Constrained Total Hip Megaprosthesis for Primary Periacetabular Tumors

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Abstract

Background Limb-salvage reconstruction for periacetabular malignant tumors is one of the most challenging problems in orthopaedic oncology. Reconstructive options include resection arthroplasty, endoprosthesis, allograft, recycled autobone graft, arthrodesis, and pseudarthrosis. However, no standard procedure exists because of rarity and clinical variability of the

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disease. We previously developed a megaprosthesis system with a constrained total hip mechanism (C-THA).

Questions/purposes We evaluated (1) survival of patients and C-THA; (2) postoperative function; and (3) complications.

Methods We retrospectively reviewed 25 patients with primary periacetabular tumors treated using C-THA between 1985 and 2009. There were 18 male and seven female patients with a median age of 44 years (range, 16–72 years). They included 11 chondrosarcomas, eight osteosarcomas, two giant cell tumors of bone (one locally aggressive benign, one malignant), and others in four. Surgical margin was wide in 18 patients, marginal in five, and intralesional in two. The minimum postoperative followup for survivors was 32 months (median, 163 months; range, 32–285 months).

Results The 10-year overall survival rate of all patients was 47%. C-THA implants survived in 19 of 25 patients at last followup. Twenty-one patients acquired ambulatory activity. There were seven local recurrences, resulting in hemipelvectomy in one patient. Postoperative complications included deep infection in eight of the 25 patients, dislocation in four, and aseptic loosening in two, necessitating five revision surgeries and three implant removals.

Conclusions Our observations suggest C-THA using an acetabular reconstruction cup is a useful reconstructive option after resection of periacetabular malignant tumors despite frequent postoperative complications.

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

Introduction

Limb-salvage surgery for primary malignant bone tumors in extremities has become a standard procedure with a variety of limb reconstruction techniques such as tumor

megaprosthesis after wide local excision combined with neoadjuvant chemotherapy and/or radiotherapy [35]. However, limb-salvage reconstruction of malignant pelvic tumors, especially in the periacetabular region, remains challenging because of the complex anatomy, the difficulty achieving wide surgical margins, and large bone and soft tissue defects after tumor resection. The reconstructive options include resection arthroplasty [7, 30, 33], iliofemoral or ischiofemoral arthrodesis [9, 12], hip transposition method (pseudarthrosis) [3, 12, 32], free-vascularized fibular graft for pelvic ring reconstruction [29], allograft [2, 22, 23, 26, 39], recycled autologous bone graft [16, 20], and endoprosthetic replacement [1, 4, 11, 14, 18, 21, 24, 25, 27, 28, 34, 36–38]. However, no standard reconstructive procedure exists after internal hemipelvectomy for malignant periacetabular tumors. Most of these procedures are associated with a high rate of postoperative complications such as delayed wound healing, infection, dislocation, aseptic loosening, limb-length discrepancy, and local recurrence [17].

In 1985 we developed a novel endoprosthesis system with a constrained hip mechanism (C-THA) to obtain iliofemoral stability with better function after resection of periacetabular malignant tumors. We previously reported the preliminary results of 13 patients with primary and five with metastatic periacetabular malignant tumors reconstructed with this C-THA, indicating its ability to achieve immediate iliofemoral stability with acceptable postoperative function [34]. However, our previous report showed only short-term outcomes of the C-THA with a mean followup period of 39 months (range, 6–96 months).

We therefore determined (1) patient and C-THA implant survival; (2) postoperative function; and (3) major complications with medium- to relatively long-term followup.

