



## Research Paper

## Pelvic reconstruction following resection of tumour involving the whole ilium and acetabulum

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## ABSTRACT

**Background:** Functional reconstruction following resection of pelvic tumours with the ileum and the acetabulum involvement is challenging and demanding. The aim of this study was to evaluate the results of these patients receiving pelvic reconstruction with a femoral head autograft plus a hemipelvic prosthesis.

**Methods:** Eighteen patients receiving pelvic reconstruction with a femoral head autograft plus a hemipelvic prosthesis following resection of pelvic tumours involving the whole ileum and the acetabulum were included in this study from April 2006 to June 2014. Oncological status, functional results, and complications of these selected patients were analysed.

**Results:** The follow-up was 15–125 months (median 43). The functional MSTS-93 scores of the 18 patients available for the functional analysis were 37–87% (mean 60.7%). Complications occurred in seven patients (31.8%); dislocation in two (9%); and deep infection in three patients (13.6%) and two patients healed well following thorough debridement and antibiotic treatment. Five patients had local recurrence (22.7%). Lung metastases occurred in eight patients; seven died of disease and one lived after the metastasectomy. The 5-year overall Kaplan–Meier survival and disease-free survival rates were 61.7% and 50%, respectively.

**Conclusions:** The procedure of femoral head autograft plus hemipelvic prosthesis was an effective method to reconstruct the defect following the whole ileum and the acetabulum resection; the functional outcomes were satisfactory, and it had an acceptable complication rate.

## 1. Introduction

Great advances in orthopaedic oncology have made limb salvage possible for pelvic tumour, and different procedures have been developed to preserve limb function. Enneking and Dunham suggested a classification system of pelvic tumour resection in 1978 [1]. Type I resection involves the whole or part of the ilium; type II resection is the removal of the periacetabular region; and type III resection is the removal of the ischio-pubic region. Different types of resection require different reconstruction method, which may lead to differences in functional status between patients. Patients with periacetabular tumour would have a severe handicap after the resection if they received hindquarter amputation or no reconstruction after the removal of the tumour. As reconstruction techniques developed, several methods including hip transposition [2], hemipelvic prostheses [3,4], and allograft and prosthesis combinations have been applied to reconstruct the defect following a type II resection [5].

As we know that pelvic tumours usually involve more than one region. For the most common combination of a type II/III resection, the

ilium is intact and serves as a pedestal for the prosthesis to be fixed [6,7]. Another frequent combination is a type I/II resection, and sometimes region III is also involved by the tumour. Both of the sacroiliac joint and the hip joint would be sacrificed following the tumour resection, leaving a vertical surface of the sacrum, which makes the reconstruction difficult, even impossible for some reconstruction method to be carried out.

A modular hemipelvic prosthesis developed in our centre to reconstruct defects following type II or type II/III pelvic resection a decade ago (Fig 1a). As most of the pelvic prostheses do, the prosthesis was intended to fix to the residual bony structure of the ilium (Fig 1b). In order to avoid amputation and obtain a better functional result for those patients with tumour involving the whole ileum and acetabulum, we developed a new reconstruction method since April 2006, which is to fix the resected femoral head and neck to the lateral side of the sacrum to build a pedestal for the prosthesis. Here, we review these cases that accepted the femoral head autograft (FHA) and pelvic prosthesis replacement to reconstruct the defect following type I/II or type I/II/III pelvic tumour resections (Fig 1c). The oncological and functional

