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Original Article

Digit-sparing surgery for hand bone tumors: results of en-bloc bone resection and repla cement with osteoarticular allografts

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Abstract

Introduction: The treatment of malignant bone tumors in the hand should be focused on the complete removal of the neoplasm. Thereby, amputation of the involved digital ray or even the whole hand is often necessary. However, a ray-sparing approach could be sufficient to eradicate locally aggressive and low-grade malignant tumors confined to the bone.

Aim: We present our experience with en-bloc resection of long bones of the hand and their replacement with osteoarticular allografts.

Materials and methods: We evaluated all our cases with locally aggressive low-grade bone tumors of the hand, treated with a whole-bone en-bloc resection and replaced with an osteoarticular allograft. Intraoperative and postoperative complications were recorded. Patients' preoperative and postoperative functionality was assessed with the MSTS score and eventual post-operative digital ray stiffness was classified using the Tubiana classification.

Results: Five patients were included in our study (1 metacarpal, 3 proximal, and 1 middle phalanx). Cases had grade 1 CS (3), GCT of the bone (1), or Gorham-Stout disease (GSD; 1). The mean FU was 19 months.

The patient with GSD (middle phalanx) had a local recurrence and underwent ray amputation. The patient treated in his metacarpal bone had a slight finger rotation (about 5°), but no stiffness. The three cases treated with proximal phalanx allografts were Tubiana 1A (1) or 1B (2). The mean MSTS score was 26.4.

Conclusions: A digit-sparing surgery, performed with a whole-bone en-bloc resection and the implant of an osteoarticular allograft, could represent a solution for selected cases with locally aggressive and low-grade malignant tumors of the long bones in the hand.

Keywords

complication, metacarpal, phalanx, reconstruction, recurrence, rehabilitation

Introduction

Bony tumors in the hand comprise 2%–11% of all bone tumors. They are mostly benign, as the malignancy rates range between 2% and 14%.[1-3] Bone metastases of the hand, in particular, are very uncommon, accounting for approximately 0.1% of all skeletal metastases.[4] For benign bone tumors of the hand, such as enchondromas, surgical treatment is necessary in case of sudden growth, imaging suspicion of malignant degeneration, or either actual or impending pathological fracture.[5]

Conversely, the treatment of malignant bone tumors in the hand, such as chondrosarcomas or osteosarcomas, should be focused on the complete removal of the neoplasm, aiming for wide resection margins. Surgeons are called to avoid intralesional approaches, minimizing the risk of disease persistence after surgical treatment. Sometimes, the tumor produces massive cortical destruction and soft tissue extension. For this reason, the amputation of the involved digital ray or even of the whole hand is often necessary in order to allow adequate control of the disease.[6,7] For locally aggressive and low-grade malignant tumors, such as the giant cell tumors of bone (GCTB), a resection limited to the bone itself could be sufficient to eradicate the disease because the disease is confined to the bone itself.[8] However, reconstruction of these areas is challenging, and there is no consensus on a surgical approach for managing these tumors. To this date, the literature lacks evidence on finger-sparing surgery in cases with locally aggressive or low-grade malignant tumors that could not receive curettage due to their extension and massive cortical scalloping in the absence of massive soft tissue involvement.[9,10]

Aim

We present our experience and our results with hand bone tumors treated performing whole-bone en-bloc resections and replacement using massive osteoarticular allografts.

Materials and methods

This single-center retrospective study was conducted according to the ethical standards in the 1964 Declaration of Helsinki and its later amendments.

Our study reviewed all patients with tumors in the long bones of their hands treated with an en-bloc resection of the whole involved bone and replacement using massive osteoarticular allografts in our institution between July 2016 and February 2024. Inclusion criteria were the involvement of metacarpals or hand bone phalanxes and a diagnosis of benign or locally aggressive bone tumor confined to the bone (Enneking IA). Exclusion criteria were a diagnosis of a high-grade malignant tumor, massive involvement of soft tissues, neurological or systemic diseases that could impede adequate postoperative rehabilitation, and a follow-up shorter than 6 months. We collected data regarding each patient's age and sex. Each patient had preoperative X-rays and MRIs to assess the localization of the disease, estimate its larger diameter, orient the diagnosis, and guide the surgical planning. Before surgery, all patients underwent a needle biopsy to confirm the radiological suspicion of a low-grade malignant tumor of locally aggressive disease. The functionality of the hand and the whole upper limb have been evaluated before surgery using the MSTS score.

