table. The surgical approach varied depending on the anatomical location of the tumour and included an extended ilioinguinal or iliofemoral approach, an extended Ollier approach [11,12] with a trochanteric osteotomy, or an anterior ilioinguinal incision combined with a Kocher-Langenbeck approach [13]. After dissection of the sartorius, rectus femoris and iliopsoas muscle, the anterior and medial aspect of the joint capsule was exposed. The posterior and lateral aspect was then exposed after dissection of gluteus minimus, piriformis, and short rotators, depending on the tumour extent. Pelvic osteotomy was performed depending on the extent and location of the tumour. The osteotomy of the femur was performed at the intertrochanteric line to avoid capsular breach or distally depending on the extent and location of the tumour.

After *en-bloc* resection of the tumour, pelvic reconstruction was performed using custom-made endoprostheses (Stanmore Implants Worldwide Ltd, Ellstree, UK), ice-cream cone prostheses (Coned Hemi-Pelvis; Stanmore Implants Worldwide Ltd, Ellstree, UK; an example in Fig. 1), or the other procedures; cemented THR or trabecular metal acetabular cup (Trabecular Metal Acetabular Augment and Restrictor; Zimmer, Indiana, USA), according to the procedures we previously reported [11,13–15]. The pelvic reconstruction type depended on the extent of the resection [16]. Initial reconstructions all involved custom-made prostheses. This procedure was deemed appropriate if sufficient ilium remained to support the prosthesis tumour resection [11,14,16]. In 2003, in an attempt to decrease the high infection rates seen in early series of prosthetic reconstruction, the ice-cream cone prosthesis was developed and introduced in our unit [13,17]. In cases in which insufficient ilium would remain after the resection, the option of extracorporeal irradiation and re-implantation was considered [18]. Limb-salvage surgery without skeletal reconstruction was performed to minimise postoperative complications in patients undergoing pre- or postoperative radiotherapy [19]. In the present study, we excluded patients who underwent reconstruction using an irradiated autograft and no skeletal reconstruction from the analysis because most of these patients underwent reconstruction

