Temporary External Fixation Can Stabilize Hip Transposition Arthroplasty After Resection of Malignant Periacetabular Bone Tumors

Running Title: Hip Transposition Arthroplasty

Toshiyuki Kunisada MD, PhD, Tomohiro Fujiwara MD, PhD, Joe Hasei MD, PhD, Eiji Nakata MD, PhD, Masuo Senda MD, PhD, Toshifumi Ozaki MD, PhD

T. Kunisada, T. Fujiwara, J. Hasei, E. Nakata, T. Ozaki
Department of Orthopaedic Surgery, Okayama University Graduate School of Medicine, Dentistry, and Pharmaceutical Sciences, Okayama, Japan

M. Senda
Department of Rehabilitation, Okayama University Hospital, Okayama, Japan

Each author certifies that neither he, nor any member of his immediate family, has funding or commercial associations (consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research*® editors and board members are on file with the publication and can be viewed on request.

Each author certifies that his institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

This work was performed at Okayama University Hospital, Okayama, Japan.

T. Kunisada ✉
Department of Orthopaedic Surgery
Okayama University Graduate School of Medicine, Dentistry, and Pharmaceutical Sciences
Department of Medical Materials for Musculoskeletal Reconstruction
Okayama University Graduate School of Medicine, Dentistry, and Pharmaceutical Sciences
2-5-1, Shikata-cho, Kita-ku, Okayama, 700-8558, JAPAN
Email: tkuni@okayama-u.ac.jp

AU: Please do not delete query boxes or remove line numbers; ensure you address each query in the query box. You may modify text within selected text or outside the selected text (as appropriate) without deleting the query.

Abstract

Background The choice of reconstructive procedure to restore limb function is challenging after internal hemipelvectomy. Hip transposition arthroplasty, also known as resection arthroplasty, removes a malignant or aggressive tumor of the pelvis and acetabulum after which the remaining femoral head is moved proximally to the lateral surface side of the sacrum or the underside of the resected ilium after internal hemipelvectomy. It may provide reasonable functional results and have some advantages such as lowering the risk of an infected implant compared with other reconstructions because no foreign implants are used. Hip transposition is generally managed with prolonged bed rest or immobilization postoperatively to stabilize the soft tissue surrounding the remaining femur. Because enabling patients to be mobile while the soft tissues heal might be advantageous, we reviewed our experience with external fixation for this procedure.

Questions/purposes (1) Does temporary external fixation facilitate postoperative physiotherapy in patients who undergo hip transposition arthroplasty? (2) What functional (Musculoskeletal Tumor Society [MSTS]) scores were achieved at short term in a small series of patients treated with hip transposition and temporary external fixation? (3) What were the complications of using external fixation in a small series of patients who received it for malignant tumors?

Methods Between 2008 and 2012, we treated seven patients (three men and four women; median age, 37 years; age range, 18–53 years) with acetabular resection for malignant bone tumors; all were managed using a hip transposition, initially stabilized using external fixation. No other types of procedures were used for this indication in this period. Minimum followup in this retrospective study was 45 months, except for one patient who died at 18 months (range of followup duration, 18–90 months; median followup, 57 months), and no

patients were lost to followup. The pins for external fixation were inserted into the affected side of the femur and the healthy contralateral ilium. External fixation was removed 6 weeks postoperatively and weightbearing was started at that time. Preoperative chemotherapy was administrated in four patients, but postoperative chemotherapy was delayed since it was given after external fixation removal in three patients. The postoperative rehabilitation course and functional results were assessed by chart review, functional results were determined using MSTS scores, tallied by physiotherapists who were not part of the surgical team, and complications were ascertained through chart review. Major complications were defined as complications that were treated with additional operations, such as deep infection, or ones that could cause severe postoperative dysfunction, such as nerve injury.

Results With temporary external fixation, standing next to a bed was achieved in median 7 days (range, 6–9 days) postoperatively, transferring to a wheel chair in median 8 days (range, 6–28 days), and gait training using parallel bars in median 15 days (range, 7–48 days). At most recent followup, three patients could walk without a crutch or cane, three could walk with a cane, and one could walk with a crutch. The median MSTS score at most recent followup (median, 57 months) was 63%. Two patients had complications that resulted in reoperations; one had a wound dehiscence, and one had an abdominal herniation that gradually developed, and which was reconstructed using polypropylene mesh 2 years after pelvic resection. Two patients had nerve palsies that recovered by the end of the first year. All patients had pin tract infections that resolved with nonsurgical approaches.

