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Comparison of Pasteurized Autograft-Prosthesis Composite Reconstruction and Resection Hip Arthroplasty for Periacetabular Tumors

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Background: Because of the high complication rate of anatomical reconstruction after periacetabular resection, the strategy of resection alone has been revisited. However, in terms of complications and functional outcome, whether resection hip arthroplasty (RHA) shows a superior result to that of pelvic ring reconstruction remains controversial.

Methods: We compared 24 RHAs and 16 pasteurized autograft-prosthesis composite (PPC) reconstructions regarding the complication rates, operative time, blood loss, and functional outcome.

Results: Compared to 16 PPC hips, 24 RHA hips showed lower major and minor complication rates ($p < 0.001$), shorter surgical time ($p < 0.001$), and superior Musculoskeletal Tumor Society scores ($p < 0.001$). Of the 24 RHA hips, bony neo-acetabulum was identified in 7 on computed tomography and partial neo-acetabulum in 9; the remaining 8 had no bony acetabular structure. The average time to bony neo-acetabulum formation was 7 months (range, 4 to 13 months).

Conclusions: RHA for periacetabular tumors can be an excellent alternative to anatomical reconstruction. It offers short surgical time, low complication rates, and functional results comparable to those of other reconstruction methods. However, this procedure is indicated for patients who can accept some limb shortening, and a tumor should be confined to the periacetabular area.

Keywords: *Acetabulum, Reconstructive surgery, Treatment outcome*

Resection and reconstruction for periacetabular tumors is one of the most difficult challenges for the orthopedic oncologist. The primary goal of the procedure is to control the tumor locally by complete resection. The secondary goal is to reconstruct the periacetabular defect to restore as much pelvic stability and hip joint function as possible. Reconstructive options after periacetabular resection can be divided into 2 categories depending on the preservation of the acetabular-femoral articulation. Nonpreservation reconstruction includes fusion, saddle prosthesis insertion, hip transposition, and pseudoarthrosis.[1-4] Preservation reconstruction includes the use of a custom-made prosthesis and allograft or recycled autograft-prosthesis composite.[5-11] When internal pelvectomy was introduced as an alternative to hindquarter amputation, iliofemoral coaptation or ischiofemoral arthrodesis was performed with the compromise of limb length shortening and hip instability.[2,12] The use of a saddle prosthesis was considered a temporary compromise to address the issue of flail hip; however, this prosthesis posed the risk of cranialization or luxation of the implant.[4,13] Therefore, to achieve pelvic continuity and durable hip function, acetabular-femoral articulation-preserving reconstruction was devised.[7,11,14-16] This provided promising results in a substantial proportion of patients, but short- and long-term complications were significant.[6,17-19] In this regard, pseudoarthrosis or hip transposition, which may avoid problems related to

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pelvic ring reconstruction, is being revisited.[1,20-22] A recent report of resection hip arthroplasty (RHA) in 27 patients has reconfirmed the usefulness of this approach, a similar technique of which was addressed in a study involving 5 patients in 1978.[2,23] Hu et al.[23] postulated that RHA would show fewer complications, shorter surgical time, less blood loss, and better functional results than those of pelvic ring reconstruction methods. However, in terms of complications and functional outcomes, whether RHA is superior to anatomical pelvic ring reconstruction is still controversial. Proponents of anatomical reconstruction speculate that functional results in patients with failed pelvic ring reconstruction would not be inferior to those of primary RHA.

In this study, we compared the results of 24 cases of RHA and 16 pasteurized bone-prosthesis composite reconstructions in terms of complication rates, operative time, blood loss, and ultimate functional outcome. Addi-

