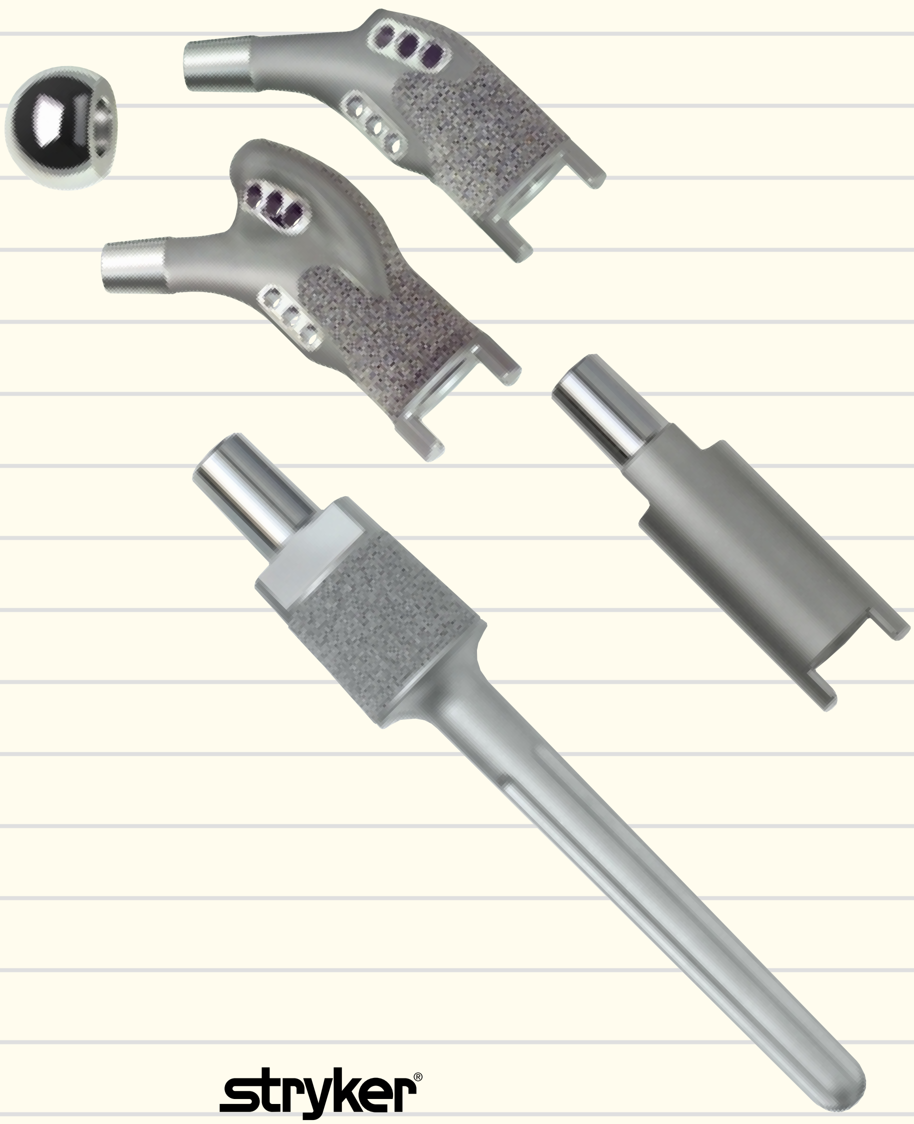
S U R G I C A L   T E C H N I Q U E

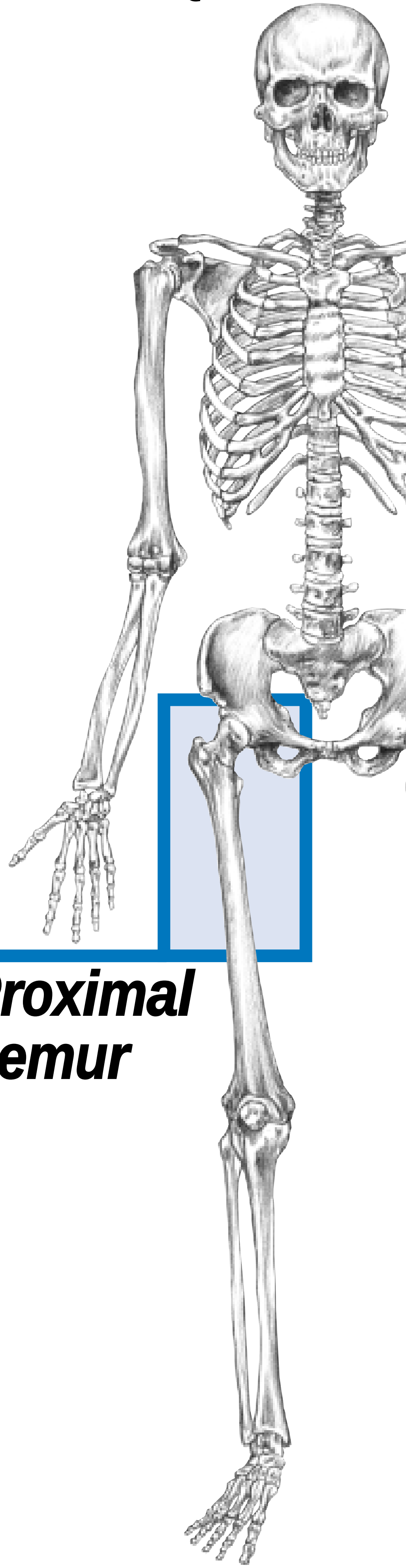
MRS

MODULAR · REPLACEMENT · SYSTEM

Proximal Femoral Resection for Large Segmental Replacements

Martin M. Malawer, MD, FACS





Proximal Femur

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Modular Replacement System[*] Proximal Femoral Resection for Large Segmental Replacements Surgical Technique

Martin M. Malawer, MD, FACS
Director, Orthopedic Oncology
Washington Cancer Institute
Washington Hospital Center, Washington, DC

Professor, Orthopedic Surgery
George Washington University School of Medicine
Washington, DC

Overview

Tumors involving the proximal femur are difficult to treat. The classic treatment of most bony sarcomas of the proximal femur has been a hemipelvectomy. Osteosarcoma and chondrosarcoma are the two most common bone sarcomas. Osteosarcomas occur primarily in adolescents and young adults, whereas chondrosarcomas occur with increasing frequency after the fourth decade of life. The proximal femur is the site in approximately 5% of osteosarcomas and 25% to 30% of chondrosarcomas of bone. Metastatic cancer to the proximal femur is the most common malignancy of the hip and can often require major surgical intervention, especially when standard surgical treatments fail or when the tumor is unusually large or recurrent. The Modular Replacement System (MRS) was initially developed to treat both primary and metastatic tumors involving the proximal femur.

Recently, the MRS has been used for difficult revision surgery, often following multiple failed attempts of hip revisions.

This publication sets forth detailed recommended procedures for using Howmedica Osteonics devices and instruments. It offers guidance that you should heed, but, as with any such technical guide, each surgeon must consider the particular needs of each patient and make appropriate adjustments when and as required.

DESCRIPTION OF THE PROXIMAL FEMORAL MODULAR REPLACEMENT SYSTEM

The Modular Replacement System (MRS)[†] was developed to meet the unique needs of patients who require reconstruction of large segmental defects for tumors. This system is designed to:

- Reconstruct large segmental defects of the proximal femur.
- Reconstruct osteoarticular defects of varying sizes.
- Allow for variation and intraoperative changes to the surgical plan.

The system consists of proximal femoral segments, body segments, and stem segments. It also includes a complete set of trial components and instrumentation. The implants utilize a male/female taper locking mechanism. The components are assembled during surgery by impacting them together. The impaction causes the tapers to securely lock the components together.

Femoral Components

The proximal femoral segments have a replacement length of 70mm which is measured to the center of the standard length femoral head.

NOTE: The Modular Replacement System Proximal Femoral Segments (6485-0-001 and 6485-0-006) accept Howmedica Osteonics femoral head implants with the 5°40' taper (V40™ femoral heads).

The Proximal Femoral Segments have fixation holes to reattach the abductor mechanism.

The femoral body segments are used to extend the replacement length, and are available in 40mm through 220mm lengths in 20mm increments. This component features a male and a female taper to attach a stem to the proximal femoral component. The body segments have an overall diameter of 28mm.

V40™ FEMORAL HEADS

PROXIMAL FEMORAL SEGMENT 6485-0-001

PROXIMAL FEMORAL SEGMENT 6485-0-006

FEMORAL BODY SEGMENT

The femoral stem segments come in two styles. The first style has an extra-cortical porous-coated body section which adds 40mm to the replacement length. The femoral stems are also available without the extra-cortical porous-coated body section. This style stem adds 11mm to the overall replacement length. Both style stems come in two lengths: 127mm and a 203mm long stem. The 203mm long stems are bowed to match the curvature of the anatomic femur. Both stem lengths taper slightly toward the end. All femoral stems are available in 11mm, 13mm, 15mm, and 17mm diameters; their respective seat diameters at the resection level are 24mm, 28mm, 32mm, and 36mm, which allows close matching of host bone diameter. The stem segments are designed to be cemented into the medullary canal.

Optional Stem Centralizers are available for the 127mm length femoral stems.

FEMORAL STEM WITHOUT BODY SECTION

FEMORAL STEM WITH POROUS COATED BODY SECTION

FEMORAL CURVED LONG STEM WITHOUT BODY SECTION

FEMORAL CURVED LONG STEM WITH POROUS COATED BODY SECTION

Acetabular Components

This surgical technique focuses on the reconstruction of the hip joint using the Howmedica Osteonics Centrax® or UHR® Bipolar components.

NOTE: The UHR® Bipolar component can only be used with the V40™ femoral heads.

If the surgeon believes adequate joint stability can be gained, or for oncological considerations, the reconstruction can also be done with any of Howmedica Osteonics fixed acetabular component offerings.

Trial Components

The implant system is complemented with a complete set of trial components. The trial components are replicas of their corresponding implants; however, they have non-locking trunnions. The trials are satin-finished so that they can easily be distinguished from the prosthesis. The body and stem segments also have large holes drilled through the major diameter to distinguish them from the implants.

Preoperative Evaluation and Staging Studies

Staging studies should be performed before biopsy if the plain radiograph suggests a malignant tumor. Preoperative studies allow the surgeon to conceptualize the local anatomy, and thereby appreciate the volume (en bloc) of tissue to be resected and the extent of surgical reconstruction that will be needed. All patients should be considered candidates for limb-sparing procedures unless a surgical oncologist familiar with these procedures believes that a non-amputative option has little chance of success.

Plain Radiographs

Plain radiographs are often the key to the accurate diagnosis of a bony lesion. If multiple lesions are noted, or if the appearance on the X-rays seems to be permeative, metastatic carcinoma is likely. Any patient over the age of 40 with involvement of the proximal femur should be considered to have metastatic disease initially; younger patients tend to have primary sarcomas of the proximal femur. Two exceptions are malignant fibrohistiocytoma (MFH) of bone, which occurs in the over 40-year-old age group, and chondrosarcoma of the proximal femur which increases in occurrence with each decade of life. The acetabulum should be evaluated at this time.

