Clinical outcomes after extra-articular resection of hip joint tumour using a custom-made osteotomy guide and 3D-printed endoprosthesis with posterior column preserved

From Second Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou City, China

Correspondence should be sent to Z. Ye yezhaoming@zju.edu.cn

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X. Yan,[1,2,3,4] K. Wang,[1,2,3,4] X. Huang,[1,2,3,4] N. Lin,[1,2,3,4] M. Liu,[1,2,3,4] Y. Ren,[1,5] Z. Ye[1,2,3,4]

[1]Department of Orthopedic Surgery, The Second Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou, China

[2]Orthopedics Research Institute of Zhejiang University, Hangzhou, China

[3]Key Laboratory of Motor System Disease Research and Precision Therapy of Zhejiang Province, Hangzhou, China

[4]Department of Orthopedics, Diagnosis and Treatment Center of Bone Metastasis, The Second Affiliated Hospital of Zhejiang University School of Medicine, Hangzhou, China

[5]State Key Laboratory of Transvascular Implantation Devices, Hangzhou, China

Aims
For rare cases when a tumour infiltrates into the hip joint, extra-articular resection is required to obtain a safe margin. Endoprosthetic reconstruction following tumour resection can effectively ensure local control and improve postoperative function. However, maximizing bone preservation without compromising surgical margin remains a challenge for surgeons due to the complexity of the procedure. The purpose of the current study was to report clinical outcomes of patients who underwent extra-articular resection of the hip joint using a custom-made osteotomy guide and 3D-printed endoprosthesis.

Methods
We reviewed 15 patients over a five-year period (January 2017 to December 2022) who had undergone extra-articular resection of the hip joint due to malignant tumour using a custom-made osteotomy guide and 3D-printed endoprosthesis. Each of the 15 patients had a single lesion, with six originating from the acetabulum side and nine from the proximal femur. All patients had their posterior column preserved according to the surgical plan.

Results
Postoperative pathological assessment revealed a negative surgical margin was achieved in all patients. At final follow-up, 13.3% (2/15) died and no recurrence occurred. The overall survival was 81.7% at five years. None of the patients showed any signs of aseptic loosening, and no wound healing issues were observed. In total, 20% (3/15) developed complications, with two cases of early hip dislocation and one case of deep infection. The cumulative incidence of mechanical and non-mechanical failure in this series was 13.7% and 9.3%, respectively, at five years. In this cohort, the mean time to full weightbearing was 5.89 (SD 0.92) weeks and the mean Musculoskeletal Tumor Society score was 24.1 (SD 4.4).

Conclusion
For patients with a hip joint tumour who met the inclusion criteria and were deemed suitable for posterior column preservation, a custom-made osteotomy guide combined with 3D-printed endoprosthesis is worth performing when treating patients who require extra-articular resection of the hip joint, as it can achieve adequate margin for local control, maximize bone preservation to maintain pelvic ring integrity, reduce the risk of complications by simplifying the surgical procedure, and allow for more precise reconstruction for better function.

Bone & Joint Open

Take home message

- Pelvic tumour resection surgery that preserves the posterior column helps to maintain pelvic ring integrity, which is crucial for improving prosthesis stability and longevity.
- Extra-articular resection is a reliable method for local tumour control in the case of tumour infiltrating the hip joint.
- Utilizing custom-made osteotomy guides and 3D-printed customized prostheses significantly enhances anatomical alignment of the hip joint and reduces complications like dislocation.

Introduction

For aggressive bone tumours, a safe resection margin helps to achieve a reduced local recurrence and improved overall survival.[1] Therefore, in rare cases where tumours infiltrate into the hip joint, extra-articular resection should be considered in the first instance. However, given the intricate nature of pelvic anatomy, surgeons face a challenge in achieving safe surgical margins while preserving as much bone volume for stable reconstruction during surgery, and prolonged prosthesis survival.

Freehand resection introduces uncertainty in balancing maximal bone preservation with a safe surgical margin, leading to conflicts with local recurrence and postoperative complication and function, particularly in patients requiring type II reconstruction. Enneking type-II resection achieves a safe surgical margin but disrupts pelvic continuity with acetabulum resection,[2] and thus increases the risk of postoperative complications such as mechanical loosening and dislocation.[3–5] Various reconstruction techniques, including allograft/allogenic reconstruction and 3D-printed customized endoprostheses, have been introduced and evolved over the years, yet ensuring accurate and stable implant placement and long-term implant survival remains a challenge for surgeons.

In an attempt to resolve these problems, we incorporated, for the first time, a custom-made osteotomy guide and 3D-printed endoprosthesis for hemipelvic reconstruction in patients with tumours originating from the proximal femur or acetabulum, necessitating extra-articular resection of the hip joint. We aimed to provide a comprehensive description of the surgical procedure and report postoperative oncological, complication-related, and functional outcomes.

Methods

Patients

This study was approved by the ethics committee of the Second Affiliated Hospital, Zhejiang University School of Medicine, and informed consent was obtained from all individual patients who were included in this study. We retrospectively review 20 patients between January 2017 and December 2022 at our institution who presented with a hip joint tumour and had undergone extra-articular resection. Five patients were excluded from this study due to tumour invasion into the ischial branches, which made it impossible to preserve the posterior column, and therefore conventional hemipelvic endoprostheses were implanted. The remaining 15 patients, who underwent tumour resection with posterior column preserved using a customized osteotomy guide and reconstruction using 3D-printed integrative endoprosthesis, were included in this study (Figure 1). Eligibility criteria for this surgical technique were a primary malignant, aggressive bone tumour, or solitary bone metastasis originating from either the proximal femur or pelvis with extension into the hip-joint cavity, or the hip joint was contaminated by sarcoma due to a pathological fracture or inappropriate biopsy; en bloc resection was suitable for oncological local control based on the consensus of three senior oncological orthopaedic surgeons (YZM, LN, YXB,HX). All patients were followed for a minimum of two years. Of these, there were six females (40%) and nine males (60%), with a mean age of 39 years (9 to 74) and a mean follow-up of 40.8 months (24 to 70). Six lesions were found originating from the acetabulum and nine from the proximal femur. Diagnoses included osteosarcoma, chondrosarcoma, type B lymphoblastoma, solitary bone metastasis, and malignant giant cell tumour. Two patients displayed pathological fracture at diagnosis. All patients except those with chondrosarcoma received neoadjuvant or adjuvant chemotherapy according to international guidelines.[6] Detailed patient characteristic information is shown in Table I.

