BACKGROUND

- The proximal femur and the midfemur are common sites for primary bone sarcomas and metastatic tumors.
- Formerly, patients who were candidates for extensive femoral resection because of malignant tumor were considered a high-risk group for limb-sparing procedures because of the extent of bone and soft tissue resections and the anticipated poor function postoperatively, as well as the deleterious consequences of adjuvant chemotherapy and radiation therapy. Hip disarticulation or hemipelvectomy were, therefore, the classic treatment options for patients with large lesions of the proximal femur or midfemur. Both procedures were associated with a dismal functional, aesthetic, and psychological outcome.
- Today, improved survival of patients with musculoskeletal malignancies, developments in bioengineering, and refinements in surgical technique have enabled these patients to undergo limb-sparing procedures. Local tumor control is good, as is the probability of a functional extremity. Proximal and total femur resection became a reliable surgical option in the treatment of primary bone sarcomas and metastatic bone disease and, more recently, of a variety of nononcologic indications. These latter indications include failure of internal fixation, severe acute fractures with poor bone quality, failed total hip arthroplasty, chronic osteomyelitis, metabolic bone disease, and various congenital skeletal defects.1,4
- Methods of skeletal reconstruction include resection arthrodesis, massive osteocarticular allograft, endoprosthetic reconstruction, and prosthetic allograft composites.1,8
- Osteocarticular allografts, which were popular in the 1970s and 1980s, aim to restore the natural anatomy of a joint by matching the donor bone to the recipient’s anatomy, but they are associated with increased rates of infection, nonunion, instability, fracture, and subchondral collapse and thus ultimate failure.6,8
- Introduced in the mid-1980s, modular prostheses revolutionized endoprosthetic reconstruction. The modular system enables the surgeon to measure the actual bone defect at the time of surgery and select the most appropriate components to use in reconstruction. Components of these interchangeable systems include articulating segments, bodies, and stems of varying lengths and diameters. Design features include extensive porous coating on the extracortical portion of the prostheses for bone and soft tissue fixation and metallic loops to assist in muscle reattachment (FIG 1).
- Prosthetic reconstruction of the proximal and total femur has been shown to be associated with good function and minimal morbidity in most patients.1 Preservation of the joint capsule and reattachment of the abductor mechanism have also been shown to considerably decrease the rate of dislocation, traditionally the most common complication of endoprosthetic reconstruction at that site.4

ANATOMY

- The intracapsular location of the femoral neck makes it biologically possible for tumors of the proximal femur to spread into the hip and adjacent synovium, joint capsule, and ligamentum teres. The ligamentum teres provides a mechanism for transarticular skip metastases to the acetabulum. Fortunately, intra-articular involvement is rare and usually occurs after a pathologic fracture. The capsule can be preserved and an intra-articular resection of the femur is usually possible. In the case of capsular or acetabular involvement or both, extra-articular resection of the hip should be considered.
- The greater trochanter, which is removed with the surgical specimen, serves as the attachment site for the hip abductors. The tendon stump should be marked and preserved for reattachment to the prosthesis.
- The lesser trochanter, which is removed with the surgical specimen, serves as the attachment site for the psoas muscle. The tendon stump should be marked and preserved for reattachment to the prosthesis. The combined attachment of the abductors and psoas to the lateral and medial aspects of the prosthesis, respectively, preserves balanced prosthetic range of motion (FIG 2).
- The femoral artery descends the thigh almost vertically within the sartorial canal toward the adductor tubercle of the femur, enters the opening of the canal of Hunter at the adductor magnus muscle, and becomes the popliteal artery. The profunda femoris artery branches to the medial aspect of the femoral artery 4 cm below the inguinal ligament. Occasionally, the profunda femoris is ligated and resected en bloc with large tumors of the proximal femur.
- Ligation of the profunda femoris in an adolescent patient with patent vasculature of the lower extremity is not expected to result in vascular compromise. However, preoperative angiography is strongly recommended in adults because ligation of the profunda femoris in the presence of an occluded superficial femoral artery may result in an ischemic extremity and the subsequent need for amputation.
- The knee joint is seldom directly invaded by tumors of the femur that extend to its distal aspect. When it does occur, invasion is usually the result of a pathological fracture, contamination due to an improper biopsy technique, or tumor extension along the cruciate ligaments. The presence of hemarthrosis suggests intra-articular disease, and intra-articular resection of the knee joint (ie, en bloc resection of the femur with the knee joint capsule and articular surface of the proximal tibia) should be considered in those cases.

