Benign bone tumors represent a unique challenge to orthopaedists. They are a very diverse group of lesions in both histologic presentation and biologic behavior. Benign bone tumors are generally classified based on their histologic characteristics. These include among others: bone-forming tumors, cartilage-forming tumors, giant cell tumor, vascular tumors, other benign connective tumors, and tumor-like conditions. Appropriate treatment of these lesions is based on specific histologic subtype of the lesion, stage of the lesion, patient symptoms, anatomic location, and whether the tumor is an isolated lesion (monostotic) or multifocal (polyostotic). Treatment options include observation, biopsy, curettage, en bloc excision, and amputation. This discussion will focus on the technique of curettage and extended curettage with adjuvants for the treatment of benign bone tumors.

Benign bone lesions present a unique challenge to the practicing orthopaedist. They are a not uncommon problem that often present in the pediatric or young adult population. The most common diagnoses include giant cell tumor of bone, aneurysmal bone cysts, unicameral (simple) bone cysts, metaphyseal fibrous defects, and fibrous dysplasia. Appropriate surgical intervention must balance acceptable recurrence rates and surgical morbidity in line with their benign diagnosis. Historically, early surgical invention had unacceptably high recurrence rates. A more aggressive surgical approach to these lesions significantly decreased recurrence rates but surgical morbidity rose to levels considered unacceptable for benign lesions. Extended curettage offers a satisfactory compromise with decreased recurrence rates and significantly less surgical morbidity. Extended curettage is a technique of intraleisonal excision where the margins of the excision are extended by a surgical, chemical, or thermal adjuvant. Adjuvant options include phenol, liquid nitrogen, high-speed burr, cementation with polymethylmethacrylate, and argon-beam coagulation. The technique described here uses a combination of high-speed burr, argon-beam coagulation, and cementation to treat benign bone lesions resulting in an acceptable recurrence rate and acceptable rate of surgical morbidity. Key Words: Benign bone lesions—Extended curettage—Intralesional curettage—Extended intralesional curettage.
cysts, and unicameral (simple) bone cysts, among others. Diaphyseal lesions include fibrous dysplasia or eosinophilic granuloma. The most common cortically based benign lesions of bone are osteoid osteoma, osteomyelitis, and osteofibrous dysplasia. The differential for posterior column, spinal lesions includes osteoid osteoma, osteoblastoma, osteochondroma, and aneurysmal bone cysts. The differential for anterior column, spinal lesions includes hemangioma, eosinophilic granuloma, and giant cell tumor.

After evaluating the anatomic location, the next step is assessing the radiographic characteristics of the lesion and the surrounding native bone. Is there a reactive rim of bone around the lesion? Is the lesion radiolucent or radiodense? Is the lesion mineralized? Is the lesion making bone or cartilage? Is the lesion geographic in nature (i.e., is there a sharp demarcation between the lesion and native bone)? Commonly, after thoroughly evaluating the radiographs and answering these questions a radiographic diagnosis can be made. Sometimes further information, such as bone scan, computed tomography (CT) or magnetic resonance imaging (MRI) is needed. Although bone scan is not very specific for diagnosing benign bone lesions, it can help diagnose polyostotic disease versus monostotic disease (e.g., fibrous dysplasia). Axial imaging is helpful in the form of CT or MRI. Generally, CT is better for looking at bony anatomy. MRI is better for looking at soft tissue and marrow anatomy. Additionally, MRI can show surrounding edema and inflammation, which may be helpful in making a diagnosis. Thin-cut CT scan findings can be pathognomonic for osteoid osteoma with a central radiolucent nidus and surrounding thickened reactive bone (Fig. 1). Although not pathognomonic, CT or MRI findings can be strongly suggestive for aneurysmal bone cyst with the separation of blood in the cystic cavities into cells and plasma showing the classic fluid-fluid levels (Fig. 2).

After completion of the imaging studies, a diagnosis or a short list of differential diagnoses is made. If there is a question as to whether the lesion is malignant or benign, an incisional biopsy should be performed. Once a biopsy proven diagnosis is made or if the treating physician is confident of the benignity of the lesion, the lesion should be staged. Benign lesions of bone are staged by Arabic numerals into one of three categories. Stage 1, or latent lesions, are usually incidental findings, are typically asymptomatic and nonprogressive. An example would be an enchondroma or fibrous dysplasia. Stage 2, or active lesions, are progressive or growing and more commonly symptomatic. An example of a stage 2 lesion is a unicameral bone cyst or osteoid osteoma. Stage 3, or aggressive lesions, are simply that—aggressive. They are destructive of cortical bone and often present with a soft tissue mass adjacent to the bony lesion. The classic stage 3 lesion is a giant cell tumor of bone that has invaded through the cortex and has an associated soft tissue mass.

The stage of a lesion is a dynamic classification that can and does change with time. A unicameral bone cyst can be stage 2 at presentation and as it is followed over...
time may involute and become a stage 1 lesion. A giant cell tumor may present as a stage 2 lesion and if left untreated progress to a stage 3 lesion with bony destruction and soft tissue mass.