Design of osteotomy guide and endoprothesis

The osteotomy guide, developed by our senior surgeons (YZM, LN, YXB, HX) and manufactured by Chunli (China), was based on 1 mm thin-slice CT scans and T1 fat-suppressed gadolinium contrast-enhanced 1.5 mm slice-thick transverse MRI preoperatively. Mimics v.20.0 software (Materialise, Belgium) was used to construct a CT/MRI fused 3D model of the pelvis and entire femur diaphysis. The resection area, identified via fused images from pre-chemotherapy Gd-enhanced MR-T1 sequences and CT scans, maintained a minimum 10 mm safe margin beyond the enhanced edge. The osteotomy guide was designed with three or four slots to perform with an oscillating saw. One or two slots were planted on the superior aspect of the acetabulum, one parallel to the posterior column of acetabulum, and the other to complete the periacetabular osteotomy. The guide slot for bone resection was 2.2 mm. The body of osteotomy guide, sterilized under high temperature and pressure, was manufactured using nylon material via 3D printing.

Careful evaluation of the position of the prothesis, number of screws, length, and trajectory were conducted jointly by surgeons (YZM, LN, YXB, HX) and engineers (Figure 2). The surface of the prosthesis was designed to match the geometry and contours of the osteotomy guide, ensuring a precise fit with the remaining host bone, and the acetabular centre of rotation was designed by mirroring the contralateral side of the acetabulum. A 2 mm thick 3D-printed interconnected trabecular layer with 500 to 700 nm porosity was designed for the contacting face of acetabular prothesis to provide better stability and bone ingrowth (Supplementary Figure a). An ultrahigh-molecular-weight polyethylene (UMWPH) liner (Johnson & Johnson, USA) was used in this series, with the acetabular component specifically designed to match the size of the liner for proper press-fit (Figure 3). The screw trajectory was designed for maximum number and length to obtain the best initial stability. Among these patients, the maximum length of implanted screws was 11 cm, with at least three screws passing through the ilium wing and two in the ischial ramus. Additionally, a customized femoral component was prepared to be cemented into the medullary cavity of the remaining femur. The scope and direction of the resection

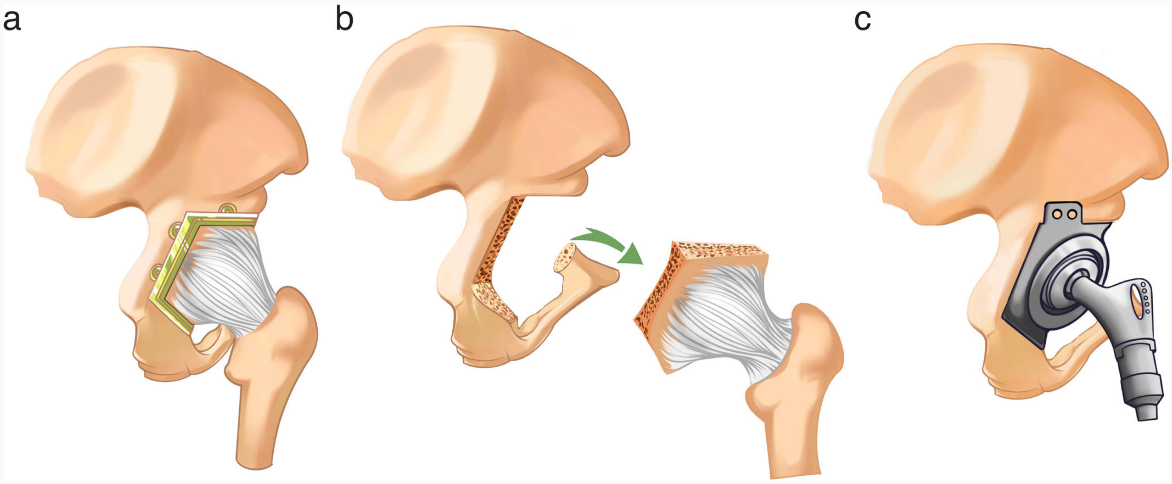

Fig. 1

a) A posterolateral incision was made to expose the posterior column of the acetabulum, ischial ramus, and acetabulum. An osteotomy guide plate was placed for excision. b) After osteotomy with an oscillating saw, the hip joint was removed together with the femoral segment and the acetabulum, but the continuity of the joint capsule was preserved. c) Customized acetabular component and modular femoral component were placed for reconstruction.

Table I. Demographic data of 15 patients treated with 3D-printed integrative endoprosthesis following extra-articular resection of the hip joint with posterior column preserved.

