Endoprosthetic replacement for tumors of the proximal humerus

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Background
The proximal humerus is one of the primary sites of tumors. Amputation of the upper limb is highly mutilating and artificial limbs provide limited function and poor cosmesis. For these reasons, limb-preserving techniques were established. The most important aspect of limb-salvage surgery is to preserve elbow and hand function after excision of tumors of the proximal humerus, although the shoulder may remain flail, with a limited active range of movement. Endoprosthetic replacement of the proximal humerus is a well-established procedure in salvage of the upper limb that provides a reasonable shoulder function with maintained excellent elbow and hand function.

Patients and methods
Ten patients were included in this case-series study. According to the staging system of Enneking and colleagues, they were classified as having eight primary bone tumors; accordingly, there were six cases graded as stage IIB, two cases graded as IB, and two cases graded as solitary metastasis at the proximal humerus. Wide resection was carried out, followed by reconstruction by a modular replacement endoprosthetic system. The mean age of the patients was 36 years (ranging from 17 to 54 years). The follow-p period of the study ranged from 42 to 96 months, with a mean of 61 months.

Results
Excellent functional outcomes were achieved in seven patients at final evaluation, with a mean of 85.5%. Three patients died because of disease progression and were excluded from the functional evaluation. There were no local recurrences, prosthetic instability, dislocation, or infection. Two patients developed radial nerve palsy, one showed spontaneous improvement, and the second showed improvement after the release of adhesions. None of the patients required any revision surgery.

Conclusion
The use of endoprosthetic replacement as a method of reconstruction after major skeletal defects created after wide resection of a tumor at the proximal humerus represents a major progress that provides a stable functional spacer after surgery. It has also obviated the need for prolonged immobilization as in cases of biological reconstruction. It results in a low complication rate and immediate stability, which facilitates normal functioning of the elbow and hand.

Keywords:
endoprosthetic, proximal humerus, tumors

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Introduction

The proximal part of the humerus is a common site for tumors, which, by destroying bone, renders the upper arm unstable and prevents useful hand function [1]. Curative resections of the tumors of proximal humerus have been made possible in this era of limb salvage, with accurate staging and clear preoperative imaging defining the margins of resection [2].

Limb salvage following resection of a tumor in the proximal part of the humerus poses many challenges. Reconstructive options are limited because of the loss of periarticular soft tissue stabilizers of the glenohumeral joint in addition to the loss of bone and articular cartilage [3].

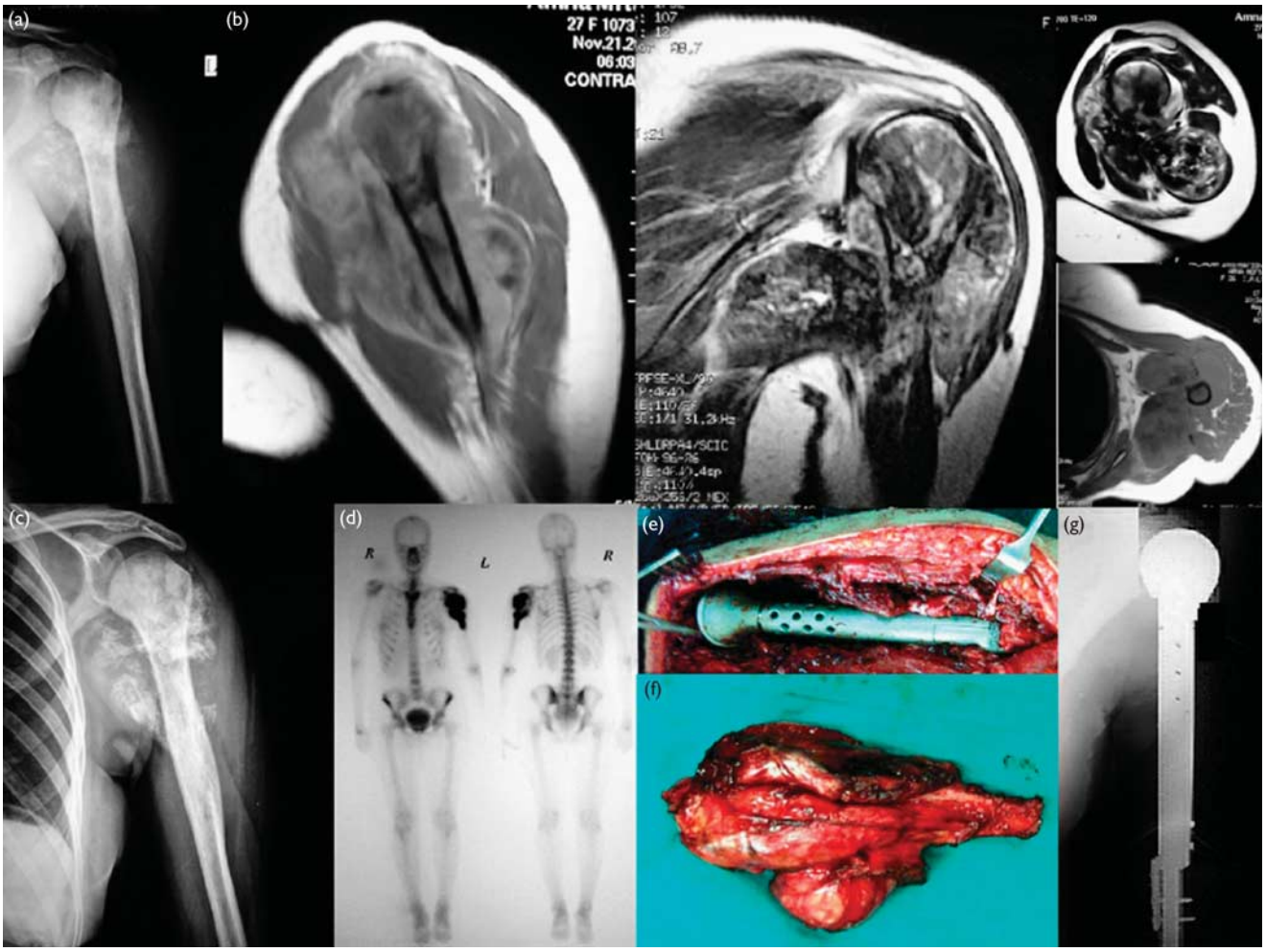
There are two main groups of reconstructive procedures for the proximal humerus. One involves arthrodesis and includes autogenous grafts [4,5], allografts [6], and composite allografts [4,7]. The other aims to preserve glenohumeral movement using functional spacers [7,8], prostheses for replacement of the proximal humerus [1,2,7], or osteoarticular allografts [9]. The advantages and disadvantages have been discussed widely.