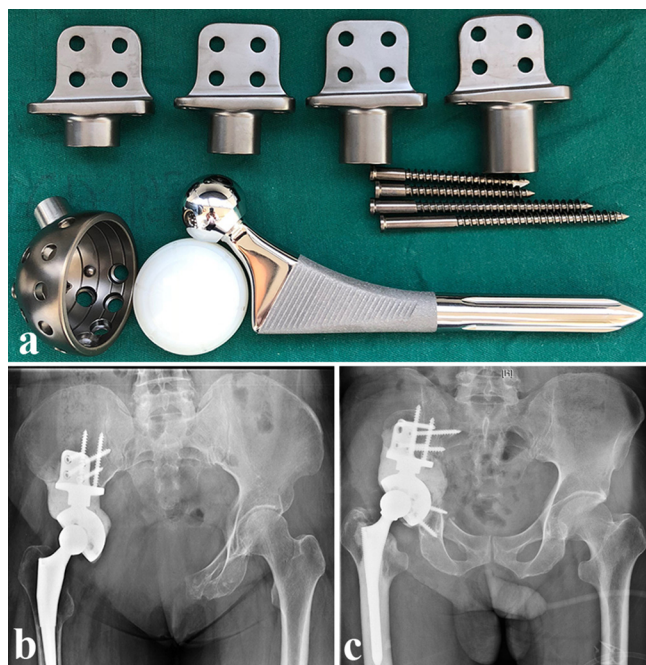
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**Fig. 1.** a, A modular pelvic prosthesis was used to reconstruct defects after type II resections of pelvic tumours. The prosthetic set consists of iliac components with variable length bushing, a metal acetabular component, a polyethylene acetabular component, and a femoral component. b, A anteroposterior view of a typical pelvic prosthesis after a type II + III resection. The residual ilium served as a pedestal for the prosthesis to be implanted. c, A anteroposterior view of a femoral head autograft and pelvic prosthesis for a type I + II tumor resection. The femoral head autograft fixed to the lateral side of sacrum serves as a pedestal for the prosthesis.

results and complications were analysed to investigate the value of the technique in the treatment of these selected patients.

## 2. Patients and methods

### 2.1. Data collection and inclusion criteria

The results of patients who received FHA and pelvic prosthesis replacement in our hospital from April 2006 to June 2014 were collected in this study. The type of resection of each pelvic tumour was determined according to the classification system of Enneking and Dunham [1]. The inclusion criteria were: patients having a primary sarcoma involving the pelvis that required a type I/II or type I/II/III resection, and patients with a solitary metastatic tumour in the same region where the purpose of the surgery was to cure the disease; the reconstruction type was FHA combined with pelvic prosthesis replacement; and the availability of pathology results, complete imaging data, and follow-up information. Patients with tumours involving the proximal femur or sciatic nerve were excluded from the study because the functional results for these patients might differ if the proximal femur or sciatic nerve is resected. After this selection, 22 patients were enrolled in the study: 12 males and 10 females. Informed consent was obtained from all patients.

The preoperative preparation consisted of routine laboratory tests, X-rays, bone scans, and magnetic resonance (MR) and computed tomography (CT) scans of the pelvis to evaluate the patients' status and the stage of the disease. Neoadjuvant chemotherapy was given to the patients with high-grade osteosarcoma, Ewing's sarcoma, and undifferentiated mesenchymal sarcoma. After the chemotherapy, the patients received bone scan, pulmonary CT scans, and CT or MR scans to re-evaluate the tumour status. All patients with primary tumours were at stage IIB according to the Enneking staging system [8].

### 2.2. Surgical technique

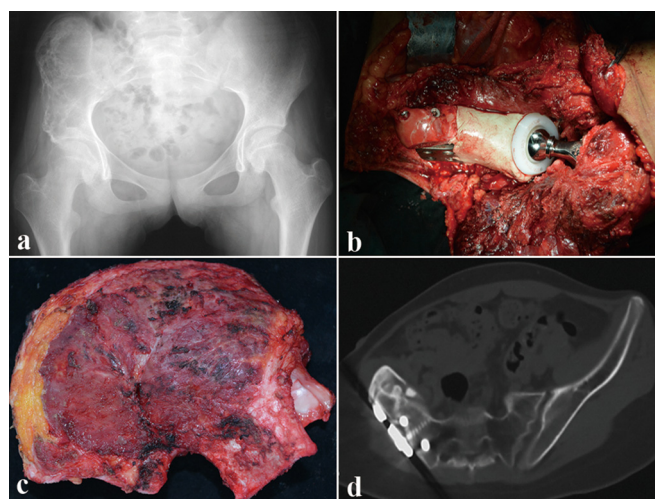
Patients were placed in a lateral position on the contralateral side of the tumour. A utilitarian pelvic incision was done for all the patients. An auxiliary incision was done from the anterior superior iliac crest to the greater trochanter for osteotomy of the femoral neck. The femoral head and neck were resected and preserved in sterile normal saline for autografting. The tumour was exposed and resected with a jig-saw or an oscillating saw through the normal bone structures after the critical structures such as the iliac and femoral vessels, the femoral nerve, and the sciatic nerve were protected and the surrounding soft tissue was dissected.