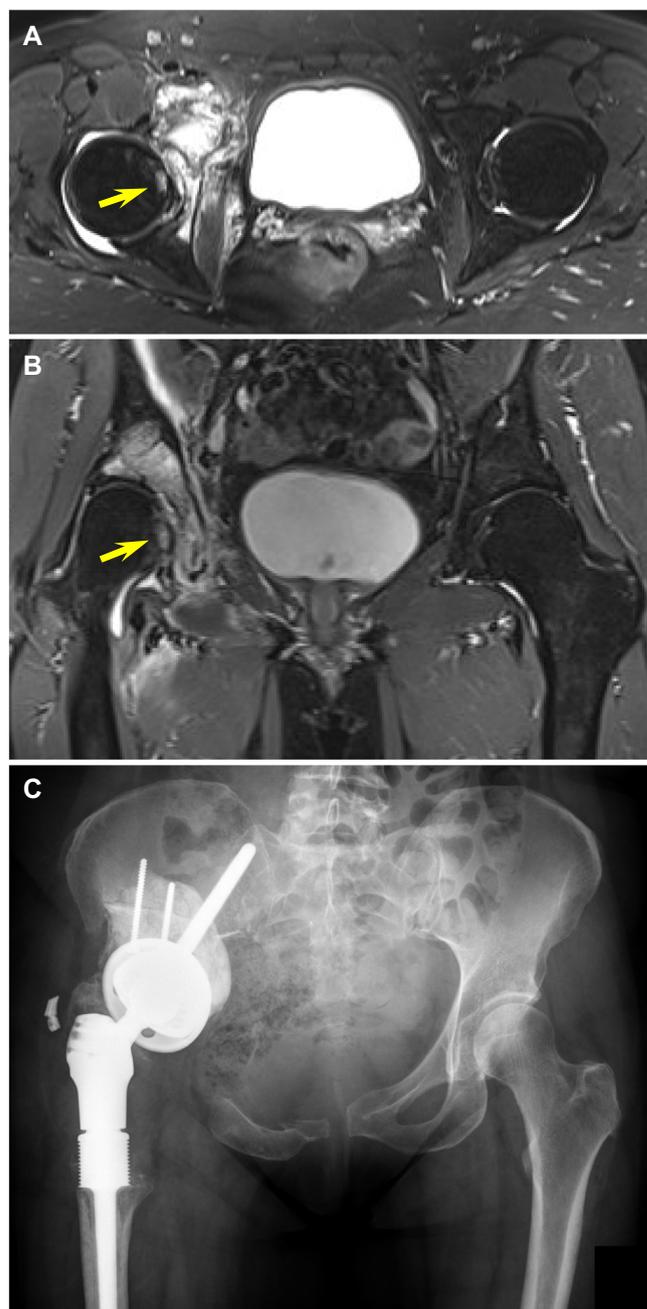


Fig. 1. A 57-year-old female with grade 2 chondrosarcoma. The axial (A) and coronal (B) images of T2-weighted magnetic resonance (MR) imaging. Tumour invasion into hip joint was suspected (yellow arrows). (C) Plain radiograph after extra-articular resection and reconstruction with an ice-cream cone prosthesis and proximal femoral replacement.

following IAR. For proximal femur reconstruction, a modular proximal femoral endoprosthesis or conventional stem prosthesis was implanted.

All statistical analyses were performed using the SPSS software (version 23; IBM, Armonk, New York, USA) or R 3.5.3 (R Foundation for Statistical Computing, Vienna, Austria). The variables of each group were compared using the chi-square test, the Fisher exact test or Mann Whitney *U* test. Analyses for disease-specific death, LR and implant failure were completed with a competing risks framework, and the differences were calculated by Gary's test [20–22]. Variables on the risks of these events were also evaluated using Fine and Gary's method [23]. We classified cause of death as

either sarcoma or another cause. In the analysis of disease-specific mortality, deaths from other causes were considered as a competing risk. The LR at a given time was defined as the cumulative incidence of LR, with death regarded as the competing event. The endpoint for implant failure was amputation or revision surgery for any cause, which was defined as removal or exchange of the prosthetic implant for any cause. Revision surgery did not include routine maintenance surgery, such as femoral head resurfacing or acetabular rebushing. Deaths from any causes were considered a competing risk in the analysis of the cumulative incidence of implant failure. Differences were considered to be statistically significant at a *p* value < 0.05.

3. Results

Seventy-five patients were included in this study. The details of patients and treatments are summarised in Table 1. The mean age at diagnosis was 47 years (range, 10–82 years), and there were 46 males (61%) and 29 females (39%). The mean follow-up periods for all patients and surviving patients were 73 months (range, 6–256 months) and 103 months (range, 24–256 months), respectively. The most common histological diagnosis was chondrosarcoma in 58 patients (77%), followed by Ewing sarcoma in 8 (11%), osteosarcoma in 5 (7%), undifferentiated high-grade pleomorphic sarcoma in 2 (3%), epithelioid haemangioendothelioma in 1 (1%), and malignant peripheral nerve sheath tumour of bone in 1 (1%). The mean tumour size was 9.4 cm (range, 4–24 cm). Eighteen (28%) and 8 (11%) patients received chemotherapy and

radiotherapy as part of the treatment regime, respectively. The resected acetabular lesions according to the classification system of Enneking and Dunham [7,8] were PII in 14 patients (19%), PII–III in 38 (51%), PI–II in 10 (13%), PI–II–III in 12 (16%), and PI–II–IV in 1 (1%). Acetabular reconstruction was performed using custom-made prosthesis in 43 (57%), ice-cream cone prosthesis in 25 (33%), and other procedures such as cemented THR in 7 (9%). Femoral reconstruction involved a proximal femoral endoprosthesis in 5 (7%), and conventional hip stem in 70 (93%). EAR and IAR were performed in 21 (28%) and 54 (72%) patients, respectively. There was no statistical difference in these variables between two groups, except in the type of femoral reconstruction (Table 1).

