The outcome of type 1 pelvic resection and reconstruction with pedicle screw-rod system without bone grafting in malignant pelvic tumour: A case series and short term review

Vivek Ajit Singh1, Nor Faissal Yasin1, Azura Mansor1, Ahmed Elsiddig Mohamed Elhadi and Mohd Ariff Sharifudin2

Abstract

Introduction: There is no consensus regarding the reconstruction method for type 1 resections around the pelvis. Various methods are currently used, such as resection without reconstruction, bone graft (autologous, recycled, allograft) with simple fixation, and pedicle screw-rod fixation with or without bone grafting. We aim to study the outcome of pedicle screw-rod reconstruction without bone grafting in type 1 pelvic resections involving sacroiliac joint to show that pedicle screw-rod construct alone is stable and has low risk of failure.

Material and methods: This is a retrospective review of eight patients who underwent type 1 resection of malignant pelvic tumours and reconstruction with a pedicle screw-rod system between 2011 and 2018. All patients who underwent type 1 resection and reconstruction with pedicle screw without bone grafting were included into this study. We reported their clinical (complication and radiological outcome), oncological (local recurrence and metastasis), and functional outcome based on Musculoskeletal Tumour Society Score (MSTS) and The Toronto Extremity Salvage Score (TESS) at their last follow-up.

Results: Eight patients were recruited into the study. The mean follow-up period was 58.5 months (range: 40 – 121 months). There were three postoperative complications in three different patients: superficial infection, surgical hernia with ipsilateral femoral avascular necrosis (AVN), and femoral nerve injury. At the end of the study period, one patient passed away due to disease progression, one patient was alive with disease, and the rest were disease-free. Mean MSTS score during last follow-up was 77.1% (range: 66.7% – 93.3%), while mean TESS score was 75.6% range (63.3% - 80.2%). There were no cases of implant failure.

Conclusion: Type 1 pelvic reconstruction with a pedicle screw-rod system is stable without a concurrent biological reconstruction, and it is feasible, with few complications, and an excellent functional outcome.

Keywords
Type-1 resection, short term outcome, pedicle screw-rod, functional score, pelvic tumours, case series

Date received: 13 May 2022; Received revised 8 July 2022; accepted: 27 July 2022

Introduction

Pelvis is a common site for bone tumours. Almost 10%–15% of all malignant bone tumours are in the pelvis. It is also the second most common site for bone metastases after the spine. Majority of bone tumours involving pelvis are usually those that metastasized.

Due to its late presentation and a complex anatomy, pelvic tumours pose a significant challenge to orthopaedic oncology surgeons. Before 1970s, most of these cases were...
treated with hindquarter amputation. Over the years, as limb salvage surgery progressed, internal hemipelvectomy gradually replaced amputation (external hemipelvectomy) as the standard treatment method for pelvic tumours. Enneking and Dunham classified pelvic resections into three types, of which resections of the ilium were type I. Resections involving the acetabulum were type II, while those involving ischium and pubic rami were type III. Pelvic resections are associated with multiple complications due to their complicated anatomy in relation to large vessels, nerve plexuses, intestines, urinary bladder, and internal sex organs. Some of these complications are related to the chosen reconstruction method. The outcome of these surgeries is less favourable due to many factors such as tumour size, local extension of tumour and anatomical complexity, and the proximity of pelvic viscera and major nerves and vessels.

Various reconstruction methods are currently employed for type I pelvic resections, ranging from no reconstruction to bone graft (vascularised and non-vascularised autograft, allograft, recycled autograft), or bone cement with or without fixation with implant ranging from plate and screws to pedicle screw-rod systems. Each method has its advantages and disadvantages. The pedicle screw-rod system is usually accompanied by structural bone grafting as a biological reconstruction for added stability and long-term longevity. However, several authors as shown in Table 2 reported complications such as infection, graft failure, and non-union, that were related to the use of bone graft.

This study aims to determine the outcome of pedicle screw-rod reconstruction without bone grafting for type I pelvic resections, to show that the pedicle screw-rod construct alone has a low risk of failure.