Patients and Methods

We retrospectively reviewed 25 patients with primary periacetabular tumors treated with C-THA reconstruction after resection of the primary tumors between 1985 and 2009. All patients were treated in one of three tertiary referral hospitals affiliated with the Osaka University Orthopaedic Oncology Group. Of these, 13 patients were reported in our previous publication [34]. There were 18 male and seven female patients with a median age of 44 years (range, 16–72 years). They included 22 patients with primary malignant bone tumors (chondrosarcoma in 11, osteosarcoma in eight [including one parosteal osteosarcoma], malignant giant cell tumor [GCT] of bone in one, Ewing's sarcoma in one, malignant fibrous histiocytoma in one), one locally aggressive benign GCT of bone, and two patients with soft tissue sarcomas (liposarcoma in one, synovial sarcoma in one). Musculoskeletal Tumor Society

(MSTS) surgical stage [10] was IB in two patients, IIB in 19, III in three, and one patient with benign GCT. Three patients had pulmonary metastasis at presentation, one of which also had concomitant bone metastasis. The primary tumors were located at the ilium in 11 patients, proximal femur in 10, ischiopubic bone in two, and groin in two. All but one patient underwent C-THA as a primary reconstructive surgery, and the other one received C-THA as a revision surgery for postoperative infection and loosening of the initial long-stem THA for an ischiopubic parosteal osteosarcoma. Pre- and/or postoperative adjuvant chemotherapy, including only preoperative intraarterial chemotherapy, was performed in 23 patients with high-grade tumors. Four patients (three high-grade chondrosarcomas, one Ewing's sarcoma) received postoperative radiotherapy (48–50 Gy). No patients were lost to followup. The minimum postoperative followup for survivors was 32 months (median, 163 months; range, 32–285 months). No patients were recalled specifically for this study; all data were obtained from medical records and imaging. We had prior institutional review board approval.

After carefully determining local extension of the tumor and its relationship to major neurovascular bundles, surrounding muscles, and other important intrapelvic structures by MRI and CT scan, we planned and performed wide resection of the tumors in the lateral position, basically using the skin incision recommended by Enneking and Dunham [9]. The type of pelvic resections according to the classification system by Enneking and Dunham [9] was Type II resection in 12 patients, Types I + II in seven, Types II + III in four, and Types I + II + III in two. After local excision of the tumor, reconstruction using the C-THA was subsequently performed.

The prosthesis consists of three major components, including (1) a metallic outer cup with a blade plate for fixation to residual ilium and sacrum; (2) proximal femoral component with a long stem; and (3) an ultrahigh-molecular-weight polyethylene (UHMWPE) bearing insert with a constrained mechanism connecting the outer cup to the femoral implant (Fig. 1A–B). The prototype of the outer cup without the blade was initially manufactured in 1985 from an outer head of a bipolar hip arthroplasty implant by adding several holes for screw fixation to the remaining pelvic bone and was used in the first four cases. Then in 1987, we developed an original acetabular reconstruction cup with a blade plate (Hip Reconstruction Cup®; Japan Medical Materials, Osaka, Japan) for further screw fixation to the remaining pelvic bone and grafting bone to reduce postoperative loosening of the outer cup.

The details of the surgical technique were previously described in our first report [34]. Briefly, (1) a cavity for placement and fixation of the metallic outer cup was made on the remaining ilium and sacrum using an acetabular

Fig. 1A–C The modular reconstruction system with a constrained total hip mechanism for periacetabular malignant tumors. (A) This system consists of three components. (B) The original acetabular reconstruction cup system with a blade plate (Hip Reconstruction Cup[®]; Japan Medical Materials) and (C) combined with these components.

reamer. In selected cases, bone grafting with a resected femoral head, autogenous fibula, and/or residual iliac wing, or allograft was required in the anterior and lateral portions of the remaining ilium or in the sacrum to ensure enough bony bed for outer cup fixation and to fix the sacroiliac joint; (2) the outer cup was placed and then fixed to the remaining iliac wing and sacrum using screws, usually three or four screws through the cup holes and one or two screws through the cup blade, and bone cement containing antibiotic powder. As for the timing of cement fixation, inserted screws were slightly loosened, and bone cement was then packed into the space between the cup and the supporting bony bed. The loosened screws were then tightened quickly before packing cement polymerized solidly; (3) the proximal femoral component with the inner head was implanted and fixed with bone cement or cementless fixation to the remaining femur and then the outer cup and proximal femoral component were firmly connected with a UHMWPE bearing insert, thereby completing the constrained hip mechanism (Fig. 1B–C). Several different types of proximal femoral components were used between 1985 and 2002, depending on the surgeon's selection, including the Kyocera Physio-Hip System (Kyocera, Osaka, Japan) in 13 patients, Kotz/Howmedica Modular Resection System (Howmedica/Stryker, Portage, MI, USA) in six (including two patients treated with total femur replacement), K-Max Hip System (Kobelco, Kobe, Japan) in one (Fig. 2), and at present we used the femoral component of Kyocera Limb-Salvage Modular

