

# Resection and Reconstruction of an Osteochondroma of the Hallux: A Review of Benign Bone Tumors and a Description of an Unusual Case

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*Osteochondroma, which is also known as exostosis, is the most common benign bone tumor. Although foot and hand surgeons frequently encounter the subungual exostosis, exostoses commonly localize to other areas of the skeleton as well. In this review, we describe the clinical and diagnostic imaging characteristics of benign bone tumors and, in particular, the osteochondroma and its surgical management. We also report the case of a patient who experienced an unusual pedal digital osteochondroma-like lesion. Level of Clinical Evidence: 4 (The Journal of Foot & Ankle Surgery 48(4):495–505, 2009)*

Key Words: chondroma, Codman's triangle, foot, graft, juxtacortical, malignancy, periosteum

The subject of bone tumors in the lower extremity has been investigated by a number of authors who researched tumor types and their prevalence within the foot and ankle (1, 2). Although the majority of these lesions are found to be benign, to gain further appreciation for neoplastic developments within the lower extremity, large populations of tumors have been studied. In 196 cases of tumor in the foot and ankle, Ozdemir et al (1) found 171 (87.2%) of these lesions to be benign. Furthermore, they noted that of those cases studied, 136 (69.4%) originated from bone, whereas 60 (30.6%) originated from soft tissue structures. In a smaller series, Chou and Malawar (2) reviewed 33 tumors of the foot and ankle and reported that 21 (63.6%) of these were benign. Among the benign bone tumors that occur in the lower extremity, the osteochondroma is most common (3). In fact, osteochondroma, which is an osteocartilaginous exostosis, is the most common tumor of bone (1, 2).

## Osteochondroma

In 1891, Virchow (4) suggested that osteochondroma is derived from the cartilaginous growth plate and, since that time, animal and human histopathological investigations have supported Virchow's understanding of the origin of this bone tumor (5–7). In essence, the excrescence results from new growth of normal tissue and is, therefore, regarded as a hamartoma. The etiology is thought to be a defect in the perichondral node of Ranvier that allows exuberant development from the physal growth center. In general, enchondral ossification continues within these lesions until osseous maturity has been reached, and most of the growth halts with closure of the epiphyseal plate (7, 8). The exostosis is covered with cartilaginous tissue, the thickness of which is variable with age and diminishes after skeletal maturity (9). The majority of these lesions occur in long bones, and the femur, humerus, and tibia are most commonly affected. Other bony sites of involvement in the foot include the calcaneus and talus (10–12). There are, moreover, reports of extraskelatal osteochondromas arising in the foot and ankle (13–15). Osteochondromas are said to make up 36%–41% of all benign bone tumors (16), and approximately 3%–5% of these occur in the foot (1). The incidence of local recurrence after resection is infrequent (17) and has been reported to be <2% (9).

The initial presentation of osteochondroma can vary. Although some osteochondromas develop in an idiopathic

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fashion, it is not uncommon to have the lesion in association with trauma. The lesion has also been reported to develop after radiotherapy during the first decade of life (18). The exostosis usually presents as a solitary lesion; however, multiple hereditary exostoses (MHE) have been well documented (19, 20). There is a slight male predominance, and approximately 75% of osteochondromas are identified before the patient is 30 years of age (1). Early identification of dorsal pedal lesions is usually the result of pressure on the thin dorsal skin from shoes, whereas plantar pressure areas are realized during weight-bearing stance and gait. Osteochondromas, moreover, vary in regard to the portion of the bone that is involved, and they may result from aberrant outgrowth of the physal plate, periosteum, cortex, or medullary canal.

### Clinical Findings Associated with Osteochondroma

An osteochondroma usually presents as a painless excrescence localized to the metaphysis of a long bone. In general, symptomatic lesions are the result of local mechanical irritation at the area of tumor protrusion. Large lesions or lesions in an area of repetitive contact or external pressure can be problematic, and dysfunction secondary to such bony prominences is common. Presentation on the proximal aspect of the anterior tibia, for example, can interfere with the ability to kneel or crawl, whereas a pedal prominence may result in friction and overlying cutaneous irritation in association with shoe wear (11, 21). When an osteochondroma infringes on adjacent soft tissue structures or neurovascular elements, symptoms such as pain and paresthesia may develop (22). Vascular complications such as arterial thrombosis, arteriovenous fistula formation, pseudoaneurysm, claudication, acute ischemia, and arterial rupture can also develop if the degree of friction and pressure is sufficient (23, 24). Attention to the clinical history may help delineate the onset of bony protrusion in association with the development of neural or vascular complaints, and may explain the cause of an associated nerve entrapment or vascular defect.

### Tumor Staging

The practice of tumor staging has utility in the perioperative management of both benign and malignant tumors. Obtaining information regarding the tumor type, location, and extent of invasiveness is obligatory in the surgical candidate and can be achieved through various imaging techniques, although the standard for bone tumors remains plain radiography. Most benign bone tumors are associated with characteristic radiographic and histological findings that allow differentiation and aid in making a specific diagnosis. Consultations in radiology, pathology, and oncology are often necessary to correlate with clinical findings, and to

**TABLE 1 Staging system for benign lesions as described by Enneking**

Stage	Description
1	<ul style="list-style-type: none"> <li>• Static lesion that tends to heal spontaneously</li> </ul>
2	<ul style="list-style-type: none"> <li>• More aggressive radiographic appearance</li> <li>• Less mature histologically</li> </ul>
3	<ul style="list-style-type: none"> <li>• Evidence of continued growth</li> <li>• Locally aggressive lesion</li> <li>• Immature histologically</li> <li>• Evidence of progressive growth</li> <li>• Not limited by natural barriers</li> </ul>

make an accurate diagnosis. Enneking has devised useful staging systems for both benign and malignant tumors (25), which have been adopted by The Musculoskeletal Tumor Society (Alexandria, Virginia, <http://msts.org/>) (26), and these are depicted in Table 1.

