

FUNCTIONAL OUTCOMES OF PATIENTS TREATED WITH MODULAR TUMOR RESECTION PROSTHESIS FOLLOWING PROXIMAL HUMERUS TUMOR

Proksimal Humerus Tümörü Sonrası Modüler Tümör Rezeksiyon Protezi ile Tedavi Edilen Hastaların Fonksiyonel Sonuçları

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ABSTRACT

Objectives: This study aims to evaluate the functional outcomes of patients undergoing hemiarthroplasty with modular tumor prostheses for proximal humeral tumors.

Material and Methods: A total of 28 patients were included in the study, with an average follow-up of 71.11 months. The mean age of participants was 47.8 years, and the cohort included various tumor types, including osteosarcoma and chondrosarcoma. Functional outcomes were assessed using the Modified Musculoskeletal Tumor Society evaluation system, the American Shoulder and Elbow Surgeons score, and the Visual Analog Scale for pain.

Results: The postoperative results demonstrated an average Modified Musculoskeletal Tumor Society score of 21.68 and an American Shoulder and Elbow Surgeons score of 52.71, reflecting substantial improvements in both shoulder function and pain management. Notably, the visual analog scale scores decreased significantly, from a preoperative average of 6.57 to a postoperative average of 3.79. This reduction in pain intensity indicates that patients experienced a marked alleviation of discomfort following the surgical intervention.

Conclusion: Modular tumor prosthesis represents a reliable and effective treatment option for proximal humerus tumors. Although low infection and recurrence rates were noted, further research with larger sample sizes and longer follow-up is necessary to fully understand the long-term durability of the prosthesis and its potential complications, particularly in younger, more active patients.

Keywords: Modular tumor prosthesis, hemiarthroplasty, proximal humerus tumor, functional outcomes

ÖZ

Amaç: Bu çalışmanın amacı, proksimal humerus tümörleri nedeniyle modüler tümör protezi ile hemiarthroplasti uygulanan hastaların fonksiyonel sonuçlarını değerlendirmektir.

Gereç ve Yöntemler: Çalışmaya ortalama 71,11 aylık takip süresine sahip toplam 28 hasta dâhil edildi. Katılımcıların ortalama yaşı 47,8 yıl olup; osteosarkom ve kondrosarkom başta olmak üzere farklı tümör tipleri mevcuttu. Fonksiyonel sonuçlar Modifiye Müskuloskeletal Tümör Derneği değerlendirme sistemi, *American Shoulder and Elbow Surgeons* değerlendirme skoru ve ağrı düzeyini belirlemek için görsel analog skala kullanılarak değerlendirildi.

Bulgular: Ameliyat sonrası değerlendirmelerde ortalama Modifiye Müskuloskeletal Tümör Derneği skoru 21,68 ve *American Shoulder and Elbow Surgeons* değerlendirme skoru 52,71 olarak saptandı. Bu bulgular, omuz fonksiyonu ve ağrı kontrolünde belirgin bir iyileşme olduğunu göstermektedir. Özellikle görsel analog skala skorlarının ameliyat öncesi ortalama 6,57'den ameliyat sonrası ortalama 3,79'a anlamlı şekilde düşmesi, cerrahi girişim sonrasında hastaların ağrılarında belirgin bir azalma olduğunu ortaya koymaktadır.

Sonuç: Modüler tümör protezi, proksimal humerus tümörlerinin tedavisinde güvenilir ve etkili bir seçenek olarak değerlendirilebilir. Düşük enfeksiyon ve nüks oranları gözlenmiş olsa da, protezin uzun vadeli dayanıklılığını ve olası komplikasyonlarını—özellikle daha genç ve daha aktif hastalarda—tam olarak anlamak için daha büyük örneklem büyüklükleriyle ve daha uzun takip süreleriyle yapılacak ileri araştırmalara ihtiyaç vardır.

