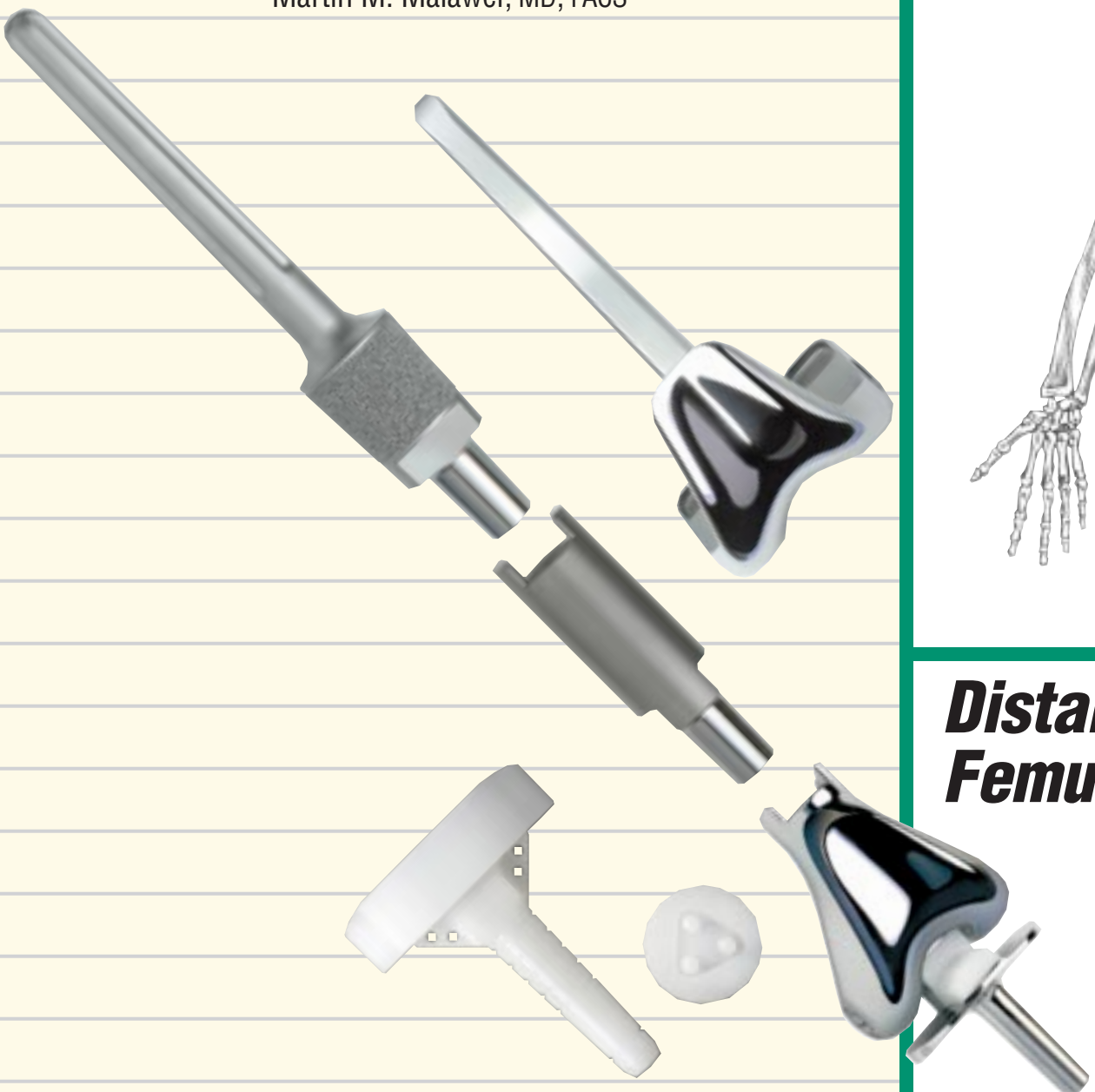
SURGICAL TECHNIQUE

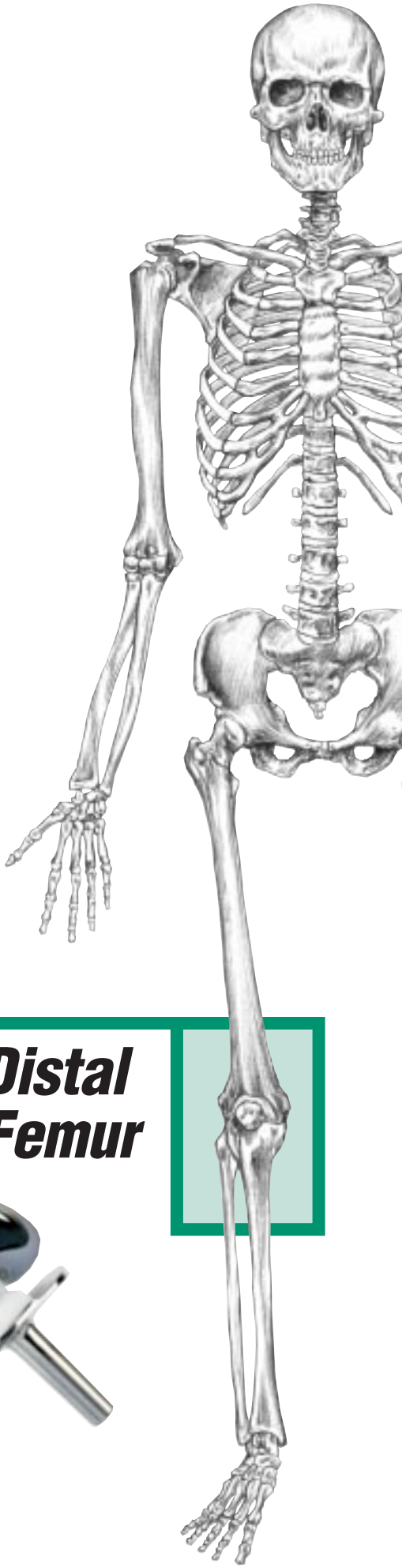
MRS

MODULAR·REPLACEMENT·SYSTEM

Distal Femoral Resection for Large Segmental Replacements

Martin M. Malawer, MD, FACS





Distal Femur

Howmedica

Modular Replacement System Distal Femoral Resection for Large Segmental Replacements Surgical Technique*

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Overview

Patients with osteosarcoma of the distal femur have traditionally been treated with a high, above-knee amputation. With early diagnosis and induction chemotherapy, the cancer can usually 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 should be evaluated in all of these patients. The Modular Replacement System (MRS) described here can provide limb salvage in a large population of patients. The functional results are excellent, and patient satisfaction is high.

Description of the Distal 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 knee.
- Reconstruct osteoarticular defects of varying sizes.
- Allow for variation in both planned and unsuspected necessary intraoperative changes.

The system consists of articular condyles, body segments, and stem segments. The modular implants are assembled by impacting a male/female taper design, securely locking them together.

Femoral Components

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 porous-coated body section. This stem style adds 11mm to the overall replacement length. Both styles of stem come in two lengths: 127mm and a 203mm longstem. The 203mm longstems are bowed to match the curvature of the anatomical 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. 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

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

The condylar segments are available in two sizes, small and standard, and both are available in left and right configurations. The standard-size condyle measures 64mm in the M/L and 54mm in the A/P, and has a 65mm replacement length. The small-size condyle measures 58mm in the M/L and 43mm in the A/P, and also has a 65mm replacement length. All condyles have a built-in 6° valgus offset. The condylar segments utilize the Kinematic® Rotating Hinge Knee components.

NOTE: The small condyles use dedicated small bushings and small axles.

FEMORAL BODY SEGMENT

FEMORAL CONDYLE

Tibial Components

All-Polyethylene Tibial Component

The all-poly tibial component is available in 5 sizes, each in 4 thicknesses (8mm, 11mm, 16mm, and 21mm). The all-poly tibial component is intended for use when it can be adequately supported by cortical bone around its periphery. If bone quality is suspect or the component cannot be properly supported, the metal-encapsulated tibial baseplate is recommended. The all-poly tibial component is designed to accept the **long** tibial bearing component **only**.

Metal-Encapsulated Tibial Baseplate

The metal-encapsulated tibial baseplate is available in 2 sizes (small and medium), with 4 stem options for each: 11mm and 15mm diameters in 110mm and 180mm lengths. Four modular inserts are available in 11mm, 13mm, 16mm, and 21mm thicknesses. The 4mm thickness of the baseplate is added to the insert thickness for the total thickness. The metal-encapsulated tibial baseplate is designed to accept the **short** tibial bearing component **only.**

METAL ENCAPSULATED
TIBIAL COMPONENT

ALL-POLY
TIBIAL COMPONENT

Additional Small Components

Smaller-diameter body segments are available in 24mm diameter for use in smaller patients. These body segments are available in 40mm to 140mm lengths, in 20mm increments, and mate with the small condylar components.

Small stem segments are available in 8mm, 9mm, and 10mm diameters, and are 102mm in length (not intended to be used in patients over 90lb). These stems are available both straight and curved, with and without the porous-coated body. Optional stem centralizers are **not** available for the 102mm stems.

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 tapers. The trials are satin-finished so that they can easily be distinguished from the prostheses. The body and stem segments also have holes through the major diameter to further 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 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.

Bone Scan

Three-phase bone scan is essential to determine if there are multiple lesions (an indication of metastatic disease) or a solitary 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 scans, as well as thallium scans, 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

CT allows accurate determination of intraosseous and extraosseous extension of skeletal tumors. CT accurately depicts the transverse relationship of the tumor, enabling the surgeon to detect which portion of the quadriceps muscle is involved and the relationship of the tumor to the popliteal vessels.

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.

Angiography

Biplane angiography is essential in determining the relationship of the tumor to the popliteal vessels. The angiogram serves as a road map for the surgeon during the operative procedure, thus permitting safe exposure of the popliteal vessels. Two views, anterior-posterior and lateral, are required to evaluate the relationship of the vessels to the tumor, 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.

A careful evaluation of all data from the preceding studies allows extremely accurate preoperative determination of tumor extent, and permits the operating surgeon to form an accurate three-dimensional image of the amount of bone and soft tissue to be resected.

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. Care should be taken to avoid contamination of the knee joint, sartorial canal, popliteal space, and rectus femoris muscle. A medial biopsy is preferred if an option exists. 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 Distal Femur

The knee is the most common anatomic site for primary tumors of the musculoskeletal system. Benign, as well as malignant, tumors arise in the distal femur. Primary bone tumors most often occur during childhood or adolescence. Osteosarcoma is the most common malignant bone tumor and occurs most often in the distal femur. Ewing's sarcoma is the second most common bony malignancy of childhood.

The traditional treatments of malignant bone tumors of the distal femur have been hip disarticulation or above-knee amputation. Metastatic tumors to the distal femur are uncommon and usually occur in adult patients above the age of forty. The treatment of bony sarcomas has dramatically changed within the past twenty-five years. Most primary bony sarcomas can be treated by a limb-sparing resection, thereby avoiding amputation. The Modular Replacement System has been developed to treat both primary and metastatic tumors involving the distal femur for pediatric, adolescent, and adult patients.

Osteosarcoma

The distal femur is the most common anatomic site for osteosarcoma to occur. Approximately 50% of osteosarcomas occur in the distal femur. Since the late 1970s, due to simultaneous developments and advances in chemotherapy, improved surgical technique, and surgical technology (endoprosthetic replacements), limb-sparing surgery is now performed on the majority of patients with femoral sarcomas. Adjuvant chemotherapy (preoperatively and postoperatively), combined with limb-sparing surgery, is now considered the state of the art. Routine amputations are not recommended. Approximately 95% of patients with osteosarcomas of the distal femur can be treated by a limb-sparing procedure following induction chemotherapy.

The majority of clinical experience with limb-salvage techniques has developed over the past twenty-five years from the treatment of patients with sarcomas around the knee. The techniques and indications are now well established.

Chondrosarcoma and Malignant Fibrous Histiocytoma (MFH)

Primary, secondary, or dedifferentiated chondrosarcomas are the most common malignant bone tumors in adults. Their overall incidence is one in four compared to osteosarcoma. Their most common anatomic sites are the pelvis and proximal femur. Involvement of the distal femur is unusual. When it does occur, the principles of staging, treatment, and surgical techniques are similar to the more common primary bony sarcomas of the distal femur. The major difference is that low-grade chondrosarcomas do not require adjuvant chemotherapy, whereas the high-grade variants do.

MFH is the least common of the spindle-cell sarcomas (about 5%). Unlike other bony spindle-cell sarcomas, most tend to be high-grade, with potential for early pathological fracture and early lymphatic spread. They have an unusual predilection for the distal femur. The principles and techniques for the treatment of MFH of bone are similar to osteosarcoma. Limb-sparing surgery and adjuvant chemotherapy are recommended. Pathological fracture may mitigate against a limb-sparing procedure.

Ewing's Sarcoma

Ewing's sarcoma occurs in young children, more often around the proximal femur, pelvis, and spine. Ewing's sarcoma is about one-half as frequent as osteosarcoma. The distal femur accounts for only 15% of these tumors. Although surgery has played a more limited role in the treatment of Ewing's sarcomas, resection, when possible, following induction chemotherapy is now considered for select individuals. Ewing's sarcoma of the distal femur is now treatable with surgery following the techniques developed for osteosarcomas.

Metastatic Cancer

Metastatic cancer to the distal femur is relatively uncommon. Most cases can be treated by radiation therapy and/or standard internal fixation with PMMA.