### Radiological Findings

Plain radiology continues to be the mainstay of diagnosis for bone tumors. The pathognomonic feature of the osteochondroma is the presence of medullary bone contiguous with the stalk of the exostoses and the underlying cortical bone (9, 27). These lesions often are pedunculated with the stalk cortex histologically identical to that of the underlying bone. Normal periosteum is uninterrupted along the lesion and its associated cortex, and calcified cartilage is often noted on plain films as small, radiodense foci. Although these lesions are usually pedunculated, they can also be attached directly to bone by a broad, sessile base.

Radionuclide scans in general are not necessary in the presence of positive plain radiographs. They can be useful, however, for identification of occult lesions in the face of negative plain films, and exostoses usually demonstrate increased uptake of radiotracer for years after skeletal maturity (27). Great care should be taken when interpreting these films, however, because synovitis and unrecognized trauma can cause associated increased areas of activity, and false positives can lead to unnecessary workup and biopsy.

Cross-sectional analysis of bone tumors can be accomplished through more sophisticated methods. Radionuclide imaging can be acquired in 3-dimensional fashion for localizing lesions with single-emission computed tomography, which can provide more meaningful information as compared with the 1-dimensional imaging of the routine bone scan with <sup>99m</sup>Tc-methylene diphosphonate (<sup>99m</sup>Tc-MDP). Computerized axial tomography (CAT) is a very useful method for evaluation of osseous elements in cross-sectional views. In fact, contrast CAT can provide excellent soft tissue detail as well as delineate bone marrow involvement when it is present. Alternately, magnetic resonance imaging

(MRI) provides superior evaluation of adjacent soft tissue structures in cross-sectional analysis. The contiguous nature of the osteochondroma with that of the medullary bone can easily be identified with these 3-dimensional technologies.

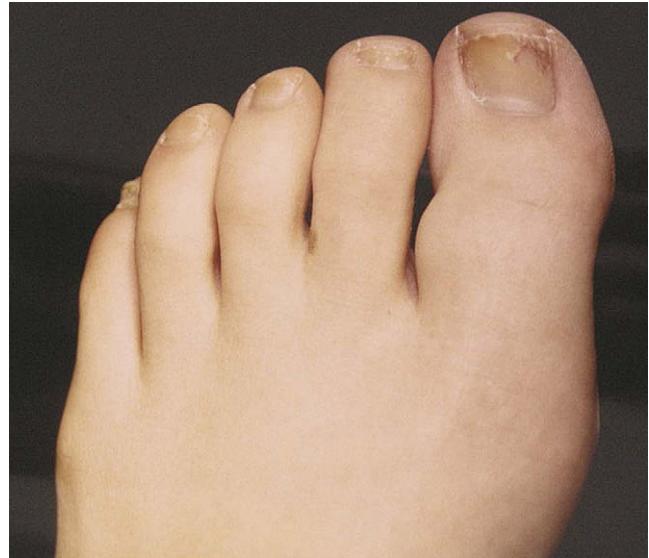
Despite the fact that the aforementioned 3-dimensional imaging methods can be very useful, it is important to keep in mind that plain radiography remains the gold-standard tool for diagnosing bone tumors, and a deliberate effort should be made to avoid excessive use and unnecessary expense of ancillary imaging. Perhaps Walling and Gasser (28) made this point best in their article on soft tissue and bone tumors within the foot and ankle when they said, "The overuse of MR imaging to rule out 'occult pathology' about the foot and ankle has become unconscionable. The basic principles in diagnosis and treatment do not mandate the use of higher technology modalities. CAT and MRI should be used with discretion in a purposeful fashion to provide specific information with regards to locality and invasiveness of a lesion."

### Potential for Malignancy

Malignant transformation of a single osteochondroma to chondrosarcoma is rare. Such accounts have been most commonly reported in patients with MHE, occurring in as many as 1% of these individuals (2, 29). Lesions within the axial skeleton are more likely to undergo malignant transformation than those within appendicular sites. When malignant transformation does occur, it usually develops after skeletal maturity has been reached. Identification of this type of transformation is suggested by the presence of a thick, cartilaginous cap (more than 1-2 cm in width) that continues to grow and expand after osseous maturity has been reached (30, 31). The symptom of pain in an enlarging mass may be delayed when these lesions present in central locations like the pelvis, and such pelvic masses may reach a tremendous size before clinical recognition (30).

### Case Report

A 19-year-old white woman presented with a chief complaint of a painful left great toe mass (Fig 1). The discomfort was described as insidious in onset after a traumatic event, wherein a 65-lb child had stepped on her foot approximately 1 year earlier. At the time of that injury, her toe pain was excruciating; however, she did not feel that there was serious injury. Therefore, no formal medical evaluation was sought, and she treated herself by means of rest and elevation. Over time, she began to notice gradual enlargement of the great toe at the site of the injury, and after approximately 1 year, the region became very firm and prominent and irritated by contact with any shoe that she wore. During the 3 weeks before presentation to our clinic, she experienced very sharp



**FIGURE 1** Clinical image of the painful left great toe with a slowly enlarging mass located about the most lateral portion of the proximal phalanx. The lesion had a texture that seemed smooth, firm, and fixed to palpation without evidence of calor or discoloration. The lesion did not transilluminate light, and the morphology of the lesion seemed to be well rounded.

pain while wearing athletic shoe gear and the lesion was felt to be more mobile under the skin, and not as firm and fixed as it had initially. Aggravated by high weight-bearing activity, even simple prolonged walking would prompt pain and required cessation of activity.

