30

Distal Femoral Resection with Endoprosthetic Reconstruction

Martin Malawer

OVERVIEW

The distal femur (Figure 30.1) is the most common site of osteosarcoma. Patients with osteosarcoma of the distal femur have traditionally been treated with a high above-knee amputation. Today, with earlier diagnosis and induction chemotherapy, approximately 95% of osteosarcomas can be resected with tumor-free margins. Careful preoperative evaluation and strict adherence to established criteria for resection of bone cancers are required to keep local recurrences at a minimum. Prosthetic reconstruction of the distal femur is an option that must be considered in all these patients. Use of the modular segmental replacement system (MRS) can provide limb salvage in many patients. The functional results are excellent, and patient satisfaction is high. The prosthesis has an excellent long-term survival rate, is reliable, and presents minimal problems of breakage or dysfunction.

This chapter describes in detail the preoperative staging, use of imaging studies, and the surgical technique of popliteal exploration, femoral resection, and prosthetic and soft-tissue reconstruction.

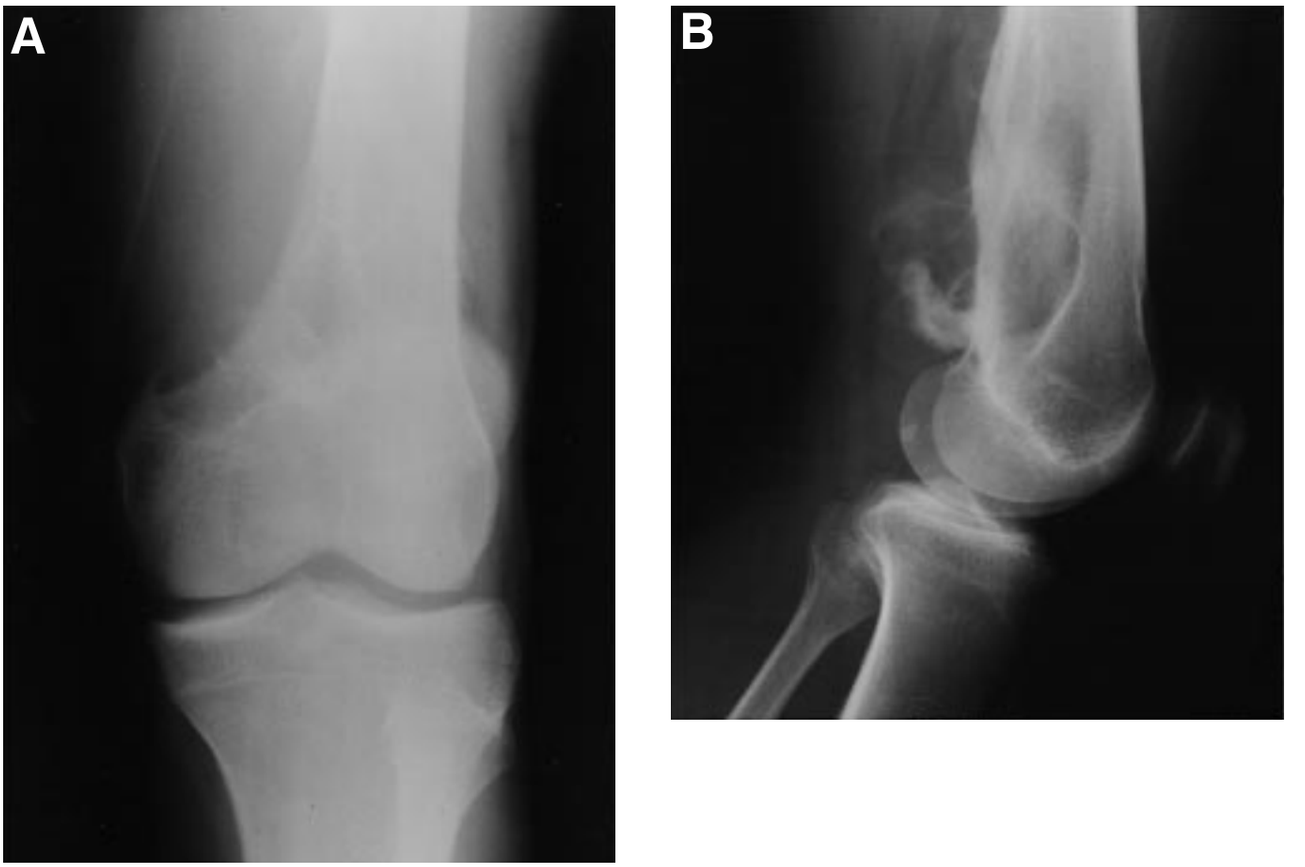


Figure 30.1 Plain radiograph showing a large osteolytic osteosarcoma arising from the posterior medial aspect of the distal femur. The distal femur is the most common location for osteosarcomas. A purely osteolytic lesion represents approximately 25% of all osteosarcomas. Most radiographic studies underestimate the extent of these lesions. (**A**) Anterior–posterior view of distal femur; (**B**) lateral view showing a large posterior component.

INTRODUCTION

Many recent studies have demonstrated a low risk of local recurrence (<5%) following limb-sparing surgery of osteosarcomas.[1–5] The continuous disease-free survival rates in patients who have undergone resection are the same as or better than those of patients undergoing amputation; presumably because of the use of appropriate selection criteria. Eckardt *et al*.[6] reported their experience at the University of California at Los Angeles with Stage IIB osteosarcoma for the period 1972–84. Seventy-eight of 116 patients (67%) were treated by a limb-sparing procedure and the local recurrence rate was 8%.[6] Simon *et al*.[7] compared results of limb-sparing procedures with those of amputation in 277 patients with osteosarcoma of the distal femur and found no difference between the two groups in the rate of metastasis or local recurrence.[7] Malawer *et al*.[8] reported a 6% local recurrence rate following limb-sparing resections.

Because of the encouraging results reported in these and other studies, limb-sparing surgery is now considered the preferred treatment for carefully selected patients with osteosarcomas and other high-grade sarcomas involving the distal femur. Amputations are reserved principally for patients whose primary tumor is unresectable. The most common factors necessitating an amputation are significant contamination of the tumor site resulting from a poor biopsy, fracture, or extensive neurovascular involvement.[8] The size and extent of the tumor are important only to the degree that they affect these three factors and influence the amount of soft tissue required to be resected, and thus the functional outcome. Even tumors with large

extraosseous components can be resected, in conjunction with most of the musculature of the distal thigh. If there is insignificant quadriceps remaining to power a prosthesis, hamstrings transfers can be performed or a primary arthrodesis performed. Muscle power is not necessary, because the "knee" will not bend.

The success of limb-sparing surgery has been dramatically improved by the use of induction (preoperative) chemotherapy. Today, most multidrug regimens are effective in "killing" the tumor, shrinking its size, and improving the surgical margins obtainable. The median tumor necrosis is 90–95%.

UNIQUE ANATOMIC CONSIDERATIONS

The specific anatomic sites to be evaluated by the preoperative staging studies and their implication on resection technique are as follows:

Knee Joint

The knee joint is rarely directly involved by sarcoma. The main mechanisms of knee joint contamination are inappropriate biopsy, extension of tumor along the intra-articular cruciate ligaments, and pathologic fracture. Occasionally the tumor may cross the knee joint extra-articularly by following the capsular mechanism to the proximal tibial side. The knee joint can reliably be evaluated by computerized tomography (CT) and magnetic resonance imaging (MRI). If the physical examination reveals any evidence of effusion, the knee joint should be aspirated and histologic samples obtained. A hemarthrosis usually indicates tumor involvement of the synovium. This is a rare event, but not an indication for amputation.

Popliteal Space

The popliteal space contains the popliteal artery and vein and the sciatic nerve. The popliteal vessels enter the popliteal space from the medial aspect through the adductor hiatus as the vessels exit the sartorial canal. The popliteal vessels are evaluated by CT with contrast, MRI, and plain angiography (Figure 30.2). It is rare to have direct vessel involvement by tumor. The vessels may be displaced as the tumor increases in size posteriorly, but usually there is a normal border or margin of popliteal fat. Exploration of the popliteal space is the first step in determining the feasibility of a limb-sparing procedure. The popliteal vessels are dissected out and the geniculate vessels are ligated. If the vessels are free of tumor, resection can usually be performed safely. A frozen section of the popliteal fat or adventitia of the popliteal vessels should be obtained intraoperatively. If there is obvious vascular involvement the vessels can be replaced by vascular graft. The popliteal vein is usually not repaired since it rarely stays patent following surgery.

Sartorial Canal

The sartorial canal occupies the space between the vastus medialis, sartorius, and adductor magnus muscles in which the superficial femoral artery passes the medial aspect of the thigh (adductor hiatus) and then enters the popliteal space. In patients where tumors are greater than 13 cm in length, the sartorial canal is often displaced. The vessels within the canal are usually protected by the deep fascia of the vastus medialis and a tough fascia surrounding the vessels. This fascia border is rarely penetrated by tumor. Biopsies of the distal femur should avoid the sartorial canal as well as the popliteal space and knee joint.

Anterior and Posterior Cruciate Ligaments

The cruciate ligaments are occasionally involved by direct tumor extension from the distal femur. This occurs through the bone–tendinous junction of the intercondylar notch of the distal femur. There is no cartilage in this area to act as a barrier for tumor growth. MRI is occasionally helpful in determining cruciate ligament involvement. Tumor nodules of the anterior and posterior cruciates occasionally can present with a hemarthrosis. The most common finding at the time of resection is tumor nodule involvement of the cruciates. This does not rule out a limb-sparing procedure. The cruciate ligaments as they attach to the proximal tibial plateau can be resected en-bloc with the proximal tibial cut. This is a safe procedure that avoids the need for a true extra-articular resection.

Preoperative staging studies focus on these four anatomic structures in order to allow the surgical team to determine the type of surgery, placement of the incision, the need for intra- or extra-articular resection, and biopsy technique and site.

PREOPERATIVE EVALUATION AND STAGING STUDIES (Figure 30.2)

Staging studies should be performed before biopsy if the plain radiographs suggest a malignant tumor.[9] Preoperative studies allow the surgeon to conceptualize the local anatomy and appreciate the volume of tissue to be resected en-bloc, and the extent of surgical reconstruction that will be needed.

All patients should be considered candidates for limb-sparing procedures unless a surgical oncologist

