

Surgical Management of Foot and Ankle Tumors: A Single-Center Retrospective Study

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Abstract

Background: Foot and ankle tumors are rare entities that pose unique diagnostic and therapeutic challenges due to the complex regional anatomy and critical role in mobility and weight-bearing. Surgical management in this area requires balancing oncologic safety with functional preservation, yet literature remains limited, particularly in low-resource settings.

Objective: This study aimed to evaluate the demographic distribution, tumor characteristics, surgical interventions, and outcomes of patients with foot and ankle tumors managed at a single tertiary referral center.

Methods: A retrospective descriptive review was conducted of patients undergoing surgical treatment for foot and ankle tumors at Dr. Moewardi General Hospital between January 2022 and April 2025. From an initial 547 patients, 145 were included after excluding incomplete records. Data on demographics, tumor type and location, surgical procedures, complications, and recurrence were collected. Descriptive statistical methods were used to analyze the data.

Results: Of the 145 patients, 57.9% were male and 42.1% were female, with the largest age group being 0–20 years (34.5%). A total of 196 surgical procedures were performed, as some patients underwent multiple interventions. Open biopsy (33.2%) was the most common procedure, followed by core biopsy (20.4%), wide excision (16.8%), amputation (13.8%), marginal excision (8.2%), and curettage (7.7%). These findings reflect the continued importance of biopsy for diagnosis, the application of excisional surgery for localized disease, and the role of amputation in advanced cases.

Conclusion: Foot and ankle tumors predominantly affect younger patients and present complex challenges in balancing oncological control with functional outcomes. Biopsy procedures remain central to diagnosis, while excisional surgeries and, when necessary, amputations serve as definitive management. This study highlights the diversity of surgical strategies employed and underscores the need for continued research to optimize patient care in this rare but significant tumor population.

Introduction

Tumors of the foot and ankle constitute a rare but clinically important subset of musculoskeletal neoplasms, representing fewer than 5% of all cases.[1,2] Despite their rarity, these lesions carry significant morbidity due to the functional complexity of the region, which plays a central role in weight-bearing, balance, and mobility.[2,3] Tumors may arise from bone, soft tissue, or neurovascular structures, and include a wide spectrum of benign, malignant, and intermediate entities.[3] Even relatively small lesions in this area can disrupt gait mechanics, complicate footwear use, and impair daily function, making their impact disproportionate to their size or incidence.[1,4]

The diagnostic process is often challenging because the foot and ankle's compact anatomy—with numerous small bones, dense ligamentous structures, and limited soft tissue coverage—restricts the feasibility of achieving wide surgical margins.[5] Clinical presentations such as pain, swelling, or deformity are

frequently nonspecific and can mimic trauma or inflammatory conditions, leading to diagnostic delays.[5,6] While imaging and biopsy remain indispensable tools, misdiagnosis or inadequate sampling is a well-documented risk.[3,6] In particular, biopsy errors have been shown to compromise future surgical options and may adversely affect oncologic outcomes, underscoring the importance of meticulous technique and multidisciplinary planning.[7,8]

Surgery remains the cornerstone of treatment, with options ranging from intralesional curettage and marginal excision for benign tumors to wide excision or even amputation for aggressive or malignant lesions.[4–6] Advances in limb-salvage surgery and reconstructive techniques have improved the potential for functional preservation, but the optimal approach is influenced by tumor biology, anatomic constraints, and institutional resources.[4,5] Biopsy procedures are often the first and most common interventions, yet definitive management depends on balancing oncologic safety with limb function.[6,8] While amputation rates have decreased in many centers due to progress in surgical oncology, it remains necessary in cases of extensive disease or when limb-sparing surgery cannot achieve negative margins.[6,9]

Despite these complexities, literature on foot and ankle tumors is limited, with most studies relying on small series or heterogeneous cohorts. Epidemiological data remain sparse, particularly in low- and middle-resource settings, where diagnostic modalities and surgical expertise may differ from those in high-income countries. Descriptive studies are therefore vital to better characterize patient demographics, surgical practices, and outcomes, and to identify practice gaps that may inform future improvements. Against this background, the present retrospective study evaluates the demographic distribution, spectrum of surgical procedures, and treatment outcomes of foot and ankle tumors at a single tertiary referral center over a three-year period.