Bone Scan

Three-phase bone scan is essential to determine if there are multiple lesions (an indication of metastatic disease) or a solitary (proximal) tumor. Bone scintigraphy is useful in determining intraosseous extension of tumor. In general, the area of uptake accurately corresponds to tumor extent. Bone scintigraphy, CT, and MRI also help determine the length of the bone to be resected. Bone scan, as well as thallium scan, can be used to follow the response of primary sarcomas following neoadjuvant chemotherapy. Both the pool and flow phases should show a decrease following induction chemotherapy.

MRI and CT

Magnetic resonance imaging and computed axial tomography are the most accurate means of determining soft-tissue extension and bony ballooning of the primary lesion. It is important to note the direction of the soft-tissue component, since this might determine the type of incision to be utilized. If soft-tissue extension is minimal and the tumor is a primary carcinoma, a standard total hip prosthesis can be used.

Extra-articular extension is evaluated by examining the hip joint and the acetabulum and looking for evidence of disease on the opposite side of the acetabulum. Osteosarcomas may present with a skip metastasis across the ligamentum teres into the periacetabular bone.

Angiography

Angiography of the iliofemoral arteries, including the superficial femoral arteries and the profundis artery, is useful prior to resection of tumors of the proximal femur. Vascular displacement is common when tumors have large extraosseous components, and would indicate a necessity for early exploration of the superficial femoral artery. The profundis femoral artery is particularly likely to be distorted by large tumors.

Preoperative embolization is very useful for metastatic carcinomas if an intra-lesional procedure is anticipated. Hypernephroma is the most common malignancy of the proximal femur that requires embolization prior to resection or segmental replacement. Hypernephromas are extremely vascular, and embolization can minimize blood loss.

Biopsy

If a resection is to be performed, it is crucial that the location of the biopsy be in line with the anticipated incision for the definitive procedure. Extreme care should be taken before biopsy 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 whenever possible. Radiographs should be obtained to document the position of the trocar. Needle biopsy usually provides an adequate specimen for diagnosis. If it proves to be inadequate, a small incisional biopsy is performed. 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.

Unique Oncological Considerations

Primary Sarcomas of the Proximal Femur

Within the past decade, techniques of surgical resection and reconstruction have been developed that successfully substitute a limb-sparing surgery for amputation in many patients. Today, high-grade sarcomas are treated with neoadjuvant induction chemotherapy in an attempt to shrink the extra-osseous component prior to surgical resection. Low-grade chondrosarcomas are not typically treated by chemotherapy. They often attain a large size and can be successfully resected.

Primary sarcomas of bone often have large extra-osseous components, and local control is of primary importance. Today, most primary malignant tumors of the proximal femur, including osteosarcomas, chondrosarcomas, and Ewing's sarcomas, can be treated by a limb-sparing procedure following induction chemotherapy.

The types of primary bone tumors treated by a proximal femoral resection in lieu of an amputation or radiation therapy are:

- High-grade osteosarcoma.
- Low- to intermediate-grade sarcoma.
- Low- or high-grade chondrosarcoma.
- Round-cell tumors of the bone, specifically Ewing's sarcoma and peripheral neuroectodermal tumors.
- Other benign primary bone tumors.

Osteosarcoma

Osteosarcomas of the proximal femur require careful preoperative imaging and neoadjuvant chemotherapy. If response to preoperative neoadjuvant chemotherapy is good, a limb-sparing resection is possible and an intra-articular or extra-articular resection is performed. Pathological fracture through a malignant tumor may indicate the need for a hemipelvectomy. Extra-articular resection may be performed.

Chondrosarcoma

Chondrosarcomas of the proximal femur can be extremely large. Traditionally, they have been treated with a modified hemipelvectomy. At present, neoadjuvant chemotherapy is not effective. Surgical resections often yield local control and a good, functional extremity. Postoperative radiation therapy may be warranted. Extreme care must be taken not to inadvertently enter the tumor, since cartilage cells easily grow in soft-tissues. Approximately one-half of all chondrosarcomas are low- to intermediate-grade.

Ewing's Sarcoma and Peripheral Neuroepidermal Tumors of Bone

Since the late 1980s, the tendency has been to treat these tumors with local surgery in lieu of high-dose radiation therapy. The goal is to increase the rate of local control, avoid delayed problems with high-dose radiation therapy, and improve the patient's quality of life. Complications of radiation therapy often include contractures, fracture, nonunion, shortening, and infection. Ewing's sarcomas and the associated other round-cell tumors (commonly called peripheral neuroepidermal tumor, or PNET), are treated under most current intergroup protocols by induction chemotherapy. Shrinkage of soft-tissue components is fairly predictable. Round-cell tumors often respond more dramatically than do the spindle-cell sarcomas. Following neoadjuvant induction therapy, imaging studies are done as discussed above. If a resection cannot be performed, radiation therapy is utilized. Amputations are not performed for Ewing's sarcomas, PNETs of bone, metastatic disease, and local recurrence. Today, induction chemotherapy, followed by primary resection and replacement with a segmental prosthesis, is recommended. Postoperative radiation therapy is usually not given if the margins are negative.

Other Benign Primary Bone Tumors

Giant cell tumors of bone, chondroblastoma, and chondromyxoidfibromas are all nonmalignant, highly aggressive, locally benign tumors that can be found in the proximal femur. They cause a large amount of bone destruction. The aggressive, Stage 3 (Campanacci - Enneking) giant cell tumor is the most common type. Occasionally, chondroblastoma can be very aggressive, as can the rare chondromyxoidfibroma. Curettage and cementation are most successful for these lesions; when this fails, reconstruction by a proximal femoral resection and replacement can be curative. They can be treated by surgical technique similar to those used for low-grade sarcomas. Only minimal soft-tissue resection is usually required.

Metastatic Cancer of the Proximal Femur

The most common malignancy of the proximal femur is metastatic carcinoma. On autopsy studies, approximately 80% of patients with carcinomas demonstrate skeletal metastases; the spine, pelvis, and the proximal femur are the most common sites. Tumors spread to the proximal femur through Batson's plexus of veins. Spread to this area is often silent and detected only following a pathological fracture or pending fracture. Tumors, other than carcinomas that may metastasize to the proximal femur, include leiomyosarcomas, melanomas, sarcomas, hematological malignancies (especially lymphomas) and clear-cell carcinomas (hypernephromas) of renal cell origin.

Many studies have attempted to identify which patients should be treated with palliative radiation therapy and which should undergo surgical reconstruction. Results of histiogenic studies have prognostic value.

Only 5%-10% of patients with metastases to the proximal femur require surgery. A large majority respond well to radiation therapy. Tumors that traditionally do not respond well to radiation therapy include lung carcinomas, hypernephromas, colorectal carcinomas, some prostate carcinomas, and other atypical carcinomas. The most common carcinomas that can be satisfactorily treated with radiation therapy are breast carcinomas and multiple myelomas.

When radiation therapy fails or the tumor progresses in size and a pathological fracture occurs, surgery is warranted. In general, large tumors of the femoral neck and subtrochanteric area are best treated by resection and insertion of a cemented long-stem endoprosthesis with a bipolar component. Care must be taken to evaluate the entire femur to ensure that all lesions in the femoral shaft are curetted and that the femoral stem is long enough. When a simple resection and endoprosthetic replacement cannot be performed or is not indicated, a primary resection of the bone and reconstruction with the Modular Replacement System can provide a functional extremity. The surgical technique and exposure can be modified when there is minimal or a large extraosseous component. In general, treatment of metastatic cancer to the proximal femur requires the same surgical techniques as do primary sarcomas; the major exception is that there is minimal soft-tissue resection.

The major indications for segmental proximal femoral resection, in lieu of insertion of a long-stem prosthesis in the treatment of metastatic carcinomas, are:

- Extremely large tumor.
- Failed radiation therapy.
- Failed previous operative procedures (standard endoprosthetic replacement or intramedullary rod placement).
- Solitary metastatic carcinoma (occurs in approximately 5% of metastatic carcinomas of the bone).

Today, lung cancer occurs with equal frequency in females and males. These patients typically live only 3 to 6 months after diagnosis. Radiation is usually not successful in obtaining local control or permitting full weight bearing; therefore, surgery is warranted. Endoprosthetic replacement is recommended.

A subgroup of patients with metastatic breast cancer deserves special consideration. These are women who develop metastatic skeletal disease without any evidence of visceral disease. In this subgroup, which constitutes approximately 20% of breast cancer patients, the average survival is significantly longer than that in patients with visceral involvement. They should be treated vigorously and aggressively with surgical reconstruction, be it by endoprosthetic replacement or segmental replacement. The goal of treatment should be long-term improvement in quality of life. Life expectancy for this subgroup may range from 2 years to 20 years.

Solitary Metastatic Hypernephroma

Solitary hypernephroma (renal cell carcinoma) of bone is rare. If there is no evidence of metastatic disease of other sites, resection may be curative. Long-term cure or control can be obtained by primary resection of these areas following the guidelines presented under sarcoma resections. It is important that hypernephromas undergo preoperative embolization to avoid excessive bleeding. Imaging studies are similar to those described above.

Figure 1a ▸

Plain radiograph of a composite allograft and long-stem prosthesis showing a persistent non-union of the graft-femur junction. This procedure was performed for a parosteal osteosarcoma of the proximal femur. This patient was non-ambulatory due to persistent pain from the non-union for two years despite several attempts at correction. In addition, this patient had sustained several dislocations and failed attempts of trochanteric (abductor) repair.

Other Non-Neoplastic Indications for Use of the Modular Replacement System

The Modular Replacement System has been used in a variety of other difficult cases, usually following failed surgery for primary tumors of the proximal femur. These include:

- Revision of failed proximal femoral allografts or osteoarticular allografts.
- Failed curettage (with or without cementation) of aggressive or recurrent benign tumors of the proximal femur (especially giant-cell tumors of bone).
- Revision of recurrent carcinomas of the proximal femur complicated by either failed intramedullary rod or endoprosthetic replacement.
- Revision of the failed femoral component in total hip replacements where there is severe proximal femoral bone loss.
- Treatment of massive radionecrosis of the proximal femur following radiation therapy for pelvic or thigh sarcomas.

Figure 1b ▸

Plain radiograph following revision with a proximal femoral MRS and reconstruction of the capsular mechanism (as described in this manual). This patient is now fully ambulatory without pain.

Unique Anatomic Considerations in the Resection and Reconstruction of the Proximal Femur

Intra-articular (intracapsular) location. The intracapsular location of the proximal femur permits easy and early spread of tumor into the hip joint and adjacent synovium, hip capsule, and ligamentum teres. It also facilitates the possibility of extra-articular skip metastasis across the ligamentum teres into the acetabulum in the area of the fovea. Careful preoperative imaging of these areas is essential.