The major indications for segmental distal femoral resection, in lieu of internal fixation, in the treatment of metastatic carcinomas are:

- Extremely large tumor.
- Failed radiation therapy with progressive tumor growth.
- Solitary metastatic carcinoma.
- Pathological fracture following radiation therapy.
- Intra-articular involvement by metastatic tumor.

Non-Neoplastic Indications for Use of MRS

- Revision of failed distal femoral allografts or osteoarticular allografts.
- Failed curettage (with or without cementation) of aggressive or recurrent benign tumors of the distal femur (especially giant-cell tumors of bone).
- Revision of failed or recurrent carcinomas of the distal femur following either intramedullary rod or internal plate fixation.
- Treatment of severe or failed fixation of osteoporotic supracondylar fractures.
- Total knee revision.
- Trauma.

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

Neurovascular structures. The superficial femoral artery (SFA) and vein lie just medial to the femur in the sartorial canal. These vessels pass through the adductor magnus foramen about 11cm above the joint line to become the popliteal artery and vein. The popliteal vessels run along the posterior border of the distal femur and are tied to the bone and joint by the geniculate vessels. Large tumors (Stage IIB) with medial or posterior extraosseous extension require exploration and retraction of the femoral and popliteal vessels. Approximately 95% of osteosarcomas will have a soft tissue component.

Preoperative imaging is essential to determine the location of these vessels. Biplane angiograms are recommended. More recently, contrast CAT or magnetic resonance angiography (MRA) may be helpful.

Surgical exploration of the vessels should begin proximally in the sartorial canal, within normal tissue, and then follow distally. It is rare for the tumor to directly invade the artery or vein. Although the vessels are often the closest structures during the resection, rarely are vascular grafts required.

Intra-articular extension. Tumors of the distal femur may cross or directly involve the knee joint. A pathological fracture will often lead to joint contamination. The most common mechanism of joint involvement is by direct extension along the cruciate ligaments (anterior and/or posterior cruciate). Joint or cruciate involvement can be determined preoperatively with MRI scans. Tumor involvement necessitates an extra-articular resection so as not to contaminate the resection. MRIs accurately identify cruciate involvement. Joint involvement on occasion may only be identified upon early arthrotomy and inspection.

Sciatic nerve. The sciatic nerve lies directly (posteriorly) behind the knee. Tumors with large posterior extra-osseous components may displace this nerve. Anatomically, the sciatic nerve is the most posterior structure in the popliteal space and is rarely directly involved by tumor. Displacement does not contraindicate a limb-sparing resection.

Patella, patellar tendon, and quadriceps muscle group. The patella and the patellar tendon are rarely involved by tumor. The joint and its structures are usually protected by the synovium, which forms a capsule around the anterior extension of the tumor. The patellar fat pad protects the patellar tendon.

Conversely, the quadriceps muscles are often involved by the extra-osseous components of large tumors. In most cases, the tumor involves only the vastus medialis or the vastus lateralis. Portions of the affected muscles have to be resected. The vastus intermedius is routinely resected, since it is the portion of the quadriceps that is closest to the bone. This permits a safe plane of dissection. CAT and MRI preoperatively easily identify muscle and popliteal extension.

Reconstruction of a portion of the quadriceps can be accomplished by the respective hamstring muscle transfer, i.e., the sartorius or semitendinosus muscles for medial defects and the biceps femoris muscle for lateral defects. Large defects, including the knee joint, can be covered by the medial gastrocnemius muscle. The medial gastrocnemius transfer provides good muscle coverage of the prosthesis and knee joint, and prevents complications if flap necrosis or wound dehiscence occurs.

It is necessary to stabilize and to balance the patella in the patellar groove to prevent subluxation or dislocation when portions of the quadriceps are resected. This is accomplished by a combination of tendon transfer and releases.

Contraindications for Limb-Sparing Surgery of Primary Tumors

The contraindications for limb-sparing surgery are as follows:

- ***Major neurovascular involvement.*** Specifically the popliteal vessels.
- ***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, making resection usually 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 (popliteal 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.
- 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.
- Adequate soft tissue coverage is needed to decrease the risk of skin flap necrosis and secondary infection. Medial gastrocnemius transfer may be required.

SURGICAL TECHNIQUE

Anatomical Location of Malignancy

Adequate en bloc resection usually includes 15cm-20cm of distal femur and proximal tibia, and portions of the adjacent quadriceps. An intra-articular resection is usually performed. The surgical planes of resection are shown (Figures 1a & 1b).

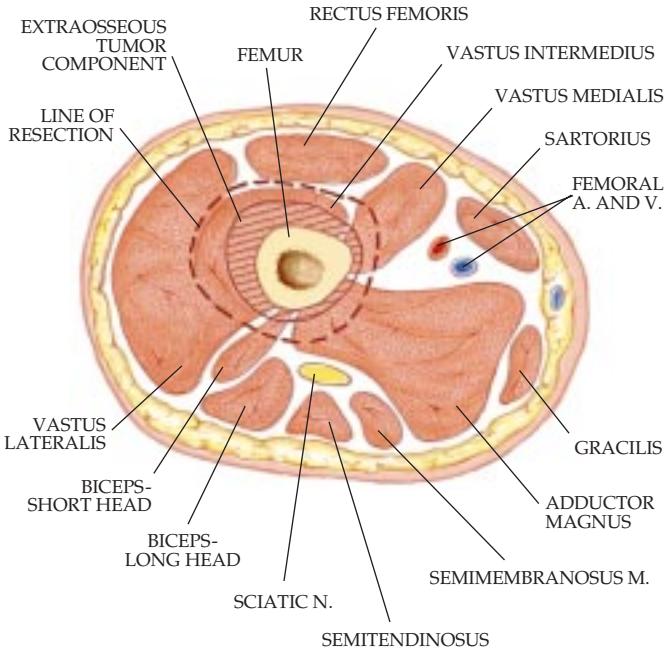

Figure 1a ▲

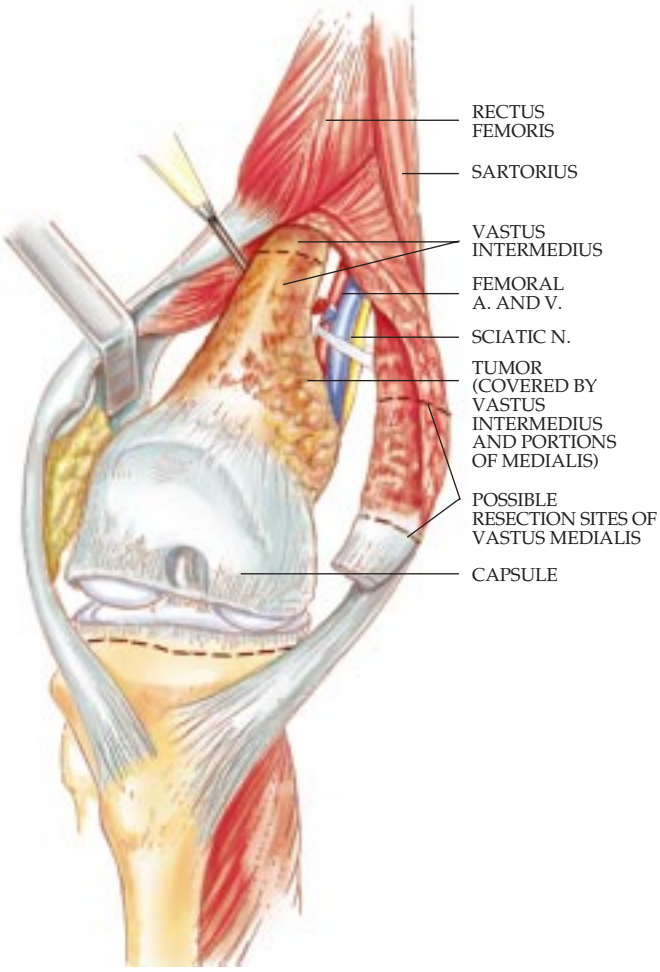

Figure 1b ▲

Surgical Approach and Incision

The patient is placed supine on the operating table. 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.

A long medial incision begins in the mid-thigh, crosses the knee joint along the medial parapatellar area and distal to the tibial tubercle, and then gently curves posteriorly to the inferior border of the pes muscles (Figure 2). The biopsy site is included, with a 3cm margin in all directions. This approach allows extensive 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, the superficial femoral vessels, and the popliteal space. It permits distal extension of the incision to develop a medial gastrocnemius muscle transposition for prosthetic coverage. Fasciocutaneous (not subcutaneous) flaps are developed.

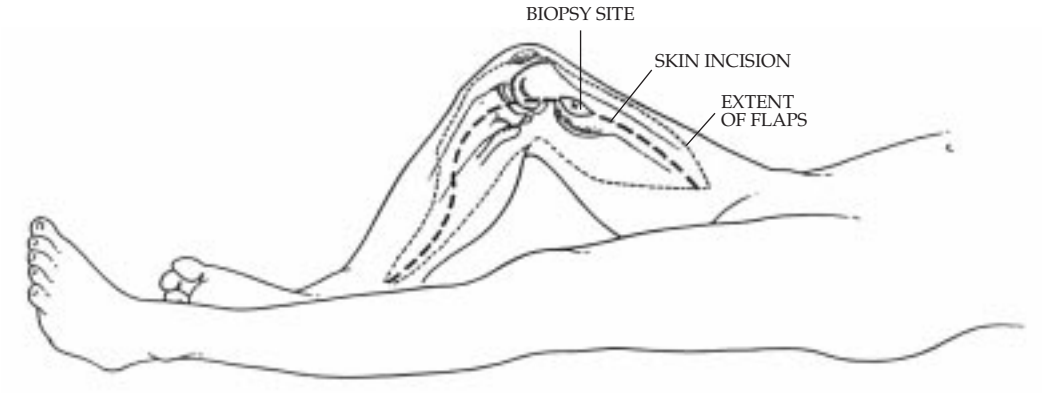

Figure 2 ▲

Popliteal Exploration

Resectability is determined by initial exploration of the popliteal space and vessels. The popliteal space is approached by detaching or retracting the medial hamstrings. The sartorius is identified (Figure 3a). The superior border is opened with the knee in a flexed position. This allows direct entry to the popliteal space, and permits exploration of the popliteal vessels and the sciatic nerve.

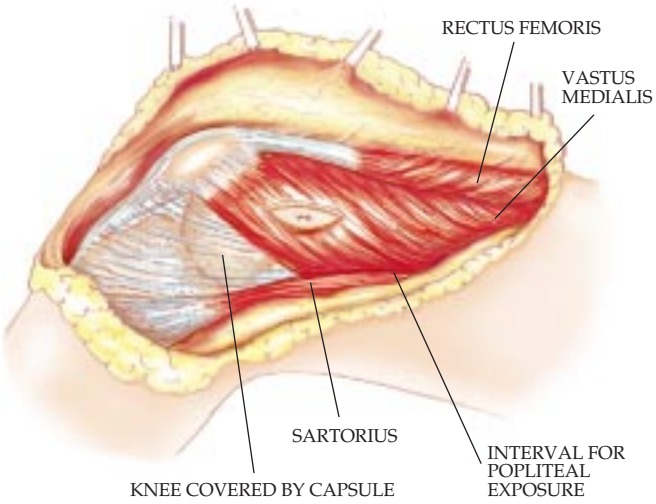

Figure 3a ▲

Superficial Femoral Artery Exploration

The superficial femoral artery (SFA) is identified within the sartorial canal. If resection length is greater than 15cm, the SFA must be mobilized from the adductors within Hunter's canal (as shown). If this is not done, the artery can be inadvertently damaged, due to its proximity to the canal and its contents, as the SFA passes anteriorly to posteriorly. The adductor magnus tendon is released at the foramen to facilitate retraction of the SFA (Figure 3b).

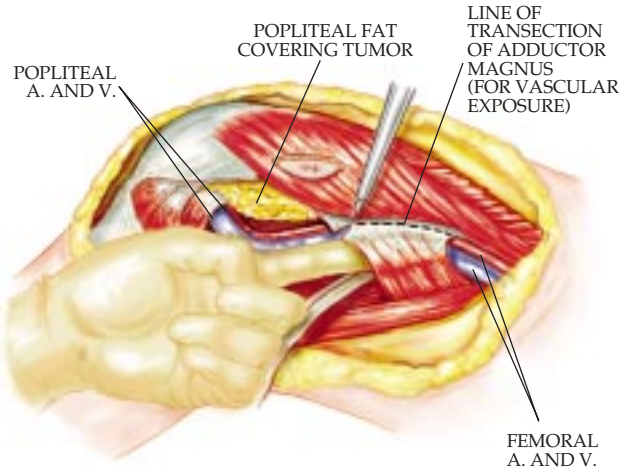

Figure 3b ▲

Posterior Exploration

The interval between the popliteal vessels and the posterior femur is then developed and explored. The popliteal artery is mobilized, and all the geniculate vessels are ligated and transected (Figure 3c). If the vessels are free of tumor, resection proceeds.