Literature Review

A. Anatomy of Foot & Ankle

1. Bone components

The skeletal components of the foot and ankle is a highly specialized structure that enables both stability for weight-bearing and flexibility for locomotion.[10] The ankle joint (talocrural joint) is formed by the distal tibia and fibula articulating with the talus, permitting dorsiflexion and plantarflexion.[11] Inferior to this, the subtalar joint between the talus and calcaneus allows inversion and eversion, essential for adapting to uneven surfaces.[11] The foot itself is composed of 26 bones arranged into three regions: the hindfoot (talus and calcaneus), midfoot (navicular, cuboid, and three cuneiforms), and forefoot (five metatarsals and fourteen phalanges).[12]

These bones form longitudinal and transverse arches that distribute body weight and act as shock absorbers during gait.[13] The hindfoot functions as the foundation, the midfoot acts as a keystone linking segments, and the forefoot provides propulsion. The compact arrangement of multiple small bones, often closely interlocked, presents significant surgical challenges.[13] Tumors in these regions can be difficult to access without disrupting joint integrity or altering biomechanics, making precise surgical planning imperative.

2. Ligament components

The foot and ankle are reinforced by an extensive ligamentous network that provides stability while permitting controlled motion.[10–12] On the lateral aspect, stability is conferred by the anterior talofibular ligament, calcaneofibular ligament, and posterior talofibular ligament, which together protect against inversion injuries.[11] Medially, the deltoid ligament complex—composed of superficial and deep fibers—supports the ankle against eversion and valgus stress. [11]

In the midfoot, the spring ligament (plantar calcaneonavicular ligament) plays a crucial role in maintaining the medial longitudinal arch, while the long and short plantar ligaments stabilize the lateral column.[13] Interosseous ligaments, including the interosseous talocalcaneal and Lisfranc ligaments, maintain alignment between tarsal and metatarsal bones.[13]

When tumors involve or displace these structures, the risk of instability, deformity, or arch collapse increases.[14]

3. Muscular components

The muscular system of the foot and ankle is divided into extrinsic muscles, originating from the leg and inserting into the foot, and intrinsic muscles, confined entirely within the foot.[10–12]

Extrinsic muscles include the anterior compartment (tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius) for dorsiflexion and toe extension, the lateral compartment (peroneus longus and brevis) for eversion, and the posterior compartment (gastrocnemius, soleus, tibialis posterior, flexor digitorum longus, and flexor hallucis longus) for plantarflexion and inversion.[11,12]

Intrinsic muscles are organized into four plantar layers and a dorsal group, contributing to fine motor control, arch support, and stabilization during stance and gait.[11,12]

Muscle preservation is critical in surgical treatment. Resection of extrinsic muscles may result in profound gait disturbances, while loss of intrinsic muscles can impair balance and fine control.[10] In cases where tumors require partial muscle resection, tendon transfers or reconstructive techniques may be considered to restore function.

4. Neurovascular components

The neurovascular anatomy of the foot and ankle is both dense and intricate. Arterial supply arises mainly from the anterior tibial artery, which continues as the dorsalis pedis artery on the dorsum, and the posterior tibial artery, which divides into the medial and lateral plantar arteries.[11–13] The peroneal artery contributes collateral branches, particularly to the lateral aspect. Venous return occurs through paired deep veins and the superficial great and small saphenous veins. [11–13]

Innervation is provided by branches of the tibial nerve (medial and lateral plantar nerves, calcaneal branches), deep peroneal nerve (to the first web space and extensor digitorum brevis), superficial peroneal nerve (supplying most of the dorsum), and the sural nerve (lateral border).[11,12] These nerves ensure both motor function and sensory perception essential for proprioception and protective feedback.

Given the limited soft tissue envelope of the foot and ankle, tumors often encroach upon neurovascular structures early in their course. Achieving oncologic clearance without sacrificing critical arteries or nerves can be difficult, and in some cases, amputation may be required when major vessels or motor nerves are involved. When feasible, microsurgical reconstruction of arteries or nerve grafting may be performed, although outcomes vary.