Conclusions Hip transposition with temporary external fixation can stabilize the bone soft tissue after pelvic resection. Although we did not have a comparison group of patients, we believe that external fixation facilitates early postoperative physiotherapy and rehabilitation and provides good functional results without major surgical complications. Because it delays the resumption of chemotherapy, more patients with longer followup are needed to determine

whether this will be associated with poorer oncologic results.

Level of Evidence Level IV, therapeutic study.

Introduction

A variety of reconstructive and ablative approaches have been used to manage patients after acetabular resections for malignant tumors. Hindquarter (external) hemipelvectomy is an accepted surgical treatment for primary malignant pelvic tumors [4, 22]. However, this treatment has cosmetic and functional disadvantages because the loss of a limb is associated with a high proportion of morbidity. Although internal hemipelvectomy with tumor resection and lower extremity sparing has been performed during the last several decades, reconstructive approaches vary according to the complicated anatomical location of the pelvis, extent of resection, functional demands of the patient, and individual surgeon preference. Reconstructive options after acetabular tumor resection include iliofemoral arthrodesis or pseudoarthrodesis, combined use of hip arthroplasty with a massive allograft or a recycled bone, and use of a pelvic and saddle prosthesis [2, 5, 9, 11, 18, 26]. No particular reconstruction method has been shown to be superior to another nor, for that matter, superior to leaving the hip flail [3, 5, 16, 25]. The choice of a reconstructive procedure to restore limb function is also challenging, and there is a high risk of mechanical, infectious, and neurovascular complications after internal hemipelvectomy [1, 10, 13, 23, 24, 26, 27]. The use of implants such as allografts, arthroplasties, or both has been associated with a high likelihood of postoperative infection because of the extent of dissection, inadequate soft tissue coverage, and a large dead space [16]. Surgical time required for resection arthroplasty is usually shorter than that when an implant is used, and the technique is usually less demanding and possibly associated with a lower complication rate than more complex reconstructive procedures are.

Hip transposition is a reconstructive technique that relies on stabilizing the bone and soft tissues after resection of the acetabulum without adding implants. The femoral head is moved proximally to the lateral side of the sacrum or the underside of the resected ilium after tumor

resection [12, 16]. Hillman et al. [15] reported that hip transposition had the lowest risk of complications after resection of the acetabulum compared with the use of a prosthesis alone or a prosthesis and an allograft. Another report suggests that hip transposition provides better quality of life and functional results compared with other types of reconstruction [16]. The absence of large implants and allografts may help to reduce surgical time and may decrease infection risk.

However, patients treated with hip transposition usually have been managed with immobilization in bed for 2 weeks followed by an additional cast or soft splint for 4 weeks postoperatively to stabilize the soft tissue surrounding the remaining femur [12], and this is an obvious disadvantage. Because of this, we began to apply temporary external fixation in patients who underwent hip transposition after resection of a periacetabular tumor to stabilize the new articulation and facilitate early postoperative physiotherapy. But to our knowledge, results using an external fixator for this indication have not been reported.

We therefore asked: (1) Does temporary external fixation facilitate postoperative physiotherapy in patients who undergo hip transposition arthroplasty? (2) What functional (Musculoskeletal Tumor Society [MSTS]) scores were achieved at short term in a small series of patients treated with hip transposition and temporary external fixation? (3) What were the complications of using external fixation in a small series of patients who received it for malignant tumors?

Patients and Methods

Study Design and Setting

Between 2008 and 2012, we treated seven patients (three men and four women; median age, 37 years; age range, 18–53 years) with acetabular resection for malignant bone tumors; all were managed using a hip transposition, initially stabilized using external fixation (Table 1).

Minimum followup in this retrospective study was 51 months, except for one patient who died at 18 months (range of followup duration, 18–102 months; median followup, 69 months), and no patients were lost to followup. The study was approved by the institutional review board of our institute.

During this time period, we did not use any other form of reconstruction in patients who underwent acetabular resection for a sarcoma. Our indication for hip transposition arthroplasty with temporary external fixation was simply a malignant primary bone tumor involving or located close to the acetabulum and for which we needed to excise the acetabulum completely (including at least P2 resection) to achieve a tumor-free margin. There were no current or previous patients who were treated this way who did not have external fixation for comparison.

