Alloprosthetic Composite is a Suitable Reconstruction After Periacetabular Tumor Resection

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Abstract

Background Resection of a tumor of the pelvis is most disabling when the acetabulum is excised and a durable reconstruction of the defect is hard to achieve. All available methods are associated with frequent complications. Few large series have been published, and fewer have focused entirely on complete resections of the acetabulum. The use of an allograft-prosthetic composite allows customization on the operating table. However, while such composites restore anatomy and function of the pelvis the use of pelvic allografts is controversial and the durability is unknown.

Questions/purposes We therefore examined (1) the frequency of allograft and prosthetic failure, (2) positive and negative factors influencing the survival of the allograft prosthetic composite, and (3) function of patients with this reconstruction.

Patients and Methods We retrospectively evaluated 35 patients who had resection of the entire acetabulum and reconstruction with an allograft-prosthetic composite. Function was scored by the Musculoskeletal Tumor Society system. Followup in 24 survivors averaged 120 months (range, 61–188 months).

Results Greater than 75% of the allografts were still in place at last followup, and the original prosthetic reconstruction was still in place in 56%. Infection was an important negative factor for allograft survival. The average functional score was 72%, with better mean scores for patients who had reconstruction with a stemmed cup and an artificial ligament (average 89%).

Conclusions An allograft-prosthetic composite provides a versatile substitution of the pelvis and hip, with functional scores approximately 75% of normal.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution approved the human protocol for this investigation and 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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Introduction

Resection of large bone tumors of the pelvis is one of the most difficult challenges for the orthopaedic oncologist. Since its first description by Enneking and Dunham [6], internal hemipelvectomy has largely replaced hindquarter amputation as the preferred procedure for patients with pelvic bone sarcomas. The difficulty of resection, reconstruction, and postoperative rehabilitation varies depending on the extent of the tumor. Various reconstructive techniques, such as iliofemoral coaptation or pseudarthrosis, and ischiofemoral arthrodesis, have been proposed to stabilize the hip with or without limb shortening [8, 9]. Use of

a saddle or a custom pelvic prosthesis reportedly improves hip function in major resections [1, 10].

We believe the combination of a pelvic allograft and hip prosthesis is the most versatile type of reconstruction. It can be used in a wide variety of patients, including children [15, 17] and patients who have received chemotherapy [5]. However, the use of a large pelvic allograft generally is considered technically difficult and associated with a high rate of complications, including infection, nonunion, and fracture [4, 17]. While such composites restore anatomy and function of the pelvis the use of pelvic allografts is controversial and the durability is unknown. Whatever the method used for reconstructing the pelvic continuity, a functional hip is difficult to achieve.

Therefore, we determined: (1) the frequency of allograft and prosthetic failure, (2) the positive and negative factors influencing the failure of allografts and hip prostheses, (3) and the final functional result of patients in relation to the type of hip reconstruction performed.

Patients and Materials

Between November 1990 and March 2002, we treated 260 patients with bone and soft tissue tumors involving the pelvic area, including 140 who had a resection of a portion of the bony pelvis. Excluding resections not involving the hip and extraarticular hip resections for tumors located in the proximal femur, 63 patients had a periacetabular pelvic resection including the hip. Thirty-five of these patients underwent reconstruction with a combination of a massive allograft and a hip prosthesis and are the subject of this study. Gender, age, and type of tumor were recorded (Table 1). Nine patients died, seven from causes attributable to their disease, and two owing to causes unrelated to the tumor. Three of the patients who died had a local recurrence of the tumor, despite wide margins, and were treated by hindquarter amputation: one at 3 months, one at 11 months, and one at 29 months after the index operation. All three patients died of disseminated disease shortly after undergoing amputation. No other patient had local recurrence. No patients were lost to followup. The minimum followup of the 26 surviving patients was 61 months (mean, 120 months; range, 61–188 months). The study was approved by the institutional ethics committee, and patients were informed about the proposed surgical procedure and alternative procedures, and informed consent was obtained in each case.