Anahtar Kelimeler: Modüler tümör protezi, hemiarthroplasti, proksimal humerus tümörü, fonksiyonel sonuçlar



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INTRODUCTION

Proximal humerus tumors are rare but serious pathologies that occur in the shoulder region and can manifest in both primary and metastatic forms. Among primary bone tumors, osteosarcoma, chondrosarcoma, and Ewing's sarcoma are frequently observed, while metastatic tumors typically result from the spread of lung, breast, and renal cancers to the humerus. In addition to these malignant lesions, benign-aggressive tumors such as aneurysmal bone cysts may also affect the proximal humerus and require similar surgical approaches when extensive bone destruction occurs.¹ These tumors, especially in advanced stages, lead to significant destruction of the bone structure and can adversely affect the patient's overall health if not treated early. Surgical treatment of tumors in the proximal humerus region is complex and challenging, requiring various approaches to both preserve shoulder function and ensure complete resection of the tumor. The extent of tumor invasion, deltoid muscle integrity, and axillary nerve involvement play major roles in postoperative functional outcomes and should be carefully evaluated during preoperative planning.²

The most commonly used surgical methods following proximal humerus tumor resection are osteoarticular allografts, tumor prostheses, allograft-prosthesis combinations, hemiarthroplasties, reverse shoulder prostheses, or megaprosthesis.³ Osteoarticular allografts preserve and reconstruct bone tissue, while tumor prostheses are primarily used in advanced-stage tumors. Although reverse shoulder prostheses have gained popularity in recent years, modular tumor prostheses remain the preferred choice in cases where deltoid preservation is limited or axillary nerve integrity is compromised. This technique provides immediate structural stability and allows early rehabilitation with acceptable complication rates.^{2,4,5} However, each of these methods presents its own unique complications. In particular, loss of shoulder function and issues related to joint stability are commonly observed.⁶

The aim of this study was to evaluate pain control, shoulder range of motion, and functional outcomes in patients treated with a modular tumor prosthesis for proximal humerus tumors, thereby assessing the effectiveness of this surgical method. The hypothesis was that satisfactory functional outcomes can be achieved regardless of tumor etiology, provided that the integrity of the deltoid muscle and axillary nerve is preserved. Additionally, the potential effects of adjuvant treatments (chemotherapy and radiotherapy) on outcomes and complication rates were analyzed.

MATERIALS AND METHODS

This retrospective, single-center, uncontrolled study analyzed data from 28 patients who underwent resection

and reconstruction with hemiarthroplasty for primary or metastatic proximal humeral bone tumors at the department of orthopedics and traumatology of our hospital between January 2011 and June 2020.

All surgeries were performed by the same orthopedic oncology team in accordance with standardized oncologic principles. Resections were classified using the Malawer system: 18 patients underwent Type IA (intra-articular resection with deltoid preservation), and 10 underwent Type IB (intra-articular resection with partial deltoid resection).⁷ Proximal humerus resections were performed with intraoperative frozen sections to ensure tumor-free surgical margins. A cemented MUTARS® modular tumor prosthesis (Implantcast GmbH, Germany) was used in all patients (Figure 1-2). In six patients, a synthetic mesh was used for soft-tissue reattachment, and in three patients, a Trevira® tube was used to reinforce deltoid and rotator cuff fixation; in the remaining cases, the rotator cuff was directly reattached to the modular prosthesis's fixation points.

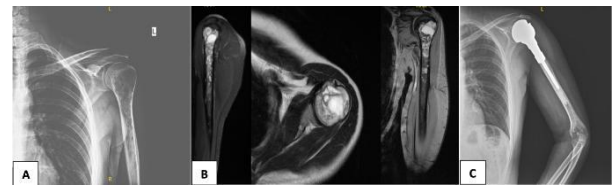


Figure 1: Representative imaging of a patient diagnosed with Ewing sarcoma (A) Preoperative plain radiograph of the humerus, (B) Preoperative magnetic resonance imaging (MRI) demonstrating sagittal, axial, and coronal views of the lesion, (C) Postoperative plain radiograph of the humerus following reconstruction with a modular tumor prosthesis