Patient	Age, yrs	Sex	Tumour location	Diagnosis	Neoadjuvant chemotherapy	Pathological fracture	Intraoperative time, hrs	Blood loss, ml	Follow-up, mths	MSTS	Oncological Status	Complications	Metastasis
1	25	M	Proximal femur	Osteosarcoma	Yes	No	4.08	1,000	54	27	AWD	Not observed	Lung metastasis
2	21	M	Proximal femur	Osteosarcoma	Yes	No	4.33	1,200	52	25	NED	Not observed	Lung metastasis
3	37	F	Proximal femur	Osteosarcoma	No	No	4.08	700	49	24	NED	Not observed	Not observed
4	54	M	Proximal femur	Osteosarcoma	Yes	Yes	3.67	600	48	26	NED	Not observed	Not observed
5	9	M	Proximal femur	Osteosarcoma	Yes	No	3.00	1,200	34	25	NED	Not observed	Not observed
6	45	M	Proximal femur	Chondrosarcoma	No	No	3.41	600	67	27	NED	Not observed	Not observed
7	16	M	Proximal femur	Osteosarcoma	Yes	No	3.08	1,000	41	26	DOD	Not observed	Lung metastasis
8	24	F	Proximal femur	Type B lymphoblastoma	Yes	Yes	3.58	600	13	NA	DOD	Not observed	Not observed
9	33	M	Proximal femur	Chondrosarcoma	No	No	5.50	2,000	28	24	NED	Not observed	Not observed
10	50	F	Acetabulum	Colon metastasis	Yes	No	4.00	500	26	27	NED	Not observed	Not observed
11	42	F	Acetabulum	Malignant giant cell tumour	No	No	4.25	1,200	29	28	NED	Not observed	Not observed
12	38	M	Acetabulum	Dedifferentiated chondrosarcoma	Yes	No	5.50	1,000	27	19	NED	Dislocation	Lung metastasis
13	53	F	Acetabulum	Chondrosarcoma	No	No	4.33	1,600	52	25	NED	Not observed	Not observed
14	65	M	Acetabulum	Chondrosarcoma	No	No	6.42	2,000	70	26	NED	Not observed	Not observed
15	74	F	Acetabulum	Chondrosarcoma	No	No	3.67	800	26	11	NED	Dislocation, deep infection	Not observed

AWD, alive with disease; DOD, died of disease; MSTS, Musculoskeletal Tumor Society score; N/A, not available; NED, no evidence of disease.

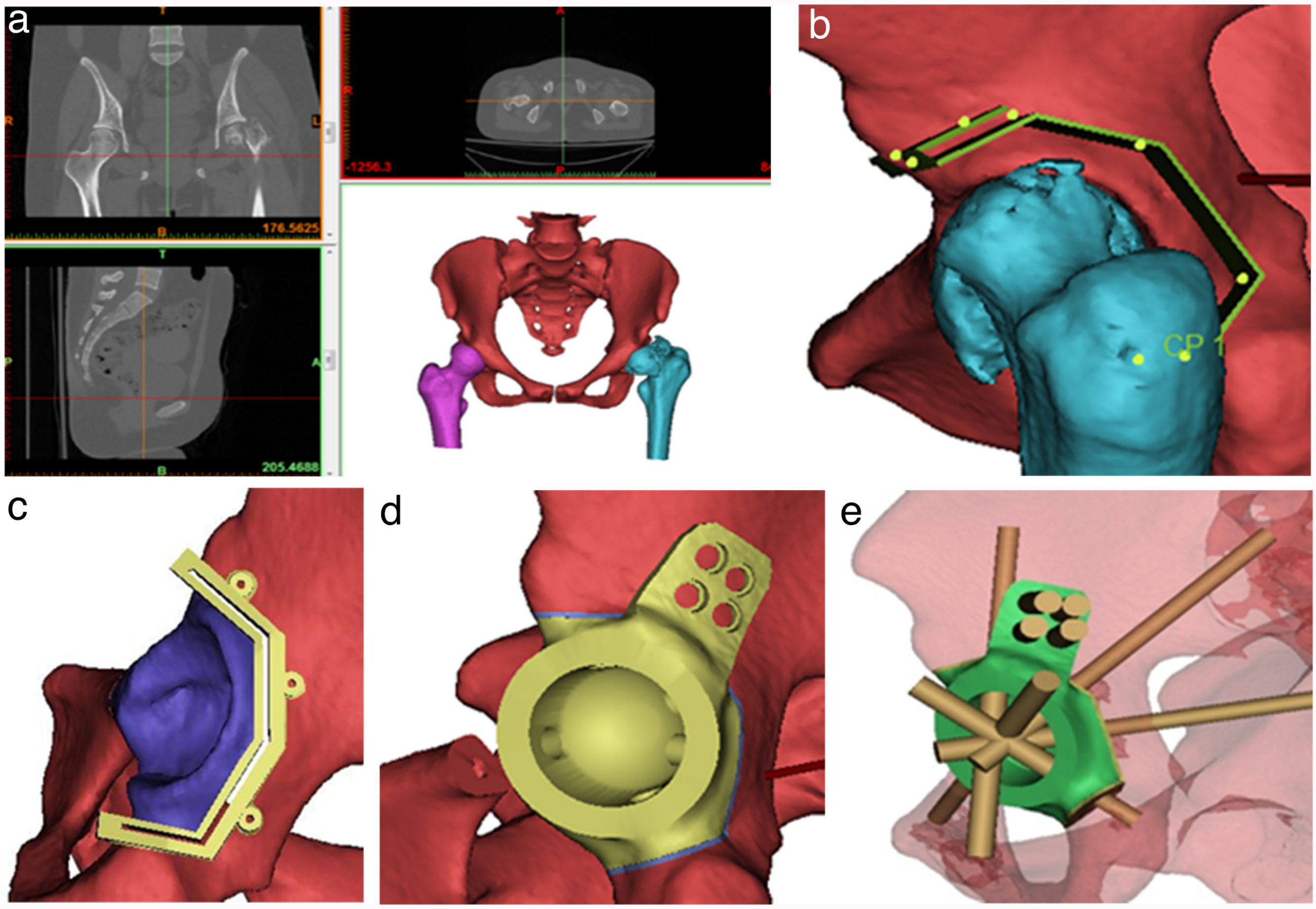

Fig. 2
Preoperative design process for osteotomy guide and prosthetic component for bony fixation. a) Model reconstruction is based on thin-sliced CT. b) Surgical resection range is constructed on 3D digital software after communication and consensus between the surgeons and engineers. c) Guide plate design is completed. d) Prosthetic component design for bony fixation is based on the resection planes. e) The number, length, and trajectory of the screws are determined.

plane, 3D-printed prothesis, screw trajectory, the amount of bone tissue loss due to pendulum sawing osteotomy, and whether the osteotomy interface is easy to prepare should all be meticulously considered during the prothesis design stage. The whole preparation period lasts six to eight days, depending on the patient's specific situation, with two to three days for model design and confirmation, two to three days for manufacturing, and one to two days for implant delivery.