In eight patients, the only surgical approach was the extended iliofemoral (lateral) approach, as described by Enneking and Dunham [6]. In all others, we added an inguinal extension to facilitate exposure of the internal pelvic mass and iliac vessels and nerves, including the

obturator bundle. In 14 patients where the tumor included the ischium or pubic area, we extended exposure into the perineum to access the ischiopubic ramus. To improve exposure of the posterior column of the pelvis, we performed an osteotomy of the greater trochanter in 12 patients, which we repaired using a tension band wire or cable grip device.

We classified the extent of the resection in three categories (Types I, II, and III), according to the method of Enneking and Dunham [6]. We performed an extraarticular resection in 25 cases, removing the entire hip en bloc during tumor excision. All reconstructions used a fresh, frozen, nonirradiated pelvic allograft, which was shaped to match the resected portion of the pelvis (Table 2). We thawed grafts in Rifampin solution (Lepetit, Milan, Italy) for 1 hour before use. After thawing, we performed cultures for aerobic and anaerobic organisms. For perioperative antibiotic prophylaxis, patients received tobramycin for 1 day and a third-generation cephalosporin for the duration of the hospital stay, followed by oral antibiotics for 6 weeks.

The first seven patients of the series (Group A) underwent our early technique (Fig. 1). We reconstructed the acetabulum using a bipolar cup (four patients), or a metal-backed cup cemented in the acetabular allograft. The surgical time averaged 8.35 hours (range, 6.5–10.5 hours). Group B consisted of 23 patients who underwent our intermediate technique (Fig. 2). In this group, we chose a variety of acetabular cups. In all cases, we inserted the acetabular implants with cement, and used bone screws to supplement the fixation of the cup to the allograft. In 21 cases, we placed a contoured neutralization plate along the innominate bone to protect the allograft from possible fracture of the medial acetabular wall. In the first 10 patients, the average surgical time was 8.5 hours (range, 6–11 hours), whereas the others averaged 6.5 hours (range, 6–7 hours). We used our latest technique on the five patients in Group C (Fig. 3). We selected a McMinn acetabular prosthesis (Waldemar Link, Hamburg, Germany), which incorporated a large central stem from 45 mm to 85 mm in length. This type of prosthesis did not use additional screws for fixation. We did not add a contoured neutralization plate in this group. The surgical time decreased to an average of 6 hours (range, 5–7 hours).

In all cases involving the iliac wing, we fixed the allograft with three or four large cancellous screws fitted with washers (Synthes, Paoli, PA, USA) that passed through the graft, into the sacrum (Fig. 2). For allograft-host junctions at the symphysis pubis, we brought the anterior plate across the contralateral pubic bone and fixed it with screws and locking nuts, or fixed the symphysis with screws and cerclage wires. In several patients, when the prosthetic joint was unstable, we fixed an artificial ligament

