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# Is It Possible and Safe to Perform Acetabular-preserving Resections for Malignant Neoplasms of the Periacetabular Region?

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**Abstract**

*Background* Primary malignant tumors located near the acetabulum are usually managed by resection of the tumor with wide margins that include the acetabulum. These resections are deemed P2 resections by the Enneking and Dunham classification. There are various methods to perform the subsequent hip reconstruction. Unfortunately, there is no consensus as to the best management. In general, patients undergoing resection at this level will have substantial levels of pain and disability as measured by the Musculoskeletal Tumor Society (MSTS) scoring system. We believe there is a subset of patients whose tumors in this location can be resected while preserving all or most of the weightbearing acetabulum using navigation and careful surgical planning.

*Questions/purposes* (1) What complications were associated with this resection; (2) what oncological outcomes (histological margins and local recurrence) were achieved; and (3) what is the function achieved by these patients?

*Methods* This was a retrospective study of patients with periacetabular primary malignancy. From 2008 to 2014, we treated 12 patients who had periacetabular primary malignant tumors and in five, we performed resection with the weightbearing portion spared. During this period, our general indications to perform a resection that spared the acetabulum were the tumor with its resection margin not involving the weightbearing portion of the acetabulum. However, we did not perform this procedure in patients who had more cranial lesion involving the weightbearing portion or whose hip stability might be in question after the tumor excision. Three patients were women and the other two were men. Four were chondrosarcomas, whereas the other one was synovial sarcoma. Ages ranged from 46 to 60 years (average, 53 years). Minimum followup was 14 months (median, 37 months; range, 14–88 months); no patients were lost to followup before a 1-year minimum was achieved, and all patients have been seen within the last 9 months.

*Results* There were no intraoperative or early postoperative complications. None of the five patients had a positive margin by histological assessment. No local recurrences were detected. The median functional score by MSTS was 28 out of 30 (range, 27–30).

*Conclusions* The roof of the acetabulum is the weight-bearing portion of the acetabulum. It also maintains the

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
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stability of the hip. With precise preoperative planning of the resection and accurate execution of the procedure, the hip-sparing approach through partial acetabular resection can be performed in selected patients with malignant periacetabular neoplasms. Navigation makes it possible to minimize the amount of bone resection. In this preliminary report of a small number of patients, we had adequate short-term local tumor control. We believe the function is good, but we do not have a comparison group of patients to document improved function.
*Level of Evidence* Level IV, therapeutic study.

## Introduction

The recent advancement in various aspects of orthopaedic surgery has opened a new horizon in orthopaedic surgical management of patients with musculoskeletal neoplasms. Malignant tumors located near the acetabulum are usually managed by resection of the tumor with wide margins that include the acetabulum. These resections are deemed Type II resections by the Enneking and Dunham classification [8]. In most instances these types of resections have avoided the need for hindquarter amputation, which results in functional loss [14, 22]. To further improve the functional outcome after limb-sparing acetabular resection, various kinds of reconstruction such as hip transposition, allograft, recycled autograft, saddle prostheses, and other endoprostheses have been developed [2, 5, 10, 13, 16–18, 22, 24, 27]. There is no one reconstructive procedure that has been universally adopted or shown to be superior to another [22]. The mean functional score by the Musculoskeletal Tumor Society (MSTS) after these limb-sparing surgeries is 14.5 out of 30 [15].

Therefore, a more conservative resection that preserved the weightbearing acetabulum would seem preferable if the oncological outcome has not worsened. In some patients, we believed it might be possible to perform an acetabular-sparing resection, which may avoid complex reconstruction and may lead to better functional outcome than the standard P2 resection. With computer-aided surgery, precision planning can be carried out preoperatively and accurately executed intraoperatively [25]. In recent years, we have applied computer-assisted pelvic resection to this group of patients based on the anatomy of the pelvis and underlying pathology.

The primary aim of this preliminary study is to review our preliminary results with this approach, which spared the weightbearing portion of the acetabulum. Specifically, we asked (1) what complications were associated with this resection; and (2) what oncological outcomes (histological margins and local recurrence) were achieved; and (3) what is the function achieved by these patients?