The cumulative incidence of disease-specific death for all patients was 38% at 5 years and 47% at 10 years; 34% and 35% at 5 years in the EAR and IAR groups, respectively (*p* = 0.943; Fig. 2A). The surgical margins achieved in the EAR group were wide in seven patients (33%), marginal in 11 (52%) and intralesional in three (14%; bone, *n* = 2; soft-tissue, *n* = 1), while those in the IAR group were wide in 21 patients (39%), marginal in 20 (37%) and intralesional in 13 (24%; bone, *n* = 7; soft-tissue, *n* = 3; unavailable, *n* = 3) (*p* = 0.435; Table 2); albeit with no statistically significant difference between the two groups. The surgical margin was significantly associated with the cumulative incidence of disease-specific death (intralesional margin: hazard ratio [HR], 3.28; 95% confidence interval [CI], 1.28–8.40; *p* = 0.036 vs. wide margin HR, 1). Among patients who underwent EAR, tumour infiltration into the joint capsule was microscopically confirmed in 15 patients

Table 1
Patient characteristics.

Variable	Total n	range, %	EAR n	range,%	IAR n	range,%	<i>p</i> value
No. of patients	75	–	21	28%	54	72%	–
Age at diagnosis (years)	47	10–82	50	15–82	46	10–81	0.409
Sex							0.197
Male	46	61%	15	71%	31	57%	
Female	29	39%	6	29%	23	43%	
Tumour size							0.568
< 80 mm	28	37%	8	38%	20	37%	
≥ 80 mm	47	63%	13	62%	34	63%	
Diagnosis							0.177
Chondrosarcoma	58	77%	18	85%	41	76%	
Ewing sarcoma	8	11%	0	0%	8	15%	
Osteosarcoma	5	7%	0	0%	4	7%	
Undifferentiated pleomorphic sarcoma	2	3%	1	5%	1	2%	
Epithelioid haemangioendothelioma	1	1%	1	5%	0	0%	
MPNST of bone	1	1%	1	5%	0	0%	
Chemotherapy							0.058
Yes	18	24%	2	10%	16	30%	
No	57	76%	19	90%	38	70%	
Radiotherapy							0.282
Yes	8	11%	1	5%	7	13%	
No	67	89%	20	95%	47	87%	
Resected area							0.205
PI involved	23	31%	7	33%	16	30%	
PI-II	10	13%	2	10%	8	15%	
PI-II-III	12	16%	4	19%	8	15%	
PI-II-IV	1	1%	1	5%	0	0%	
PI uninvolved	52	69%	14	67%	38	70%	
PII	14	19%	0	0%	14	26%	
PII-III	38	51%	14	67%	24	44%	
Acetabular reconstruction							0.240
Custom-made prosthesis	43	57%	9	43%	34	63%	
Ice-cream cone prosthesis	25	33%	10	48%	15	28%	
THR (cemented/uncemented)	7	9%	2	9%	5	9%	
Femoral reconstruction							0.001
Proximal endoprosthesis	5	7%	5	24%	0	0%	
Conventional stem	70	93%	16	76%	54	100%	
Follow-up period (mean, months)	73	6–256	52	6–233	79	6–256	0.070

Abbreviation: EAR, extra-articular resection; IAR, intra-articular resection; MPNST, malignant peripheral nerve sheath tumour