In this study, 10 patients with tumors of the proximal humerus were treated with wide resection and endoprosthetic reconstruction. The aim of this study was to evaluate the complications, oncological, and functional results of endoprosthetic proximal humeral replacement.

Patients and methods

Ten patients underwent resection of the proximal humerus and modular endoprosthetic replacement for the diagnosis of osteosarcoma ($n = 3$), parosteal osteosarcoma ($n = 1$), chondrosarcoma ($n = 2$), metastasis ($n = 2$),

Figure 1



Case 2: Osteosarcoma at the proximal humerus in a 19-year-old woman. (a) Prechemotherapy radiograph, (b) MRI postchemotherapy showing the extent of the lesion with an intact neurovascular bundle, (c) postneoadjuvant chemotherapy radiograph showing marked response to chemotherapy, (d) isotope bone scan showing the absence of metastatic lesions, (e) the modular prosthesis *in situ* after tumor resection, (f) resected 18 cm of the proximal humerus including the tumor, (g) follow-up radiograph after 2 years showing stable prosthesis.

malignant fibrous histiocytoma ($n = 1$), and fibrosarcoma ($n = 1$). The mean age of the patients was 36 years, ranging from 17 to 54 years.

The staging system of Enneking *et al.* [10] was used to classify primary bone tumors; accordingly, there were six cases graded as stage IIB, two cases graded as IB, and two cases graded as solitary metastasis at the proximal humerus from cancer breast and renal cell carcinoma.

The follow-up period of the study ranged from 42 to 96 months, with a mean of 61 months.

Before surgery, the extent of disease and the presence of metastases were determined by clinical assessment and staging studies including plain radiographs, computed tomography, MRI, and isotope bone scan (Figs 1–5). Angiography was also performed to evaluate tumor relation to the axillary bundle. Open biopsy was performed in all cases to make a histological diagnosis.

Limb-sparing surgery was planned, if wide excision could be performed, without sacrificing major nerves or vessels as indicated by the staging studies. Imaging studies were used to determine the level of resection and to calculate the proportion of the humerus resected.

Neoadjuvant (preoperative) chemotherapy was used in three cases; all were osteosarcoma. All of them were managed by the same preoperative chemotherapy protocol of three cycles at a 3-week interval. In each cycle, the patient was administered adriamycin 75 mg/m^2 and cisplatin 150 mg/m^2 for 3 days. After completion of the three cycles, restaging of the tumor was performed using the same preoperative imaging studies.

Surgical technique

All patients underwent wide excision of the tumor with clear margins. The patient was placed in a semisitting position, and the proximal humerus was dissected using an anterolateral approach.