Table 1. Demographic Data of 24 Patients with Resection Hip Arthroplasty

Case	Age (yr)/ sex	Diagnosis	Tumor stage	TV (cc)	Extent of iliac lesion (cm)	Resection type	Surgical margin	Surgical time (hr)	RBC transfusion (pint)*	LR	Meta.	Final status	F/U (mo)
1	21/F	GCT	Benign	115	2.3	II	m	2.2	7	+	-	NED	54
2	17/F	OS	IIB	145	1.2	II + III	w	4.8	1	-	-	CDF	70
3	17/F	CS	IIB	648	1	II + III	w	4.8	10	-	-	CDF	182
4	32/M	GCT	Benign	66	0	II + III†	m	2.7	2	+	-	NED	118
5	43/F	FS	IIB	111	1.7	II + III	w	3.9	4	-	+	DOD	41
6	47/F	CS	IIB	172	0	II + III	w	5.1	2	-	-	CDF	61
7	68/M	CS	IIB	103	2.5	II + III	m	4.8	11	+	-	AWD	66
8	34/M	CS	IIB	66	4.5	I† + II	w	1.8	2	-	-	CDF	37
9	43/M	CS	IIB	165	4.9	I† + II	w	1.7	0	-	-	CDF	35
10	46/M	CS	IIA	87	3.7	I† + II	w	2.0	0	-	-	CDF	32
11	47/M	CS	IIA	67	3.4	I† + II	w	1.7	3	-	-	CDF	29
12	15/M	SS	III	165	1.7	I† + II + III	m	2.7	4	-	-	CDF	37
13	21/M	SS	III	147	2.5	I† + II + III	m	4.7	9	-	-	CDF	280
14	22/M	OS	IIB	330	0.9	I† + II + III	w	8.8	12	-	-	CDF	69
15	27/M	OS	IIB	125	3.3	I† + II + III	m	5.4	7	-	-	CDF	43
16	30/M	GCT	Benign	144	5	I† + II + III†	w	5.5	10	-	-	CDF	132
17	32/M	OS	IIB	204	2.2	I† + II + III	w	5.0	11	-	-	CDF	26
18	34/F	CS	IIB	414	2	I† + II + III	w	5.8	8	-	-	CDF	301
19	36/F	OS	IIB	383	4.4	I† + II + III	m	5.2	20	+	+	DOD	36
20	39/M	CS	IIB	116	0	I† + II + III	w	5.1	4	-	-	CDF	56
21	41/M	CS	IIB	212	3.4	I† + II + III	m	2.9	6	+	+	NED	26
22	46/M	CS	IIB	725	8	I† + II + III	i	3.5	12	+	-	NED	42
23	61/M	CS	IIB	565	1.6	I† + II + III	m	5.9	15	-	-	CDF	35
24	65/M	CS	IIB	162	3.4	I† + II + III	w	5.5	5	-	-	CDF	69

TV: tumor volume, iliac lesion: measured from the top of the femoral head, RBC: red blood cell, LR: local recurrence, Meta.: metastasis, GCT: giant cell tumor, m: marginal, +: local recurrence confirmed, NED: no evidence of disease, OS: osteosarcoma, w: wide, CDF: continuous disease-free, CS: chondrosarcoma, FS: fibrosarcoma, DOD: died of disease, AWD: alive with disease, SS: synovial sarcoma, i: intralesional.
*RBC 1 pint: 400 cc. †Partial resection of involved bone.

tionally, in cases of RHA, we described the pattern of neo-hip joint formation according to the extent of iliac bone resection or the mode of postoperative management.

METHODS

Between January 1990 and March 2015, 99 patients with pelvic bone and soft tissue tumors underwent periacetabular resection at Korea Cancer Center Hospital. According to the pelvic resection category described by Enneking and Dunham,[12] 43 were type I + II, 28 were type I + II + III, 25 were type II + III, and 3 were type II resections. Among these, we selected 24 patients who underwent RHA and 16 patients who underwent pasteurized autograft-prosthesis composite (PPC) reconstruction. Exclusion criteria were: (1) iliac resection at the sacroiliac joint (37 patients); (2) reconstruction with saddle prosthesis (8 patients); and (3) less than 2 years of follow-up without an event (14 patients). Finally, 23 male and 17 female patients with an average age of 35.3 years (range, 15 to 68 years) were included. Follow-up duration was a minimum of 13 months (average, 101 months; range, 13 to 301 months).

The criteria for RHA were: (1) tumors located mainly in region II and III (some partially involved region I) and (2) preoperative magnetic resonance imaging (MRI) showing no sign of femoral head involvement by tumor. PPC reconstruction was indicated for tumors when at least 1 of 2 landmarks on plain pelvic anteroposterior radiographs (ilioischial and iliopectineal lines) was intact.

Of the 24 patients who underwent RHA, 18 had primary malignant bone tumors, 3 had soft tissue sarcomas, and 3 had giant cell tumors (Table 1). Of the 16 patients who underwent PPC reconstruction, 11 had primary malignant bone tumors, 3 had benign aggressive bone tumors, and 2 had metastatic tumors (Table 2). Preoperative staging included plain radiography and MRI of the pelvis, computed tomography (CT) of the chest, and whole body technetium bone scan. Staging was determined accord-

Table 2. Demographic Data of 16 Patients with Pasteurized Autograft-Prosthesis Composite Reconstruction