## Patients and Methods

This study retrospectively assessed patients with a primary malignancy in the periacetabular region of the pelvis undergoing limb-sparing resection with or without reconstruction after resection at the Queen Mary Hospital and Queen Elizabeth Hospital in Hong Kong. The hospital records were retrieved and reviewed. From 2008 to 2014, we had 12 patients with tumors involving the periacetabular region of the pelvis. Of these 12 patients, there were five hip-sparing procedures performed. The remaining five form the basis for this report (Table 1). The other seven patients were assessed in the same period as the five patients and deemed to be unsuitable for the acetabulum-sparing procedure because of extensive involvement of the weightbearing portion of the acetabulum or risk of hip instability with the hip-sparing procedure. There were three ways to carry out the hip-sparing resection. These are as follows: (1) unicortical, either the inner (Fig. 1) or outer table resected, and the subchondral bone of acetabulum was intact (Fig. 2); (2) uniplanar lower acetabular resection, single-plane osteotomy (Fig. 3); and (3) V-shaped biplanar lower acetabular resection (Fig. 4). For the V-shaped biplanar lower acetabular resection, the exposed joint was closed down by a free fascia lata graft and then a piece of bone allograft was put into the valley-like crevasse. No femoral head replacement was performed at this time.

We retrospectively evaluated patient records for any associated complications, oncological outcome, and functional outcome of this small cohort.

The study was approved by the University of Hong Kong/Hospital Authority Hong Kong West Cluster Institutional Review Board (reference No. UW 15-414). All patients signed an informed consent form before surgery.

### *Procedures* (illustrated with Patient 5)

Before surgery, all patients had a full assessment including the histology and extent of disease both local (Fig. 5) and systemic (PET-CT scan or CT scan thorax + bone scan). The indication of limb-sparing surgery was ascertained. Based on the grading, the width of the margin was also predetermined before actual planning of the resection.

The planning of the resection was carried out with computer navigation software. The DICOM images of each patient's CT scan and MRI scan were imported to the computer. The images were fused by the software. The tumor image on each MR image was outlined and these outlines were transferred onto each corresponding CT scan image. At this point, the virtual three-dimensional (3-D) image of the tumor could be created within the virtual 3-D

**Table 1.** Patients undergoing hip-sparing resection

| Patient number | Sex | Age (years) | Histology | Resection | Histologic margin (closest) | Followup (months) | Oncologic outcome | Complications | MSTS score |
|---|---|---|---|---|---|---|---|---|---|
| 1 | F | 54 | CSII | Lower acetabulum resection, no bone Reconstruction | 20 mm (bone) 10 mm (soft tissue) | 88 | No recurrence | | 29 |
| 2 | M | 46 | Synovial sarcoma | Outer table resection, no bone Reconstruction | 13 mm (bone) 2 mm (soft tissue) | 14 | No recurrence | | 27 |
| 3 | F | 60 | CSI | Inner table resection, no bone Reconstruction | 3 mm (bone) | 41 | No local recurrence Suspected asymptomatic regional recurrence | Incisional hernia resulting from extensive abdominal muscle resection | 27 |
| 4 | M | 49 | CSI | V-shaped acetabulum osteotomy, onlay allograft | 10 mm | 33 | No recurrence | Stress fracture of the inferior pubic ramus asymptomatic inguinal hernia | 28 |
| 5 | F | 58 | CSI | V-shaped acetabulum osteotomy, onlay allograft | 9 mm | 37 | No recurrence | Asymptomatic broken screws | 30 |

MSTS = Musculoskeletal Tumor Society; F = female; M = male; CSI = Grade I chondrosarcoma; CSII = Grade II chondrosarcoma.