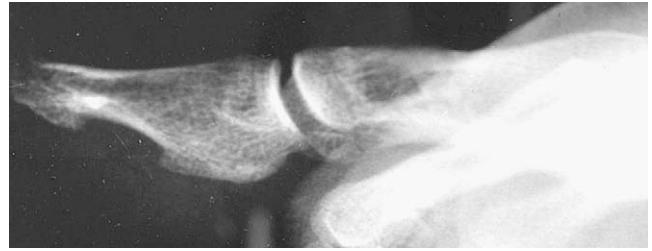
The patient's past medical history was unremarkable, as were her birth history and childhood. Her family history was consistent with paternal hypertension and coronary artery disease, and maternal hypothyroidism. No associated orthopedic abnormalities or tumors could be recounted from the family history.

Plain radiographs were taken, and a chronic, stable-appearing lesion was noted within the distal lateral third of the articular surface of the hallux interphalangeal joint (IPJ) (Figs 2 and 3). An ovoid lesion, eccentrically located, showed a well-defined, sclerotic margin abutting the endosteum of the lateral cortex on the anteroposterior (AP) view. On the lateral view, the lesion appeared centrally located within the metaphysis and was seated approximately 1 cm proximal to the articular surface of the IPJ. A subsequent computerized tomographic (CT) scan revealed a defect within the phalanx, which permeated the dorsolateral aspect of the cortical margin (Fig 4). Special soft tissue-weighted images were pursued to identify the contents of the mass, and these showed the matrix to be mixed fibrous and calcific tissues, and the mass was found to extend from the surface of the bone and displayed a pedunculated dorsal extension. The mass was not fluid laden, and the matrix of the neoplasm appeared to be fibrous in nature and displayed a homogeneous

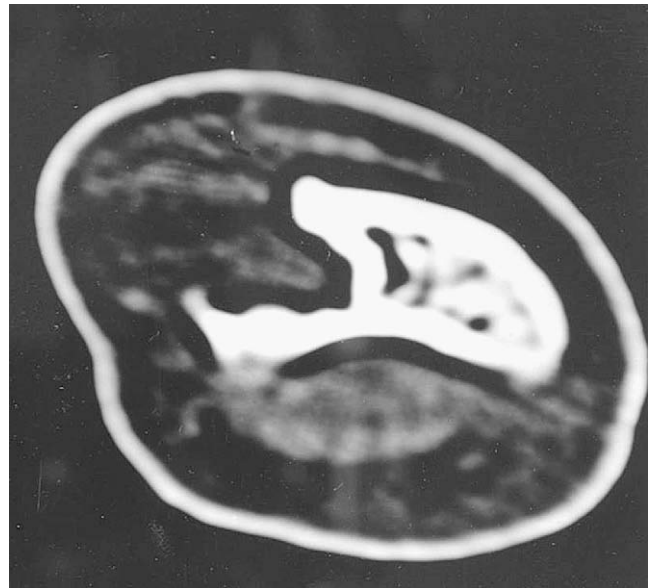


**FIGURE 2** Dorsoplantar radiograph reveals an eccentrically oriented ovoid lesion with a thick, sclerotic margin. There is no evidence of pathological fracture, periostitis, or other periosteal reaction noted. There is increased soft tissue density in this region consistent with the complaint of mechanical irritation associated with shoe gear.

intensity that approximated other normal soft tissue and fibrous structures of the forefoot. The sclerotic margin within the medullary canal was easily identified, and it demarcated the most medial extension of the lesion. The plain films were to be evaluated by a radiologist, a pathologist, and an oncologist before development of a treatment plan. As a result of these consultations, a diagnosis of a benign bone tumor



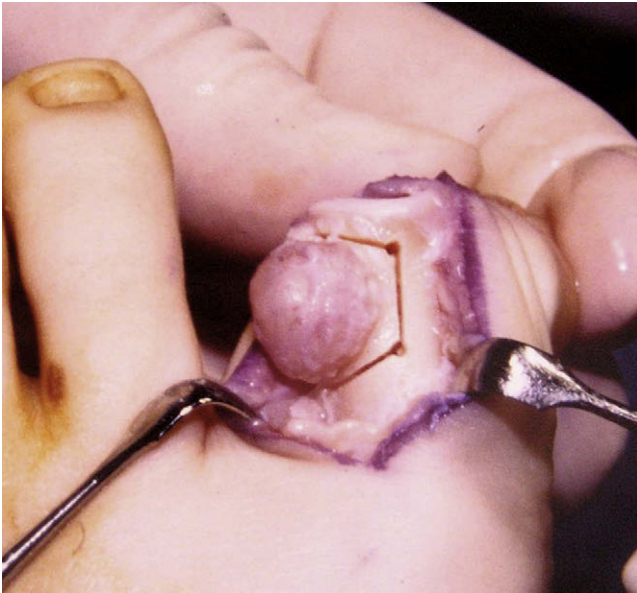
**FIGURE 3** Lateral radiograph reveals a centrally located ovoid lesion with well-demarcated margins devoid of sclerosis. On this view, the margins of the lesion are delineated. However, there is no sclerotic change, suggesting that the host of the cortical reaction is taking place on the dorsum of the bone as suggested from the dorso-plantar view.