Case	Age (yr)/ sex	Diagnosis	Tumor stage	TV (cc)	Resection type	Surgical margin	Surgical time (hr)	RBC transfusion (pint)*	LR	Meta.	Final status	F/U (mo)
1	35/M	OS	IIB	52	II	w	7	6	-	+	DOD	24
2	19/F	GCT	Benign	188	II + III	w	5.8	8	-	-	CDF	271
3	20/F	OS	IB	63	II + III	m	7	7	-	-	CDF	246
4	49/F	HES	IB	187	II + III†	w	6.4	6	-	-	CDF	243
5	52/M	CS	IIB	251	II + III	w	8	9	-	-	CDF	125
6	54/F	CS	IIB	110	II + III	w	6.3	9	-	-	CDF	108
7	18/F	ES	IIB	201	I† + II	m	7.3	7	+	+	DOD	13
8	20/F	OS	IIB	377	I† + II	m	7.6	16	-	-	CDF	150
9	21/M	MFH	IIB	31	I† + II	w	7.3	5	-	-	CDF	254
10	24/F	DF	Benign	82	I† + II	m	6.8	9	-	-	CDF	120
11	34/F	MC	III	79	I† + II	w	7.9	13	+	-	NED	224
12	54/F	MC	III	26	I† + II	w	6.6	7	-	-	CDF	161
13	25/M	CS	IIB	653	I† + II + III†	m	9.3	15	-	-	CDF	141
14	30/M	OS	IIB	226	I† + II + III	w	7.3	4	+	+	DOD	69
15	31/F	CS	IIB	63	I† + II + III†	w	6.8	8	-	-	CDF	63
16	45/M	CS	IIB	141	I† + II + III	w	7.3	10	+	+	DOD	21

TV: tumor volume, RBC: red blood cell, LR: local recurrence, Meta.: metastasis, OS: osteosarcoma, w: wide, +: local recurrence confirmed, DOD: died of disease, GCT: giant cell tumor, CDF: continuous disease-free, m: marginal, HES: hemangioendothelioma, CS: chondrosarcoma, ES: Ewing sarcoma, MFH: malignant fibrous histiocytoma, DF: desmoplastic fibrosarcoma, MC: metastatic carcinoma, NED: no evidence of disease.
*RBC 1 pint: 400 cc. †Partial resection of involved bone.

ing to Enneking's criteria.[24] Neoadjuvant and adjuvant chemotherapy were administered to 13 patients. Initial tumor volume, pathologic diagnosis, extent of iliac lesion on MRI, osteotomy level from iliac crest, resection type, surgical time, surgical margin, and amount of transfusion were recorded. The tumor volume was calculated using 3 parameters (height, width, and depth) by the ellipsoid formula: [$V = (4\pi/3)\times a\times b\times c$].[25] The height, width, and depth of a tumor were measured on the coronal and axial plane MRI scans. The resection and reconstruction included the following procedures. An ilioinguinal approach was used for the main incision, and a satellite incision was made from the anterosuperior iliac spine to the greater trochanter, if necessary. In 12 of the 24 patients who underwent RHA, 2 or 3 osteotomies were made to preserve the iliac bone-hip flexor or abductor continuity, and to displace the bone block-muscle complex inferiorly and laterally. Pelvic resection was classified according to the system of Enneking and Dunham.[12] In 16 cases of PPC reconstruction, 6 cases were type I + II, 5 were type II + III, 4 were type I + II + III, and 1 was a type II resection. In 24 cases of RHA, 13 were type I + II + III, 6 were type II + III, 4 were type I + II, and 1 was a type II resection. The margin in the 40 patients was wide in 25, marginal in 14, and intralesional in 1, according to Enneking's criteria.[24] The preparation of pasteurized bone and reconstruction using a total hip prosthesis was performed as described previously.[9] In RHA, the average osteotomy length from the iliac crest was 9.5 cm (range, 4 to 14.5 cm). After tumor removal, the femoral head was pushed up to the inferior aspect of the resected ilium. In 12 cases, the femoral head was fixed to the remaining ilium with wire. In the remaining 12 cases, no fixation was undertaken. In 12 cases of RHA, previously detached iliac bone block-muscle complex was repositioned to the iliac wing with wire. Postoperatively, patients who underwent PPC reconstruction were usually immobilized for 8–10 weeks in a one-and-a-half hip spica cast, which was followed by crutch walking until radiographic union was achieved. In patients who underwent RHA, only 3 were immobilized in a hip spica cast. The remaining 21 were allowed to ambulate when drains were removed (around 2 weeks after the surgery). Monthly plain anteroposterior and bilateral oblique radiographic examinations were performed until 2 years after the index operation. In patients who underwent RHA, trimonthly pelvic CT was performed to evaluate the formation of bony neo-acetabulum. More than 3/4 of circular bony neo-acetabulum formation was defined as complete, and less than 1/2 of a circle as partial (Fig. 1).

