The Risk for Fractures after Curettage and Cryosurgery Around the Knee

Tamir Pritsch, MD*; Jacob Bickels, MD†; Chia-Chun Wu, MD*; Hart M. Squires, MS*; and Martin M. Malawer, MD, FACS*,‡,§

Curettage and cryosurgery have been used successfully for treatment of benign locally aggressive and some low-grade malignant bone tumors. After treating these lesions, we reconstruct residual bone defects around the knee with cement, intramedullary pins, and autogenous bone graft for subchondral augmentation and closure of cortical windows. We questioned the incidence of fractures and the rates of nonunion and malunion and asked whether patients at risk for fractures can be identified. We conducted chart and radiographic reviews of 60 consecutive patients who had curettage and cryosurgery of primary bone lesions in the distal femur or proximal tibia. Ten of the 60 patients (17%) sustained postoperative intraarticular fractures. Patients who sustained fractures had (1) more freeze-thaw cycles; (2) metaphyseal defect ratios greater than 0.6 and 0.8 on the anteroposterior and lateral projections, respectively; and (3) 4 mm or less proximity of the defect to the joint. Only one fracture united in good alignment. Radiographic measurements can assist in identifying patients at risk for fractures after curettage and cryosurgery around the knee. We expect the fracture rate to decline by reducing the number of freeze-thaw cycles and improving our reconstruction method.

Level of Evidence: Level III, prognostic study. See the Guidelines for Authors for a complete description of levels of evidence.

Cryosurgery of bone lesions was introduced as an adjuvant therapy by Marcove and Miller in 1969 to treat proximal humeral metastases. Although the role of cryosurgery is still controversial, it has been reported effective as an adjuvant therapy for benign locally aggressive bone tumors and some low-grade malignant bone tumors. While killing residual tumor cells, cryosurgery also damages the healthy surrounding bone. Malawer et al observed 7 to 12 mm of bone necrosis when liquid nitrogen was used in a dog model, and Marcove et al reported three freeze-thaw cycles produced tumor cell death as much as 2 cm from the cavity margins.

Consequently, cryosurgery increases the risk for postoperative fractures and may impair bone healing. Initially, the postoperative pathologic fracture rate after cryosurgery was high (25–50%) because little attempt was made to reconstruct the residual bone defect. This changed in the early 1970s when polymethylmethacrylate (PMMA) became available. The fracture rate declined once surgeons reconstructed the defects with cement, bone graft, and metal hardware.

The proximal tibia and distal femur are common locations for benign locally aggressive and low-grade malignant bone tumors, especially giant cell tumors. During the gait cycle, the knee has to withstand a force of two to four times the body weight. The cancellous metaphyseal bone and subchondral bone of the proximal tibia and distal femur absorb part of the load, thus protecting the integrity of the articular surface. Curettage and cryosurgery result in a metaphyseal defect with an eggshell-like rim of dead bone, and a reconstructive procedure is necessary to provide mechanical support and prevent fractures.

For the past 26 years, the senior author (MMM) has been treating benign locally aggressive and some low-
grade malignant bone tumors around the knee with curet-
tage and cryosurgery. Similar to other authors, cement and
intramedullary pins were used routinely for reconstruc-
tion of residual bone defects.\textsuperscript{4,16,18,35} In addition, we used au-
togenous corticocancellous bone graft to close the cortical
windows and augment any exposed subchondral bone. We
recognized the potential for inferior bone healing after
cryosurgery and the difficulty in achieving stable fixation
in the presence of extensive bone loss. Nonetheless,
encouraged by an impression of good outcomes, the senior
author extended this approach at the beginning of the
1990s and started treating lesions regardless of their size or
proximity to the articular surface in an attempt to preserve
the biologic joint in lieu of prosthetic reconstruction.

We determined the rate of pathologic fractures after
curettage and cryosurgery of the proximal tibia and distal
femur. We determined the rates of nonunion and malunion
and how many patients consequently had endoprosthetic
reconstruction. Finally, we asked whether patients at risk
for fractures could be identified based on radiographic
observations of patterns and whether a higher number of
freeze-thaw cycles was a risk factor for developing a
pathologic fracture.