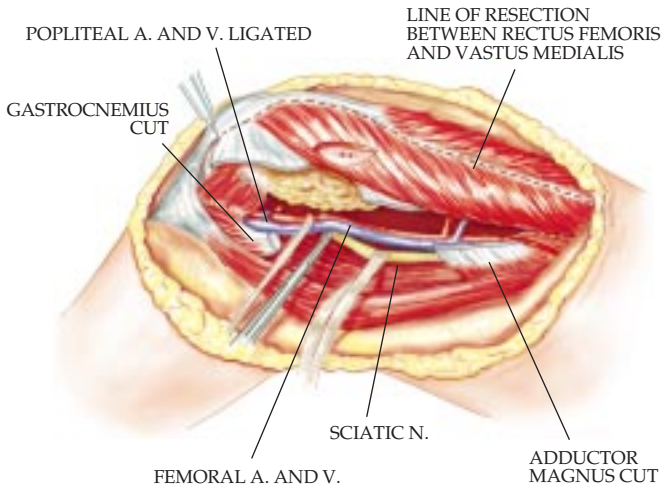

Figure 3c ▲

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 remain as a covering around it. If necessary, the entire portion of the vastus medialis muscle can be removed en bloc with the tumor at its insertion under direct vision. The entire capsular insertion onto the tibia may be partially or completely released (Figure 4). (The stability of the prosthesis is not dependent on the capsule.) The majority of the soft tissue detachments of the distal femoral structures should now 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.

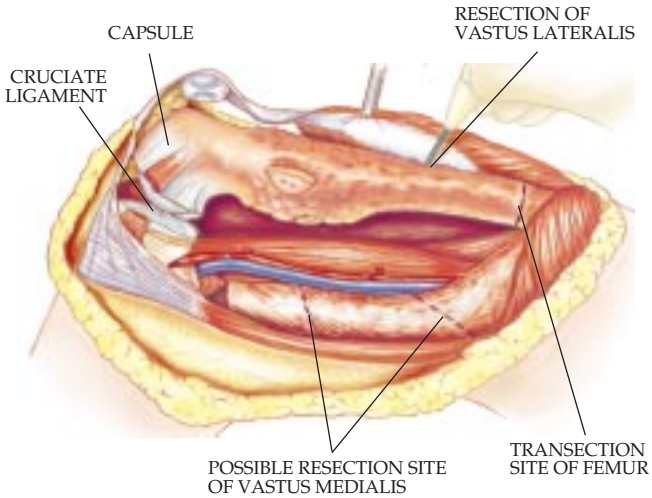

Figure 4 ▲

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 distal femoral resection caliper can be used to guide the resection to a level that can be exactly reproduced by the available implants (Figure 5). 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 lateral condyle 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 bodyless stem, the total replacement length will be 156mm, including the 65mm condylar segment. When the same 80mm body is used with the porous-coated stem with the built-in 40mm body, the replacement length will be 185mm.)*** 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 condylar component.

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

It is important to note that if the condyles of the prosthesis are placed at the level of the pre-op condyles (i.e., the femoral prosthesis is the exact length of the resected distal femur), a 17mm tibial resection is required. Typically, 10mm-12mm are removed from the proximal tibia. The femoral resection is therefore usually about 5mm longer than the prosthesis.

NOTE: ***It is important to ensure proper patellar tracking. The length of the femoral resection and prosthetic replacement must be considered with the tibial resection to recreate leg length and establish proper patellar tracking. One must therefore take patellar tracking, tibial cut, and leg length into consideration when making the femoral resection.***

Surgical Tip: **As an aid in restoring leg length, a reference measurement can be established across the joint. With a bovie or similar device, a mark is made on the femur proximal to the femoral resection, along with a mark on the tibia distal to the tibial resection. The distance between these marks can be measured before the resection is made and checked again, with the trials or implants in place, after the resection is made.**

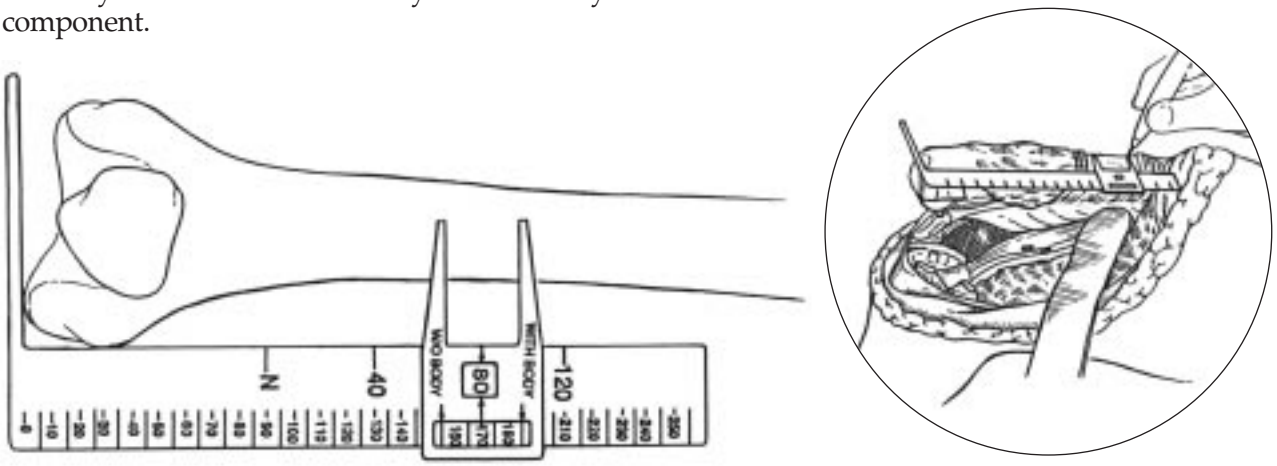

Figure 5 ▲

Rotational Alignment Marking

Using a straight edge, the anterior cortex of the femur is marked above the resection level in line with the trochlear groove of the distal femur (Figure 6). The line should be directly anterior to the linea aspera. This reference mark will be used later to aid in rotational orientation of the prosthetic components. The stem implants and trials are marked in line with the trochlear groove of the distal femoral component. As a guide to rotational orientation, the indicator marking on the implant stem can be oriented to the mark made on the anterior cortex above the resection level.

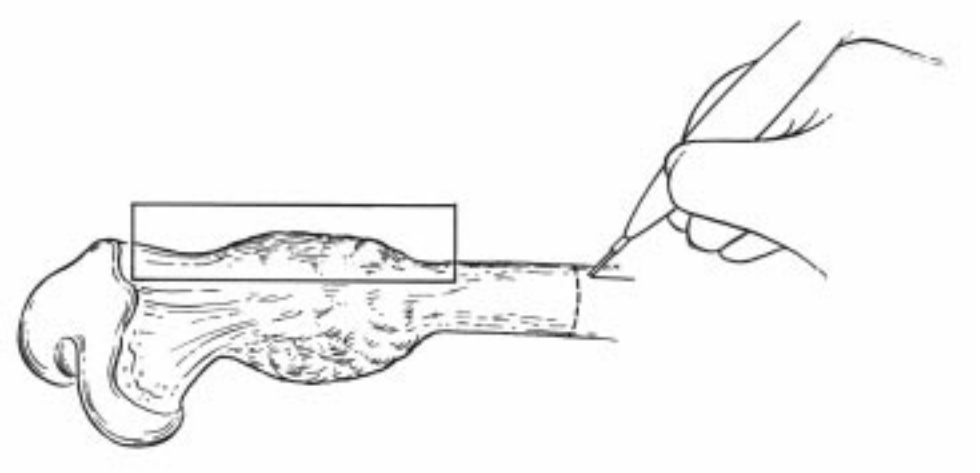

Figure 6 ▲

Femoral Osteotomy

All remaining soft tissue at the level of transection is cleared. The osteotomy, perpendicular to the femoral shaft, is performed after the posterior and medial structures have been protected and retracted; special care is taken to protect the SFA (Figure 7). A frozen section of the bone marrow from the distal end of the remaining femur is performed. Following the osteotomy, it is helpful to pull the distal end of the femur forward in order to expose the remaining soft tissue attachments, (usually remaining fibers of the short head of the biceps, intermuscular septums, and capsular structures). The distal femur is then passed off the operative field.

CAUTION: ***It is extremely important not to distract the tibial extremity following the resection; one assistant must be assigned to monitor this. The end of the femoral osteotomy should be kept well padded to avoid injuring the popliteal/SFA vessels. The length of the resected specimen should be checked and measured again following resection.***

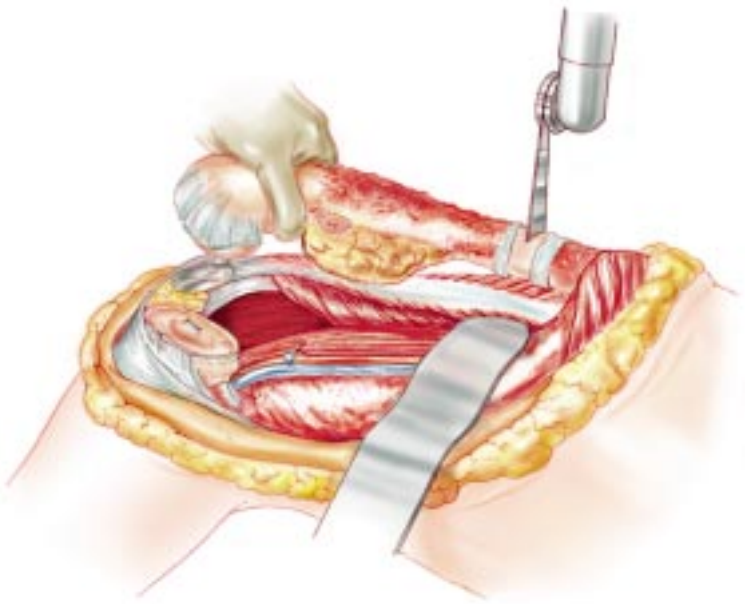

Figure 7 ▲

Preparation of the Femur

A flexible guide wire is inserted into the femoral canal. Flexible reamers are utilized to progressively ream 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 facing reamer (Figure 8) 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.

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

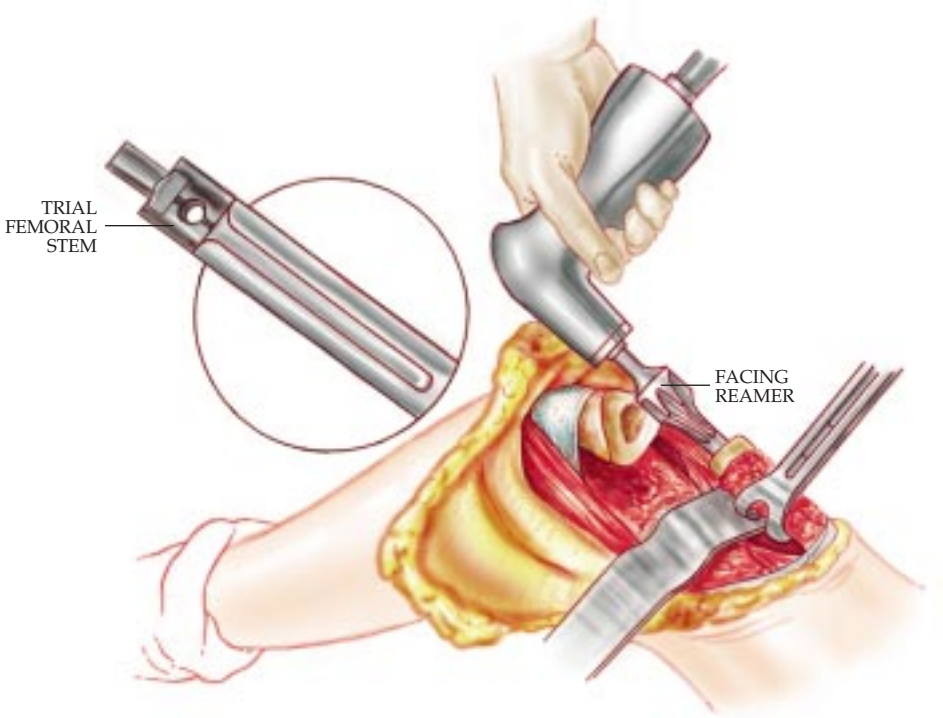

Figure 8 ▲

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 9).

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

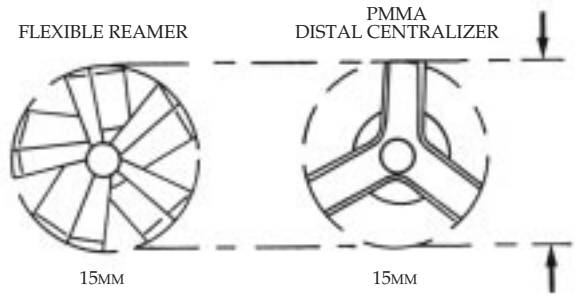

Figure 9 ▲

Proximal Tibial Resection

This technique illustrates the preparation for the Kinematic® Rotating Hinge All-Poly Tibial Component which articulates with the Modular Replacement System distal femur. The technique for the Kinematic® Rotating Hinge Metal-Encapsulated Tibial Component, which also articulates with the Modular Replacement System distal femur, is illustrated in *Appendix I*.

The required proximal tibial cut is neutral to the tibial axis in all planes, i.e., cut in classical alignment with no posterior slope. The amount of bone to be removed, when taken in consideration with the femoral resection, will reconstruct the pre-op joint line and leg length. The instrumentation provides two options for determining the resection level of the proximal tibia. The first option uses a tibial marking guide to mark the tibial cut in relation to the femoral prosthesis trials. The second option utilizes a stylus to set the depth of the tibial cut.