INDICATIONS

- Primary bone sarcomas (FIG 3)
- Benign aggressive tumors associated with extensive bone destruction (FIG 4A)
Metastatic tumors associated with extensive bone destruction (FIG 4B).

Nononcologic indications include failure of internal fixation, severe acute fractures with poor bone quality, failed total hip arthroplasty with segmental bone loss below the level of the lesser trochanter, chronic osteomyelitis, metabolic bone disease, and various congenital skeletal defects (FIG 4C).

Proximal femur resection is performed for metaphyseal-diaphyseal lesions that (1) extend below the lesser trochanter, (2) cause extensive cortical destruction, and (3) spare at least 3 cm of the distal femoral diaphysis. Total femur resection is performed for diaphyseal lesions that (1) extend proximally to the lesser trochanter and distally to the distal diaphyseal-metaphyseal junction and (2) cause extensive bone destruction (FIG 4D).

**IMAGING AND OTHER STAGING STUDIES**

- Proximal and total femur resections are major surgical procedures that necessitate an especially detailed preoperative evaluation. Physical examination and imaging studies are done to determine (1) the extent of bone resection and dimensions of the required prosthesis, (2) the extent of soft tissue...
resection and reconstruction possibilities, and (3) the proxim-
ity of the tumor to the femoral vessels, femoral nerve, and sci-
atic nerve.

Most complications can be avoided by predicting their
likelihood before surgery and modifying the surgical tech-
nique accordingly. A full range of imaging studies is needed,
including plain radiography, computed tomography (CT),
and magnetic resonance imaging (MRI) of the whole femur
and the hip and knee joints. CT and plain radiography are
used to evaluate the extent and level of bone destruction;
MRI is used to evaluate the medullary and extraosseous
components of the tumor, the intracapsular tumor extension,
and the presence of skip metastases within the femoral canal
and in the acetabulum.

Angiography of the iliofemoral vessels is essential before
resection of tumors of the proximal femur. Vascular displace-
ment is common when tumors have a large, medial extraosseous
component: the profundus femoral artery is particularly vulner-
able to distortion or, less commonly, to direct incorporation
into the tumor mass. If the tumor has a large medial extra-
osseous component and ligation of the profundus femoral
artery is anticipated, the presence of a patent superficial femoral
artery must be documented by angiography before surgery.
Preoperative embolization may be useful to prepare for resec-
tion of metastatic vascular carcinomas if an intrallesional proce-
dure is anticipated. Metastatic hypernephroma is an extreme
eexample of a vascular lesion that may bleed extensively and
cause exsanguination if an intralesional procedure is done with-
out prior embolization.

**SURGICAL MANAGEMENT**

- Limb-sparing surgery that involves endoprosthetic replace-
ment of the proximal or the entire femur is done in three steps:
tumor resection, endoprosthetic reconstruction, and soft tissue
reconstruction. The technique of proximal femur endopros-
thetic replacement is described in the following paragraphs.
The additional steps required for total femur resection are
described at the end of the appropriate sections.

- In general, surgery for metastatic tumors to the proximal
femur is not different from surgery for primary sarcomas of
bone. The main differences are that metastatic lesions have a
smaller extraosseous component than primary lesions, and the
surrounding muscles are usually invaded by the metastatic
lesions (as opposed to the “pushing” border of bone sarcomas).
TUMOR RESECTION

Position and Incision

- The patient is placed in a lateral position and a long lateral incision is made extending from 3 to 4 cm proximal to the greater trochanter to the distal two thirds of the thigh (TECH FIG 1A,B). An ilioinguinal extension to that incision is added if the tumor has an extensive, medial soft tissue component along the proximal femur. This approach allows exposure of the proximal third of the femur and the retrogluteal area and allows for identification of the femoral canal, femoral triangle, superficial and profundus femoral artery, and sartorial canal.

- Posterior reflection of the gluteus maximus muscle exposes the retrogluteal area and allows for identification of the femoral canal, femoral triangle, superficial and profundus femoral artery, and sartorial canal.

- Posterior reflection of the gluteus maximus muscle exposes the retrogluteal area, external rotators, sciatic nerve, abductors, and posterior capsule. If total femur resection is performed, the incision is brought distally to the proximal femur. This approach allows exposure of the proximal third of the femur and the retrogluteal area and allows for identification of the femoral canal, femoral triangle, superficial and profundus femoral artery, and sartorial canal.