B. Tumors of Foot & Ankle

Tumors of the foot and ankle are uncommon, representing less than 5% of all musculoskeletal neoplasms, yet they pose disproportionately high diagnostic and therapeutic challenges.[1,2,6] The rarity of these tumors often leads to delayed recognition, as their initial presentation can mimic more common conditions such as infection, trauma, or degenerative disease.[5] Moreover, the intricate anatomy of the foot and ankle, characterized by compact bony structures, limited soft tissue coverage, and the presence of critical neurovascular bundles, complicates both diagnosis and surgical management. A broad spectrum of benign and malignant lesions may arise in this region.[3,5,6] Benign bone tumors include enchondromas, osteochondromas, chondroblastomas, and giant cell tumors, many of which present as localized swelling or incidental findings on imaging.[1,15] Soft tissue tumors such as lipomas, fibromas, and ganglion cysts are also frequent, often mistaken for non-neoplastic masses. Although benign lesions predominate, their location in weight-bearing areas can still produce significant morbidity due to pain, deformity, or functional impairment.[16]

Malignant tumors, while less common, are of critical concern given their aggressive nature.[14] Primary bone malignancies such as osteosarcoma, Ewing sarcoma, and chondrosarcoma have been documented in the foot and ankle, though they occur less frequently than in the long bones.[6,14] Soft tissue sarcomas, including synovial sarcoma, clear cell sarcoma, and epithelioid sarcoma, may present in the distal extremities and tend to be associated with poorer prognoses due to delayed detection and the difficulty of achieving wide surgical margins. In addition, secondary malignant neoplasms, particularly metastases to

bone (most commonly from breast, lung, or prostate primaries), occasionally involve the ankle and calcaneus, underscoring the importance of systemic evaluation in patients with known malignancy. [5,6] A unique diagnostic category is that of neoplasms of uncertain or intermediate behavior, which are not clearly benign or malignant. These include lesions such as atypical fibroxanthomas, dermatofibrosarcoma protuberans, and some giant cell-rich tumors.[17] Their classification remains challenging, especially in resource-limited settings where advanced immunohistochemistry or molecular diagnostics may not be routinely available. Misdiagnosis in this category can lead to undertreatment or, conversely, overly aggressive interventions that compromise function unnecessarily.[7]

The clinical presentation of foot and ankle tumors is often subtle. Patients may report swelling, localized pain, or reduced range of motion, but these symptoms are nonspecific and frequently attributed to minor injuries or inflammatory conditions.[5,6] Because of this, diagnosis is frequently delayed compared to tumors in other musculoskeletal sites. In some cases, ulceration, rapid growth, or neurovascular compromise may herald malignancy. However, the overlap in symptoms between benign and malignant lesions emphasizes the importance of thorough evaluation.[15,18,19]

Imaging studies play a pivotal role in diagnosis and surgical planning.[3,5] Plain radiographs are often the first step, revealing lytic, sclerotic, or mixed lesions within bone. MRI is the modality of choice for assessing local tumor extent, marrow involvement, and soft tissue infiltration, while CT can aid in evaluating cortical bone destruction. Nuclear medicine techniques, including bone scintigraphy and PET-CT, may provide additional information regarding metabolic activity and systemic spread. Ultimately, biopsy and histopathological evaluation remain the gold standard for definitive diagnosis, with core needle biopsy preferred due to its minimally invasive nature and reliability.[5,8,20]

Prognosis varies widely depending on tumor type, grade, and stage at diagnosis. Benign lesions generally carry favorable outcomes when adequately treated, though recurrence can occur with incomplete excision. Malignant tumors of the foot and ankle historically carried poor outcomes due to delayed diagnosis and high rates of local recurrence.[21] However, advances in imaging, biopsy techniques, adjuvant therapies, and reconstructive surgery have markedly improved both survival and limb-salvage rates.[21] Today, the emphasis lies on a multidisciplinary approach, integrating orthopedic oncology, radiology, pathology, plastic surgery, and rehabilitation to optimize both oncologic control and functional preservation.

C. Surgical Treatment for Tumors

1. Core Biopsy

Core needle biopsy is considered the first-line diagnostic approach in the evaluation of musculoskeletal tumors, including those of the foot and ankle.[22] It provides sufficient tissue for histopathological and immunohistochemical analysis while minimizing surgical morbidity.[22,23] The technique is minimally invasive, often performed under imaging guidance (ultrasound, CT, or fluoroscopy) to enhance accuracy, particularly in small or deep lesions.[23] A major principle is to plan the biopsy tract along a line that can be excised during definitive surgery, thereby reducing the risk of tumor cell seeding. Despite its reliability, limitations include inadequate sampling in heterogeneous tumors and potential misclassification, necessitating repeat or open biopsy in selected cases.[22,23]