The surgical incision extends distally from the middle one-third of the clavicle, passes just medial to the coracoids process along the deltopectoral groove, and follows the course

Figure 2

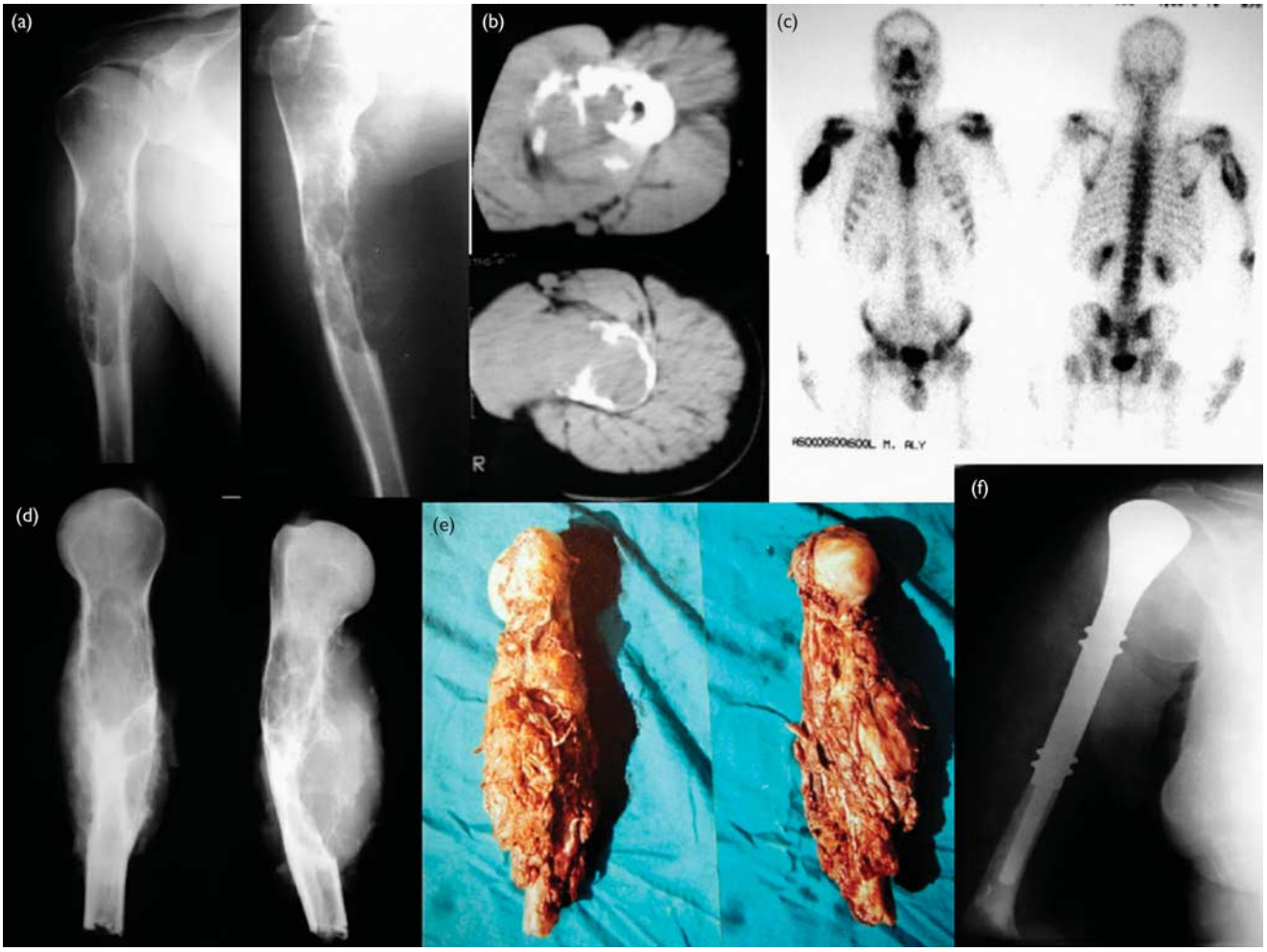
Case 5: Chondrosarcoma at the proximal humerus in a 49-year-old woman. (a) Preoperative radiograph, (b) MRI showing the extent of the lesion intramedullary and extraosseous proximally, (c) postoperative radiograph showing the isoelastic prosthesis applied after tumor resection, (d) follow-up radiograph after 3 years showing no local complication in those who survived with this type of prosthesis.

of the neurovascular bundle, distally along the anteromedial aspect of the arm. The biopsy site is removed in an elliptical manner in continuity with the skin incision and is left attached to the surgical specimen. Full-thickness, fasciocutaneous skin flaps are developed medially and laterally.

The deltopectoral groove is identified and the cephalic vein is ligated, divided, and resected proximally and distally at the wound margins. The inferior border of the pectoralis major is identified and the fascia is opened.