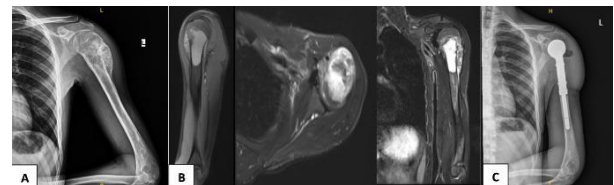


Figure 2: Representative imaging of a patient diagnosed with osteosarcoma (A) Preoperative plain radiograph of the humerus, (B) Preoperative magnetic resonance imaging (MRI) demonstrating sagittal, axial, and coronal views of the lesion, (C) Postoperative plain radiograph of the humerus following reconstruction with a modular tumor prosthesis

The patients were evaluated for age, sex, primary tumor type, extent of resection, adjuvant therapy, postoperative complications, and follow-up duration. Of the 28 patients, 20 received adjuvant chemotherapy and 10 received radiotherapy, based on histopathological diagnosis and tumor aggressiveness. Metastatic lesions primarily originated in the kidney, breast, and lung.

During the surgical procedures, all patients underwent resection of the tumor-involved segment of the humerus, followed by reconstruction with modular tumor prostheses via hemiarthroplasty. Postoperatively, shoulder immobilization was maintained for 6 weeks to ensure proper healing, after which a regimen of active

and passive shoulder exercises was initiated. The rehabilitation protocol was standardized for all patients and supervised by a physical therapist specializing in oncologic shoulder reconstruction. Postoperative exercises were initiated at predefined time points that served as standardized clinical milestones. Passive-assisted range of motion began after the 6th week, followed by active strengthening at 3 months postoperatively.

Functional outcomes were assessed using the Modified Musculoskeletal Tumor Society (MSTS) evaluation system, the American Shoulder and Elbow Surgeons (ASES) score, and the visual analog scale (VAS). Additionally, shoulder joint range of motion, including flexion, extension, abduction, adduction, internal, and external rotation, was recorded. All functional evaluations were performed by an independent orthopedic specialist who was not involved in the surgical procedures to minimize observer bias. Functional outcomes were expressed as both raw MSTS scores and as percentages of the maximum achievable score. Radiological follow-up of the patients was performed using X-rays.

The IBM SPSS Statistics 20 software was used for data analysis, with a threshold for statistical significance set at $p < 0.05$. Descriptive statistics for continuous variables included mean, standard deviation, median, minimum (min), and maximum (max) values, while categorical variables were analyzed as percentages.

Normality of distribution was verified using the Shapiro–Wilk test. The Mann–Whitney U test was applied for non-parametric comparisons between groups (primary vs metastatic), and Spearman correlation analysis was used to evaluate relationships between MSTS scores and resection length.

The study was initiated after approval from the local ethics committee (I02-95-22) in accordance with the principles of the Declaration of Helsinki.

RESULTS

Of the 28 patients in the study, 20 were male and 8 were female (Table 1). According to available records, 11 patients died of natural causes during follow-up; however, all had a minimum follow-up duration of 24 months (Table 1). The mean age of the patients was 47.8 years (min:18, max:82), and the mean follow-up duration was 71.11 months (min: 68, max: 144).

Table 1: Patient demographics and treatment characteristics

Variable	n
Male	20
Female	8
Alive	17
Deceased	11
Received chemotherapy	20
Received radiotherapy	10

The cohort included 6 cases of osteosarcoma, 4 of chondrosarcoma, 3 of Ewing's sarcoma, 2 of malignant mesenchymal tumors, 2 of malignant fibrous histiocytoma, 1 of angiosarcoma, and 1 of aneurysmal bone cyst. Nine patients underwent surgery for metastasis. The extent of resection was determined based on tumor size, with an average of 11.25 cm (min: 8 cm, max: 16 cm). Chemotherapy was administered to 20 patients, and radiotherapy to 10 patients. When the functional outcomes of patients who underwent modular tumor prosthesis for proximal humerus tumors were evaluated, the mean MSTS score was 21.68 (min: 14, max: 30), and the ASES score was 52.71 (min:8, max:82).

