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Original article

# Total elbow arthroplasty for primary and metastatic tumor

R. Casadei, M. De Paolis, G. Drago*, C. Romagnoli, D. Donati

*Department of Musculoskeletal Oncology, Istituto Ortopedico Rizzoli, Via Pupilli 1, 40136 Bologna, Italy*

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ABSTRACT

*Background:* Prostheses can be used in elbow reconstruction in both primary and metastatic lesions. Several authors have reported their experience with different types of implant, but not with modular prostheses.
*Hypothesis:* Limb salvage using an elbow prosthesis is effective in obtaining good functional results and reliable local tumor control.
*Material and methods:* Forty-seven patients treated at the Rizzoli Institute for elbow neoplasm from 1990 to 2012 were evaluated. There were 30 primary tumors (64%), 24 bone tumors and 6 soft tissue sarcomas, and 17 bone metastases. Elbow reconstruction used a modular prosthesis in 25 patients and a standard prosthesis in 22. Reconstruction was primary in 30 patients and secondary in 17.
*Results:* At last control, 15 (32%) were dead of disease (DOD) at a mean follow-up of 35 months, 12 (25%) were alive with disease (AWD) at a mean follow-up of 29 months, 19 (40%) showed no evidence of disease (NED) at a mean follow-up of 80 months. Early complications were related to unexpected neurological damage, observed in 12 patients (25%): in 5 cases the deficit resolved in a mean 6 months; in the others, no or only partial recovery was observed. Two implants (4%) developed infection: 1 was treated with antibiotic therapy, and the other required implant revision. One implant showing cement extrusion was revised. In 3 patients (6%) radiography showed a radiolucent halo around the stem (2 humeral, 1 ulnar); no measures were taken, as the patients were completely asymptomatic at every follow-up. In 3 patients (6%) partial resorption of the allograft was observed on X-ray, but remained unchanged at last follow-up, without pain or functional impairment. Seven local recurrences (15%) were observed, at a mean of 16 months after surgery; 5 were treated by resection and/or radiotherapy, and 2 by amputation. Mean functional scores on MEPS and MSTS were respectively 84% and 22/30 (73%).
*Conclusions:* Elbow prostheses provided better function in primary than in metastatic tumor. Elbow prosthesis reconstruction after tumor resection is a viable option both for primary and secondary bone neoplasms.
*Type of study:* Therapeutic.
*Level of evidence:* IV, retrospective study.



## 1. Introduction

The elbow is a rare site for bone and soft tissue tumor (<1%). Before the 1970s, amputation was the most frequent curative treatment for primary malignant tumor of the upper limb. Limb-salvage surgery has since become the most common attitude in carefully selected patients, due to better functional results and emotional acceptance compared with amputation. However, achieving good oncological margins around the elbow often requires nerve and muscle sacrifice, resulting in functional disability [1,2]. Reconstructive options include arthrodesis, osteoarticular allograft, allograft-prosthesis composite (APC), and prosthetic reconstruction. Arthrodesis is poorly tolerated by patients and technically difficult to perform [3]. Reconstruction with osteoarticular allograft frequently shows instability, pain, high rates of major complications and poor functional outcome [4]. APC and elbow prostheses, on the other hand, restore bone defects, with satisfactory function and pain relief and relatively few complications [5–8]. Prosthetic elbow reconstruction for degenerative joint disease, rheumatoid arthritis and trauma has been extensively studied, but series of reconstruction after tumor resection are rare [9,10].

The purpose of this study was to assess whether limb salvage by elbow prosthesis provides benefit without compromising local or systemic disease control.

* Corresponding author.
*E-mail addresses:* roberto.casadei@ior.it (R. Casadei), massimiliano.depaolis@ior.it (M. De Paolis), gabriele.drago@ior.it, gabriele.drago@libero.it (G. Drago), carlo.romagnoli@ior.it (C. Romagnoli), davide.donati@ior.it (D. Donati).

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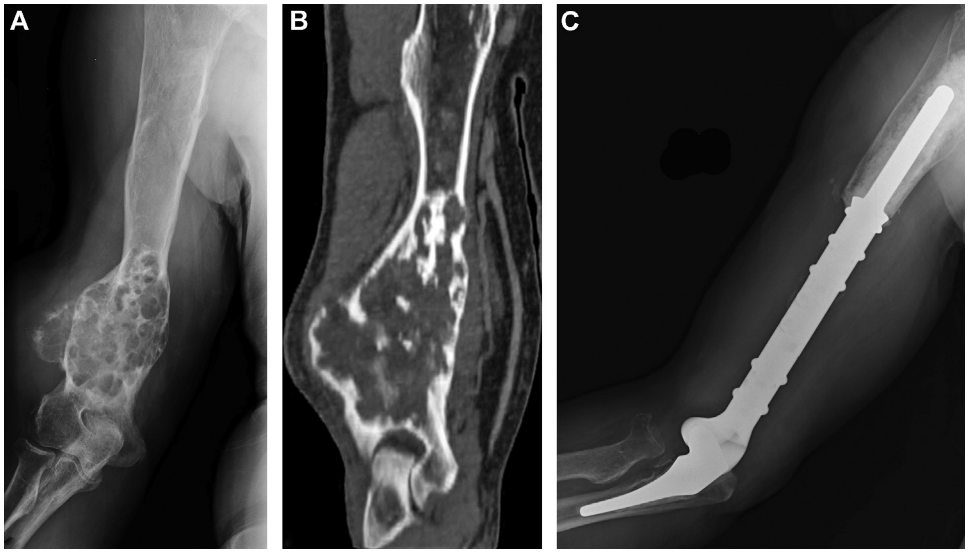