At final follow-up, 28 patients were event-free, 6 died of their disease, 5 had no evidence of disease, and 1 was alive with disease. Nine patients (22.5%) developed local recurrence, and their surgical margin status was marginal in 6, wide in 2, and intralesional in 1. Functional results were assessed by the Musculoskeletal Tumor Society (MSTS) system.[26] Scores were recorded at the last visit for patients with intact PPC and who underwent RHA. For PPC reconstruction patients whose graft was removed, the functional scores before and after graft removal were recorded. Final limb length discrepancy on radiographs and the shoe heel height to compensate for limb shortening were recorded. Reconstruction failure was defined as the removal of the composite or iliac wing-femoral head coaptation due to complications. Time to failure (months) was defined as the time elapsed between the first surgery and the date of reconstruction removal. A major complication was defined as the one that eventually necessitated removal of the graft or prosthesis as a revision procedure. A

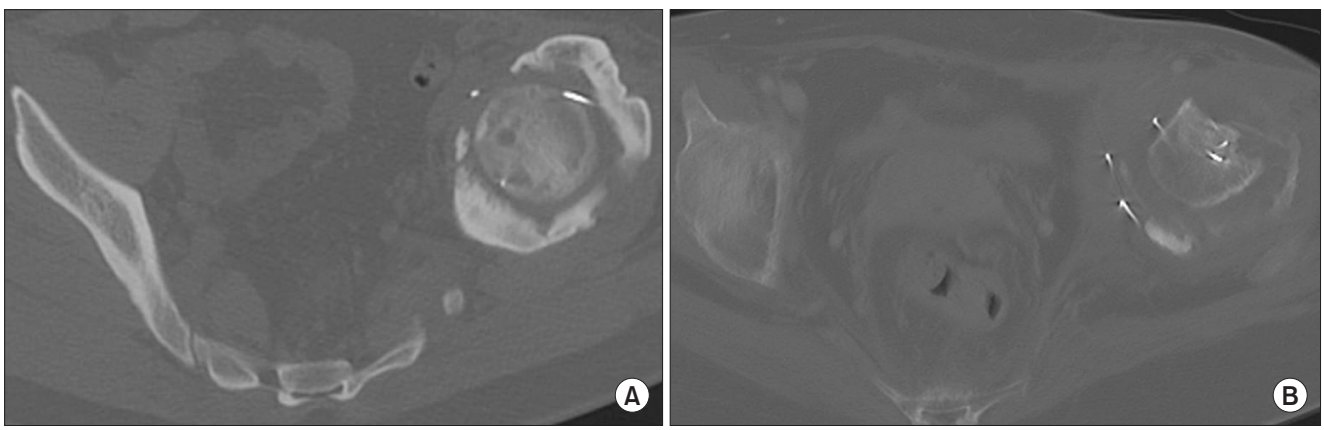

Fig. 1. (A) The axial pelvic computed tomography (CT) shows complete bony neo-acetabulum formation 9 months postoperatively. (B) The axial CT shows partial bony neo-acetabulum formation (less than 1/2 of the femoral head circumference).

Table 3. Comparison of Tumor Characteristics and Surgical Outcome between Resection Hip Arthroplasty (n = 24) and Pasteurized Autograft-Prosthesis Composite Reconstruction (n = 16)

Variable	Resection hip arthroplasty (%)	Pasteurized autograft-prosthesis composite reconstruction (%)	*p*-value
Age (yr)			0.505
≤ 40	14 (58.3)	11 (68.8)	
> 40	10 (41.7)	5 (31.2)	
Sex			0.037
Male	17 (70.8)	6 (37.5)	
Female	7 (29.2)	10 (62.5)	
Initial tumor volume (cc)			
Mean (range)	226.5 (66–725)	170.6 (26–653)	0.334
≤ 150	12 (50.0)	9 (56.3)	0.698
> 150	12 (50.0)	7 (43.7)	
Resection type			0.581
I + II + III	17 (70.8)	10 (62.5)	
II + III	7 (29.2)	6 (37.5)	
Surgical time (hr)			
Mean (range)	4.2 (1.7–8.8)	7.2 (5.8–9.3)	< 0.001
≤ 6	23 (95.8)	1 (6.3)	< 0.001
> 6	1 (4.2)	15 (93.8)	
Transfusion (pint)			
Mean (range)	6.9 (0–20)	8.7 (4–16)	0.219
≤ 6	12 (50.0)	4 (25.0)	0.114
> 6	12 (50.0)	12 (75.0)	
Surgical margin			0.505
Wide	14 (58.3)	11 (68.8)	
Marginal, intralesional	10 (41.7)	5 (31.2)	
Major complication			< 0.001
Present	0	12 (75.0)	
Absent	24 (100)	4 (25.0)	
Minor complication			< 0.001
Present	2 (8.3)	15 (6.3)	
Absent	22 (91.7)	1 (93.7)	
Final leg length discrepancy (cm)			
Mean (range)	3.7 (1.3–6.4)	3.7 (0–7)	0.943
≤ 3.0	10 (41.7)	6 (37.5)	0.792
> 3.0	14 (58.3)	10 (62.5)	
MSTS score			
Mean (range)	23.5 (15–28)	14.8 (8–26)	< 0.001
≤ 20	6 (25.0)	13 (81.3)	0.001
> 20	18 (75.0)	3 (18.8)	
Local recurrence			1.000
Recurred	6 (25.0)	4 (25.0)	
Not recurred	18 (75.0)	12 (75.0)	
Distant metastasis			0.407
Occurred	3 (12.5)	4 (25.0)	
Not occurred	21 (87.5)	12 (75.0)	
Final outcome			0.138
Alive	23 (95.8)	12 (75.0)	
Dead	1 (4.2)	4 (25.0)	
Total	24 (100)	16 (100)	

MSTS: Musculoskeletal Tumor Society.