**FIGURE 4** CAT scan revealing a large cortical defect with rounded margins about the distal dorsolateral margin of the hallux proximal phalanx.

was made, and it was felt that the lesion could be safely and definitively diagnosed by an en block resection of the tumor. It was suggested that a fresh-frozen section be obtained as the first step in the procedure before any manipulation elsewhere in the foot or ankle. This was deemed a prudent step in the process because the decalcification process ordinarily delays the definitive diagnosis from the excisional biopsy, and, although a frozen section is not generally used to confirm a diagnosis, it can be used to identify cellular atypia if it is present.

The patient was informed that she had a bony neoplasm within the hallux, which exhibited many benign characteristics radiographically. Formal and definitive diagnosis of the lesion was understood to be dependent on pathological inspection of the biopsy specimen. Informed consent for



**FIGURE 5** Intraoperative view of large, eccentrically located neoplasm resting on the dorsolateral cortical surface of the hallux proximal phalanx. The mass had a firm and rubbery texture and was barely pigmented with a pearly white-rose hue. Seen here is the preparation of the cortex for resection. A 2.0-mm drill bit would be used to define the perimeter of the intended resection. A short, 10-mm oscillating blade would be used.

the excisional biopsy was obtained, and the procedure and its associated risks and benefits were reviewed in full. Consent was obtained for the potential use of autogenous and/or allogeneic bone graft. The possibility of recurrence and the need for further surgeries were underlined and discussed.

### Surgical Procedure

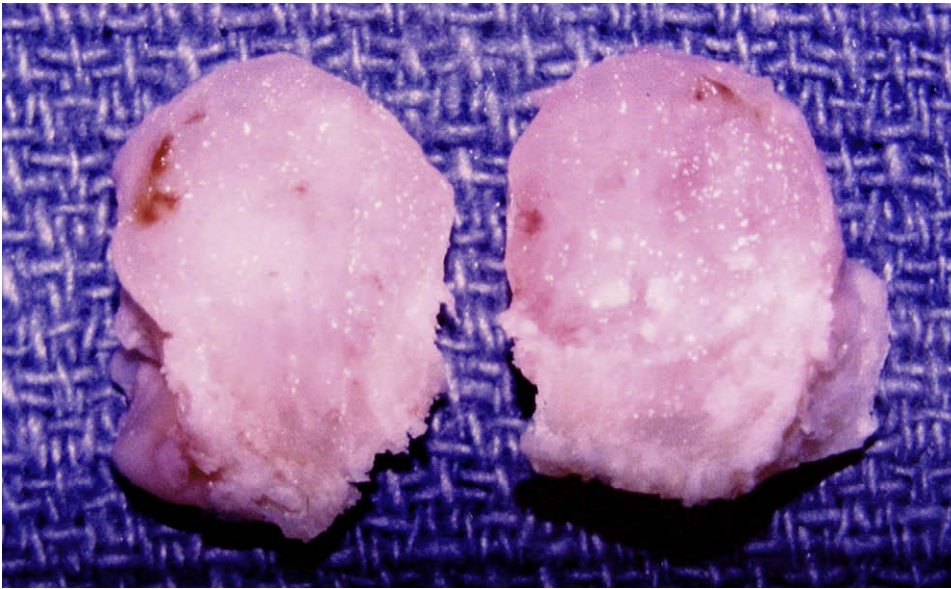
The patient was placed on the operating table in the supine position, the limb was externally rotated for optimal exposure, and a thigh tourniquet was used; and the operation was performed with the patient under general anesthesia using endotracheal intubation. Attention was directed to the dorsal aspect of the hallux, where a dorsal-linear incision was made to bisect the soft tissue sleeve of the proximal phalanx in the sagittal plane. This 4-cm incision began at the metatarsophalangeal joint and ended 5 mm distal to the IPJ. This incision was deepened with sharp and blunt dissection, the bone tumor was noted to be superficial within the wound, and no neurovascular structures permeated the lesion. The adjacent subcutaneous structures appeared to be normal and there was no evidence of necrotic debris, or discoloration or periostitis about the proximal phalanx. The bulbous dorsal extension of the mass was pearly white and rose colored, and it displayed a firm, fibrous texture. Fluctuation was not present, and no fluid was expressed from the site. In its greatest dimensions, the mass measured  $1.6 \times 1.0 \times 0.6$  cm and was composed

predominantly of a thick, firm, rubbery material. The dorso-lateral cortex of the phalanx was intact and appeared confluent with the base of the lesion. The cortical margin appeared to envelop the pedunculated stalk of the mass, as it seemed to emanate from the medullary compartment of the phalanx. The stalk consisted of a rubbery material confluent with the well-rounded tumor with an appearance similar to that of a mushroom on a short stalk (Fig 5).