**Fig. 1.** A 63 year-old man with Ollier disease. X-ray (A) and CT (B) show cartilaginous neoplasms involving the distal humerus. Resection and reconstruction with a Mutars modular prosthesis was performed; X-ray (C) shows control at 2 years' follow-up.

## 2. Material and methods

Forty-seven patients with musculoskeletal tumor located in the elbow were retrospectively evaluated. All were treated in the same institute, by the same surgical team, between 1990 and 2012. Inclusion criteria were:

- primary or metastatic cancer involving the elbow;
- reconstruction by prosthesis, with or without graft;
- complete follow-up information.

All medical records, histology slides, radiographs and outcome were reviewed. A lateral approach to the upper arm and an anterior approach to the forearm were the most common exposures, modified according to tumor extension. The biopsy tract was always excised, including it in the surgical incision or using another incision. When possible, nerves were detached from the tumor, leaving the sheath attached to the mass so as to secure a wide margin. The triceps tendon was usually spared. Bone resection was planned on MRI. In young patients, primary benign tumors, primary malignant tumors with short resection or small soft-tissue mass, and metastatic lesions without muscle sacrifice, APC was preferred. Cement was applied when only a few centimeters of the distal humerus were resected; when longer resection was necessary, an allograft was used. Total humerus reconstruction was performed after failure of previous treatment of the diaphyseal to proximal humerus or after a very large humerus resection in primary malignant tumor.

Twenty-five modular prostheses were implanted: 18 (38%) HMRS (Stryker-Howmedica Inc., Rutherford, NJ) and 7 (15%) Mutars (Implantcast GmbH, Buxtehude, Germany). Twenty-two standard elbow prostheses were used: 3 (6%) Latitude (Tornier, Stafford, TX) and 19 (40%) Coonrad-Morrey (Zimmer, Warsaw, IN). In 16 cases (72%) a standard prosthesis was combined with allograft (APC); the remaining 6 used cement or small bone grafts. In 15% of patients (7/47), total humerus reconstruction was performed (Figs. 1–3).

All patients had their arm immobilized in a sling for 2 weeks until the wound healed. Active and passive finger movement was initiated in first postoperative day. Active elbow movement was initiated at 1 week in cemented prostheses, 4 weeks in uncemented prostheses, and 6–8 weeks in APC. Functional analysis used the Mayo Elbow Performance (MEP) and Musculo-Skeletal Tumor Society (MSTS) scores. The Toronto Extremity Salvage Score (TESS) was used to evaluate daily life activities. Tests were administered at last check-up. Implant survival was evaluated on Kaplan-Meier survival curves, with date of surgery as starting point and amputation, revision or implant ablation as end-points. Comparison was performed between patients with primary tumor versus metastasis, and between primary implantation versus secondary resection and reconstruction.

## 3. Results

Patient data are reported in Table 1. Fifteen patients (32%) died of disease at a mean 35 months (range, 7–168 months), 12 (25%) were alive with disease at a mean 29 months (10–54 months), 19 (40%) were continuously disease-free at a mean 80 months (27–226) and 1 was disease-free after resection of lung metastasis and local recurrence at 12 months post-surgery. Thirty-five patients had between 5 and 20 cm distal humerus resection, for a mean of 12 cm. The ulna was resected for 7.5 cm in 1 patient with osteosarcoma, for 12 cm in 1 with metastasis from lung carcinoma, and for 3 cm plus 8 cm of the distal humerus in 1 patient with synovial sarcoma. The radius was resected for 10 cm in 1 patient with soft-tissue sarcoma, and for 5 cm plus 12 cm of the distal humerus in 1 patient with osteosarcoma bone metastasis. In 7 patients (15%), the whole of the humerus with the elbow joint was removed. Surgical margins were wide in 37 patients (79%), wide and contaminated in 3, marginal in 3 and intralesional in 4. Further surgery was not performed for inadequate margins, but chemotherapy and/or radiotherapy when possible. Six cases of local recurrence were observed: 3 primary tumors, and 3 metastases.