Table 1. Oncologic data for 35 patients included in the series

Number	Gender	Age (years)	Stage	Type	Margins	Postoperative chemotherapy	Local recurrence	Status	Patient followup (months)
1	M	61	IIA	CHS dediff	Wide	No	Yes	DOD	16
2	F	53	IIB	Central CHS	Wide	No	No	NED	171
3	M	29	3	GCT	Wide	No	No	NED	188
4	M	53	IA	Central CHS	Wide	No	No	NED	173
5	M	50	IB	Central CHS	Wide	No	No	NED	111
6	M	57	IIB	CHS dediff	Wide	No	No	NED	158
7	F	56	IIA	Central CHS	Wide	No	No	NED	168
8	F	37	IIB	Central CHS	Wide	No	No	NED	165
9	M	65	IIB	Central CHS	Wide	No	No	NED	157
10	M	21	3	Chondroblastoma	Marginal	No	No	NED	163
11	M	51	IIB	Central CHS	Wide	No	No	DOD	25
12	M	68	IB	Central CHS	Intralesional	No	No	DOC	13
13	F	25	IIB	Central CHS	Wide	No	No	NED	151
14	M	50	IIB	CHS dediff	Wide	No	No	NED	83
15	F	17	IIB	OGS	Wide	Yes	Yes	DOD	10
16	M	34	3	GCT	Wide/cont	No	No	NED	136
17	F	24	IIB	CHS dediff	Wide	No	No	NED	133
18	M	22	IA	Low grade OS	Wide/cont	No	No	NED	124
19	F	49	IIB	CHS dediff	Wide	Yes	No	NED	92
20	F	17	IIB	OGS	Wide	Yes	No	NED	112
21	M	40	3	GCT	Wide/cont	No	No	NED	112
22	F	59	IIB	Central CHS	Wide	No	No	NED	110
23	M	52	IB	Low grade OGS	Wide	No	No	NED	77
24	F	33	3	GCT	Wide	No	No	NED	102
25	F	49	IIB	CHS dediff	Wide	Yes	No	DOC	5
26	F	22	IIB	OGS	Wide	Yes	No	NED	95
27	F	51	IIB	SCS	Wide	Yes	No	DOD	86
28	F	48	IIB	CHS dediff	Wide	Yes	Yes	DOD	38
29	F	25	IIB	OGS	Wide/cont	Yes	No	DOD	30
30	M	49	IIB	SCS	Wide	No	No	NED	68
31	F	35	IIB	SCS	Wide	Yes	No	NED	63
32	M	38	IA	Central CHS	Wide	No	No	NED	86
33	M	40	IIB	Central CHS	Wide/cont	No	No	NED	67
34	F	39	III	OGS	Wide/cont	Yes	No	DOD	23
35	F	44	IIB	Central CHS	Wide	No	No	NED	61

OGS = osteosarcoma; GCT = giant cell tumor; CHS dediff= dedifferentiated chondrosarcoma; SCS = spindle cell sarcoma; cont =; NED = no evident disease; DOD = dead of disease; DOC = dead of other cause; cont = contaminated.

(SEM - Science et Medecine, Montrouge, France) under the plate of the innominate bone and attached it to the trochanter with staples to improve stability of the hip [15]. All patients had a prosthetic femoral stem placed in the femur, the type and design of which varied during the series. We cemented 12 of the stems, and press-fitted the others.

Margins were classified as intralesional, marginal, wide, and wide contaminated. A wide contaminated margin results when macroscopic evidence of tumor is found at the margins of the initial bone resection. In these cases,

additional bone resection is performed and both specimens are sent to the pathologist for evaluation. The final margin is confirmed by the pathologist based on the microscopic findings.

Patients had regular followups, usually four times each year for the first 3 years, every 6 months in the fourth and fifth years, and yearly thereafter. All patients were seen by the first author (DD) at last followup. During the visit, plain radiographs of the pelvis and CT scans of the chest were obtained to assess functional status, status of the disease,