Material and methods

This is a retrospective study. We reviewed all patients who underwent internal hemipelvectomy (complete type I pelvic resection) through the sacroiliac joint with reconstruction using a pedicle screw-rod system without bone grafting for malignant pelvic tumours, from November 2011 to September 2020, with a minimum follow up of 3 years from surgery date. The malignant pelvic tumours included in this study were primary and secondary malignant bone tumours. The secondary malignant bone tumours included were ought to be either a localised metastasis or a single bone metastasis which requires a primary wide resection of the pelvis similar to a primary malignant bone tumour. The resections were performed following Enneking’s classification of pelvic bone tumours. We excluded patients who underwent other forms of resections, partial resections, or resections not involving the sacroiliac joint. All the surgeries were carried out by the senior author (single surgeon).

All patients had plain radiographs, magnetic resonance images (MRI), and computed tomography (CT) of the chest and pelvis taken to assess the tumour’s local and systemic extent, after which biopsy was carried out to obtain a histopathological diagnosis and grade the tumour. After reviewing all biomedical images, we planned the surgery.

We reported the clinical outcome, which consisted of associated complications, oncological outcome (local recurrence and metastasis), and functional outcomes. The functional outcome was assessed using the Musculoskeletal Tumour Society Score (MSTS Score) and Toronto Extremity Salvage Score (TESS). Data obtained were analysed with the Excel sheet software programme (Microsoft Office Excel 2013).

Surgical procedure

All surgeries were conducted under general anaesthesia. Bowel preparation was carried out the day before surgery. Prophylactic antibiotics were delivered at the time of induction of anaesthesia. Our institution’s common antibiotics for pelvic resections are intravenous Vancomycin and Metronidazole. The skin incision was made along the iliac crest from the posterior superior iliac spine to the anterior superior iliac spine, followed by dissection carried along with the iliac bone’s inner and outer tables. The patient was placed in the floppy lateral position on the operating table. The tumour was then exposed with a muscle cuff (iliacus in the internal table and the gluteus medius and minimus in the outer table). Subsequently, en-bloc resection was performed through the sacroiliac joint posteriorly and an osteotomy through a major sciatic notch anteriorly in the supra-acetabulum area (sparing the acetabulum) after isolating major blood vessels and nerves and protecting of pelvic viscera. Pelvic ring reconstruction was performed by inserting two polyaxial pedicle screws into the sacrum (intrapelvic fixation) and two polyaxial screws into the remaining pelvic bone after resection, at the supra-acetabular region along the iliopectineal and ilio-ischial lines. These screws were then connected with a rod to complete the pelvic ring, as shown in Figure 1.

Results

A total of eight patients (six males and two females) underwent type-I pelvic resection with pedicle screw-rod reconstruction without strut graft or cement augmentation for malignant bone tumours. The mean age was 49.9 years (range 14 – 74 years), while mean follow-up duration was 58.5 months (range: 40 – 121 months). (Table 1).

All patients were diagnosed with malignant tumours. Five patients were diagnosed with primary bone tumours,
two had primary soft tissue sarcoma (STS) involving the iliac bone, and one had secondary metastatic disease. Among the primary bone tumours, two were cases of Ewing’s sarcoma (both received neoadjuvant chemotherapy and postoperative adjuvant chemotherapy and radiotherapy), while the other three were one case each of chondrosarcoma (treated with just surgical resection), malignant giant cell tumour (GCT), and pleomorphic sarcoma of the bone, out of which the latter two received postoperative radiation. For those with primary soft tissue sarcomas, one had low-grade myofibroblastic sarcoma eroding iliac bone while the other one had fibrosarcoma. Both patients received postoperative radiotherapy. The sole case of metastasis was secondary from uterine leiomyosarcoma, in which there was metastasis to the left iliac bone at the time of operation and lung metastasis. Lung metastasis was also present among patients with Ewing’s sarcoma and malignant GCT. The lung metastasis in the patient with Ewing’s resolved with chemotherapy, while the ones in the malignant GCT patient were observed and remained stable at last review.