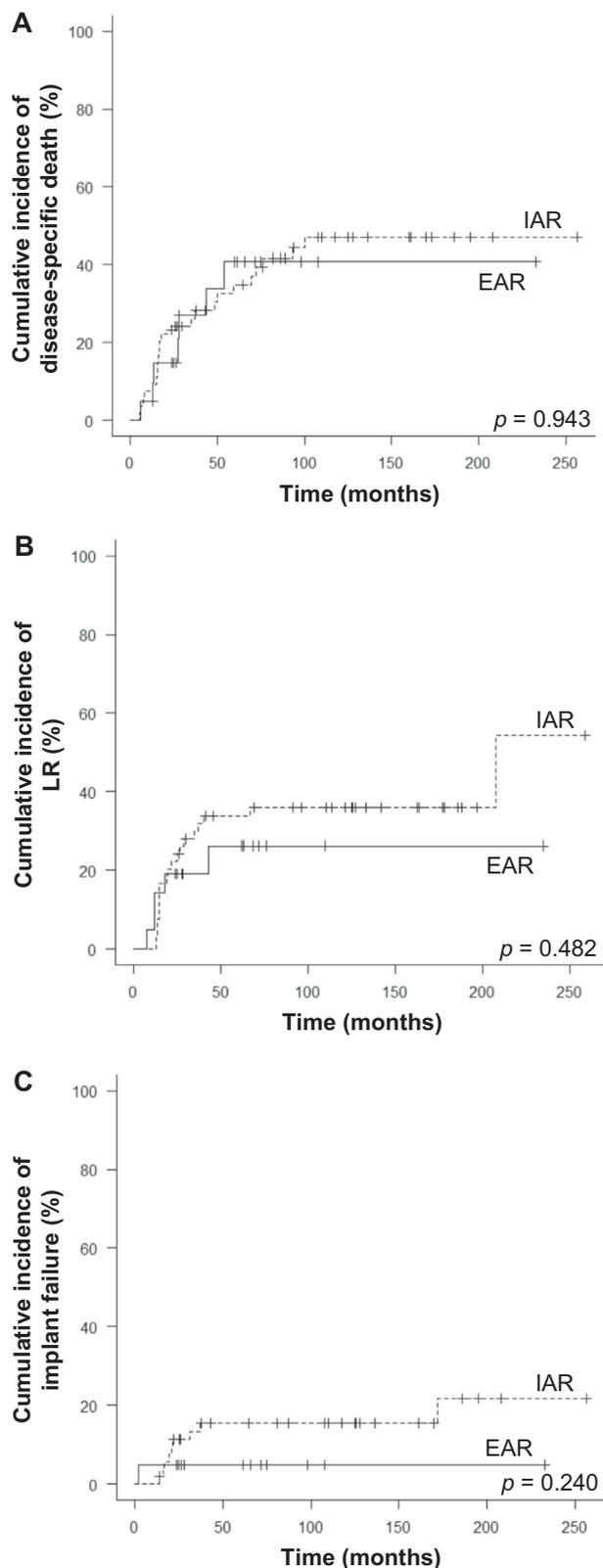


Fig. 2. Competing analysis showing the cumulative incidence of disease-specific death ($p = 0.943$; A), local recurrence ($p = 0.482$; B), and implant failure ($p = 0.240$; C). EAR, extra-articular resection; IAR, intra-articular resection.

(71%). There was one case of chondrosarcoma (grade 2) where the hip joint capsule was involved despite IAR; the tumour microscopically permeated through the acetabulum but the resection margin

was positive at the osteotomy site in the ilium. LR was seen at the ilium 35 months after the initial tumour resection but was not seen around the hip joint, which required re-excision. Twenty-six patients (35%) developed LR; the 5-year cumulative incidence of LR was 26% and 34% in the EAR and IAR groups, respectively ($p = 0.482$; Fig. 2B). Surgical margin was the only factor that was significantly associated with the incidence of LR (intralesional margin: hazard ratio [HR], 13.27; 95% confidence interval [CI], 2.94–59.91; $p < 0.001$ vs. wide margin HR, 1) among all the variables analysed. Overall, there was no major statistically significant difference in oncological outcomes between the groups.

Complications following surgery, classified according to Henderson *et al.* [24,25], was type 1 in 22 (29%), type 2 in 10 (13%), type 3 in 5 (7%), type 4 in 25 (33%), and type 5 in 26 (35%) (Table 3). The most common complications were dislocation (28%; 4 (19%) in the EAR group and 17 (31%) in the IAR group; $p = 0.217$) and deep infection (28%; 6 (29%) in the EAR group and 15 (28%) in the IAR group; $p = 0.579$). There was no significant difference in the rates of major complication between the two groups ($p = 0.077$), which required further surgical interventions. Implant failure secondary to deep *peri*-prosthetic infection was seen in one patient (5%) in the EAR group. Nine patients (17%) in the IAR group suffered implant failure, due to *peri*-prosthetic infection in 4 (7%), LR in 4 (7%) and persistent pain in 1 (2%). The 5-year cumulative incidence of implant failure was 13% for all patients; 5% in the EAR group and 16% in the IAR group, albeit without any statistically significant difference ($p = 0.240$; Fig. 2C).