The pectoralis major insertion is released from the humerus using cautery. The pectoralis major is retracted medially. The musculocutaneous nerve is dissected inferomedial to the coracoid in the interval between the pectoralis minor and coracobrachialis and short head of

Figure 3



Case 6: Fibrosarcoma at the proximal humerus in a 30-year-old man. (a) Preoperative radiographs showing destruction of the bone with soft tissue extent, (b) CT scan showing bony destruction and triceps infiltration, (c) isotope bone scan showing a solitary lesion, (d) radiographs of the resected specimen, (e) resected specimen with cuff of soft tissue around the tumor, (f) follow-up radiograph after 5 years showing the modular prosthesis with no signs of loosening.

the biceps insertions, where it enters these latter muscles. With the musculocutaneous nerve protected, the coracobrachialis and short head of the biceps complex is released from its coracoid insertion. This is followed by the release of the pectoralis minor.

At this point, the entire neurovascular bundle can be observed from the clavicle to the humerus. The anterior and posterior humeral circumflex vessels are ligated and divided to retract the neurovascular bundle away from the tumor pseudocapsule (subscapularis muscle).

Intra-articular resection was performed through the sequential release of the deltoid, long head of the biceps, latissimus–teres major complex, rotator cuff, and gleno-humeral joint capsule from their insertions.

The osteotomy was performed through the proximal humerus 3–4 cm distal to the tumor extent to ensure a wide margin. Any brachialis muscle overlying tumor was resected en bloc.

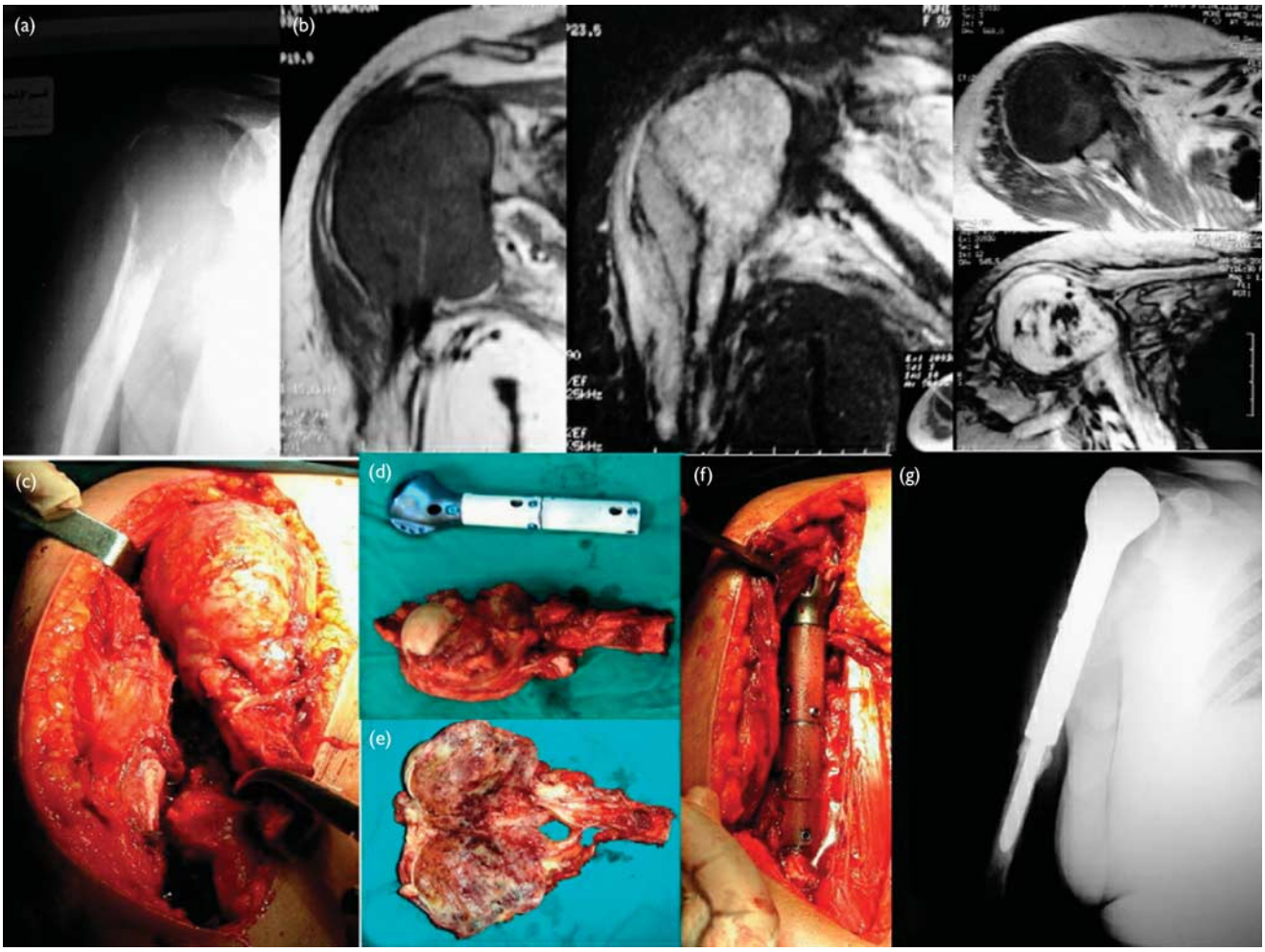
Following resection of the proximal humerus, the length of the resected segment or the defect was measured. The resultant defects ranged from 14 to 18 cm, with a mean of 16.4 cm.