It is important to note that if the condyles of the prosthesis are placed at the level of the pre-op condyles (i.e., the femoral prosthesis is the exact length of the resected), a 17mm tibial resection is required. Typically, 10mm-12mm are removed from the proximal tibia. The femoral resection is therefore usually about 5mm longer than the prosthesis.

Establishing the Depth of the Tibial Cut: Femoral Referencing Method

Construct the trial femoral prosthesis by joining the trial femoral stem segment with the trial femoral body segment and the trial condylar segment.

With the femoral trial prosthesis in place, the tibial cut indicator (Figure 10) is attached to the condylar trial with two 1/8-inch pins or drills. An alignment rod is attached to the cut indicator to aid in aligning the tibia. The tibia is gently distracted in line with the alignment rod with the appropriate amount of tension on the soft tissues.

Surgical Tip: **The amount of tension placed on the tibia while marking the resection level can be guided by the leg-length reference marks made earlier. The lower extremity can be tensed until the distance between the mark on the femur and tibia match the pre-op measurement.**

The tibia is marked at the level of the marking surface on the tibial cut indicator. Begin by setting the marking guide for the thinnest tibial component. If the resection level will not remove any bone, the tibial cut indicator can be set for a thicker tibial component and then marked. Be certain not to place too much tension on the tibia during distraction.

If the surgeon feels that too much tibia must be removed for the thinnest tibial component, additional bone can be removed from the femur. It is suggested that whenever additional bone is removed from the femur, the level of the patella is checked in reference to the prosthesis to ensure proper patellar tracking.

Once the level of the tibial cut has been marked, either the extramedullary referencing or the intramedullary referencing instrumentation can be used to align the tibial cutting block. The depth of the cutting block is then set at the marked resection level.

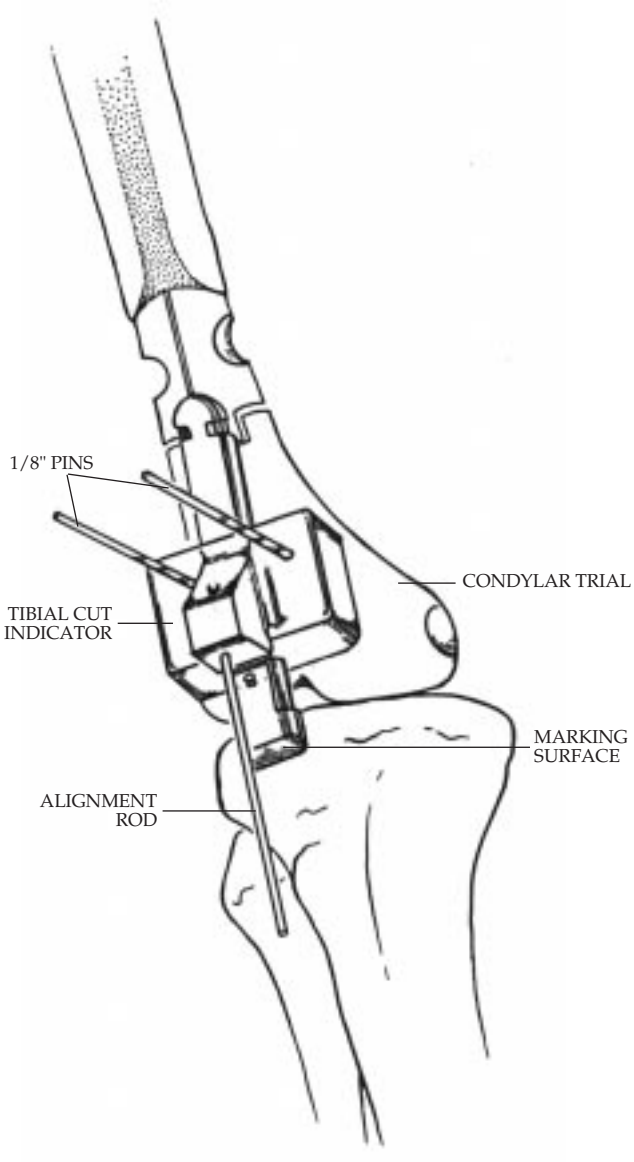

Figure 10 ▲

Positioning the Tibial Alignment Jig

There are two options for aligning the tibial cut: extramedullary referencing alignment and intramedullary referencing alignment.

OPTION A - Extramedullary Referencing

The proximal tibial cutting assembly has two parts: the ankle clamp and the proximal alignment guide. These are assembled first. Then the tibial cutting jig is positioned over the thin section of the proximal guide assembly shaft, slid proximally, and locked into position (Figure 11).

The system offers a 0° posterior slope and 0° M/L tibial cutting jig. The cutting jig, available in left and right configurations, is designed to avoid soft tissue impingement (Figure 12).

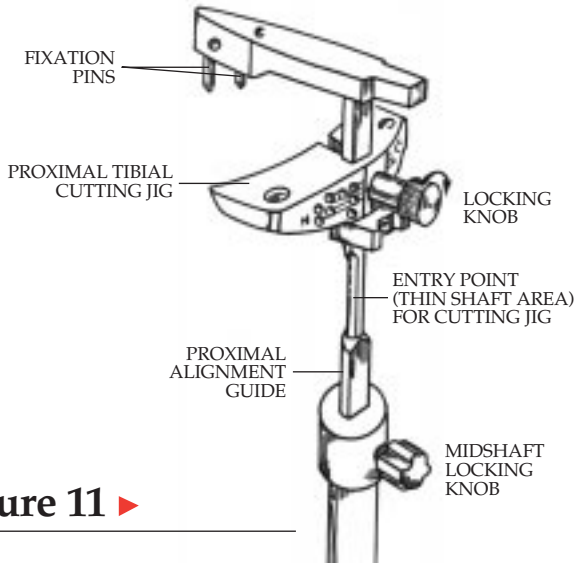

Figure 11 ▶

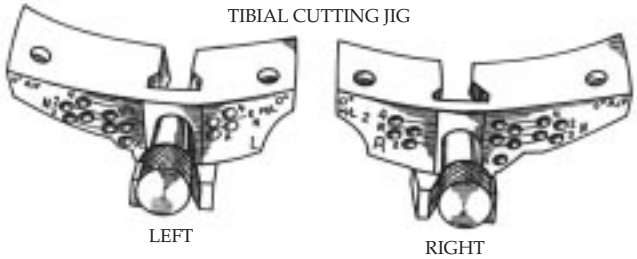

Figure 12 ▲

Flexion/Extension Alignment

The long fixation pin of the proximal alignment guide is partially seated in the proximal tibia to stabilize the assembly.

Flexion/extension alignment is correct when the long axis of the assembly parallels the midcoronal plane of the tibia. Flexion/extension alignment can be further confirmed by seeing that the long axis of the assembly is parallel to the fibula. Distal locking knob "A" is then tightened (Figure 13).

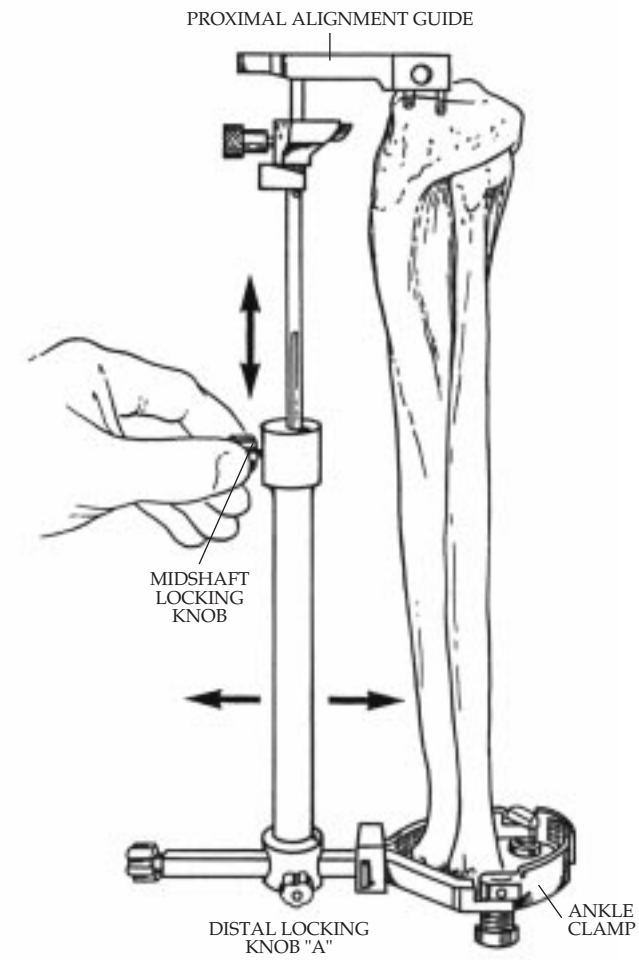

Figure 13 ▲

Medial/Lateral Alignment

Medial/lateral offset can be adjusted using distal locking knob "B" (Figure 14). The assembly is slid medially until the jig shaft intersects the center of the tibia.

Once triaxial alignment is achieved, fully tighten the midshaft locking knob. Fix the whole assembly in place by striking the proximal end of the alignment rod with a mallet, securing the two fixation pins.

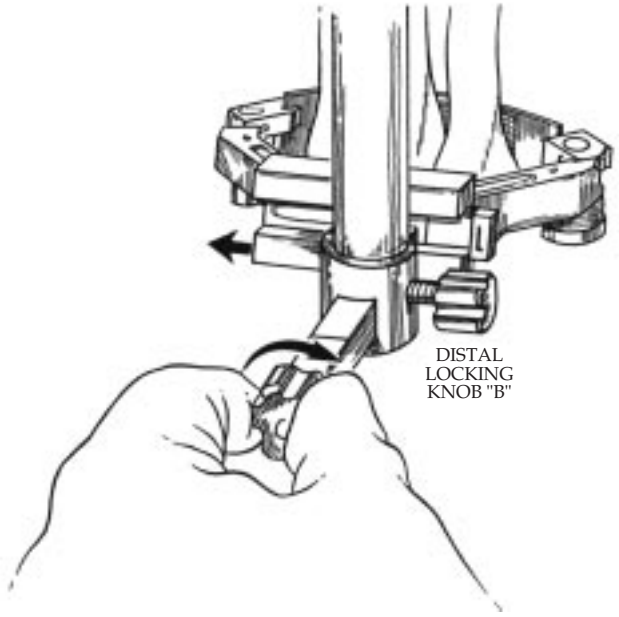

Figure 14 ▲

OPTION B - Intramedullary Referencing

A 5/16" hole is drilled in the location determined by the preoperative X-rays (Figure 15).

Slowly pass the IM rod into the canal, clearing the canal. Remove the rod and then reinsert it into the body of IM alignment jig. The assembly is then inserted into the canal, and the IM rod is passed into the canal until the isthmus is engaged (Figure 16).

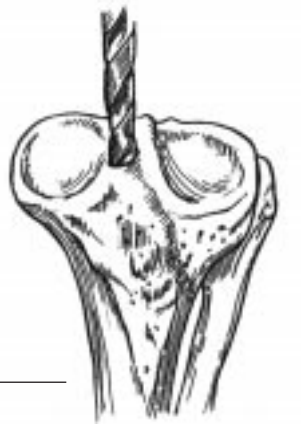

Figure 15 ▶

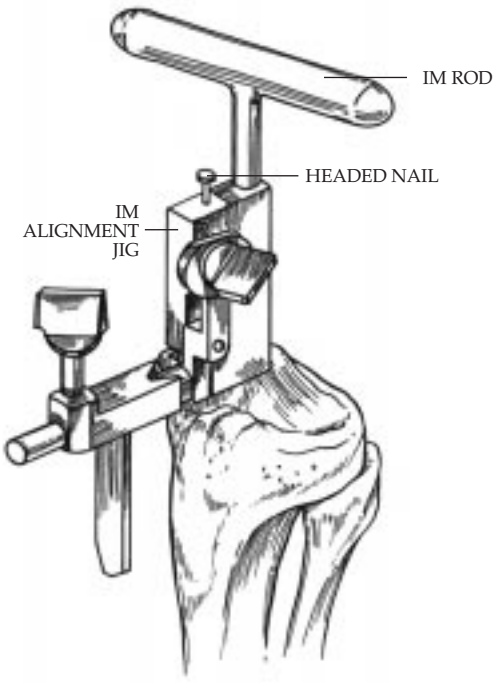

Figure 16 ▲

Varus/Valgus Alignment

Assemble the appropriate tibial cutting jig (left or right) onto the mounting bar, and lightly tighten the locking knob on the face of the cutting jig. Attach the alignment handle to the cutting jig, and slide a long alignment pin through the neutral tibial "NT" alignment hole. When varus/valgus alignment is correct, the pin should be centered over the ankle.

If varus/valgus adjustment is needed, locking knob "1" is loosened. The mounting bar is pulled toward the surgeon, and the jig is rotated until proper varus/valgus orientation is achieved (Figure 17). Once the alignment pin is centered over the ankle, the locking knob is securely tightened.