Three patients developed postoperative complications. The first patient had superficial infection treated with debridement and intravenous antibiotics. The second patient developed a surgical hernia and ipsilateral femoral head avascular necrosis (AVN) due to partial erosion of the hip.

Figure 1. Shows an example of a 52 years old lady with Malignant GCT of the left ilium. (a) Plain radiograph shows rarefaction with irregularity within the left iliac bone. (b) CT scan shows destructive lesion within the left iliac bone sparing the left sacroiliac joint. (c) MRI shows heterogenous changes within the left ilium. (d) Shows intraoperative picture of the pedicle screw rod reconstruction. (e) Shows postoperative pedicle screw reconstruction of the left pelvis.
from one pedicle screw (iatrogenic). He was treated conservatively due to his age and comorbidities. The third patient had partial femoral nerve injury attributed to its proximity to the tumour. There were no cases of implant failures at last review.

The oncological outcome was as follows; one patient died due to primary disease progression, one was alive with disease, and the remaining patients were free of disease. The patient with chondrosarcoma developed soft tissue recurrence 2 years after the primary resection, and it was excised with clear margins.

The functional outcome at final follow up showed a mean MSTS score of 23.6 ± 3.0 (77.1% ± 21.9) \{range (20 – 28/66.7% – 93.3%)}; and a mean TESS score of 75.6% \{range (63.3% - 80.2%)}.

**Discussion**

With advances in diagnostic tools, therapeutic measures of chemotherapy, radiotherapy, and surgical techniques, internal hemipelvectomy has become the treatment of choice.\(^{10}\) Nevertheless, extensive resection surgeries performed to obtain tumour free margins usually result in structural defects, thus compromising the integrity of the pelvic ring.\(^{15,26}\)

Ogura et al. emphasised the importance of reconstruction after pelvic resection around the sacroiliac joint to restore the pelvic ring, which is essential for the pelvis and spinal column’s stability.\(^{9}\) These objectives could be achieved with a reconstruction that provides stability, hence preventing superior migration and collapse of the remaining hemipelvis.\(^{12}\) In contrast, Beadel et al.\(^{13}\) and Puri\(^{14}\) reported excellent results with type 1 resections without reconstruction, and their outcomes were compatible with those who underwent reconstruction. However, we favour reconstruction as we feel that it would prevent the superior migration of the pelvis, which is encountered in cases where no reconstruction is done and leads to limb length discrepancy. Our study is unique as we only used the pedicle screw and rod system for reconstruction and did not augment it with biological reconstruction (structural bone graft). The advantage of this technique is a shorter operating time, no donor site morbidity from fibular autograft, lower risk of infection and lower cost due to no usage of additional bone grafting (autografts or allografts). The advantage of using a structural bone graft as a biological form of reconstruction is that once it incorporates, it has a lower failure rate. However, we feel that this additional surgical procedure is unnecessary as the pedicle screw and rod reconstruction can be a permanently stable form of reconstruction. We could also avoid complications associated with the use of structural bone graft. The most dreaded complication in a pelvic reconstruction involving biological
Table 2. Shows comparison between this studies and the various studies published in the literature.