2. Open Biopsy

Open biopsy is indicated when core needle biopsy fails to yield diagnostic material or when more extensive tissue is required for analysis.[8,22] This technique provides direct visualization of the lesion, allowing surgeons to obtain larger and more representative specimens. However, the approach carries higher risks, including infection, hematoma formation, and soft tissue contamination, all of which may adversely impact definitive surgical management.[24] To mitigate these risks, meticulous hemostasis and careful wound closure are essential. Importantly, the incision must be planned in consultation with the oncologic team, ensuring that it lies within the future resection field if wide excision becomes necessary.[24] While more invasive, open biopsy remains a valuable tool in complex or diagnostically ambiguous cases.[22]

3. Curettage

Curettage is widely applied in the treatment of benign and low-grade tumors such as enchondromas, giant cell tumors, and aneurysmal bone cysts.[25] The procedure involves intralesional removal of tumor tissue using curettes, often followed by the application of local adjuvants such as phenol, hydrogen peroxide, cryotherapy, or high-speed burring to eradicate residual cells[25]. Cavity reconstruction may be achieved using bone grafts or polymethylmethacrylate (PMMA) bone cement, the latter offering the additional benefit of thermal necrosis of residual tumor cells.[26] While curettage preserves surrounding bone and joint structures, its main drawback is the relatively high recurrence rate, particularly in more aggressive tumors.[25] Functional outcomes, however, are generally excellent, making curettage the preferred approach in young patients where preservation of mobility is paramount.

4. Marginal Excision

Marginal excision entails removing the tumor along with its surrounding pseudocapsule and a thin rim of reactive tissue.[27] This method is typically reserved for benign or locally aggressive lesions such as lipomas, schwannomas, or some intermediate-grade soft tissue tumors.[28] Its principal advantage lies in preserving anatomical integrity and function, especially in the foot and ankle where soft tissue is limited. However, marginal excision poses an increased risk of recurrence if the lesion demonstrates infiltrative growth beyond the pseudocapsule.[27,28] Careful patient selection, combined with adjuvant treatments where appropriate, helps balance oncological control with functional preservation. Literature suggests that marginal excision is most successful when preoperative imaging confirms well-defined tumor margins.[27,28]

5. Wide Excision

Wide excision remains the gold standard for most malignant bone and soft tissue tumors.[29,30] The principle is removal of the tumor en bloc with a cuff of normal tissue to ensure negative surgical margins.[29] In the foot and ankle, this may involve resection of multiple bones or extensive soft tissue, often followed by reconstructive procedures such as vascularized bone grafts, tendon transfers, or free flap coverage to restore form and function.[29,31] Wide excision significantly reduces the risk of local recurrence compared to marginal techniques, though at the expense of greater functional morbidity.[29] Advances in reconstructive microsurgery have expanded the feasibility of limb-sparing procedures, allowing patients to retain mobility while still achieving oncologic control.[31] Despite these improvements, achieving adequate margins in the foot and ankle remains technically challenging due to their compact anatomy.

6. Amputation

Amputation is considered when limb salvage is not feasible, either because of extensive tumor involvement of critical neurovascular structures, poor soft tissue coverage, or when achieving oncologically safe margins would severely impair function.[4,32] Historically, amputation was the standard treatment for many foot and ankle malignancies, but limb-salvage rates have improved with better imaging, chemotherapy, and reconstructive techniques.[32] Nevertheless, amputation remains necessary in a subset of patients and can provide excellent local control with relatively low recurrence rates.[33] Modern prosthetics and rehabilitation programs have greatly enhanced functional outcomes, allowing many patients to resume near-normal activities. However, amputation also carries significant psychological and social implications, emphasizing the need for preoperative counseling and multidisciplinary support.[32,33]

Research Methodology

A. Study Design

This study employed a retrospective descriptive design, analyzing medical records of patients who underwent surgical management for foot and ankle tumors at a single tertiary referral center. The study period spanned from January 2022 to April 2025. This design was chosen to provide an overview of patient demographics, tumor characteristics, surgical interventions, and outcomes in a real-world tertiary care setting.

B. Research Ethics

Ethical approval was obtained from the Institutional Review Board of Dr. Moewardi General Hospital, Surakarta, Indonesia. Patient confidentiality was maintained by anonymizing personal identifiers and securing all collected data. Informed consent was waived due to the retrospective nature of the study, in accordance with national regulations. All procedures were conducted in compliance with the principles of the Declaration of Helsinki.