The mean functional score according to the MSTS system [10] at the final follow-up with at least two year postoperative follow-up ($n = 50$) was 65% (range, 23–97%). The mean score was 66% (range, 30–93%) and 65% (range, 23–97%) in the EAR group and IAR group, respectively ($p = 0.795$). With regard to the use of walking aids, 29% walked without aids, 43% used a single stick or crutch, 21% needed 2 sticks or crutches, and 7% mobilized using a wheelchair in the EAR group. In the IAR group, 28% walked without aids, 25% walked with a single stick or crutch, 33% needed 2 sticks or crutches, 11% needed a walking frame, and 3% used a wheelchair. There was a trend towards worse function after including PI-involved (PI-II, PI-II-III, and PI-II-IV) resection (59%) compared to the PI-uninvolved (PII or PII-III) (68%) with respect to the resected areas, but without statistical significance ($p = 0.191$). In the present cohort, the presence of deep infection was a significant determinant of poor functional outcome (present, mean 52% vs. absent, mean 69%; $p = 0.013$), indicating that avoiding major complications is crucial regardless of whether or not EAR was performed.

Further analysis was performed in patients with chondrosarcoma, which was a major histological tumour type in the present study ($n = 58$; 77%). Among these, 62% ($n = 36$) underwent PI-uninvolved PII resections, most of which were PII-III resection ($n = 26$). Among patients who underwent PII-III resection, EAR and IAR were performed in 10 patients (38%) and 16 patients (62%), respectively. None of these patients received neoadjuvant or adjuvant chemotherapy, and there was no difference in tumour grade between the EAR and IAR groups; grade 1, 2, and 3 tumours were seen in 4 (25%), 7 (44%), and 5 (31%), respectively, in the IAR group, whereas grade 2 and 3 tumours were seen in 6 (60%) and 4 (40%), respectively, in the EAR group ($p = 0.228$).

There was no significant difference in survival outcome and local control between the two groups for patients who underwent PII-III resection for chondrosarcoma. The 5-year cumulative incidence of disease-specific survival for these patients was 36%; 33% in the EAR group and 37% in the IAR group ($p = 0.523$; Table 2). The 5-year cumulative incidence of LR was 43%; 32% in the EAR group and 50% in the IAR group ($p = 0.350$; Table 2). We identified no significant difference in the major complication rate; rates of major complication were 40% and 44% in the EAR and IAR groups,

Table 2
Surgical margin achieved and oncological outcomes.

Outcome	Total		EAR		IAR		p value
	n	%	n	%	n	%	
Surgical margin							
All patients (n = 75)							0.435
Wide	28	37%	7	33%	21	39%	
Marginal	31	41%	11	52%	20	37%	
Intralesional	16	21%	3	14%	13	24%	
Chondrosarcoma, PII-III resection (n = 26)							0.483
Wide	7	27%	4	40%	3	19%	
Marginal	12	46%	4	40%	8	50%	
Intralesional	7	27%	2	20%	5	31%	
Cumulative incidence of local recurrence (5-year)							
All patients (n = 75)	75	32%	21	26%	54	34%	0.482
Chondrosarcoma, PII-III resection (n = 26)	26	43%	10	32%	16	50%	0.350
Cumulative incidence of disease-specific death (5-year)							
All patients (n = 75)	75	38%	21	34%	54	35%	0.943
Chondrosarcoma, PII-III resection (n = 26)	26	36%	10	33%	16	37%	0.523

Abbreviation: EAR, extra-articular resection; IAR, intra-articular resection

Table 3
Complications and functional outcomes.