| Patients | Mean age | Gender | Follow up (months) | Diagnosis | Method | Complications | MSTS | TESS | Oncology outcome |
|----------|----------|--------|-------------------|-----------|--------|---------------|------|------|-----------------|
| Kamal¹   | Total 9 (type 11 case) | 62 years old | Female 16.1 | Metastatic | Bone cement spacer | Infection | 60% | NA | AWD |
| Ogura⁹   | 9        | 31     | 5 males 5 females | 55 | Chondrosarcoma 4 Ewing's 3 Osteosarcoma 2 | DBVFG +2 plates +4 pedicle screw system | 2 scoliosis 1 PID 2 deep infections 1 implant failure | 57% (23 – 86%) | NA | 3 dead 1 AWD 5 DF Mortality rate: 33% |
| Zhou¹¹   | 16       | 42     | 6 males 10 females | 35 | Chondrosarcoma 4 Osteosarcoma 3 Giant cell tumour 3 Angiosarcoma 1 Plasmacytoma 1 Synovial sarcoma 1 MFH 1 Adenocarcinoma 1 Transitional cell carcinoma 1 | Pedicle screw system + fibula graft + Bone chips | 2 infection 1 skin necrosis | 94.6% | NA | 4 dead 6 AWD 6 DF Mortality rate: 25% |
| Lin peng¹² | 30       | 40.7   | 16 males 14 females | 40.4 | Chondrosarcoma 9 Osteosarcoma 6 Giant cell tumour 4 Metastatic Ca 4 ABC 1 Benign tumours 3 MFH/Fibrosarcoma 2 Ewings 1 | Pedicle screw system | Wound complication 3 Infection 1 bone non union 5 implant failures | 81% | NA | 9 local recurrence 10 metastasis 8 DF 11 dead Mortality rate: 37% |

(continued)
| Patients | Mean age | Gender | Follow up (months) | Diagnosis | Method | Complications | MSTS | TESS | Oncology outcome |
|----------|----------|--------|--------------------|-----------|--------|---------------|------|------|-----------------|
| Beadel13 | 16       | 35 no recon 6 male 45 - no recon 10 female 43 recon | Chondrosarcoma 7 Osteosarcoma 3 Ewing’s 2 Giant cell tumour 3 | 4 biological 12 no recon | 1 graft fracture 1 graft removed due to infection 7 wound infection 2 abd hernia 1 disc PID 2 DVT 1 pulmonary Embolism 1 heterotopic ossification 1 ureteric obstruction 1 GI bleeding 1 sacral Osteomyelitis 1 neurogenic bladder 1 pubic rami stress fracture | No recon 58% (23–90) No recon: Recon: 72% (55–100) Recon: 68% (59–86) | 4 dead 12 DF | Mortality rate: 25% |
| Puri14   | Total 103 (38 type I and III) | 32 69 males 42 females | Chondrosarcoma 65 Ewing’s 25 Osteosarcoma 10 Synovial sarcoma 3 MFH 1 High grade sarcoma 1 Epitheloid hemangiothelioma 1 | 1 pedicle screw system 1 ECRT Other no reconstruction | Wound infection 4 1 nerve palsy 90% (type I and III) NA | 43 dead 14 AWD 46 DF | Mortality rate: 42% |
| Akiyama16 | 10 | 39.8 7 males 29 females | Chondrosarcoma 4 Ewing’s 3 Osteosarcoma 1 MPNST 1 MFH 1 | Non vasculised fibula Non union 4 75.4% NA | 1 dead 1 AWD 8DF | Mortality rate: 10% |
| Nishida J17 | 5 | 38.9 2 males 76 females | Chordoma 1 Giant cell tumour 3 Schwannoma 1 | Vascularised bone graft + pedicle screw system | I wound complication 92% NA | 5 DF | Mortality rate: 0 |
| Patients | Mean age | Gender | Follow up (months) | Diagnosis | Method | Complications | MSTS | TESS | Oncology outcome |
|----------|----------|--------|-------------------|-----------|--------|---------------|------|------|-----------------|
| Nassif NA\(^{18}\) 6 | 41 | 2 males 4 females | 33 | Chondrosarcoma 2 Fibrosarcoma 1 Ewing’s 1 Post radiation sarcoma 2 | Vascularised ilium graft + pedicle screw system | 4 pseudoarthrosis 1 implant failure 2 wound breakdown 1 infection | 72% | 66% | 1 dead Mortality rate: 17% |
| Sabourin\(^{19}\) 24 | 33.5 | 10 males 14 females | 57.6 | Chondrosarcoma 8 Ewing’s 8 Osteosarcoma 2 MFH 3 Malignant schwannoma 1 Hemangiopericytoma 1 Leiomyosarcoma 1 | Bone graft + pedicle screw system | Infection 33% Revision surgery 41% Pseudoarthrosis 41.7% | 61% | NA | 1 I dead 1 AWD 12 DF Mortality rate: 46% |
| Niethard M\(^{20}\) 27 (total) 6 (type 1) | 44.6 | 15 males 12 females | 33 | Total: Chondrosarcoma 8 Ewing’s 9 Osteosarcoma 4 Synovial sarcoma 1 MFH 1 Metastasis 4 | Bone graft (fibula and iliac crest) | Infected fibula graft | 56.3% (type 1) | NA | All: 7 dead 5 AWD 15 DF Mortality rate: 26% |
| Andrea angelini\(^{21}\) 129 (total) 23 (type 1) | 43.7 | 76 males 53 females | 75.6 | Total: Chondrosarcoma 80 Ewing’s 18 Osteosarcoma 17 Metastatic 4 Giant cell tumour 4 Spindle cell sarcoma 2 Others 2 | Type 1: Allograft 23 Total: Infection 23.6% | 70% (all) | NA | 33 dead 13 AWD 81 DF Mortality rate 26% |
| Yuen A\(^{22}\) 49 (total) 9 (type 1) | 43.2 | 25 males 24 females | 27 (total) | Total: Chondrosarcoma 12 Ewing’s 5 Osteosarcoma 5 Metastatic 5 Benign 6 | 1 vascularised fibula 1 bone cement | 2 infections | 76% | NA | Total: 19 dead Mortality rate: 39% |
| This study 8 | 49.9 | 6 males 2 females | 44 | Chondrosarcoma 1 Ewing’s 2 Pleomorphic sarcoma 1 Leiomyosarcoma 1 Myofibroblastic sarcoma 1 Malignant GCT 1 Fibrosarcoma 1 | Pedicle screw system | 1 infection 1 AVN hip 1 femoral nerve injury | 77.1% | 75.6% | 1 I dead 1 AWD 6 DF Mortality rate: 12.5% |