C. Population and Sample

The study population consisted of all patients diagnosed with foot and ankle tumors who underwent surgical treatment at the orthopedic department during the study period. A total of 547 patients were initially identified. However, cases with incomplete or missing medical records were excluded, resulting in a final cohort of 145 patients who met the inclusion criteria. Patients were eligible if they had a histologically or radiologically confirmed tumor in the foot or ankle and underwent at least one surgical intervention.

D. Data Collection

Data were retrieved retrospectively from hospital electronic medical records, operative notes, and outpatient follow-up reports. Variables collected included demographic characteristics (age, sex), and, type of surgical procedure(s) performed, postoperative complications, and recurrence status. As patients could undergo multiple surgical interventions during a single admission, each procedure was recorded separately.

E. Statistical Analysis

Descriptive statistics were applied to summarize study findings. Categorical variables, including sex, tumor type, surgical procedure, and complication rates, were presented as frequencies and percentages. No inferential statistical tests were performed.

F. Outcome Measures

The primary outcomes included surgical interventions performed, tumor characteristics, and recurrence rates at follow-up. Secondary outcomes encompassed patient demographics, ward utilization, and postoperative complications. Functional preservation and oncologic control were considered clinical endpoints; however, assessment was limited to the available follow-up data. These measures were chosen to capture both oncological safety and functional outcomes, aligning with the study's objective to describe surgical management patterns in foot and ankle tumors.

Result

From the initial population of 547 patients with foot and ankle tumors, only 145 cases met the inclusion criteria after excluding patients with incomplete or inadequate clinical data. As shown in **Table 1**, males accounted for a slightly higher proportion (57.9%) compared to females (42.1%). The age distribution revealed that the majority of patients were in the younger age groups, with the highest proportion between 0–20 years (34.5%), followed by 21–30 years (20.0%). Patients aged 31–40 years comprised 14.5%, while the proportions decreased progressively in the older age groups, with only 2.8% of cases in the 71–80 years group. These findings indicate that foot and ankle tumors in this cohort most frequently affected younger individuals, with a tendency to decline in incidence with advancing age.

Table 1. Characteristics of the patient

Characteristics	Total (n)	Percentage
Gender		
Male	84	57.9%
Female	61	42.1%
Age		
0-20	50	34.5%
21-30	29	20.0%
31-40	21	14.5%
41-50	11	7.6%
51-60	20	13.8%
61-70	10	6.9%
71-80	4	2.8%

Total	145	100%
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Regarding surgical management, a total of 196 interventions were performed, as some patients underwent more than one surgical procedure during their treatment course (Table 2). Open biopsy was the most frequently performed procedure (33.2%), followed by core biopsy (20.4%) and wide excision (16.8%). Curettage and marginal excision were less common, accounting for 7.7% and 8.2% of procedures, respectively. Amputation was performed in 13.8% of cases, reflecting the need for more radical intervention in selected patients, particularly those with advanced or aggressive tumors. These results highlight the diverse surgical approaches employed in managing foot and ankle tumors, ranging from diagnostic procedures to limb-salvage techniques and, in more severe cases, definitive amputations.

Table 2. Surgery intervention given

Surgery	Total (n)	Percentage
Core Biopsy	40	20.4%
Open Biopsy	65	33.2%
Curettage	15	7.7%
Marginal excision	16	8.2%
Wide excision	33	16.8%
Amputation	27	13.8%
Total	196	100%

Discussion

This study provides an overview of the demographic profile and surgical management of patients with foot and ankle tumors in our institution, focusing on a subset of 145 patients from an initial cohort of 547. The predominance of male patients (57.9%) over females (42.1%) aligns with previous reports suggesting that musculoskeletal tumors, particularly in the extremities, occur slightly more frequently in males.[15,16,18,34] This may be attributed to differences in occupational exposure, physical activity, and possibly hormonal or genetic factors that influence tumor biology.[1,15] However, the difference is not stark, and further studies with larger samples may help clarify whether gender plays a significant role in susceptibility to foot and ankle tumors.

The age distribution in this study demonstrated that the majority of patients were in the younger population, with the highest proportion observed in those aged 0–20 years (34.5%). This finding is consistent with literature reporting that benign and malignant bone tumors often peak in children, adolescents, and young adults.[1,14,15,19,34,35] Osteosarcoma and Ewing sarcoma, for example, are classically diagnosed during the second decade of life.[14,15,36] In contrast, older age groups tended to show a lower prevalence, reflecting the overall epidemiological trend of primary bone tumors being more common in younger individuals, while secondary or metastatic lesions are more frequently encountered in older adults.[37] The relatively small proportion of patients above 60 years in our cohort likely reflects this biological distribution.