In 6 patients (13%), nerves were sacrificed to obtain wide margins: 5 radial and 1 ulnar. Early complications due to unexpected neurological damage were observed in 12 patients (25%): 7 involving the radial nerve (58%), 4 the ulnar nerve (33%) and 1 all elbow nerves (8%). Only 2 partial radial nerve palsies persisted at last follow-up; the other 5 patients showed complete recovery at a mean 6 months. Paresthesia persisted in all patients with ulnar nerve deficit. In the patient in whom all three nerves were involved, only radial nerve deficit persisted at 1 year post-surgery.

Two patients (4%) had postoperative infection. In 1 case, antibiotic therapy maintained chronic infection without implant removal until death from the oncological disease. In the other infected


**Fig. 2.** A 51 year-old women with breast cancer metastases of the distal humerus. X-ray (A)and MRI (B) show a pathologic fracture and soft-tissue involvement. Reconstruction with Coonrad-Morrey prosthesis and cement was performed; X-ray (C) shows control at 12 months' follow-up. Anterior cement extrusion prevented good motion. Unsuccessful pivot locking was due to surgical error. Probably, motion restriction prevented detachment of the pivot. The patient refused revision surgery until 2 years after resection, satisfied with the poor result; after surgical revision, good range of motion was obtained.

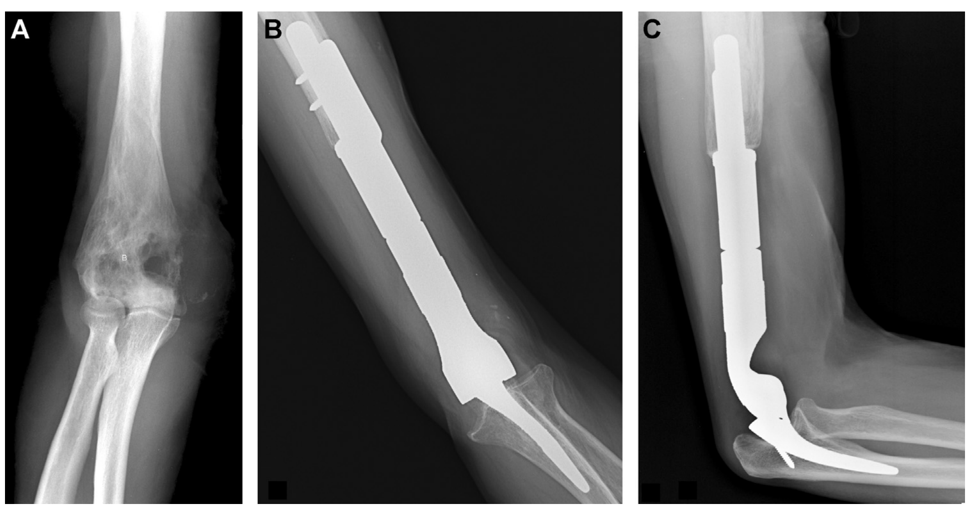


**Fig. 3.** A 62 year-old women with osteosarcoma of the distal humerus, as seen on AP X-ray view (A). Reconstruction with the HMRS modular prosthesis was performed; (B) and (C) show control at 5 years.

implant, surgical debridement was not sufficient to obtain a good result and the prosthesis was removed.

In 1 patient, an anterior cement extrusion was excised at 2 years post-surgery, and in 3 patients (6%) a radiolucent halo around the stem (2 humeral, 1 ulnar) of the prosthesis was observed on X-ray. This suggested mobilization, but the radiographic aspect was in contrast with clinical findings; the patients were completely asymptomatic at every follow-up. In 3 patients (6%), partial resorption of the allograft was observed on X-ray, but remained unchanged at last follow-up without pain or functional impairment.

Seven cases of local recurrence (15%) were observed, at a mean of 16 months post-surgery, and were treated by amputation in 2 patients, local resection followed by radiotherapy in 3 cases, new 9 cm humerus resection and a longer prosthesis in 1 patient, and isolated radiotherapy in the last case.

Only 4 (8%) prosthetic failures were observed: 2 cases of local recurrence, 1 infection in primary tumor, and 1 progression of the disease in a metastatic patient. Three failures occurred in secondary implants, all with modular prostheses.

Mean elbow range of motion after resection was 70° in patients with primary tumor and 40° in those with metastasis. Mean MEP and MSTS scores were respectively 84% and 22/30 (73%).

Tables 2–4 compare data for primary tumors, primary implants and modular elbow prostheses versus metastases, secondary implants and standard elbow prostheses, respectively.