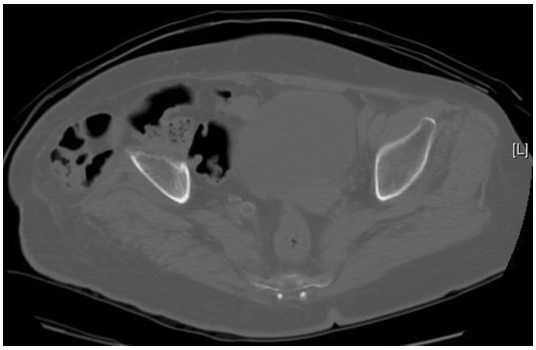


**Fig. 1** The postoperative CT scan of Patient 3 showed that the inner table was resected.

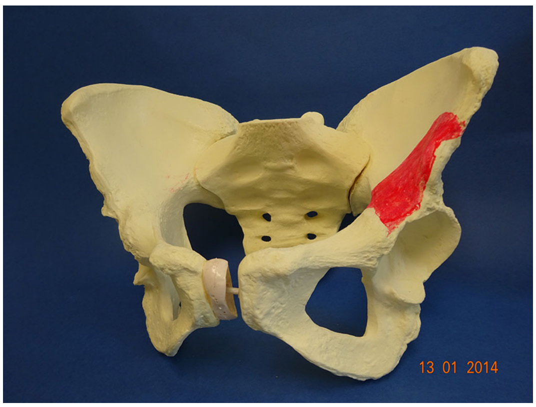


**Fig. 2** The plastic model shows the inner table to be resected (Type 1 resection). The area in red represents the resected bone.

CT image of the pelvis. Then the tumor image was magnified digitally in all directions by the width of margin, which was predetermined according to the histology and the grading. Then the insertion of parallel Kirschner wires was planned. Each pair of parallel Kirschner wires would form a resection plane [25]. Resection would be planned through a single resection plane formed by two Kirschner wires to enable easier resection. If there was too much bone resection, we would change it to a multiplanar, Type 3 resection (Fig. 6). Moreover, if the dome was unable to be preserved, a conventional P2 resection (supraacetabular resection) would be considered.

The key to successful surgery is to have the resection plane designed just outside the predetermined margin and also to include minimum normal tissue in the specimen as far as possible (bone-conserving approach) (Fig. 7) while still preserving the weightbearing portion of the acetabulum (Fig. 8).

All patients were given general anesthesia and appropriate intravenous access and arterial lines. They were positioned on the radiotransparent operation table in the floppy lateral position. The exact incision was determined by the site and extent of the tumor. After pelvic bone exposure, the tumor was excised under the guidance of

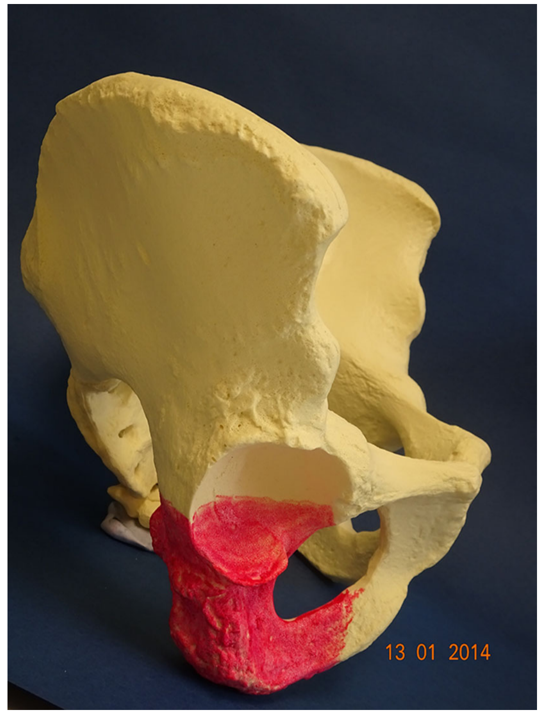


**Fig. 3** The plastic model shows the uniplanar lower acetabulum resection (Type 2 resection). The area in red represents the resected lower acetabulum.