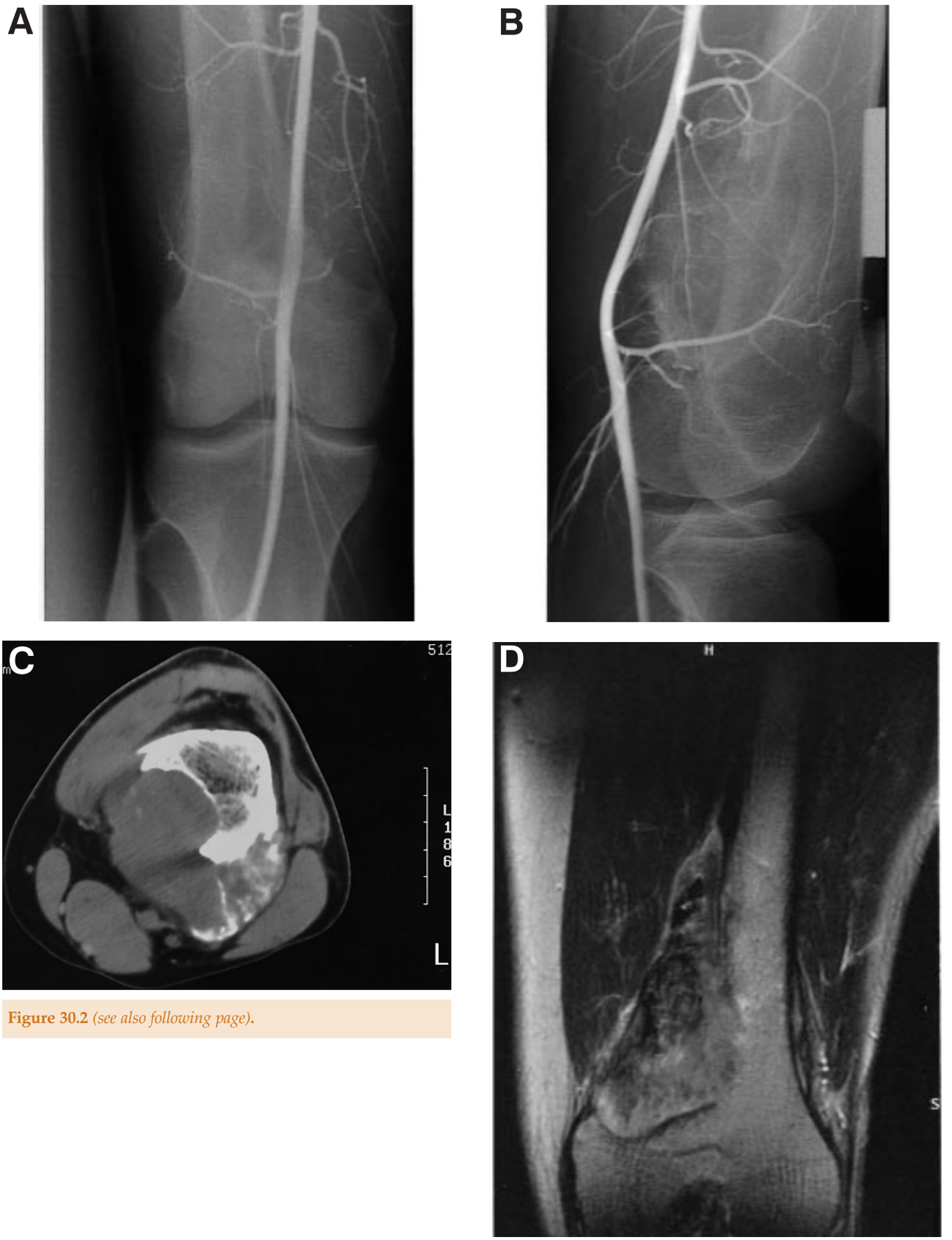


Figure 30.2 *(see also following page).*

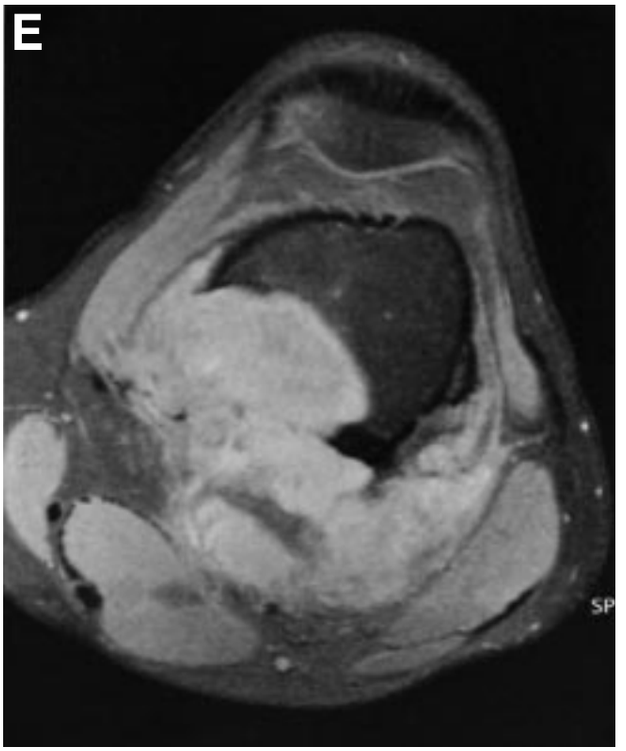


Figure 30.2 *(previous page and left)* Preoperative evaluation (local staging) prior to surgery. Preoperative imaging studies are essential to determine the extent of surgical resection and to permit adequate surgical resections with negative margins. Routinely angiography, CT, and MRI are utilized. (**A,B**) Anterioposterior and lateral angiograms of the distal femoral osteosarcoma following induction treatment. Note that there is minimal vascularity to the tumor that indicates a good tumor response; that is, a high percentage of tumor necrosis. The popliteal artery is displaced posteriorly and may require a vascular graft depending upon the margins of the adventitia at the time of exploration. (**C**) Axial CT demonstrating a large posterior component without involvement of the knee joint anteriorly and with some ossification of the tumor on the medial aspect. CT is often utilized with MRI in order to determine the intra- and extraosseous extent of the tumor. (**D,E**) Coronal and axial MRI views of the same tumor. The coronal view shows the soft-tissue extent and the proximal extent within the marrow. The axial view shows the tumor extent posteriorly that corresponds well with the CT. The MRI is the most reliable study to determine intraosseous extension that will permit accurate osteotomy of the femur. CAT scans and MRIs are considered complementary examinations when evaluating bony tumors. Additional information is often obtained from each study.

familiar with these procedures feels that a non-amputative option has little chance of success. The final surgical decision is made only after the last cycle of induction chemotherapy, at which time all the staging studies are repeated and re-evaluated.

Bone Scans

Bone scintigraphy is useful in determining intraosseous extension of tumor. The area of uptake corresponds to tumor extent and closely estimates the tumor volume. Bone scans are not reliable in detecting extraosseous metastases. Flow and pool studies are helpful in determining tumor vascularity. Comparisons of pre- and postchemotherapy studies can help determine tumor necrosis.

Computerized Tomography

CT allows accurate determination of intraosseous and extraosseous extension of skeletal tumors. It also accurately depicts the transverse relationship of the tumor and enables the surgeon to detect which portion of the quadriceps muscle is involved and the relationship of the tumor to the popliteal vessels. CT is more accurate than MRI in determining the response to induction chemotherapy. New bone (reparative) formation, tumor reossification, and fracture healing are best evaluated by CT.

Magnetic Resonance Imaging

MRI allows detailed evaluation of tumor involvement and extent within the marrow of the medullary canal. It also provides details of soft-tissue extension. Of all preoperative studies, MRI is generally the most affected by a prior biopsy or manipulation of the tumor. MRI following a biopsy often overestimates tumor size because of unrelated surgical changes. MRI has not proved reliable in determining tumor necrosis, despite many attempts to evaluate different sequencing techniques with or without gadolinium.

Angiography

Biplane angiography is essential in determining the relationship of the tumor to popliteal vessels.[10,11] The angiogram serves as a road map for the surgeon during the operative procedure and permits safe exposure of the popliteal vessels. Both anterior posterior and lateral views are required to evaluate the relationship of the vessels to the tumor and the potential plane of

resection, and to detect any anatomic distortions or anomalies. The decrease in vascularity of osteosarcomas following neoadjuvant chemotherapy correlates well with tumor necrosis.[12] Pre- and post-induction chemotherapy angiographic studies, taken in combination, provide the most reliable means of assessing tumor necrosis prior to surgery.

Thallium Scans

The use of thallium to evaluate patients with osteosarcoma has become more popular (Figure 30.3). The decrease of thallium uptake has been shown to correlate with the tumor-killing effect of chemotherapy. A careful evaluation of all data from the preceding studies allows accurate preoperative determination of tumor extent and permits the surgeon to form a three-dimensional image of the amount of bone and soft tissue to be resected.

BIOPSY

Traditionally, open (incisional) biopsies were performed to obtain tissue for diagnosis. Core needle biopsy, however, usually provides an adequate specimen for diagnosis. If it proves to be inadequate, a small incisional biopsy is performed. A medial biopsy is preferred if an option exists. Fine-needle aspirations (FNA) are not recommended. Today, most biopsies are performed under CT guidance or fluoroscopy. Multiple cores can be obtained during a single procedure, through the same puncture site.

It is crucial that the biopsy site be in line with that of the anticipated incision for the definitive procedure. Extreme care should be taken not to contaminate potential tissue planes or flaps that would compromise the management of the lesion. To minimize contamination, a needle biopsy of soft-tissue masses or of extraosseous components should be attempted prior to an incisional biopsy. Radiographs should be obtained to

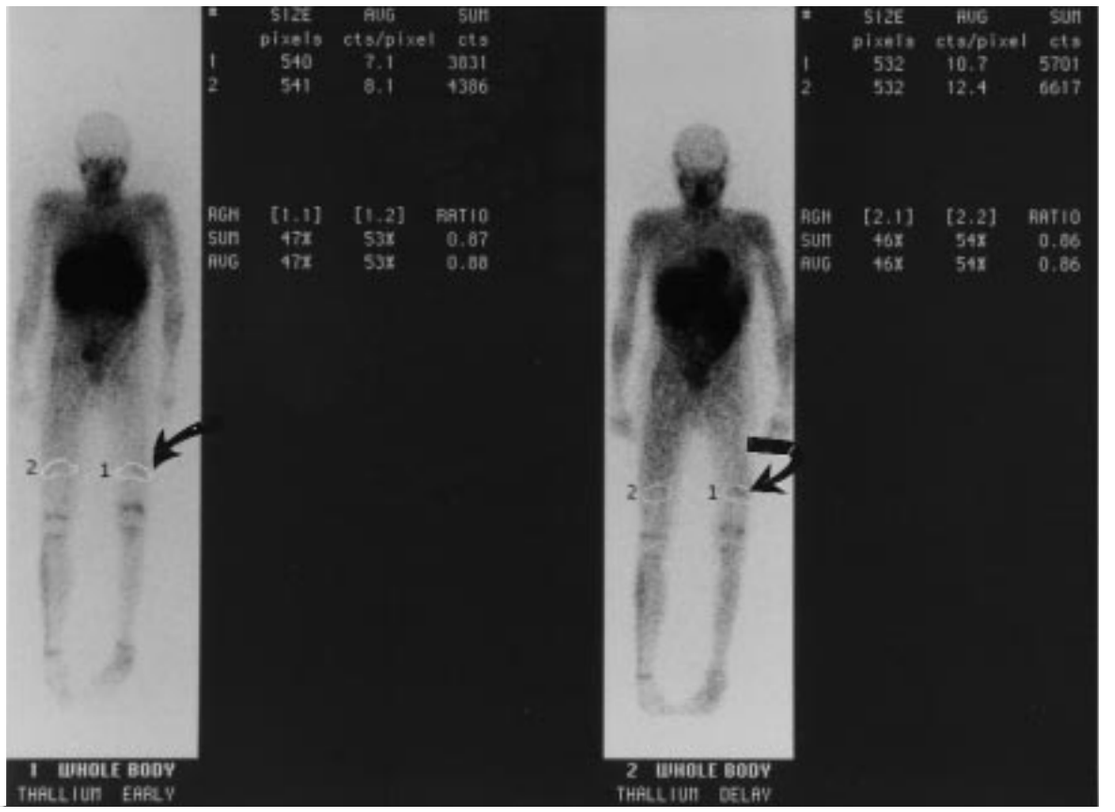


Figure 30.3 Thallium scan (early and late) post-induction chemotherapy. The scan compares the affected side to the normal extremity. Note there is minimal difference in uptake, indicating a good response to chemotherapy. This patient has 100% tumor necrosis.

document the position of the needle or the trocar. Care should be taken to avoid contamination of the knee joint, sartorial canal, popliteal space, and rectus femoris muscle.

Regardless of the biopsy technique utilized, tumor cells will contaminate all tissue planes and compartments traversed. All biopsy sites must therefore be removed en-bloc when the tumor is resected.

CONTRAINDICATIONS FOR LIMB-SPARING SURGERY

The contraindications of limb-sparing surgery are as follows:[3–5,9]

Major Neurovascular Involvement

Major neurovascular involvement, specifically of the popliteal vessels, is usually a contraindication to a limb-sparing procedure. Vascular involvement in itself, however, does not negate a limb-sparing procedure. A vascular graft can replace the popliteal vessels.

Pathologic Fractures

A fracture through a bone affected by a tumor spreads tumor cells via the hematoma beyond limits that can be accurately determined. The risk of local recurrence increases following a pathologic fracture and makes a resection more difficult. There has been increasing experience with limb-sparing surgery in patients with a fracture that heals following induction chemotherapy. In general, if plain radiography and CT show good fracture healing with reossification of the tumor, a limb-sparing resection can be safely performed.

Inappropriate Biopsy Sites

An inappropriate or poorly planned biopsy jeopardizes local tumor control by contaminating normal tissue planes and compartments.