The required dimensions of the prosthesis were estimated using radiographs in all patients and the final confirmation was made intraoperatively. Three types of prosthesis were used: cemented modular prosthesis in three cases (Figs 3 and 4), cementless modular with extracortical fixation through a side plate in five cases (Figs 1 and 5), and isoelastic prosthesis in two cases (Fig. 2).

Local soft tissue reconstruction was performed using dacron tapes for static suspension to secure the prosthesis proximal to the acromion process.

Continuous suction was required for 3–5 days after surgery to prevent fluid collection. Perioperative intravenous antibiotics were administered until the sutures were removed on day 15.

Figure 4



Case 8: Metastatic solitary lesion from cancer breast at the proximal humerus in a 48-year-old woman. (a) Preoperative radiograph, (b) MRI showing the extent of the lesion with marked destruction of the humeral head, (c) intraoperative dissection and osteotomy at the mid humerus, (d) the modular prosthesis and resected proximal humerus, (e) the resected specimen opened showing the extent of the tumor, (f) the modular prosthesis in situ with dacron tapes for static suspension to secure the prosthesis proximally to the acromion process, and (g) radiograph 1 year postoperatively.

Postoperatively, the upper limb was immobilized with a stockinette-Gilchrist bandage for 3 weeks, followed by an exercise of active and passive movement. Seven cycles of postoperative chemotherapy were performed after 3 weeks from the surgical treatment analogical to the preoperative chemotherapy.

Postoperative adjuvant therapy was used in six cases in the form of chemotherapy for four cases (three cases of osteosarcoma and one of malignant fibrous histiocytoma) and radiotherapy in two cases of metastasis.

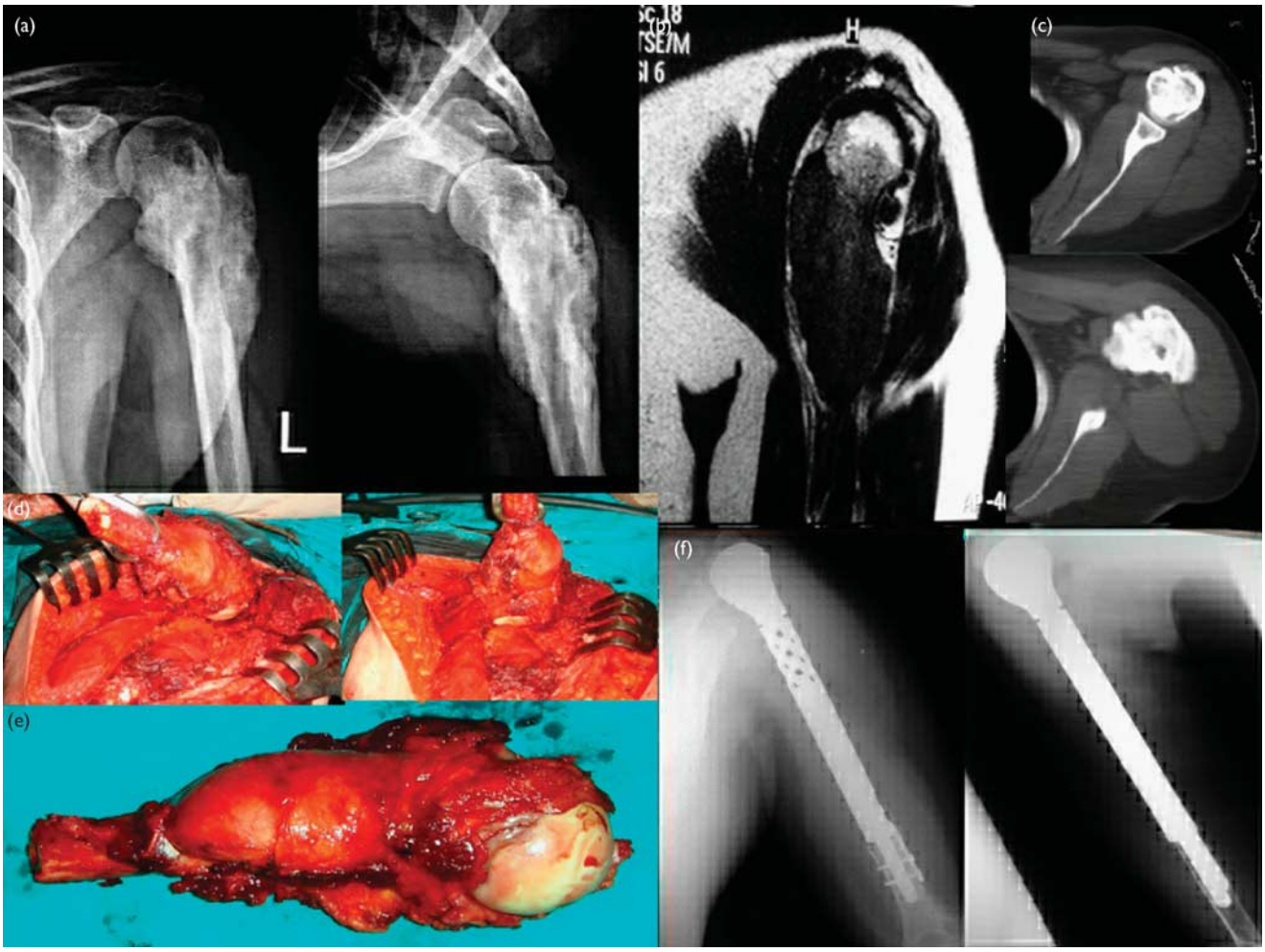
Follow-up examinations with standard radiograph series were performed at 1, 3, and 6 months, followed by every 6 months for 2 years and then annually. We analyzed the functional outcome, the risk of revision of the prosthesis, the incidence of failure of limb salvage because of amputation, and complications such as dislocation and infection following the use of the modular prosthetic replacement of the proximal humerus.