- Posterior reflection of the gluteus maximus muscle exposes the retrogluteal area, external rotators, sciatic nerve, abductors, and posterior capsule. If total femur resection is performed, the incision is brought distally to the proximal third of the femur and the retrogluteal area and allows for identification of the femoral canal, femoral triangle, superficial and profundus femoral artery, and sartorial canal.

Gluteus Medius and Maximus Detachment

- The iliotibial band is opened longitudinally to allow adequate anterior and posterior exposure and partial detachment of the femoral insertion of the gluteus maximus muscle. Posterior reflection of the gluteus maximus muscle allows ligation of the first perforating artery, which is in intimate apposition with the gluteal tendon attachment. The gluteus maximus is then further retracted in a posterior direction, exposing the retrogluteal area, external rotators, sciatic nerve, abductors, and posterior capsule (TECH FIG 2A,B).

- The sciatic nerve lies directly posterior to the external rotators. In general, as primary bone sarcomas expand, the external rotators are pushed outward and act as protective barrier to the sciatic nerve. As such, the sciatic nerve is often not in its usual anatomic location in these patients and must be identified early, isolated, and mobilized posteriorly to prevent injury. The abductors are identified with their anterior and posterior intervals. If there is no tumor involvement, the greater trochanter or small bony attachment is osteotomized; otherwise, the abductors are transected through their tendinous attachments and retracted, exposing the hip joint and acetabulum (TECH FIG 2A,B).

Vastus Lateralis Reflection

- The vastus lateralis is transected from its origin at the vastus ridge and reflected distally, and the posterior perforating vessels are ligated (TECH FIG 3A,B). The vastus lateralis must be preserved because of its future role in soft tissue coverage of the prosthesis: it will be advanced proximally and sutured to the abductors (see FIG 4 • A. Giant cell tumor of the proximal femur with a pathological hip fracture. B. Metastatic carcinoma of the proximal femur with a pathological subtrochanteric fracture. C. Chronic and neglected osteomyelitis of the proximal femur, associated with a nonunion of an insufficiency fracture, debilitating pain, and loss of function. Performance of a proximal femur resection with endoprosthetic reconstruction resulted in complete resolution of pain and considerable functional improvement. D. Section through a large osteosarcoma of the femur, the medial perosteal reaction of which extended beyond the lesser trochanter, thus necessitating total femur resection for its removal.
Chapter 24 PROXIMAL AND TOTAL FEMUR RESECTION WITH ENDOPROSTHETIC RECONSTRUCTION

TECH FIG 1 • Illustration (A) and operative photograph (B) showing a long lateral incision used for resection of the proximal or the whole femur. C,D. The incision is brought distally to the anterolateral aspect of the patellar tendon and tibial tuberosity for exposure of the entire femur. If the tumor has medial or posterior soft tissue extensions at the distal femur that require dissection at the medial aspects of the knee and popliteal fossa, the incision is curved medially at its distal part. (A: Reprinted with permission from Clin Orthop Relat Res 2000;375:218–230.)

TECH FIG 2 • The proximal femur after posterior retraction of the gluteus maximus and exposure of the retrogluteal area, external rotators, sciatic nerve, abductors, and posterior capsule. Because of tumor extension into the greater trochanter in the illustrated case, the abductors are identified and transected through their tendinous attachments and retracted, exposing the hip joint and acetabulum. If the greater trochanter is not involved by tumor extension, it is osteotomized and reflected with the abductor tendon. (A: Reprinted with permission from Clin Orthop Relat Res 2000;375:218–230.)
“Soft Tissue Reconstruction” below). Care is taken not to ligate its main pedicle, which crosses anteriorly and obliquely along the rectus femoris fascia.

- The femoral nerve is identified below the fascia (TECH FIG 3A,B). The superficial and profundus femoral artery and vein are identified in the sartorial canal and retracted. If they are invaded by the soft tissue extension of the tumor, the profundus artery and vein may be ligated just distal to their takeoff from the common femoral vessel.