Infection

Implantation of a metallic device or an allograft in an infected area is contraindicated. Sepsis jeopardizes the effectiveness of adjuvant chemotherapy. If an infection occurs following a limb-sparing procedure, an amputation is often required in order to be able to give high-dose chemotherapy safely.

Immature Skeletal Age

In the lower extremity the predicted leg-length discrepancy (when the patient has achieved adult stature) should not be greater than 6–8 cm. Upper-extremity reconstruction is independent of skeletal maturity. An expandable prosthesis or a rotation plasty can be utilized in a young child.[13,14]

Extensive Muscle Involvement

Enough muscle must remain to reconstruct a functional extremity. In the author's experience the presence of a single contraindication may not dictate an amputation; however, resection is inadvisable in the presence of two or more contraindications.

SURGICAL GUIDELINES

Surgical guidelines for limb-sparing surgery, as practiced by the author, are as follows (Figures 30.4 and 30.5):

1. The major neurovascular bundle (popliteal vessels) must be free of tumor.
2. The resection of the affected bone should leave a wide margin and a normal muscle cuff (i.e. 1–2 cm) in all directions.
3. All previous biopsy sites and all potentially contaminated tissues should be removed en-bloc. All needle biopsy tracts must be removed.
4. To avoid intraosseous tumor extension, bone should be resected 3–5 cm beyond abnormal uptake, as determined by preoperative studies.
5. The adjacent joint and joint capsule should be resected. Adequate motor reconstruction must be accomplished by regional muscle transfers. The type of transfer depends on functional requirements.
6. Adequate soft-tissue coverage is needed to decrease the risk of skin flap necrosis and secondary infection. A medial gastrocnemius rotation flap provides excellent coverage of the prosthesis when required.

PRINCIPLES OF SOFT-TISSUE RECONSTRUCTION

Clinical experience of the past decade has emphasized the need for careful soft-tissue reconstruction and coverage of the prosthesis in order to optimize the functional outcome; decrease the incidence of post-operative complications, infection, and skin flap necrosis; and provide reliable motor function and stability of the knee joint. The principles of soft-tissue reconstruction are described in the following paragraphs.

Restoration of Motor Power

Portions of the quadriceps muscle are usually resected with the distal femur in order to obtain an adequate

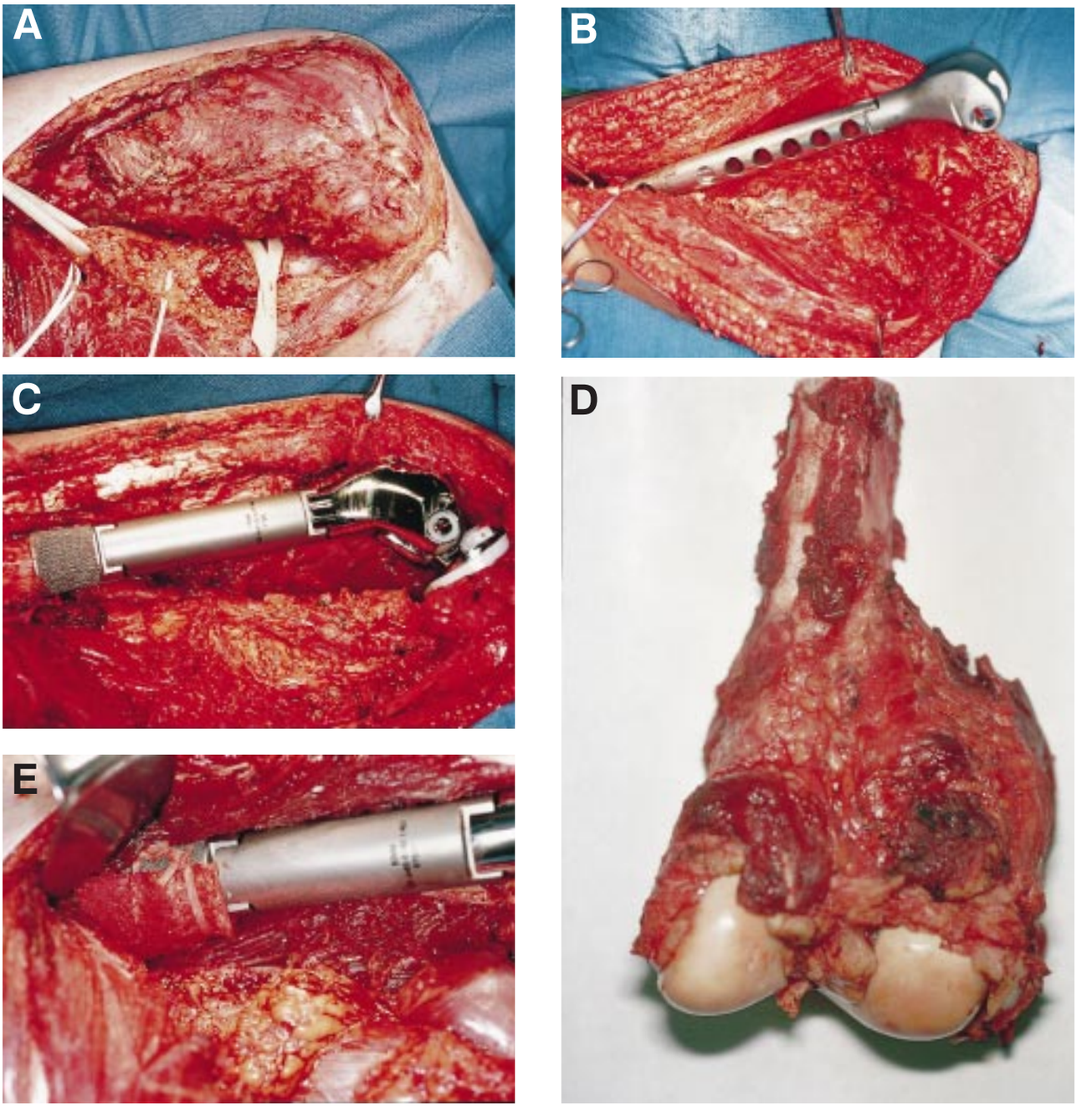


Figure 30.4 *(see also following page)* Operative photographs of a distal femoral resection for an osteosarcoma with reconstruction using the modular replacement system. Popliteal exposure. Note the Penrose drains are along the popliteal artery distally and at the level of the adductor hiatus proximally. (**A**) The initial step in resection is exposure of the popliteal vessels and ligation of the geniculate arteries. This permits exploration of the popliteal vessels and mobilization that allows resection of the distal femur intraarticularly without any surgical complications. (**B**) Trial distal femoral prosthesis in place. (**C**) Distal femoral prosthesis in place. (**D**) Gross specimen of distal femoral tumor. *Note*: muscle surrounds the entire extraosseous component. (**E**) Close-up of bone graft held with Dacron tape along femur–prosthesis seat (porous coated) for extracortical fixation. (**F**) Lateral view. (**G**) Anterior–posterior view. Postoperative radiograph of a typical distal femoral resection utilizing the Modular Replacement System (Howmedica, Inc.). The original design of the Modular Replacement System required cementation of both the femoral and tibial components. The second-generation MRS will permit a choice of stems to permit press fit fixation or cementation.

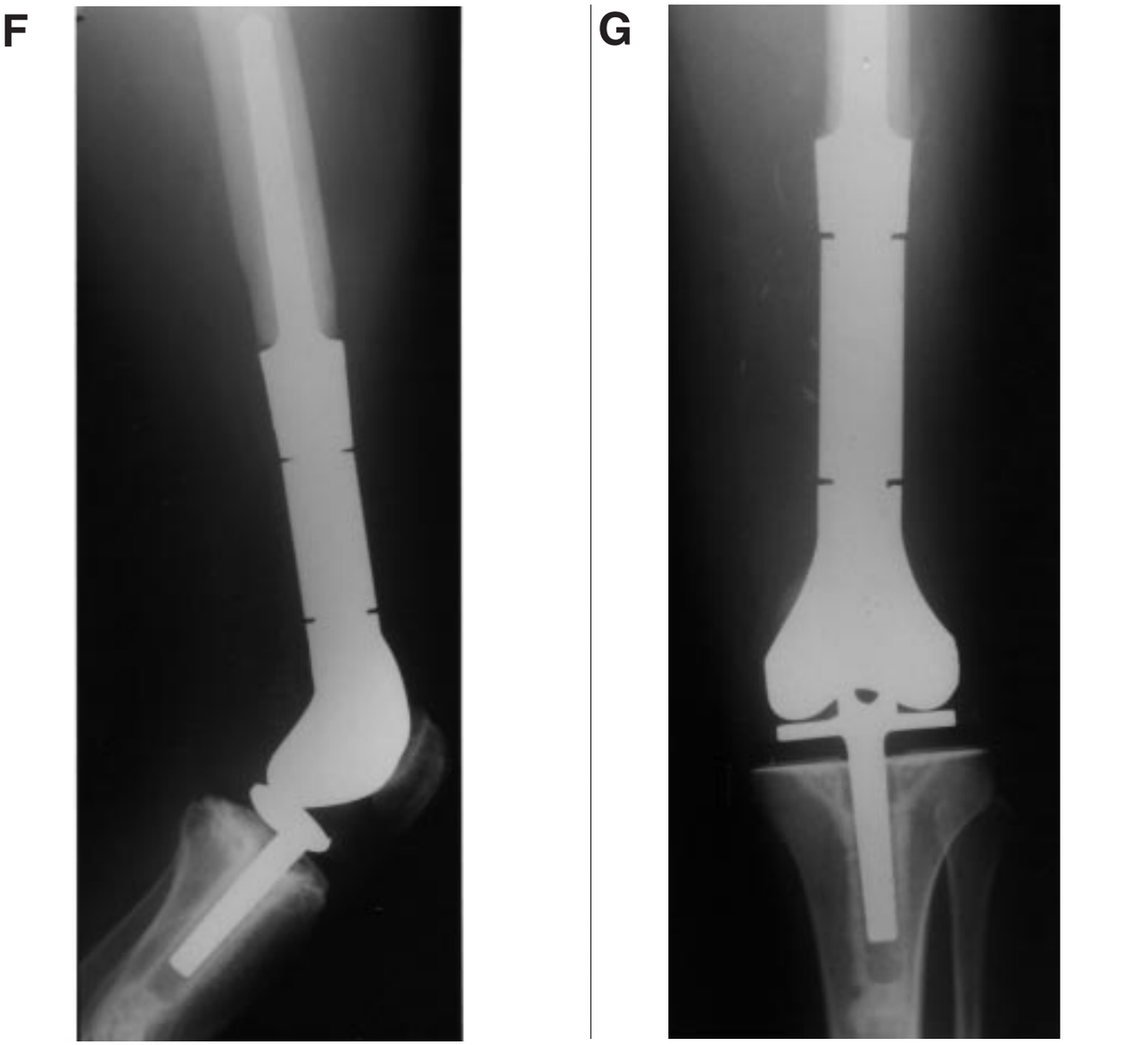


Figure 30.4 F,G

margin. It is our practice to utilize primary hamstring transfers to reconstruct portions of the quadriceps muscles that have been resected. The biceps femoris is an excellent muscle for transfer to the anterior aspect of the knee for both coverage and restoration of loss of the vastus lateralis muscle. The sartorius muscle, which is innervated by the femoral nerve, is an excellent muscle to transfer on the medial aspect of the prosthesis to restore some function lost when the vastus medialis muscle has been resected.

In addition, these transfers are important in stabilizing the patella following resection. Patellar realignment and stabilization is an important component of limb-sparing surgery as well as of total knee replacement.