Demographics, Description of Study Population

The pathological diagnoses were three chondrosarcomas, two osteosarcomas (one conventional and one postradiation), one Ewing sarcoma, and one undifferentiated sarcoma. Patients with the two osteosarcomas (modified Neoadjuvant Chemotherapy for Osteosarcoma [NECO-95] protocol), the Ewing sarcoma (EUROpean Ewing tumour Working Initiative of National Groups [EURO-EWING]. Ewing Tumour Studies 1999 protocol), and the undifferentiated sarcoma (ifosfamide 10 g/m^2/Days1-5 and doxorubicin 60 mg/m^2/Days 1-2) received preoperative and postoperative chemotherapy. Radiotherapy (54.4 Gy) was conducted preoperatively on the Ewing sarcoma. One patient with osteosarcoma (Patient 7) underwent preoperative selective arterial embolization to reduce intraoperative blood loss. Acetabular lesions were excised according to the classification system proposed by Enneking and Dunham (Fig. 1) [7], describing the various subtypes based on the portion of bone removed. P12 resection was performed on three patients, P123 resection on two, P124 resection on one, and P23 resection on one.

Description of Experiment, Treatment, or Surgery

All patients underwent en bloc resection with an adequate wide margin, planned previously according to Kawaguchi's classification guidelines [19]. The patient was placed in a loose lateral position, which allows the patient to be flipped forward and backward to provide better visualization of the front and back of the pelvis. The extended ilioinguinal or iliofemoral approach was used depending on the involvement of the anterior part of the pelvis.

After tumor resection, a modified hip transposition procedure, as reported by Gebert et al. [12], was conducted for resection hip arthroplasty (Fig. 2). The femoral head was moved proximally to the lateral surface side of the sacrum or the underside of the resected ilium. The remaining soft tissue, such as muscle on the femur, sacrum, remaining pelvis, was sutured to stabilize the proximally-moved femoral head on the sacrum or the remaining ilium. Especially, if the gluteus maximus and/or medius were remained sufficiently, the suture of those muscles to the abdominal wall muscles could result in good stability. We avoided using a polyethylene terephthalate mesh tube, which can be used to reconstruct the capsule of the new hip joint, as reported previously [12, 15], because artificial materials present a possible cause of deep infection. After skin closure, the patient was placed in the supine position. The pins for external fixation were inserted into the affected side of the femur (subtrochanteric region) and the healthy contralateral ilium (iliac crest) under an image intensifier (Fig. 3). The affected femoral head was pressed to the lateral surface of the sacrum or the underside of the resected ilium, and external fixation was applied and tightened (Fig. 4), with the new hip articulation in 20º of flexion and 20º of abduction. The median total surgical duration was 418 minutes (range, 317–619 minutes), and the median duration to apply external fixation was 39 minutes (range, 37–50 minutes). The median intraoperative blood loss was 3160 mL (range, 720–4650 mL).

Aftercare

Patient who underwent external fixation started physiotherapy by transferring to a wheelchair and performing gait training with 10-kg partial weightbearing on the affected limb immediately after surgery. External fixation removal was planned 6 weeks after tumor resection. Pin tracts were managed with cleaning using wound antiseptic and dressing changes every 1 or 2 days by doctors or nurses. At the time of removal, the stability between the femoral head and remaining pelvis was assessed with an image intensifier. After external fixation removal, flexion of the new hip articulation and full weightbearing on the affected leg was sufficient to begin physiotherapy. Because two patients (one osteosarcoma and one Ewing's sarcoma) who were supposed to get postoperative chemotherapy demonstrated good response to preoperative chemotherapy and there would be some risks of deep infection due to early start of postoperative chemotherapy, we discussed with the patients and their family and decided that chemotherapy was given immediately after external fixation removal. One patient with UPS simply refused starting postoperative chemotherapy until he could move around by himself.

Variables, Outcome Measures, Data Sources, and Bias

Postoperative functional recovery, such as standing, transferring to a wheelchair, and gait training, was abstracted by chart review performed by physiotherapists or occupational therapists in charge of the patient's rehabilitation.