The cartilage and the subcartilaginous bone were removed to expose the cancellous bone of the sacral ala to prepare for autografting. The femoral head was trimmed to the width of the femoral neck and fixed to the sacral ala with the angle of the longitudinal axis of the femoral head and the sacrum at 40–50° to rebuild the pelvic incidence (PI) in the sagittal plane, which was important to maintain body balance [9]. The hemipelvic prosthesis was from Chunlizhengda Medical Instruments Co., Ltd., Beijing, P. R. China was adopted. First, an iliac component with adequate length that aimed to restore the sagittal pelvic thickness (SPT) was selected and implanted to the autograft and lateral side of the sacrum. Then the bushing part of the metal acetabular component was inserted in the iliac component and fixed.

The polyethylene cup bearing an anti-dislocation shoulder was augmented to the metal acetabular component with gentamycin-embedded cement, and the extroversion and anteversion of the cup were adjusted to an angle of 45° during this procedure. A femoral component was implanted, and reduction of the hip joint was made (Fig 2). Soft tissue reconstruction was achieved by suturing the gluteus medius and gluteus maximus muscles to the erector spinae and quadratus lumborum muscles posteriorly, and the abdominal muscle laterally and anteriorly, with the hip joint being placed at an abducent position.

### 2.3. Post-operative management and complications assessment

Partial weight-bearing with a brace was permitted after 3 months and the brace was retained until union was evident on a CT scan. Patients were followed up every 3 months for the first 3 years, then every 6 months for another 2 years, and then annually. Bony union was



**Fig. 2.** A 13-year-old female patient had an osteosarcoma at her right pelvis. The tumour involved the ilium and the roof of the acetabulum. a, A anteroposterior view after the chemotherapy. b, following the tumour resection, the femoral head was fixed to the lateral side of the sacrum, then a pelvic prosthesis was fixed to the femoral head and the sacrum and the femoral component was implanted. c, The specimen of the resected tumour. d, The autograft was healed 9 months after the surgery on a CT scan.

assumed when the continuous bone callous was visible on a CT scan (Fig 2). Functional outcome was evaluated according to the Musculoskeletal Tumour Society (MSTS)-93 system at the latest follow-up [10]. Complications, including infection, wound dehiscence, and mechanical problems, were documented up to the final follow-up. Local recurrence and any metastases were documented during the follow-up. The margin of each tumour was evaluated by the method described by Enneking et al. [11], namely a wide, marginal, or intralesional resection.

### 2.4. Statistical analysis

The 5-year survival rate of the patients was estimated by Kaplan–Meier analysis using IBM SPSS statistics (v. 19.0; IBM Corp., Armonk, NY).

## 3. Results

### 3.1. Patient's characteristics

The age range was 13–70 years (mean 37 years). The histopathological diagnoses were summarized in Table 1. Twenty-one patients were diagnosed and treated in our department primarily, and one patient was referred to our department after unsuccessful surgery at another medical centre.

The operation time range was 170–410 min (mean 269 min). The bleeding volume was 300–3500 ml (mean 1700 ml). According to the classification system of Enneking and Dunham, a type I+II resection was performed for 12 patients, and a type I+II+III resection was performed for 10 patients. Resection margins were wide in 11 patients (50%), marginal in 8 patients (36%), and intralesional in three patients (14%).

### 3.2. Complications

Complications (Table 1) occurred in seven patients during the follow-up (31.8%). Dislocation occurred in one patient perioperatively (9%), both of whom underwent open reduction. Dislocation occurred in one patient (4.5%) 2 years after the surgery, and open reduction was

performed. Deep infection occurred in three patients (13.6%); two of these healed well after thorough debridement and antibiotic treatment. One patient lived with the infection and left the chronic sinus untreated. One patient suffered from symptomatic thrombosis and received anti-coagulant therapy. One patient with wound dehiscence received debridement and healed well after the treatment.