Soft-tissue Coverage of the Prosthesis

It is essential to cover the prosthesis with normal muscle. The experience of the 1970s and 1980s showed that a prosthesis or allograft in the subcutaneous position has a relatively high infection rate because of wound flap necrosis. The medial gastrocnemius muscle is the "workhorse" of soft-tissue reconstruction around the

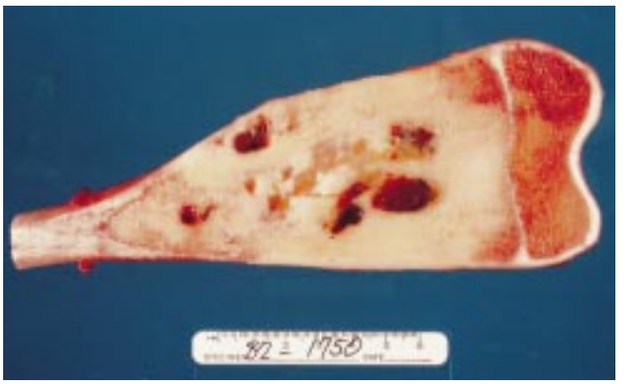


Figure 30.5 Gross specimen of a low- to intermediate-grade intraosseous osteosarcoma. Note there is a small soft-tissue component. This was one of the first limb-sparing resections performed with a custom prosthesis in 1982. The prosthesis has survived 17 years.

knee joint. It is routinely used to cover the knee joint and prosthesis as well as to reconstruct the soft tissue of the medial aspect of the knee. The transfer of this muscle is based on the medial sural artery, which is always retained following popliteal exploration. This muscle can be transferred transversely to cover the joint or rotated proximally to cover approximately 20 cm of an exposed medial prosthesis. The thick anterior and posterior fascia are routinely removed from the gastrocnemius muscle to permit skin grafting if necessary.

Stability

The prosthesis is inherently stable. Although it is not necessary to reconstruct any ligaments with the Modular Replacement System (MRS), increased strength and stability are necessary to ensure an optimal functioning extremity. Therefore, the above muscle transfers are required to cover and stabilize the prosthesis as well to provide rotational stability.

Technique of Medial Gastrocnemius Transfer

The medial gastrocnemius muscle is the mainstay of muscle transfers of the distal femur. The technique of medial gastrocnemius transfer was described by Malawer and Price.[15] According to this procedure the medial gastrocnemius muscle is dissected free of its tendinous and midline insertions in the calf following cementation of the prosthesis. It may then be rotated transversely or proximally, depending on the area to be covered. On most occasions the skin can be closed directly over the transferred muscle, but if there is any skin tension or swelling, the skin flaps are sutured directly to the muscle transfer and the remaining defect is closed with a split-thickness skin graft onto the muscle directly at the time of surgery.

It is important to note that the medial gastrocnemius muscle is fed by one major branch: the medial sural artery off of the popliteal artery. The origin of this branch is below the knee joint line. At the time of popliteal exploration and dissection, it is essential to preserve this branch and not mistake it for a geniculate vessel. The lateral gastrocnemius is rarely utilized because it is a much smaller muscle and its arc of rotation is decreased by the peroneal nerve and the fibula.

THE MODULAR REPLACEMENT SYSTEM

The MRS was developed to meet the needs of patients who require reconstruction of large segmental defects of the knee, shoulder, or hip (Figure 30.6). It is also used to reconstruct osteoarticular defects of varying sizes. The system is assembled intraoperatively and eliminates waiting time otherwise needed to create custom-made devices. Another major advantage of the MRS is that it allows for variation in both planned and unexpected necessary intraoperative changes. The MRS also provides a means of strengthening the implant by extracortical fixation.

The MRS consists of articular components, body segments, stem sections, and a set of trial components. The articular components utilize a male/female Morse taper locking mechanism. They are assembled during surgery by impacting them together. The impaction causes the male/female tapers to produce a cold-type lock. The body segments are available in 40 mm lengths with 20 mm increments. The articular component features a male/female taper for attaching proximal and distal components. The body segments have a diameter of 28 mm. The stem sections have a 40 mm replacement length with tapered 127 mm stem that is available in 11, 13 and 15 mm diameters; their respective seat diameters are 24, 28 and 32 mm, which allows close matching of host bone. There are two types of stems; one for cementation and the other for noncementation fixation. One area of the body of the stem segment is porous-coated. The porous coating offers the option for bone graft and extracortical fixation.[16,17] The stem segments are designed to be cemented into the medullary canal. The condylar section has a 65 mm replacement length and is available in left or right. The condyle has a built-in 6° offset. The knee component is a standard, rotating, kinematic hinge-knee component. Smaller femoral components have recently become available for use in pediatric patients.

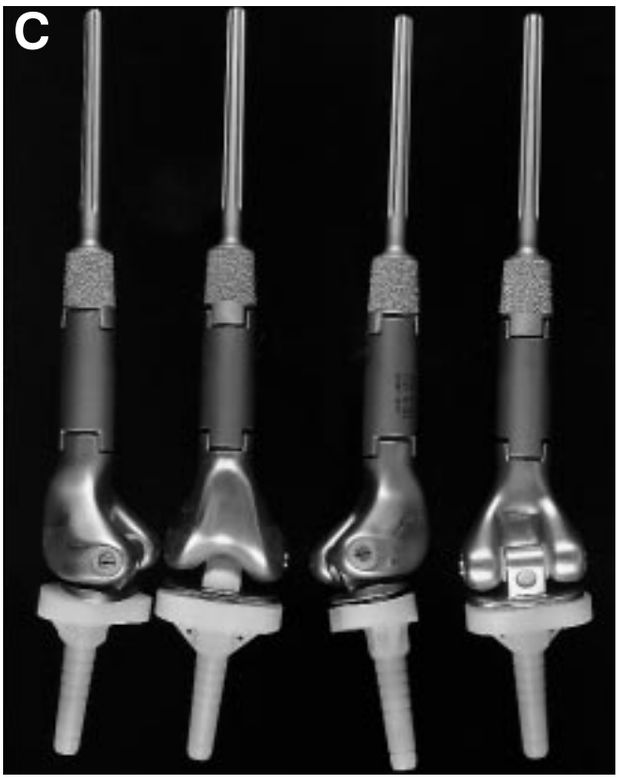


Figure 30.6 *(see also following page)* Distal femoral modular replacement. The most current prosthetic design for replacement of the distal femur is a modular replacement. It consists of a stem of various diameters, a body of various lengths, and a right and a left condyle. These components can be interchanged at the time of surgery, thus avoiding the need for a custom prosthesis in most patients. (**A**) Composite view of two distal femoral prosthesis with and without an intervening body segment. (**B**) AP view of a distal femoral replacement without a body segment. (**C**) A composite photograph showing the range of rotation of the distal femur within its polyethylene (tibial) component. The knee joint is a rotating hinge and permits full flexion, extension, and rotation. Control of the extremity is absolutely necessary by the patient's remaining muscles, which may necessitate muscle transfers. (**D**) Composite photograph showing the range of knee flexion of the tibial component on the modular distal femur prosthesis.

Figure 30.6 D

The trial components are replicas of their corresponding implant; however, they have nonlocking trunnions. The articulating trials are satin-finished so that they can easily be distinguished from the prosthesis. The body sections have several large holes drilled through the major diameter that distinguish them from the implant. The stem sections do not have porous coating. All trial articulating components are made of cast Vitallium, and all body segments are made of machined stainless steel.

INTRAMEDULLARY REAMERS

Intramedullary facing reamers correspond to the diameter of the proximal stem. They are used to plane the seat area of bone for the prosthesis. The cutting flutes re-create in bone the radius at the stem/seat junction of the stem and seat. The reamers are available in 11, 13 and 15 mm diameters, with corresponding seat diameters for the femoral system.

Prosthetic Survival Analysis and Results

Major advances have been made in the design and quality of the distal femoral prosthesis, specifically the MRS (Howmedica, Inc., Rutherford, NJ) Henshaw *et al.*[18] have reported the estimated 10-year survival rate associated with use of the distal femoral prosthesis to be 91%. ("Survival" meant the prosthesis did not require removal) (Figure 30.7). No mechanical failures of the

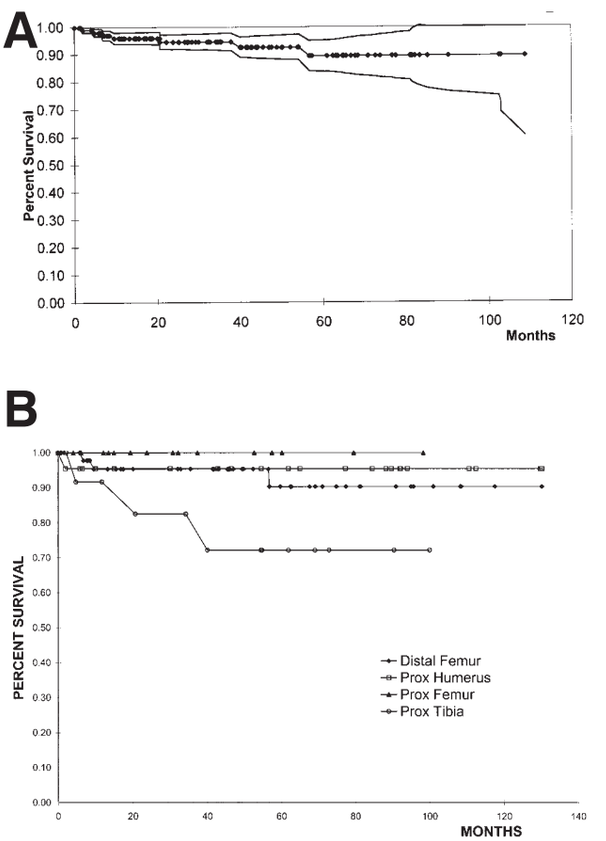


Figure 30.7 (**A**) Kaplan–Meier analysis of 105 patients treated with a modular replacement prosthesis; 95% of all prostheses were in place at 100 months. (**B**) Kaplan–Meier analysis of prosthetic replacement by anatomic site. The distal femoral replacements had an overall 91% survival rate at 120 months (10 years).

prosthesis, taper dissociations, or stem breakage occurred. The incidence of polyethylene failure was less than 10% and usually was a result of failure of the polyethylene bushings. Bushing failure is best detected by a varus and valgus stress test. Bushing failure was rarely seen before 7 years. Failure of the tibial component was rare.

Functional Evaluation

Eighty percent of patients with distal femoral resections and reconstructions with prosthetic replacements have excellent functional results, and 20% have good results. Range of motion is from 0 to 120 degrees (Figure 30.8). Most patients enjoy a normal lifestyle, with limitations only on running and some contact sports.

Postoperative Management

After surgery, the following procedures are advised:

1. The extremity is kept elevated for 3–5 days. This prevents edema, which may delay wound healing.
2. Continuous suction is required for 3–4 days to avoid fluid collection. This operative procedure involves a large dead space. A 28-gauge chest tube to 20 cm of suction is used.
3. Routine perioperative antibiotics are continued until the drainage tubes are removed.
4. Isometric exercises are started the first postoperative day. Knee motion is generally not permitted until the wound is examined and there is adequate muscle control.
5. Muscle control is essential to prevent rotation of the prosthesis in the early postoperative period. This is a unique consideration associated with this procedure. A knee immobilizer or posterior splint is required.
6. Epineural marcaine catheters inserted into the sciatic nerve are recommended. A continuous infusion of 4–8 ml of 0.25% marcaine is continued for 3–4 days and offers excellent pain relief (Figure 30.9).

PALLIATIVE RESECTIONS OF THE DISTAL FEMUR

A rare but increasingly common indication for distal femoral resection of a high-grade sarcoma, especially an osteosarcoma, is palliation in the face of progressive local and systemic disease. The aims of palliative surgery are to avoid the complications associated with tumor progression, to permit the patient to continue ambulation and function at a fair quality of life, and to control pain. Amputation or limb-sparing resection can accomplish all three aims.