Table 4. Postoperative Course and Functional Outcome of 16 Patients with Pasteurized Autograft-Prosthesis Composite Reconstruction

Case	Major complication	Management of major complication (no. of operations)	Minor complication	Management of minor complication (no. of operations)	Final status (months from index operation to prosthesis removal)	Final LLD (cm)	MSTS score before prosthesis removal	Final MSTS score
1	Graft fracture	Prosthesis removal (1)	Infection	Debridement (1)	Pseudoarthrosis (12)	4	22	12
2	Acetabular cup loosening, graft fracture	Cup revision (1), saddle prosthesis (1)	Infection, proximal migration of saddle prosthesis	Incision and drainage (4)	Saddle prosthesis (125)	6	28	11
3	Graft fracture	Saddle prosthesis (1)	Plate pull out	Plate removal (1)	Saddle prosthesis (89)	5	24	9
4	Graft fracture, dislocation	Cup revision (1), saddle prosthesis (1)	Saddle mechanism failure	Revision (3)	Saddle prosthesis (98)	7	27	8
5	Infection	Prosthesis removal (1)	Dislocation	Closed reduction (1)	Pseudoarthrosis (12)	5	19	15
6	Graft fracture	Prosthesis removal (1)	Plate fracture, pin protrusion	Foreign body removal (2)	Pseudoarthrosis (62)	3	21	14
7	-	-	Autograft infection	Debridement (1)	Intact	0	-	15
8	Graft fracture	Prosthesis removal (1)	-	-	Pseudoarthrosis (4)	5	18	18
9	Graft resorption, cup loosening	Cup revision (2), bone graft (1), prosthesis removal (1)	Dislocation, infection	Open reduction (2), debridement (2)	Pseudoarthrosis (218)	6	28	12
10	Dislocation	Cup revision (1)	Dislocation	Open reduction (3)	Intact	0	-	26
11	Graft fracture	Prosthesis removal (1)	Dislocation	Open reduction (1)	Pseudoarthrosis (95)	7	26	14
12	-	-	Dislocation	Open reduction (1)	Intact	0	-	22
13	Infection	Prosthesis removal (1)	-	-	Pseudoarthrosis (1)	6	15	14
14	Nonunion	Prosthesis removal (1)	Wound infection	Debridement (1)	Pseudoarthrosis (11)	5	19	9
15	-	-	Dislocation	Open reduction (1)	Intact	0	-	24
16	-	-	-	-	Intact	0	-	14

LLD: limb length diascrepancy, MSTS: Musculoskeletal Tumor Society.

Table 5. Postoperative Course and Functional Outcome of 24 Patients with Resection Hip Arthroplasty

Case	Osteotomy level from iliac crest (cm)	Fixation (femoral head to ilium)	Postoperative immobilization	Bony neo-acetabulum/time to neo-acetabulum formation (mo)	Complication	Limb length discrepancy (cm)	Shoe heel height (cm)	Walking aid	MSTS score
1	10.5	None*	None	Complete/9	-	2.6	None	None	28
2	9	None	None	Complete/13	-	3	1	None	25
3	11	Wire	Hip spica cast	None/NA	-	3	1.5	None	24
4	14.5	None	None	Partial/8	-	1.3	None	None	28
5	10.7	Wire	None	Partial/6	-	3	1.5	None	25
6	10.7	None	None	Partial/7	Re-exploration	3.3	2	None	25
7	8.2	None	None	Partial/6	-	2.4	None	None	24
8	9.2	None*	None	Complete/6	-	3.1	2	None	26
9	9.3	Wire*	None	Partial/7	-	4.3	3	1 Cane	19
10	10	None*	None	Partial/6	-	3.5	2	None	25
11	10	None*	None	Partial/5	Flap necrosis	2.4	None	None	27
12	9.3	Wire*	None	Complete/4	-	2	None	None	28
13	10.5	Wire	Hip spica cast	None/NA	-	4.7	3	1 Cane	19
14	11.2	Wire	None	Complete/7	-	4.7	3	None	25
15	9	Wire*	None	Complete/6	-	4.5	3	None	26
16	9	None	None	None/NA	-	5.8	3	1 Cane	19
17	9.4	Wire*	None	Complete/6	-	2.5	None	None	27
18	9.6	Wire	Hip spica cast	Partial/13	-	5.2	3	None	22
19	6.6	Wire*	None	None/NA	Chronic pain	6.4	3	1 Crutch	17
20	9	None	None	None/NA	-	6	4	1 Crutch	25
21	8.8	Wire*	None	None/NA	-	4.5	3	1 Cane	18
22	4	None*	None	None/NA	-	5.5	3	1 Crutch	15
23	10	Wire*	None	Partial/5	Re-exploration	2.4	None	None	24
24	8.8	None	None	None/NA	-	3.7	2	None	23