The Musculoskeletal Tumor Society (MSTS) score described by Enneking *et al.* [11] was used to assess functional outcome. Functional outcomes were evaluated after 1 year and at the latest follow-up. Numerical values from 0 to 5 points were assigned for each of the following six categories: pain, function, emotional acceptance, hand dexterity, lifting ability, and hand positioning. These values were added, and the functional score was presented as a percentage of the maximum possible score (the full score is 30). The results were graded according to the following scale: excellent, 75–100%; good, 70–74%; moderate, 60–69%; fair, 50–59%; and poor, $< 50\%$.

Results

The average duration of follow-up was 61 months (range 42–96 months). Three patients died because of systemic metastasis and were excluded from the functional evaluation. Functional outcome was evaluated in seven patients using Enneking's modified system of functional evaluation after surgical management of MSTS (Tables 1 and 2).

Figure 5



Case 1: Parosteal osteosarcoma at the proximal humerus in a 42-year-old woman. (a) Preoperative radiographs, (b) MRI showing the extent of the lesion, (c) CT scan showing the surface lesion, (d) intraoperative dissection showing the safety margin, (e) resected specimen showing the surface lesion extending to the humeral head, and (f) follow-up radiographs after 2 years showing the modular prosthesis stability.

Table 1 Epidemiological characteristics of the study group

Case	Age	Sex	Diagnosis	Stage	Type of prosthesis	Neoadjuvant therapy	Adjuvant therapy (m)	Length of the resected segment (cm)
1	17	F	Osteosarcoma	IIB	Modular prosthesis	Chemotherapy	Chemotherapy	16
2	19	F	Osteosarcoma	IIB	Modular prosthesis	Chemotherapy	Chemotherapy	18
3	19	M	Osteosarcoma	IIB	Modular prosthesis	Chemotherapy	Chemotherapy	16
4	44	M	Chondrosarcoma	IIB	Isoelastic prosthesis	None	None	16
5	49	F	Chondrosarcoma	IIB	Isoelastic prosthesis	None	None	18
6	30	M	Fibrosarcoma	IB	Modular prosthesis	None	None	14
7	54	M	Metastasis	–	Modular prosthesis	None	Radiotherapy	16
8	48	F	Metastasis	–	Modular prosthesis	None	Radiotherapy	18
9	38	M	MFH	IIB	Modular prosthesis	None	Chemotherapy	16
10	42	F	Parosteal osteosarcoma	IB	Modular prosthesis	None	None	16

F, female; M, male; MFH, malignant fibrous histiocytoma.

Excellent functional outcomes were achieved in all patients, with a mean of 85.5%, ranging from 76 to 93%. All survivors received a score of 5 (best possible rating) in the areas of pain, hand dexterity, and emotional acceptance. No patient complained of pain. All patients had normal functional use of the hand (normal sensation; grade 5 motor strength) and all patients were accepted the procedure and outcome.

Patients lost points in the following areas: function, hand positioning, and lifting ability. All patients had normal functional use of the elbow and elbow motor strength was at least grade 4 in all patients.