In this study, biopsy procedures emerged as the most frequently performed surgical interventions, with open biopsy (33.2%) and core biopsy (20.4%) together accounting for more than half of all procedures. This trend reflects the indispensable role of biopsy in establishing an accurate histopathological diagnosis prior to definitive surgical management.[3,6,8] While open biopsy predominated, its higher frequency compared to core biopsy contrasts with recommendations in several reports advocating image-guided core biopsy as the gold standard due to its minimally invasive nature, lower complication rates, and comparable diagnostic accuracy.[8,20] The preference for open biopsy in our setting may reflect institutional practice patterns, surgeon familiarity, or limitations in access to advanced imaging modalities, underscoring how local resources and expertise influence surgical choices.

Beyond diagnosis, therapeutic surgical procedures demonstrated the wide spectrum of management strategies tailored to tumor type, location, and extent. Wide excision (16.8%) and marginal excision (8.2%)

were performed in accordance with oncological principles that prioritize achieving clear margins while striving to preserve function.[38] Curettage (7.7%) was selectively employed for benign or low-grade tumors, consistent with literature emphasizing its role in reducing morbidity while maintaining structural integrity.[39] Notably, amputation was required in 13.8% of cases, reflecting its continued relevance as a salvage option in advanced or aggressive disease when limb-sparing surgery is not feasible. These findings mirror global surgical practices, highlighting the delicate balance between diagnostic precision, oncological safety, and functional preservation that defines contemporary management of foot and ankle tumors.

Conclusion

This study highlights the demographic trends and surgical treatment patterns of foot and ankle tumors in our institution. The predominance in younger patients and males is consistent with known epidemiological patterns of musculoskeletal tumors. Open and core biopsies formed the majority of interventions, reflecting the emphasis on accurate diagnosis, while excision and amputation were tailored to tumor severity and resectability. These results reinforce the need for multidisciplinary approaches that prioritize both oncological safety and functional outcomes in foot and ankle tumor management. Future research with larger, multicenter cohorts may provide deeper insights into optimizing surgical strategies for this patient population.

References

- [1] Scheele C, Toepfer A, Beischl S, Dammerer D, Harrasser N, von Eisenhart-Rothe R, et al. Insights into the Distribution Patterns of Foot and Ankle Tumours: Update on the Perspective of a University Tumour Institute. *J Clin Med* 2024;13:350. <https://doi.org/10.3390/jcm13020350>.
- [2] Toepfer A, Harrasser N, Recker M, Lenze U, Pohlig F, Gerdesmeyer L, et al. Distribution patterns of foot and ankle tumors: a university tumor institute experience. *BMC Cancer* 2018;18:735. <https://doi.org/10.1186/s12885-018-4648-3>.
- [3] Angelini A, Biz C, Cerchiaro M, Longhi V, Ruggieri P. Malignant Bone and Soft Tissue Lesions of the Foot. *J Clin Med* 2023;12. <https://doi.org/10.3390/jcm12083038>.
- [4] Kokubu Y, Fujiwara T, Nakagawa K, Setsu N, Endo M, Fukushima J, et al. Postoperative clinical and functional outcomes in patients with tumor and tumor-like lesion of foot and ankle. *J Foot Ankle Res* 2022;15. <https://doi.org/10.1186/s13047-022-00582-z>.
- [5] Hegazi TM, Aljamaan YM, Alghamdi SG, Alsaygh JS, Awary KB, Aladel FI, et al. Review of Soft Tissue Masses of the Foot and Ankle. *Saudi J Med Med Sci* 2023. https://doi.org/10.4103/sjmms.sjmms_66_22.
- [6] Mascard E, Gaspar N, Brugières L, Glorion C, Pannier S, Gomez-Brouchet A. Malignant tumours of the foot and ankle. *EFORT Open Rev* 2017;2:261–71. <https://doi.org/10.1302/2058-5241.2.160078>.
- [7] Hodel S, Laux C, Farei-Campagna J, Götschi T, Bode-Lesniewska B, Müller DA. The impact of biopsy sampling errors and the quality of surgical margins on local recurrence and survival in chondrosarcoma. *Cancer Manag Res* 2018;10:3765–71. <https://doi.org/10.2147/CMAR.S178768>.
- [8] Mavrogenis A, Altsitzoglou P, Tsukamoto S, Errani C. Biopsy Techniques for Musculoskeletal Tumors: Basic Principles and Specialized Techniques. *Current Oncology* 2024;31:900–17. <https://doi.org/10.3390/curroncol31020067>.
- [9] Baysal O, Saglam F, Sofulu O, Yigit O, Sirin E, Erol B. Indications of amputation after limb-salvage surgery of patients with extremity-located bone and soft-tissue sarcomas: A retrospective clinical study. *Acta Orthop Traumatol Turc* 2021;55:154–8. <https://doi.org/10.5152/j.aott.2021.20115>.
- [10] Angin S, Demirbüken İ. Ankle and foot complex. *Comparative Kinesiology of the Human Body*, Elsevier; 2020, p. 411–39. <https://doi.org/10.1016/B978-0-12-812162-7.00023-0>.
- [11] Manganaro D, Khalid A. Anatomy, Bony Pelvis and Lower Limb: Ankle Joint. *StatPearls* 2023.
- [12] Manganaro D, Dollinger B, Nezwek TA, Sadiq NM. Anatomy, Bony Pelvis and Lower Limb, Foot Joints. *StatPearls* 2023.
- [13] Chauhan HM, Taqi M. Anatomy, Bony Pelvis and Lower Limb: Arches of the Foot. *StatPearls* 2022.