### Detachment of Posterior Hip Musculature and Capsule, Dislocation of Femur

- With the retrogluteal area exposed, the rotator muscles are detached en bloc 1 cm from their insertion on the proximal femur. The hip joint capsule has a major role in securing and stabilizing the head of the prosthesis within the acetabulum, and if not invaded by tumor, it should remain intact.
- The capsule is opened longitudinally along its anterolateral aspect and detached circumferentially from the femoral neck. The femur is dislocated anterolaterally. Special care is taken not to fracture the femoral neck, especially if a primary bone sarcoma is being resected. The acetabulum is inspected for evidence of joint involvement (TECH FIG 4A,B). If total femur resection is performed, a tibial osteotomy is carried out in the same manner as a standard knee joint arthroplasty, in which about 1 cm of bone is removed, the cut is perpendicular to the long axis of the tibia, and the insertion of the biceps femoris muscle is retained.
- After femoral osteotomy or disconnection of the entire femur after tibial osteotomy, the femur is retracted laterally. The remaining medial structures are now clearly visible: they consist of the psoas and adductor muscles, which should be identified either now or at some point before the femur is osteotomized. The muscles are serially dissected, clamped with Kelly clamps, and tagged with Dacron tapes. Care is taken to dissect the profundus femoral artery.
- If oncologically indicated, the profundus femoral artery may be ligated, but only after patency of the superficial femoral artery has been confirmed.

### Distal Femoral Osteotomy and Release of Medial Structures

- Femoral osteotomy is performed at the appropriate location, as determined by the preoperative imaging studies. In general, 3 to 4 cm beyond the farthest point is appropriate for primary sarcomas and 1 to 2 cm for metastatic carcinomas. An oscillating saw is used for the osteotomy, and a malleable retractor is placed medially to the femoral shaft to prevent inadvertent injury to the soft tissues. The cut should be at a right angle to the shaft (TECH FIG 5).
- It is important not to distract the extremity after removal of the proximal femur to avoid placing tension on the sciatic nerve and femoral vessels. If total femur resection is performed, a tibial osteotomy is carried out in the same manner as a standard knee joint arthroplasty, in which about 1 cm of bone is removed, the cut is perpendicular to the long axis of the tibia, and the insertion of the biceps femoris muscle is retained.

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Chapter 24  PROXIMAL AND TOTAL FEMUR RESECTION WITH ENDOPROSTHETIC RECONSTRUCTION

TECH FIG 4 • Illustration (A) and operative photograph (B) showing detachment of the posterior hip musculature and capsule. Illustration (C) and operative photograph (D) showing the arthrotomy of the knee joint that is required to accomplish total femur resection. An anterolateral arthrotomy using the initial lateral incision is usually feasible. However, if the tumor extends toward the popliteal fossa and delicate dissection of the popliteal vessels is anticipated, anteromedial knee exposure and medial exposure of the popliteal fossa are done as for resection of the distal femur. The femur will be removed with the overlying vastus intermedius; the rectus femoris and patella are spared. (A: Reprinted with permission from Clin Orthop Relat Res 2000;375:218–230; C: Courtesy of Martin M. Malawer.)

TECH FIG 5 • Distal femur osteotomy and removal of the proximal femur. The femoral osteotomy is done 3 to 4 cm beyond the farthest point of tumor extension for primary sarcomas and 1 to 2 cm for metastatic carcinomas. (A: Courtesy of Martin M. Malawer.) (continued)
ENDOPROSTHETIC RECONSTRUCTION

- After resection of the proximal femur, the length of the resected specimen, the size of the femoral head, and the diameter of the distal medullary canal are measured. A trial femoral head prosthesis is used to test the suction fit. The proximal end of the remaining femur should be kept well padded to avoid injuring the superficial femoral artery. A frozen section from the canal is evaluated for evidence of residual tumor before reaming the femoral canal.

Reaming the Intramedullary Canal

- The largest possible stem diameter should be chosen, especially for primary tumors. A 1-mm cement mantle is required around the stem. The intramedullary canal is therefore reamed 2 mm larger than the chosen stem diameter (TECH FIG 6).

Trial Articulation

- Modular trial prosthetic components should be assembled to match the length of the resected specimen. These include body parts, a neck, and prosthetic head (TECH FIG 7A–C). Total femur prostheses are joined to the tibial component with a rotating hinge mechanism (TECH FIG 7D,E). After trial positioning of the prosthesis, the pulses are palpated distally: a shorter prosthesis will be required if they are diminished. The joint capsule is pulled over the femoral head component, and the range of motion of the hip joint is tested. The prosthesis should be stable in flexion, adduction, and internal rotation.
Chapter 24 PROXIMAL AND TOTAL FEMUR RESECTION WITH ENDOPROSTHETIC RECONSTRUCTION

Prosthetic Assembly and Implantation

- The modular prosthesis is assembled and cemented into the medullary canal. The orientation of the prosthesis is critical. With the linea aspera as the only remaining anatomic guideline, the prosthesis is placed with the femoral neck anteverted about 5 to 10 degrees with respect to an imaginary perpendicular line from the prosthesis and a line is drawn from the linea aspera through the body of the prosthesis (TECH FIG 8).