Abbreviations: Double barrel vascularised fibular graft (DBVFG); Alive with disease (AWD); Disease free (DF); Not Available (NA); Malignant fibrous histiocytoma (MFH); Malignant peripheral nerve sheath tumour (MPNST).
reconstruction is deep infection, as once it is established, the graft usually must be removed.

Various methods of reconstruction have been proposed in literature (Table 2), namely, biological reconstruction using vascularized or non-vascularized fibular graft, vascularized iliac autograft, bone cement with pedicle screw-rod system or plate and screws fixation, and bone cement alone.

Several complications were reported after pelvic resections, including infections and wound healing problems, bleeding, thrombosis, nerve and visceral injuries, and implants’ failure (Table 2). Our series’ complication rate was 37.5%, which was lower than other studies (40–60%). The low complication rate was probably due to multiple factors including relatively simple reconstruction, shorter operating time, and no additional bone grafting procedures.

Our series’ infection rate was only 12.5% (one out of eight patients), and it was a superficial infection. This was far less compared to other reported studies (22.2–30%). This was probably because we did not use any biological material like bone or foreign material like cement or polypropylene mesh, thus decreasing the possibility of infections. In our series, we had one case of a partial femoral nerve injury and one case of erosion of a hip due to the pedicle screw’s misplacement. There were no cases of visceral injuries, as reported in other studies.

One patient (12.5%) passed away 3 months after surgery due to primary disease progression (due to lung metastasis). Our mortality rate was lower compared to other studies (5.9–12.14) (22.2–30%). This was probably because we did not use any biological material like bone or foreign material like cement or polypropylene mesh, thus decreasing the possibility of infections. In our series, we had one case of a partial femoral nerve injury and one case of erosion of a hip due to the pedicle screw’s misplacement. There were no cases of visceral injuries, as reported in other studies.