Table 2. Data on the reconstructions for 35 patients included in the series

Number	Group	Type of resection	Section of iliopsoas	Artificial ligament	Surgical time (hours)	Infection	Joint instability	Fracture/nonunion	Acetabular failure	Status of the reconstruction	Allograft followup (months)	MSTS score/functional grade
1	A	I-II	Yes	No	9.5	No	Yes	No	Yes	Hindquarter amputation	11	Not evaluated
2	A	I-II	Yes	No	8.5	No	Yes	Fracture	Yes	Flail hip	171	8/Poor
3	A	I-II-III	No	No	9	No	No	Fracture	Yes	Stem and cup revised	188	16/Fair
4	A	I-II-III	Yes	No	8	No	Yes	Fracture	Yes	Flail hip	173	13/Poor
5	A	I-II-III	Yes	No	6.5	Yes	No	No	No	Hindquarter amputation	9	Not evaluated
6	A	I-II-III	Yes	No	6.5	Yes	Yes	Fracture	Yes	Flail hip	158	8/Poor
7	A	II	Yes	No	10.5	No	No	Fracture	Yes	Cup revised	168	17/Fair
8	B	I-II-III	No	Yes	9	No	No	Fracture	No	Intact	165	28/Excellent
9	B	II-III	No	Yes	11	No	No	No	No	Intact	157	27/Excellent
10	B	I-II-III	No	Yes	7.5	Yes	No	No	Yes	Cup revised	156	20/Fair
11	B	I-II-III	Yes	Yes	10	Yes	Yes	No	No	Hindquarter amputation	5	Not evaluated
12	B	I-II	Yes	No	6	No	No	No	No	Intact	13	Not evaluated
13	B	I-II-III	No	Yes	6.5	No	No	No	Yes	Cup revised	145	24/Good
14	B	I-II-III	Yes	Yes	10	Yes	No	No	No	Hindquarter amputation	1	Not evaluated
15	B	I-II-III	No	No	10	No	No	No	No	Hindquarter amputation	3	Not evaluated
16	B	I-II-III	No	Yes	7.5	Yes	No	No	Yes	Revised to saddle	60	17/Fair
17	B	I-II-III	Yes	No	7.5	No	Yes	No	No	Intact	133	23/Good
18	B	I-II-III	No	No	7	No	No	Nonunion	Yes	Revised to saddle	21	17/Fair
19	B	I-II-III	No	Yes	6	No	No	No	Yes	Cup revised	92	21/Fair
20	B	I-II-III	No	Yes	6	No	No	No	Yes	Cup revised (x 2)	112	19/Fair
21	B	II-III	No	Yes	7	No	No	No	No	Intact	112	30/Excellent
22	B	I-II	No	Yes	6	No	No	No	No	Intact	110	28/Excellent
23	B	I-II	No	Yes	7	Yes	No	No	Yes	Long revision stem/cup in sacral wing	29	Not evaluated
24	B	II-III	No	Yes	6	No	No	No	Yes	Revised cup	102	29/Excellent
25	B	I-II-III	No	Yes	7	No	No	No	No	Intact	5	Not evaluated
26	B	I-II	No	Yes	7	No	No	No	No	Intact	95	29/Excellent
27	B	II-III	No	Yes	7	No	No	No	No	intact	65	23/Good
28	B	I-II-III	No	Yes	6	No	No	No	No	Hindquarter amputation	29	Not evaluated
29	B	I-II-III	No	No	7	Yes	No	No	No	Cement spacer	2	Not evaluated
30	B	I-II	Yes	No	6	No	No	No	No	Intact - femoral fracture	68	17/Fair
31	C	I-II	No	Yes	7	No	No	No	No	Intact	63	25/Good
32	C	II-III	No	Yes	6	No	No	No	No	Intact	86	30/Excellent
33	C	I-II-III	No	Yes	7	No	No	No	No	Intact	67	27/Excellent
34	C	I-II-III	No	Yes	5	No	No	No	No	intact	23	Not evaluated
35	C	II-III	No	Yes	6	No	No	No	No	Intact	61	25/Good

Fig. 1 The radiograph shows the reconstructive technique used in patients in Group A. A bipolar hip prosthesis was used.

Fig. 2 A radiograph shows the reconstructive technique used in patients in Group B. We supplemented acetabular fixation with screws and placed a contoured neutralization plate along the innominate bone.

and status of the reconstruction. We calculated functional scores using the Musculoskeletal Tumor Society functional evaluation instrument [7].

Fig. 3 A radiograph shows the reconstructive technique used in patients in Group C. A stemmed cup was used and the neutralization plate was eliminated.