Reconstruction System (Japan Medical Materials) with cementless fixation for primary malignant periacetabular tumors in five patients. After completing the reconstruction, the wound cavity was thoroughly washed with a jet irrigator device, and a suction drainage tube was placed into the wound for approximately 1 or 2 weeks until the draining fluid decreased to less than 50 mL per day. To reduce postoperative infection, we have routinely used peri- and postoperative antibiotics, a laminar airflow-conditioned operating room, and since the mid-1990s we have also introduced air-conditioned disposable surgeon hoods for endoprosthesis surgery.

Wide surgical margins were achieved in 18 patients, marginal in five, and intralesional in two. Intralesional surgical margins were unavoidably experienced in two patients, both with huge iliac chondrosarcomas, which we had been preoperatively planned to resect with wide margins, but the margins were contaminated during resection. Surgical margins were estimated by assessment macroscopically using whole resected tumor specimens and microscopically at least five or more cross-sectional samples. Three patients required extraarticular resection, and the sciatic nerve was sacrificed in one patient because of direct tumor invasion. Seven patients experienced local recurrence: iliac chondrosarcoma in four patients and ischiopubic chondrosarcoma, iliac osteosarcoma, and groin liposarcoma in one patient each.

Patients were permitted out of bed 2 to 7 days after surgery and bear weight within 2 to 4 weeks. The postoperative

Fig. 2 A 39-year-old female patient with right ischiopubic parosteal osteosarcoma. She underwent C-THA reconstruction using a Hip Reconstruction Cup® (Japan Medical Materials, Osaka, Japan) combined with a proximal femoral implant of the K-Max Hip System (Kobelco, Kobe, Japan) as revision surgery for salvage after deep infection and loosening of the primary endoprosthesis. She could walk with a single cane until the last followup of 176 months after C-THA revision surgery and was continuously disease-free for 285 months after initial definitive surgery.

rehabilitation was planned on a case by case manner without a standardized protocol. Given the patients were treated over a long period, the postoperative rehabilitation has been considerably changed over time.

Patients were followed at our outpatient clinic at least every 2 to 3 months within the first 2 years after surgery and then 3 to 6 months or annually. At each visit we performed a physical examination and obtained chest radiographs. Chest CT with/or without local MRI was obtained at 6- or 12-month intervals. At last followup, function was assessed using the MSTS/ISOLS functional evaluation system [8]. We defined postoperative complications requiring surgical interventions as major complications and all other complications as minor according to the classification proposed by Dingo et al. [6].

Patient and implant survival was estimated by the Kaplan-Meier method [19] calculated from the date of definitive surgery to the time of patient death or of implant removal/revision or the last followup for survivors, respectively. To estimate implant survival, patient death was interpreted as censored. JMP Version 9.0 statistical analysis software (SAS Institute, Cary, NC, USA) was used for these analyses.

Results

The cumulative overall survival rate of all patients was 47% at both 5 and 10 years postoperatively (Fig. 3). At last followup, eight patients were continuously disease-free for 32 to 285 months (median, 163 months). Two additional patients were alive with no evidence of disease: one a 33-year-old man surviving at 143 months with a large iliac low-grade chondrosarcoma after hindquarter amputation for local recurrence and one a 53-year-old woman

surviving at 189 months with proximal femoral osteosarcoma who had resection of a rib metastasis. One patient with iliac dedifferentiated chondrosarcoma was still alive with disease with metastases to the lung, mediastinal, and supraclavicular lymph nodes at 105 months after initial surgery. Thirteen patients had died of disease as a result of lung with/or without other metastases (10 patients) or progression of local relapse (three patients with iliac chondrosarcoma) at 4 to 34 months (median, 16 months). The other patient had died of newly diagnosed lung cancer 270 months after surgery. The C-THA implant survived in 19 of 25 patients (76%) at last followup. The cumulative C-THA survival rate in all patients was 67% at both 5 and 10 years postoperatively (Fig. 4).