Sciatic nerve. The sciatic nerve lies directly posterior to the external rotators. Large tumors of the proximal femur expand centrifugally, pushing the external rotators and the sciatic nerve. The sciatic nerve is often not in its usual anatomic location in these patients. To help prevent nerve damage, it must be identified early in the exploration. In general, as the tumor expands, the capsule and external rotators act as a protective barrier to the sciatic nerve.

Anterior neurovascular structures. The common femoral, superficial femoral, profundis femoral arteries and veins, and femoral nerve lie anterior to the proximal femur, separated only by the floor of the femoral triangle (pectineus muscle) and the proximal portion of the rectus femoris muscle. Although these vascular and iliopsoas structures are usually not involved by simple metastatic lesions of the proximal femur they are often displaced by large extraosseous components arising from primary sarcomas of the proximal femur. Preoperative imaging is essential to determine the location of the superficial femoral and the profundis femoral arteries.

The profundis femoral artery and vein must be carefully evaluated preoperatively as well as identified intraoperatively. Ligation of the profundis is often required due to its proximity to, or direct involvement by, the tumor. In addition, it is essential that the superficial femoral artery be documented prior to surgery (especially in the elderly) if the ligation of the profundis femoral artery is anticipated.

Abductor musculature. The abductor muscles arise from the wing of the ilium and attach to the greater trochanter. They may be attenuated by an enlarging mass from the proximal femur, but are rarely directly involved. It is important that these muscles be preserved following resection of most proximal femoral sarcomas, since they are crucial to the soft-tissue reconstruction, stability of the prosthetic replacement, and good functional outcome.

The psoas muscle arises from the transverse processes of the lumbar vertebra and joins with the iliacus muscle to form the iliopsoas muscle, which inserts onto the lesser trochanter. The psoas muscle is in close proximity to the anterior medial aspect of the hip joint. If a tumor enlarges anteriorly or postero-medially, a portion of this muscle may have to be resected. It is important that the remaining muscle be preserved for use in soft-tissue reconstruction of the hip joint (see hip joint reconstruction on page 24). Pre-surgical staging studies should evaluate the iliopsoas muscle for local extension of tumor.

Contraindications for Limb-Sparing Surgery of Primary Tumors

The contraindications of limb-sparing surgery are as follows:

- ***Major neurovascular involvement.***
- ***Pathologic fractures.*** A fracture through a bone affected by a tumor spreads tumor cells via the hematoma beyond accurately determined limits. The risk of local recurrence increases following a pathologic fracture, usually making resection inadvisable.
- ***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 in an infected area is contraindicated. Sepsis jeopardizes the effectiveness of adjuvant chemotherapy.
- ***Extensive muscle involvement.*** Enough muscle must remain to reconstruct a functional extremity.

Surgical Guidelines

The surgical guidelines and technique of limb-sparing surgery as utilized by the author are summarized as follows:

- The major neurovascular bundle (femoral vessels) must be free of tumor.
- The resection of the affected bone should leave a wide margin and a normal muscle cuff in all directions.
- All previous biopsy sites and all potentially contaminated tissues should be removed en bloc.
- To avoid intraosseous tumor extension, bone should be resected 5cm-6cm beyond abnormal uptake, as determined by preoperative studies.
- Adequate motor function of the abductor musculature must be retained or reconstructed.
- Careful reconstruction of the hip capsule is necessary for joint stability.

SURGICAL TECHNIQUE

Anatomic Location

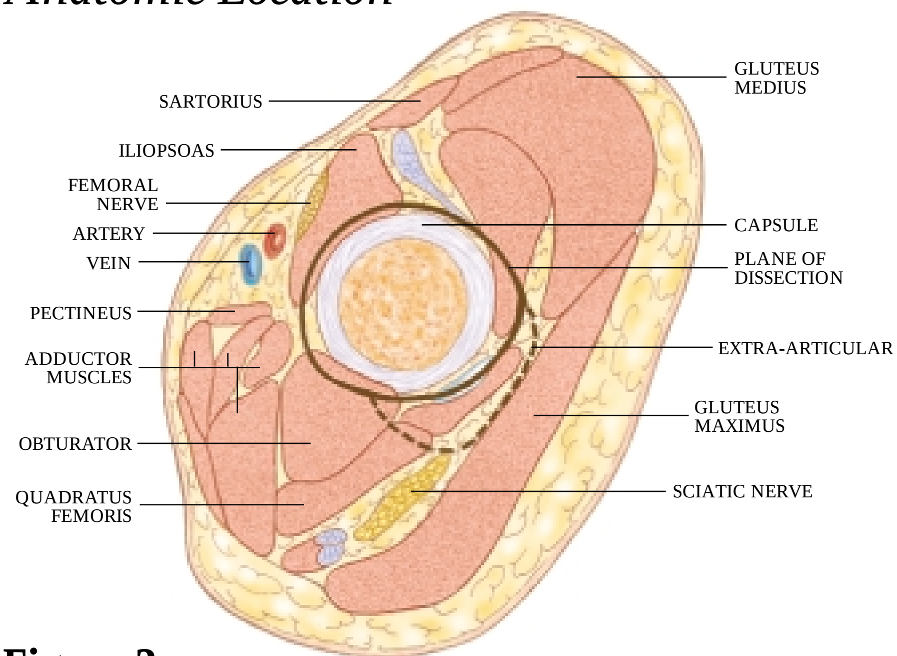


Figure 2a ▲

Cross-sectional anatomic analysis.

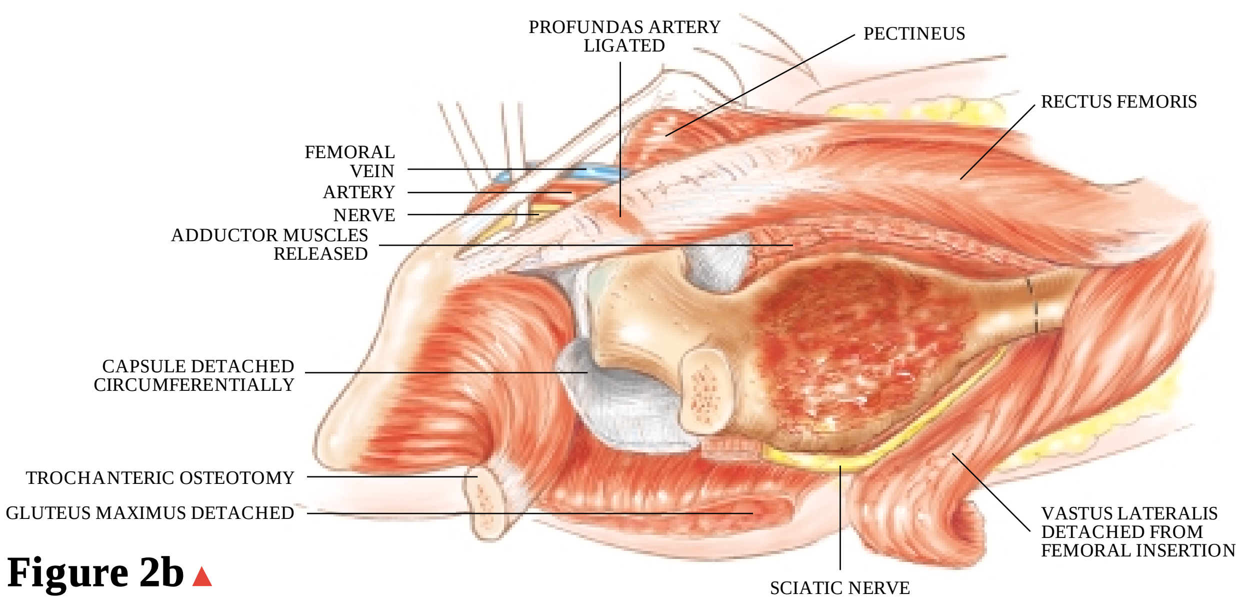


Figure 2b ▲

An intra-articular resection is usually performed. The surgical planes of resection are shown.

Surgical Approach and Incision

The patient is placed in a lateral position on the operating room table (Figure 3a). A sandbag is placed to allow the patient to roll slightly from the anterior to posterior lateral position. This permits exposure of both the anterior aspects of the thigh, including the femoral triangle, as well as the posterior anatomic structures, sciatic nerve, and the hip capsule.

A long postero-lateral incision is made (Figure 3b), and flaps are elevated (indicated by the dashed lines), which permits both an anterior and posterior dissection, depending on the preoperative staging studies. The biopsy site is included, with a 1-3cm margin in all directions. The sciatic nerve must be identified. Anterior dissection of the femoral triangle and the profundis vessels is required if there is an antero-medial mass.

This approach allows extensive exposure of the proximal third of the femur, the retrogluteal area, and the anterior neurovascular structures. It allows simple and safe exploration of the femoral canal, femoral triangle, and subsartorial canal, and identification of the profundis and superficial femoral arteries. Posterior extension of the incision permits easy exploration and identification of the sciatic nerve. The iliotibial band is opened and "T'd" to allow adequate anterior and posterior exposure. The retractors are placed around the femur adjacent to the greater trochanter and posteriorly to the femur and a third retractor adjacent to the sciatic notch.

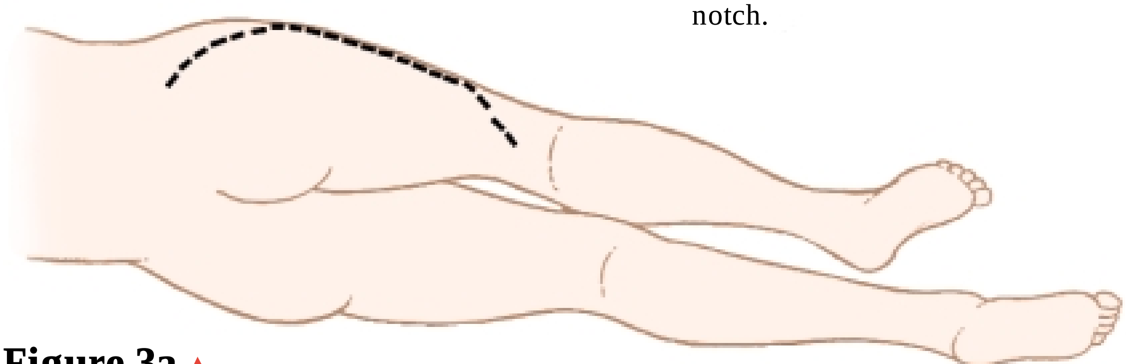


Figure 3a ▲

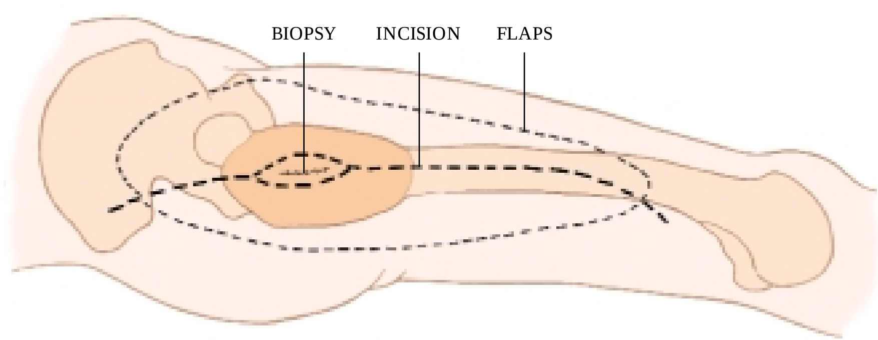


Figure 3b ▲

Identification of the Sciatic Nerve and Detachment of Abductor Musculature

The abductors are identified, including their anterior and posterior intervals. The greater trochanter is osteotomized if there is no tumor involvement (Figure 4); otherwise, the abductors are transected through their tendinous attachments and retracted cephalad, exposing the hip joint and acetabulum.