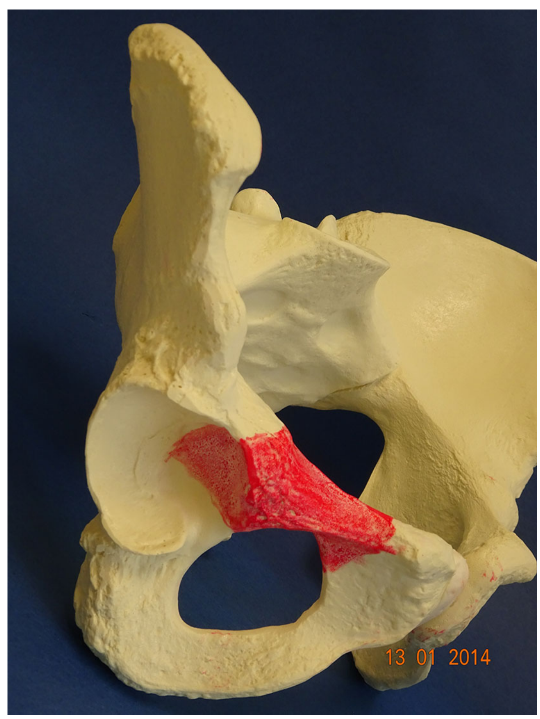


**Fig. 4** The plastic model shows the V-shaped lower acetabulum resection (Type 3 resection). The area in red represents the sector of bone to be resected.

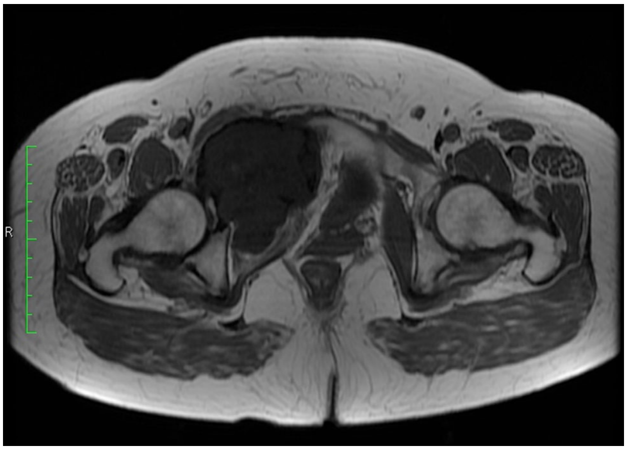

**Fig. 5** This was the T1 image of the MRI scan of Patient 5.

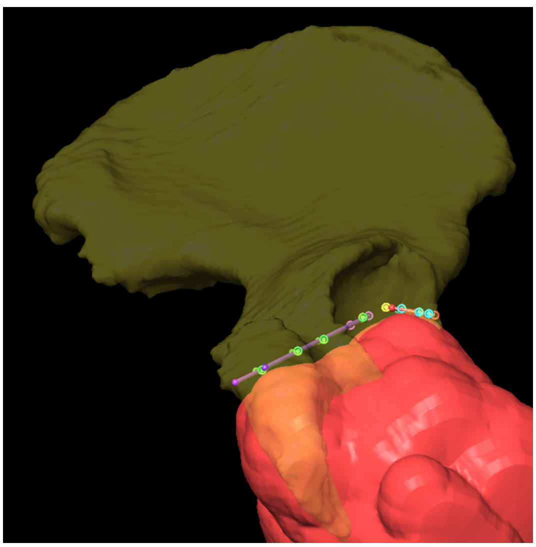

**Fig. 6** The 3-D CT scan image of Patient 5 shows the planning of the V-shaped cut. If the bone cut had been in one plane, the hip would have been unstable after the osteotomy. The red area is the tumor with its planned margin.

execution software of the computer navigation machine based on the preoperative design. The CT scan images were transferred to the execution platform. Then the preoperative CT images were fused to the intraoperative fluoroscan images to indicate the exact sites the parallel Kirschner wires should be inserted into and then the navigation machine guides the osteotomy [25].

For all except one, the intraoperative bone osteotomies were navigated by computer-aided surgery. After tumor resection, three patients had joint capsule reconstruction and two had bone grafting for the acetabular defect (Type 3 resection) (Fig. 9).

Before closure of the wound, the hip was moved passively in all ranges to determine any risk of instability or dislocation in any direction.

Postoperatively, all patients had a supervised course of physiotherapy to improve the functional outcome. The indication for postoperative radiotherapy or chemotherapy would depend on the final histology. They were given to one patient with synovial sarcoma. The patients with chondrosarcoma did not receive any adjuvant treatment. The median followup was 37 months (range, 14–88 months); no patients were lost to followup before a 1-year minimum was achieved, and all patients have been seen within the last 9 months. They had regular followup for any complication, the ultimate functional status, and also searching for any local or systemic recurrence. Our hospitals' standard practice is to have 3-monthly clinical followups in the initial postoperative year. Then the clinical followups will be 6-monthly for another 4 years before the long-term annual followups. In the early postoperative period, radiographs (Fig. 9), CT scans/MRI scans of the pelvis, whole-body bone scans, and CT scans of the thorax are taken every 6 months to 1 year until 5 years postoperatively. Then the patient has annual radiographs of pelvis assessments.