Surgical procedure and postoperative care

The method for pelvic tumour resection was the same as in a previous report.[7] All patients were placed in a lateral position on the contralateral side. For patients with proximal femoral tumours, a single Kocher-Langenbeck (K-L) approach was conducted, and for patients with acetabular tumours, an ilioinguinal incision combined with the K-L approach was used (Figure 2). For proximal femoral cases, the gluteus maximus and medius were detached at the insertion, and the gluteus minimus at the origin. The external surface of the ilium was exposed from the ilium crest to the anterior-inferior iliac spine. For acetabular cases, the gluteus maximus and medius remained attached at the insertions to the femur, and a submuscular 'tunnel' was created between the external iliac plate and the muscle group that attached to it for guide placement. Integrity of the joint capsule was maintained at the femoral side resection. Resection was performed using an oscillating saw at the greater trochanter and the femoral neck base, followed by a thorough examination to ensure complete femoral head detachment. Adequate soft-tissue ablation of the ischial ramus allowed for guide displacement (Figure 4).

Since the prosthetic surface is consistent with that of the osteotomy guide, precise ilium prosthetic fitting can be achieved with minimal errors. Pre-designed screws were inserted into the iliac crest and sciatic branch through the preset screw hole, leveraging their length for strength (Figure 3). A standard hip polyethylene cup (Johnson & Johnson) with a 36 mm head was employed in all cases. Depending on the tumour location, patients received either a Corail or Tri-Lock stem for the acetabulum cases, or a cemented stem for the proximal femoral cases.

Post-surgery, two drainage tubes were routinely placed until daily drainage fell below 50ml, followed by antibiotics and a seven-day course of low-molecular-weight heparin, then 28 days of oral rivaroxaban. Rehabilitation including early muscle static training began after drainage tube removal. Non-weightbearing limb activity began two weeks for acetabular cases and four weeks for femoral cases, then followed by partial weightbearing training at four and six weeks, respectively. This progressed to full weightbearing, tailored to each patient's healing progress.

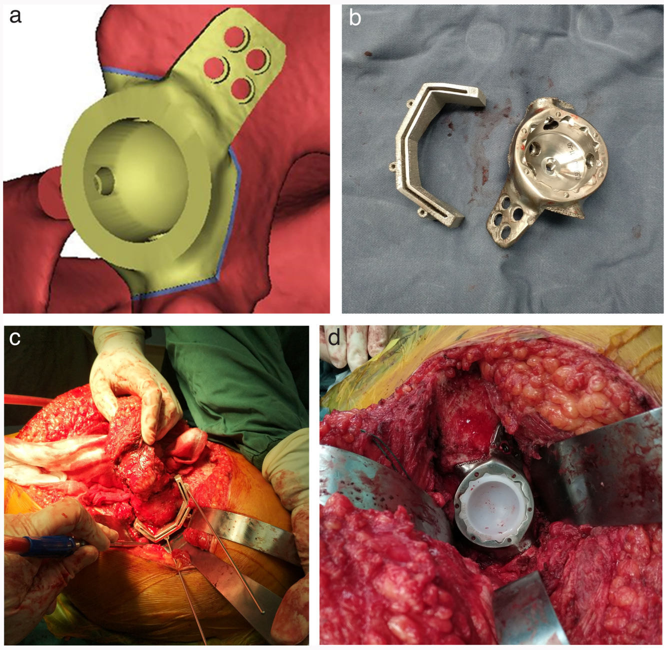

Fig. 3
Preoperative endoprosthesis design and perioperative endoprosthesis placement. a) Computer-simulated osteotomy plate and acetabular component. b) The 3D-printed plate and acetabular component were prepared. c) The osteotomy plate was placed during surgery. d) There was a complete match of the acetabular component.

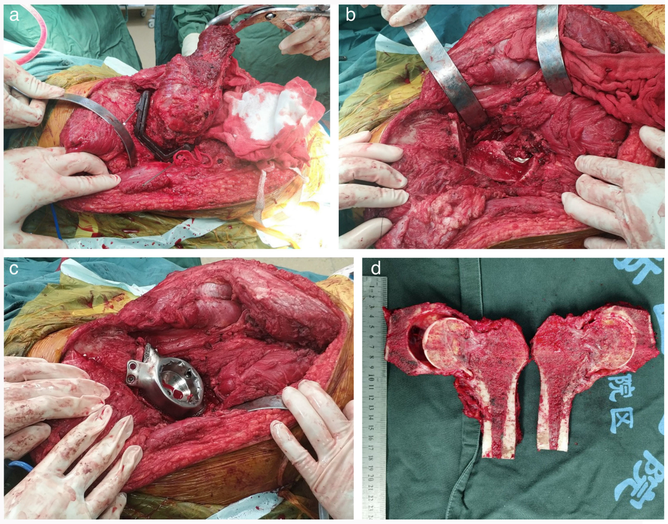

Fig. 4
Surgical procedure. a) After the ischial ramus and ischial tuberosity were exposed, the guide plate was placed. b) The tumour was removed with the hip joint using the oscillating saw. c) The acetabular component was placed with three surfaces attached to osteotomy surface. d) The joint capsule remained intact based on the coronal section of the tumour.