**SURGICAL MARGINS OR TREATMENT**

Once a lesion has been staged, treatment recommendations can be made. Treatment recommendations should parallel the stage of these tumors. Stage 3, or aggressive lesions, should be treated with aggressive surgery. Stage 1, or latent lesions, often do not require surgery and are usually followed with serial radiographs. If serial radiographs support an upgrade in stage, a change in treatment recommendations should be considered. Stage 2 lesions may require surgery depending on the patient’s symptoms.

Tumor surgery is described by the margins obtained at the time of surgery: intralesional, marginal, wide, or radical. Intralesional excision involves piecemeal removal of the tumor from the inside-out (e.g., curettage of an aneurysmal bone cyst). This type of surgery will theoretically leave tumor cells behind at the margin of the resection, but is less morbid for the patient than more extensive margins, particularly when the lesion is juxta-articular. This is usually appropriate for treatment of benign tumors or palliative treatment of malignant lesions. Marginal excision is removal of the tumor through the reactive zone surrounding the lesion. This type of surgery theoretically removes all of the tumor cells but can potentially leave behind satellite lesions or local metastases. This may be appropriate for benign lesions where there is no more morbidity than intralesional excision or malignant lesions treated with adjuvant therapy (i.e., radiation therapy or chemotherapy). Wide excision is removal of all of the tumor and surrounding reactive zone. This would be appropriate treatment for a recurrent or aggressive benign lesion or a malignant lesion. Radical excision involves removal of the entire compartment(s) where a lesion is located (e.g., amputation). This is generally reserved for malignant lesions.

The challenge in the treatment of benign bone tumors is balancing satisfactory recurrence rates with acceptable surgical morbidity. Intralesional excision can often preserve cortical architecture with little to no surgical morbidity. However, early attempts at intralesional excision had recurrence rates of 50% or higher. In giant cell tumor of bone, with its high propensity for recurrence, intralesional curettage alone had a recurrence rate of 27% to 58%. This was deemed unacceptable and there was a shift in surgical treatment to more aggressive margins (i.e., marginal or wide). This solved the problem of high recurrence rates but also had unacceptable high morbidity rates, especially in lesions adjacent to joints. Marginal or wide excisions in juxta-articular locations required resection of the articular surface on at least one side of the joint. The subsequent reconstructions required either osteoarticular allografts, or allograft-prosthetic composites, or large modular endoprostheses. These reconstructive procedures have high complication rates that in the setting of malignant disease is sometimes acceptable, but not in the setting of benign disease. When benign lesions occur in expendable bones (e.g., diaphysis of the fibula, or body of scapula) they can be resected with a marginal or wide margin without significant morbidity. When these lesions occur in more difficult locations, a different approach is needed.

Extended curettage is an attempt by either mechanical, chemical, or thermal means to extend the margin of the intralesional excision to decrease the recurrence rates. Common adjuvants used include liquid nitrogen, phenol, methylmethacrylate, high-speed burr, and argon-beam coagulation. Use of adjuvants in combination with intralesional curettage has decreased recurrence rates to 2% to 13% (Fig. 3).

**BACKGROUND ON THE USE OF SPECIFIC ADJUVANTS**

Extended curettage with the use of phenol as an adjuvant has decreased recurrence rates in benign bone tumors to 6% to 7%. After the curettage is completed phenol is either poured into the cavity or applied to the surface of the cavity with a cotton swab. The phenol causes cellular necrosis to a depth of 1 to 2 mm. Untoward effects of phenol are that it is extremely caustic and can burn any normal tissue that it comes into contact with. Additionally, phenol can be systemically absorbed and affect the heart, lungs, liver, and nervous system.

Liquid nitrogen is another adjuvant used in the treatment of benign bone tumors—termed cryosurgery. Again, after curettage a funnel is used to direct the flow of liquid nitrogen into the cavity. Then the liquid nitrogen is allowed to evaporate, whereas the adjacent tissues are protected from freezing by irrigation with warm saline. This process is repeated two to three times. The freeze-thaw cycle forms intracellular ice crystals that then disrupt the cellular membrane, causing cell death. This results in necrosis of tissue to a depth of 8 to 10 mm. The most common complication arising in patients treated with cryosurgery is fracture. Recurrence rates in giant cell tumors treated with cryosurgery is 2% to 13%.
An in vitro study published in 1993 looked at the effect of cementation on thermal necrosis. Using a temperature range between 42 to 47°C, as sufficient to cause cell death, they concluded that a zone of 1 to 2 mm around a cement plug would be necrosed by the heat of polymerization. They suggest that this would explain the approximately 50% decrease in recurrence rate in patients treated with curettage and cementation versus those treated with curettage alone.

The use of a high-speed burr has been looked at about recurrence rates in giant cell tumor. A report published out of Toronto had a recurrence rate of 12% with the use of curettage, high-speed burr, and autograft bone with or without allograft bone; no additional adjuvants were used. This was obviously a considerable improvement on historic recurrence rates of 27% to greater than 50%. They suggested that recurrence rates were more likely related to thoroughness of the excision rather than the use of any specific adjuvant.