Function was assessed by the MSTS system [9]. The evaluation was performed on an irregular basis during clinical followups and also in the latest followup.

## Results

We reviewed the clinical data of the two hospitals and of the 12 patients with periacetabular resection performed in this time period; five of the resections could spare the weightbearing portion of acetabulum and were treated by partial acetabular resection (Table 1). Three patients were women and the other two were men. Four were chondrosarcomas, whereas the other one was synovial sarcoma. Ages ranged from 46 to 60 years (average, 53 years).

There were no intraoperative or early postoperative complications. There was no intraoperative hip instability or postoperative hip dislocation. No patient developed an infection. One patient (Patient 3) had a wide-based incisional hernia, which was treated without further surgery (Fig. 10). One patient (Patient 4) sustained a late stress fracture of the inferior pubic ramus at 11 months. He recovered without any surgical treatment. He also had an asymptomatic inguinal hernia of the same side under the care of the surgeon. Another patient (Patient 5) had an asymptomatic broken screw shown on a followup radiograph.

Histologically, all postresection specimens showed clear margins from tumor involvement. There was no local recurrence, but one patient (Patient 3) was found by the 40$^{th}$ -month postoperative MRI scan to have a suspicious regional recurrence at the aortic bifurcation; it was

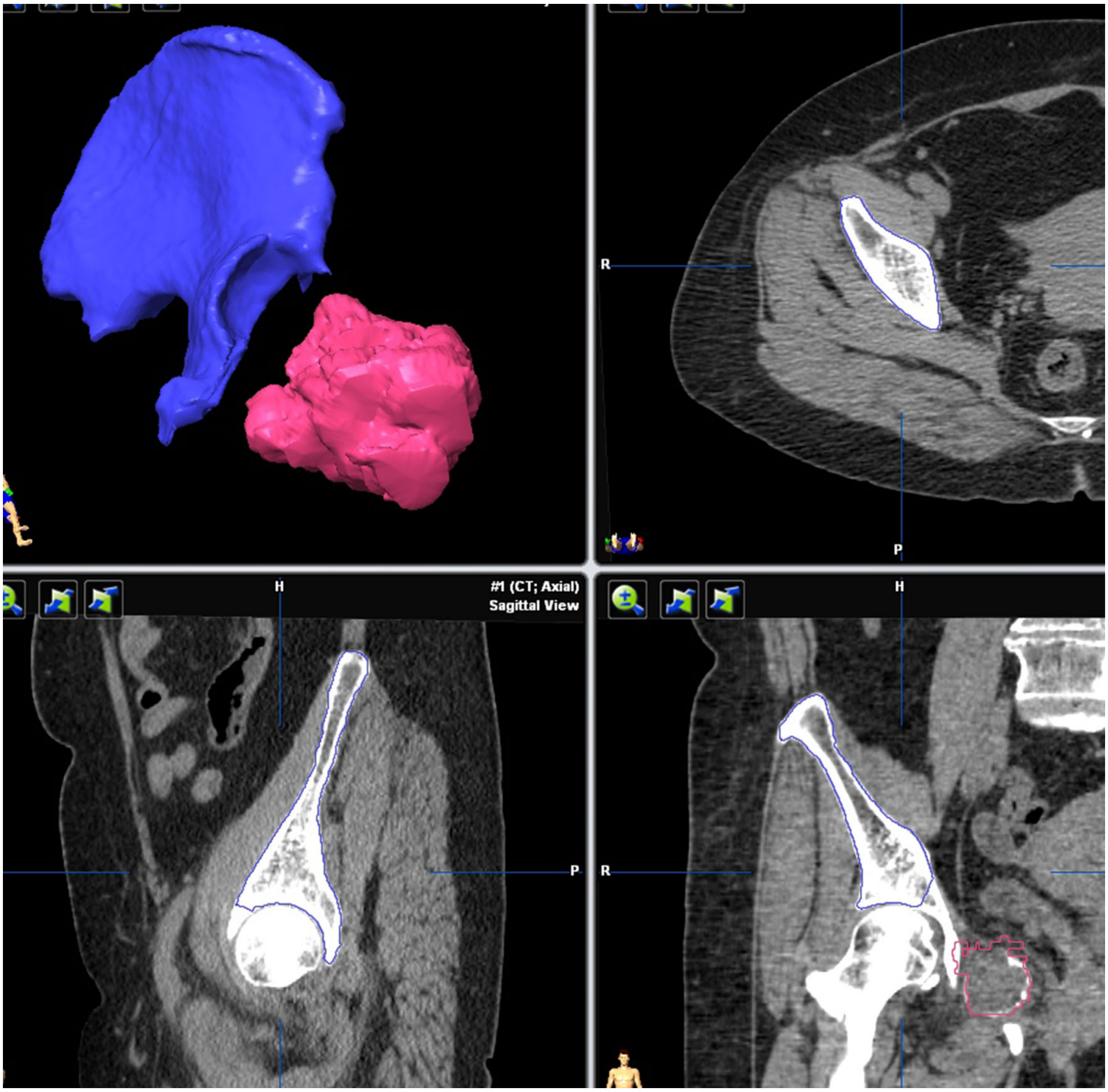