Complications/scores	Total		EAR		IAR		p value
	n, score	range, %	n, score	range, %	n, score	range, %	
Mechanical complication							
Soft-tissue complication (type 1)							
Dislocation	21	28%	4	19%	17	31%	0.217
Subluxation	1	1%	0	0%	1	2%	0.720
Aseptic loosening (type 2)	10	13%	2	10%	8	15%	0.427
Structural complication (type 3)	5	7%	1	5%	4	7%	0.568
Non-mechanical complication							
Infection (type 4)							
Deep infection	21	28%	6	29%	15	28%	0.579
Superficial infection	4	5%	1	5%	3	6%	0.689
Tumor progression (type 5)							
Local recurrence	26	35%	6	29%	20	37%	0.341
Other complications							
Limb-length discrepancy	7	9%	0	0%	7	13%	0.089
Nerve palsy	6	8%	1	5%	5	9%	0.458
Wound necrosis	5	7%	2	10%	3	6%	0.432
Deep-vein thrombosis	4	5%	2	10%	2	4%	0.311
Lymphoedema	3	4%	0	0%	3	6%	0.367
Visceral injury	1	1%	0	0%	1	2%	0.720
Urinary/sexual dysfunction	1	1%	0	0%	1	2%	0.720
Major complication							
All patients (n = 75)	33	44%	6	29%	27	50%	0.077
Chondrosarcoma, PII-III resection (n = 26)	11	42%	4	40%	7	44%	0.588
Implant failure							
All patients (n = 75)	10	13%	1	5%	9	17%	0.164
Chondrosarcoma, PII-III resection (n = 26)	1	4%	0	0%	1	6%	0.615
MSTS score							
All patients (n = 75)	65%	23–97	66%	30–93	65%	23–97	0.795
Chondrosarcoma, PII-III, custom-made prosthesis	66%	43–93	61%	47–77	69%	43–93	0.522
Chondrosarcoma, PII-III, ice-cream cone prosthesis	66%	30–97	67%	30–90	65%	47–97	0.919

Abbreviation: EAR, extra-articular resection; IAR, intra-articular resection; MSTs, Musculoskeletal Tumour Society

respectively ($p = 0.588$). One of 16 patients (6%) in the IAR group experienced implant failure whereas no failure was observed in the EAR group ($p = 0.615$). The mean MSTs score was 66% (range, 30–97%); 63% (range, 30–90%) in the EAR group and 68% (range, 43–97%) in the IAR group ($p = 0.707$). The mean scores in patients who underwent pelvic reconstruction using a custom-made prosthesis following PII-III resection for chondrosarcoma were 61% (range, 47–77%) and 69% (range, 43–93%) in the EAR and IAR groups, respectively ($p = 0.522$; Table 3). These scores in patients with pelvic reconstruction using an ice-cream cone prosthesis were 67% (range, 30–90%) and 65% (range, 47–97%) in the EAR and IAR groups, respectively ($p = 0.919$; Table 3). Collectively, after minimising the selection bias for comparison by focusing on a sin-

gle group of histological diagnosis, area of pelvic resection and type of reconstruction, there was no statistical difference in oncological, clinical, and functional outcomes.

4. Discussion

EARs of the knee and shoulder joint in patients with sarcomas are known to be associated with an increased risk of local failure, complications, and subsequent failure of limb-salvage [1,2,26–28]. However, little is known about the oncological and functional risk of EARs of the hip joint in patients with sarcomas. We first report the results of comparison of EAR vs. IAR of the hip joint in

patients with sarcomas who were treated in a single tertiary sarcoma centre where the treatment strategy was fairly consistent throughout the study period. Our results demonstrated that there is no increased oncological and functional risk in patients with primary bone sarcomas of the pelvis who underwent EARs of the hip joint compared with those who underwent IARs. This was confirmed in a comparison based on the same background of oncological-related and treatment-related factors, i.e., in patients with chondrosarcoma who underwent pelvic reconstruction using a custom-made prosthesis or an ice-cream cone prosthesis, respectively, following PII-III resection, a major resection type in the present study. These data are encouraging for surgeons and patients in the decision-making process of surgical treatment. Given that the primary goal of surgical treatment for sarcomas is complete excision with adequately wide margins, surgeons are expected to undertake EAR of the hip joint if preoperative imaging demonstrates or suggests articular tumour involvement without alarming increased risk of postoperative functions.

There was no statistically significant difference in functional outcomes between the EAR and IAR groups. A previous study of EAR of malignant primary bone tumours at the knee joint described worse functional outcomes compared with those of IAR primarily due to the compromised extensor mechanisms [29]. However, the following reports demonstrated comparable function between the EAR and IAR groups with preservation of the extensor mechanism [30,31]. In our recent study, we equally described similar results between the two groups [26]. Conversely, in comparison to IAR, EAR of the hip joint involves comparable muscle resection, which might explain the similar functional outcomes between the present two groups and why our functional outcomes were comparable to those in the previous literature [6]. Notably, deep *peri*-prosthetic infection led to significantly worse function leading us to conclude that avoidance of postoperative infection is crucial regardless of whether or not EAR was performed.