The region of bone resection was plotted with the aid of a 2.0-mm wire-pass drill bit. Drill holes were placed to circumscribe a 5-mm margin around the neoplastic segment to be resected. This facilitated bone resection by allowing the cortical bone cuts to be precisely made to avoid violation of the joint space and to minimize the risk of creating stress risers. A fine-toothed 10-mm oscillating blade was then used to cut the cortical margins between the drill holes, thereby enabling resection of the bone tumor en toto. The mass was hemisectioned to provide specimens for both pathology and microbiology examinations. The gram stain was reported as negative for bacteria or leukocytes. The content of the mass appeared to be a mixture of fibrous and cartilaginous tissue with stippling calcinosis present as evidenced within the gross specimen (Fig 6). The cortical resection extended through the plantar cortex of the phalanx, and the surrounding soft tissue sleeve appeared to be of normal color and texture without evidence of tumor extension into the plantar forefoot. The long and short tendons about the hallux were also normal and healthy appearing. A fresh-frozen section of the mass suggested benignity and supported the diagnosis of an enchondroma or osteochondroma. The subchondral bone of the head of the proximal phalanx was substantially undermined and, as such, was felt to be insufficient for subsequent weight-bearing function (Fig 7). An autogenous bone graft was harvested from the ipsilateral calcaneus to support the osteochondral surface and promote primary repair of the bone defect (Fig 7). The harvest site and graft were designed slightly larger than the actual bone defect in the hallux, to facilitate precise tapering of the graft for a flush fit. Internal fixation of the graft was completed with small 1.5-mm cortical lag screws applied using the standard osteosynthesis technique. Allogeneic bone graft was also prepared to create a press-cut fit for the harvest site defect within the superior pole of the calcaneus, and no fixation was used for the donor site graft.

Pathological inspection of the excised tumor revealed segments of pearly white and rubbery tissue with margins of normal-appearing cortical bone (Fig 8). The thick, cartilaginous cap of the tumor was composed of hyaline cartilage with groupings of underlying chondrocytes. No abnormal mitotic elements or nuclear atypia were identified on the formal pathological analysis, which was reviewed by 3 different pathologists, and all were in agreement that the lobulated osteocartilaginous tissue was consistent with osteochondroma.

The flush apposition of the bone graft and adequate position of the internal fixation devices, as well as the harvest



**FIGURE 6** The gross specimen was hemisected and displayed a firm, rubbery texture with sparse calcific stippling throughout. The inner contents of the lesion were palpated without disrupting the tissue. A fibrous and mealy texture, with hardened areas of calcification, was appreciated.

site within the posterior superior calcaneus filled with allogeneic bone, were confirmed intraoperatively with plain radiographs (Fig 9). The patient's postoperative course entailed nonweightbearing in a below-the-knee cast for approximately 6 weeks, after which she gradually resumed weight-bearing activities. Her postoperative course progressed unremarkably, she enjoyed full, unrestricted weight-bearing activity without exception, and the shoe gear irritation that she had experienced preoperatively was fully relieved. Long-term follow-up radiographs showed complete incorporation of the autogenous and allogeneic grafts, and good maintenance of joint space integrity in the hallux (Fig 10). No evidence of hardware migration was noted, and stable osteosynthesis was present at 12 months postoperative. At this time, moreover, she displayed a full, unrestricted, and noncrepitant range of motion of the hallux IPJ and metatarsophalangeal joint. Her gait was fully propulsive and uninterrupted in her stride through the office, and there was no evidence of residual antalgia or vaulting. The patient was fully satisfied with the outcome of the surgery, having achieved complete relief of her preoperative pain, with no residual pain at either the recipient or harvest bone graft sites. She was subsequently discharged with a diagnosis of surgically resolved osteochondroma with strict instructions to monitor for any evidence of local irritation that may represent recurrence.

## Discussion

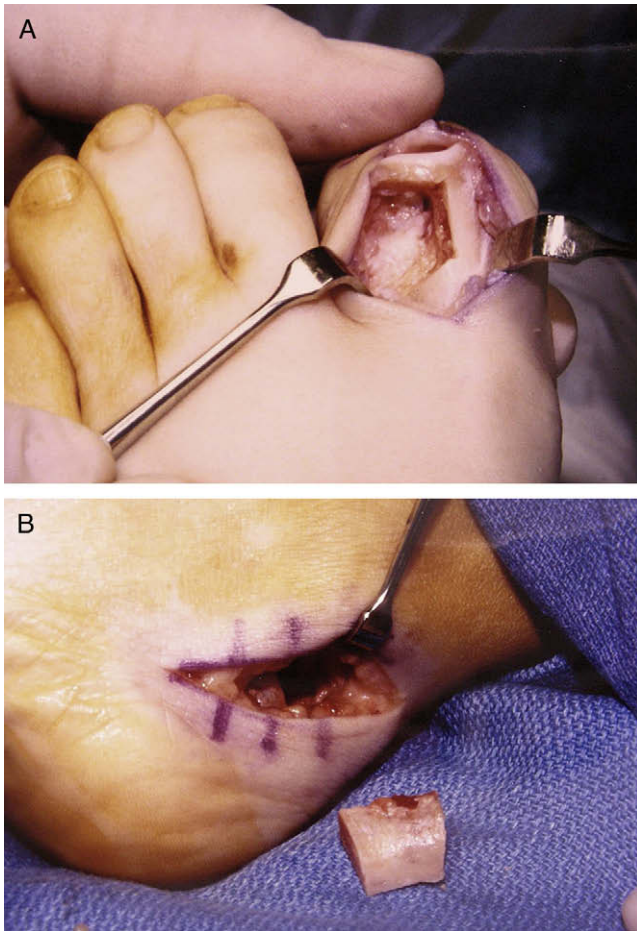
The goal of this review and case study is to underline the value of preoperative investigation and planning in patients presenting with a bony neoplasm. To identify a reasonable differential diagnosis before ancillary imaging and surgical intervention is valuable, and is thought to decrease the likeli-

hood of false-positive diagnoses. It is essential for surgeons to formulate reasonable criteria to distinguish between benign and malignant tumors. A systematic approach is prudent and involves some key diagnostic elements (2). The clinician should begin by considering what the tumor is doing to local bone structures. A typical presentation for the benign tumor is a neoplastic growth that remains confined by the walls of the surrounding cortical bone. These growths can impose stress on bone margins and may cause cortical bone expansion; however, typical benign tumors do not destroy bone. Usually these lesions are slow to grow and may cause the bone to marginate, reacting to the tumor growth by expansion. Radiographically, there are a number of characteristics associated with benign neoplastic disease. Using the following radiographic markers, a clinician can reasonably formulate a clinical opinion as to the biological nature of the lesion. From these specific features of neoplastic growth and development, the most prudent method for further evaluation and treatment can be surmised. Specialized consultations should be pursued when applicable, especially when there is any suggestion of malignancy. Radiographic and ancillary imaging studies should be sought in advance of surgical intervention. Gitelis et al (20) published a diagnostic strategy for evaluation and differentiation of tumors, and their overview is the basis for the following outline.