Variable measurement
Our primary goal was to assess the clinical outcomes of these patients. Patients were prospectively followed up via clinical and radiological evaluation every three months for the first two years after surgery, every four months for the third year, and every six months thereafter. Complications were defined according to Henderson's failure mode as mechanical failure (type 1, soft-tissue failure; type 2, aseptic loosening; type 3, structural failure) and non-mechanical failure (type 4, infection; type 5, tumour progression).[8,9] All times to event outcomes were determined from the date of surgery to the date of a specific event (death, recurrence, metastasis, complication). Surgery-related outcomes including intraoperative blood loss/transfusion and operation time were also recorded. Functional results were evaluated using the Musculoskeletal Tumor Society (MSTS) 93 score and were prospectively recorded.[10,11]

Statistical analysis
The statistical analyses were performed using SPSS Statistics software v. 19 (IBM, USA). Descriptive statistics were used for patients' specific and surgery-related characteristic. Patient overall survival estimates were calculated using Kaplan-Meier method. The cumulative incidence of complication plot (mechanical and non-mechanical failure) with death as a competing risk was also generated. Functional outcomes throughout time were assessed using line plot.

Results
Oncological outcomes
The overall survival was 81.7% at five years. At final follow-up, two patients (13.3%) died, four patients (26.7%) developed lung metastases, and no recurrence occurred. One patient died 13 months post-surgery due to underlying systematic disease progression, and one died 41 months post-surgery due to lung metastasis. Among patients with lung metastases, two underwent lobectomy for pulmonary olimetastases and were alive at last follow-up. Of the remaining two, one received targeted therapy and survived until the most recent follow-up, while the other had palliative therapy and died 41 months post-surgery. Postoperative pathological assessment revealed that a negative margin was achieved in all patients and no recurrence was observed.

Complications outcomes
The total complication rate was 20% (3/15). There were two cases of early dislocation (both within three months) and one case of deep infection (three months post-surgery). Closed reduction was performed for both dislocated patients and no further dislocation was observed. Debridement surgery was treated for infection, but it remained unresolved, and the prothesis was removed and replaced with a cement spacer. Up to the latest follow-up, no patient experienced aseptic loosening or other wound healing problems. The cumulative incidence of mechanical and non-mechanical failure in this series was 13.7% and 9.3%, respectively, at five years (Figures 5 and 6). The mean overall operation duration was 4.19 hours (3.00 to 6.42), and the mean overall intraoperative blood loss was 1,067 ml (500 to 2,000).

Functional outcome
Patients with tumours originating from the proximal femur started partial weightbearing at four weeks postoperatively and achieved full weightbearing in about six weeks, while those with tumours originating from the acetabulum started at two weeks postoperatively, and progressed full weightbearing by four weeks. The overall mean time to full weightbearing was 5.89 weeks (SD 0.92). The mean MSTS scores

at most recent follow-up were 22.7 (SD 6.5) and 25.5 (SD 1.2), respectively, for patients with periacetabular tumour and femoral tumour. In general, patients with tumours originating from the acetabulum displayed relatively lower MSTS scores compared to those originating from the proximal femur (Figure 7).

Osseointegration outcomes

Osseointegration of the implant was assessed using pelvic CT scans at three months, six months, one year, and two years post-surgery. Osseointegration was evaluated based on the contact interface between the prosthesis and the remaining bone. In all cases, the CT scans demonstrated good integration between the prosthesis and the surrounding bone tissue, and no radiolucent lines were observed (Figure 8).

Discussion

In order to treat proximal femoral or lateral acetabular malignancy infiltrating the hip joint, extra-articular resection is essential for a safe surgical margin. From an oncological standpoint, surgeons prioritize achieving a safe margin without contamination to enhance patient survival. Li et al[3] in 2018 reported that achieving successful periacetabular tumour resection required extensive surgical experience, especially without patient-specific osteotomy guides. Nevertheless, in their study, one patient had an intralesional margin and developed local recurrence. In our approach, we used a patient-specific 3D-printed osteotomy guide based on preoperative CT/MRI imaging to achieve a safe margin alongside pelvic integrity and combined individualized 3D-printed endoprosthetic reconstruction to enhance such limb salvage surgery. To our knowledge, this is the first and largest series to date that has applied a 3D-printed customized resection guide and endoprosthesis in extra-articular resection and reconstruction for hip joint tumour to report patients' oncological, functional, and complication outcomes.

Reconstruction following periacetabular tumour resection is challenging due to the intricate anatomy, extensive resections, and high risk of complications. With a prolonged exposure time and wide exposure range, the possibility of tissue ischaemia is high, with reported wound infection rates ranging from 7% to 55.6%.[12–14] In 2019, Fujiwara et al[15] reported a 20.6% deep infection rate post extra-articular resection. At our institution, initial surgeries used freehand for extra-articular resection and autologous bone or modular endoprosthesis for reconstruction. This involved a large ilioinguinal incision with a Watson-Jones approach, requiring meticulous soft-tissue management, making the T-shaped incision susceptible to necrosis or infection. These surgeries averaged six hours, sometimes exceeding seven hours in cases involving reconstruction using liquid nitrogen-inactivated autologous bone, and included complications such as one case of massive bleeding (2,200 ml) and subsequent thrombosis.

In this cohort of 15 patients, employing personalized osteotomy guides and prostheses significantly simplified procedures of the bone cutting and implantation, yielding a substantial decrease in operating time compared to five previous cases conducted at our institution and elsewhere in the literature.[16,17] The mean operating time was 4.19 hours, notably less than the commonly reported range of five to seven hours. Additionally, ilioinguinal combined with a posterolateral K-L hip joint incision was employed in all 15 patients to better enhance the vascular supply to the gluteal region, reducing the likelihood of incisional necrosis. Consequently, none of the 15 patients experienced skin necrosis or infection during follow-up.