MSTS: Musculoskeletal Tumor Society, NA: not assessed, Re-exploration: during follow-up, exploration of a lesion suspicious of local recurrence on magnetic resonance imaging turned out to be a new bone in neo-acetabulum formation.
*During surgery, 2 or 3 iliac wing osteotomies were carried out to preserve the iliac crest-hip flexor or abductor muscle continuity.

minor complication was defined as a problem other than those described above, which necessitated an additional surgical procedure or conservative management. Demographic and treatment variables in the 2 study groups were compared using the *t*-test and Fisher exact test. Analyses were performed using SPSS ver. 13.0 (SPSS Inc., Chicago, IL, USA), and *p*-values less than 0.05 were considered significant.

RESULTS

Compared to the 16 cases of PPC reconstruction, the 24 cases of RHA showed lower major and minor complication rates ($p < 0.001$), shorter surgical time ($p < 0.001$), and superior MSTS score ($p < 0.001$) (Table 3). No patients who underwent RHA experienced disruption of the femoral head-iliac wing articulation. However, 11 of the 16 PPCs (69%) were removed at an average of 66 months (range, 1 to 218 months). Causes of PPC failure were graft fracture in 8, infection in 2, and nonunion in 1. The 11 failed PPCs were converted to pseudoarthrosis in 8 and a saddle prosthesis in 3. Minor complications in patients who used PPC included wound infection, plate failure, and dislocation. Overall, 16 patients who used PPC underwent 17 major and 24 minor additional procedures after the index operation (Table 4). The average functional score of the 11 failed PPC patients was 22.4 (74%) until removal of the construct, and their average score deteriorated to 12.4 (41%) after removal. Mean leg length discrepancy of the 11 patients with failed PPC was 5.4 cm (range, 3 to 7 cm). One each RHA case showed flap necrosis and chronic pain. Another 2 patients who had RHA underwent re-exploration for suspicious recurrent lesions; however, these proved to be new bones in neo-acetabulum formation.

Of the 24 patients who underwent RHA, circular bony neo-acetabulum on CT was identified in 7 and par-

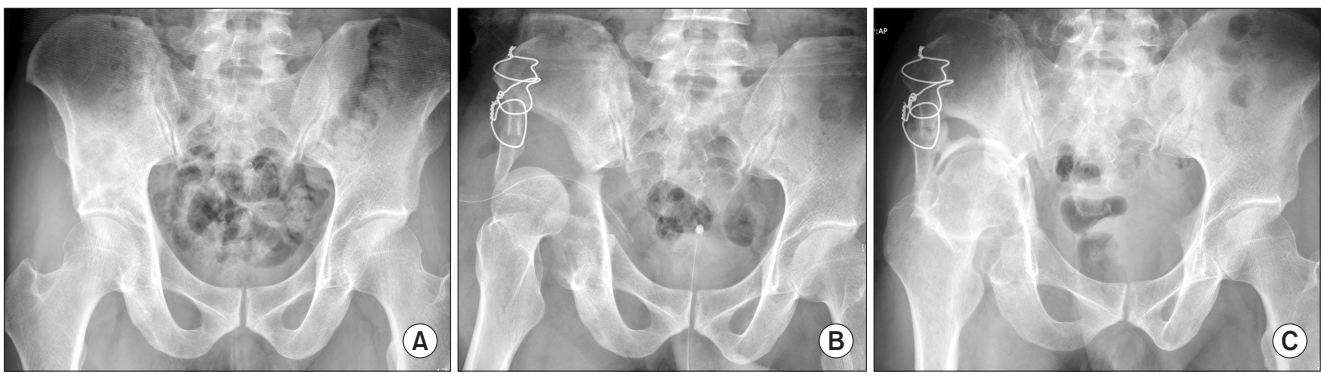

Fig. 2. (A) The preoperative plain radiograph shows a mixed osteolytic and sclerotic lesion in the right ilium and acetabulum in a 34-year-old male patient with chondrosarcoma (case 8). (B) The postoperative plain radiograph shows Enneking type II + I (partial) resection and repositioning of the previously detached iliac bone block-muscle complex with wire. (C) The follow-up plain radiograph shows complete neo-hip joint formation; the patient is fully active with shortening by 3 cm.