Total humerus reconstruction was performed in 4 patients with primary tumor, and in 4 cases as secondary surgery; the radial

**Table 1**
Data 47 patients.

| Age | Diagnosis | Surgery | Prosthesis | Chemotherapy | RT | ND | NC | C | LR | Outcome | Oncology results | FU months | MSTS Score | MEPS Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 35 | OBL | S | CM | – | – | – | – | – | – | – | NED | 36 | Good | Excellent |
| 37 | OS | P | HMRS | Yes | – | – | R | Resorption | – | – | NED | 239 | Good | Fair |
| 15 | OS | P | HMRS | Yes | – | – | – | – | – | – | NED | 152 | Excellent | Excellent |
| 35 | OS | S | APC-CM | Yes | – | – | – | – | – | – | DEAD | 36 | Fair | Good |
| 10 | OS | S | HMRS | Yes | – | – | – | – | – | – | NED | 24 | Excellent | Excellent |
| 62 | OS-Paget | P | HMRS | Yes | – | – | – | – | – | – | NED 2 M | 72 | Excellent | Excellent |
| 27 | OS | P | HMRS | Yes | – | – | – | – | – | – | NED | 127 | Excellent | Excellent |
| 23 | OS | P | HMRS-T | Yes | – | – | – | – | – | – | NED | 84 | Good | Excellent |
| 10 | SE | P | HMRS | Yes | – | – | – | Resorption | – | – | NED | 120 | Excellent | Good |
| 13 | SE | P | HMRS | Yes | – | – | – | – | – | – | NED | 120 | Excellent | Excellent |
| 9 | SE | P | APC-Tor | Yes | – | – | – | Resorption | – | – | NED | 84 | Excellent | Excellent |
| 9 | SE | P | APC-Tor | Yes | – | – | – | – | – | – | NED | 48 | Excellent | Excellent |
| 23 | SE | P | APC-CM-T | Yes | – | – | – | – | – | – | AWD | 54 | Good | Excellent |
| 39 | CS | P | APC-CM-T | – | – | – | R | – | – | – | NED | 48 | Good | Excellent |
| 63 | CS | P | Mutars | Yes | – | R | – | – | – | – | AWD | 24 | Fair | Good |
| 86 | LR CS | S | HMRS-T | – | – | – | – | – | – | – | NED | 84 | Good | Excellent |
| 61 | SE st | S | HMRS | Yes | Yes | – | R | – | Yes | Excision + RT | Dead | 208 | Good | Excellent |
| 16 | SE st | S | Mutars | Yes | Yes | – | R | – | – | – | AWD | 30 | Fair | Good |
| 21 | SS st | P | APC-CM | Yes | Yes | U | – | Resorption | – | – | NED | 113 | Fair | Good |
| 64 | Leio | S | HMRS | – | Yes | U | – | – | Yes | Amputation | Dead | 36 | Good | Excellent |
| 76 | LR SCS st | S | Mutars | Yes | Yes | R | – | Resorption | Yes | Amputation | AWD | 36 | Poor | Fair |
| 82 | SCS | P | CM | – | – | – | – | Ossification | – | Excision | NED | 48 | Good | Good |
| 57 | SCS | P | HMRS | Yes | – | – | – | – | – | – | Dead | 44 | Excellent | Excellent |
| 69 | SCS st | S | CM | Yes | Yes | R | – | Infection | – | – | NED | 84 | Poor | Good |
| 15 | FS st | S | CM | Yes | Yes | – | – | – | – | – | NED | 24 | Good | Good |
| 36 | OS | P | APC-CM | Yes | – | – | – | Resorption | – | – | NED | 14 | Excellent | Excellent |
| 10 | OS | S | CM | Yes | Yes | – | – | – | – | – | NED | 12 | Good | Good |
| 9 | SE | P | APC-Tor | Yes | – | – | – | – | – | – | NED | 24 | Excellent | Excellent |
| 35 | GCT | P | APC-CM | – | – | – | – | – | – | – | NED | 16 | Good | Excellent |
| 51 | SE | P | HMRS | Yes | Yes | – | R | – | – | – | NED | 12 | Fair | Good |
| 15 | M-OS | P | HMRS | Yes | Yes | – | R | – | – | – | Dead | 8 | Good | Fair |
| 65 | M-Liver | S | HMRS | Yes | – | – | R | – | – | – | Dead | 14 | Fair | Good |
| 54 | M-Kidney | P | Mutars | Yes | Yes | – | – | – | – | – | AWD | 16 | Excellent | Good |
| 72 | M-Kidney | P | CM | Yes | Yes | – | U | – | Yes | Excision | AWD | 36 | Fair | Fair |
| 65 | M-Kidney | P | Mutars | Yes | Yes | R | – | – | Yes | Implant revision | AWD | 15 | Fair | Good |
| 57 | M-Breast | P | CM | Yes | Yes | – | – | – | – | – | AWD | 48 | Excellent | Excellent |
| 74 | M-Urotel | P | Mutars | Yes | – | – | R | – | – | – | AWD | 10 | Excellent | Excellent |
| 58 | M-Lung | P | HMRS | Yes | Yes | – | – | – | – | – | Dead | 8 | Excellent | Good |
| 81 | M-Breast | P | APC-CM | Yes | – | – | – | – | – | – | Dead | 10 | Fair | Fair |
| 51 | M-Breast | P | HMRS | Yes | Yes | – | – | – | – | – | Dead | 50 | Excellent | Excellent |
| 63 | M-Breast | S | APC-CM | Yes | Yes | – | U | – | – | – | Dead | 12 | Good | Good |
| 60 | M-Kidney | S | HMRS-T | Yes | Yes | – | R | – | – | – | Dead | 10 | Good | Good |
| 57 | M-Kidney | S | Mutars | Yes | Yes | – | U | Infection | – | Surgery impossible | Dead | 30 | Poor | Poor |
| 69 | M-Thyroid | S | APC-CM | Yes | – | – | – | – | – | – | AWD | 14 | Good | Good |
| 55 | M-Kidney | P | APC-CM | Yes | – | – | – | – | – | – | AWD | 72 | Excellent | Good |
| 51 | M-Breast | S | HMRS | Yes | – | – | – | – | Yes | Radiotherapy | AWD | 13 | Poor | Poor |
| 47 | M-Lung | P | APC-CM | Yes | Yes | – | U | – | – | – | NED | 16 | Fair | Fair |