There were no local recurrences in any of the patients. Complications were reported in two patients in whom transient radial nerve palsy was present; in one case,

Table 2 Results

Case	Follow up (m)	Functional results	Complications	Second operations
1	60	28	None	None
2	44	27	Transient radial nerve palsy	None
3	49	25	None	None
4	Dead of lung metastasis after 12 months	–	None	None
5	84	26	None	None
6	96	28	Transient radial nerve palsy	Nerve exploration
7	Dead of the disease after 16 months	–	None	None
8	Dead of the disease after 24 months	–	None	None
9	42	24	None	None
10	54	23	None	None

it resolved spontaneously within 6 months after surgery (case 2) and in the second case, radial nerve exploration was performed at 8 months and a constriction band was found and excised, followed by gradual nerve recovery (case 6). There was no prosthetic instability or dislocation, clinically or radiographically. There was no infection. No patients developed late traction neurapraxias from the weight of the upper extremity. None of the patients required any revision surgery or major second operations.

Discussion

The proximal humerus is the third most common site of origin for osteosarcoma [12–15]. Before 1970, most patients with high-grade sarcomas arising in this location were treated with a forequarter amputation [16].

Marcove *et al.* [17] extended the indications for limb-sparing shoulder girdle resections to include high-grade sarcomas of the proximal humerus. Surgical margins and local tumor control rates were similar to those achieved with forequarter amputation. Most importantly, survival did not seem to be compromised and a functional hand and elbow were preserved. Limb-sparing resection for patients with high-grade osteosarcoma of the proximal humerus, in lieu of a forequarter amputation, subsequently became widely accepted [18].

Reconstruction of the proximal humerus after tumor resection with autogenous grafts, osteoarticular allografts, prosthetic replacements, allograft–prosthetic composites, and autograft–prosthetic composites have all been described in the literature. Each of these methods has been the subject of extensive discussion, and each presents unique problems .

Jensen and Johnston [22] reported on 14 patients who were treated with composite reconstruction of the proximal humerus (allograft or autoclaved autograft combined with proximal humerus Neer II prosthesis) after intra-articular resection. These authors reported a 25% local recurrence rate. Active shoulder abduction was good in all the patients. Most patients, however, had low-grade or high-grade tumors that were entirely intraosseous and, therefore, the majority of resections were of a smaller magnitude than those presented in the current study. Function according to the MSTS system was at least 24 (80%) in 12 of the 14 patients, which is comparable with this study.

Some surgeons have advocated arthrodesis after extra-articular resection to restore shoulder stability and improve abduction. Complications and failures have occurred frequently with this method of reconstruction and functional results do not seem to be superior to those presented in the current study. Gebhardt *et al.* [23] reported on 12 patients treated with allograft arthrodesis. Five of 12 patients (42%) were considered to have failed results.

In a study of O'Connor *et al.* [7] reconstruction was recommended through arthrodesis with a combination of an intercalary allograft and a vascularized free fibula construct for young patients treated with an extra-articular resection. Function according to the MSTS system averaged 66% for this group. The current study results was much better than the previous results. Complications were also more prevalent and of a greater magnitude.

Wittig *et al.* [24] reported excellent local tumor control, consistently good to excellent function, and excellent long-term prosthetic survival for 23 patients with osteosarcoma of the proximal humerus who had limb-sparing resection and endoprosthetic reconstruction.

Shoulder instability (prosthetic dislocation or subluxation) is a potential complication after a limb-sparing procedure for a proximal humerus sarcoma. Soft tissue reconstruction along with prosthetic reconstructions is important in achieving shoulder stability. A combination of static and dynamic reconstructions can prevent flail shoulder and improve function in prosthetic arthroplasty [25,26]. None of the patients in the current series developed prosthetic instability. This may be attributable to the method of soft tissue reconstruction used.

Endoprosthetic replacement for tumors of the proximal humerus with modular prostheses is a safe and reliable option that works as a functional spacer that has a low complication rate and immediate stability, which facilitates normal functioning of the elbow and hand.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

References

1 Ross A, Wilson J, Scales J. Endoprosthetic replacement of the proximal humerus. J Bone Joint Surg 1987; 69-B:656–661.

2 Malawer MM, Chou LB. Prosthetic survival and clinical results with use of large-segment replacements in the treatment of high-grade bone sarcomas. J Bone Joint Surg Am 1995; 77:1154–1165.

3 Abdeen A, Hoang B, Athanasian E, Morris C, Boland P, Healey J. Allograft–prosthesis composite reconstruction of the proximal part of the humerus: functional outcome and survivorship. J Bone Joint Surg Am 2009; 91: 2406–2415.

4 Wood MB. Free vascularized bone transfers for nonunions, segmental gaps and following tumor resection. Orthopedics 1986; 9:810–816.