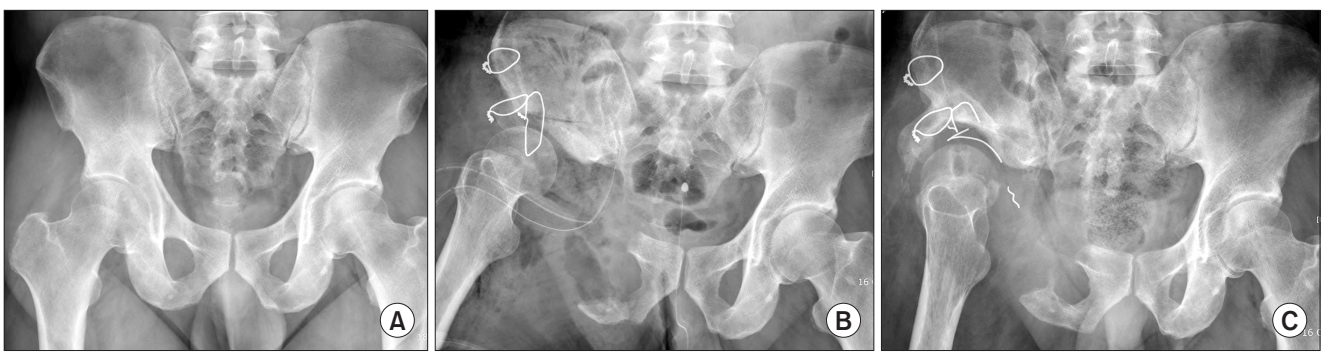

Fig. 3. (A) The plain radiograph shows an osteolytic lesion in the right acetabulum in a 41-year-old patient with chondrosarcoma (case 21). (B) The postoperative radiograph demonstrates Enneking type I (partial) + II + III (partial) resection and the femoral head fixed to the remaining iliac wing with a single wire. (C) At 6 months postoperatively, because of the high iliac osteotomy level, only partial bony neo-acetabulum had formed. The patient had no pain and could walk with one cane.

tial neo-acetabulum in 9; the remaining 8 patients did not show a bony acetabular structure (Table 5). Average time to bony neo-acetabulum formation was 7 months (range, 4 to 13 months) (Fig. 2). Excluding 2 patients who had a hip spica cast postoperatively, all 13 patients with an osteotomy > 9 cm from the iliac crest showed partial or complete bony neo-acetabulum formation, while only 3 of 9 patients with osteotomy level < 9 cm demonstrated bony neo-acetabulum (Fig. 3). The average MSTS functional score in 9 patients with < 9 cm of the remaining iliac wing was 21 (70%), while that of 15 patients with > 9 cm of the ilium was 25 of 30 points (83%). Average limb shortening in 24 patients who underwent RHA was 3.7 cm (range, 1.3 to 6.4 cm).

DISCUSSION

Excision of periacetabular tumors usually leaves a large skeletal defect, and attempts at reconstruction by arthrodesis or pseudoarthrosis often result in considerable limb shortening and poor function.[17] In this regard, anatomical reconstruction of the hip and hemipelvis by biological or mechanical means were suggested to provide improved functional outcomes and walking ability.[1,11,14,27-29] However, most reconstructions had high complication and failure rates. Therefore, a strategy of resection alone has been revisited.[6,7,23,28,30] In our comparative study of anatomical reconstruction and RHA, we confirmed that RHA is a reliable primary procedure for periacetabular tumors, with low complication rates, good functional results, and short surgical time. Moreover, in patients who underwent RHA, less iliac wing resection and early postoperative mobilization seemed to facilitate early stable bony neo-acetabulum formation.

This study has several limitations. First, there are many confounding factors in relatively small comparative cohort groups. We acknowledge the heterogeneity due to factors such as the amount of bone and soft tissue resection, differences in postoperative management, use of chemotherapy, and the nonrandomized choice of reconstruction type. In addition, because we compared our recent cases of RHA with past PPC reconstruction cases, improvement in surgical skill may have influenced the complication rate. However, between 2 groups, no differences were found in tumor size, pathologic diagnosis, resection type, local recurrence, or metastasis rate. Furthermore, the high proportion of male patients in the RHA group may be related with the superior functional outcome. However, this factor cannot offset the time-related failure pattern in the PPC group.