### 3.3. Patient's oncological results

The median follow-up time was 43 months (range 15–125) up to December 2016. Local recurrence occurred in five patients (22.7%). One of these received local resection of the tumour that recurred in soft tissue and had no evidence of disease. Two of them received hind-quarter amputation; one died of local progression of the disease, and another died of lung metastasis. Two patients with recurrence received radiation: one died of lung metastasis, and one lived with disease. Lung metastasis occurred in eight patients, and seven died of it. One patient suffered from multiple bony metastases and still lives with disease. The 5-year overall Kaplan–Meier survival and disease-free survival rates were 61.7% and 50%, respectively.

### 3.4. Bone union and patient's functional results

Bone healing was not evaluated in three patients with local recurrence, and they were ruled out of our analysis of bone healing status. The remaining patients had bone healing at a mean time of 10 months (range 6–15 months). No bone fracture or mechanical problem of the prosthesis was observed during the follow-up (Table 1).

Three patients did not receive functional evaluation because local recurrence affected their bone healing, and one patient because of poor general health status. The functional outcome of the remaining 18 patients according to MSTS-93 ranged from 37% to 87% (average 60.7%). No patient required a wheel-chair for mobilization, except one patient who was in a poor general state of health after the surgery.

## 4. Discussion

We limited our study to patients who received a type I/II or a type I/II/III pelvic resection because reconstruction of such a defect was quite

**Table 1**  
General data, complications, and follow-up data of all patients.

No.	Age	Gender	Tumour	Location	Patient's status	Bone healing (months)	Relapse	Follow-up (months)	Complications	MSTS-93 score
1	31	F	CS	I+II+III	NED	9		119		17
2	36	F	CS	I+II	NED	12		110	Deep infection	11
3	36	F	CS	I+II+III	DOD	<sup>a</sup>	Local, lung	20	Dislocation	
4	18	F	OS	I+II+III	NED	9		103	WD	20
5	35	F	OS	I+II	DOD	9	Lung	23	Dislocation	21
6	70	M	RCC	I+II	NED	12		86	DVT	
7	58	F	OS	I+II+III	NED	9		82		25
8	16	M	OS	I+II+III	DOD	6	Local	28		16
9	51	M	CS	I+II	DOD	12	Lung	28		16
10	53	M	UPS	I+II	DOD	9	Lung	29		18
11	48	M	OS	I+II	DOD	<sup>a</sup>	Lung	9	Deep infection	16
12	53	F	CS	I+II	NED	9	Local	57		17
13	13	M	OS	I+II+III	NED	12		50		18
14	39	F	CS	I+II+III	DOD	<sup>a</sup>	Local, lung	14		
15	59	F	LOS	I+II+III	NED	9		39		26
16	30	M	OS	I+II	AWD	9	Lung, bone	39		21
17	62	M	CS	I+II	AWD	9	Local	38	Deep infection	
18	18	M	EWS	I+II+III	NED	9		36		13
19	15	F	EWS	I+II	NED	12		47		16
20	15	M	OS	I+II+III	DOD	15	Lung	30		15
21	23	M	OS	I+II	NED	12		27		14
22	25	M	CS	I+II	NED	6		24		26

F, female. M, male. CS, chondrosarcoma. OS, osteosarcoma. RCC, renal clear cell carcinoma. EWS, Ewing's sarcoma. UPS, undifferentiated pleomorphic sarcoma. LOS, low grade osteosarcoma. NED, no evidence of disease; DOD, dead of disease; AWD, alive with disease. WD, wound dehiscence. DVT, deep vein thrombosis.

<sup>a</sup> These patients were excluded because of local recurrence.

different compared with type II or type II/III resections. Accordingly, the functional status between different types could vary. The femoral head and neck was uninjured in this series of patients because the cartilage of the hip joint serves as a barrier; and it needs to be resected for the implant of the femoral component when prosthesis was used as a reconstruction method. As we know that the sacro-iliac joint is a rigid one, the hip joint is a mobile one. So, we trimmed the femoral head and neck, and then fixed it to the lateral side of the sacrum to build a concrete pedestal for the pelvic prosthesis. The pelvic prosthesis was fixed further to the autograft and the sacrum to build a mobile hip joint. A solid bone union between the femoral autograft and the sacrum was achieved in all patients at a mean time of 10 months except for three patients with local tumour recurrence. We considered that the large contact surfaces, the cancellous bones of both sides, the solid and gapless fixation were reasons for the high union rate. The functional outcomes were satisfactory, and it was proved to be an effective method to reconstruct the defect.