## Pearls in Practice for Evaluation and Differentiation of Bone Tumors

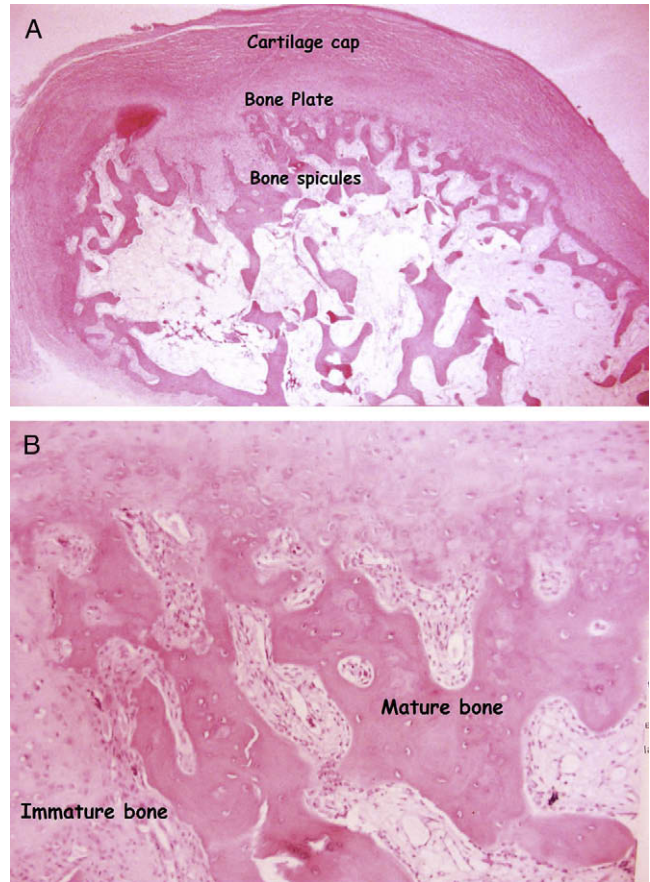
### Margin

When you begin looking at the radiograph, take a close look at the margin of the lesion. There are 5 separate grades



**FIGURE 7** (A) Intraoperative view of the bone defect after excisional biopsy. The entire plantar aspect of the phalanx was removed. There was no evidence of discoloration or necrosis within the adjacent bone or soft tissue structures. (B) Intraoperative view of the autogenous graft from the superior surface of the calcaneus shows that the graft was larger than the biopsy defect. This was intentional because the graft would be fashioned to create a flush “press fit” before fixation.

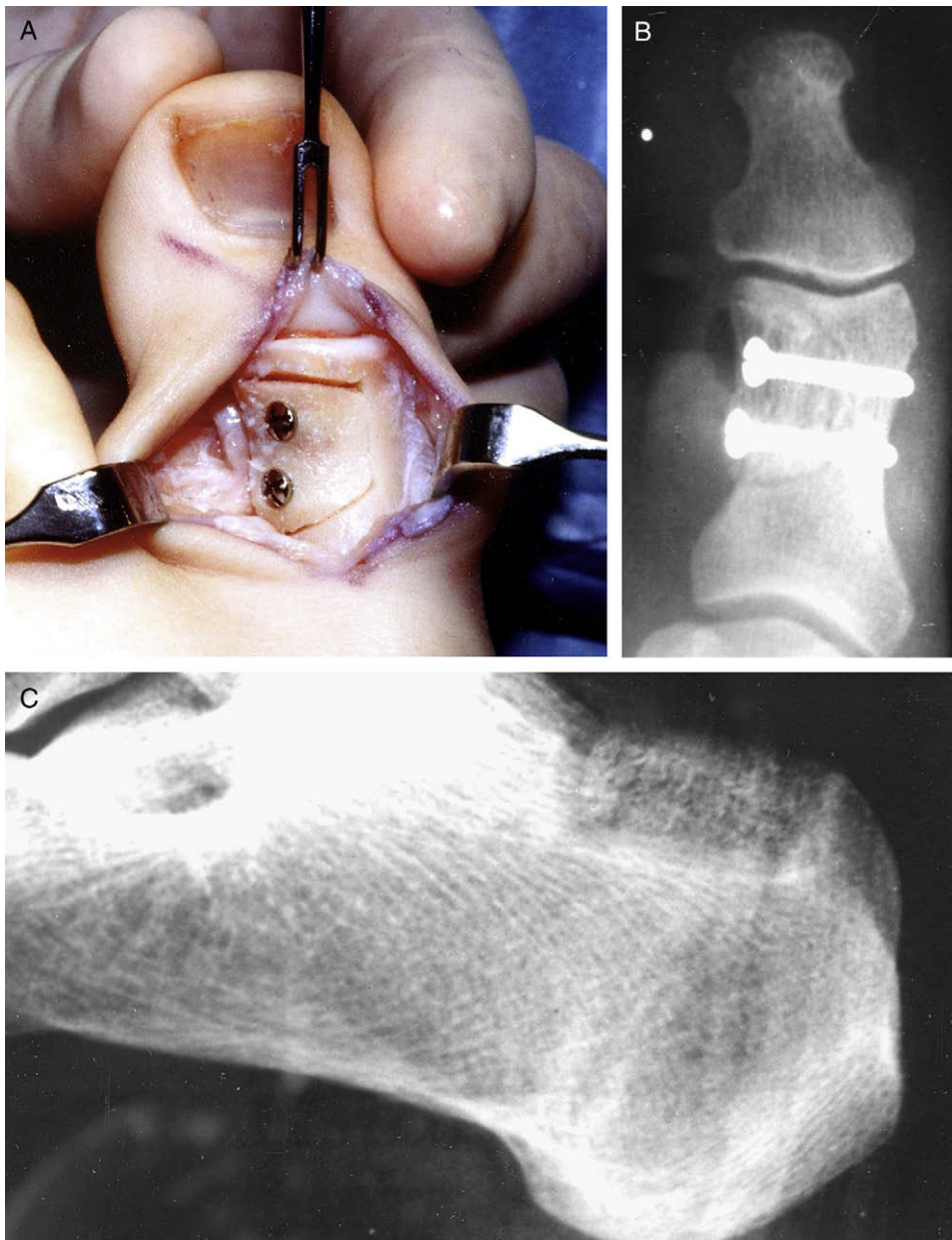
of growth described for bone tumors based on the bone margins. Grade IA is geographic destruction with a sclerotic margin. This demonstrates the slowest growth rate and most often represents a benign process. Grade IB is a geographic type of destruction without a sclerotic margin, despite the presence of a well-defined zone of transition. This lesion is also slow growing and most often benign. Grade IC is geographic destruction with an ill-defined margin, and these lesions are slightly faster growing and are not clearly benign. Grade II lesions represent a combination or changing pattern within a single lesion, and this pattern is suggestive of a more aggressive lesion than grade I. Grade III lesions are overtly moth-eaten (IIIA) or permeative (IIIB) in their destruction and are the most aggressive bone tumors, and these are likely to be malignant (29, 30, 32–35).