More recently argon beam coagulation has been used as an adjuvant. This uses a controlled stream of argon gas to desiccate tissue. No studies have been done to measure depth of necrosis with this technique. Argon beam coagulation has been shown in one study to have a recurrence rate of 10%. It is easier and more controlled to use than other adjuvants. After thorough curettage and use of high speed burr to remove the lesion the coagulator is used like a fine paintbrush to spray the inside of the cavity. Again, fracture was the most common complication. However, all of the patients were treated nonoperatively and healed uneventfully.

**PREOPERATIVE PLANNING**

After radiographic work-up, possible biopsy, and staging is performed, treatment recommendations are made. For most active and aggressive benign bone tumors not in an expendable bone, extended curettage is the most appropriate treatment. The surgical procedure requires thorough preoperative planning. If the diagnosis was made based on radiographic findings, then an incisional biopsy should be made before the excision. Incisions need to be made in consideration of a potentially malignant lesion requiring wide excision. Incisions are generally longitudinal and directly over the lesion. Special attention should be made to avoid contaminating multiple compartments or joint spaces. In lesions that could potentially be approached from different directions, the potential for reconstructive procedures and soft tissue coverage should be considered as well. The larger incision required for excision of the lesion is usually an extension of the incisional biopsy site.

Equipment required in the operative room includes a wide variety of straight and angled curettes, high-speed burr and appropriately sized tip, and argon-beam coagulator. A pulse lavage is helpful for irrigation of the lesion. Depending on the specific lesion and surgeon preference, sufficient quantities of either bone graft or polymethylmethacrylate (PMMA) are needed to fill the

**FIG. 3.** Two common adjuvants used to extend the margin in intraleisional curettage include phenol (A) and liquid nitrogen (B).
defect. Pathologic fractures will obviously require fixation after treatment of the bony lesion. Larger defects may also require prophylactic fixation with plate and screw constructs. Fracture systems designed specifically for the anatomic location of the lesion or general fracture fixation systems should be available as well.

**INCISIONAL BIOPSY OR EXCISION (EXTENDED CURETTAGE)**

The patient is positioned on a well-padded operative table that is radiolucent in the area of the bone lesion. Preoperative antibiotics are usually held if the diagnosis is not known. If the lesion was biopsied in the process of a work-up, antibiotics can be given and proceed directly to the excisional portion of the procedure. If the lesion was not previously biopsied, the first step of the procedure is an incisional biopsy with careful consideration of the factors discussed above. If the biopsy confirms the presumed diagnosis or similarly benign lesion, then proceed with the excision. If there is a question regarding the possibility of a malignancy or primary sarcoma of bone, the procedure should stop and await final pathologic diagnosis.

Assuming a benign diagnosis, the incision is extended at least the length of the lesion and carried down to the bone. The cortical window from the biopsy site is visualized. Initially, the lesion is curetted from the original cortical window. Using the high-speed burr, the window is further opened exposing more tumor. This is curettaged, irrigated, and the high-speed burr is again used to further open the cortical window. Adequate resection of the lesion requires complete visualization of the bony defect. The cortical window is large enough when the entire cavity is exteriorized. This is the key portion of the procedure. The mistake that is made here is that in an attempt to minimize the size of the cortical defect, tumor cells are left behind on the deep side of the cortical bone just adjacent to an inadequate cortical window (Fig. 4). Once the lesion is completely exteriorized, alternate with curettage, high-speed burr, and irrigation until the entire cavity is normal bone. At this point, the argon-beam coagulator is used to paint the entire surface of the cavity. As the argon-beam coagulator is applied the color of the bone changes to black as carbon is deposited. After the entire cavity is ‘painted black’, the cavity is thoroughly irrigated. The defect is now ready to be reconstructed. Specific reconstruction technique depends on the histology of the lesion and the risk of recurrence. In cases of giant cell tumor bone defects are reconstructed with PMMA (bone cement). PMMA provides immediate skeletal stability and facilitates postoperative surveil-

*FIG. 4.* The shaded portion represents a giant cell tumor of the distal femur. (A) Demonstrates a cortical window that is inadequate for appropriate intralesional excision. (B) Shows complete exteriorization of the lesion, appropriate exposure is key to an intralesional excision.
lance for recurrence. If bone graft is used it is sometimes difficult to differentiate between graft resorption and tumor recurrence, based on plain radiographs. In most other benign diagnoses allograft or autograft is used to reconstruct the bone defect. Consideration of a combination of preoperative planning and ultimate intra-operative bony defect is used to determine if prophylactic fixation is required.

POSTOPERATIVE CARE

Postoperative care is considerably varied based on definitive surgical treatment. In general terms, lesions treated with PMMA have immediate skeletal stability and can weight bear as tolerated in the immediate postoperative period. Lesions reconstructed with bone graft typically require incorporation of bone graft to achieve bony stability and ability to weight bear. All patients require close postoperative surveillance for early detection of recurrence or prevention of other postoperative problems.

REFERENCES