Patients were followed every 3 to 6 months, mainly so we could evaluate for local and distant relapse with imaging. On the same day of their visit to our clinic, they presented to the department of rehabilitation to undergo physical, psychological, and social examinations. A physiotherapist or occupational therapist measured limb length discrepancy and function, and we analyzed data collected from the patient records. The MSTS scoring system for the lower

limb [8] was used to assess functional outcomes at the outpatient clinic every 3 to 6 months. The physiotherapist or occupational therapist evaluated the MSTS score. The MSTS scoring system is based on the analysis of six factors: pain, emotional acceptance, restriction, walking distance, support, and gait. Each variable is given a value ranging from 0 to 5 according to specific criteria. The overall score is expressed as the sum of all variables, and is then converted into a percentage of the maximum possible score.

Major complications were defined as the complication that was treated with additional operation such as deep infection, or that could cause severe postoperative dysfunction such as nerve injury. Minor complications were defined as the complication that was treated conservatively such as superficial wound infection, or that was not directly related to postoperative function. Complications were abstracted by chart review performed by the treating surgeons (TK, TF).

Oncologic Results

A postoperative evaluation of the surgical margin demonstrated an adequately wide margin (at least 2 cm in width) in six patients and a marginal margin in one (Patient 7). The patient with osteosarcoma (Patient 7) had local recurrence 8 months postoperatively, which was treated with carbon ion radiotherapy; however, this patient developed multiple lung metastases. The patient with an undifferentiated sarcoma (Patient 1) developed multiple lung metastases 33 months after tumor resection and underwent three metastasectomies. These two patients with lung metastases died of their disease at 18 and 48 months after primary tumor resection. These two patients were functionally assessed at the time of the most recent outpatient clinic visit. The remaining five patients were continuously disease-free.

Results

Table 2 summarized timing of postoperative physiotherapy of each patient. The patients

treated with temporary external fixation were able to stand next to a bed within median 7 days (range, 6–9 days) after surgery, transfer to a wheel chair within median 8 days (range, 6–28 days), and begin gait training using parallel bars within median 15 days (range, 7–48 days) (Fig. 5). External fixation was removed under general anesthesia at 42 days (6 weeks) after surgery. At the time external fixation was removed, the image intensifier demonstrated that all new articulations between the femoral head and resected surface of the pelvis were sufficiently stable to allow passive mobilization at 90º flexion and 40º abduction. After removal, all patients started gait training with full weightbearing and continued postoperative physiotherapy. Gait training with two crutches was started within median 51 days (range, 13–75 days) after the initial surgery.

Median MSTS score was 63% (range, 57%–100%) (Table 3). Postoperative function had been improved until about 1 year after surgery, and since then MSTS score showed little change in all patients. All patients remained ambulatory after surgery and walked into our outpatient clinic at the latest followup examination (69 months, 76 months, 102 months postoperatively)(Fig.6). Three patients were able to ambulate without a cane or crutch and two could walk using a heightened shoe heel because of limb length discrepancy due to the transposition of the femoral head (Fig. 7). The remaining four patients used one crutch or cane with an elevated shoe heel. In our series, there was no deterioration of MSTS score during the followup period. Patient 6, who underwent P23 resection with the round osteotomy around the acetabulum like rotational acetabular osteotomy, showed 100% of MSTS score (Fig. 8).

Two patients had complications resulting in reoperations, one who had a wound dehiscence, and one who had an abdominal herniation gradually developed in one patient, and it was reconstructed using polypropylene 2 years after pelvic resection. The patient who had a wound dehiscence had preoperative chemotherapy and radiotherapy and underwent surgical

débridement to treat the dehiscence. An abdominal herniation gradually developed in one patient, and it was reconstructed using polypropylene mesh 2 years after pelvic resection. Transient nerve palsy was identified postoperatively in two patients; one had femoral nerve palsy and one had peroneal nerve palsy, both of which recovered within 1 year of surgery. All patients demonstrated pin tract infections that healed after débridement and simple suture after external fixation removal. There was no deep infection related to pelvic resection or temporary external fixation. The median limb length discrepancy among all patients was 5 cm (range, 1–7cm), and five of the seven patients used an elevated shoe heel (median 5cm, range; 3–6.5cm) when walking.

Discussion

Hip transposition arthroplasty, one type of resection arthroplasty, is a good option for some patients given the frequent complications associated with prosthetic reconstructions. However, this procedure is usually accompanied by a lengthy convalescence period during which time the patient can hardly walk, which itself can cause complications associated with recumbency [6, 12, 15, 25]. We therefore began to use external fixation in these patients. However, results with this approach have not, to our knowledge, been reported. In the present study, hip transposition with temporally external fixation led to good postoperative function such as reasonably quick mobilization and decent MSTS scores at about 4 years. There were some complications, although they were less common than one would expect from major surgery.