Intraoperatively, patients underwent a dorsolateral or dorsomedial approach to the involved bone. While identifying and protecting the main vessels and nerves in the surgical site, the surface of the bone is gradually exposed, preceding both on its dorsal and plantar surfaces. On these latter, volar plates and pulleys were preserved and detached from the cortical bone when feasible **(Figs 1A, 1B)**. The treated hand ray's extensor and flexor apparatus should be located and secured during dissection to prevent iatrogenic damage or excessive elongation. The distal articulation is then disarticulated, preserving the articular capsule as much as possible and avoiding iatrogenic damage on the facing cartilage **(Fig. 1C)**. Once the distal articulation can be displaced, surgeons could isolate the side of the bone opposite the approach site, allowing a complete mobilization of the bone shaft and distal epiphysis **(Fig. 1D)**.

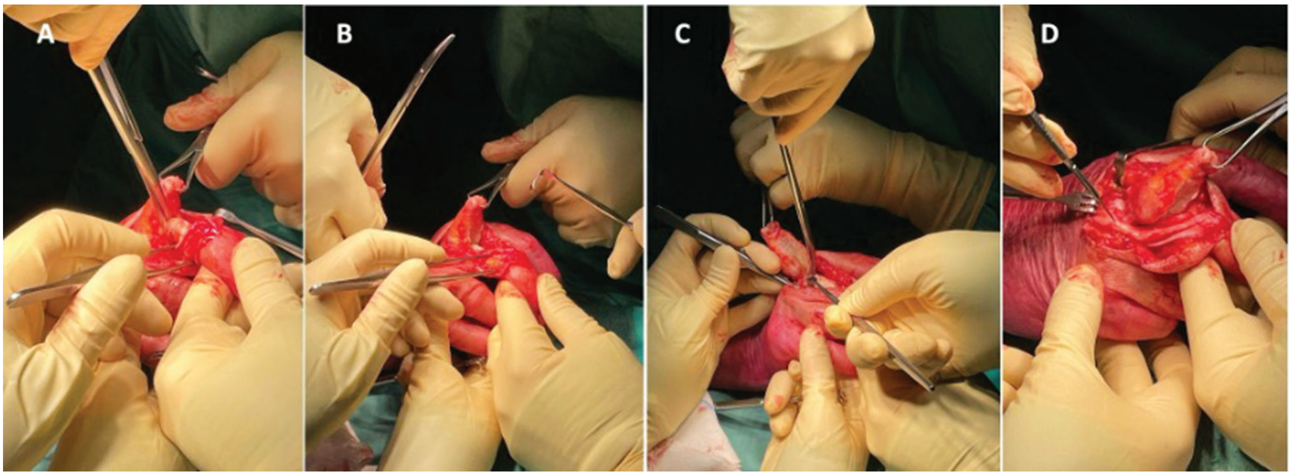

Figure 1. Intraoperative images of dissection for a tumor of the proximal phalanx. The surgeon performs a dissection between the bone and the flexor apparatus (**A**). Once the dissection has been completed and the two tissues have been separated (**B**), the surgeon could complete the dissection on the side opposite to the original surgical approach (**C**) and finally complete the resection by performing a disarticulation of the metacarpophalangeal joint (**D**).

Finally, the proximal articulation is disarticulated, allowing the en-bloc resection of the bone **(Fig. 2A)**.

Our pathologists examined surgical specimens to confirm the previous histological diagnosis or formulate a new one using routine histology, histochemistry, and immunohistochemistry techniques. The pathologists also confirmed the size of the treated lesions.

The removed bones were then replaced with massive osteoarticular bone allografts with comparable size and shape **(Fig. 2B)**. What remained of the proximal and distal articular capsules was sutured to the epiphyses with transosseous sutures. The extensor and flexor apparatus are relocated to lay on the graft's posterior and anterior surface, respectively.

The preserved pulleys are sutured to the allograft directly, or – in case of complete absence – replaced by gauze stripes made of resorbable cellulose (Tabotamp Haemostatic Wound Gauze, Ethicon Inc., Raritan (NJ), USA). The correct positioning of the allograft is also confirmed by intra-operative fluoroscopy. After evaluating the correct axis, rotation, and mobility of the finger, surgeons implanted a K-wire to allow temporary immobilization in the first postoperative period **(Fig. 3)**. The surgical access was sutured, and the digit ray was immobilized in a long Zimmer splint (for phalanx reconstructions) or plaster cast (for metacarpal resections).