For patients who undergo hemipelvic reconstruction following type II resection, hip stability depends more on the extent of osseointegration, as extensive resection of defected bone and surrounding tissue is inevitable. Unlike patients who underwent general hip joint arthroplasty, the prosthesis survival rate and functional score are relatively lower in patients who undergo hemipelvic reconstruction, potentially due to longer life expectancy and higher activity levels. Holzapfel et al[18] reported a ten-year prosthesis survival rate of 68.6%, which is lower than that of the general hip joint arthroplasty. Additionally, such a low implant survival rate could be attributed to the unique mechanical environment of the pelvis. In cases where the integrity of the pelvic ring is destroyed due to complete acetabulum resection, the contacting surface between the acetabular component and iliac bone is subjected to substantial force from the trunk. Due to the interruption of the continuity of the pelvic ring, hemipelvic prosthesis under lateral stress can cause sacroiliac joint separation, resulting in prosthetic valgus and dislocation. Some authors are aware of this problem and have improved the design of the prosthesis to stabilize the sacroiliac joint to reduce prosthetic valgus.[19] For carefully selected cases in this study, we used a custom osteotomy guide to perform extra-articular hip resection and maintain the posterior column of all these patients. By doing so, the continuity of the pelvic ring was preserved, and a close contact between the prosthetic surface and the host bone was ensured. This approach allowed for accurate positioning of the acetabular component based on the relationship between the osteotomy surface and bone-implant contact surface.

We also assessed the stability of the prosthesis by comparing the acetabular abduction angles in patients on immediate postoperative pelvic radiographs and during subsequent follow-up visits. We found that patients with posterior column preserved did not demonstrate a significant prosthesis displacement after two years of weightbearing activity; their abduction angle changed by less than 1°. In contrast, we found abduction angles change exceeded 10° after two years' follow-up in Enneking II resection patients at our institution, indicating that, at least for radiological stability, this newly described technique demonstrated superior results. Among all 15 patients, the change in hip valgus was minimal, with a mean of 0.96° (SD 1.50°). In contrast with previous work, patients underwent autograft reimplantation or hemipelvic prostheses exhibited a considerably larger change at a mean of 11.25° (SD 14.86°). Notably, no signs of prosthetic loosening were found in any of the patients during follow-up. Furthermore, there were no occurrences of prosthetic valgus or sacroiliac joint separation.

The functional outcomes after tumour resection and pelvic reconstruction vary greatly in relation to the type and extent of resection and reconstruction method.[20] Holzapfel et al[18] reported the mean MSTS score was 60.1% (SD 42%) (score = 18.1 (SD 12.6)) in 56 cases of periacetabular tumour using custom-made osteotomy plates and endoprostheses. Li et al[3]

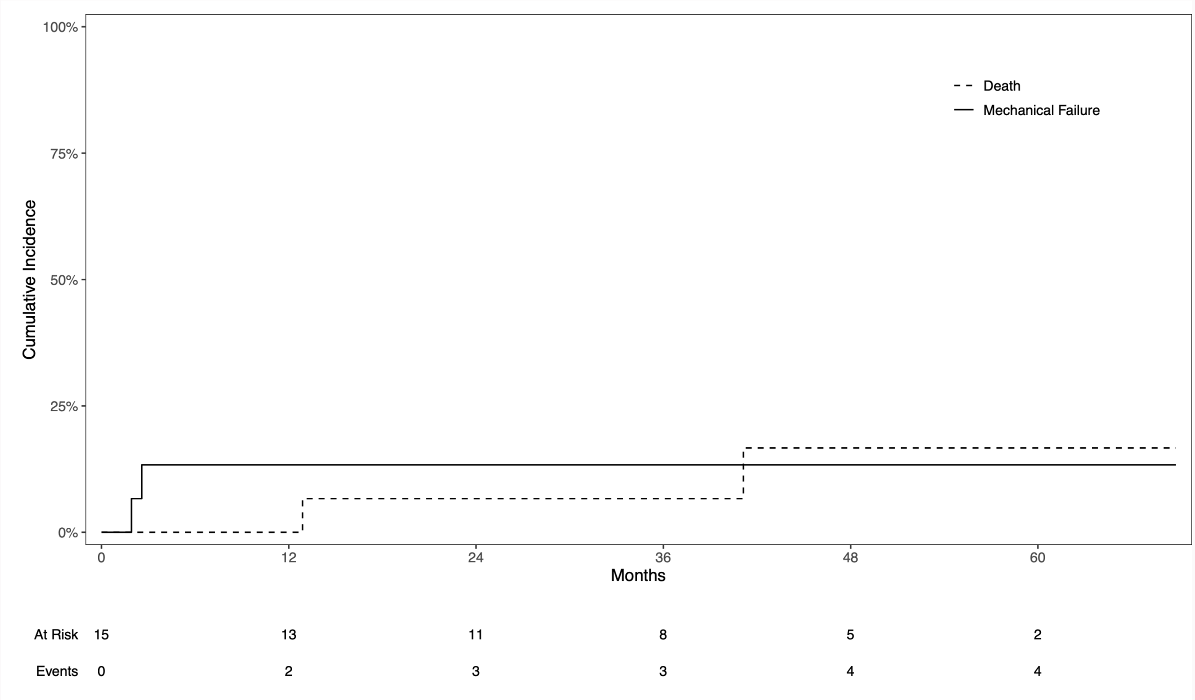

Fig. 5
The cumulative incidence of mechanical failure with death considered a competing event.