- [14] Rammelt S, Fritzsche H, Hofbauer C, Schaser K-D. Malignant tumours of the foot and ankle. *Foot and Ankle Surgery* 2020;26:363–70. <https://doi.org/10.1016/j.fas.2019.05.005>.
- [15] Toepfer A, Harrasser N, Recker M, Lenze U, Pohlig F, Gerdesmeyer L, et al. Distribution patterns of foot and ankle tumors: a university tumor institute experience. *BMC Cancer* 2018;18:735. <https://doi.org/10.1186/s12885-018-4648-3>.
- [16] Foo LF, Raby N. Tumours and tumour-like lesions in the foot and ankle. *Clin Radiol* 2005;60:308–32. <https://doi.org/10.1016/j.crad.2004.05.010>.
- [17] Apalla Z, Liopyris K, Kyrmanidou E, Fotiadou C, Sgouros D, Patsatsi A, et al. Clinical and Dermoscopic Characteristics of Cutaneous Sarcomas: A Literature Review. *Diagnostics* 2023;13:1822. <https://doi.org/10.3390/diagnostics13101822>.
- [18] Neyisci C, Erdem Y. Battle Against Musculoskeletal Tumors: Descriptive Data of Military Hospital Experience. *Front Public Health* 2020;8. <https://doi.org/10.3389/fpubh.2020.00097>.
- [19] Keil L. Bone Tumors: Primary Bone Cancers. *FP Essent* 2020;493:22–6.
- [20] Pohlig F, Kirchhoff C, Lenze U, Schauwecker J, Burgkart R, Rechl H, et al. Percutaneous core needle biopsy versus open biopsy in diagnostics of bone and soft tissue sarcoma: a retrospective study. *Eur J Med Res* 2012;17:29. <https://doi.org/10.1186/2047-783X-17-29>.
- [21] Angelini A, Biz C, Cerchiaro M, Longhi V, Ruggieri P. Malignant Bone and Soft Tissue Lesions of the Foot. *J Clin Med* 2023;12. <https://doi.org/10.3390/jcm12083038>.
- [22] Crenn V, Vezole L, Bouhamama A, Meurgey A, Karanian M, Marec-Bérard P, et al. Percutaneous Core Needle Biopsy Can Efficiently and Safely Diagnose Most Primary Bone Tumors. *Diagnostics* 2021;11:1552. <https://doi.org/10.3390/diagnostics11091552>.
- [23] Seng C, Png W, Tan MH. Accuracy of Core Needle Biopsy for Musculoskeletal Tumours. *Journal of Orthopaedic Surgery* 2013;21:92–5. <https://doi.org/10.1177/230949901302100123>.
- [24] Bowen S, Lepkowsky E, Khan F. The Management of an Open Biopsy Tract Site Infection and Ulceration in the Setting of Osteosarcoma. *JAAOS: Global Research and Reviews* 2022;6. <https://doi.org/10.5435/JAAOSGlobal-D-22-00038>.
- [25] Kundu ZS, Gupta V, Sangwan SS, Rana P. Curettage of benign bone tumors and tumor like lesions: A retrospective analysis. *Indian J Orthop* 2013;47:295–301. <https://doi.org/10.4103/0019-5413.111507>.
- [26] Radev BR, Kase JA, Askew MJ, Weiner SD. Potential for thermal damage to articular cartilage by PMMA reconstruction of a bone cavity following tumor excision: A finite element study. *J Biomech* 2009;42:1120–6. <https://doi.org/10.1016/j.jbiomech.2009.02.005>.
- [27] Lee S, Joo M, Kim J-Y, Bernthal N. Postoperative Imaging of Bone and Soft Tissue Tumors in the Extremity: A Comprehensive Review. *Diagnostics* 2024;14:2794. <https://doi.org/10.3390/diagnostics14242794>.
- [28] Sambri A, Caldari E, Fiore M, Zucchini R, Giannini C, Pirini MG, et al. Margin Assessment in Soft Tissue Sarcomas: Review of the Literature. *Cancers (Basel)* 2021;13:1687. <https://doi.org/10.3390/cancers13071687>.
- [29] Gonzalez MR, Mendez-Guerra C, Goh MH, Pretell-Mazzini J. Principles of Surgical Treatment of Soft Tissue Sarcomas. *Cancers (Basel)* 2025;17:401. <https://doi.org/10.3390/cancers17030401>.
- [30] Khabiri SS, Shooroki KK, Saberi S, Naghizadeh H. Osseous invasion in extremity soft-tissue sarcomas: prevalence, diagnosis, and surgical management- A narrative review. *J Bone Oncol* 2025;100712. <https://doi.org/10.1016/j.jbo.2025.100712>.
- [31] Ring A, Kirchhoff P, Goertz O, Behr B, Daigeler A, Lehnhardt M, et al. Reconstruction of Soft-Tissue Defects at the Foot and Ankle after Oncological Resection. *Front Surg* 2016;3. <https://doi.org/10.3389/fsurg.2016.00015>.
- [32] Rana Muhammad Sohail Afzal khan, Shaheer Abdullah, Tooba Javaid, Muhammad Umer, Umair Ishfaq, Hasnat Gull. LIMB SALVAGE SURGERY COMPARED TO AMPUTATION IN BONE AND SOFT TISSUE TUMORS: A CRITICAL ANALYSIS OF CURRENT EVIDENCE. *Journal of Medical & Health Sciences Review* 2025;2. <https://doi.org/10.62019/0jnbee68>.