The mean MSTS/ISOLS scores in 11 patients (10 survivors and one patient with osteosarcoma who died of concurrent lung cancer 270 months after C-THA reconstruction) at last followup was 55% (range, 30%–80%) (Table 1). The scores in the category of pain were relatively high (4–5 points in most cases) and supports generally showed low scores (0–1 point in all cases). Twenty-one of 25 patients acquired walking ability after surgery; two patients were ambulatory with no aids, 11 with a cane or single crutch, and eight with double crutches. Two patients required wheelchair transfer because of advanced age (72- and 64-year-old women) and knee osteoarthritis. The other two patients, who had proximal femoral osteosarcoma metastatic to the lung and bone at presentation and who had iliac high-grade chondrosarcoma with progressive local relapse and postoperative deep infection, resulted in continuous lack of walking ability until death. Seven of 11 survivors could have returned to their community with no aids or a single cane/crutch at last followup of 32 to 285 months (median, 163 months). Limb length shortening of

Fig. 3 The cumulative overall survival curve estimated by the Kaplan-Meier method in all patients ($n = 25$). The 5- and 10-year postoperative overall survival rates were both 47%. The broken lines show 95% confidence intervals.

Fig. 4 The cumulative C-THA implant survival curves estimated by the Kaplan-Meier method ($n = 25$). The 5- and 10-year postoperative cumulative survival rates of the C-THA implant were both 67%. The broken lines show 95% confidence intervals.

the affected side was less than 3 cm in all but one patient, who had an ischiopubic parosteal osteosarcoma, presenting maximally 4-cm shortening after revision surgery for salvage reconstruction after deep infection and loosening of the primary implant.

There were 13 major complications and four minor complications postoperatively in the present series. Eight patients developed deep infection, four dislocations, and two aseptic loosening. In terms of deep infection, the implants were saved by débridement and antibiotic administration in three patients, but implant removal was needed to suppress infection in the other five, two of whom underwent revision surgery and the remaining three patients unfortunately died of disease at 9 to 32 months (median, 16 months) after C-THA reconstruction. Two patients experienced peroneal nerve palsy (one was transient, the other was permanent). Another patient had a pubic fatigue fracture during followup.

A total of 11 of 25 patients (44%) had one or more postoperative complications, eight of whom (32%) experienced major complications, causing five revision surgeries and three implant removals. There was no intra-/or perioperative mortality in the present series.

Discussion

Limb-salvage surgery for periacetabular tumors is one of the most challenging issues for orthopaedic oncologists. Restoration of iliofemoral stability with better functional reconstruction is the major surgical demand. There have been variables of reconstructive methods after internal hemipelvectomy; however, no standard procedure exists, and patients still experienced frequent postoperative complications and morbidity. We developed a novel endoprosthesis (C-THA) in 1985 to obtain iliofemoral stability after resection of periacetabular tumors [34]. We therefore determined (1) patient and C-THA implant survival; (2) postoperative function; and (3) major complications with medium- to relatively long-term followup.

Our study is subject to several limitations. These limitations mostly related to the rarity of this disease. First, it is a retrospective review that lacked a control group. We attempted to mitigate this limitation by comparing our series with other similar series in the literature. Second, the number of patients is small, and the observations required confirmation with larger cohorts of patients from other centers. Third, this study covers a long period over 20 years with many modifications in indications for the C-THA reconstruction, surgical technique, and selection of adjuvant treatment. Given the small numbers of patients and many variables, we cannot attribute the findings to particular factors. Despite such limitations, we can still make certain statements about the clinical usefulness of C-THA and, thus, use these outcome measures to address our study questions.