Three of us (DD, HD, CDB) independently evaluated all radiographs. We specifically examined for radiographic signs of union, resorption of the graft, and failure or migration of the osteosynthesis devices and the prosthetic components, comparing the last xray films with all previous ones, including the postoperative control. Union was defined as the bridging of the host-graft junctions combined with the absence of migration. Failure of union was defined as the absence of union by 1 year after surgery. Allograft resorption was present when greater than 1 cm of the margins or body of the allograft progressively eroded with time, or when large progressive lucencies appeared around the fixation devices. We observed gradual surface remodeling of the allograft in patients with longer followup, but this was not defined as resorption. Failure of the prosthetic reconstruction was defined as removal or revision of the femoral or acetabular components. Migration of the prosthetic or osteosynthesis implants was defined as the presence of a halo associated with movement greater than 5 mm from the original postoperative position.

We expressed all continuous data in terms of mean $\pm$ standard deviation, and the grouping variables as proportions or percentages. We determined the allograft and acetabular prosthesis survival using Kaplan-Meier analysis [11]. The end point for allograft survival was amputation or allograft removal, whereas revision surgery was the end point for acetabular cup. We determined the influence of gender, extent of the resection, type of reconstruction, chemotherapy, and presence of the artificial ligament using

Kaplan-Meier with the log-rank test with the same end points. We used Cox regression univariable analysis to assess the influence of continuous data (age). Finally, we performed the Cox regression multivariable analysis (with Wald's backward method) to identify the most important factors influencing graft survival and mechanical complications. Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) software version 9.0 (SPSS Inc, Chicago, IL, USA).

Results

The probability of having the allograft in place was greater than 75% for as many as 13 years followup (Fig. 4). The probability of retaining the original prosthetic reconstruction was 56% after 12 years followup (Fig. 5). Excluding the eight patients who died with short followup and the three in whom reconstruction failed owing to early deep infection, 24 patients with more than 2 years followup were

Fig. 4 A Kaplan-Meier plot shows the cumulative survival of the allograft evaluated for the 35 patients. A number of early failures occurred, but greater than 75% have survived at 13 years followup. Late failures highlight the need for long-term followup.

Fig. 5 A Kaplan-Meier plot shows the cumulative survival of the acetabular prosthesis evaluated for the 35 patients in the series. Infection and local recurrence account for a 20% failure rate during the first 2 years. At 12 years, greater than 50% of the original acetabular prostheses have survived.

available for analysis of late mechanical complications and functional results. In this group, the mean followup was 121 months (range, 61–188 months). Of these 24 evaluable patients, 12 experienced failure of the reconstruction after an average of 57 months (median, 46 months; range, 14–136 months). In Group A, reconstructions failed in all five evaluable patients; three patients ended with flail hip and two underwent an acetabular revision with a cage. Among the 16 evaluable patients in Group B, nine retained their original joint and seven has failed reconstructions. Two had saddle prosthesis replacements, whereas the other five were treated with cage-type augmentation plates. Of the three evaluable patients in Group C, none had undergone revision after an average followup of 71 months. However, in two patients, a lucent line or halo developed around the proximal part of the stem, but the patients were without symptoms at 2 years followup.

The only factor that negatively influenced ($p = 0.001$) allograft survival was infection, whereas gender, extent of the resection, type of reconstruction, and chemotherapy did not. Infection ($p = 0.001$) and chemotherapy ($p = 0.027$) increased the probability of graft failure. A deep infection developed in eight patients (23%), six of whom ultimately underwent removal of the allograft. Altogether, patients with an artificial ligament had better ($p = 0.001$) prosthetic survival than those without.

The mean Musculoskeletal Tumor Society score was 72% (range, 27–100%). The scores showed considerable improvement as the surgical technique evolved. The average score was 41% (range, 27–57%) in Group A, 78% (range, 57–100%) in Group B, and 89% (range, 83–100%) in Group C.