This study had several important limitations. First, there was no comparison group or randomization in this study. We described patients who underwent external fixation, and we cannot compare our result of hip transposition using temporary external fixation with the results of that without external fixation, or of other types of periacetabular reconstructions, because all patients included in this study had a single clinical indication and only one

treatment was used for this indication. Owing to the small number of patients with pelvic tumors involving the acetabulum who underwent internal hemipelvectomy, we are unable to provide a control group for comparison. Multicenter trials may be able to compare groups of patients in the future. Second, the small number of patients is not likely to adequately represent uncommon complications and outcomes, which are less likely to be detected in a study of this size.

In the present study, the patients were able to mobilize the day after the surgery, stand next to a bed with partial weightbearing at a median 7 days after surgery, and transfer to a wheelchair by a median 8 days after surgery. Temporary external fixation for pelvic reconstruction combined with resection arthroplasty was first reported by Kusuzaki et al. [20]. Their patients were able to move using a walker 3 weeks postoperatively, and after the external fixator was removed at 6 weeks, the patients used an additional hip abduction brace and began to walk with double crutches at 10 weeks. In their series of five patients, three could walk without a cane or brace. External fixation can provide adequate stability between the femoral head and remaining pelvis that is sufficient to allow early rehabilitation, which appears to be an improvement over the 4 to 6 weeks of bedrest that has been reported [6, 12]. Assessment using an image intensifier at 6 weeks showed that the transferred femoral head was located in the same position during its traction, flexion, and abduction; thus, the external fixator was removed at that time. All patients then began physiotherapy with full weightbearing, without the use of a hip brace. Temporary external fixation can effectively facilitate early postoperative physiotherapy and stabilize the new hip articulation after hip transposition.

We found MSTS scores to be generally good (median, 63%; range 57%–100%) at a median followup of nearly 5 years. Hoffmann et al. [ ] evaluated postoperative function on 20 patients treated with hip transposition and reported mean 61% of MSTS score at median followup of 69 months [16], which is similar to the present study. They concluded that hip

transposition resulted in better function and fewer complications than other procedures such as prosthetic reconstruction. The joint capsule for hip transposition arthroplasty was originally reconstructed with a polyethylene terephthalate mesh tube [16], and inducing local scarring of the soft tissue could also facilitate stable reconstruction [12]. Although we did not use the mesh tube, hip transposition with temporal external fixation might provide good postoperative function without prolonged bed rest and brace.

We had several serious complications, including two patients who underwent further surgery (one for a wound dehiscence, and one for a large abdominal hernia), as well as two patients who had neurapraxias that resolved within a year of surgery. We believe that these major complications were caused by surgical resection of pelvic tumor and hip transposition, not by temporary external fixation. The current study also demonstrated that the application of temporary external fixation without the use of a tube resulted in no postoperative deep wound infections in our patients, even in those treated with high-dose adjuvant chemotherapy. This is in stark contrast to one prior study, in which infection was seen in a large proportion of patients treated with hip transposition and reconstruction with a polyethylene terephthalate mesh tube [13]. They reported postoperative deep infection in 10 of 36 Type IIa hip transposition arthroplasties, resulting in mesh tube removal in five patients. Other studies regarding resection arthroplasty or flail hip without the use of artificial mesh reported no postoperative deep infection [17, 25]. Because the high rate of infection in their series of patients with hip transposition might have been partially because of the use of an artificial tube and external fixation without using the tube could provide adequate stability of a new hip articulation, we avoided using a tube. Other studies have found high rate of complication rate ranging from 55% to 77% of patients [1, 2, 3, 5, 13, 14, 18, 21]; main documented complications are wound healing problems, implant loosening, and deep infection. One study on 62 patients with hip transposition demonstrated 14 wound healing problems, 18 deep

infection, six neurological deficits and 25 revision surgeries [13]. The incidence of complications in pelvic tumor surgery is generally higher than that in extremity tumor surgery, since pelvic tumor surgery has a longer operative time and more extensive soft tissue dissection, and results in massive blood loss.