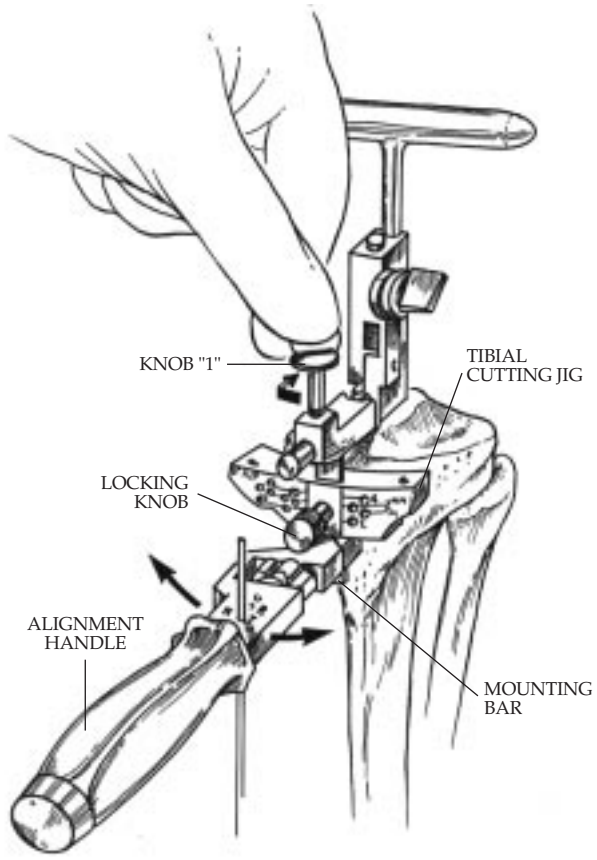

Figure 17 ▲

Flexion/Extension Alignment

If the posterior slope must be adjusted (keeping in mind that the tibial cutting jigs do not include posterior slope and that the cut should not be sloped posteriorly), loosen locking knob "2" and set the appropriate level of slope. Once the correct 0° slope is attained, securely tighten locking knob "2" to set the final position of the jig (Figure 18).

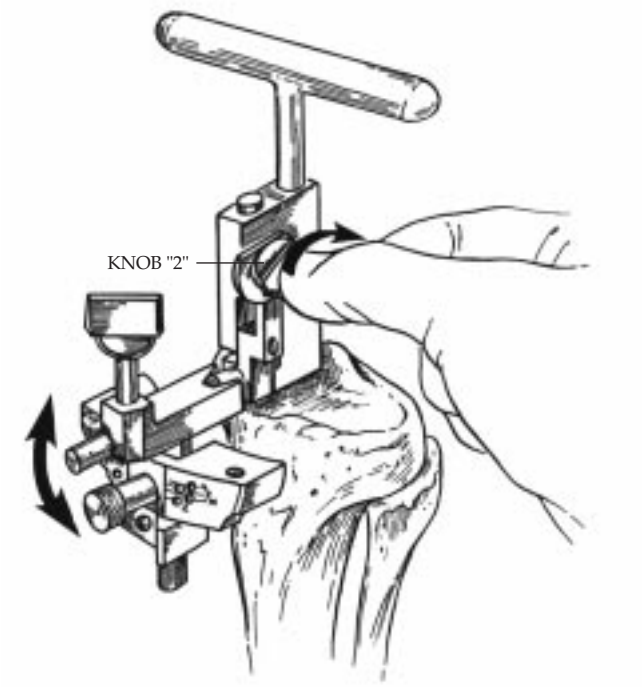

Figure 18 ▲

Establishing the Depth of the Tibial Cut: Tibial Referencing Method

[NOTE: The following applies to both extramedullary and intramedullary alignment.]

The tibial marking stylus attaches to the tibial cutting jig, with the "8mm" end referencing the lowest level of the midplateau on the unaffected compartment (Figure 19). (The "8mm" marking refers to the 8mm All-Poly Tibial Component.) 12mm of bone will be resected. Alternatively, if the "0mm" end of the tibial marking stylus is used, the amount of bone resected will be in line with the tip of the stylus.

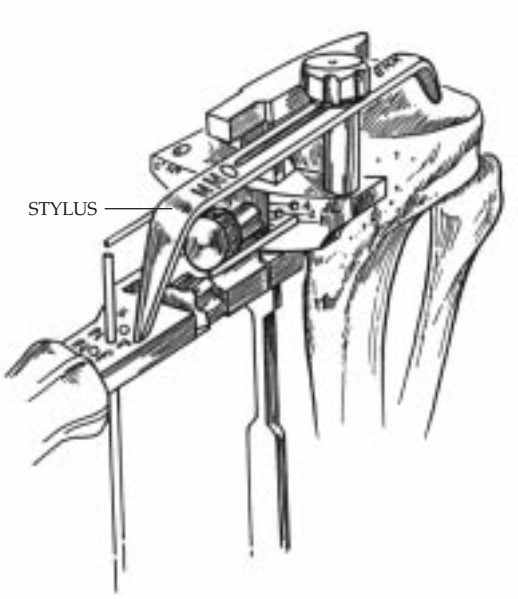

Figure 19 ▲

Two 1/8" drill pins are placed into the "N" [neutral] holes, fixing the level of the tibial cutting jig. The extramedullary ankle clamp and proximal alignment guide or the IM rod and the intramedullary alignment jig are removed, leaving the cutting jig in place. If additional stability of the jig is required, utilize the oblique "X" hole.

Cutting the Proximal Tibia

Resection of the proximal tibia is now completed (Figure 20). The pin puller is then used to remove the tibial cutting jig.

Select the appropriate size tibial template, and lock it onto the tibial alignment handle. The appropriate size template will achieve cortical support around the periphery of the template.

NOTE: It is important that the correct size be selected to fully support the all-poly tibial component around the periphery with cortical bone.

The short posterior tabs on the tibial template help stabilize the template at the posterior cortical surface (Figure 21).

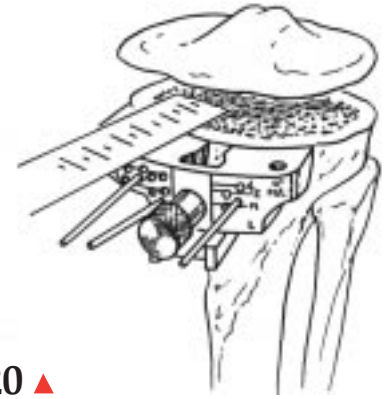

Figure 20 ▲

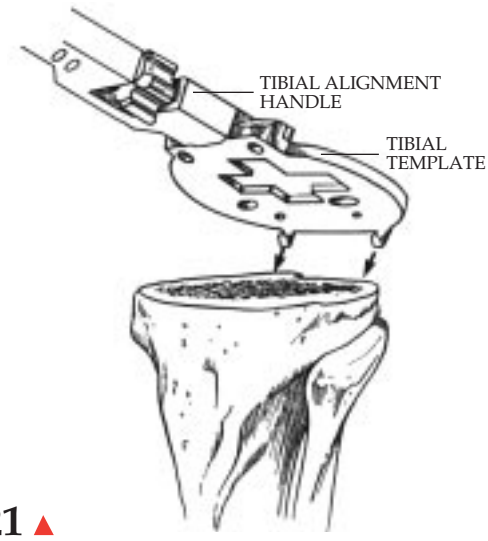

Figure 21 ▲

Verifying Alignment

The alignment handle verifies rotational, varus/valgus, and flexion/extension alignment (Figure 22). Rotational alignment is correct when the drill bit placed in a hole from the previous step parallels the handle (Figure 23). Varus/valgus and flexion/extension alignment are verified with a long alignment pin. Since a classical tibial cut has been made, use the neutral tibial "NT" alignment hole. The pin should be centered distally over the center of the ankle.

Holes are located on the anterior face and the posterior surface of the template. Headed nails or drills through these holes may be used to temporarily fix the template.

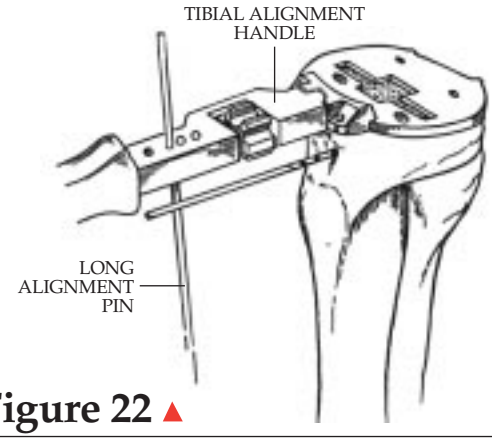

Figure 22 ▲

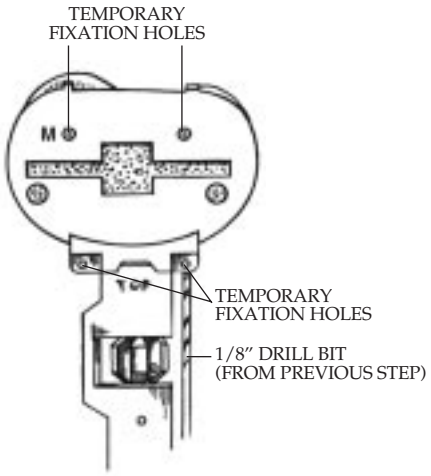

Figure 23 ▲

Round Stem Punch

To begin preparation for the Kinematic® Rotating Hinge All-Poly Tibial Component, place the stem punch guide (Figure 24) on the tibial template. Insert the stem punch into the guide and slowly impact the punch until it is flush with the guide. The plunger is then inserted into the hole of the stem punch and impacted flush. This will position a bone plug at the distal tip of the tibial component stem, plugging the canal. Remove the plunger. The stem punch can be removed with the impactor/extractor.

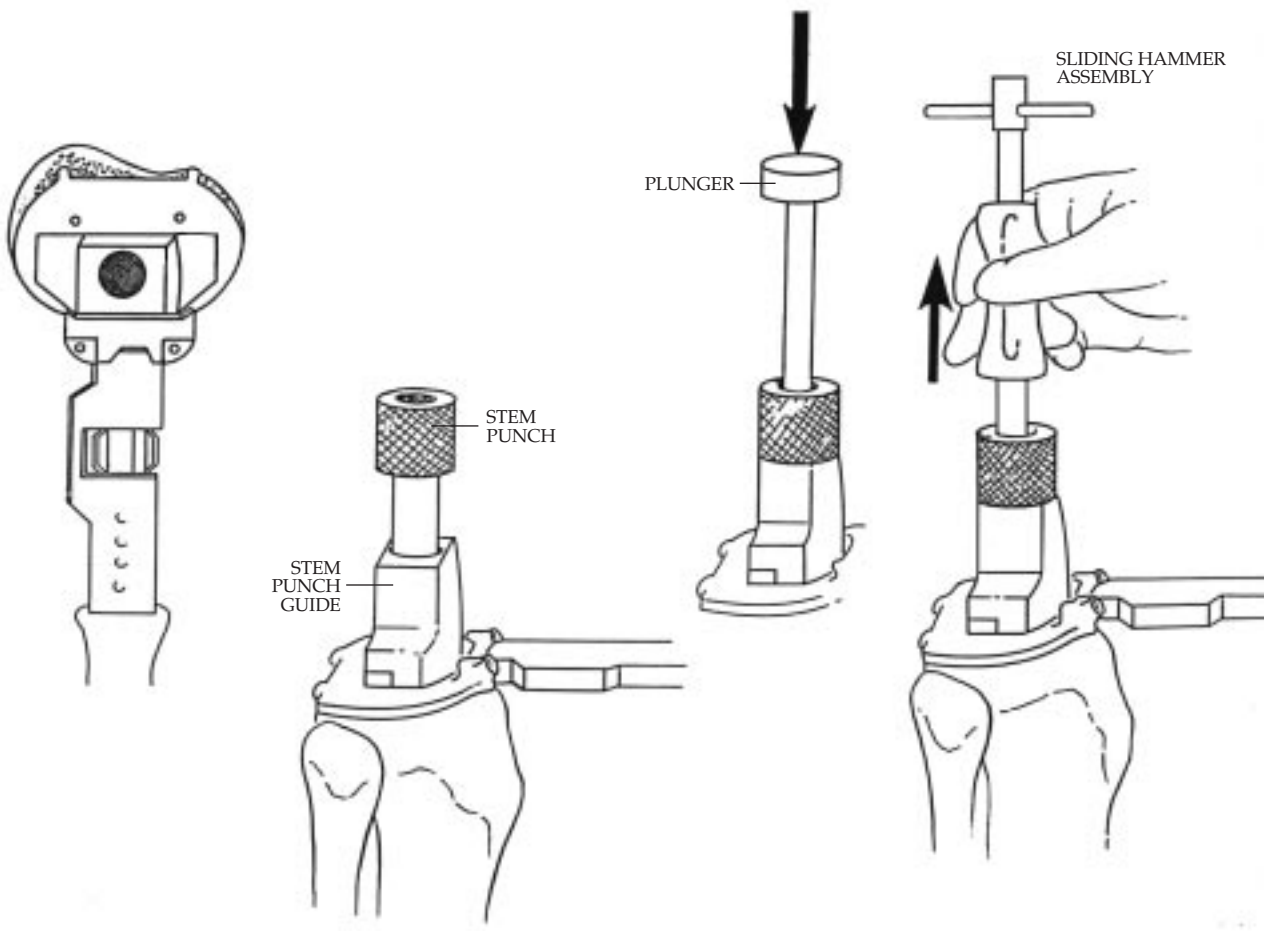

Figure 24 ▲

Initial Fin Punch

Place the rectangular fin/box punch guide on the tibial template (Figure 25). Insert the initial "thin" fin stem punch into the cutout of the guide and slowly impact the punch until it is flush with the surface of the guide. During insertion, it is important to precisely control the stem punch, maintaining it perpendicular to the resected surface. Slowly impact the fin punch to allow expansion of the bone.