Vastus Lateralis Reflection and Detachment

The vastus lateralis is reflected distally from its origin. Several posterior perforating vessels are ligated. Care is taken not to ligate its main pedicle, which crosses anteriorly and obliquely along the rectus femoris fascia. The vastus lateralis is later advanced to the abductor muscles for closure (see Figure 5).

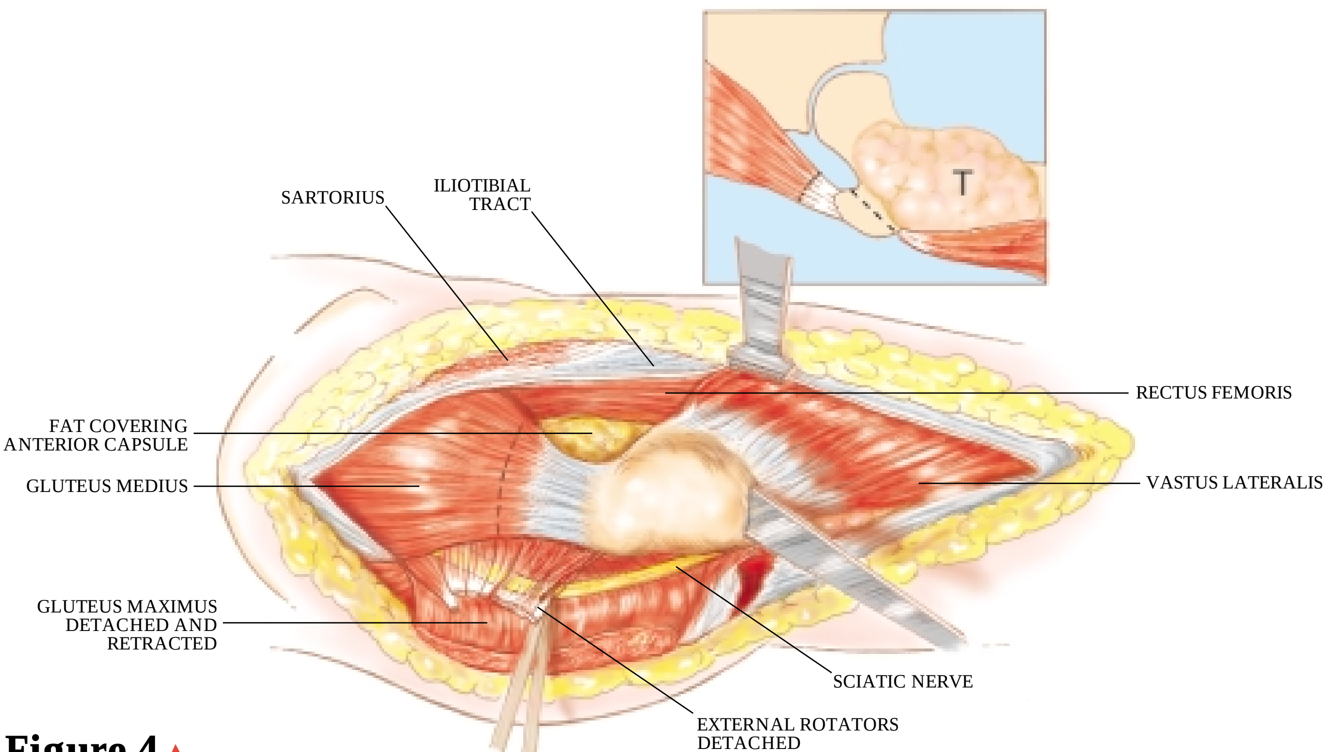


Figure 4

Gluteus Maximus Detachment

The gluteus maximus has already been partially detached by releasing the iliotibial band. Its femoral insertion is now detached under direct vision with care to ligate the first perforating artery, which is in intimate apposition with the gluteal tendon attachment. The gluteus maximus is then retracted posteriorly, exposing the retrogluteal area, sciatic nerve, posterior capsule, abductors, and external rotators (Figure 5).

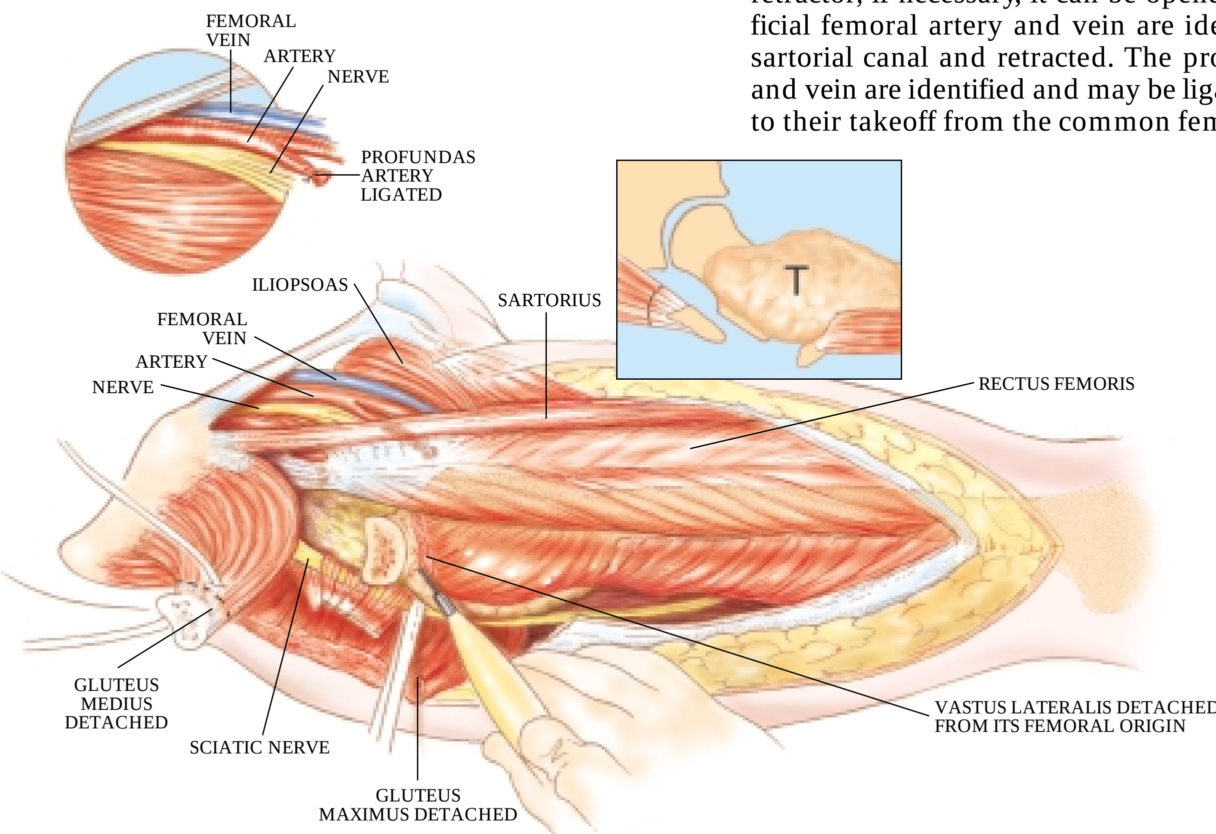


Figure 5 ▲

Anterior Exposure and Exploration of the Femoral Nerve and Artery and Vein Exploration

If the tumor has a large antero-medial component, the femoral triangle must be identified. The medial interval of the sartorius muscle is initially opened, exposing a portion of the iliacus muscle as it passes over the superior pubic ramus. The femoral nerve is identified below the fascia. The femoral triangle is identified and retracted medially by a blunt Cobra retractor; if necessary, it can be opened. The superficial femoral artery and vein are identified in the sartorial canal and retracted. The profundis artery and vein are identified and may be ligated just distal to their takeoff from the common femoral artery.

Detachment of Posterior Hip Musculature and Capsule

The retrogluteal area has been previously exposed. The rotator muscles are now detached en bloc 1cm from their insertion on the proximal femur. The posterior capsule can be removed with the rotators, or left as a separate plane, depending on the oncological requirements of an additional margin. The previously identified sciatic nerve is retracted.

Capsule Detachment

The hip capsule is opened longitudinally along its postero-lateral aspect and detached circumferentially from the femoral neck. It is important to preserve the capsule for later reconstruction (Figure 6).