**MATERIALS AND METHODS**

Using a musculoskeletal tumor database, we retrospectively
identified 90 patients with benign locally aggressive and
low-grade malignant bone lesions of the proximal tibia or distal
femur who had curettage and cryosurgery from 1980 to 2003. We
only included patients with histopathologic diagnoses for which	

treatment with curettage and cryosurgery was substantiated in
the literature, namely, giant cell tumor, chondroblastoma, aneu-
yrsmal bone cyst, and low-grade chondrosarcoma. We excluded
patients whose lesions involved only the diaphysis. An ortho-
paedic surgeon (TP) not involved in the operations or routine
followups conducted chart and radiographic reviews of 60 con-
secutive patients with lesions involving the metaphysis, epiph-
ysis, or both. We identified patients who sustained postoperative
pathologic fractures. We first determined the fracture patterns
and then compared the radiographic measurements of their post-
operative residual bone defects with patients who did not sustain
pathologic fractures. We also compared age, gender, and the
number of freeze-thaw cycles between the two groups. In addi-
tion, we documented the fracture treatment (operatively or non-
operatively), nonunion and malunion rates, and number of pa-
ients who had endoprosthetic reconstruction.

There were 35 females and 25 males with a median age of 35
years (range, 9–47 years). The minimum postoperative followup
was 2 years or until patients had resection and endoprosthetic
reconstruction (median, 50.5 months; range, 6–216 months).
Twenty patients had proximal tibial lesions and 40 had distal
femoral lesions (Table 1). Six patients presented with preopera-
tive pathologic fractures and none of the 60 patients had known
distant metastases. All patients had staging studies, including
plain radiographs, bone scan, CT, and chest radiographs.

Patients who presented with pathologic fractures were first
treated for the fracture. Curettage and cryosurgery were delayed
for up to 2 months. This allowed swelling to decrease and en-
abled bone healing, thereby reforming the tumor cavity and sim-
plifying curettage and cryosurgery. At the time of curettage, we
removed the gross tumor with hand curettes and used a high-
speed burr to remove the inner reactive shell. Cryosurgery was
applied after identifying and sealing bony perforators and pro-
tecting the surrounding soft tissues by mobilizing structures and
shielding them with Gelfoam (Upjohn Co, Kalamazoo, MI). In
55 patients, liquid nitrogen was poured directly into the cavity
using the technique described by Marcove et al.\textsuperscript{24} One to three
freeze-thaw cycles were applied. The remaining five patients
were treated during the past 10 years for relatively small lesions
with a new technique using cryoprobes (Endocare Inc, Irvine, CA).

In 56 patients, the concurrent reconstruction technique in-
cluded four steps (Fig 1): (1) augmenting any exposed subchon-
dral bone with autogenous corticocancellous iliac bone graft; (2)
placing three or four intramedullary pins running from the sub-
chondral and metaphyseal bone to the intramedullary canal, by-
passing the cortical defect by 3 to 5 cm; (3) filling the residual
cavity with PMMA; and (4) sealing the cortical window with
autogenous corticocancellous bone graft. The remaining four
patients, operated on during the 1980s, had reconstruction only
with bone graft.

Patients were kept nonweightbearing for the first 6 postop-
erative weeks, after which weightbearing was allowed gradually,
pending clinical and radiographic signs of bone healing.

Patients were evaluated by physical examination and plain
knee radiographs every 3 months for the first 2 years, then semi-
annually for an additional 3 years, and annually thereafter.

We were able to locate the postoperative radiographs of 52 of
the 60 patients and assessed the size of their residual bone de-
fects. Of these 52 patients, nine sustained postoperative patho-
logic fractures. The residual metaphyseal bone defects were
categorized based on their size and proximity to the articular
surface. We formulated a ratio that best represents the relative
size of the residual bone defect: the largest horizontal diameter
of the residual metaphyseal cavity in the anteroposterior (AP)
and lateral projections divided by the horizontal diameter of the
metaphysis at the same level. This ratio was termed the defect
metaphyseal ratio (Fig 2). In addition, the distance between the
bone defect and the articular surface on the AP and lateral pro-
jections was measured and divided by the level of radiographic
magnification (Fig 2). The smallest value of the two measure-
ments was called the proximity of the defect to the joint. To