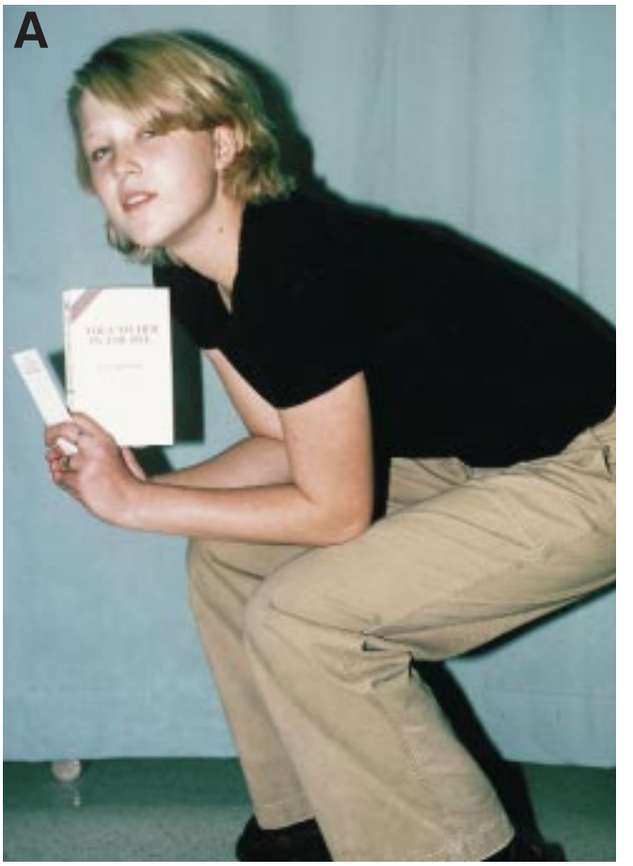


Figure 30.8 Two patients following distal femoral resection and replacement with a modular distal femoral prosthesis showing excellent knee flexion. This is a typical result following distal femoral endoprosthetic replacement. (**A**) Two years following surgery. (**B**) Three years following surgery.

Osteosarcomas that progress locally may present the following clinical findings:

1. hemorrhage into the tumor with significant blood loss;
2. secondary infection; or

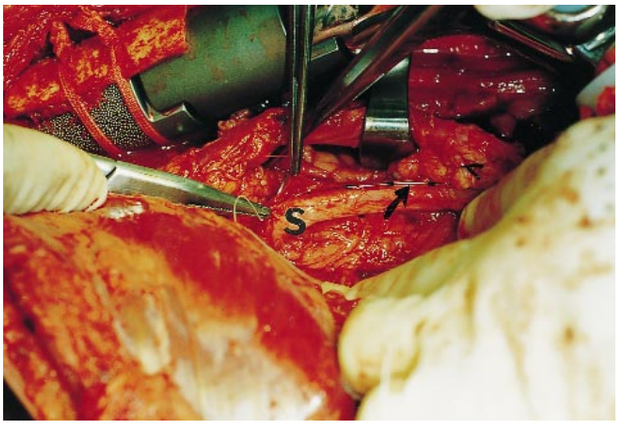


Figure 30.9 Placement of an epineural catheter into the sciatic nerve following segmental resection of the distal femur and replacement with a modular prosthesis. The catheter is shown being sutured into the nerve sheath (catheter, arrows). A continuous marcaine infusion of the major nerves (following a limb-sparing resection) has been utilized by this author for over 10 years. It has been shown to reduce the postoperative use of narcotics by approximately 90%.(large arrow, sciatic nerve; small arrow, marcaine epineural catheter). The catheter is brought out of the skin through a separate stab wound. Marcaine (0.25%) is infused at a rate of 4–8 ml/h. This provides excellent pain relief.

3. tumor fungation with secondary infection and bleeding.

This scenario has been seen recently in two specific clinical situations: a patient with multicentric osteosarcoma treated with chemotherapy with minimal hope of cure; and a patient who presents with unresectable pulmonary disease treated solely with chemotherapy. Virtually all these patients die from the disease, and surgery for the primary tumor has therefore often been delayed. The large primary site almost always continues to grow, despite chemotherapy, and often progresses to the point where an amputation becomes necessary. The surgeon and the medical oncologist must determine whether the tumor is progressing and should be treated surgically before the inevitable tumor fungation, infection, sepsis, hemorrhage, and chronic pain occur. A relatively early resection is recommended, despite the fact that there is metastatic disease and multicentric disease. This decision to proceed with surgery is not simple; however, surgery does offer the patient an alternative to additional chemotherapy, radiation, and amputation.

The guidelines and the staging studies prior to a palliative resection are generally similar to those that precede a primary resection, with the following modifications:

1. A marginal excision (around the pseudocapsule) with preservation of all function is the goal of surgery.
2. Thick fasciocutaneous flaps with muscle transfers are used if needed to prevent tumor fungation or local infection.
3. Long-term suppressive antibiotics are used if there is an infection.

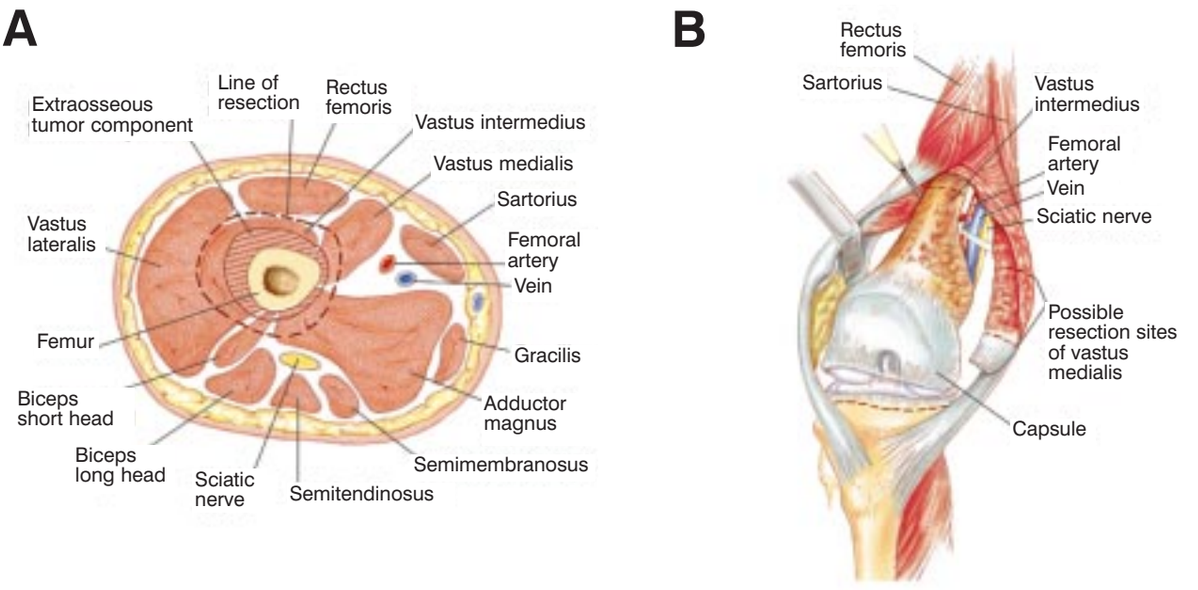


Figure 30.10 (**A**) Anatomic location of malignancy. Adequate en bloc resection includes 15–20 cm of the distal femur and proximal tibia and portions of the adjacent quadriceps. (**B**) An intra-articular resection is usually performed. The surgical planes of resection are shown.

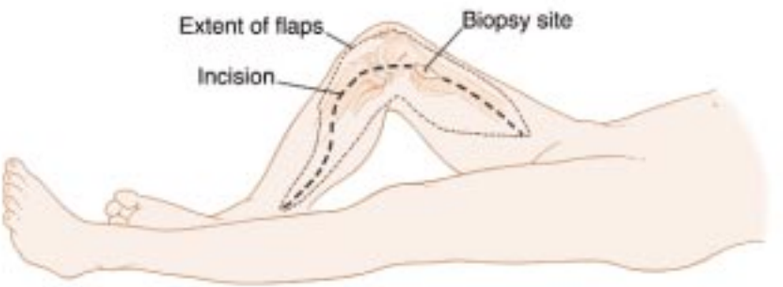


Figure 30.11 Surgical approach and incision. The patient is placed supine on the operating table. A sandbag is placed under the ipsilateral buttock to facilitate taking a bone graft. The entire extremity, including the groin and pelvis, is prepped and draped. The groin should always be included to allow for the rare instance in which exposure of the common femoral vessels is required. The pelvis (used for bone graft) is draped separately. A long medial incision begins in the midthigh, crosses the knee joint along the medial parapatellar area and distal to the tibial tubercle, and passes gently posterior to the inferior border of the pes muscles. The biopsy site is included, with a 3 cm margin in all directions. This approach allows an extensile exposure of the distal one-third to one-half of the femur and knee joint and identification of the important muscle intervals. It allows simple and safe exploration of the sartorial canal, superficial femoral vessels, and popliteal space. It permits distal extension of the incision to develop a medial gastrocnemius muscle transposition for prosthetic coverage. Fasciocutaneous flaps are developed.

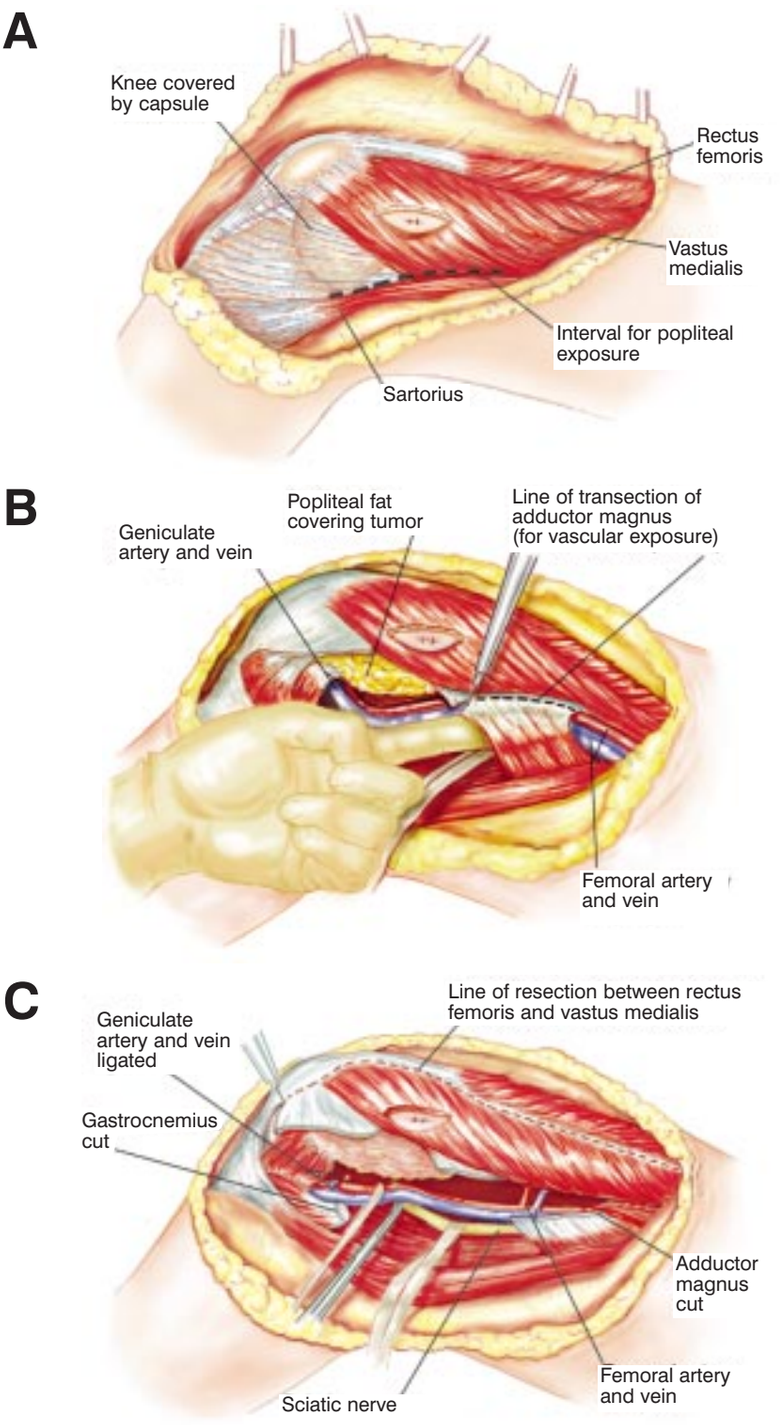


Figure 30.12 (**A**) Popliteal exploration. Resectability is determined by exploration of the popliteal space and vessels. The popliteal space is approached by detaching or retracting the medial hamstrings. The sartorius is identified. The superior border is opened with the knee in a flexed position. This allows direct entry to the popliteal space and exploration of the popliteal vessels and sciatic nerve. (**B**) Superficial femoral artery exploration. The superficial femoral artery is identified within the sartorial canal. If the resection length is greater than 15 cm, the SFA must be mobilized from the abductors. If this is not done the artery can be inadvertently damaged because of its proximity to the canal as it passes anteriorly to posteriorly. The adductor magnus tendon is released at the foramen to facilitate retraction of the SFA. (**C**) Posterior exploration. The interval between the popliteal vessels and the posterior femur is developed and explored. The popliteal artery is mobilized, and the geniculate vessels are ligated and transected. If the vessels are free of tumor, resection proceeds.