Nonunion at the ilioiliac allograft-host junction occurred in one patient, and the allograft was replaced by a saddle prosthesis. Clinical union at the iliosacral allograft-host interface was achieved successfully by all patients. Six patients had nonunion or resorption of the pubic-allograft host interface, with breakage of the plate and/or screws, but this did not affect their functional status. Fracture of the allograft was the cause of acetabular failure in five patients, all occurring in Group A at 19, 22, 25, 36, and 128 months postoperatively. Of these five patients, three had joint instability with marked pistoning of the prosthetic hip. This complication was avoided with the use of the artificial ligament.

Discussion

The surgical treatment of tumors of the pelvic bones requiring resection of the entire acetabulum is a formidable problem. Pelvic continuity and durable hip function are difficult to achieve. The use of allograft combined with hip

prosthetic replacement is a versatile means of reconstruction, which can accommodate the entire range of defects left by the tumor resection [2–4, 14, 17, 18]. However, the use of an allograft can be burdened by some complications, such as infection, fracture, and nonunion. Moreover, osseointegration between the allograft and the acetabular prosthesis is difficult to achieve, and nonunions can be caused by late failure of the allograft prosthetic implant. We specifically determined (1) the frequency of allograft and prosthetic failure, (2) positive and negative factors influencing the survival of the allograft prosthetic composite, and (3) the function of patients with this reconstruction.

Our study has some limitations. First, the primary independent variables, which are the tumor procedure and the reconstructive procedure, have an inconstant and uniquely confounding effect on the dependant variables of allograft survival and prosthesis survival. The difficulty in disentangling these two variables limits the internal validity of this study, as it does in many studies of this type. We included only a narrowly defined subset of all the pelvic reconstructions performed at our institution, yet many uncontrolled variables remain. Uncontrolled variables include tumor grade, extent, and treatment, patient age, preoperative functional status, body mass index, and others. A more tightly defined group would improve the internal validity of the study at the expense of generalizability. Second, we have compared our most recently treated patients with a group of patients treated very early on. The observed differences between the groups may be explained partly by ongoing changes in the overall process of surgical care, rather than changes in surgical techniques. In addition, as acetabular failure and allograft failure become more likely with time, it also is possible that the differences we observed between the groups will disappear with longer followup. There have been only five previous reports of internal pelvic resections replaced with an allograft and a hip prosthesis (Table 3). It is difficult to compare those results with results of our series because of differences in tumor type, extent of resection, reconstruction methods, and length of followup [13]. Additionally, comparison of periacetabular reconstruction outcomes is hampered by differences in the source and treatment of the grafts [12, 17].

We observed three local recurrences (9.5%), a rate similar to other series. All three occurred in resections classified as wide. Mankin et al. [16] reported a local recurrence rate of 7% including all internal pelvic resections performed for malignant tumors, and others have reported rates ranging from 4.5% to 29% (Table 3). The risk of local recurrence depends on several factors, including the quality of the margin, the invasiveness of the tumor, and the application of adjuvant treatments such as

chemotherapy. In the series by Delloye et al. [5], four of seven local recurrences occurred after a wide margin, and similar results were reported by Bell et al. [2]. In our series, low-quality margins (intralesional, marginal, and wide contaminated) were present in eight resections. Six of these were in benign or low-grade malignant tumors, and two in high-grade tumors. Despite the low-quality margins, none of these patients had a local recurrence. We believe this may be partly attributable to patient selection. Patients who were selected for this technique had acetabular tumors with limited extension into the sacroiliac and pubic regions and limited involvement of the gluteal musculature. Based on our experience, these patients were likely to have a better functional outcome. As a result, less invasive tumors were selected which may have lowered the risk of local recurrence.