5 Usui M, Naito T, Yamawaki S, Ishii S. Free vascularized fibular graft for treatment of malignant tumor of proximal humerus. In: Vastamaki M, Jalovaara P, editors. *Surgery of the shoulder*. Amsterdam: Elsevier Science; 1995. pp. 471–474.

6 Alman BA, De Bari A, Krajbich JI. Massive allografts in the treatment of osteosarcoma and Ewing sarcoma in children and adolescents. J Bone Joint Surg Am 1995; 77-A:54–64.

7 O'Connor MI, Sim FH, Chao EYS. Limb salvage for neoplasms of the shoulder girdle: intermediate reconstructive and function results. J Bone Joint Surg Am 1996; 78-A:1872–1888.

8 Enneking WF, Eady JL, Burchardt H. Autogenous cortical bone grafts in the reconstruction of segmental skeletal defects. J Bone Joint Surg Am 1980; 62-A:1039–1058.

9 Gebhardt MC, Roth YE, Mankin HJ. Osteochondral allografts for reconstruction in the proximal part of the humerus after excision of a musculoskeletal tumor. J Bone Joint Surg Am 1990; 72-A:334–345.

10 Enneking WF, Spanier SS, Goodman MA. A system for surgical staging of musculoskeletal sarcoma. Clin Orthop Relat Res 2003; 415:4–18.

11 Enneking WF, Dunham W, Gebhardt MC, Malawer M, Douglas J. A system for functional evaluation of reconstructive procedures after surgical treatment of tumors of the musculoskeletal system. Clin Orthop Relat Res 1993; 286:241–246.

12 Glasser DB, Lane JM, Huvos AG, Marcove RC, Rosen G. Survival, prognosis and therapeutic response in osteogenic sarcoma: the memorial hospital experience. Cancer 1992; 69:698–708.

13 Malawer MM, Link MP, Donaldson SS. Sarcomas of bone. In: DeVita VT Jr, Hellman S, Rosenberg SA, editors. *Cancer: principles and practice of oncology*. 5th ed. Philadelphia: Lippincott-Raven Publishers; 1997. pp. 1891–1935.

14 Marcove RC, Abou-Zahr K. En bloc surgery for osteogenic sarcoma: analysis and review of ninety operative cases. Bull N Y Acad Med 1984; 60: 748–758.

15 Marcove RC, Mike V, Hajek JV, Levin AG, Hutter RVP. Osteogenic sarcoma under the age of twenty one. J Bone Joint Surg 1970; 52A:411–423.

16 Marcove RC, Rosen G. En bloc resections for osteogenic sarcoma. Cancer 1980; 45:3040–3044.

17 Marcove RC, Lewis MM, Huvos AG. En bloc upper humeral interscapulothoracic resection: the Tikhoff–Linberg procedure. Clin Orthop Relat Res 1977; 1124:219–228.

18 Asavamongkolkul A, Eckardt JJ, Eilber FR. Endoprosthetic reconstruction for malignant upper extremity tumors. Clin Orthop Relat Res 1999; 360: 207–220.

19 Black R, Szabo R, Titelman R. Treatment of malignant tumors of the proximal humerus with allograft–prosthesis composite reconstruction. J Shoulder Elbow Surg 2007; 16 **(Issue 5):** 525–533.

20 Bos G, Sim F, Pritchard D, Shives T, Rock M, Askew L, Chao E. Prosthetic replacement of the proximal humerus. Clin Orthop Relat Res 1987; 224:178–191.

21 De Wilde LF, Van Ovost E, Uyttendaele D, Verdonk R. Results of inverted shoulder prosthesis after resection for tumor of the proximal humerus. Rev Chir Orthop Reparatrice Appar Mot 2002; 88:373–378.

22 Jensen KL, Johnston JO. Proximal humeral reconstruction after excision of a primary sarcoma. Clin Orthop Relat Res 1995; 311:164–175.

23 Gebhardt MC, Flugstad DI, Springfield DS, Mankin HJ. The use of bone allografts for limb salvage in high grade extremity osteosarcoma. Clin Orthop Relat Res 1991; 270:181–196.

24 Wittig J, Bickels J, Kellar-Graney K, Kim F, Malawer M. Osteosarcoma of the proximal humerus: long-term results with limb-sparing surgery. Clin Orthop Relat Res 2002; 397:156–176.

25 Malawer MM, Sugarbaker PH, Lampert M, Baker AR, Gerber NL. The Tikhoff–Linberg procedure: report of ten patients and presentation of a modified technique for tumors of the proximal humerus. Surgery 1985; 97:518–528.

26 Rodl RW, Gosheger G, Gebert C, Lindner N, Ozaki T, Winkelmann W. Reconstruction of the proximal humerus after wide resection of tumours. J Bone Joint Surg Br 2002; 84:1004–1008.