We did not experience any implant failure in our series. However, Lin P et al. reported 22.7% implant failure, and their series used the pedicle screw-rod reconstruction augmented with either strut fibula graft or cementation. Similarly, other series which also utilised pedicle screw-rod systems for stabilisation, such as Zhou YJ Ogura K et al. Sabourin, and Nishida J also reported no implant failures. However, in these series, the reconstruction was augmented with bone graft as a form of biological reconstruction. It contrasts our series, where we only used pedicle screws and rods. Based on our series (Table 1), the longest survivor was 121 months (10 years) and the patient was disease free in his last follow up. The second longest survivors were four patients with a duration of 69–78 months (5.75 – 6.5 years) and all of them were disease free except one who passed away due to advanced disease. Based on this, majority of our construct (62.5%) can safely last a minimum of 5 years and up to 10 years without implant failure. This longevity is adequate to confer patients with stability for daily usage after completion of primary treatment.

We are of the opinion that the advantage of using just a pedicle screw-rod system alone compared to a combined implant and biological reconstruction is that shortens the operating time as there is one less procedure to be carried out, there is no donor site morbidity (the standard biological reconstruction done is fibula autograft), and a lower infection rate as biological material is not inserted into the operative site. Compared to biological reconstruction alone, implants give immediate stability, early weight-bearing, and a lesser possibility of early failure. However, biological reconstructions do have the advantage of longevity compared to implant reconstruction alone, provided they incorporate well to the host bone.

Our study’s mean MSTS score at final follow-up was 77.1%, which is compatible with other studies with type I pelvic resections reconstructed with pedicle screw-rod reconstruction (57% - 94.6%) The high scores might be attributed to early rehabilitation in these patients due to stable reconstruction and lower mechanical complications. The series with biological reconstructions reported a mixed functional outcome (MSTS) ranging from 51% to 75.4%. This is probably due to delay in full weight-bearing, as biological forms of reconstruction usually take time to incorporate into the host bone and become stable.

The limitation of this study is the small number of cases. This is due to rarity of the disease as established in previous studies. Hence, we only included patients of complete type I pelvic resections. Due to the rarity of the cases, it is not feasible to create a control group for this study. Furthermore, we were unable to compare the preoperative and the postoperative functional scores as this is a retrospective study, and the preoperative functional scores were not documented.

Conclusion

In conclusion, a pedicle screw-rod system without grafting is a reliable option of reconstruction in pelvic resections around the sacroiliac joint due to fewer complication rates, early rehabilitation, its feasibility, and the affordability of implants.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.
Funding
The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs
Vivek Ajit Singh https://orcid.org/0000-0001-8899-9266
Nor Faisa1 Yasin https://orcid.org/0000-0001-6524-8451
Mohd Ariff Shariﬁdun1 https://orcid.org/0000-0002-6796-2904