Final Fin Broach

Insert the final "thick" fin broach (Figure 26) into the cutout of the guide and slowly impact the broach until it is flush with the surface of the guide. During insertion, it is important to precisely control the final stem broach, maintaining it perpendicular to the resected surface.

Remove the final fin broach with the extractor.

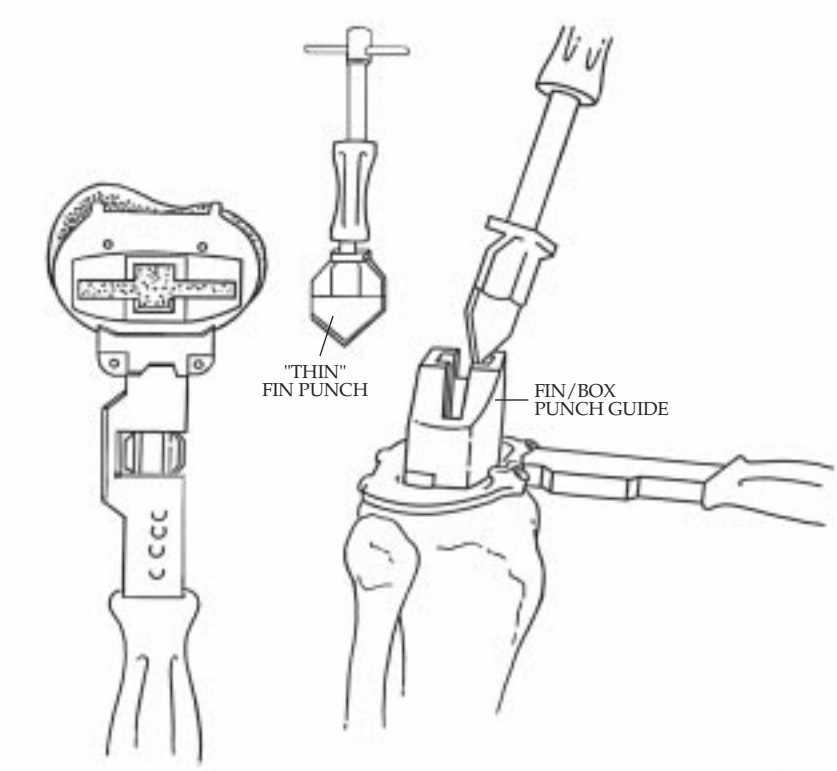

Figure 25 ▲

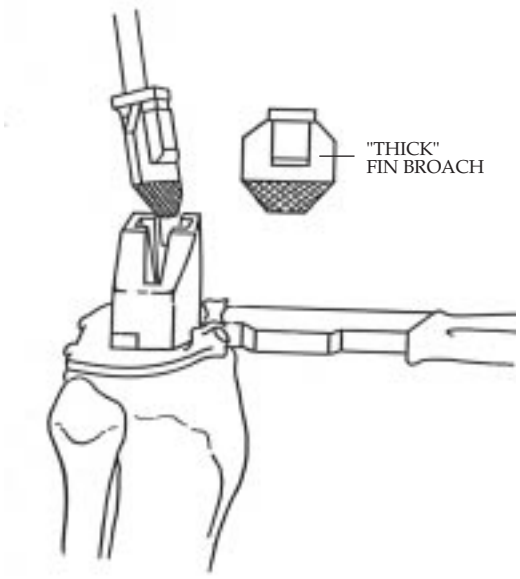

Figure 26 ▲

Box Broach

Insert the box broach (Figure 27) into the cutout of the guide and slowly impact the broach until it is flush with the surface of the guide. During insertion, it is important to precisely control the box broach, maintaining it perpendicular to the resected surface.

Remove the box broach with the extractor.

Final Stem Preparation

The tibial template is removed. The stem reamer (Figure 28) is inserted into the center hole of the tibia and slowly turned in a clockwise direction and advanced into the tibia until the circumferential depth mark is flush with the cut surface of the tibia.

Technical Hint: **Several shallow drill holes can be made in the proximal tibia to enhance cement fixation.**

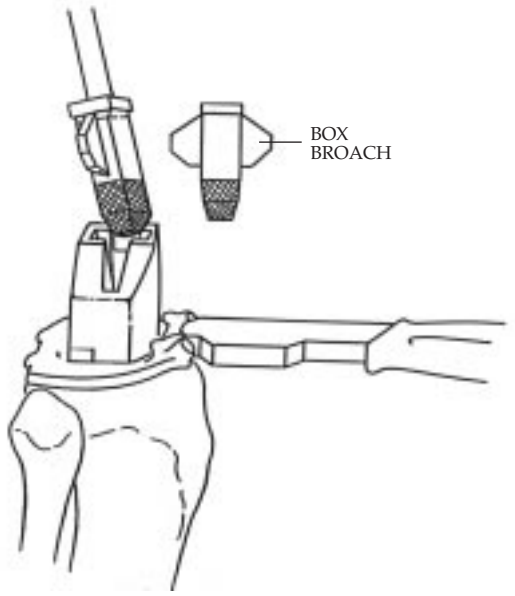

Figure 27 ▲

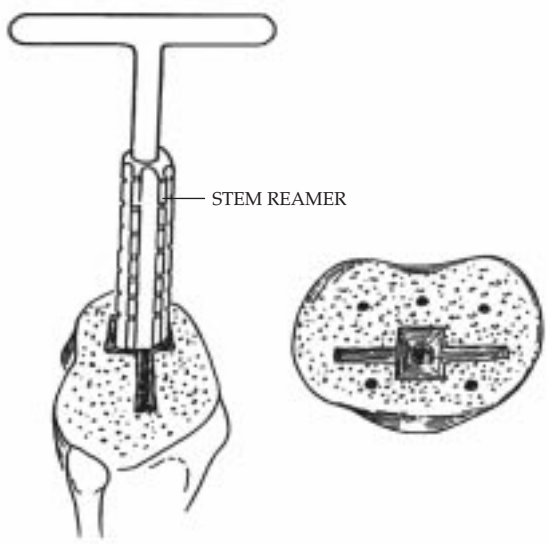

Figure 28 ▲

Patellar Preparation

If the patella is to be resurfaced, the proper size patellar component should be selected to obtain suitable coverage and to reconstruct the patella to its original thickness (or thinner). The patella can be measured with a caliper to determine its original thickness, and is sized with the patellar sizing templates provided (Figure 29). The Kinematic® Patellar Components are available in small, medium, and large. Each is 9mm thick. Please refer to the Monogram® Patellar Preparation Technique for details on Howmedica's patellar preparation instrumentation options.

Once the patella has been resected, center the appropriate size patellar template over the patella. The holes are prepared with the appropriate drill.

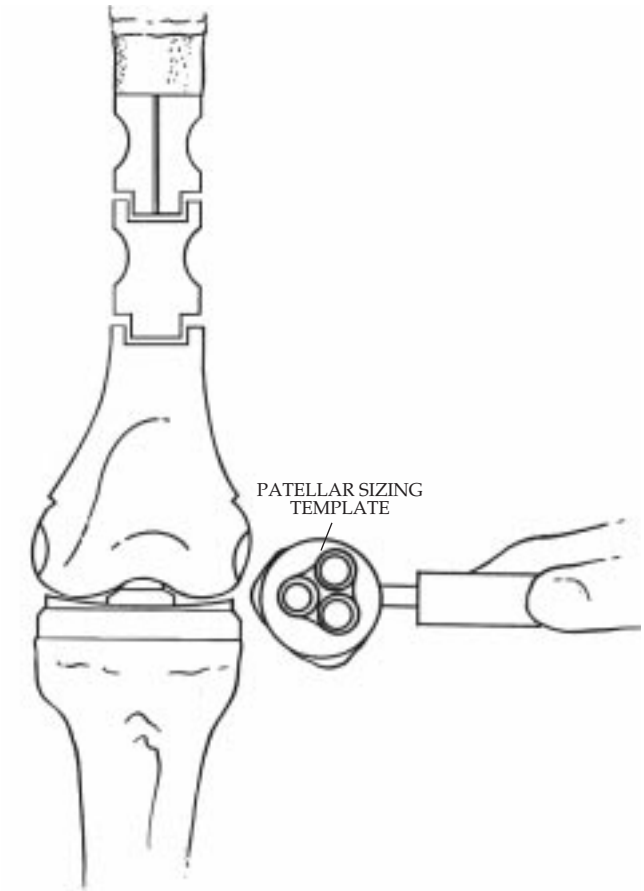

Figure 29 ▲

Trial Assembly

Construct the trial femoral prosthesis by joining the trial femoral stem segment with the trial femoral body segment and trial condylar segment (Figure 30). The trial tibial bearing component is assembled to the trial condyle with the trial axle/ bushing. The trial axle/bushing is held in place with the trial bumper.

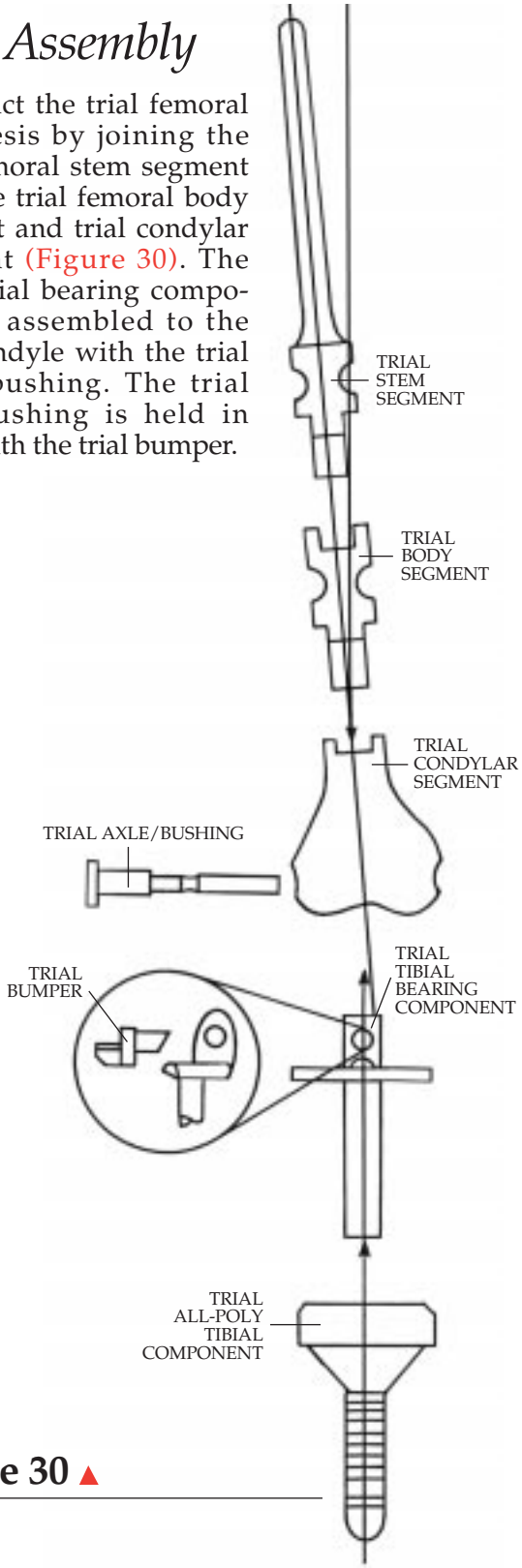

Figure 30 ▲

Trial Reduction

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 (Figure 31). 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.

Insert the trial tibial component into the tibia, and impact it using the tibial impactor until it is flush with the cut surface.

Insert the stem of the trial femoral assembly into the femur. As a guide to rotational orientation, align the rotational alignment mark on the femoral stem segment with the rotational reference mark previously made on the anterior cortex of the femur (Figure 31, inset). The linea aspera can also

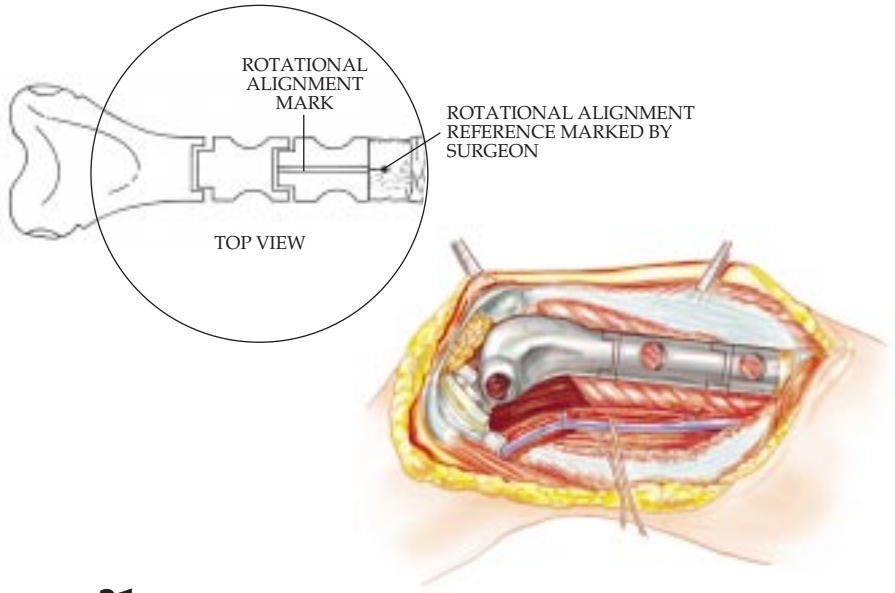

Figure 31 ▲

be used as a guide (Figure 32). Construct an imaginary perpendicular plane that passes directly anterior, originating from the linea aspera. The horizontal axis of the prosthesis (the axle) should be perpendicular to this plane. Slight external rotation may aid in patellar tracking.