The immobilization devices and the K-wires were removed within three weeks after the intervention. After their removal, active and passive mobilization were encouraged and performed with progressive intensity **(Table 1)**.

The postoperative follow-up consisted of serial clinical evaluations, and X-rays were performed within one month (clinical evaluation only), 2, 3, 6, and 12 months after surgery, and later once per year. In parallel, MRIs were performed within 6 and 12 months and later on a yearly basis. Additional clinical or imaging evaluations were scheduled depending on the necessities of each case.

Imaging evidence was used to diagnose local recurrences and assess eventual complications such as fractures and graft resorption.

Each complication with a grade II or higher, according to the Clavien-Dindo classification, was reported.

Each patient's functional outcome of the treated limb was assessed using the upper limb MSTS score at their latest follow-up.

Results

Five patients (three men and two women) met our inclusion criteria and were included in our study. Their mean age was 45.4 years (18-63). All of them came to our attention due to symptoms attributable to their tumors. The mean pre-operative MSTS score was 18.5 (15-21).

One patient had his lesion in his fifth metacarpal, whereas in the remaining four cases, tumors were localized in the phalanxes: proximal phalanx in three cases and mid phalanx in one.

In all cases, the neoplasm involved the shaft and at least one of the epiphyses. Two of our five cases had fractures in the involved bones before surgery.

Three cases had a diagnosis of atypical chondromatous tumor (ACT; previously grade 1 chondrosarcoma), one had a giant cell tumor of the bone (GCTB) with a secondary aneurysmal bone cyst (ABC), and one was diagnosed with a Gorham-Stout disease (GSD).

No major intra-operative complication occurred. The mean follow-up was 28.4 (12-54). The case with Gor-

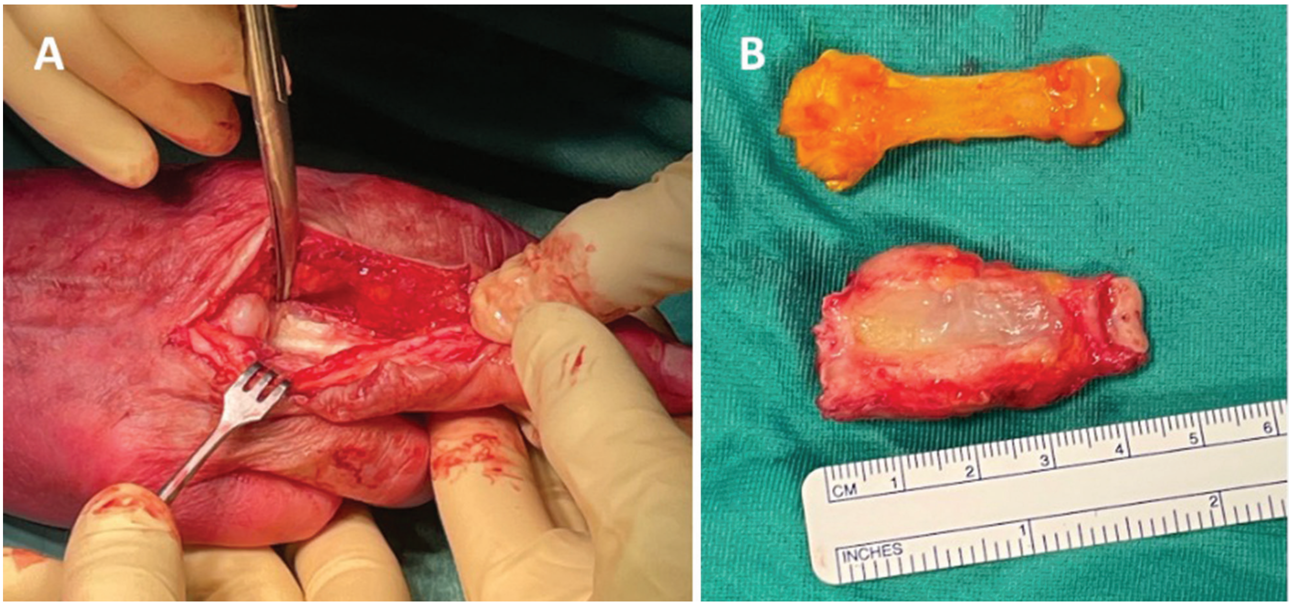

Figure 2. On the left, an intraoperative image of an exposed proximal phalanx after an en-bloc bone resection (**A**). On the right, the removed phalanx hosting the tumor is placed next to the allograft that will replace it (**B**). This latter appears yellow since it has been immersed in a rifampicin bath during the demolition surgical procedure.