Significant improvement in pain control was achieved, with the mean VAS score decreasing from 6.57 preoperatively to 3.79 postoperatively. This indicates a substantial reduction in pain severity during the postoperative period. Regarding shoulder joint range of motion, the mean values were recorded as follows: flexion 105.36°, extension 23.57°, external rotation 27.5°, internal rotation 32.32°, abduction 47.86°, and adduction 25.71°. The range of motion indicates that shoulder function was partially preserved postoperatively.

A detailed analysis of the MSTS functional scores revealed that the average lifting ability was 3.43 (min: 2, max: 5), indicating partial limitation, and the average pain level was 3.57 (min: 1, max: 5), classified as mild. Additionally, the patients' hand dexterity and hand positioning were measured at averages of 4.25 and 3.36, respectively. These findings indicate that the patients' hand dexterity and overall functional ability were preserved postoperatively. Other parameters determining functional capacity included emotional status, which had an average score of 3.43, reflecting a satisfactory condition, while function scored an average of 3.46, indicating limitations that did not significantly interfere with recreational activities (Table 2).

During the follow-up period, local recurrence was observed in 3 patients, 2 of whom developed wound infections. However, none of the patients required revision surgery. Additionally, no significant postoperative complications such as joint instability or subluxation were observed. All patients responded positively to the postoperative rehabilitation process. The preservation of shoulder range of motion and effective pain control post-surgery allowed the majority of patients to return to their daily activities.

The most common postoperative complications were infection and local recurrence; however, no clinically or radiographically significant implant-related issues or cases requiring prosthesis revision were observed, and no clinically or radiographically significant glenoid erosion was detected during follow-up.

Table 2: Functional scores, pain, and range of motion measurements

No	Parameter	Mean	Minimum	Maximum
1	VAS	3.79	0.0	8.0
2	MSTS score	21.68	14.0	30.0
3	Lifting capacity	3.43	2.0	5.0
4	Pain	3.57	1.0	5.0
5	Manual dexterity	4.25	3.0	5.0
6	Hand positioning	3.36	2.0	5.0
7	Function	3.46	2.0	5.0
8	Emotional acceptance	3.43	0.0	5.0
9	Preoperative VAS	6.57	0.0	10.0
10	Follow-up time (months)	71.00	68.0	144.0
11	ASES score	52.71	8.0	82.0
12	Shoulder flexion (°)	105.36	60.0	150.0
13	Shoulder extension (°)	23.57	10.0	40.0
14	Shoulder external rotation (°)	27.50	5.0	60.0
15	Shoulder internal rotation (°)	32.32	15.0	60.0
16	Shoulder abduction (°)	47.86	0.0	90.0
17	Shoulder adduction (°)	25.71	0.0	45.0

VAS: Visual analogue scale, MSTS: Musculoskeletal Tumor Society score, ASES: American Shoulder and Elbow Surgeons score.

DISCUSSION

This study aimed to evaluate the functional outcomes of patients who underwent modular tumor prosthesis due to proximal humerus tumors and to assess the efficacy of this surgical technique. The results demonstrated that both functional outcomes and pain control in patients treated with modular tumor prostheses were successful. The mean MSTS score was 21.68, the ASES score was 52.71, and the VAS score postoperatively was recorded as 3.79. These findings indicate a general improvement in shoulder function and a significant reduction in pain levels. The results of our study support that modular tumor prosthesis surgery is an effective treatment option for proximal humerus tumors.