---

**TABLE 1. Histopathologic Diagnoses and Locations of 60 Bone Lesions**

<table>
<thead>
<tr>
<th>Tumor Type</th>
<th>Number of Patients</th>
<th>Proximal Tibia</th>
<th>Distal Femur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giant cell tumor</td>
<td>40</td>
<td>14</td>
<td>26</td>
</tr>
<tr>
<td>Chondroblastoma</td>
<td>6</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Aneurysmal bone cyst</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Low-grade chondrosarcoma</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
<td>20</td>
<td>40</td>
</tr>
</tbody>
</table>
determine the pattern of the fractures, the radiographs of patients who sustained pathologic fractures were reviewed. The fracture pattern of one patient whose radiographs were not available was determined based on the radiographic descriptions and interpretations in his chart. This method also was used to determine nonunion and malunion rates.

We used the Mann-Whitney test to compare the defect metaphyseal ratios (on the AP and lateral projections) and the proximity of the defect to the joint between patients who sustained postoperative pathologic fractures and those who did not. This test also was used to determine whether patients who sustained pathologic fractures had more freeze-thaw cycles than patients who did not and whether there was any significant age difference between the two groups. We used the Kruskal-Wallis test to determine whether larger lesions were treated with significantly more freeze-thaw cycles. Fisher’s exact test was used to establish whether there was a gender difference between patients who sustained fractures and those who did not. A p value < 0.05 was considered significant.

RESULTS

Ten patients (17%) sustained postoperative fractures. Six patients had distal femoral fractures, four had proximal tibial fractures, none had a history of trauma, and none was diagnosed with local recurrence. One patient was diagnosed with a fracture 5 years postoperatively. The other patients were diagnosed during the first 2 postoperative years. The metaphyseal defects in all 10 patients originally were reconstructed with cement, intramedullary pins, and autogenous bone graft for subchondral augmentation and
closure of the cortical window. Eight of the 10 patients who sustained postoperative fractures originally were operated on from 1993 to 2003. Of the 10 patients with fractures, six were treated nonoperatively, two had open reduction and internal fixation and subchondral bone graft augmentation, and two had resection and endoprosthetic reconstruction with no previous attempt to treat the fracture. Only fractures nondisplaced on first presentation were treated nonoperatively.

Four patients with postoperative fractures had nonunions develop, three had malunions, and seven subsequently had endoprosthetic reconstruction. Three of the six fractures treated nonoperatively healed, and one of the two fractures treated operatively healed. All fractures treated nonoperatively healed in unsatisfactory alignment and posttraumatic arthritis developed.

Of the 10 patients who sustained pathologic fractures, two had immediate endoprosthetic reconstructions, and five had endoprosthetic reconstructions as a result of symptomatic nonunions or severe posttraumatic degenerative changes. The extensive metaphyseal bone loss precluded the use of conventional total knee implants and was the indication for segmental endoprostheses. One patient with a displaced nonunion of the distal femur considered endoprosthetic reconstruction, and only two patients did not require endoprosthetic replacements; one had a femoral fracture that was treated successfully with open reduction and internal fixation and bone graft augmentation, and the other had an asymptomatic nonunion of the tibial plateau. The general joint salvage rate in our series was 87%, and the joint salvage rate of patients who sustained postoperative fractures was 20%.

All postoperative fractures were intraarticular. Five of the six distal femoral fractures were condylar fractures occurring through the lateral or medial aspects of the intercondylar notch. The femoral fracture pattern typically resulted in detachment of the involved femoral condyle (Fig 3A). All four proximal tibial fractures were characterized by collapse of the subchondral bone (Fig 3B). The residual bone defects of patients who sustained pathologic fractures occupied a larger portion of the metaphysis and were closer to the articular surface compared with patients who did not sustain fractures. Patients who sustained pathologic fractures had higher defect metaphyseal ratios on the AP and lateral radiographs (p < 0.001 and p = 0.01, respectively), and their residual reconstructed metaphyseal defects were closer (p = 0.007) to the articular cartilage. Postoperative fractures occurred only in patients whose defect metaphyseal ratios on the AP and lateral radiographs were greater than 0.6 and 0.8, respectively, and whose proximity of the defect to the joint was 4 mm or less. Eight patients who did not sustain postoperative fractures had defects of similar dimensions. Accordingly, patients with these defect dimensions had a 53% risk of sustaining a pathologic fracture and a 59% joint salvage rate (Fig 4). There was no difference in age or gender between patients who sustained postoperative pathologic fractures and those who did not.