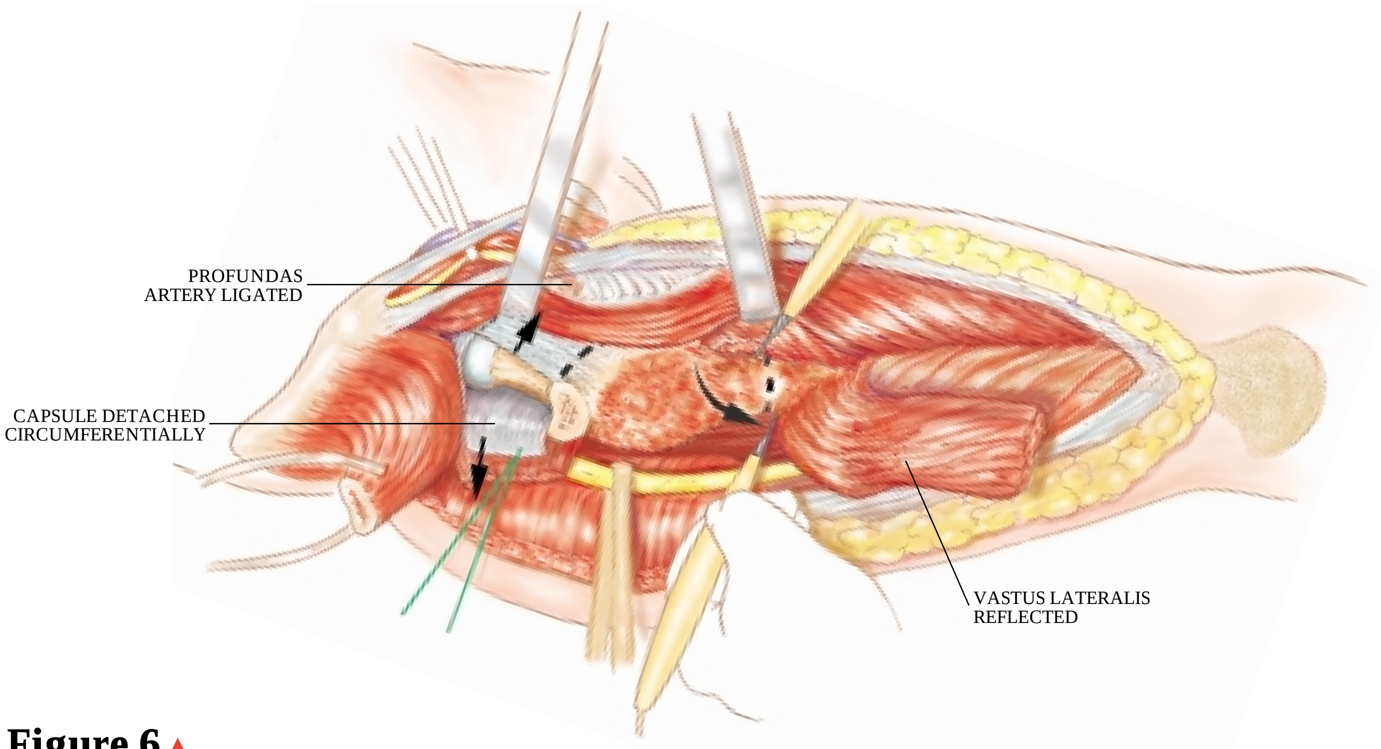


Figure 6 ▲

Measuring Resection Length

The resection level is first established at the recommended margin by the staging studies. In general, 5cm-6cm beyond the farthest point is appropriate for primary sarcomas; 1cm-2cm suffices for metastatic carcinomas. The proximal femoral resection caliper can be used to guide the resection to a level that can be exactly reproduced by the available implants (Figure 7). The caliper is read at one of two markings. One marking is read when using a stem with a porous-coated body. The second marking is for the stem without a porous-coated body. The caliper is calibrated to measure from the center of the femoral head along the axis of the femur. The jaw for the selected stem style is placed at the desired resection level. The resection level can be adjusted until the caliper displays the body segment to be used in the window. When the resection level is set for where an exact reconstruction is possible from the implant offerings, the body length will show through the window and line up with the indicator marking. ***(In this case, an 80mm body segment is indicated. When the 80mm body segment is used with the bodiless stem, the total replacement length will be 161mm, including the 70mm proximal femoral segment. When the same 80mm body is used with the porous-coated stem with the built-in 40mm body, the replacement length will be 190mm.)*** If the desired resection length best lines up with the “N” on the caliper, no body extension is used, i.e., either stem style is assembled directly to the proximal femoral component.

The anterior cortex of the femur is marked with a bovie or similar device to indicate the resection level.

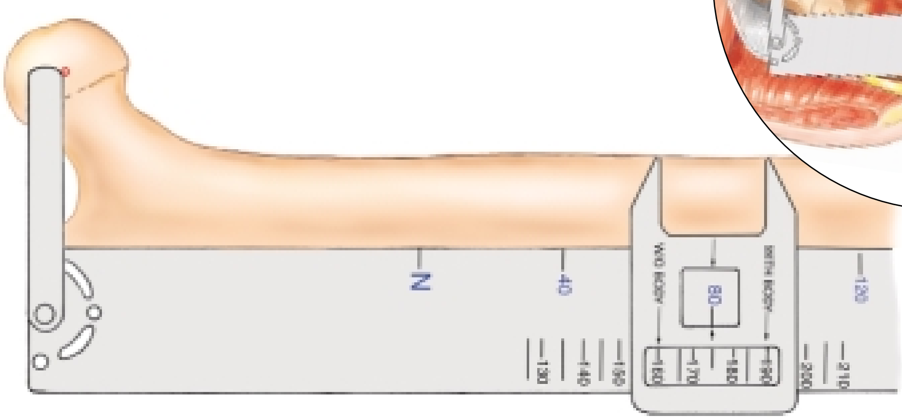


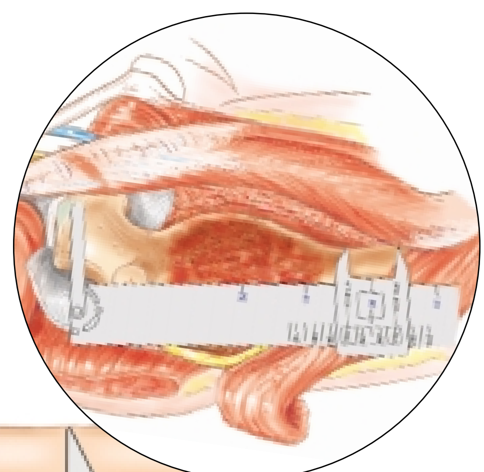
Figure 7 ▲

Marking Anterior Aspect of Femur

A line representing the anterior point on the femur should now be marked distal to the resection level to aid in rotational orientation of the prosthesis. A guide to the placement of this mark is the linea aspera on the posterior aspect of the femur. The anterior mark should be a line formed at the intersection of a sagittal plane passing anteriorly through the linea aspera and the anterior cortex of the femur.

Femoral Osteotomy

The remaining soft-tissue attachments around the femur are transected with the cutting cautery. A malleable retractor is placed medially to the femoral shaft to prevent inadvertent injury to the soft-tissue structures. An oscillating saw is used for the osteotomy. The cut should be at a right angle to the shaft. It is ***important*** not to distract the extremity following removal of the proximal femur in order to avoid placing tension on the sciatic nerve and the femoral vessels. One assistant must be assigned to monitor this.



Dislocation of Hip

The hip is dislocated either anteriorly or posteriorly, depending on the approach used. If a primary sarcoma is being resected, care is taken not to fracture the femoral neck (Figure 8).

Release of Medial Structures (Adductor Muscles)

The medial structures consist of the psoas and adductor muscles, which attach to the proximal femoral shaft. They are serially clamped with Kelly clamps and ligated. Care is taken to dissect the profundis femoral artery if this has not already been done. The artery is either preserved or ligated, depending on the oncological needs. Following osteotomy of the femur distally, the proximal femur (tumor) is retracted laterally. The remaining medial structures are now well visualized, and the adductor muscles are now ligated and transected (Figure 9).

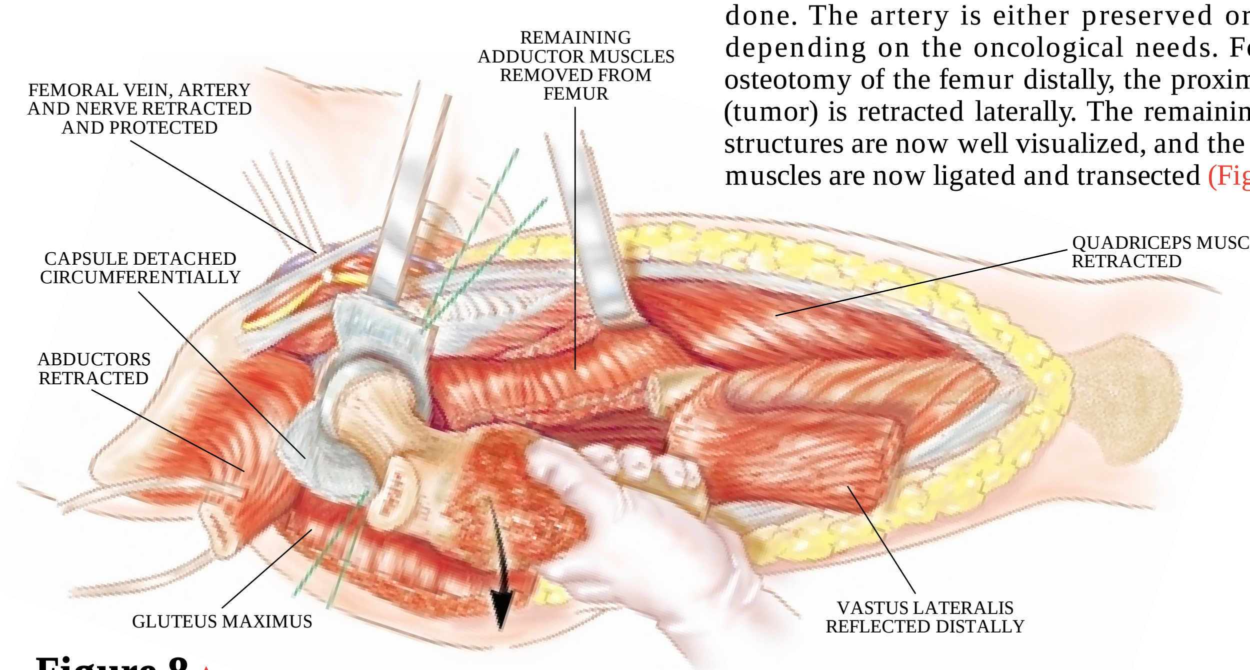


Figure 8 ▲

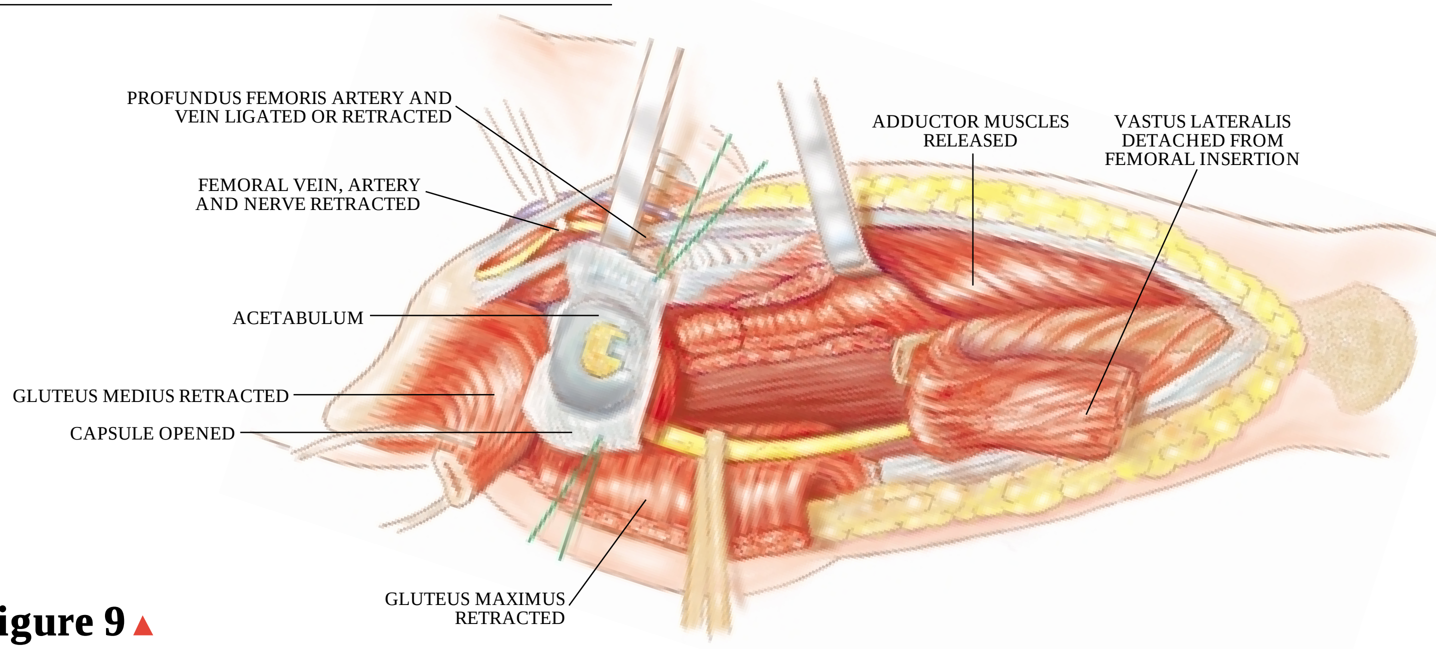


Figure 9 ▲

Preparation of the Femur

Following resection of the proximal femur, the length of the proximal femur to be replaced is confirmed, and the size of the femoral head is measured. The acetabulum is inspected for signs of joint contamination. Prior to reaming of the femoral canal, a frozen section from the canal is routinely sent to the laboratory to evaluate for any evidence of residual tumor.