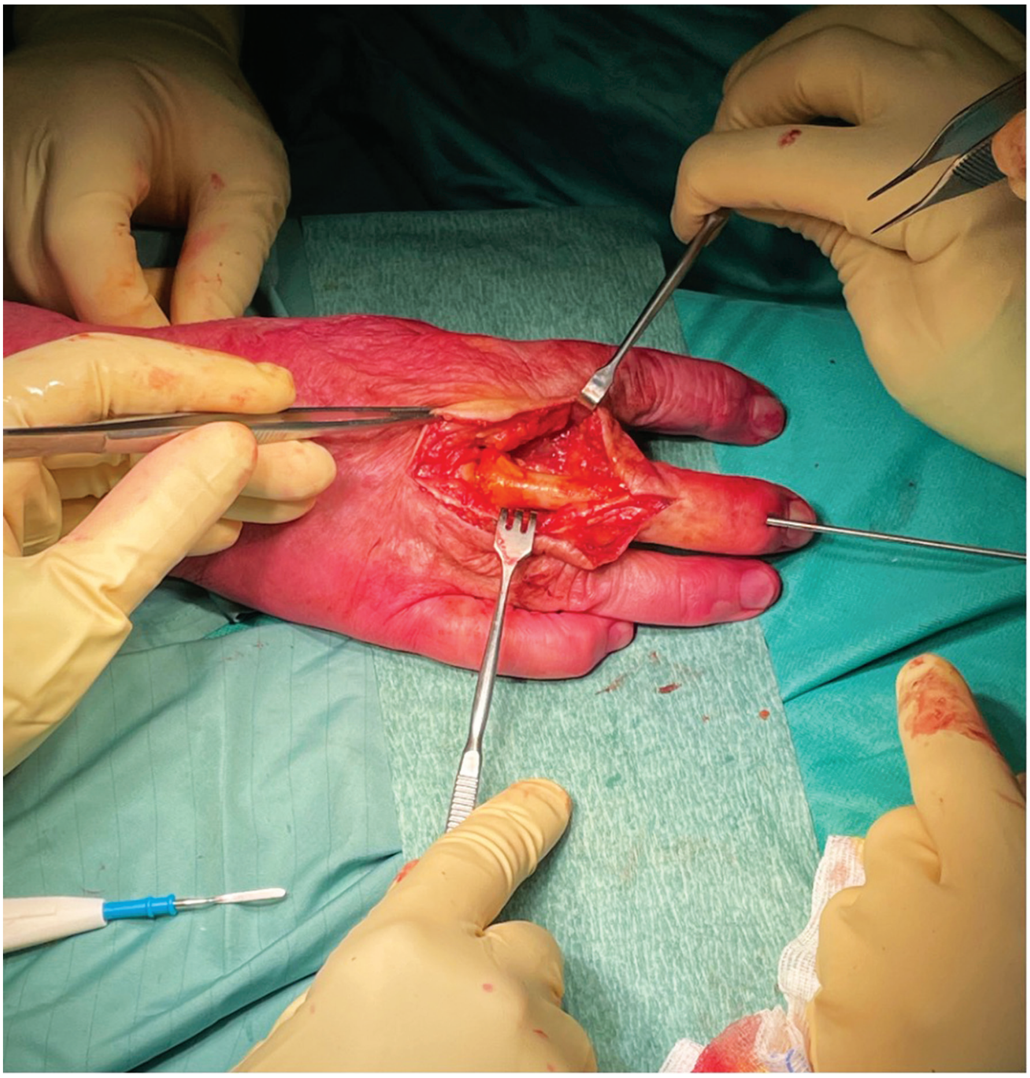

Figure 3. The osteoarticular allograft is set in place of the native proximal phalanx bone. The metacarpophalangeal joint and the proximal interphalangeal joint are temporarily stabilized with a K-wire.