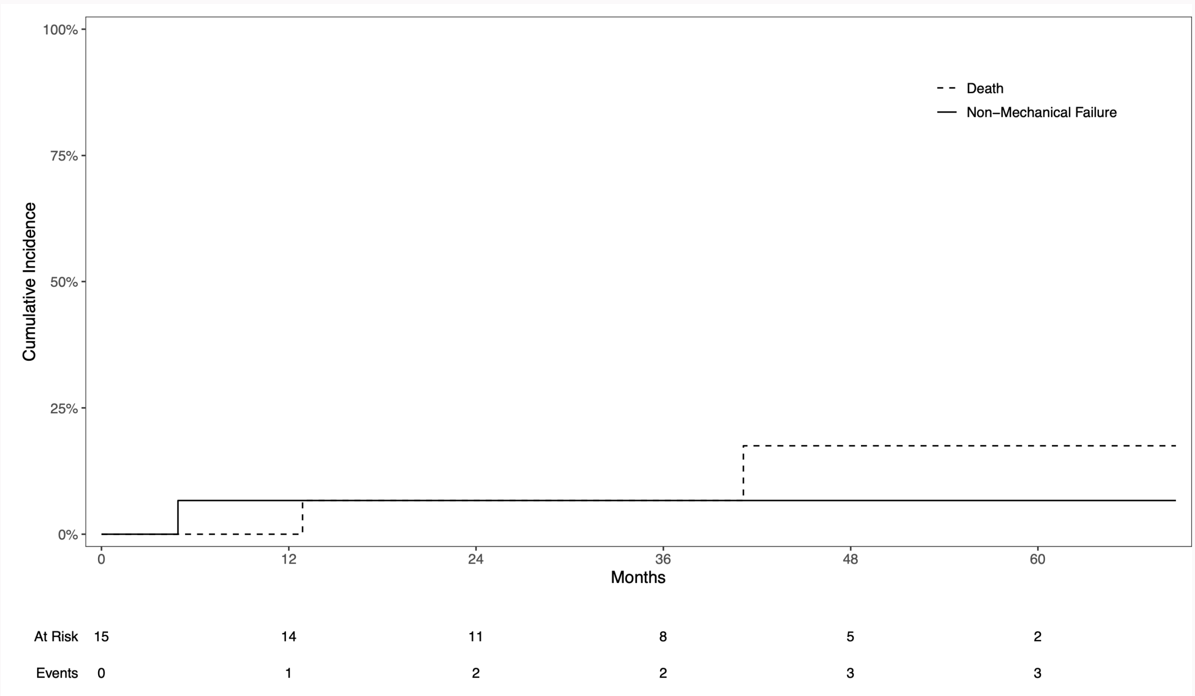

Fig. 6
The cumulative incidence of non-mechanical failure with death considered a competing event.

also reported the mean MSTS score was 63.5% (SD 10.8%) (score = 19.05 (SD 3.24)) in 18 patients with extra-articular resection. For tumours originating from the proximal femur, Fujiwara et al[15] reported in 2019 that the median MSTS score was 73% (21.9) after resection and reconstruction, compared to 63.5% (19.05) in patients with type II resection.[3] For patients with proximal femoral tumours involving the hip joint and which undergo total joint resection, the strength of the gluteus medius is typically inadequate post-surgery, primarily due to the inevitable removal of the gluteus medius attachment from the greater trochanter of the femur. Consequently, postoperative MSTS scores vary significantly across studies, ranging from 16.9 to 24.3. Generally, improved functional results can be achieved through enhanced soft-tissue repair

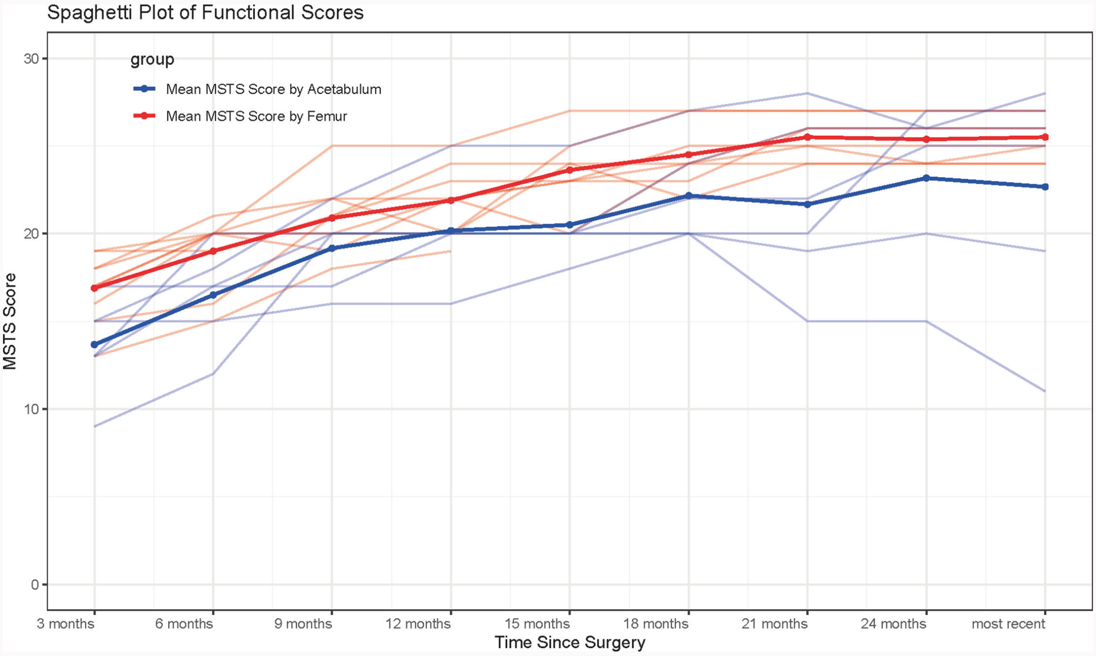

Fig. 7
Line plot illustrating the trend of Musculoskeletal Tumor Society (MSTS) scores in all patients over time post-surgery.