**Fig. 7** (Patient 5) The CT scan shows the relationship of remaining bone (blue) to the tumor (red) compared with the sagittal, coronal, and axial cuts in the CT scan image.

asymptomatic. No surgical treatment was planned at the time. All patients survived and four were disease-free.

The MSTS score [9] was measured in all patients (Table 2). The median functional score (MSTS) was 28 out of 30 (range, 27–30), whereas the median score for other seven hip-sacrificing procedures performed in the same period was 22 out of 30 (range, 5–26).

## Discussion

Improvements in orthopaedic surgery in various subspecialties have improved the quality of patient care. Recent advances in imaging techniques including CT scan, MRI scan, and PET scan allow us to accurately locate the extent of the tumor lesion in the bone and soft tissue structure. With computer-aided tumor surgery, the tumor image can be well visualized intraoperatively [28]. The seamless model of preoperative planning and intraoperative execution of the plan has been demonstrated by So et al. [25]. We believe there is a subset of patients whose tumors in this location can be resected while preserving all or most of the weightbearing acetabulum using navigation and careful surgical planning (Fig. 11); however, to my knowledge, there has been only a single patient reported with this approach [12]. The author of the report did not demonstrate how the patient was selected, how the margin of resection was planned, and what the indication for the procedure was. Nevertheless, the transacetabular resection in the report cannot be applied to our Type 3 resection (Patients 4

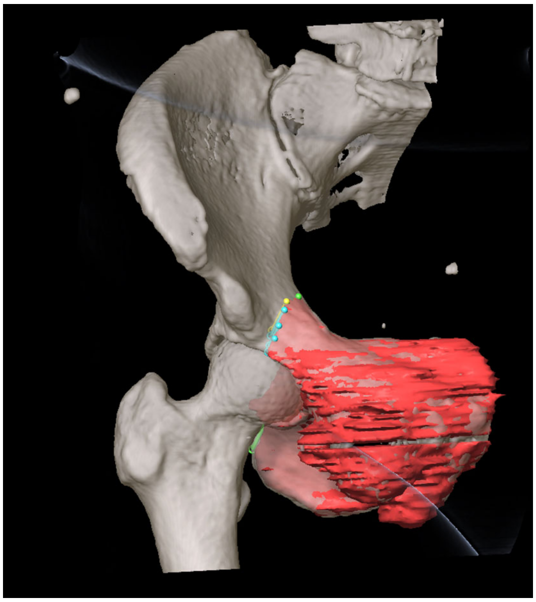

**Fig. 8** (Patient 5) This was another view to show the resection from a different angle. The resected portion was in red.