Hold the femoral components in one hand to prevent rotation, and extend the leg fully. Palpate the femoral vessels to determine the status of the pulse, or evaluate the pulses at the ankle with a sterile Doppler. If the pulse is diminished, flex the knee to determine if it increases. This will indicate the need for either modifying the length of the prosthesis or for removing additional bone from the distal femur or proximal tibia.

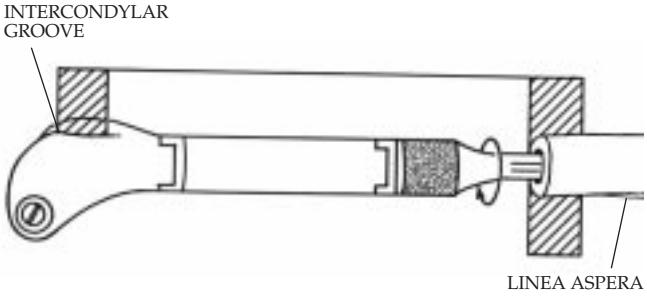

Figure 32 ▲

Surgical Tip: **As an aid in checking leg length, the distance between the leg-length reference marks on the tibia and femur can now be rechecked.**

If it is determined that the prosthetic construct is too long, the length of distal femoral bone resected should be rechecked against the length of the assembled prosthesis. If the prosthesis is too long, either additional bone can be removed from the femur, or the length of the prosthesis can be adjusted.

If the surgeon feels that removing additional bone from the femur or shortening the femoral prosthesis will have a negative effect on patellar tracking, additional bone must be removed from the tibial side.

A final test of the range of motion of the knee with the patella tracking in place is then performed. If the patella will be resurfaced, this must be done with the patellar trial in place. A full range of motion should be obtained. Note whether the capsular mechanism can be easily closed. These factors, taken together, will determine the adequacy of the length of the resection.

The two most important factors in accepting final length are:

1) Proper patellar tracking.

2) Distal pulses.

The decision can now be made if a gastrocnemius flap or muscle transfer will be required, dependent upon the presence or absence of the capsule or portions of the quadriceps.

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), and the femoral condylar segment (Figure 33). Check that the correct side for the condyle and the correct sizes of all components have been chosen before assembly. If necessary, it is acceptable to stack two femoral bodies to construct the necessary length. The instruments used for the assembly of the prosthesis are the impaction tube, trunnion impactor, and assembly pad along with a mallet.

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

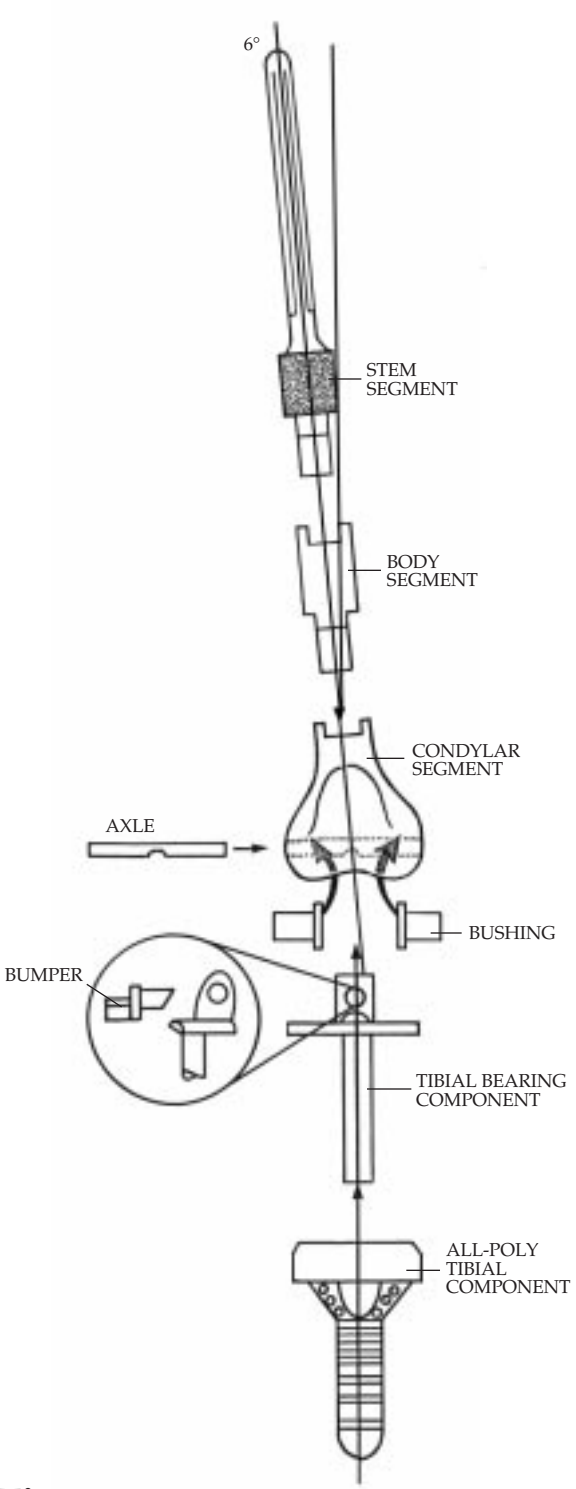

Figure 33 ▲

Exploded View of Assembled Distal Femoral Implant Components.

The femoral body segment and femoral stem segment are assembled first (Figure 34). The impaction tube head corresponding to the stem diameter is assembled to the impaction tube base (A). The femoral stem is placed into the impaction tube (B), and the femoral body segment is mated with it (C). The trunnion impactor is placed over the taper of the femoral body segment (D), and impacted with several swift blows of a heavy mallet to lock the tapers.

Next, the stem/body construct is assembled to the condyle. A lap pad is placed on the condylar assembly pad to protect the polished finish of the condylar implant. The condylar implant is then placed on the assembly pad and held securely in place by the cross-bolt. The femoral stem and body assembly are mated with the condyle component (E). The impaction tube is inverted and placed over the stem and impacted with several swift blows of a heavy mallet.

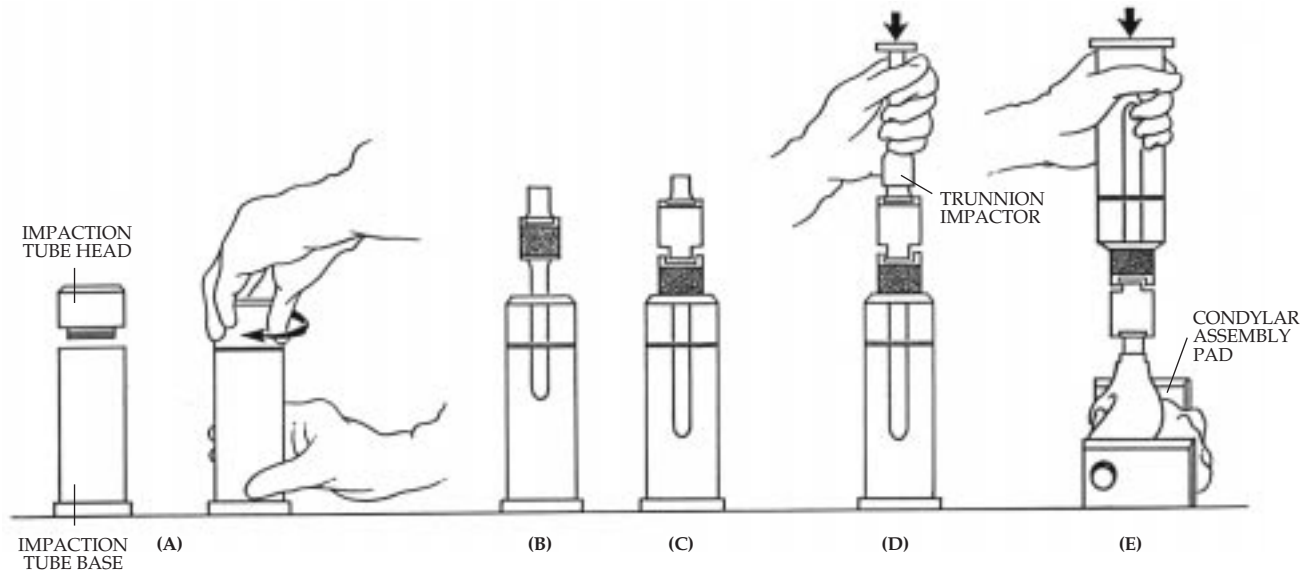

Figure 34 ▲

The parts needed to assemble the Rotating Hinge mechanism to the condyle are labeled numbers 1-4, and are shown in Figure 35. The two bushings are first inserted into the condyle from the inside as shown (1). The long tibial bearing component (2) (used with the all-poly tibial component) is brought up between the bushings. The axle is then introduced as shown. A relief exists on the axle to accept the bumper. The axle (3) is slotted on each end to rotate the axle so that the relief can be lined up with the anterior hole in the tibial bearing component to accept the bumper (4). The bumper is then inserted as shown to lock the assembly together.

NOTE: After the bumper is in place, the axle should NOT be rotated. It will be in its final position.

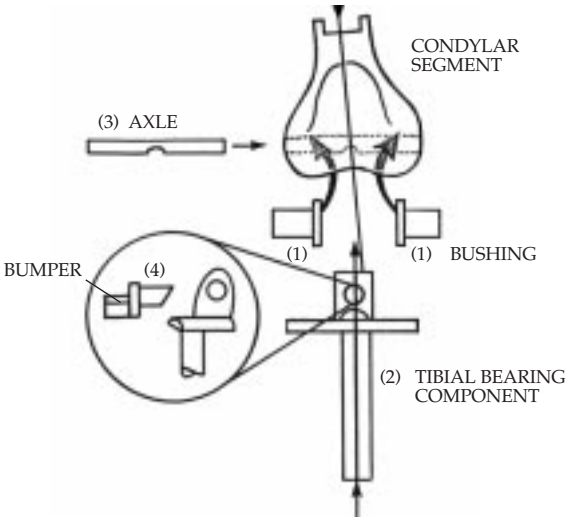

Figure 35 ▲

Final Trial Articulation with Prosthesis

Once the prosthesis is assembled, it is brought into place in the wound and articulated with the trial all-poly tibial component (Figure 36). The articulation of the actual prosthesis is identical to that of the trial structure. As a guide to rotational orientation, align the rotational alignment mark on the femoral stem segment with the rotational reference mark previously made on the anterior cortex of the femur. Hold the femoral components in one hand to prevent rotation, and extend the leg fully. Palpate the femoral vessels to determine the status of the pulse, or evaluate the pulses at the ankle with a sterile Doppler. If the pulse is diminished, flex the knee to determine if it increases. This will indicate the need for either modifying the length of the prosthesis or for removing additional bone from the distal femur or proximal tibia.

If it is determined that the prosthetic construct is too long, refer to the steps on **Page 32** to correct the length.

A final test of the range of motion of the knee with the patella tracking in place is then performed. If the patella will be resurfaced, this must be done with the patellar component in place. A full range of motion should be obtained. Rotational orientation should be set to allow for proper patellar tracking. Slight external rotation of the prosthesis may aid in proper patellar tracking.

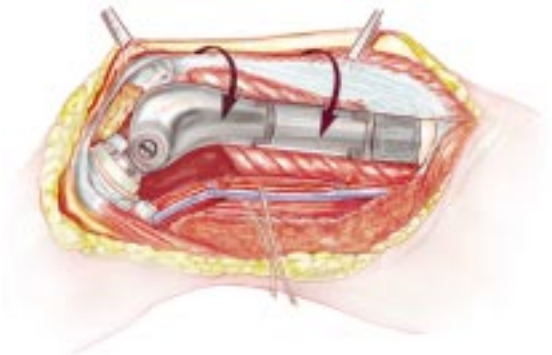

Figure 36 ▲

Implantation and Orientation of the Femoral and Tibial Prostheses

To implant the tibial component, the medullary canal is irrigated and dried. Surgical Simplex® P bone cement is injected with a cement gun to fill the canal and coat the undersurface of the tibial prosthesis. The prosthesis is introduced and impacted until it is flush with the cut surface. Excess cement is removed.

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 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. Simplex bone cement is mixed and injected into the canal to ensure complete filling of the canal. Some cement is then placed around the stem of the prosthesis.

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

The prosthesis is then inserted into the femoral canal until the stem seat is flush with the host bone at the osteotomy site. Excess cement is removed from around the prosthesis. Care is taken to prevent cement from getting into the extramedullary porous-coated section. It is firmly held in place at the rotational orientation determined by the trial reduction while the cement cures.

With the knee in flexion, the tibial bearing component is inserted into the all-poly tibial component.

If a patellar component is used, it is implanted by applying sufficient amount of bone cement to the patellar implant and bone. Cement should be applied to both the bone surface and back of the patellar implant, including the "pocket."