We summarized the patient and implant survival rate in the present and previous series with relatively long-term followup (Table 2). The 5- and 10-year overall survival rate in the present series was 47%, which seemed relatively low compared with that in the literature, although survival of patients might be influenced by various factors, including patient's age, histological tumor type, grade, local tumor extent, disease stage, and biased by patient selection for the treatment. In terms of implant survival, C-THA survived in 19 of 25 patients (76%) at last followup, and the 5- and 10-year cumulative survival rate was 67%, which seemed comparable to that in the literature.

The mean MSTs/ISOLS functional score in the present series was 55%, which was comparable to other series (Table 3). The present C-THA has some advantages

Table 1. Postoperative MSTS/ISOLS functional evaluation scores [8] in the present study (n = 11*)

Case number	Age(years)/sex	Primary location	Histological diagnosis	Final followup (months)	Pain	Function	Emotional acceptance	Supports	Walking ability	Gait	Total score (%)
1	72/F	Ilium	Osteosarcoma	70	4	0	3	0	1	1	9 (30)
2	66/M	P-F	Osteosarcoma	270	5	3	4	1	4	3	20 (67)
3	44/M	P-F	MFH	251	5	3	3	1	3	3	18 (60)
4	52/F	Ischium	GCT of bone	193	3	3	1	0	3	1	11 (37)
5	44/M	P-F	Chondrosarcoma	163	5	5	5	1	3	5	24 (80)
6	53/F	P-F	Osteosarcoma	189	5	1	3	1	1	1	12 (40)
7	19/M	P-F	Osteosarcoma	136	5	3	4	1	3	3	19 (63)
8	39/F	Ischiopubic	Parosteal osteosarcoma	285	5	3	4	1	3	3	19 (63)
9	53/M	Ilium	Dedifferentiated chondrosarcoma	105	5	3	3	0	4	3	18 (60)
10	64/F	Ilium	Chondrosarcoma	46	3	1	3	1	1	3	12 (40)
11	32/M	Groin	Synovial sarcoma	32	5	3	4	1	3	9	19 (63)

* Thirteen patients were excluded from MSTS/ISOLS functional evaluation because they died of disease at 4–34 months postoperatively, and another one patient was excluded as a result of hindquarter amputation performed for local recurrence of iliac chondrosarcoma after C-THA; MSTS/ISOLS = Musculoskeletal Tumor Society/International Society of Limb Salvage; F = female; M = male; P-F = proximal femur; MFH = malignant fibrous histiocytoma; GCT = giant cell tumor.

Table 2. Comparison of patient and implant survival rate in review of the literature*

Study	Number of patients	Mean followup period (range)	Type of reconstruction	Patient overall survival rate (%)	Implant survival rate (%)
Schwartz et al. [30]	8	8.2 years	Resection arthroplasty	63%	NA
Fuchs et al. [12]	32	97 months (14–226 months)	Iliofemoral arthrodesis (solid fusion) 21 Hip transposition (pseudarthrosis) 11	47%	NA
Bell et al. [2]	17	7 years (4–14 years)	Hemipelvic allograft [†]	76%	71%
Abdu et al. [1]	35	84 months (12–312 months)	Custom-made hemipelvic endoprosthesis	60%	83%
Jaiswal et al. [18]	98 [‡]	65 months (2 months to 33.5 years)	Custom-made hemipelvic endoprosthesis	67% at 5 years 54% at 10 years	76%
Current study	25	163 months (32–285 months)	“Reconstruction cup” (C-THA) endoprosthesis	47% at 5 and 10 years	76% [§]

* Case series with a mean followup period over 60 months are only listed in Table 2; [†]15 of 17 patients were primarily treated with an allograft-THA prosthesis composite; [‡]primary malignant bone and soft tissue tumors in 82 patients, solitary metastatic bone tumors in seven, plasmacytoma/myeloma in six, and benign bone tumors in three (fibrous dysplasia two, chondroblastoma one); [§]the cumulative implant survival rate of C-THA was 67% at 5 and 10 years postoperatively, when patients' death was interpreted as censored to calculate cumulative survival rate.

compared with other periacetabular reconstructive methods: (1) easy-to-achieve immediate iliofemoral stabilization with reduced risk of hip dislocation; and (2) it is not necessary to reconstruct pelvic ring disruption. Several hemipelvic implants with a similar concept as our C-THA, with a constrained hip mechanism, have been recently reported [11, 24, 38] and are now widely available. Their mean MSTS/ISOLS functional scores were also similar to the present series although postoperative function was

considerably affected by complications such as deep infection and implant dislocation.