The proximal end of the remaining femur should be kept well padded to avoid injury to the superficial femoral artery and popliteal vessels.

A flexible guide wire 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 2mm larger than the selected stem of the prosthesis. (Note: The four femoral stem diameters are 11mm ,13mm, 15mm, and 17mm.)

A stem / seat reamer is used to plane the osteotomy site so as to ensure direct contact and accurate seating of the prosthesis upon the cortices. The correct reamer size is selected for the chosen stem to prepare the osteotomy site for the radius on the stem at the stem / seat junction (Figure 10).

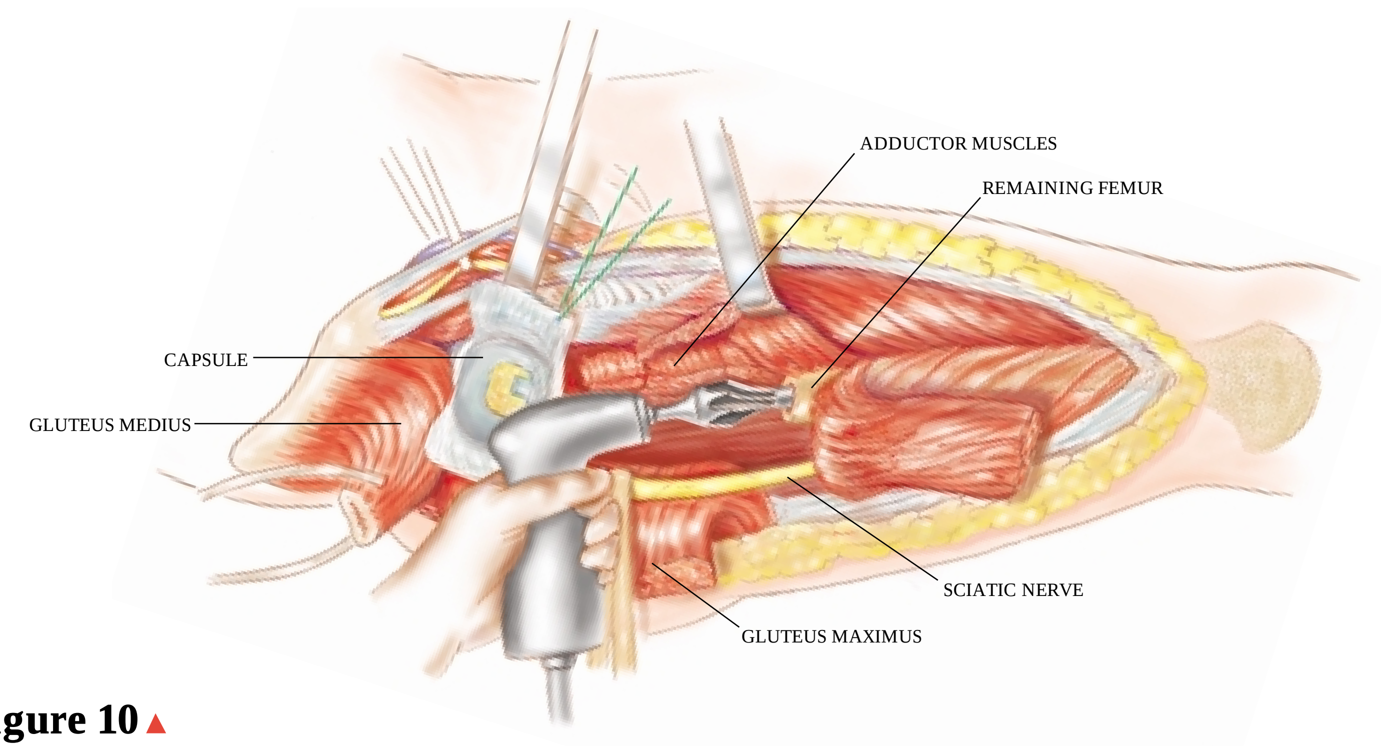


Figure 10 ▲

The chosen trial femoral component is placed in the reamed femur to facilitate ease of insertion and appropriate cement mantle. If there is any difficulty, continue reaming until trial fits freely in canal, or reassess stem size. It is extremely important to verify the close apposition of the seat of the femoral trial to the proximal femoral cortex.

Optional stem centralizers are available for the 127mm length femoral stems. The last size flexible reamer used corresponds to the diameter of the distal centralizer necessary for correct positioning of the stem tip (Figure 11).

Stem Diameter	Suggested Flexible Ream Diameter	Seat Diameter
11mm	13mm	24mm
13mm	15mm	28mm
15mm	17mm	32mm
17mm	19mm	36mm

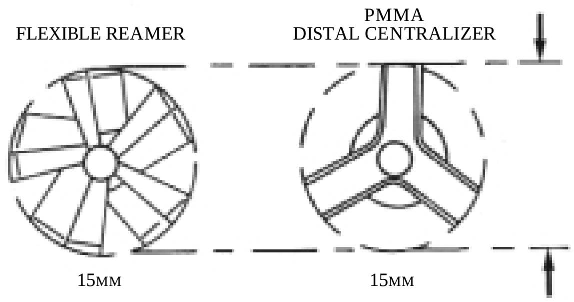


Figure 11▲

Bipolar Head Sizing

A trial Howmedica Osteonics Centrax® or UHR® Bipolar femoral head prosthesis is chosen, based on the measurement taken from the femoral head that has been resected. The trial is utilized to test the "suction" fit of the head in the acetabulum. Full seating of the trial should be checked. It is important to pull the remaining capsular structures over the attempted head reduction to try to recreate the suction fit. The trial should however still move freely in the acetabulum.

NOTE: It is suggested that the detailed Surgical Technique for the Howmedica Osteonics Centrax® or UHR® Bipolar system be reviewed.

Trial Reduction

The purpose of the trial reduction is to determine the ease of insertion of the femoral prosthesis and bipolar 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. If it is too short, stability can be compromised.

The parts that must be assembled to articulate the proximal femoral trial include: the stem segment trial, body segment trial (when needed based on resection length), proximal femoral segment trial, femoral head trial, and bipolar head trial.

Place the appropriate head trial on the proximal femoral trial. The 26mm and 28mm heads have five neck length options: Standard, +4mm, +8mm, +12mm, and +16mm. Choose the option which re-establishes leg length and joint stability. The assembled trial prosthesis is then placed into the femoral canal. Assemble the Howmedica Osteonics Centrax® or UHR® Bipolar trial onto the appropriate head trial; then reduce into the acetabulum (Figure 12).

The proper anteversion of the trial assembly can be checked against the rotational alignment marks on the trial femoral stems. The alignment marks on the femoral stems are in the same plane and in a plane 90° to the plane of the proximal femoral component. These marks can be used to aid in setting the appropriate anteversion of the prosthesis.

As a guide to anteversion alignment, align the rotational alignment mark on the femoral stem segment with the rotational reference mark previously made on the anterior cortex of the femur, and antevert the prosthesis 10° to 15°. The linea aspera can also be used as a guide. Construct an imaginary sagittal plane that passes directly anterior, originating from the linea aspera. The prosthesis is placed with the femoral neck anteverted about 10°-15° with respect to a second coronal plane perpendicular to the sagittal plane through the linea aspera (see Figure 14, page 23).

The pulses are palpated distally. If the pulse is diminished, a shorter prosthesis is required. This will necessitate modifying the length of the prosthesis or removing additional bone from the femur. Range of motion of the hip joint is tested with the capsule pulled over the femoral head component. The prosthesis should be stable in flexion, adduction, and internal rotation.

Fine-tuning of the prosthetic length can be performed with the selection of femoral head neck lengths available.