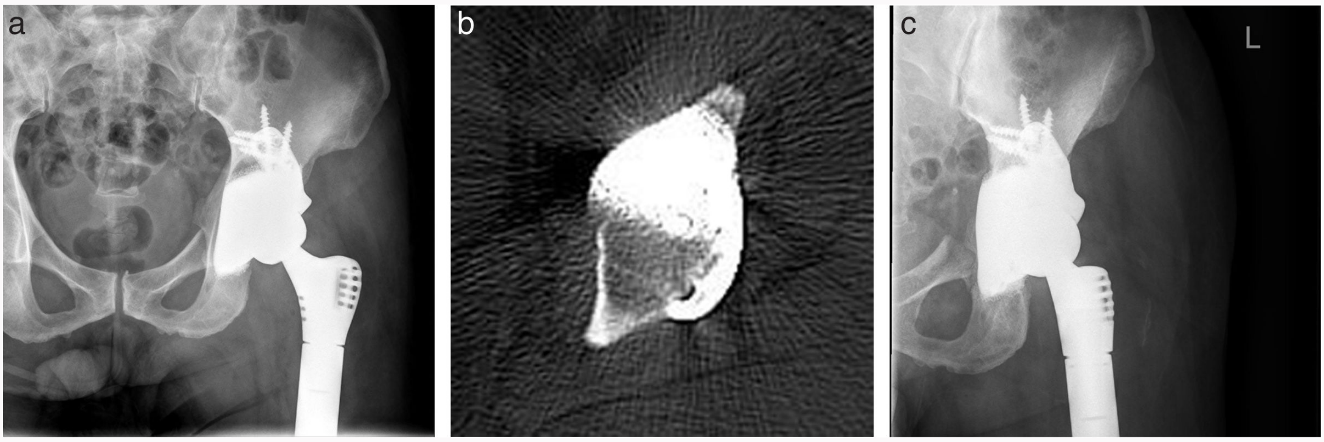

Fig. 8
a) Postoperative anteroposterior (AP) radiograph of a 54-year-old male patient who presented to our hospital with femoral osteosarcoma, taken six months after surgery. The prosthesis was restored to its anatomical position. b) Transverse CT scan taken two years after surgery. The CT scans demonstrated a good integration between the prosthesis and the surrounding bone tissue, and no radiolucent lines were observed. c) AP radiograph taken two years after surgery. The prosthesis was restored to its anatomical position and displays a good and stable fit.

or trochanteric attachment to the prosthesis.[21,22] For periacetabular tumour, the placement of prothesis represents a critical factor influencing the functional results of the hip joint. Usually, the MSTS score for patients undergoing type II pelvic resection ranges from 18 to 19.5.[12,23] In our study, the MSTS scores at final follow-up were 22.7 for lesions originating from the acetabulum and 25.5 for those from the proximal femur. However, it should be noted that the lower MSTS score in the acetabulum group could be attributed to one patient who underwent endoprosthesis removal due to deep infection. Nevertheless, when this patient was excluded, the average MSTS score was 25.0), which was very similar to those originating from the proximal femur. Despite this, the demonstrated MSTS scores exceed those of other acetabular resection and reconstruction methods commonly documented in the existing literature.

To our knowledge, our study is the first and largest review of patients undergoing extra-articular resection of the hip joint with preservation of the posterior column using a 3D-printed patient-specific osteotomy guide and custom-made endoprosthesis. Our study did, however, have some limitations. First, the sample size is relatively small, a constraint inherent to the rare occasions necessitating extra-articular resection when tumours infiltrate into the hip joint. Moreover, our inclusion criteria were stringent, focusing only on cases without contamination in the ischial branches and deemed suitable for posterior column preservation. All resulted in a limited number of patients for this analysis, and more cases need to be included in the future to validate our preliminary findings. Second, patients in this series are heterogeneous with regard to both diagnosis and location. Though oncological and functional outcomes might vary due to different diagnosis and location of the tumour, all patients had a wide negative margin, and MSTS function was evaluated independently in patients with tumours originating from the proximal femur and those from the acetabulum. Despite this, it is the surgical procedure and reconstruction method that we mainly focused on. We aimed to introduce a unique surgical approach for hip joint extra-articular resection and reconstruction which can ensure a negative margin while maximizing bone retention and maintaining pelvic integrity, allowing for a more stable reconstruction and improved postoperative function.

In conclusion, our study demonstrates that satisfactory oncological, complication, and functional outcomes were achieved in all 15 patients who underwent hip joint extra-articular resection followed by reconstruction using a customized osteotomy guide and 3D-printed endoprosthesis. For a carefully selected subgroup without tumour involvement of the ischial branches, posterior column can be preserved to maintain the integrity of the pelvis for more stable reconstruction. Overall, these techniques are worth performing in treating patients requiring extra-articular resection and reconstruction of the hip joint, offering advantages including simplified surgical procedures, reduced operati time, improved local control rate, decreased postoperative complications, and better postoperative function.

Supplementary material

Photographs of a customized 3D-printed acetabular implant, approach taken during the procedure, and screws of varying lengths; and CT scans showing installation and direction of iliac and sciatic screws.

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Author information

X. Yan, MD, Orthopaedic Surgeon
K. Wang, MS, Biostatistician
X. Huang, MD, Orthopaedic Surgeon
N. Lin, MD, Orthopaedic Surgeon
M. Liu, MD, Orthopaedic Surgeon
Z. Ye, MD, Orthopaedic Surgeon
Department of Orthopedic Surgery, The Second Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou, China; Orthopedics Research Institute of Zhejiang University, Hangzhou, China; Key Laboratory of Motor System Disease Research and Precision Therapy of Zhejiang Province, Hangzhou, China; Department of Orthopedics, Diagnosis and Treatment Center of Bone Metastasis, The Second Affiliated Hospital of Zhejiang University School of Medicine, Hangzhou, China.

Y. Ren, BD, Deputy Chief Nurse, Department of Orthopedic Surgery, The Second Affiliated Hospital, Zhejiang University

School of Medicine, Hangzhou, China; State Key Laboratory of Transvascular Implantation Devices, Hangzhou, China.

Author contributions

X. Yan: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Writing – original draft.
K. Wang: Data curation, Visualization, Writing – review & editing.
X. Huang: Resources, Validation.
N. Lin: Resources, Validation, Funding acquisition, Supervision.
M. Liu: Resources.
Y. Ren: Supervision, Validation.
Z. Ye: Conceptualization, Project administration, Supervision.

X. Yan and K. Wang contributed equally to this work.

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Data sharing

The datasets generated and analyzed in the current study are not publicly available due to data protection regulations. Access to data is limited to the researchers who have obtained permission for data processing. Further inquiries can be made to the corresponding author.

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Ethical review statement

Conducted by the principles of the Helsinki Declaration, this single-center, retrospective study was approved by the Human Research Ethics Committee of the Second Affiliated hospital of Zhejiang University School of Medicine.

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