OBL: osteoblastoma; OS: osteosarcoma; SE: Ewing sarcoma; CS: chondrosarcoma; SS: synovial sarcoma; Leio: leiomyosarcoma; SCS: spindle-cell sarcoma; st: soft tissue; M: metastasis; P: primary implant; S: secondary implant; CM: Coonrad-Morrey; HMRS: Howmedica Modular Resection System; Mutars: Implantcast System; APC: allograft-prosthesis composite; T: total humeral resection; Tor: Tornier; RT: radiotherapy; ND: nerve dissection during surgery; NC: neurological complications after surgery (U: ulnar, R: radial); C: mechanical complications; LR: local recurrence; NED: no evidence of disease; AWD: alive with disease; MSTS: musculoskeletal tumor system; MEPS: Mayo elbow prosthesis system; FS: Fibrosarcoma; FU: Follow Up; T: Total Humerus replacement.

nerve was sacrificed in 1 patient, and in 1 other transient radial nerve palsy was observed. Only 1 local recurrence occurred and was treated by radiotherapy. Two patients were alive without disease at 84 months, 3 were alive with disease at respectively 12, 14 and 48 months, and 2 died at 10 and 54 months. Only 1 patient was classified as poor on both MSTS and MEP.

## 4. Discussion

Only case reports and small series of elbow prostheses used in reconstruction after tumor resection are reported in the literature [4,6,11,12]. To have an adequate number of patients, many authors include both primary tumors and elbow metastases [1,3,8–10,13–15], elbow reconstructions and total humerus replacements [3,10,15,16], primary and secondary implants [5,17,18], or reconstructions with custom-made [10,14,15,19,20] and standard prostheses.

Ninety-two percent of implants in the present series survived at a mean follow-up of 51 months (Fig. 4). This percentage was higher than that reported by Hanna et al. [4] (78%). No prognostic factors for major complications or failure were significant on Kaplan-Meier analysis. Failure was more frequent in revision surgery (18%) and in patients with primary tumor (10%).

The incidence of major complications in this series (30%) was comparable to those reported in the literature, ranging from 25% to 50% (Table 5).

According to other authors, neurologic damage is the most frequent complication (5–27%) [1–3,9,10,14,15,21], in line with the present results (25%). In the present series, persistent nerve palsy was significantly more frequent ($P = 0.01$) in patients with secondary than primary tumor. In secondary implants, the rate showed a tendency to be higher than in primary reconstruction, but the difference was not statistically significant. Neurologic complications occurred more frequently when reconstruction used a modular

**Table 2**
Primary tumor and metastasis.

| | Primary tumor 30 cases | Metastasis 17 cases |
|---|---|---|
| *Modular prostheses* | 15 | 10 |
| *Standard prostheses* | 15 | 7 |
| *Pathologic fracture* | 3 (10%) | 11 (65%) |
| *Margins* | 26 W–2 WC–1 M–1 IL | 12 W–1 WC–2 M–2 IL |
| *Preoperative radiotherapy* | 9 (30%) | 4 (23%) |
| *Nerve section* | 4 (13%) | 2 (29%) |
| *Unexpected nerve palsy* | 5 (17%) | 7 (41%) |
| *Persistent deficit at follow-up* | 1 (3%) | 5 (29%) |
| *Infection* | 1 (3%) | 1 (6%) |
| *Asymptomatic halo of radiolucency* | 3 (10%) | 0 |
| *Asymptomatic allograft resorption* | 3 (10%) | 0 |
| *Local recurrence* | 4 (15%) | 3 (18%) |
| *NED* | 18 (60%) | 1 (6%) |
| *AWD* | 4 (15%) | 8 (47%) |
| *Dead* | 7 (23%) | 8 (47%) |
| *NED2* | 1 (3%) | 0 |
| *MSTS score* | 22/30 (73%) | 21/30 (70%) |
| Excellent + good | 23 (77%) | 10 (59%) |
| Fair + poor | 7 (23%) | 7 (41%) |
| MEP Score | 88% | 77% |
| Excellent + good | 28 (93%) | 11 (65%) |
| Fair + poor | 2 (7%) | 6 (35%) |
| *Prosthesis failures* | 3 (10%) | 1 (6%) |
| | 1 removed for infection | – |
| | 2 amputations for LR | 1 removed for LR |