The outcomes achieved with modular tumor prostheses appear highly favorable when compared to other surgical approaches reported in the literature. In a systematic review by Teunis et al., it was noted that allograft-prosthesis combinations and osteoarticular allografts offer similar functional outcomes, though the allograft-prosthesis combinations were associated with lower complication rates.⁸ Similarly, in our study, no major complications were observed, and no cases required prosthesis revision. We attribute this to the meticulous surgical procedures performed by two senior surgeons, one of whom specializes in hand and upper extremity. Furthermore, the local recurrence rate in our patient cohort was recorded at 10%, which is notably lower than the rates reported in the literature.^{8,9}

In our study, shoulder joint range of motion and functional outcomes were generally favorable. However, shoulder function was limited after extensive resections, particularly when associated with deltoid muscle loss; additionally, the fact that all patients received adjuvant or neoadjuvant chemoradiotherapy may have contributed to this finding.¹⁰ It has been noted that the loss of shoulder function is closely related to whether the deltoid muscle is preserved.¹⁰ In our study, cases where the deltoid muscle was not fully preserved showed a noticeable restriction in movement. Additionally, patients with axillary nerve injury exhibited significant reductions in shoulder abduction and elevation, which contributed to the lower range of shoulder abduction (mean:46.8°) in our patients compared to the literature.¹¹ These findings demonstrate the critical importance of both the tumor's soft tissue involvement and the preservation of the deltoid muscle and axillary nerve during surgery in determining the functional outcomes.

In terms of postoperative complications, the infection rate in our study remained low. Similarly, a study by Wang et al. reported low infection rates in patients treated with modular tumor prostheses, while the infection risk was found to be higher in those with osteoarticular allografts.¹⁰ In our study, wound infection was observed in only two patients, both of whom were treated with local therapies and did not require revision surgery. This finding supports the notion that modular tumor prostheses may be a safer option with regard to infection risk. In terms of functional outcomes, the MSTS scores in our study are consistent with the averages reported in the literature.¹² Although it has been shown that functional scores may be better with reverse shoulder prostheses, a meta-analysis of 1,089 studies reported an average MSTS score of 78.¹³ In our study, the MSTS score was determined to be an average of 72%, which indicates that modular tumor prosthesis is a satisfactory option in terms of functional outcomes for the treatment of proximal humerus tumors. Additionally, according to this meta-analysis, the shoulder range of motion at the second postoperative year showed a flexion range of 105° and an external rotation of 26°.¹³ Similarly, in our study, the flexion range was measured at 105.3° and the external rotation range at 27.5°.

The average ASES score for the patients in this study was 52.71, which is consistent with the values reported in the literature.^{8,12,14} Similar results were obtained when compared to patients treated with reverse shoulder prostheses.^{13,15,16} These results suggest that the age range for hemiarthroplasty could potentially be broadened.

This study has several limitations. First, as it was a retrospective, single-center, uncontrolled study, more

controlled and standardized data that could have been obtained through prospective studies were not available. Additionally, the follow-up period was an average of 71.11 months, which may not be sufficient to fully evaluate long-term prosthesis durability and complications. Longer follow-up, especially in younger and more active patients, could provide more comprehensive information regarding the long-term success of the prosthesis and the need for revision.

Secondly, the sample size was limited, which may reduce the generalizability of the results to a larger population. Studies with larger sample sizes, particularly including patients from different age groups and tumor types, would provide more reliable results. Furthermore, the variability in the post-surgical rehabilitation processes applied to each patient could be another factor influencing functional outcomes.

Lastly, the study was conducted at a single center, and no comparisons were made between different surgical techniques and postoperative care methods. Data from multiple centers would allow for the comparison of surgical techniques in modular tumor prosthesis applications and could enhance the generalizability of the results obtained.

Evaluation of patients who underwent hemiarthroplasty with modular tumor prostheses for proximal humerus tumors shows that this surgical approach is effective for pain control and functional outcomes. The mean MSTS and ASES scores indicate significant postoperative improvement, enabling patients to return to daily activities. Infection and local recurrence rates were low, and the prosthesis demonstrated satisfactory long-term durability and functional results. However, further investigation is needed into long-term durability and potential complications, especially in younger, more active patients. This study suggests that hemiarthroplasty with modular tumor prostheses is an acceptable and reliable treatment option for selected patients with proximal humerus tumors.

Conflict of Interest: The authors have no conflicts of interest to declare.

Researchers' Contribution Rate Statement: Concept/Design: MCG; Analysis/Interpretation: YY; Data Collection: MA; Writer: MCG, MOK; Critical Review: YY, MA; Approver: YY.

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