References
1. Kamal AF, Wahyudi M and Prabowo Y. Outcomes of pelvic resections from malignant pelvic tumours: a case series. Int J Surg Open 2019; 16: 34–39.
2. Garcia JG, Martinez A, Filho RJ, et al. Epidemiological characteristics of patients with pelvic tumours submitted to surgical treatment. Rev Bras Ortop 2018; 53(1): 33–37.
3. Müller PE, Dürre HR, Wegener B, et al. Internal hemipelvectomy and reconstruction with a megaprosthesi. Int Orthop 2002; 26(2):76–79.
4. Qureshi A, Ahmad Z, Azam M, et al. Epidemiological data for common bone sarcomas. Asian Pac J Cancer Prev 2010; 11:393–395.
5. Traub F, Andreou D, Niethard M, et al. Biological reconstruction following the resection of malignant bone tumors of the pelvis. Sarcoma 2013; 1–7.
6. Frassica FJ and Sim FH. Pathogenesis and prognosis. In: Sim FH (eds) Diagnosis and Management of Metastatic Bone Disease: A Multidisciplinary Approach. New York, NY: Raven Press; 1988. pp. 1–6.
7. Mavrogenis AF, Soutlanis K, Patapis P, et al. Pelvic resections. Orthopedics. 2012; 35(2): 232–243.
8. Enneking WF and Dunham WK. Resection and reconstruction for primary neoplasm involving the inominate bone. J Bone Jt Surg 1978; 60: 731–746.
9. Ogura K, Sakuraba M, Miyamoto S, et al. Pelvic ring reconstruction with a double-barreled free vascularised ﬁbula graft after resection of malignant pelvic bone tumor. Arch Orthop Trauma Surg 2015; 135: 619–625.
10. Zang J, Guo W, Yang Y, et al. Reconstruction of the hemipelvis with a modular prosthesis after resection of a primary malignant peri-acetabular tumour involving the sacroiliac joint. Bone Jt J 2014; 96: 399–405.
11. Zhou YJ, Yunus A, Tian Z, et al. The pedicle screw-rod system is an acceptable method of reconstructive surgery after resection of sacroiliac joint tumours. Contemp Oncol 2016; 20: 73–79.
12. Lin P, Shao Y, Lu H, et al. Pelvic reconstruction with different rod-screw systems following Enneking type I/I + IV resection: a clinical study. Oncotarget 2017; 8: 38978–38989.
13. Beadel GP, McLaughlin CE, Aljassir F et al. Iliosacral resection for primary bone tumors: is pelvic reconstruction necessary. Clin Orthop Relat Res. 2005; 438: 22–29.
14. Puri A, Pruthi M and Gulia A. Outcomes after limb sparing resection in primary malignant pelvic tumors. Eur J Surg Oncol 2014; 40: 27–33.
15. O’Connor MJ and Sim FH. Salvage of the limb in the treatment of malignant pelvic tumors. J Bone Jt Surg Am 1989; 71: 481–494.
16. Akiyama T, Clark JC, Miki Y, et al. The non-vascularised ﬁbular graft: a simple and successful method of reconstruction of the pelvic ring after internal hemipelvectomy. J Bone Jt Surg Br 2010; 92: 999–1005.
17. Nishida J, Shiraishi H, Okada K, et al. Vascularized iliac bone graft for iliosacral bone defect after tumor excision. Clin Orthop Relat Res 2006; 447: 145–151.
18. Nassif NA, Buchowski JM, Osterman K, et al. Surgical technique: Iliosacral reconstruction with minimal spinal instrumentation. Clin Orthop Relat Res 2013; 471: 947–955.
19. Sabourin M, Biau D, Babinet A, et al. Surgical management of pelvic primary bone tumors involving the sacroiliac joint. Orthop Traumatol Surg Res 2009; 95: 284–292.
20. Niethard M, Tiedke C, Andreou D, et al. Bilateral ﬁbular graft: biological reconstruction after resection of primary malignant bone tumors of the lower limb. Sarcoma 2013; 1–8,
21. Angelini A, Calabro T, Pala E, et al. Resection and reconstruction of pelvic bone tumors. Orthopedics. 2015; 38(2): 87–93.
22. Yuen A, Ek ET and Choong PF. Is resection of tumours involving the pelvic ring justiﬁed?: A review of 49 consecutive cases. Int Semin Surg Oncol 2005; 2(1): 9.
23. Enneking WF, Dunham W, Gebhardt MC, et al. A system for the functional evaluation of reconstructive procedures after surgical treatment of tumor of the musculoskeletal system. Clin Orthop Relat Res 1993; 286: 241–246.
24. Davis AM, Wright JG, Williams JI, et al. Development of a measure of physical function for patients with bone and soft tissue sarcoma. Qual Life Res 1996; 5(5): 508–516.
25. Davis AM, Bell RS, Badley EM, et al. Evaluating functional outcome in patients with lower extremity sarcoma. Clin Orthop 1999; 358: 90–100.
26. Huth JF, Eckardt JJ, Pignatti G, et al. Resection of malignant bone tumors of the pelvic girdle without extremity amputation. Arch Surg 1988; 123: 1121–1124.
27. Chang DW, Fortin AJ, Oates SD, et al. Reconstruction of the pelvic ring with vascularised double-strut ﬁbular ﬂap following internal hemipelvectomy. Plast Reconstr Surg 2008; 121: 1993–2000.
28. Sakuraba M, Kimata Y, Iida H, et al. Pelvic ring reconstruction with the double-barreled vascularised ﬁbular free ﬂap. Plast Reconstr Surg 2005; 116: 1340–1345.