Our study showed that temporary external fixation can yield good stability between the femoral head and remaining pelvis and facilitate postoperative physiotherapy in the early postoperative period in patients treated with hip transposition after pelvic sarcoma resection. The MSTS scores at a median of nearly 5 years after surgery reflected good function among our small group of patients, and the complications we observed were not surprising in the setting of major pelvic surgery for a life-threatening diagnosis. Future studies might evaluate the long-term functional outcome and complications in more patients treated with hip transposition and temporal external fixation and the possibility of reducing the time required for temporal external fixation. Because it delays the resumption of chemotherapy, more patients with longer followup are also needed to determine whether this technique might be associated with poorer oncologic results. Since it might be extremely difficult to analyze clinical outcome sufficiently on such rare disease as pelvic sarcoma, a multicenter study should be conducted to compare each group of reconstructions.

Acknowledgments

We thank all the staff (doctors, physiotherapists, and occupational therapists) at the Department of Rehabilitation, Okayama University Hospital, Okayama, Japan, who conducted physiotherapy and rehabilitation of patients treated with hip transposition for helping us study their functional outcome.

References

1. Angelini A, Drago G, Trovarelli G, Calabro T, Ruggieri P. Infection after surgical resection for pelvic bone tumors: an analysis of 270 patients from one institution. *Clin Orthop Relat Res*. 2014;472:349-359.

2. Bell RS, Davis AM, Wunder JS, Buconjic T, McGoveran B, Gross AE. Allograft reconstruction of the acetabulum after resection of stage-IIB sarcoma. Intermediate-term results. *J Bone Joint Surg Am*. 1997;79:1663-1674.

3. Brown TS, Salib CG, Rose PS, Sim FH, Lewallen DG, Abdel MP. Reconstruction of the hip after resection of periacetabular oncological lesions: a systematic review. *Bone Joint J.* 2018;100-B(1 Supple A):22-30

4. Carter SR, Eastwood DM, Grimer RJ, Sneath RS. Hindquarter amputation for tumours of the musculoskeletal system. *J Bone Joint Surg Br.* 1990;72:490-493.

5. Dominkus M, Darwish E, Funovics P. Reconstruction of the pelvis after resection of malignant bone tumours in children and adolescents. *Recent Results Cancer Res.* Fortschritte der Krebsforschung. Progres dans les recherches sur le cancer. 2009;179:85-111.

6. Eilber FR, Grant TT, Sakai D, Morton DL. Internal hemipelvectomy--excision of the hemipelvis with limb preservation. An alternative to hemipelvectomy. *Cancer*. 1979;43:806-809.

7. Enneking WF, Dunham WK. Resection and reconstruction for primary neoplasms involving the innominate bone. *J Bone Joint Surg Am*. 1978;60:731-746.

8. Enneking WF, Dunham W, Gebhardt MC, Malawar M, Pritchard DJ. A system for the functional evaluation of reconstructive procedures after surgical treatment of tumors of the musculoskeletal system. *Clin Orthop Relat Res*. 1993:241-246.

9. Farfalli GL, Albergo JI, Ritacco LE, Ayerza MA, Muscolo DL, Aponte-Tinao LA. Oncologic and clinical outcomes in pelvic primary bone sarcomas treated with limb salvage surgery. *Musculoskelet Surg*. 2015;99:237-242.

10. Fisher NE, Patton JT, Grimer RJ, Porter D, Jeys L, Tillman RM, Abudu A, Carter SR. Ice-cream cone reconstruction of the pelvis: a new type of pelvic replacement: early results. *J Bone Joint Surg Br*. 2011;93:684-688.

11. Fuchs B, O'Connor MI, Kaufman KR, Padgett DJ, Sim FH. Iliofemoral arthrodesis and pseudarthrosis: a long-term functional outcome evaluation. *Clin Orthop Relat Res*. 2002:29-35.

12. Gebert C, Gosheger G, Winkelmann W. Hip transposition as a universal surgical procedure for periacetabular tumors of the pelvis. *J Surg Oncol*. 2009;99:169-172.

13. Gebert C, Wessling M, Hoffmann C, Roedl R, Winkelmann W, Gosheger G, Hardes J. Hip transposition as a limb salvage procedure following the resection of periacetabular tumors. *J Surg Oncol*. 2011;103:269-275.

14. Han I, Lee YM, Cho HS, Oh JH, Lee SH, Kim HS. Outcome after surgical treatment of pelvic sarcomas. *Clin Orthop Surg*. 2010;2:160-166.