Because of the rarity of pelvic tumours, almost all studies of pelvic reconstruction following tumour resection were included different resection types in a same cohort. Actually the reconstruction following a type I/II resection was quite different with that of a type II or type II/III resection. Most pelvic prosthesis—such as pedestal cup prostheses [6,12], saddle prostheses [7], modular prostheses [13] were not suitable to reconstruct the defect following a type I/II resection because the ilium, which served as a pedestal for the majority of the prostheses, was resected. Even now, hindquarter amputation is still the choice for these patients with wide involvement of pelvic tumour, which would lead to severe handicap. Some authors used endoprosthesis to reconstruct the defect following tumour resection to avoid amputation. Zang et al. reported reconstruction of the defect following tumour resection with the sacroiliac joint involvement with a rod and pelvic prosthesis system [14]. The mean MSTS-93 of the 17 patients was 58%; eight patients (47.1%) had complications with a deep infection rate of 11.7%. Bo et al. reported patients with a rod combined hemipelvic endoprosthesis for the reconstruction of types I/II/IV resection [15]. The mean MSTS-93 score was 53.9%. One patient (16.7%) had aseptic loosening; one patient (16.7%) had deep infection. The main problem of the rod and pelvic prosthesis introduced by them was the weak connection between the prosthesis and the sacrum; stress on the rods may endanger the long-term stability of the prosthesis. Computer-aided designed prosthesis was a choice for these selected patients, as reported by Wirbel et al. [16] and Ozaki et al., [17] the functional status was fair and acceptable. But the functional results and complications were the mixture of different resection and reconstruction types.

Arthrodesis or pseudoarthrodesis may be performed for these patients. Gebert et al. reported a method of hip transposition for the treatment of such resections, which was to lift the femoral head to the lateral side of the sacrum and confine it with a pseudo-capsule made by a Mutars re-attachment tube [2]. The functional outcome measured by MSTS-93 was 62% for the total of 62 patients and the deep infection rate was 32% (20/62). A high reoperation rate was also observed in the study: 40% of the patients required surgery because of shortening of the lower limb, necrosis, or displacement of the femoral head. Almost all the patients have a problem of hip function and required at least one crutch to walk. Fuchs et al. reported a series of 21 patients with iliofemoral arthrodesis and 11 patients with iliofemoral pseudarthrosis [18]. The non-union rate was 14% in the arthrodesis group, and the mean MSTS score in the six patients who had a radiologically solid union and in the 6 patients with pseudarthrosis were 71% and 25%, respectively. In this study, all resections were Type II or Types II/ III resection so that the ilium was left to minimize leg length discrepancy and to enhance fusion.

Allograft or inactivated autograft and prosthesis composite were another choice of reconstruction following such a resection. The complication rates, especially the infection and fracture rate, are high. Beadel et al. reported 21 cases of patients who received allografts

combined with a hip joint replacement to reconstruct the defect following a type I+II or a type I+II+III resection of pelvic tumour [5]. The high complication rate, such as deep infections, bone fractures rate was 47% and mechanical failure and reoperation rate (30%). Campanacci D reported a series of patients reconstructed with allograft and a total hip prosthesis [19]. In this study, 17 patients had a type I/II or type I/II/III resection. The deep infection, aseptic loosening, the dislocation and Sciatic nerve palsy rate were 35.3%, 5.9%, 23.5% and 35.3%, respectively. The mean functional result of the ten patients in this group was 53.3% according to MSTS 93. The high complication rate renders this method less favourable for reconstruction following pelvic tumour resection. Wafa et al. reported a series of 18 young patients with a mean age of 24.8 years who received extracorporeally irradiated tumour-bearing autograft and total hip joint prosthesis [20]. Eleven patients underwent a type I+II resection. The non-oncologic complication rate was 55% and re-operation rate was 28% in total, which was similar to that of reconstructed with allograft. Proximal femur autografting combined with prosthesis was also reported for reconstructing pelvic bony defects [21,22]. In our study, the femoral head and neck were large enough to build a support for the prosthesis, and a small bone chunk also facilitated the bone union. Some authors reported pelvic tumours involving different regions in a single study [23,24]; that make it difficult to compare the functional outcomes and complications with our results.