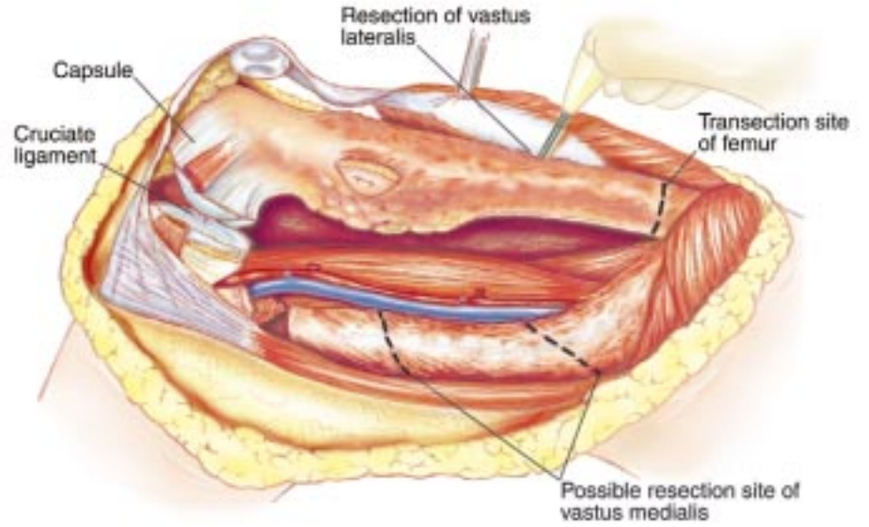


Figure 30.13 Distal femoral resection. The interval between the rectus femoris and vastus medialis muscle is identified and opened, exposing the underlying vastus intermedius muscle. The vastus intermedius must remain intact around the femoral shaft and the extraosseous tumor component. If there is a medial extraosseous component, a cuff of normal muscle must cover it. If necessary, the entire portion of the vastus medialis muscle can be removed en-bloc with the tumor. The entire capsular insertion onto the tibia is completely released. (The stability of the prosthesis is not dependent on the capsule.) The majority of the soft-tissue detachments from the distal femur structures should be performed prior to osteotomy. The remaining muscle attachments to the distal femur, which must be severed, include the medial and lateral intermuscular septa, the short head of the biceps, and both medial and lateral heads of the gastrocnemius muscles.

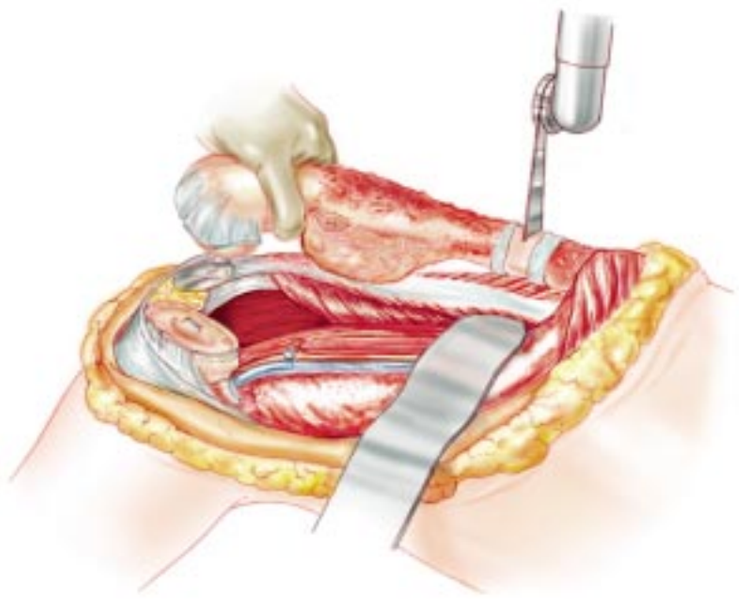


Figure 30.14 Proximal femoral osteotomy. The length of the resection is measured from the medial joint line to the correct area on the femur and then marked. All remaining soft tissue at the level of transection is cleared. The osteotomy is performed after the posterior and medial structures have been protected and retracted; special care is taken to protect the SPA. A frozen section of the bone marrow is performed from the proximal end.

Following the osteotomy, it is helpful to pull the distal end of the femur forward in order to expose the remaining soft-tissue attachments, any remaining fibers of the short head of the biceps, intermuscular septa, and capsular structures. The distal femur is then passed off the operative field.

Caution: It is extremely important not to distract the extremity following the resection; one assistant must be assigned to monitor this. The end of the proximal femoral osteotomy should be kept well padded to avoid injuring the popliteal/SFA vessels. The length of the resected specimen should be remeasured following resection.

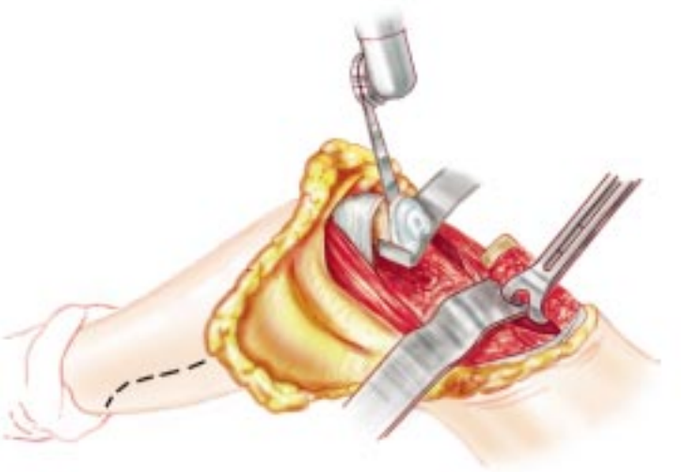


Figure 30.15 Tibial osteotomy and preparation of the femur. The tibial osteotomy is performed in the same manner as the standard knee joint replacement. Approximately 1 cm of bone is removed. The cut should be perpendicular to the long axis of the tibia. Do not discard this bone; it can be utilized for bone graft for the extracortical fixation of the distal femoral component.

A flexible guidewire is inserted into the femoral canal. Flexible reamers are utilized to widen the canal to the appropriate diameter. To permit an adequate cement mantle, the canal should be reamed to 2 mm larger than the selected stem of the prosthesis. (The three femoral stem widths are 11, 13 and 15 mm.) A stem/seat rasp is used to plane the osteotomy site so as to ensure direct contact and accurate seating of the prosthesis upon the cortices. The rasp is designed to expand the diameter of the shaft to allow the increased radius of curvature of the stem/prosthesis junction to fit accurately into the canal.

The chosen trial femoral component is inserted to ensure ease of insertion. (The trial components are 2 mm oversized.) If there is any difficulty, one must ream an additional 1 mm. It is extremely important to verify the close apposition of the seat of the femoral trial to the cortex. If necessary, a high-speed burr is used to adjust or trim the osteotomy site.

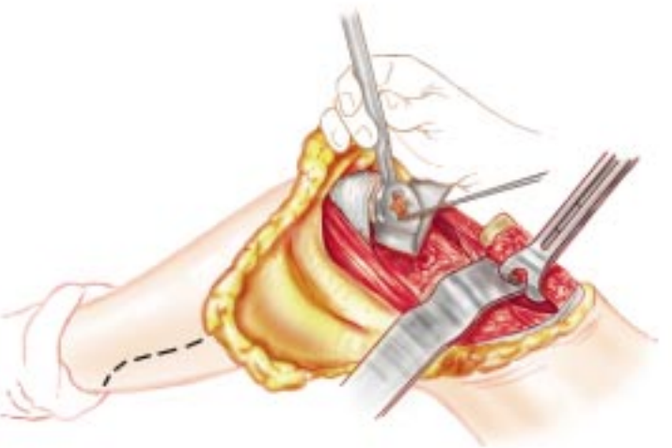


Figure 30.16 Preparation of the proximal tibial canal. The tibial canal is located with a curette. The canal is reamed to the appropriate size, as determined by the preoperative evaluation of the width of the proximal diaphyseal canal. (The stem diameters of the tibial bearing plug component measure 8, 11, 16 and 21 mm; the tibial trial components are not oversized.) The canal is reamed 2 mm larger than the chosen stem diameter to permit an adequate cement mantle. All trial components, with their respective sizes, are marked as trials. The standard tibial template from the Kinematic II (Howmedica, Inc., Rutherford, NJ) rotating hinge is used to outline the rectangular cut for the box portion of the tibial-bearing plug component. The trial tibial-bearing plug component is then impacted with a mallet. The seating of the component must be checked carefully. If necessary, the fit can be adjusted with a small curette or high-speed burr.

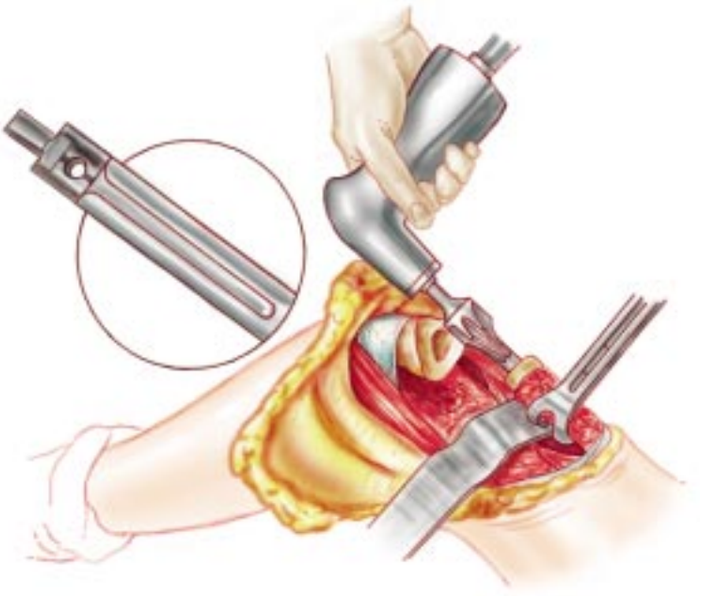


Figure 30.17 Preparation of distal femur. The femur is reamed to 2 mm larger than the stem of the femoral prosthesis. The femoral stems are 11, 13, and 15 mm. The largest stem possible should be used. The corresponding "facing reamer" is used to shape the opening of the femur to permit accurate seating of the prosthesis.

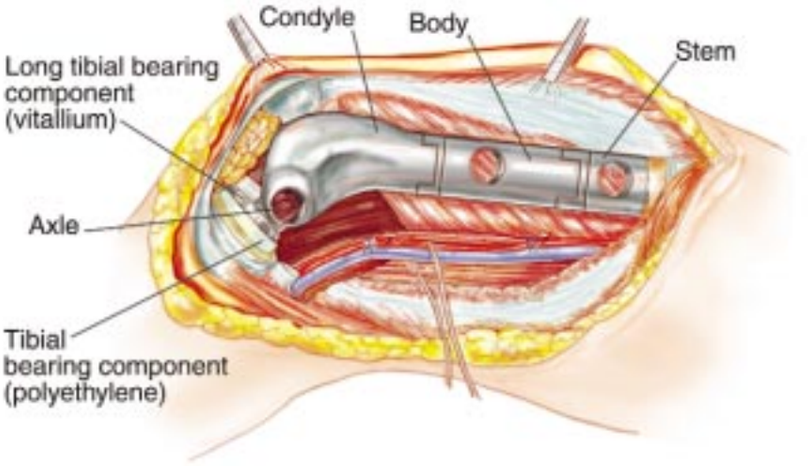


Figure 30.18 Trial reduction wth templates. The purpose of the trial reduction is to determine the ease of insertion of the femoral and tibial components prior to cementing, and to determine whether the length of the prosthesis is appropriate.