Patients who sustained postoperative pathologic fractures had more (p = 0.027) freeze-thaw cycles than patients who did not sustain fractures. Of the 10 patients who sustained postoperative fractures, five had three freeze-
thaw cycles, three had two freeze-thaw cycles, and two had one freeze-thaw cycle. Nevertheless, the number of freeze-thaw cycles was not determined by the size of the lesions. Patients who had more freeze-thaw cycles did not have higher defect metaphyseal ratios on the AP and lateral projections or defects closer to the joint (p = 0.507, p = 0.440, p = 0.260, respectively). In addition, there was no difference in the number of freeze-thaw cycles between the patients who had local recurrences (n = 5) and those who did not (p = 0.952) and between patients with giant cell tumors who had local recurrences (n = 4) and those who did not (p = 0.944). Of the four patients with giant cell tumors who had recurrences develop (10%), two had one freeze-thaw cycle, one had two freeze-thaw cycles, and one had three freeze-thaw cycles of cryosurgery.

DISCUSSION
Curettage and cryosurgery may produce a large cavity with a rim of eggshell-like dead bone. When such a cavity

**Fig 4.** A flow chart summarizes the results of the radiographic analysis of 55 patients who had curettage and cryosurgery around the knee. Patients whose defect metaphyseal ratios (DMR) on the AP and lateral projections were greater than 0.59 and 0.81, respectively, and whose proximity of the defect (PDJ) to the joint was 4 mm or less were at increased risk of sustaining a postoperative pathologic fracture. Patients who did not meet these criteria did not sustain postoperative fractures.
is created close to the knee, a reconstructive procedure is necessary to prevent mechanical failure. Treating pathologic fractures that occur after curettage and cryosurgery is often problematic, because bone healing is impaired and it is difficult to stabilize and fixate the eggshell-like remaining bone.2,19,24 Our aim was to determine the fracture rate after curettage and cryosurgery around the knee, to identify patients at risk for fractures, and to determine the outcomes of the patients who sustained fractures. We are not aware of similar studies in the English literature.

We note several limitations to our study. We measured the residual bone defects using plain radiographs instead of more sophisticated imaging modalities. However, plain radiographs are readily available and easiest to measure in an outpatient clinic. The PMMA used for reconstructing most defects clearly defined the margins of the residual cavities, simplifying the measurements. Additional limitations may include insufficient power to determine whether the local recurrence rate increases when fewer freeze-thaw cycles are applied. The nonsignificant difference in recurrences between patients who had one, two, or three freeze-thaw cycles might be related to the small sample size. We do not consider the nonuniform histopathologic features of the lesions a study limitation. Previous studies showed the effectiveness of curettage and cryosurgery in the treatment of all tumor types included in this series.1,2,15,17,18,20,22–24,29,32–34,39,41 Moreover, because curettage and cryosurgery often completely eradicate the tumor and because none of the patients in our series who sustained postoperative fractures had local recurrences (which might have implied a relationship between fractures and residual microscopic disease), it is reasonable to assume the occurrence of postoperative fractures was not affected by the histopathologic diagnosis.

The fracture rate in our series was 17%. Most fractures occurred in patients operated on since the beginning of the 1990s, probably because the senior author (MMM) gradually treated larger lesions closer to the articular cartilage with curettage and cryosurgery in lieu of resection and endoprosthetic reconstruction and, unlike some others, rarely performed primary resections.5,13,36,40,42 This explains the lower fracture rate reported in a previous study.17 Using similar reconstruction methods, some authors reported lower fracture rates after curettage and cryosurgery.18,33 However, they reported a general fracture rate without focusing on a specific anatomic site, and although not reported, we assume their indications were limited by the size of the lesions and their proximity to the articular cartilage. The only published study regarding cu-

Fig 5. An AP radiograph shows a patient 8 years after curettage and cryosurgery of a giant cell tumor in the proximal tibia. The autogenous bone graft used for cortical window closure is fully incorporated.