Allograft failure has been reported to range from 20% to 41% [2, 5, 17, 18]. Delloye et al. [5] reported the lowest rate of allograft failure; however, only 13 patients had reconstruction with a hip prosthesis and the average followup was relatively short (41 months). In this study, only three patients had more than 36 months followup, and two of them reported allograft failure. Ozaki et al. [17] reported data for 22 patients, with only 10 having a Type II resection and reconstruction. In our series, 35 patients were included, all of whom were treated with an allograft and hip prosthetic reconstruction, and with a mean followup of 121 months for the 24 long-term survivors. Our allograft failure rate was 25%, including amputation for local recurrence and deep infection. Infection is one of the most problematic complications that can occur in pelvic allografts [3, 5, 18]. In six of the eight patients with deep infections in our series, the allograft ultimately was removed. Two of these infections were related to contaminated allografts, which raises the question of whether irradiation of the allograft might reduce the risk of this complication. Based on the negative data reported by Ozaki et al. [17], we believe irradiation of the allograft leads to a substantial increase of failure risk; however, not enough data exist to definitively answer the question. Shorter surgical times and simplified reconstructive techniques also may decrease the infection rate. Prolonged administration of antibiotics is not sufficient to avoid this critical complication.

There are no reports specifically dealing with long-term results of the allograft prosthetic composite in the hip; however, several complications in the hip are reported (Table 3) to lead to failure in a wide range of cases (from 0% to 67%) with relatively short mean followup (41–96 months). We reported 50% acetabular revision in patients with an average of 121 months followup. Allograft fracture is still a major concern in this type of reconstruction; it frequently leads to failure of the implant and

Table 3. Published data on alloprosthetic composites after pelvic resections

Study	Period of study (years)	Number of patients	Mean age (years)	Tumor grade	Local recurrence (%)	Type of resection	Allograft irradiation	Allograft failure	Patients with hip prosthesis and allograft	Hip prosthesis complication	Mean followup (months)	Mean MSTS score
Ozaki et al. [17]	6	22	27	19 high grade, 3 low grade	1 (4.5)	12 type I, 10 type II	19 irradiated	41%	9	67%	48 (18 long-term survivors)	1 good, 2 fair (3 patients)
Bell et al. [2]	12	17	40	All high grade	3 (17.6)	All type II	16 irradiated	29%	14	0	84 (8 long-term survivors)	Enneking score 62% (8 patients)
Yoshida et al. [18]	20	19	43	14 high grade, 1 low grade, 4 benign		All type II	No, sterilely procured	37%	11	36%	57 (all patients)	37% satisfactory results, all patients, Mankin score
Langlais et al. [14]	14	13	Not reported	3 metastasis, 7 high grade, 2 low grade, 1 benign	2 (15)	10 type II, 3 proximal femur resection	No, sterilely procured	Not reported	12	20%	96 (6 long-term survivors)	56.4% (12 patients)
Delloye et al. [5]	18	24	34	12 high grade, 9 metastasis, 3 low grade	7 (29)	6 type I, 18 type II	No, sterilely procured	20%	13	38%	41 (all patients)	73% (23 patients)
Current study	12	35	42	24 high grade, 6 low grade, 5 benign	3 (8.5)	All type II	No, sterilely procured	25%	35	50%	121 (24 long-term survivors)	72% (24 patients)

acetabular cup loosening. The problem of the acetabular bone weakening can be limited by saving the graft subchondral bone, as proposed by Bell et al. [2]. The use of a stemmed cup helps achieve the necessary fixation, avoiding the need for insertion of screws or a contoured plate inside the pelvis, eliminating potential weakening of the allograft by drill holes, and reducing the operative time. However, the McMinn cup and its stem must be fully seated to be stable. This may be the reason we had some subsidence of the prosthesis stem in the first two patients who underwent surgery. A high number of fractures occurred in the early cases, with marked joint instability. We use an artificial ligament to reduce joint instability, which appears effective based on our data.