**FIGURE 8** (A) Histology slide (magnification X40 hematoxylin and eosin) revealed thickened cartilage cap, bone plate, and spicules deep within the mass. The thick, cartilaginous cap of this tumor was composed of hyaline cartilage with groupings of chondrocytes beneath the rim. No abnormal mitotic elements or nuclear atypia was identified. Three different pathologists reviewed the slides, and all were in agreement that this lobulated, osteocartilaginous tissue segment represented osteochondroma. (B) Histology slide (magnification X200 hematoxylin and eosin) magnified view of mature and immature bone within the lesion.

## Periosteum

Evaluation of the periosteal reaction can be a significant clue as to whether a lesion is benign or malignant. If the covering of bone has had time to react to the expansion of the tumor, mature bone will be laid down in a solid band. A solid periosteal reaction is the hallmark of a benign process. Periosteal reactions continuous with underlying cortical destruction are consistent with unicameral bone cyst, intraosseous lipoma, and fibrous dysplasia. Sequential layering or “onion-skinning” suggests a rapidly progressing tumor, which can occur in both benign and malignant entities. A Codman’s triangle represents rapid periosteal elevation subsequent to reactive changes and is most commonly seen in Ewing’s sarcoma and eosinophilic granuloma,



**FIGURE 9** (A) The bone graft was fashioned to create a press fit that matched flush against the bone defect. The 2.0-mm cortical screws purchase both cortices of the phalanx and were not prominent on either side of the hallux. The hallux interphalangeal joint was not violated in this maneuver, and its function remained unchanged from preoperative findings. (B) Intraoperative radiograph confirming position and alignment of the graft. (C) Intraoperative film confirmed placement of allogeneic bone graft filling the harvest site.

although it can also be seen in the chronic destructive inflammatory changes of gout. Complex periosteal reactions are mixtures of the aforementioned types, and the more complex the reaction, the more aggressive the lesion. An example is the “sun-burst” appearance that may represent malignancy (30).

#### Soft Tissue Extension

A neoplasm may originate in bone or soft tissue. When the origin is in soft tissue or upon the surface of bone, continued growth of the lesion may infringe on the adjacent soft tissue structures. Extension into soft tissues is an ominous sign and is suggestive of malignancy or a very rapidly progressive

benign condition. Chondrosarcomas and osteosarcomas are common examples of bone tumors that can penetrate and invade surrounding soft tissues due to the aggressiveness of the lesions. Chondromyxoid fibromas as well as malignant fibrous histiocytoma are other types of tumors that can involve bone, and that may involve soft tissue extension in more aggressive cases (30).