The major complication rate in the present and other series is summarized (Table 3). Among the postoperative complications, deep infection was the most serious and frequent complication also in the present series (32%), similar to other reconstructive procedures; the rates of deep infection have been reported as 18% to 33% in saddle prostheses [4, 21, 25, 28], 25% to 30% in custom-made

Table 3. Comparison of postoperative MSTS/ISOLS functional score and major complication rate in review of the literature

Study	Number of patients	Mean followup period (range)	Type of reconstruction	MSTS/ISOLS functional score, mean percent (range)	Major complication rate (%) [*]
Schwartz et al. [30]	8	8.2 years	Resection arthroplasty	73.3% (53.3%–80%)	NA
Fuchs et al. [12]	21	97 months (14–226 months)	Iliofemoral arthrodesis (solid fusion)	71% (60%–80%)	NA
Fuchs et al. [12]	11	97 months (14–226 months)	Hip transposition (pseudarthrosis)	25% (23%–30%)	NA
Bell et al. [2]	17	7 years (4–14 years)	Hemipelvic allograft [†]	65% (13%–87%)	29%
Yoshida et al. [39]	19	57 months (12–228 months)	Hemipelvic allograft [‡]	NA (Mankin scale; excellent 1, good 6, fair 5, failure 7)	42%
Kim et al. [20]	11 (primary 9)	40 months (12–116 months)	Pasteurized autologous bone graft [§]	61% (53%–93%)	27%
Cottias et al. [4]	17 (primary 16)	42 months (8–84 months)	Saddle prosthesis	57% (37%–77%)	65%
Kitagawa et al. [21]	16 (primary 12)	37 months (12–85 months)	Saddle prosthesis	47% (20%–57%)	42%
Renard et al. [28]	15 (primary 9)	6 months	Saddle prosthesis	50%	40%
Abdu et al. [1]	35	84 months (12–312 months)	Custom-made hemipelvic endoprosthesis	70% (50%–90%)	60%
Jaiswal et al. [18]	98 (primary 85)	65 months (2 months to 33.5 years)	Custom-made hemipelvic endoprosthesis	NA (mean TESS score, 59.4%)	32%
Ozaki et al. [27]	12	57 months (26–77 months)	Custom-made hemipelvic endoprosthesis	39% (20%–53%)	25%
Windhager et al. [36]	21	41 months (12–190 months)	Hemipelvic endoprosthesis (9 saddle prosthesis, 6 custom-made prosthesis, and others)	52%	28%
Wirbel et al. [37]	39	58 months (15–110 months)	Hemipelvic (37) and saddle (2) endoprosthesis	Good/excellent 76%	41%
Fisher et al. [11]	27 (primary 19)	39 months (18–80 months)	“Ice cream cone” endoprosthesis	NA (mean TESS score, 69%)	37%
Guo et al. [14]	28 (primary 24)	30 months (10–59 months)	Modular hemipelvic endoprosthesis	62% (30%–83%)	18%
Menendez et al. [24]	17 (primary 8)	29.4 months (13–108 months)	PAR hemipelvic endoprosthesis	67% (37%–90%)	56%
Witte et al. [38]	40 (primary 29)	24 months (1–60 months)	MUTARS TM hemipelvic endoprosthesis	50% (10%–70%)	58%
The current study	25	163 months (32–285 months)	“Reconstruction cup” (C-THA) endoprosthesis	55% (30%–80%)	32%