15. Hillmann A, Hoffmann C, Gosheger G, Rodl R, Winkelmann W, Ozaki T. Tumors of the pelvis: complications after reconstruction. *Arch Orthop Trauma Surg*. 2003;123:340-344.

16. Hoffmann C, Gosheger G, Gebert C, Jurgens H, Winkelmann W. Functional results and quality of life after treatment of pelvic sarcomas involving the acetabulum. *J Bone Joint Surg Am*. 2006;88:575-582.

17. Huth JF, Eckardt JJ, Pignatti G, Eilber FR. Resection of malignant bone tumors of the pelvic girdle without extremity amputation. *Arch Surg*. 1988;123:1121-1124.

18. Jansen JA, van de Sande MA, Dijkstra PD. Poor long-term clinical results of saddle prosthesis after resection of periacetabular tumors. *Clin Orthop Relat Res*. 2013;471:324-331.

19. Kawaguchi N, Ahmed AR, Matsumoto S, Manabe J, Matsushita Y. The concept of curative margin in surgery for bone and soft tissue sarcoma. *Clin Orthop Relat Res*. 2004:165-172.

20. Kusuzaki K, Shinjo H, Kim W, Nakamura S, Murata H, Hirasawa Y. Resection hip arthroplasty for malignant pelvic tumor. Outcome in 5 patients followed more than 2 years. *Acta Orthop Scand*. 1998;69:617-621.

21. Langlais F, Lambotte JC, Thomazeau H. Long-term results of hemipelvis reconstruction with allografts. *Clin Orthop Relat Res*. 2001:178-186.

22. Masterson EL, Davis AM, Wunder JS, Bell RS. Hindquarter amputation for pelvic tumors. The importance of patient selection. *Clin Orthop Relat Res*. 1998:187-194.

23. O'Connor MI, Sim FH. Salvage of the limb in the treatment of malignant pelvic tumors. *J Bone Joint Surg Am*. 1989;71:481-494.

24. Schwameis E, Dominkus M, Krepler P, Dorotka R, Lang S, Windhager R, Kotz R. Reconstruction of the pelvis after tumor resection in children and adolescents. *Clin Orthop Relat Res*. 2002:220-235.

25. Schwartz AJ1, Kiatisevi P, Eilber FC, Eilber FR, Eckardt JJ. The Friedman-Eilber resection arthroplasty of the pelvis. *Clin Orthop Relat Res*. 2009;467:2825-30.

26. Sys G, Uyttendaele D, Poffyn B, Verdonk R, Verstraete L. Extracorporeally irradiated autografts in pelvic reconstruction after malignant tumour resection. *Int Orthop*. 2002;26:174-178.

27. Ueda T, Kakunaga S, Takenaka S, Araki N, Yoshikawa H. Constrained total hip megaprosthesis for primary periacetabular tumors. *Clin Orthop Relat Res*. 2013;471:741-749.

Legends

Fig. 1 A classification system proposed by Enneking and Dunham [8] was generally used for pelvic tumor resection.

Fig. 2 This scheme illustrates hip transposition arthroplasty.

Fig. 3A-B An AP radiograph at 3 weeks postoperatively of 43-year-old patient with chondrosarcoma (Patient 2) (A) and 18-year-old patient with Ewing's sarcoma (Patient 4) (B), show external fixation with pins inserted into the affected femur and the contralateral healthy ilium.

Fig. 4 This postoperative photograph demonstrates the appearance of external fixation.

Fig. 5A-B Photographs show the patients sitting on a wheel chair (A) and walking exercise using parallel bars (B) at the time of postoperative physiotherapy with external fixation.

Fig. 6A-C An AP view of radiographs of Patient 2 taken 1 month after removal of external fixation (A), at 1 year after surgical resection (B) and at 4 years after surgical resection (C) show that the femoral head slightly indicated an osteoarthritic change at 4 years after surgery. The patient is able to walk without crutch or cane at the most-recent followup (9 years postoperatively).

Fig. 7A-B Three-dimensional CT imaging show the limb length discrepancy of Patient 2 at 9 years postoperatively (A) and of Patient 4 at 6 years postoperatively (B)

Fig. 8A-C An AP view (A) and oblique views (B, C) of three-dimensional computed tomography imaging show semicircular resection of the acetabulum with remaining posterior part of posterior column of the pelvis at 2 years 9 months postoperatively of Patient 6.