Surgical Tip: **Application of cement in a low-viscosity state will allow the implant to fully seat and facilitate interdigitation of cement and bone.**

Extracortical Fixation

The extracortical porous-coated area of the femoral stem can be utilized for additional bony or soft tissue support implication to form a "noose" around the stem. Theoretically, this will limit any debris entering the bone-cement interface, which could cause cement and prosthetic loosening. If bone graft is used, it should be fixed in place with Dacron™ tape (Figure 37). The cortical surface of the femur can be roughened with a mechanical burr. Care must be taken not to place bone graft adjacent to the SFA.

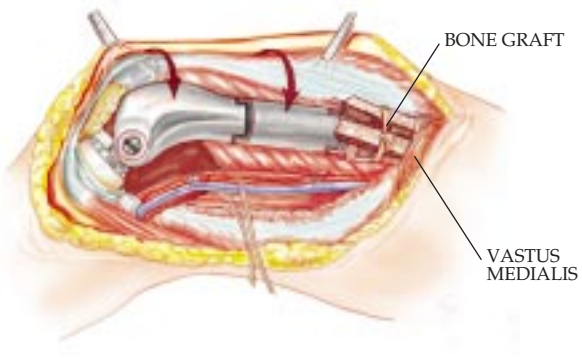

Figure 37 ▲

Closure of Soft Tissue Reconstruction with Medial Gastrocnemius Transfer

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 (Figure 38). A large medial defect requires a medial gastrocnemius transfer. Similarly, a lateral defect is closed with a lateral gastrocnemius transfer.

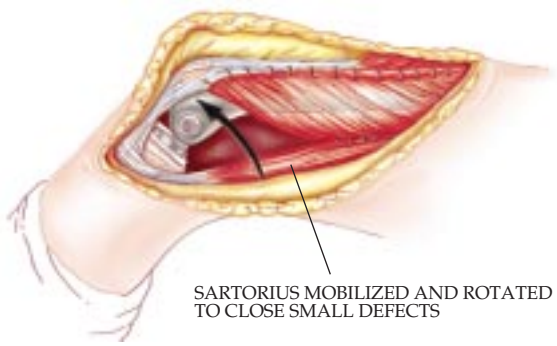

Figure 38 ▲

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 musculo-tendinous junction; 2) Create a posterior-based mid-line fasciocutaneous flap in order to expose the midline of the two gastrocnemius muscle bellies; and 3) Expose and open the interval between the medial gastrocnemius muscle and soleus muscle by lifting the medial gastrocnemius muscle by finger dissection. Stop at the midline (Figure 39).

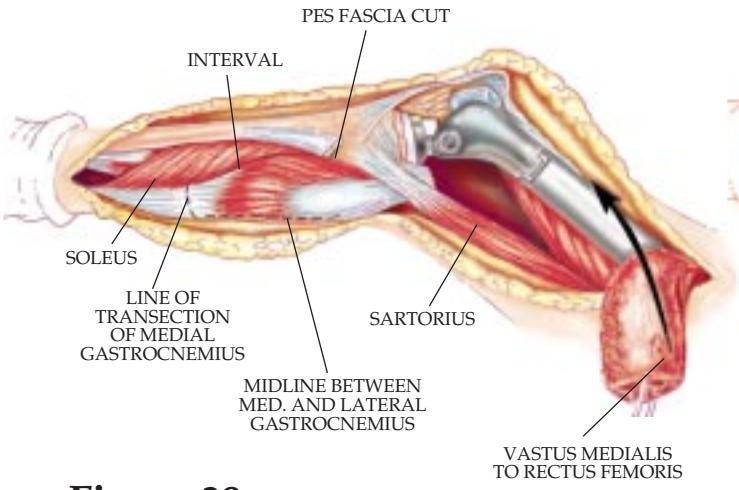

Figure 39 ▲

Fascia of Pes Muscles Released

Detach the medial portion of the musculotendinous junction and separate the two muscle bellies along the midline (Figure 40).

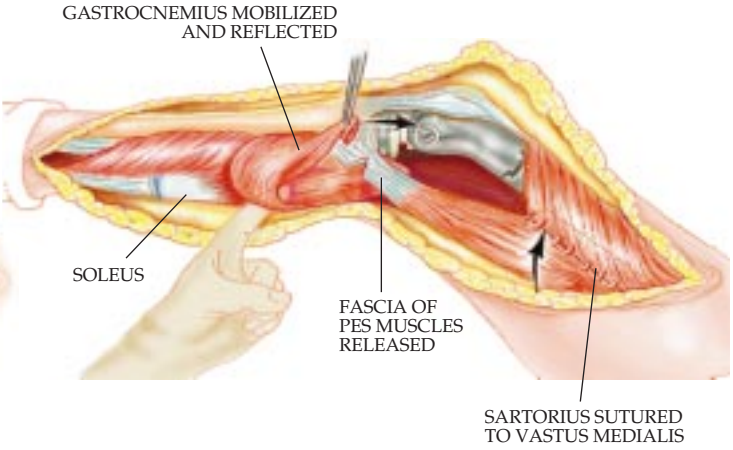

Figure 40 ▲

Rotation of the Muscular Flap

Rotate the flap anteriorly over the prosthesis (Figure 41). Occasionally, the fascia of the pes musculature must be released to increase the arc of rotation. Remove the thick anterior and posterior fascia of the medial gastrocnemius in order to spread the muscle over a larger area.

Wound Closure

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

A 28-gauge chest tube attached to Pleurovac™ suction (20cm of water) is used (Figure 42). The pulses are checked following wound closure and prior to removing the patient from the table. A knee immobilizer is used.

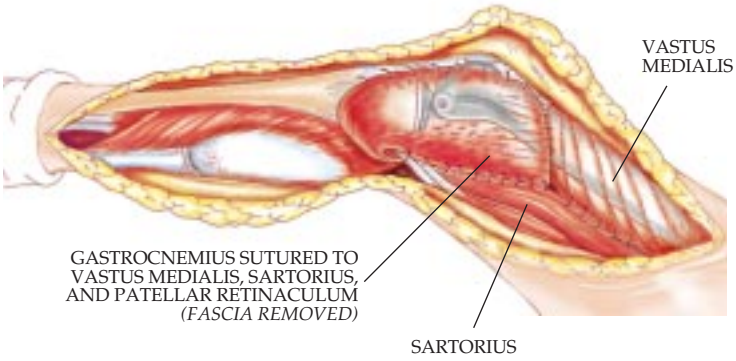

Figure 41 ▲

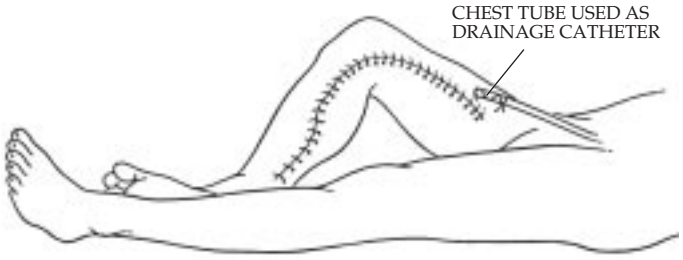

Figure 42 ▲

Postoperative Management

- The extremity is kept elevated for three to five days until the wound is checked. This prevents postoperative edema, a risk to wound healing.
- Continuous suction is required for three to five days to avoid fluid collection. This operative procedure involves a large space. A 28-gauge chest tube to 20cm of suction is used.
- Routine perioperative antibiotics are continued until drainage tubes are removed, usually within three to five days.
- Isometric exercises are started the first postoperative day. Knee motion is not generally permitted until the wound is examined, and there is adequate muscle control.

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.

Summary

The distal femur is the most common site for osteosarcoma. Limb-sparing surgery is now considered the preferred treatment for the majority of patients with osteosarcoma as well as those with other high-grade sarcomas (malignant fibrous histiocytoma, fibrosarcoma, and malignant giant cell tumors). Almost all low-grade sarcomas of the distal femur (especially parosteal osteosarcoma and chondrosarcoma) can be treated 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 be evaluated by CT, MRI, bone scintigraphy, and biplane angiography before any limb-sparing resection is undertaken. Similarly, all patients should be evaluated for a limb-sparing option prior to proceeding with an amputation.

APPENDIX I

Tibial Preparation for the Kinematic® Rotating Hinge Metal-Encapsulated Tibial Baseplate

The proximal tibial cut for the metal-encapsulated tibial baseplate is a neutral tibial cut similar to the cut for the Kinematic® Rotating Hinge All-Poly Tibial Component; i.e., classical alignment with no posterior slope.

The metal-encapsulated baseplate comes in two sizes, small and medium, with four stem options for each: 11mm and 15mm diameters in 110mm and 180mm lengths. Each size has insert thicknesses in 11mm, 13mm, 16mm and 21mm. The 4mm thickness of the baseplate is added to the insert thickness for the total thickness.

As with the Kinematic® Rotating Hinge All-Poly Tibial Component, to properly re-establish the joint line, the articulating surface of the tibial insert should be at the correct level to ensure proper patellar tracking. A tibial cut indicator is available for the metal-encapsulated tibial baseplate to aid in establishing the correct resection level. It is used in the same manner as the all-poly tibial cut indicator, which is described on **Page 21**.

Select the appropriate tibial template by referencing the size determined during preoperative planning. The correct size is the one that best covers the cut surface of the tibia without overlapping the medial margin of the tibia. The templates are used for selecting the size of the tibial component and as a guide to locating the center of the cavity to be prepared for the stem. The center of the hole in the template can be marked with a sharp awl to facilitate canal preparation.

Flexible reamers are used to prepare the canal to the appropriate diameter, based on the diameter of stem to be used.

The proximal tibial canal is prepared with a hand reamer to accept the proximal stem geometry of the baseplate. The reamer has cutting teeth that cut when the reamer turns in a clockwise direction while being advanced. The reamer can also be used as a broach, i.e., advanced into the canal with a mallet. If the broaching becomes difficult, the reamer should be removed, and its teeth should be cleared. It is important not to strike the reamer with too much force, to avoid fracturing the tibia.

The reamer is advanced until the circumferential depth mark is at the level of the cut tibia.

Trial components are available for each metal-encapsulated tibial baseplate and insert.

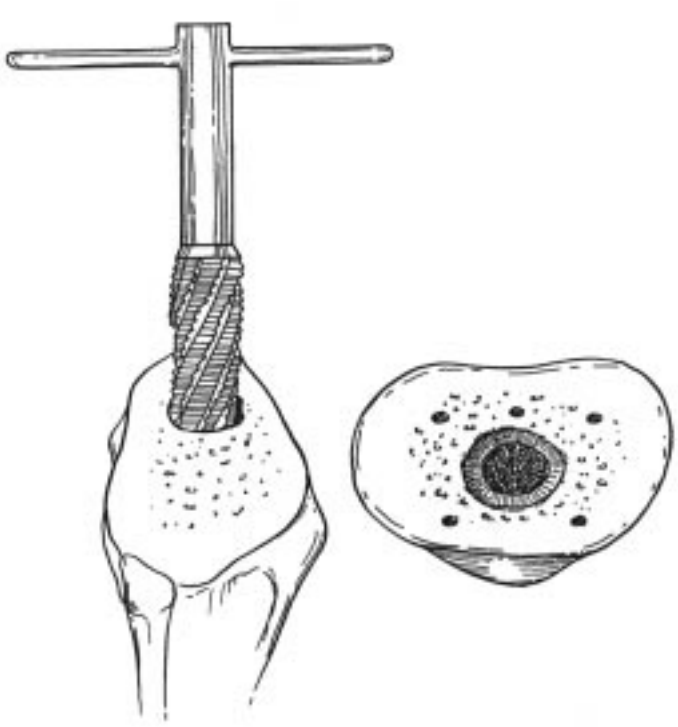

Figure A1 ▲

APPENDIX II

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. Using the wrench provided, the wedges are further advanced 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.

Technical Hint: **Introducing a vibration by tapping the prosthesis near the taper separator may aid in disassembling the prosthesis.**

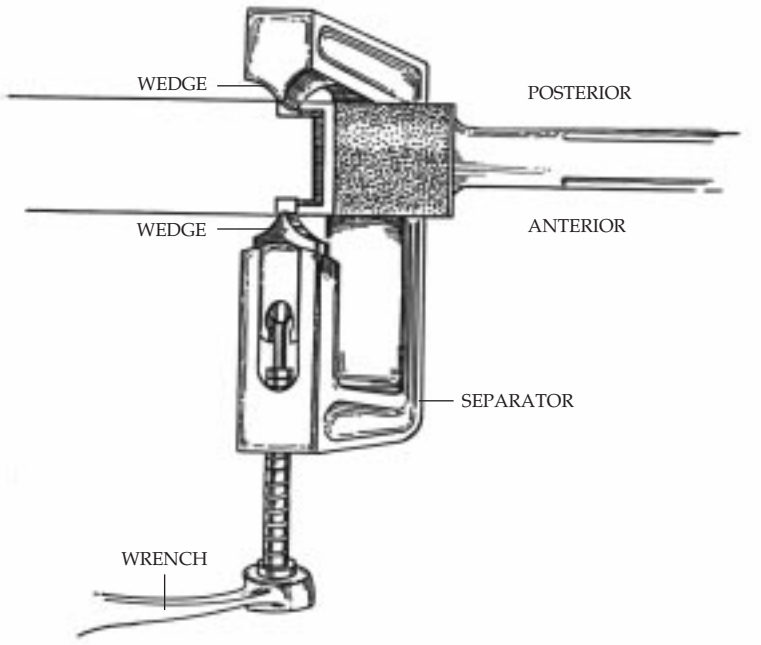

Figure A2 ▲

Taper disengagement.

Notes

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