- Two bags of bone cement are usually required, and the cementing technique consists of pulsatile lavage, use of an intramedullary cement restrictor, reduction of the cement by centrifugation, use of a cement gun, pressurization of the cement, and enhancement of the prosthesis–cement interface by precoating the proximal portion of the femoral or tibial stem with bone cement. While the bone cement hardens, the surgeons continuously verify the correct positioning of the prosthesis.

SOFT TISSUE RECONSTRUCTION

- Special attention is given to re-establishing hip stability and providing adequate muscle coverage of the prosthesis. The remaining hip capsule is sutured tightly with a 3-mm Dacron tape (Deknatel, Falls River, MA) around the neck of the prosthesis, forming a noose that provides immediate stability (TECH FIG 9A–D). Dacron is a nonabsorbable synthetic polyester (polyethylene-terephthalate) that allows approximation of the cut ends of the joint capsule under considerable tension. It provides the initial mechanical support needed for healing and scar formation throughout the capsule. The surgeon cannot dislocate the prosthesis in a capsule that is
adequately closed. Stabilization of the prosthesis is reinforced by rotating the external rotator muscles proximally and suturing them to the posterolateral aspect of the capsule. The psoas muscle is rotated anteriorly and tenodesed to the anterior capsule as additional reinforcement (TECH FIG 9E,F).

- The extracortical component of the prosthesis can be used for additional bone and soft tissue fixation in the form of a noose around the prosthesis. Bone struts, either autografts or allografts, are held circumferentially with Dacron tape to the prosthesis-host bone interface. Theoretically, this procedure will prevent debris from entering the bone-cement interface, thereby reduce the possibility of aseptic loosening.

- If the greater trochanter had been resected en bloc with the surgical specimen, the remaining abductor tendon is attached with Dacron tape to the lateral aspect of the prosthesis through a metal loop. If there is a remaining fragment of the greater trochanter, it is fixed to the prosthesis with a cable grip system (TECH FIG 9G). Dynamic reconstruction is obtained by tenodesing the vastus lateralis to overlie the abductor muscle fixation. The remaining muscles are sutured to the vastus lateralis anteriorly and the hamstrings posteriorly (TECH FIG 9H,I).

- The wound is closed over a 28-gauge chest tube that is attached to a continuous suction at 20 cmH₂O (TECH FIG 9J). The patient is placed in balanced suspension or tibial pin traction with the hip elevated and flexed 20 degrees.

TECH FIG 9 • A–D. The remaining hip capsule is sutured tightly with a 3-mm Dacron tape (Deknatel, Falls River, MA) around the neck of the prosthesis. E. The psoas muscle is rotated anteriorly and tenodesed to the anterior capsule as additional reinforcement. F. Alternatively, a circumferential polyethylene-terephthalate tube may be applied on the prosthesis to which the surrounding muscles and tendons can be sutured. G. Fixation of the greater trochanter to the lateral aspect of the prosthesis with a cable grip system. (continued)
POSTOPERATIVE CARE
- The extremity is kept in balanced suspension for at least 5 days. An abduction brace is customized for the patient. Continuous suction is required for 3 to 5 days, and perioperative intravenous antibiotics are continued until the drainage tubes are removed.
- Postoperative mobilization with an abduction brace and weight bearing as tolerated are continued for 6 weeks. Active hip abduction is required before the brace can be removed and before unprotected, full weight bearing can be allowed.

OUTCOMES
- More than 80% of patients who undergo proximal or total femur resection report good to excellent function. Most of them do not require a walking aid (crutches, walker, or cane), although some abductor insufficiency and Trendelenburg gait are common.
- No differences in function were found between patients who underwent proximal femur replacement and those who underwent total femur replacement.
- Dislocations of the prosthesis have become rare due to the combined use of capsular repair and reconstruction of the abductor mechanism. Because of the excellent blood supply around the proximal thigh and hip joint and the options for prosthetic coverage with viable muscle tissue, flap ischemia, deep infections, and prosthetic loosening are rare.

COMPLICATIONS
- Deep infection
- Dislocation
- Abductor insufficiency and Trendelenburg gait
- Local tumor recurrence
- Prosthetic loosening

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