Functional outcome scores after periacetabular tumor resections have been reported. Bell et al. [2] evaluated eight of 17 patients according to the rating system of the Musculoskeletal Tumor Society, and found a mean score of 62% in eight long-term survivors. Delloye et al. [5] reported a mean score of 73%, including all patients with all types of reconstruction. In our series, the mean Musculoskeletal Tumor Society score (72%) is comparable to scores in those series. The optimal joint function and long-term durability could be achieved, improving muscle balance (preserve iliopsoas whenever possible), cup fixation, and joint stability, as observed by the better result achieved in Group C versus Groups A and B.

Despite the substantial risk of complications, we recommend this type of reconstruction for patients younger than 60 years with resectable periacetabular pelvic tumors, for whom postoperative radiation is not planned.

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References

1. Aboulafia AJ, Buch R, Mathews J, Li W, Malawar MM. Reconstruction using the saddle prosthesis following excision of primary and metastatic periacetabular tumors. *Clin Orthop Relat Res*. 1995;314:203–213.
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. Boyle MJ, Hornicek FJ, Robinson DS, Mnaymneh W. Internal hemipelvectomy for solitary pelvic thyroid cancer metastases. *J Surg Oncol*. 2000;75:3–10.
4. Capanna R, van Horn JR, Guernelli N, Briccoli A, Ruggieri P, Biagini R, Bettelli G, Campanacci M. Complications of pelvic resections. *Arch Orthop Trauma Surg*. 1987;106:71–77.
5. Delloye C, Banse X, Brichard B, Docquier PL, Cornu O. Pelvic reconstruction with a structural pelvic allograft after resection of a malignant bone tumor. *J Bone Joint Surg Am*. 2007;89:579–587.
6. Enneking WF, Dunham WK. Resection and reconstruction for primary neoplasms involving the innominate bone. *J Bone Joint Surg Am*. 1978;60:731–746.
7. 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;286:241–246.
8. 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;397:29–35.
9. Gerrand CH, Bell RS, Griffin AM, Wunder JS. Instability after major tumor resection: prevention and treatment. *Orthop Clin North Am*. 2001;32:697–710, ix–x.
10. Jaiswal PK, Aston WJ, Grimer RJ, Abudu A, Carter S, Blunn G, Briggs TW, Cannon S. Peri-acetabular resection and endoprosthetic reconstruction for tumours of the acetabulum. *J Bone Joint Surg Br*. 2008;90:1222–1227.
11. Kaplan EL, Meier P. Nonparametric estimation from incomplete observations. *J Am Stat Assoc*. 1958;53:457–481.
12. Kim HS, Kim KJ, Han I, Oh JH, Lee SH. The use of pasteurized autologous grafts for periacetabular reconstruction. *Clin Orthop Relat Res*. 2007;464:217–223.
13. Kollender Y, Shabat S, Bickels J, Flusser G, Isakov J, Neuman Y, Cohen I, Weyl-Ben-Arush M, Ramo N, Meller I. Internal hemipelvectomy for bone sarcomas in children and young adults: surgical considerations. *Eur J Surg Oncol*. 2000;26:398–404.
14. Langlais F, Lambotte JC, Thomazeau H. Long-term results of hemipelvis reconstruction with allografts. *Clin Orthop Relat Res*. 2001;388:178–186.
15. Langlais F, Vielpeau C. Allografts of the hemipelvis after tumor resection: technical aspects of four cases. *J Bone Joint Surg Br*. 1989;71:58–62.
16. Mankin HJ, Hornicek FJ, Temple HT, Gebhardt MC. Malignant tumors of the pelvis: an outcome study. *Clin Orthop Relat Res*. 2004;425:212–217.
17. Ozaki T, Hillmann A, Bettin D, Wuisman P, Winkelmann W. High complication rates with pelvic allografts: experience of 22 sarcoma resections. *Acta Orthop Scand*. 1996;67:333–338.
18. Yoshida Y, Osaka S, Mankin HJ. Hemipelvic allograft reconstruction after periacetabular bone tumor resection. *J Orthop Sci*. 2000;5:198–204.