**Fig. 9** (Patient 5) The postoperative radiograph indicates the pelvic defect after resection. The plate was used to keep the allograft in place and to make sure that there will be no motion between the bone allograft and the host bone.

and 5) because a uniplanar osteotomy will remove too much bone making the hip unstable (Fig. 6). In our limited series, we show preliminary data to suggest how the pelvic tumor resections in selected patients with periacetabular neoplasms may be performed while preserving the weightbearing dome of the acetabulum.

There were several limitations to our study. First, this is a very small number of patients to report and represents less than half of the patients with periacetabular tumor we treated in this time period. We believe that proper patient selection is important; we believe that patients are potentially eligible for this resection when the lesion is in the caudal part of the acetabulum without the need to remove the dome in the resection plan or when the lesion involves the inner or the outer table of the pelvis without involving the subchondral area, whereas patients not meeting these criteria should be treated as the conventional P2 resection [8]. Clearly, this technique cannot be performed for every periacetabular neoplasm. Second, our duration of followup is very short. With longer followup, local recurrences or distant metastases may be detected. Low-grade chondrosarcomas are at risk for recurrence for several years after resection [11] and we might expect some incidence of recurrence with more patients and longer followup.

**Fig. 10** The radiograph of Patient 3 that was taken after surgery. The muscle and bone defect was the cause of incisional hernia.

**Table 2.** Function as assessed by MSTS score [9]

| Patient number | Pain | Emotional acceptance | Assisted devices | Function | Walking | Gait |
|---|---|---|---|---|---|---|
| 1 | 5 | 5 | 5 | 5 | 5 | 4 |
| 2 | 5 | 3 | 5 | 4 | 5 | 5 |
| 3 | 5 | 5 | 5 | 5 | 5 | 2 |
| 4 | 5 | 5 | 5 | 4 | 5 | 4 |
| 5 | 5 | 5 | 5 | 5 | 5 | 5 |

For the three women (Patients 1, 3, 5), they are housewives and they do not have any regular sports activity; for the two men, they returned to the original work (Patient 2: engineer, Patient 4: bus driver); there is some limitation in sports for Patient 2; Patient 4 does not have any regular sports activity; MSTS = Musculoskeletal Tumor Society.

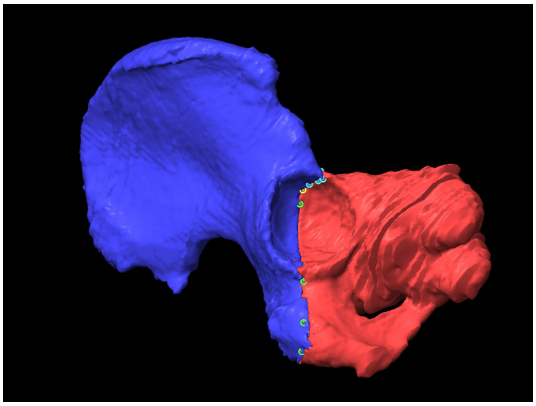

**Fig. 11** (Patient 5) This was the 3-D CT scan image with the planned caudal resection (red) and the remaining cranial part (blue) separated by a junctional line, which was the planned osteotomy line.

Moreover, there is not any anatomical study on the amount of acetabulum loss before becoming an unstable hip. Hence, we are currently not aware of the safe zone for the bone removal. We have no comparison group so we cannot definitively state that our resection type is superior to others with regard to tumor control or function. Larger studies will be necessary to determine this. There were only a few suitable tumor cases of partial acetabulum involvement. Therefore, ours is like most of the previous reports that consisted of only a few patients [11, 22, 24]. Moreover, whether partial loss of the acetabulum in the long run will contribute to microscopic instability or accelerated osteoarthritis is still unknown to us.

The complications we observed with this procedure were few and they were minor. However, the series was small, and it was very carefully planned. These are large procedures, and it may be quite probable if larger studies on this technique may observe major complications. The potential specific complications related to this procedure may include infection, skin necrosis, hematoma, abdominal hernia, fracture, postoperative pain, accelerated osteoarthritis, and postoperative hip dislocation. The complication rate was quite high in the conventional reconstruction [16, 22]. In a series of 17 saddle prosthesis reconstructions, there were 14 local complications including infection, dislocation, and limb length discrepancy [16]. For the allograft reconstruction, there was 28% infection [29]. With precision and accuracy provided with preoperative planning and navigation assistance intraoperatively, we showed that it is possible to perform acetabulum-sparing resections in a selected proportion of patients without compromising the hip stability or increasing the local complication rate.