W: wide margins; WC: wide contaminated margins; M: marginal margins; IL: intralesional margins; LR: local recurrence; NED: no evidence of disease; AWD: alive with disease; LR: local recurrence.

**Table 3**
Implants.

| | Primary implant 30 cases | Secondary implant 17 cases |
|---|---|---|
| *Modular prostheses* | 15 (50%) | 10 (59%) |
| *Standard prostheses* | 15 (50%) | 7 (41%) |
| *Preoperative radiotherapy* | 2 (7%) | 10 (59%) |
| *Nerve section* | 2 (7%) | 4 (23%) |
| *Unexpected nerve palsy* | 7 (23%) | 5 (29%) |
| *Persistent deficit at follow-up* | 3 (10%) | 3 (18%) |
| *Infection* | 0 | 2 (12%) |
| *Asymptomatic halo of radiolucency* | 2 (7%) | 1 (6%) |
| *Asymptomatic allograft resorption* | 3 (10%) | 0 |
| *Local recurrence* | 3 (10%) | 4 (23%) |
| *MSTS Score (mean values)* | 23/30 (77%) | 20/30 (67) |
| MSTS (excellent + good) | 23 (77%) | 11 (65%) |
| MSTS (fair + poor) | 7 (23%) | 6 (35%) |
| *MEP score (mean values)* | 86% | 76% |
| MEP (excellent + good) | 25 (83%) | 13 (76%) |
| MEP (fair + poor) | 5 (17%) | 3 (24%) |
| Prosthesis failures | 1 (3%) | 3 (18%) |
| | 1 removed for LR | 1 removed for infection<br>2 amputated for LR |

LR: local recurrence.

prosthesis compared to standard implants (65% vs. 35%), perhaps because Coonrad-Morrey prostheses need less aggressive surgery. In contrast with the present findings, some series were totally free of neurological damage [2,8,13,19,20]. One or more nerves had to be sectioned to obtain wide margins in 13% of the present patients, compared to only 4–5% in other studies [1,3,9]; in one small series of large elbow tumors reported by Schwab et al. [9], the rate was 60%.

**Table 4**
Prosthesis.

| | Modular prosthesis 25 cases | Standard prosthesis 22 cases |
|---|---|---|
| Primary tumors | 15 (60%) | 15 (68%) |
| Metastases | 10 (40%) | 7 (32%) |
| Primary implant | 15 (60%) | 15 (68%) |
| Secondary implant | 10 (40%) | 7 (32%) |
| Preoperative radiotherapy | 6 (24%) | 6 (27%) |
| Nerve section | 5 (20%) | 1 (4%) |
| Unexpected nerve palsy | 7 (28%) | 5 (23%) |
| Persistent deficit at follow-up | 3 (10%) | 3 (18%) |
| Infection | 1 (4%) | 1 (4%) |
| Asymptomatic halo of radiolucency | 3 (12%) | 0 |
| Asymptomatic allograft resorption | 0 | 3 (12%) |
| Local recurrence | 5 (13%) | 2 (23%) |
| MSTS Score (mean values) | 20/30 (67%) | 21/30 (70%) |
| MSTS (excellent + good) | 18 (72%) | 15 (68%) |
| MSTS (fair + poor) | 7 (28%) | 7 (32%) |
| MEP Score | 86% | 80% |
| MEP (excellent + good) | 20 (87%) | 19 (88%) |
| MEP (fair + poor) | 5 (13%) | 3 (12%) |
| Prosthesis failures | 4 (16%) | 0 |