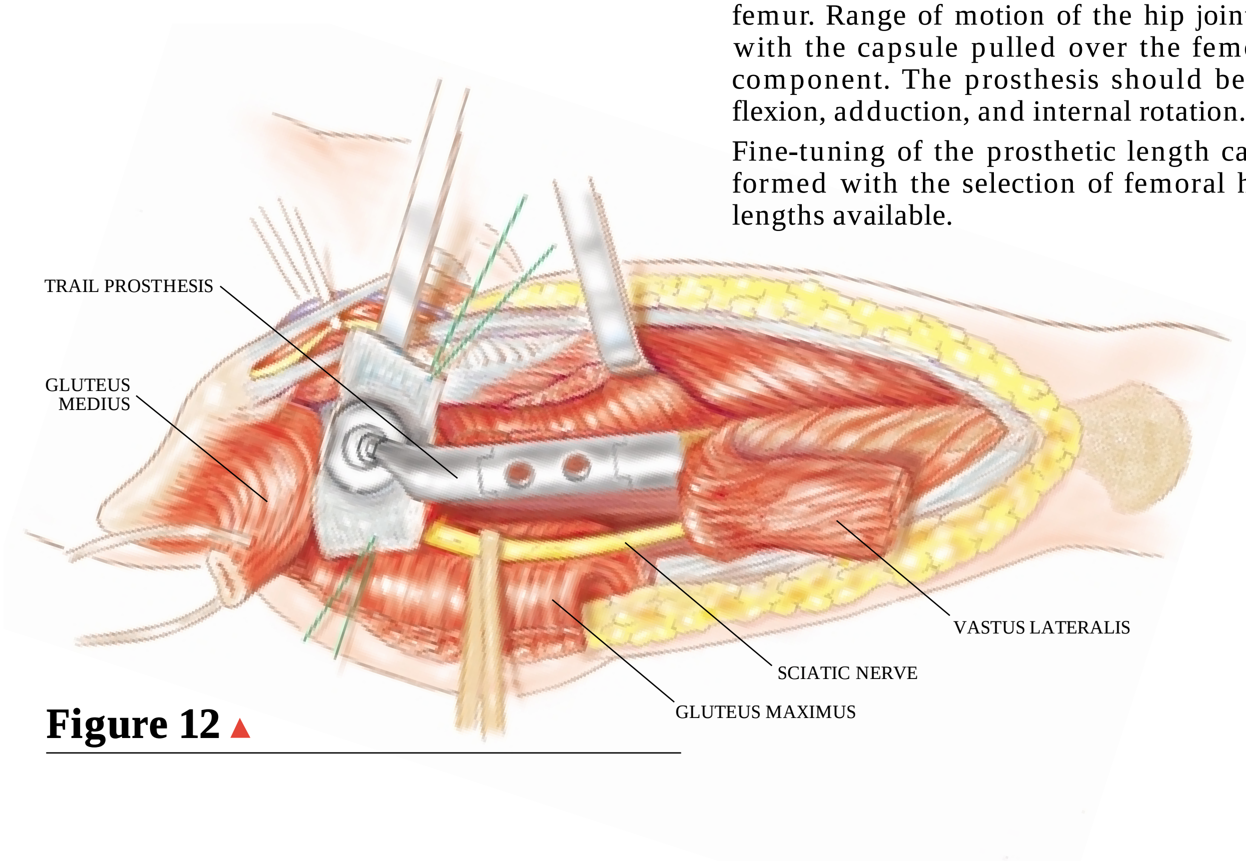


Figure 12 ▲

Assembly of the Prosthesis

The femoral prosthesis consists of the femoral stem segment, femoral body segment (when needed based on the length of the reconstruction), the proximal femoral segment, and the femoral head. Check that the correct sizes of all components have been chosen before assembly. If necessary, it is acceptable to join two femoral bodies to make up the necessary length. The instruments used for the assembly of the prosthesis are the impaction tube, trunnion impactor, and proximal femoral "V-block."

NOTE: Before joining any of the tapers, make sure the male and female components are completely clean and dry.

The femoral body and femoral stem are assembled first. The impaction tube head corresponding to the stem diameter is assembled with the impaction tube base (A). The femoral stem segment is placed into the impaction tube (B), and the femoral body is mated with it (C). The trunnion impactor is placed over the taper of the femoral body (D), and impacted with several swift blows of a heavy mallet to lock the tapers.

Next, the stem / body construct is assembled to the proximal femoral segment . A lap pad is placed on the "V-block" to protect the male trunnion of the proximal femoral segment. The femoral stem and body assembly are mated with the proximal femoral segment, which is held as shown (E). The impaction tube is placed over the stem, and impacted with several swift blows of a heavy mallet.

The appropriate femoral head is then impacted onto the proximal femoral trunnion. The Howmedica Osteonics Centrax® or UHR® Bipolar is placed onto the femoral head.

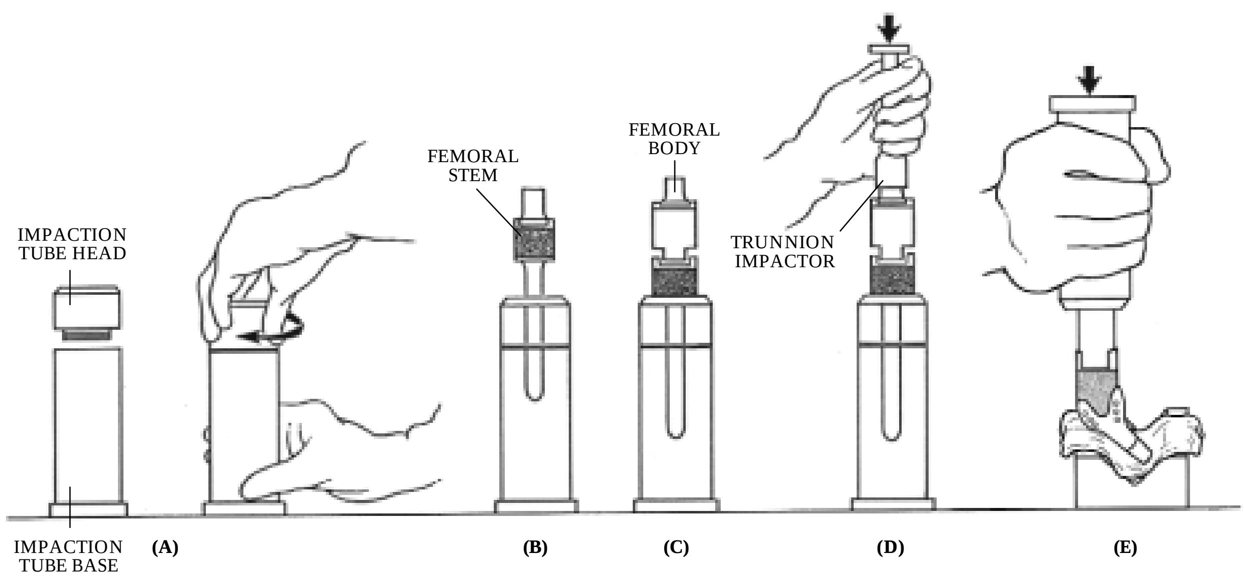


Figure 13 ▲

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 trial femoral stem to verify 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. Surgical Simplex® P bone cement is then mixed and injected into the canal to ensure complete filling of the canal. Some cement is then placed around the stem of the prosthesis.

NOTE: If a stem centralizer is not being used, plug the hole in the stem with bone cement.

The orientation of the prosthesis is critical. As a guide to appropriate anteversion, align the rotational alignment mark on the femoral stem segment with the rotational reference mark previously made on the anterior cortex of the femur, and antevert the prosthesis 10° to 15°. The linea aspera can also be used as a guide. Construct an imaginary sagittal plane that passes directly anterior, originating from the linea aspera. The prosthesis is placed with the femoral neck anteverted about 10°-15° with respect to a second coronal plane perpendicular to the sagittal plane through the linea aspera (Figure 14).

NOTE: The assembled prosthesis does *not* have a "built-in" anteversion.

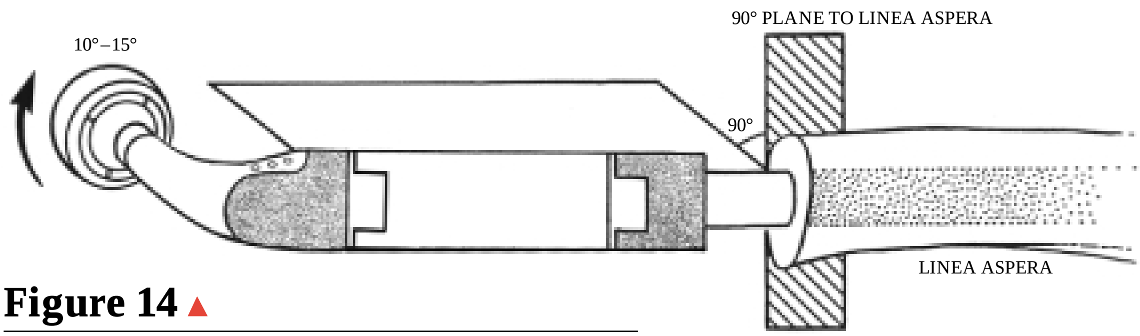


Figure 14 ▲

Reconstruction of Hip Capsule and Abductor Mechanism

The prosthesis is then inserted into the femoral canal at the proper anteversion until the stem seat is flush with the host bone at the osteotomy site (Figure 15). Excess cement is removed from around the prosthesis. Care is taken to prevent cement from getting into the porous-coated area on the stem. The prosthesis is firmly held in place while the cement cures.

Once the permanent prosthesis is cemented into place, the remaining hip capsule and abductors are reconstructed to ensure a stable prosthesis. The hip capsule is then sutured together. A 3mm Dacron™ tape is wrapped around the inferior portion of the capsule, forming a noose around the femoral neck. This is to provide immediate stability. The capsule can be reinforced by rotating the external rotator muscles proximally, and suturing them to the repaired capsule. The remaining psoas muscle can be rotated anteriorly to close and reinforce the capsular repair (Figure 16).

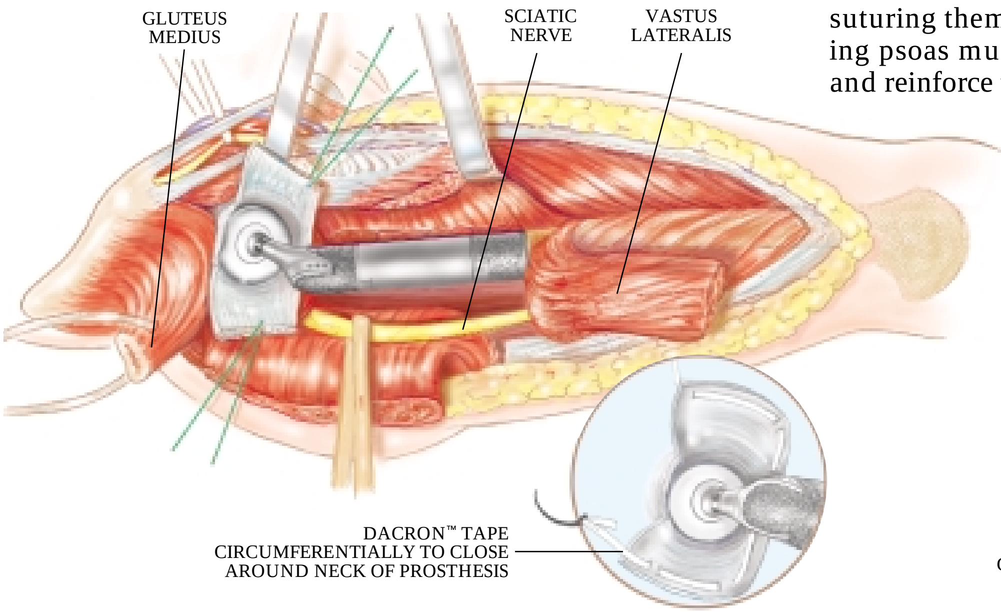


Figure 15 ▲

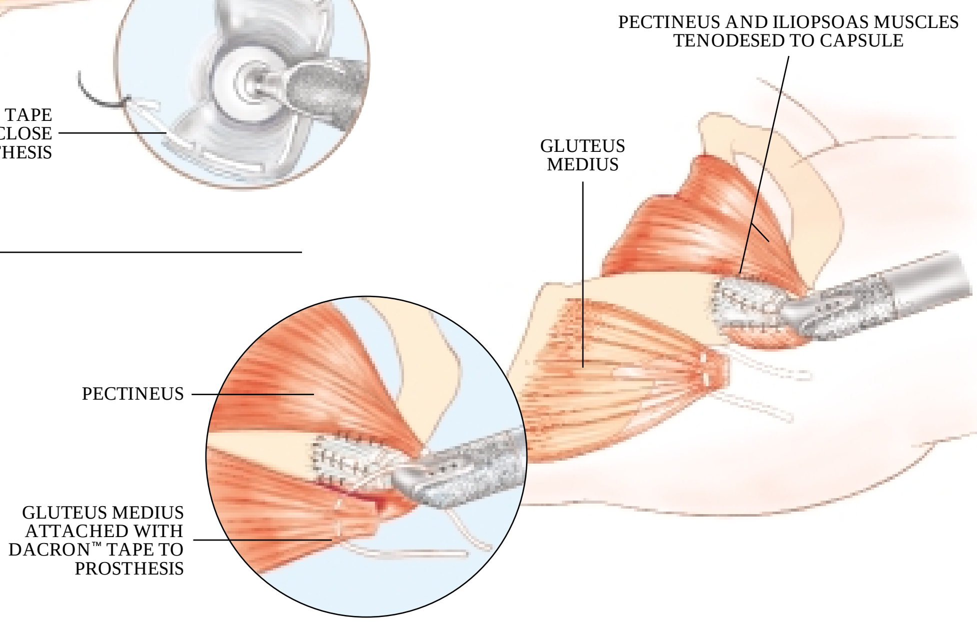


Figure 16 ▲

Extra-cortical Fixation

The extra-cortical porous-coated area of the femoral stem can be utilized for additional bony or soft-tissue support to form a “noose” around the stem. Theoretically, this will limit any debris entering the bone-cement interface that could cause cement and prosthetic loosening. If bone graft is used, it should be fixed in place with Dacron™ tape. The cortical surface of the femur can be roughened with a mechanical burr (Figure 17).