Table 1. A schematic resume of the post-operative rehabilitation protocol suggested to our patients during their post-operative follow-up

DAYS	ACTIVITY (Metacarpal)	ACTIVITY (Phalanx)
0-20	Immobilization in plaster cast	Immobilization in Zimmer splint
21	Removal of K-wire and cast	Removal of K-wire and splint
22-30	Intense active mobilization Light passive mobilization No weight lifting	Intense active mobilization Light passive mobilization No weight lifting
31-60	Intense active mobilization Intense passive mobilization No weight lifting	Intense active mobilization Intense passive mobilization No weight lifting
60-90	Intense active mobilization Intense passive mobilization Partial weight lifting (<5 kg)	Intense active mobilization Intense passive mobilization Partial weight lifting (<2 kg)
90-120	Intense active mobilization Intense passive mobilization Partial weight lifting (<15 kg)	Intense active mobilization Intense passive mobilization Partial weight lifting (<5 kg)
120+	Intense active mobilization Intense passive mobilization Weight lifting allowed	Intense active mobilization Intense passive mobilization Weight lifting allowed

ham-Stout disease was diagnosed with a local recurrence 6 months after surgery. Although he had an almost complete functional recovery, the patient had developed pain and focal swelling. X-rays and an MRI highlighted a massive allograft resorption and a mass in the nearby soft tissues. An amputation of the whole IV digit ray was made necessary to eradicate the disease. The remaining four cases did not develop any recurrence. Although none of our cases developed evident axis deviations in their treated fingers, one had a vicious rotation of 10 degrees. In three cases, treated fingers slightly reduced their active and passive maximal extension (Tubiana I). No other major complication was recorded after surgery. The mean MSTS score at each patient's latest follow-up was 26.4 (23-30).

The results of each single patient is schematically reported in **Table 2**.

Discussion

The treatment of hand bone tumors can be challenging even for the most experienced orthopedic oncologist. The surgical approach of choice varies depending on several factors, including the tumor's localization, size, spread to the nearby soft tissues, and mainly histological diagnosis.[1-7,9,10] For tumor-like lesions, benign, and selected locally aggressive bone tumors, curettage represents the surgery of choice, dovetailing local effectiveness with reasonable complication rates and minimal invasivity towards the nearby healthy tissues. Studies reported excellent clinical and functional outcomes, even for cases with pathological fractures.[1,5,11,12]

Conversely, primary malignant bone tumors require wide resection margins in order to minimize the risk of postoperative local recurrences. Therefore, an intralesional approach such as curettage should be discouraged. The narrow spaces of the hand generally do not allow wide resection margins while preserving the involved segment, making amputations often necessary. For decades, amputations have been the unanimous treatment of choice for all malignant bone and soft tissue tumors of the hand.[13,14] Although generally effective in terms of local control of the disease, extended amputations severely undermine the functionality of the whole upper limb and impede most of the activities of daily living.[15] Furthermore, the esthetic damage may have a negative psychological impact on patients and reduce their emotional acceptance.[16]

The resection of single or multiple hand digit rays has been introduced as an alternative to partially overcome these limitations in selected cases. Pioneered by Bunnell in the 1920s and implemented on a large scale in the last decades for lesions confined to a single digit, ray amputations preserve a large share of patients' hands, preserve part of their functionality, and limit the visive and psychological impact of complete amputation.[17-19] However, although these procedures represent a step forward in functionality and personal acceptance compared to whole-hand amputations, they still imply the complete loss of a whole-digit ray.[20] This sacrifice is necessary for most malignant bone tumors, particularly high-grade lesions that extend to the nearby soft tissues. Conversely, it might be excessive for selected cases with locally aggressive low-grade lesions that extend to a large share of the involved bone but are still primarily confined to it.[21] In such conditions, where amputation could represent an overtreatment and curettage might not be sufficient due to extensive cortical bone thinning, the resection and replacement of the involved bone alone could be advisable. In this scenario, the en-bloc resection of the bone as a whole should be followed by the implant of a biological or prosthetic substitute, following the principles of modern limb-sparing surgery.[21-24]

In 2018, Giovanni Beltrami[25] published the use of a 3D-printed custom-made implant to treat a recurrent giant cell tumor of the bone in a proximal phalanx. One year after surgery, the ROM in the MCP joint was maintained, and the ROM in the PIP joint remained limited to 80° flexion. The radiographs showed a fusion of the PIP joint; however, the joint remained stable and pain-free, with subjective satisfactory results. No sign of local recurrence was recorded within two years after surgery.