If the prosthesis is too long, too much tension will be placed upon the neurovascular structures when the knee is extended. In addition, the extensor mechanism will be tight, causing loss of flexion and difficulty in closing the soft tissues. To determine the appropriate length, one must extend the knee and monitor the distal pulse with the trial prosthesis in place. A sterile Doppler can be used to evaluate the posterior tibial and dorsalis pedis pulses. The trial tibial-bearing component is inserted into the tibia and impacted with a mallet. Insert the femoral stem segment into the femur. The femoral stem segment is aligned using the linea aspera as a guide (see Figure 17.11). An imaginary perpendicular line is constructed that passes directly anterior, originating from the linea aspera. The horizontal axis of the prosthesis should be perpendicular to this line. The trial femoral prosthesis is assembled by joining the femoral stem segment with the trial femoral body segment and condylar segment.

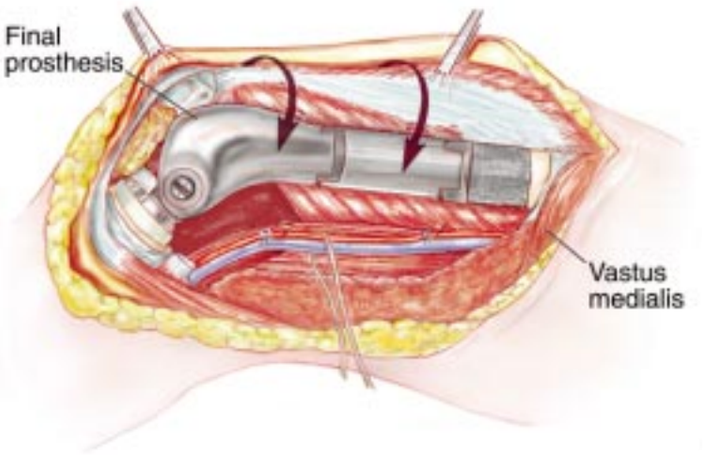
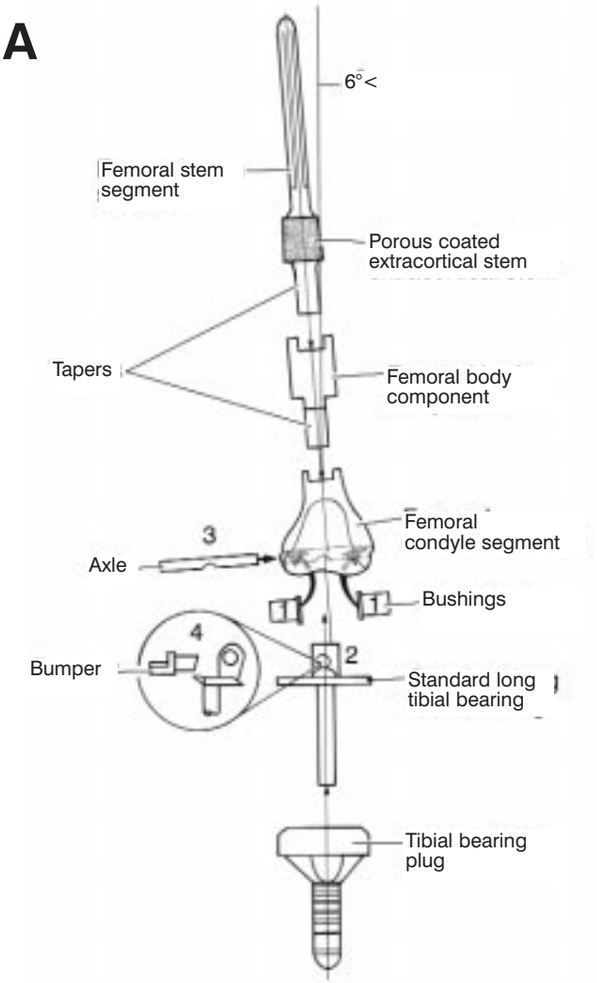


Figure 30.19 Trial articulation. Four parts must be assembled to articulate the femoral and tibial components: standard long tibial bearing (Vitallium), an axle, two bushings, and a bumper. Once the prosthesis is articulated, the femoral components are held in one hand to prevent rotation, and extend the legs fully. The femoral vessels are palpated to determine the status of the pulse or evaluate the pulses at the ankle with a sterile Doppler. If the pulse is diminished, the knee is flexed to determine if it increases. This will indicate the need either for modifying the length of the prosthesis or for removing additional bone from the distal femur. The range of motion of the knee with the patella relocated is tested. A full range of motion should be obtained. The surgeon must note whether the capsular mechanism can be easily closed. These factors, taken together, determine the adequacy of the length of the resection.



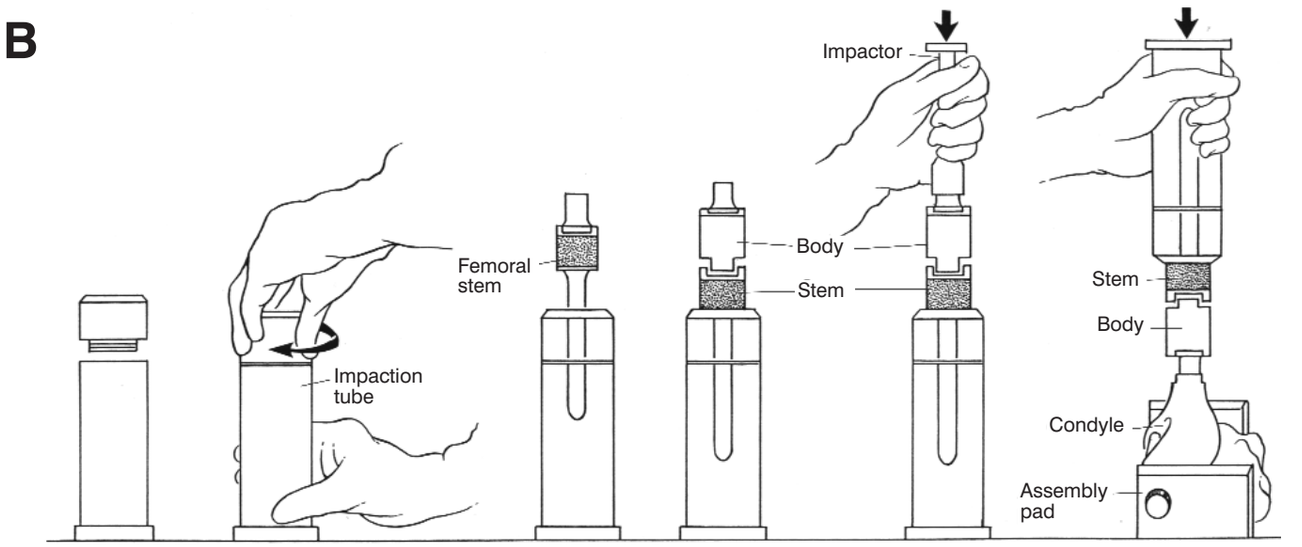


Figure 30.20 Assembly of prosthesis. (**A**) The femoral prosthesis consists of three components: the femoral stem segment, femoral body component, and femoral condyle segment. There are two femoral condyle components: right and left. The correct side and the lengths of all components are checked before assembly. The three instruments necessary for the assembly are the impaction tube, impactor and assembly pad. Before joining any of the tapers, one must make sure that all components are completely dry. (**B**) The femoral body component and femoral stem segment are assembled first. The femoral stem segment is placed into the impaction tube (1,2) and the femoral body component is mated with it (3). The impaction tool is placed over the taper of the femoral body component (4) and impacted with a swift blow of the heavy mallet.

The femoral condyle component is placed onto the distal end of the femoral body component (5). The entire prosthesis is removed from the impaction tube and placed with the femoral condyles against the assembly pad. The impaction tool is placed over the stem against the base of the prosthesis and impacted with a swift blow. Once the prosthesis is assembled, the tapers should not be disengaged.

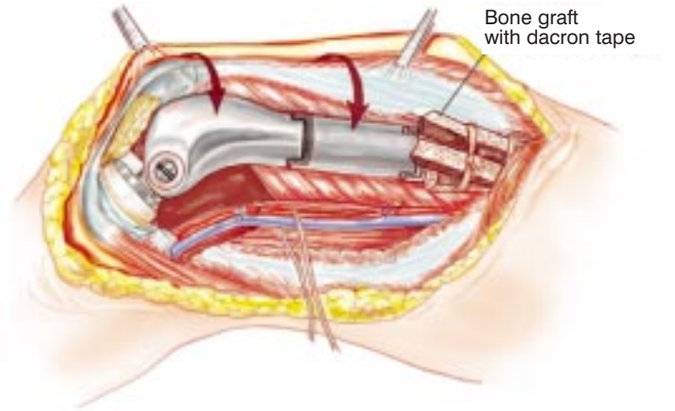


Figure 30.21 Implantation and orientation of the femoral prosthesis. The femoral canal is thoroughly irrigated. A cement plug is placed at the appropriate depth. This depth is checked by inserting the actual prosthesis and verifying complete seating. The femoral canal is again irrigated and dried. The soft tissues, especially those that are near the neurovascular structures, are protected and packed off with wet lap pads. Two packs of PMMA are mixed and injected into the canal to ensure complete filling of the canal. Some PMMA is then placed around the stem of the prosthesis. The femoral prosthesis is oriented with the linea aspera as the guide. This is the only landmark. There is no guide for femoral alignment. The prosthesis is then impacted. Excess cement is removed from around the prosthesis. Care is taken to prevent cement from getting into the porous-coated section. The articulation of the actual prosthesis is identical to that of the trial structure.

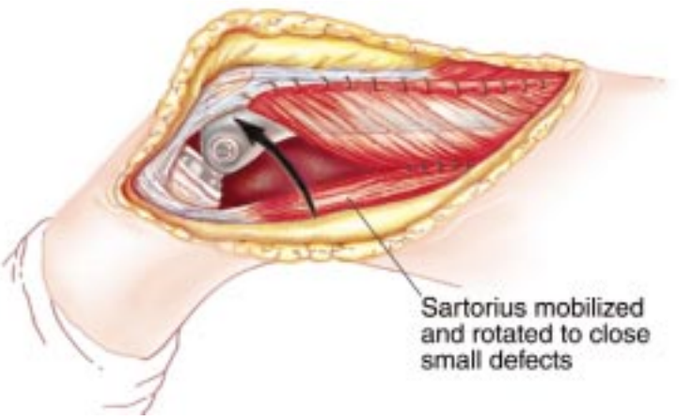


Figure 30.22 Sartorius muscle. It is essential to completely cover the prosthesis with soft tissue. The prosthesis should not be left in a subcutaneous position. The remaining vastus medialis muscle is sutured to the rectus femoris. The sartorius muscle can be mobilized and rotated anteriorly for closure of a small remaining defect. A large defect requires a medial gastrocnemius transfer; a lateral defect is closed with a lateral gastrocnemius transfer.

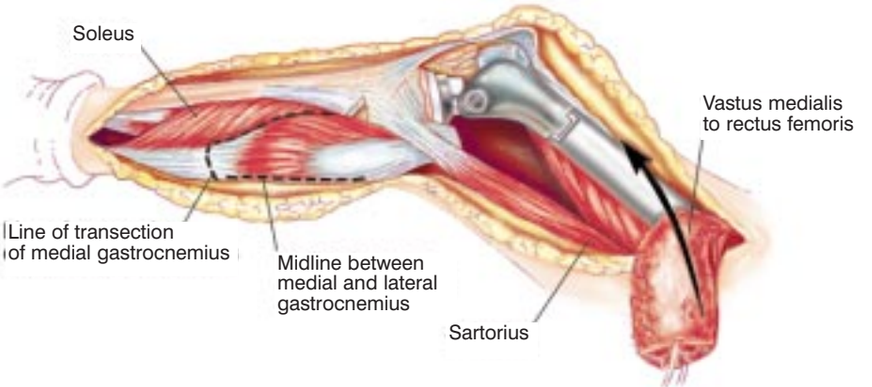


Figure 30.23 Exposure of the medial gastrocnemius. To adequately expose the medial portion of the gastrocnemius muscle, one must: (1) increase the length of the incision distally to the level of the musculotendinous junction; (2) create a posterior-based midline fasciocutaneous flap; (3) expose and open the interval between the medial gastrocnemius muscle and soleus muscle by lifting the medial gastrocnemius muscle by finger dissection. Exposure stops at the midline.