Table 6. Comparison with Previous Studies

Study	No. of patients	Type of pelvic reconstruction (n)	Deep infection (%)	Amputation due to infection (%)	Reconstruction failure (%)	Local recurrence (%)	Mean MSTS score/LLD (cm)
Current series	40	PPC (16) RHA (24)	2/16 (12) 0	0 0	11/16 (69) 0	3/16 (18) 6/24 (25)	14.8/3.7 23.5/3.7
Hu et al. (2012)[23]	27	RHA	0	0	0	0	22.6/5
Angelini et al. (2014)[28]	270	No reconstruction (133) Allograft (57) APC (59) Pelvic prosthesis (21)	20/133 (15) 16/57 (28) 12/59 (20) 7/21 (33)	5/55 (9)	16/137 (11) Reconstruction removed for infection	NA	NA
Gebert et al. (2011)[1]	62	Hip transposition	20/62 (32)	1/62 (1)	25/62 (40) Had revision	6/62 (9.6)	18.6/5
Donati et al. (2011)[11]	35	APC	8/35 (22)	0	15/35 (42)	3/35 (8.5)	21.6/NA
Jaiswal et al. (2008)[7]	98	Pelvic prosthesis	17/98 (18)	1/98 (1)	22/98 (23.7)	29/98 (31)	59.4% (TESS)

MSTS: Musculoskeletal Tumor Society, LLD: leg length discrepancy, PPC: pasteurized autograft-prosthesis composite, RHA: resection hip arthroplasty, APC: allograft prosthesis composite, NA: not assessed, TESS: Toronto Extremity Salvage Score.

Our comparative study and previous reports show that RHA is a valuable primary procedure after periacetabular resection, with much reduced complication rates or need for further surgery (Table 6). Chronologically, patients with pelvic resection face 2 major complications: infection and mechanical failure. Infection is a devastating event that may lead to removal of the reconstruction hardware or hindquarter amputation. However, pelvic reconstruction was also reported as an independent contributory factor to infection.[28] Lower rates of infection in the resection alone group may be explained by the shorter operative time, no foreign body, and reduced dead space by permitting proximal migration of the femoral head. Ensuing problems are mechanical, and include nonunion or fracture of biologic material and loosening or breakage of the prosthesis.[7,28] These late mechanical complications also necessitate the removal of the construct in a substantial proportion of patients, and the functional results of failed cases after intervention are worse than those of primary RHA. Conceptually, because either RHA or failed reconstruction is a pseudoarthrosis, failed reconstruction is assumed to have a functional score similar to that of resection alone. However, 2 factors are related to superior outcome of RHA. One critical factor is the integrity of the femoral head. Patients with failed reconstruction invariably lose the femoral head, and this leads to an additional shortening of around 5 cm (the usual height of the femoral head), compared to RHA patients. Moreover, this loss of femoral head precludes the development of neo-acetabulum. In this regard, in patients who can accept initial shortening of the affected limb, RHA would be a valuable procedure with long-term durability and low risk of complications.

RHA after periacetabular resection is not new. As early as 1978, one study reported the procedure as a satisfactory substitute for hindquarter amputation in 5 patients with chondrosarcoma.[2] Since then, several series have reported the usefulness of RHA after pelvic resection with some variation in technique and concept.[18,20,30] However, for better results, there are points to consider with regard to optimal indications, surgical technique, and postoperative care. To create a bony or fibrous "neo hip joint," the femoral head should not be involved by the tumor and a substantial portion of the iliac wing should be saved. Patients with less iliac wing resection (preferably iliac osteotomy level > 9 cm from the iliac crest) show minimal limb shortening and an increased percentage of bony neo-acetabulum formation. At the time of surgical approach, the origins of hip abductors and hip flexors are detached inferiorly and laterally through osteotomies made along the iliac crest and anterior iliac spine. This approach seems to facilitate repair after resection and functional recovery. To maintain the iliac wing-femoral head contact and to minimize the external rotation of the femoral head, a single wire was tied between the femoral head and ilium in half of our patients. However, as the case number increased, we found that this wire fixation was not necessary. In a previous report, to control the location of the femoral head postoperatively, skin traction with rotation-proof shoes or skeletal traction was applied (ambulation was started 4–6 weeks later).[23] In our series, except for the 3 early cases with postoperative hip spica cast, all patients were encouraged to ambulate around 2 weeks after surgery. Early active exercise seemed to promote the formation of a neo-hip joint. In active young patients, walking without aid and neo-hip joint formation was observed around 6 months postoperatively; however, at older ages, independent walking took up to 1 year. The average MSTS functional score in patients with neo-acetabulum formation was 25.3, while that of patients without neo-acetabulum was 20.1.

In conclusion, our comparative study confirmed that RHA for periacetabular tumors can be an excellent alternative to anatomical reconstruction. RHA offers a short surgical time, low complication rates, and functional results comparable to those of other reconstruction methods. However, this procedure is indicated for patients who can accept some shortening of the limb, and the tumor should be confined to the periacetabular area.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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