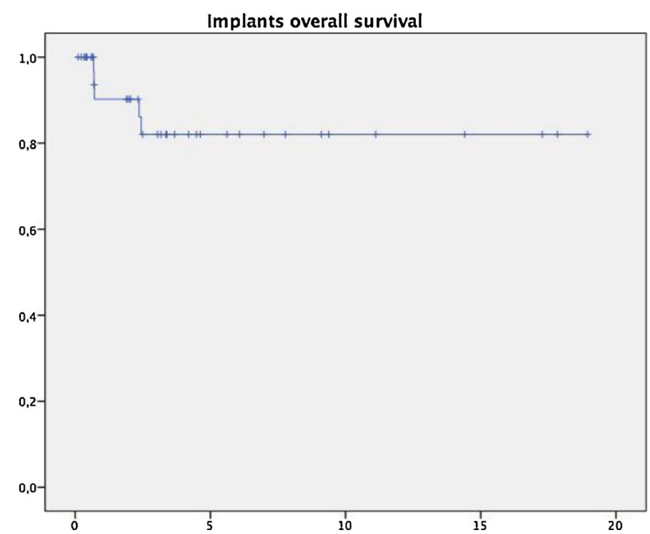


**Fig. 4.** Implants survival rate for all 47 elbow joint replacements was 83% after one year.

In the present series, the nerve section rate was much higher in secondary than primary implants (23%-7%), probably due to scarring and surgical difficulties.

Mechanical complications reported in literature range from 8% to 30%. Aseptic loosening was reported in 4% to 30% of cases [3,4,8,10,14,15,20]. Weber et al. (with a rate of 13%) [10] and Ross et al. (11.5%) [3] reported cases where loosening was not treated by implant revision.

In the present series, clinical and radiographic features did not show any true aseptic loosening of the prosthesis, but only a limited halo around the stem, without symptoms or instability. This was not observed in metastatic patients, probably owing to short follow-up.

In the present series, infection was not a frequent or severe complication [1,8,9,11,15,17,20]. Superficial infection (5–18%) [3,10,14,17,19] was treated by debridement and antibiotic therapy without removing the prosthesis. Prosthesis ablation healed deep infections, occurring in 5% to 11% of cases reported in the

**Table 5**
Complications reported in the literature.

| Author | Total | Neurologic | Mechanical | Vascular | Infection | Other | LR | Mets |
|---|---|---|---|---|---|---|---|---|
| Athwal [1] | 50% | 25%<br>5% S<br>19% T | 20%<br>5% WB<br>9% NU | – | – | 9% PF<br>5% CF | 25% | – |
| Kulkarni [8] | 30% | – | 30% AL | – | – | – | – | – |
| Hanna [4] | 50% | 5% | 16% AL | – | 6% Inf | 5% PF | 11% | 11% |
| Guo [13] | – | – | 17% AL | – | – | – | 11% | 22% |
| Sperling [2] | 46% | 8% | 8% RS | – | – | 8% HO | 23% | – |
| Weber [10] | 35% | 17%<br>4% S<br>13% T | 30%<br>18% AL<br>22% AR | 4% Th | 9% NWH | – | 26% | 61% |
| Ross [3] | 65% | 31%<br>4% S<br>27% T | 15% AL | – | 11% Inf<br>8% NWH | – | 14% | – |
| Tang [15] | 24% | 8% | 16% AL | 4% VI | – | – | 16% | 28% |
| Natarajan [19] | 36% | – | 9% SI<br>9% USB | – | 18%NWH | – | 18% | 9% |
| Rolf [20] | 25% | – | 25% AL | – | – | – | – | – |
| Bickels [16] | – | – | – | – | 5% Inf | – | – | – |
| Schwab [9] | – | 20% T<br>60% S | 25% NU | – | – | – | – | 40% |
| Amirfeyz [5] | – | – | 83% HNU<br>12% UNU | – | 9% Inf | – | – | – |
| Mansat [17] | 54% | – | 15% HNU | – | 23% Inf<br>8% NWH | – | – | – |

S: section; T: traction; AL: aseptic loosening; HNU: humerus non-union; UNU: ulnar non-union; NU: non-union; WB: wear bushing; RS: replacement screws; AR: allograft resorption; SI: shoulder impingement; USB: ulnar stem blow-out; Th: thrombosis; VI: vascular injury; Inf: infection; NWH: no wound healing; PF: periprosthetic fracture; CF: ulnar component fracture; HO: heterotopic ossification; LR: local recurrence.

literature [3,14,16]. In the present series, only 2 infections were observed, both in patients with a secondary implant. There is no clear explanation for this low rate of infection. Pre- and postoperative antibiotic therapy was the same as in other surgical procedures. In the present series, antibiotic-loaded cement was not used. The site may be an important factor, because surgical wound was small, the soft tissue had abundant blood supply, and operative time was short.

The present rate of infection lay between the 9% reported by Amirfeyz and Stanley [5] and the 30% of Mansat et al. [17].