- [33] Li X, Zhang Y, Wan S, Li H, Li D, Xia J, et al. A comparative study between limb-salvage and amputation for treating osteosarcoma. *J Bone Oncol* 2016;5:15–21. <https://doi.org/10.1016/j.jbo.2016.01.001>.
- [34] Bergovec M, Kubat O, Smerdelj M, Seiwerth S, Bonevski A, Orlic D. Epidemiology of musculoskeletal tumors in a national referral orthopedic department. A study of 3482 cases. *Cancer Epidemiol* 2015;39:298–302. <https://doi.org/10.1016/j.canep.2015.01.015>.
- [35] Breden S, Stephan M, Hinterwimmer F, Consalvo S, Lenze U, von Eisenhart-Rothe R, et al. Pediatric Bone Tumors: Location and Age Distribution of 420 Cases. *Diagnostics (Basel)* 2024;14. <https://doi.org/10.3390/diagnostics14222513>.
- [36] Bone sarcomas: ESMO Clinical Practice Guidelines for diagnosis, treatment and follow-up. *Annals of Oncology* 2014;25:iii113–23. <https://doi.org/10.1093/annonc/mdu256>.
- [37] Hosseini H, Heydari S, Hushmandi K, Daneshi S, Raesi R. Bone tumors: a systematic review of prevalence, risk determinants, and survival patterns. *BMC Cancer* 2025;25:321. <https://doi.org/10.1186/s12885-025-13720-0>.
- [38] Singh M, Ranjan R, Singh L, Arava S. Margins in skin excision biopsies: Principles and guidelines. *Indian J Dermatol* 2014;59:567. <https://doi.org/10.4103/0019-5154.143514>.
- [39] Tsukamoto S, Mavrogenis AF, Tanzi P, Leone G, Akahane M, Tanaka Y, et al. Curettage as first surgery for bone giant cell tumor: adequate surgery is more important than oncology training or surgical management by high volume specialized teams. *European Journal of Orthopaedic Surgery & Traumatology* 2020;30:3–9. <https://doi.org/10.1007/s00590-019-02535-y>.