If the bone graft is obtained from a separate donor site, the surgeons must change gloves and gowns and use separate instrumentation to avoid contamination of the donor site.

Reconstruction of Abductor Mechanism

If the entire bone has been resected, including the greater trochanter, the remaining abductors may be brought down to the holes in the proximal femur with 3mm tape. The vastus lateralis can now be rotated proximally to overlie the abductor muscle fixation. Soft-tissue closure of the vastus lateralis to the abductor muscles is performed. The remaining muscles are sutured to the vastus lateralis anteriorly and the hamstrings posteriorly (Figure 18).

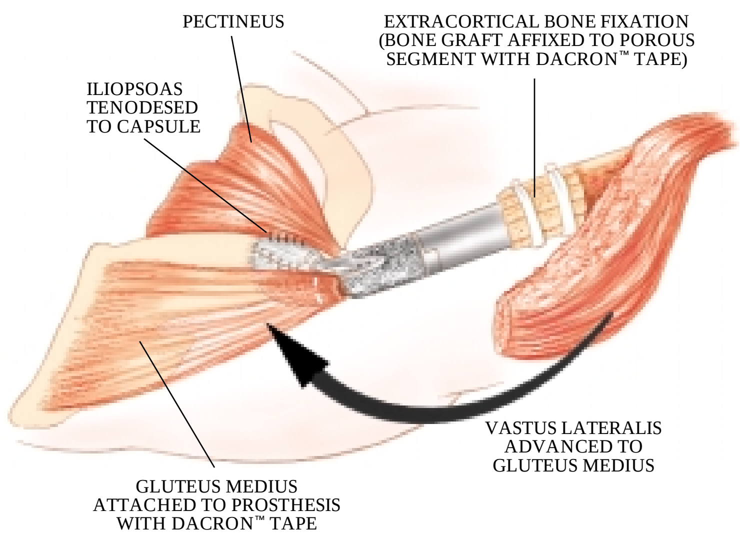


Figure 17 ▲

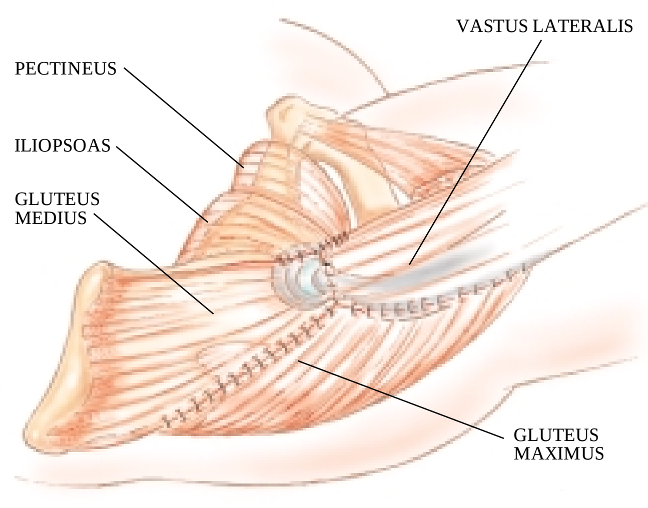


Figure 18 ▲

Wound Closure

Closure of the fascia, subcutaneous tissue, and skin is carried out in standard fashion.

A 28-gauge chest tube is attached to a Pleurovac™ suction to 20cm water. The pulse is checked following wound closure and prior to removing the patient from the table. Plain radiography is obtained to ascertain good hip reduction. The patient is then placed in balanced suspension traction with the hip abducted, or in tibial pin traction (Figure 19).

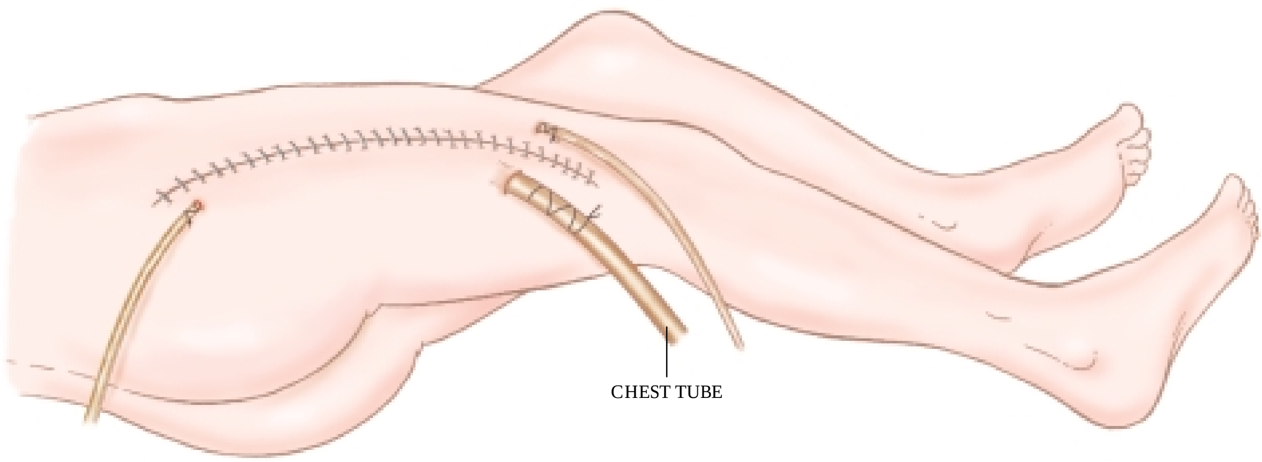


Figure 19 ▲

Postoperative Management

- The extremity is kept elevated and in balanced suspension traction for at least 7-10 days. This helps to prevent postoperative edema and prosthetic dislocation.
- Continuous suction is required for 3-5 days to avoid fluid collection.
- Perioperative antibiotics are continued until drainage tubes are removed (usually within 4-5 days).
- Isometric exercises are started on the day after surgery.
- Postoperative immobilization with an abduction brace is required for 3-6 weeks, depending on the extent of the soft-tissue resection and satisfactory soft-tissue reconstruction. Good muscle control is required before the brace is removed.

Summary

The proximal femur is the most common site for metastatic carcinoma. Limb-sparing surgery is now considered preferable to hemipelvectomy for the large majority of primary bone sarcomas of the proximal femur. The major indications are: osteosarcomas, chondrosarcomas, Ewing's sarcomas, and PNETs. Almost all low-grade sarcomas of the proximal femur can be treated with a limb-sparing resection. The majority of metastatic carcinomas may be treated by a simple long-stem endoprosthetic replacement; about 5%-10% require proximal femoral segmental replacement. The MRS Proximal Femoral Replacement is an easily assembled reconstructive device.

APPENDIX I

Taper Disassembly

Should it be necessary to disengage an assembled taper joint, a taper separator is provided. The taper separator utilizes the mechanical advantage of a wedge and a lever arm to overcome the locking forces of the tapers and separate the components. It is important that the separator be positioned so that the wedges **do not** act against the anti-rotation tabs of the implants. The correct orientation for the femoral system is in an anterior-to-posterior direction. The implants are designed to withstand the forces generated by the separator in this direction. Placement of the separator wedges against the anti-rotation tabs may damage them, making disengagement difficult.

The wedges are initially advanced by hand to bring them in contact with the implant at the joint to be disengaged. The wedges are advanced by turning the jack screw in a clockwise direction. The wedges are then further advanced, using the wrench provided, until the tapers disengage.

Caution should be taken when disengaging any taper-locked joint. The high forces that hold a taper-locked joint together may result in a sudden and forceful action upon disengagement along the axis of the tapers.

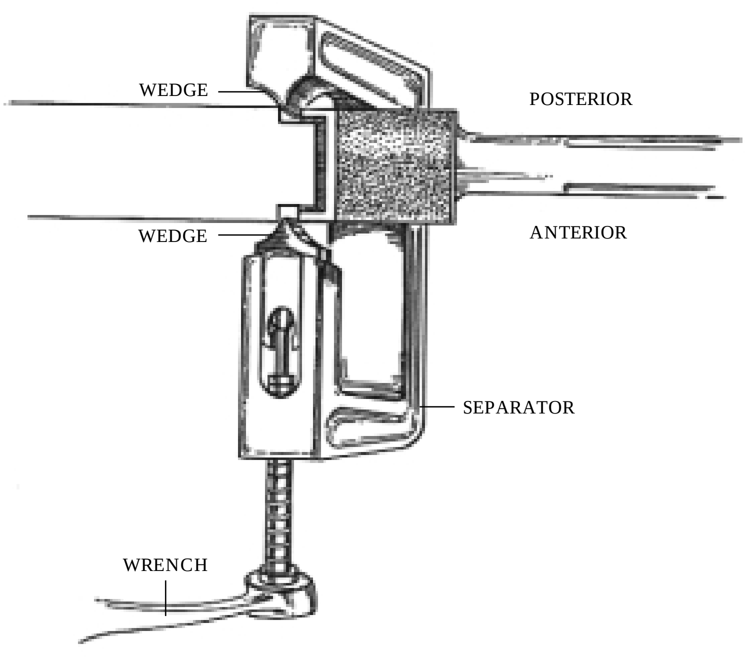


Figure 20 ▲

Taper disengagement.

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 †These devices are currently marketed in the United States for use only with bone cement. *US Patent Nos. 4,578,081; 4,764,171; 4,790,854; 5,192,324; and 5,441,537. ♻Printed in USA on recycled paper. LMRS/ST 1.5M 12/99 5985 TG/CP

359 Veterans Boulevard
Rutherford, NJ 07070

59 Route 17 South
Allendale, NJ 07401