^{*} To calculate major complication rate, only local wound-related complications (wound infection, fistulas, skin necrosis, etc) and implant-related complications (deep infection, loosening, fracture, dislocation, etc) were included, whereas tumor-related complications (local recurrence, distant metastasis), systemic complications (pulmonary embolism, cardiovascular failure, etc), and postoperative leg-length discrepancy were excluded;

[†]15 of 17 patients were primarily treated with an allograft THA prosthesis composite; [‡]11 of 19 patients primarily underwent allograft-BHA (bipolar hip arthroplasty) prosthesis composite; [§]all 11 patients primarily underwent pasteurized autologous graft-THA prosthesis composite; MSTS/ISOLS = Musculoskeletal Tumor Society/International Society of Limb Salvage; NA = not available; TESS = Toronto Extremity Salvage Score [5].

hemipelvic prostheses [1, 18, 27, 36, 37], 11% to 24% in modular-type hemipelvic prostheses [11, 14, 24, 38], and 8% to 60% in allograft reconstruction [2, 22, 23, 26, 39]. To reduce the risk of postoperative deep infection, we need to

adopt intraoperative repeated and meticulous ultrasonic irrigation, routine use of antibiotic-loading bone cement, application of muscle/or musculocutaneous flap, and two-staged reconstruction after tumor resection followed by a

bone cement spacer in selected cases. Silver-coated megaprotheses in animal models and humans [13, 15] and iodine-supported titanium implants [31] have recently been developed and are expected to prevent postoperative deep infection. Dislocation and aseptic loosening of endoprotheses are other major postoperative complications. The rates of dislocation (16%) and aseptic loosening (8%) in the present series were also comparable to other reported series: 2.5% to 17% for dislocation [1, 11, 14, 24, 27, 36–38] and 3.7% to 25% for aseptic loosening of implants [11, 14, 21, 27, 38]. Four patients sustained dislocations caused by violent falls despite the use of a constrained joint mechanism, three of whom also had concomitant deep infection. To reduce implant dislocation, Fisher et al. [11] mentioned the importance of postoperative buttercup exercises, correctly known as buttock-up exercises, to try to keep the hip joint by contracting the buttock muscles before attempting to move the legs. A polyethylene terephthalate synthetic mesh, named the Trevira tube (Implantcast, Buxtehude, Germany), is useful to prevent dislocation by forming a pseudocapsule around the hip [11, 18, 38]. We alternatively use a proline synthetic mesh to reduce the risk of C-THA dislocation in some cases on demand. Aseptic loosening occurred in the earlier two patients; one was of the cup and the other of the intramedullary femoral stem. These two patients underwent revision surgery and function was restored to the previous favorable level. There was a substantial learning curve according to the treatment period (1985–1990 versus 1991–2009), possibly leading to an improvement in the C-THA implant survival (Fig. 5). The major reasons for the learning curve of implant survivorship seemed (1) improvement of the fixation technique of the implant to the bony bed as well as design betterment of the cup to add a blade plate for screw fixation; and (2) appropriate preoperative patient selection for an indication of this reconstructive

method. Recognizing the potential advantages of not having to drill through cured cement, it seems that cementing the implant using third-generation techniques and then supplementing the fixation with screws into bone, not just cement, would seem to offer a better chance of further long-term acetabular cup survivorship. In terms of postoperative limb-length discrepancy (LLD), we could adjust it by using a proximal femoral component with proper length; however, we have experienced some difficulty in adjusting the LLD intraoperatively in the early phase of this series. Careful preoperative planning to adjust LLD is important. Moreover, reattachment of the remaining muscles around the hip to the femoral implant through mesh is also an important point for postoperative walking ability.

In summary, this C-THA provided in most cases of the present series pain-free hip reconstruction with immediate iliofemoral stability with minimal limb-length shortening and without pelvic ring reconstruction, suggesting this procedure is a useful reconstructive option after resection of primary periacetabular malignant tumors despite frequent postoperative serious complications.

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Fig. 5 There was a time trend of improvement on C-THA implant survival with a substantial learning curve according to the treatment period (1985–1990 versus 1991–2009, $p = 0.1454$).

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