While surgical margin was an independent prognostic factor for disease-specific death and LR, type of resection (EAR or IAR) was not a prognostic factor. Indeed, there was no significant difference in surgical margin between the EAR and IAR groups, although it is presumed to be more difficult to achieve adequate margins in the former. Pathological reports showed contaminated margins in the pubic ramus ($n = 2$) and soft-tissue at the superficial, medial site ($n = 1$) in the EAR group, and in the pubic ramus ($n = 4$), ischium ($n = 2$), ilium ($n = 2$), soft-tissue at the proximal ($n = 1$) and posterior ($n = 1$) site in the IAR group (not recorded; $n = 3$). These sites are distant from the joint capsule of the hip, indicating that EAR does not pose a risk of contaminated margins or poor oncologic outcomes.

High complication rates have been reported in acetabular reconstructions [13,16,32–35]. Among various types of complications, deep infection and LR are the most serious and frequent and are common causes of implant failure [16,19,33,35–38]. Following limb-sparing surgery by skeletal reconstruction, deep infection and LR have been reported at rates ranging from 12% to 47% [39] and 12% to 44% [40], respectively. The rate of LR and deep infection in this study are comparable to those in the published literature [39,40]. These complications mostly occurred in the early series during the study period. After we introduced computer navigation in 2010, the rate of an intralesional margin decreased, consequently resulting in a reduced rate of LR [41]. Similarly, acetabular reconstruction was performed using a custom-made prosthesis in the early series. However, from 2004, we introduced reconstruction using an ice-cream cone prosthesis using antibiotic-laden cement for support, which decreased the rate of deep infection to 14% [37]. To reduce the risk of deep infection, non-skeletal reconstruction such as hip transposition would be an alternative procedure. Hip transposition, also termed resection arthroplasty,

is a reconstruction with no use of massive implants/graft, which minimised the rate of deep infection [19,40,42,43]. Although this procedure produces substantial leg-length discrepancy, there have been reports of relatively good functional outcomes using a shoe lift [19,33,42,43]. Thus, hip transposition arthroplasty would be a good alternative, especially for patients at a high risk of complication. In our institute, however, all cases with hip transposition arthroplasty were treated with IAR and, thus, the surgical characteristics of patients in the IAR and EAR groups would be unequal if we were to include these patients. We acknowledge that it is important to compare the outcomes in both groups eliminating possible selection bias to draw clinically relevant conclusions. We thus added sub-analyses on more focused series of patients in terms of diagnosis (chondrosarcoma) and resection type (PII-III resection) that were a major group in this study, which confirmed undistinguishable oncological, clinical and functional outcomes between the EAR and IAR groups.

We acknowledge several limitations to this study. First, this study was based on a retrospective design with a relatively limited sample size. However, our institution is a large specialist tertiary sarcoma centre with a prospectively maintained database enabling the accurate recording of all patient episodes. Second, this study covers a relatively long period with some alterations made to the indications for the type of reconstruction, surgical technique and adjuvant treatment. Third, functional outcome was evaluated by the MSTs system, which is evaluated subjectively. It was used because of its acceptance within the field of musculoskeletal oncology and because it was the only consistent outcome measure recorded throughout the study. More objective outcome measures or patient-reported outcome measures could provide more precise analyses. Despite these limitations, this study, for the first time reporting the surgical outcome in comparison of the EAR and IAR of the hip joint, provides useful guidance to surgeons when making decisions about surgical treatment of pelvic bone sarcomas.

In conclusion, EAR and limb-salvage reconstruction for bone sarcomas involving the acetabulum has no risk in terms of not only oncological but also functional outcome compared to IAR and reconstruction. If the tumour involvement is equivocal on the preoperative images, the risk should not be taken by compromising to IAR.

5. Code availability

Not applicable

6. Availability of data and material

Data available on request from the authors.

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Ethical approval and consent to participate

The study protocol was approved by the Institutional Review Board of the Royal Orthopaedic Hospital.

CRediT authorship contribution statement

Tomohiro Fujiwara: Conceptualization, Methodology, Investigation, Writing – original draft, Funding acquisition. **Yusuke Tsuda:** Investigation, Validation. **Jonathan Stevenson:** Writing –

review & editing. **Michael Parry:** Writing – review & editing. **Lee Jeys:** Resources, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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