#### Matrix

The tumor matrix defines the contents of the lesion. If the matrix is fluid, one can imagine the contents to be hemorrhagic, serous or purulent. Alternately the tumor matrix





**FIGURE 10** Postoperative weight-bearing radiographs 1 year after the operation display satisfactory graft incorporation, anatomical reconstruction, and no evidence of periosteal reaction or recurrence of the bone tumor. (A) Dorsoplantar view. (B) Lateral view.

may be composed of fibrous, cartilaginous, calcific, ossific, or some combination of materials depending on the physiology producing the tumor's content. Identifying the inner contents of the tumor is important in regard to bone destruction. For instance, a calcified lytic lesion of a phalanx may represent the localized destruction caused by an enchondroma, which is a cartilage-containing tumor. Tumor matrix may either be cartilaginous or ossific, and calcifying cartilaginous matrix can be classified as punctate or stippled, flocculent, or curvilinear. Stippled or punctate patterns are most commonly encountered in enchondromas and osteochondromas as well as chondroblastomas. Ossific matrix is created by 1 of 3 mechanisms: direct formation, metaplasia, or ischemic injury. Direct formation is seen with various sarcomas, and metaplasia is seen in Paget's disease as well as hyperparathyroidism. Intraosseous lipoma can cause ischemic injury and necrosis of marrow fat that yields a zone of transition

between necrotic and normal tissues. This interface results in a combination of dystrophic bone with an admixture of metaplastic bone formation creating linear or serpiginous canals running centrally throughout the marrow cavity (30), and this neoplastic change is suggestive of a bone infarct. Bone or soft tissue infarct can also occur due to trauma and so a history of gunshot wound for example may explain the presence of such ossific lesion or heterotopic calcifications.

### Zone of Transition

Benign tumors produce a geographic type of destructive pattern, which can sharply demarcate the transition between host bone and tumor. A malignant lesion would produce a more permeative or moth-eaten process as it represents a gradual destruction and results in a poorly defined zone of transition. The incidence of primary bone tumors in the foot is approximately 2%, taking into consideration benign and malignant neoplasms, and chondrosarcoma is the most common primary malignant bone tumor of the foot (30, 36). In contrast, osteochondroma represents the most common benign bone tumor of the foot and ankle.

### Location

The location of a neoplasm also gives a pertinent clue as to the biology of the tumor. Metaphyseal bone lesions are typically benign. Some of the more common benign neoplasms include giant-cell tumor, aneurysmal bone cyst, and chondroblastoma. Although these entities typically represent benign conditions, they are commonly found as an epiphyseal growth. Chondromyxoid fibroma is a rare, benign diaphyseal lesion. Diaphyseal lesions are rare, and they most likely entail fibrous dysplasia or eosinophilic granuloma. Cortical manifestations commonly represent osteoid osteoma or osteomyelitis. Localized to the cortical surface of bone, periosteal chondroma, periosteal desmoid, and periosteal aneurysmal bone cyst represent benign manifestations (30).

### Imaging

Nuclear medicine bone scanning can help determine if a lesion is monostotic or polyostotic, that is, involving one or more bones. Benign conditions such as MHE, enchondromatosis, and fibrous dysplasia are all polyostotic processes easily identified with triphasic bone-scanning techniques. The bone scan is particularly useful in identifying cases of osteoid osteoma, and yields a characteristic pattern described as the "double density" or target sign on the third phase of imaging. CAT imaging is useful for the assessment of cortical bone integrity. In the case of an osteoid osteoma, the region of cortical lysis is the area best suited for intralesional biopsy,

so CAT can be used as a guide for specimen acquisition in this event. MRI can be used to assess all characteristics of tumor structure and content. Perhaps most importantly, MRI can identify the presence of neurovascular components, which may feed the tumor or become impinged or compromised because of displacement by the neoplastic growth (27).

## Biopsy

The only way to definitively diagnose a tumor is to examine fresh tissue specimens. There are many ways to perform this task, but to obtain the best pathology specimen, an excisional or intralesional biopsy is performed. Needle aspirates and other limited acquisitions can fall short in the histological analysis should they yield an insufficient sample. That is to say the needle biopsy is only as accurate as the target tissue identified and so blind procurement of a specimen; percutaneous acquisition may yield a false negative study if the region of pathology was missed. This technical problem is a potential hazard of the needle biopsy. Therefore, the location of biopsy via the aspirate technique should be guided by preoperative and intraoperative imaging techniques, mapping out the most desirable region for harvest via fluoroscopy, ultrasound, or CAT.

The differential diagnosis for the case described in this report included osteochondroma and enchondroma, the former having a 1% chance of malignant degeneration to chondrosarcoma (2, 29). Chondrosarcoma accounts for 10%-15% of primary bone tumors and is most frequently found in men between 30 and 60 years of age, so it was not likely present in the young woman we described (32). To the contrary, enchondroma has minimal potential for malignant transformation. Other tumors in the differential diagnosis included juxtacortical chondroma (periosteal chondroma), eosinophilic granuloma, chronic infection, periosteal sarcoma, and parosteosarcoma. It is interesting to note that the lesion described in our case report was originally declared an osteochondroma by the entire team involved, including a radiologist, 2 pathologists, and an oncologist. In preparing this article and case report, a radiologist (JR) Joel Rosner, MD, an expert in lower extremity MRI, and a foot and ankle surgeon (LO) Larry Osher, DPM with a subspecialty in radiology surmised that this case actually represented a juxtacortical osteochondroma, the characteristics of which correlate well with the radiographic studies obtained.

In conclusion, not all tumors are readily categorized as malignant or benign; however, in the lower extremity, the majority of bone tumors tend to be benign. Whether this is actual fact or the result of insufficient reporting is not clear. When the clinician is faced with a neoplasm, it is the responsibility of the physician to pursue a formal workup, beginning with a detailed history and physical examination, followed by appropriate consultations and ancillary testing when indi-

cated. The radiologist and oncologists can provide a host of valuable information before the pursuit of biopsy when it is required. Plain radiographic evaluations are considered the cornerstone of imaging to determine the diagnosis. The gold standard for definitive diagnosis, however, is histological inspection of an appropriate biopsy specimen. Before biopsy, however, the surgeon should attempt to categorize the lesion based on a thorough compilation of the clinical and radiographic findings.

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