The use of custom-made prostheses is progressively increasing in modern orthopedic oncology. However, their use to treat hand tumors is still limited. Compared to custom-made implants, allografts have both intra-operative

Table 2. A schematic resume of our results, sorted per patient

Case	Age (yr)	Pre-op Fract.	Diagnosis	Digit Ray	Bone	Pre-op MSTS	Complications	TC	LR	Post-op MSTS	FU (m)
1	18	No	ACT	V	MTC	19	None	0	No	30	54
2	45	Yes	ACT	V	PP	17	Rotation (10°)	1	No	25	46
3	63	No	ACT	III	PP	21	None	1	No	28	16
4	62	Yes	GCTB+ ABC	II	PP	15	None	1	No	23	12
5	39	No	GSD	IV	MP	21	Bone resorption	0	Yes	26*	14

LR: local recurrence; FU: follow-up; ACT: atypical chondromatous tumor; GCTB: giant cell tumor of the bone; ABC: aneurysmal bone cyst; GSD: Gorham-Stout disease; MTC: metacarpal; PP: proximal phalanx; MP: middle phalanx; TC: Tubiana classification; *: Value recorded after the digit ray amputation received to treat the recurrence.

and post-operative advantages. Intra-operatively, allografts can be molded, resurfaced, or cut in case of discrepancy between the allograft itself and the receiving site, while surgeons cannot reshape a metal prosthesis. Furthermore, unlike most prostheses, allografts can be colonized by patients' own cells, acting like a biological scaffold. In many cases, this eventuality could increase the chances of grafts' long-term success and good functional recovery.[26]

Adani et al.[27] also reported on using osteoarticular allografts to replace part of the phalanx or metacarpals, stabilizing the graft to what remained of the native bone. Used in three cases with recurrent neoplasms, this approach provided encouraging ranges of motion without significant pain or major complications. Despite these promising outcomes, a focal resection might not be sufficient for treating lesions involving a larger share of the hosting phalanx or metacarpal, requiring the removal of the whole bone. In our study, we extended the use of osteoarticular allografts to completely replace the long bones of the hand. Massive osteoarticular allografts allowed our patients not only to maintain their hands and fingers, with evident benefits from a psychological and social point of view but also experience a significant increase in their hand performance. Despite a tendency to develop mild residual flexion stiffness for phalanx cases, all our patients reported a total or subtotal return to their natural flexion mobility and an adequate restoration of grip strength. A mean MSTS score of 26.4 testifies to the functional effectiveness of our treatment, especially compared to a possible amputation.

We acknowledge that our study is not free of limitations. One of them is represented by the retrospective nature of our study, which did not allow the complete standardization of the surgical procedures and the postoperative follow-up procedures for each patient. The small size of our cohort, mainly attributable to the low incidence of locally aggressive hand bone tumors, did not allow us to operate with a broader population and impeded advanced statistical evaluations. These issues could be overcome by performing similar evaluations on a prospective basis and broader populations. Another limitation is represented by the absence of control groups treated with amputation or other limb-sparing approaches, such as endoprostheses, impeding a comparison with the different treatment options. Beyond these limitations, our study testifies to an unprecedented experience using massive osteoarticular allografts to treat large, locally aggressive, or low-grade malignant hand tumors, mainly localized within the bone. This approach should be considered in selected cases that could not be treated with curettage due to the absence of adequate cortical coverage or articular involvement and whose tumors could not be completely removed with partial resections. When anatomical and histological considerations are feasible, finger-sparing surgery with massive osteoarticular allografts should be considered to preserve the anatomy and functionality of patients' hands. By preserving functional fingers and hands, surgeons can allow their patients to perform most of their daily activities and avoid the social stigma of amputation, thereby significantly increasing their quality of life in a long-term scenario.

Conclusion

Digit-ray amputation still represents the treatment of choice for most malignant tumors of the long bones in the hand. However, a digit-sparing approach should be considered for selected cases with locally aggressive low-grade lesions that, although they may extend to a large share of the involved bone, are still primarily confined to it. A surgical approach consisting of a whole-bone en-bloc resection followed by the implant of an osteoarticular allograft can allow adequate local control of the disease and restore the functional performance of the treated hand.

Conflict of interest

The authors declare no conflict of interest.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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