We recorded three deep infections in our study; the reason for this relatively low rate of infection might be that the autografts and pelvic prostheses we used were much smaller compared with the tumour size, which improved the soft tissue coverage of the prosthesis. No mechanical failure was observed in our study, except for two patients who suffered from local recurrences. The results indicate that autografting combined with a pelvic prosthesis was an effective method for pelvic reconstruction following pelvic tumour resection. However, longer follow-up time is required to draw a solid conclusion. The functional outcomes, oncological status, and complications of some similar studies were summarized in Table 2.

The recurrence rate of pelvic tumours is much higher than that of tumours involving other parts of the body because of the complexity of the regional anatomy. The local recurrence rate was 22.7% in our study, which was similar to the values reported in the literature that ranged from 10% to 35%.

There were a few limitations to our study. Owing to the rarity of pelvic tumours, more studies are required to draw any clear conclusions. Another limitation was that the heterogeneous nature of the tumours required different treatment modalities, which could affect the accuracy of the oncological results. Although the subjects in our study were confined to those patients who had pelvic tumours involving the ilium and acetabulum, the age of the patients, the tumour size, and soft tissue involvement were not the same. Furthermore, as 3D printed technique emerges, whether individualized prosthesis with porous structure has an advantage over our method still required more study.

## 5. Conclusion

FHA combined with modular hemipelvic prosthesis was an effective method for reconstructing defects following pelvic resection with tumour involving the whole ilium and acetabulum. The functional outcomes were satisfactory, and the approach had acceptable infection and reoperation rates compared with results reported in the literature.

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None.

## Conflict of interest statement

On behalf of all authors, the corresponding author states that there

**Table 2**  
Oncological results, functional status, and complication analysis.

Reference	Case numbers	Follow-up months (range)	Reconstruction	Death perioperatively	Local recurrence	Five-year survival	Deep infection	Dislocation	Revision	Wound dehiscence	MSTS-93
Gebert (2011)	62	30 (5–185)	HT	0	6 (9.6%)	80.5%	20 (32.2%)	6 (9.6%)	25 (40.3%)	14 (22.5%)	62%
Campanacci D	17 <sup>a</sup>	34.6(2–137)	ALP	0	3(17.6%)	NA	6(35.3%)	1(5.9%)	NA	NA	53.3%
Wafa	11 <sup>b</sup>	51.6(4–185)	IAP	0	0	NA	3(27.2%)	1(9.1%)	2(18.2%)	1(9.1%)	74.2%
Bo (2015)	50 <sup>c</sup>	54 (12–113)	MP	0	18%	64%	14%	4%	10%	28%	61.4%
Zang (2014)	17	33 (15–59)	RSP	0	6 (35%)	62.4%	2 (11.7%)	1 (5.8%)	0	5 (29.4%)	58%
Gordon (2005)	21 <sup>d</sup>	5–180	ALP	2	3 (15%)	40%	9 (47.3%)	0	3 (30%)	NA	64%
This study	22	47 (9–119)	AUP	0	5 (22.7%)	61.7%	3 (13.6%)	2 (9%)	0	1 (4.5%)	60.7%

HT, hip transposition. MP, modular prosthesis. RSP, rod and screw + prosthesis. ALP, allograft prosthesis. AUP, autograft prosthesis. IAP, irradiated autograft and prosthesis. + Survival rate at the last follow-up. NA, not available.

<sup>a</sup> The total number of the case series was 33 patients with 17 patients received a type I/II or I/II/III resection.

<sup>b</sup> The total number of the case series was 18 patients with 11 patients received a type I/II resection.

<sup>c</sup> Thirty-eight patients received type I/II or I/II/III resections.

<sup>d</sup> The authors reported two groups of patients. One group of the patients included twenty-one patients who received type I/II or I/II/III resections.

is no conflict of interest.

**Ethical approval**

This study was approved by the institutional research ethic board of People's Hospital of Beijing University.

**Author contribution**

Huayi Qu contributed to the drafting of the manuscript and approval of the final version of the manuscript.

Dasen Li contributed to collection of the clinical data, including general data of patients, operation data, complications, etc.

Shun Tang contributed to the revision of the manuscript.

Jie Zang contributed to collection of the follow-up data and functional evaluation of the patients.

Yifei Wang contributed to analysis of the data.

Wei Guo contributed to the conception and design of the study.

**Supplementary material**

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jbo.2019.100234.

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