Fig 6. A schematic diagram shows a modified reconstruction technique used to decrease the occurrence of intraarticular fractures. We suggest adding crossmetaphyseal screws to our traditional reconstruction technique that includes subchondral bone graft augmentation, PMMA, intramedullary pins (I. pins), and closing the cortical window with autogenous iliac bone graft.
Curettage, cryosurgery, and reconstruction with subchondral bone graft, intramedullary hardware, cementation, and cortical bone graft to seal the cortical defect

Postoperative fracture (displaced/nondisplaced)

Open reduction, internal fixation, and subchondral bone graft augmentation

Unsatisfactory intraoperative reduction and fixation

Satisfactory intraoperative reduction and fixation

Proximal tibia fracture

Distal femur fracture

Symptomatic nonunion or severe symptomatic degenerative changes

Prosthetic reconstruction

Accept most results

Symptomatic nonunion or severe symptomatic degenerative changes

Fracture united with no degenerative changes

Patient gradually returns to regular daily activities

United with no degenerative changes

Fig 7. A suggested algorithm shows management of postoperative pathologic fractures around the knee after curettage and cryosurgery.

Curettage and cryosurgery of periarticular lesions around the knee was by Aboulafia et al.1 Using similar reconstructive methods as ours, they reported one intraarticular fracture in a series of 11 patients.

Similar to other authors, our reconstruction method usually included placing three to four intramedullary pins that tightly filled the medullary canal and supported the subchondral bone and packing the residual cavity with PMMA.4,16,18,35 In addition, corticocancellous iliac bone graft was used to augment exposed subchondral bone and seal cortical windows. Several biomechanical studies suggested there was no advantage to adding intramedullary

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.
pens to the cement; however, they only tested the axial strength and not the torsional strength of the reconstructed bones. Conversely, a biomechanical study by Randall et al supported the use of Steinmann pin augmentation in the reconstruction of proximal tibial defects. Our reconstruction method also included subchondral bone graft augmentation to enhance healing of the damaged subchondral bone, to protect the articular cartilage from the potentially damaging heating effect of PMMA, and to create a buffer zone between the elastic cartilage and the rigid bone cement. We sealed the cortical window with bone graft to provide torsional reinforcement and decrease the rate of extraarticular fractures (Fig 5). Toy et al performed a biomechanical study testing the failure under compression forces of reconstructed distal femurs and suggested a new method of reconstruction using PMMA and crossed metaphyseal screw augmentation. They found mechanical failure of distal femurs reconstructed with PMMA and Steinmann pins resulted in intraarticular fractures (similar to our series), whereas the mechanical failure of distal femurs reconstructed with PMMA and cross-metaphyseal screws resulted in extraarticular fractures. Accordingly, we suggest a modified reconstruction technique to decrease the fracture rate, combining our traditional reconstruction method with crossmetaphyseal screws (Fig 6).

We observed a high nonunion rate of fractures after curettage and cryosurgery. Open reduction and internal fixation with bone graft augmentation yielded the best results. We suggest an algorithm for management of intraarticular pathologic fractures around the knee after curettage and cryosurgery (Fig 7). We do not recommend nonoperative treatment because all fractures in our series treated nonoperatively malunited or did not unite. Achieving a good open reduction and stable internal fixation of a broken eggshell-like distal femur can be difficult. Because function is poor in patients whose fractures malunite or fail to unite and because distal femoral replacement is safe with low complication rates and good long-term functional results, we recommend performing primary distal femoral endoprosthetic reconstruction if good reduction and stable fixation cannot be achieved. Conversely, because proximal tibial endoprosthetic reconstructions have high complication rates and poor functional results and survival, we advocate against performing primary prosthetic tibial reconstructions. Instead, most operative results should be considered acceptable and proximal tibial replacement reconstruction should be reserved as a salvage procedure. We do not recommend operative intervention for patients with asymptomatic nonunions because cement and hardware probably provide adequate support.

In light of a high fracture rate, one may be hesitant to use cryosurgery for lesions around the knee, even for giant cell tumors for which the positive adjuvant effect of cryosurgery has been reported. We believe the choice of an adjuvant treatment should be guided primarily by its ability to reduce recurrences and thus the probable need for secondary resection and prosthetic or allograft reconstruction. We recommend cryosurgery for giant cell tumors because, unlike diverse reports regarding the efficacy of other adjuvant treatments in reducing local recurrences, the reported local recurrence rate after cryetage and cryosurgery has been consistently 10% or less.

References
9. Clark CR, Morgan C, Sonstegard CA, Matthews LS. The effect of


Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.