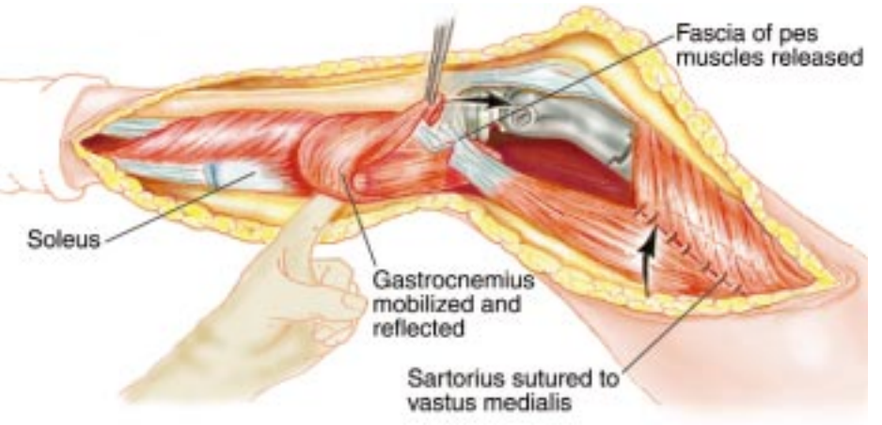


Figure 30.24 Mobilization of medical gastrocnemius muscle. The medial portion of the musculotendinous junction is detached and the two muscle bellies are separated along the midline.

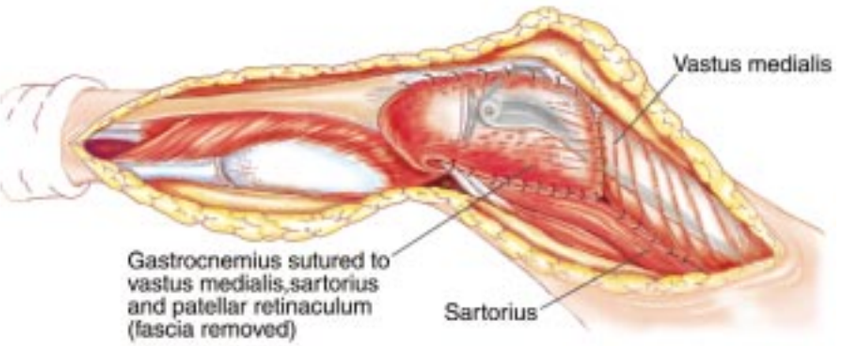


Figure 30.25 Rotation of the muscular flap. Rotate the flap anteriorly over the prosthesis. Occasionally, the fascia of the pes musculature must be released to increase the arc of rotation. The thick anterior and posterior fascia of the medial gastrocnemius is removed in order to spread the muscle over a larger area.

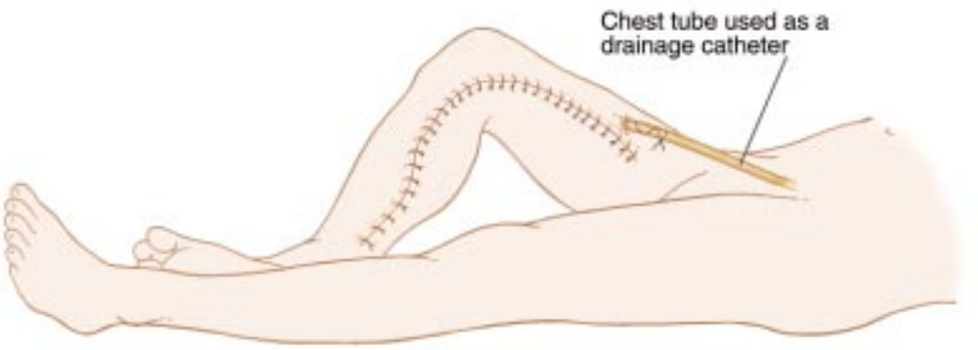


Figure 30.26 Wound closure. A 28-gauge chest tube is attached to Pleurovac suction (20 cm of water). The pulses are checked following wound closure and prior to removing the patient from the table. A knee immobilizer is used.

DISCUSSION

Limb-sparing surgery is now the preferred treatment for the majority of patients with osteosarcomas or other high-grade sarcomas (e.g. malignant fibrous histiocytoma, fibrosarcoma, and malignant giant cell tumors).[1–8] Almost all low-grade sarcomas of the distal femur, especially parosteal osteosarcoma and chondrosarcoma, can be treated safely with a limb-sparing resection. Careful preoperative planning and patient selection are crucial to a successful outcome. All patients with high-grade bone sarcomas of the distal femur should undergo preoperative CT, MRI, bone scintigraphy, and biplane angiography. All patients should be evaluated for a limb-sparing option prior to proceeding with an amputation.

Preoperative (induction) chemotherapy has changed our indications for patient selection.[19–22] Approximately three-fourths of patients who would formerly have been considered unresectable were converted to limb-sparing procedures following induction chemotherapy consisting of two cycles of intra-arterial cisplatinum and continuous intravenous Adriamycin.[8,21,23]

This chapter describes prosthetic replacement as the method of reconstruction of a large tumor defect. We assume that a prosthesis such as that described here may have to be revised. The use of improved cement techniques, extracortical fixation, and newer metals such as titanium will, it is hoped, increase the longevity of the prosthesis. Some surgeons favor osteoarticular allografts. In general they are not recommended for patients with high-grade sarcomas requiring adjuvant chemotherapy because of the increased risk of infection, nonunion, fracture, and subsequent delay in receiving chemotherapy. Arthrodesis (fusion) is a reliable procedure that may last the life of the patient.[23] Its major drawback is a stiff knee. We prefer arthrodesis only as a limb salvage procedure.

Several considerations can help decrease the complications of limb-sparing procedures. These are as follows:

1. A single medial incision, which allows adequate exposure of most lesions, is recommended.
2. A wide exposure is necessary in order to avoid tumor contamination. Large fasciocutaneous flaps are required.
3. Adequate soft-tissue reconstruction is mandatory in order to avoid wound breakdown. A medial (occasionally, lateral) gastrocnemius transfer is required to cover the prosthesis.
4. Adequate and prolonged tube drainage of the resection site is needed to decrease secondary wound problems.
5. We recommend the use of a 28-gauge chest tube for 3–5 days.

The MRS is a design that incorporates the advantages of several different features of prosthetic design. It increases the longevity of the prosthesis.[10] The kinematic rotating hinge component, which has been used since 1981, is one of the most effective means of decreasing stress on the stem and ensuring stability.[18] In general, the stem is the most vulnerable site of potential prosthesis loosening and failure. Mechanical stability is required, since all soft-tissue attachments to the knee are usually removed in order to adequately resect the tumor. The hinge component provides stability, and the rotary component permits a large amount of rotation. In comparison with a straight hinge, or earlier knee designs, there is significantly less stress on the bone–cement interface. The MRS mates this design with a modular system that permits immediate availability of prostheses of different sizes. The extracortical porous coating may provide additional bony fixation with the prosthesis, which may further decrease the stress on the stem and permit more physiologic cortical transmission of forces.

References

1. Campanacci M, Bacci G, Bertoni F *et al*. The treatment of osteosarcoma of the extremities: twenty years' experience at the Instituto Orthopedico Rizzoli. Cancer. 1981;48:1569–81.
2. Eilber F, Morton DL, Eckardt J *et al*. Limb salvage for skeletal and soft tissue sarcomas: multidisciplinary preoperative therapy. Cancer. 1984;53:2579–84.
3. Eilber FR, Eckhardt J, Morton DL. Advances in the treatment of sarcomas of the extremity. Current status of limb salvage. Cancer. 1984;54:2695–701.
4. Kotz R, Winkler K, Salzer Kuntchik M *et al.* Surgical margins influencing oncological results in osteosarcoma. In: Yamamuro T, editor. New Developments for Limb Salvage in Musculoskeletal Tumors. Tokyo: Springer Verlag; 1989: 83–91.
5. Morton DL, Eilber FR, Townsend CM Jr *et al.* Limb salvage from a multidisciplinary treatment approach, for skeletal and soft tissue sarcomas of the extremity. Ann Surg. 1976;184:268.

6. Eckardt JJ, Eilber FR, Grant TO *et al.* The UCLA experience in the management of stage IIB osteosarcoma. In: Eckardt JJ, Eiber FR, Grant TO *et al.,* editors. Limb Salvage in Musculoskeletal Oncology. New York: Churchill Livingstone, 1987:314–26.
7. Simon MA, Aschliman MA, Thomas N *et al.* Limb salvage treatment versus amputation for osteosarcoma of the distal end of the femur. J Bone Joint Surg Am. 1986;68:1331–7.
8. Malawer M, Priebat D, Buch R *et al.* The impact of preoperative intra-arterial chemotherapy on the choice of surgical procedure for high grade bone sarcomas Clin Orthop. (to be published).
9. Malawer MM, Link M, Donaldson S. Bone sarcomas. In: DeVita VT Jr, Helman S, Rosenberg SA , editors. Principles and Practice of Oncology, 3rd edn. Philadelphia: JB Lippincott; 1989: chap. 41.
10. Malawer M, McHale KA. Limb-sparing surgery for high-grade malignant tumors of the proximal tibia: surgical technique and a method of extensor mechanism reconstruction. Clin Orthop. 1989;239:231–48.
11. Hudson TM, Hass G, Enneking WF *et al.* Angiography in the management of musculoskeletal tumors. Surg Gynecol Obstet. 1975;141:11–21.
12. Chuang VP, Wallace S, Benjamin RS *et al.* The therapy of osteosarcoma by intraarterial cis platinum and limb preservation. Cardiovasc Intervent Radiol. 1981;4:229–35.
13. Kotz R, Salzer M. Rotation plasty for childhood osteosarcoma of the distal part of the femur. J Bone Joint Surg. 1982;64A:959.
14. Salzer M, Knahr K, Kotz R *et al.* Treatment of osteosarcoma of the distal femur by rotationplasty. Arch Orthop Traum Surg. 1981;99:131.
15. Malawer MM, Price WM. Gastrocnemius transposition flap in conjunction with limbsparing surgery for primary sarcomas around the knee. Plast Reconstruc Surg. 1984;73:741–9.
16. Malawer M, Canfield D, Meller I. Porouscoated segmental prosthesis for large tumor defects. A prosthesis based upon immediate fixation (PMMA) and extracortical bone fixation. In: Yamamuro T, editor. International Symposium on Limb Salvage in Musculoskeletal Oncology. New York: Springer Verlag; 1988;247–55
17. Malawer M, Meller I. Extracortical fixation of large segmental prostheses and description of a modular segmental replacement system (MSRS). In Fifth International Symposium of Limb Sparing Surgery. St Malo, France, September 1989.
18. Henshaw RM, Jones V, Malawer MM. Endoprosthetic reconstruction with the modular replacement system. Survival analysis of the first 100 implants with a minimum 2 year follow-up. Fourth Annual combined Meeting of the American and European Musculoskeletal Tumor Societies; May 1998; Washington, DC.
19. Rosen G, Marcove RD, Caparros B *et al.* Primary osteogenic sarcoma. The rationale for preoperative chemotherapy and delayed surgery. Cancer. 1979;43:2163–77.
20. Huvos AG, Rosen G, Marcove RC. Primary osteogenic sarcoma. Pathologic aspects in 20 patients after treatment with chemotherapy, en bloc resection, and prosthetic bone replacement. Arch Pathol Lab Med. 1977,101:14.
21. Winkler Beron G, Kotz R *et al.* Neoadjuvant chemotherapy for osteogenic sarcoma: results of a cooperative German/ Austrian study. J Clin Oncol. 1984;2:617.
22.
23. Enneking WF, Shirley PD. Resection arthrodesis for malignant and potentially malignant lesions about the knee using an intramedullary rod and local bone graft. J. Bone Joint Surg Am. 1977;59:223–35.