In present series, nerve section, neurological complications and infection were significantly more frequent in patients treated by preoperative radiotherapy: respectively, $P = 0.03$, 0.02, and 0.0001. No significant relationship was observed between preoperative radiotherapy and local recurrence or functional results. In secondary implants, preoperative radiotherapy was very frequent and the surgical scar made it difficult to identify and isolate nerves without stretching them. Preoperative radiotherapy thus appeared to be an important risk factor for complications in elbow surgery. This was confirmed in the study of Bickel et al. [16], where 33% of patients with infection had had preoperative radiotherapy. However, Athwal et al. [1] and Schwab et al. [9] did not observe infections or wound complications in patients with peri-operative radiotherapy.

In the present series, the local recurrence rate (17%) was comparable with those reported in the literature: 11–26% [1–3,10,14,15,19]. Only two series reported no local recurrence [8,9]. In the present study, local recurrence was much more frequent in patients with metastatic lesions and after secondary implantation, because secondary surgery was often performed after previous inadequate surgery. For local recurrence without systemic diffusion, above-elbow amputation is performed [3,10,19], as in two of the present patients. When local recurrence occurred in soft tissue, resection without implant removal is performed, as in another two of our patients and as also reported by Athwal et al. [1] and Tang et al. [15]. Finally, when recurrence extends into the bone, Hanna et al. [4], Sperling [2] and Weber et al. [10] suggest new resection and reconstruction, as performed in 1 of the present patients.

Mild pain persisted in 17% of the present patients, compared with 18% reported by Hanna et al. [4] and Tang et al. [15]. In patients with metastatic lesions, pain was significantly ($P = 0.006$) more frequent than in those with primary tumor, as reported by Sperling [2]. Residual pain can be observed in all types of reconstruction, as reported by other authors [1,10,15]. Sixty-eight percent of the present patients had only recreational restrictions, compared to only 30% in other series [14,15]. Emotional acceptance was very good, both in the present (79%) and in other series (85%) [9,19,21–23], comparing reconstruction with amputation. In the present study, hand positioning was limited in 36% of cases, as also reported by Hanna et al. [4] and Tang et al. [15]. In their studies manual dexterity was very good and only 6% of patients had limitations, whereas in the present series 19% of patients had restricted manual dexterity due to nerve palsy. Lifting ability was the poorest function, and was severely limited in 42% of cases reported by Hanna et al. [4] and Tang et al. [15] and in 38% in the present series.

In the literature, elbow range of motion after resection is the same in primary tumors (from 55° to 140°) [1,2,10,13] and in metastatic lesions [16,20]. Patients who had only proximal ulnar replacement showed better function than those who had distal humeral replacement [15]. The present data are comparable to those reported by Sperling et al. [2], where range of motion improved from 40° to 81° in patients with primary tumor and from 17° to 65° in metastatic patients. Lack of full elbow extension does not limit good hand function [3,10,19]. When standard prostheses are used for different non-tumoral diseases of the elbow, mean range of motion improves by only 26°. Better results (33°) were obtained with Coonrad-Morrey prostheses [22]. This difference in range of motion was due to wide soft-tissue resection in elbow tumor, reducing the scar and adhesions.

The present mean MEP and MSTS scores were comparable with those reported in literature for elbow prostheses: respectively, 84% vs. 75–82% [1,15], and 73% vs. 76–84% [8,10,14]. In the present series, with these scores, excellent and good results were more frequent in patients with primary tumor, and poor results in patients with metastases, although the difference was statistically significant only for MEP scores. Comparing patients with primary versus secondary implants, excellent and good results were more frequent in primary reconstruction. Moreover, the same rate of excellent and good results (72%) was observed in patients with modular and standard prostheses. When a Coonrad-Morrey prosthesis was used for non-tumoral disease, scores were better (91%, with 97% excellent or good results) because less bone and soft tissue was sacrificed [23]. Mean TESS score (70%) was comparable to those reported in the literature (73%). Patients found activities related to daily life and social relations easy (TESS > 4.5), but not those related to sports or heavy manual work. Activities that remained difficult (TESS < 3) were gardening and lifting a box to an overhead shelf. Patients could pick up small objects with the operated arm, but lifting larger and heavier objects such as shopping bags was difficult [10,13].

## 5. Conclusion

An elbow prosthesis is indicated when wide resection can be obtained in primary tumor; in patients with bone metastases, to allow fast functional recovery and maintain daily life activities; when solitary metastasis or extensive tumor-induced bone loss precludes intralesional treatment; when previous fixation around the elbow failed; or in case of locally recurrent disease.

Elbow prosthesis reconstruction after tumor resection is a viable option for both primary and secondary bone neoplasms, but also as primary and secondary implant. Nerve palsy is the most common complication, but is often transient. Other complications, such as infection or loosening, are infrequent. Only 8% of the prostheses failed. Better functional results are obtained in patients with primary tumor, primary implant and using standard elbow prostheses (MSTS > 70%). Total elbow arthroplasty does not compromise the quality of tumor resection, as risk of local recurrence is independent of type of reconstruction but rather related to type of resection.

## Disclosure of interest

The authors declare that they have no competing interest.

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