This suprabone-conserving approach in bone tumors resection allows us to save bone while still achieving a wide margin in the bone resection (Table 1). Avedian et al. [1] concluded that the bone-conserving wide margin resection was an alternative for carefully selected patients. Although our followup is short, we found no instances of local recurrence in our five patients. Bindiganavile et al. [4] stated that the overall survival of chondrosarcoma was 91.6%, 84.1%, and 84.1% at 5, 10, and 15 years, respectively. The high histologic grade and axial location were the two negative outcome predictors. There was also evidence that low-grade chondrosarcoma could have a very late recurrence. Gaston et al. [11] reported a patient who had local recurrence 13 years after the initial excision. In view of the three patients with low-grade chondrosarcoma in our series, long-term followup is required.

When compared with the traditional surgical technique, it may improve the functional outcome without jeopardizing the oncological result. Jensen et al. [16] reported the series of saddle prosthesis reconstruction with a mean MSTS score of 47 out of 100 at long-term followup. With pasteurized autograft, the MSTS score was 61 out of 100 [17]. There was another report on the allograft reconstruction with only seven of 19 patients in the categories of excellent or good in function [29]. We observed relatively good function as assessed by the MSTS functional assessment system. All five patients with acetabulum preservation had scores better or equal to 27 of 30. We cannot say this will hold up long term but seems to be favorable to reports of P2 resections, which remove the entire acetabulum [10, 16, 18, 19, 23, 29]. Gerbers and Jutte [12] reported a uniplanar transacetabular resection in a Grade 2 chondrosarcoma under computer navigation guidance with a satisfactory outcome at 3.5 years followup. The MSTS score was 29 out of 30. From our study, the five patients undergoing hip-sparing surgery had a better MSTS score than the other seven patients undergoing hip sacrifice surgery in the same study period, although we know more extensive tumor involvement in the hip sacrifice group may have a significant effect on the poor functional outcome. The roof of the acetabulum bears the load transmitted across the hip and the acetabulum also maintains the stability of the femoral head inside the hip. Because the weightbearing portion of the acetabulum is not only at the zenith, the lateral margin of the weightbearing portion is difficult to define by the current imaging technique [7]. Although the inferior acetabulum may contribute to some hip stability, it is less important than the superior portion [20]. There is no consensus on the roof-arc angle of the critical weightbearing dome that the acetabulum dome is necessary to maintain stability of the hip. The medial, anterior, and posterior roof-arc angles in the corresponding AP view, obturator oblique view, and iliac oblique views of the radiograph have been suggested to be 30°, 45°, 50° [21], 45°, 25°, 70° [26], and 46°, 52°, 62°, respectively [6].

Matityahu et al. [20] stated that the single-leg stance (46°, 25°, 72°) and sit-to-stand (91°, 67°, 101°) had different roof-arc angles. Therefore, if most of the upper acetabulum is preserved like in the resection, the short-term stability of the hip should not be a problem. However, to be on the safe side, reconstruction of the joint capsule should be performed if technically feasible. Bone grafting on the V-shaped crevasse after Type 3 resection may restore the integrity of the acetabulum. It may have a positive effect on the ultimate function of the hip.

## Conclusion

With careful analysis of the anatomy of the acetabulum and the extent of tumor, we have shown in a preliminary fashion that we can plan resections to preserve the acetabulum in a select group of patients with periacetabular malignant tumors. Moreover, these operations can be carried out uneventfully with the aid of computer navigation. The hip-sparing surgery seems to be more functional. If these observations are confirmed by others and with more patients and longer followup, it may be possible to "personalize" acetabular resections for patients with pelvic primary malignancy so that some can avoid the P2 resection [3] currently performed for most of these patients. Future studies might include hip stability after partial resection of acetabulum in cadaveric bone and the long term effect of partial acetabular resection. Further software development will allow better visualization of the anatomy of the virtual image and real-time execution of an osteotomy plan by robotics may minimize intraoperative human error.

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