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# External Fixation of the Femur: Basic Concepts

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**Summary:** This article discusses the application of femoral external fixators, with emphasis on the cross sectional anatomy, mechanical considerations, and fixator configurations. *Safe*, *unsafe*, and *hazardous* corridors are described, with recommendations for optimal and ideal pin placement. Fixator configurations and the biomechanics are touched upon, with suggestions for difficult clinical situations such as osteopenic bone, small fracture fragments, and heavy patients. **Key Words:** Femoral external fixation—Safe corridors—Ideal pin plane.

Of all external fixators currently used, probably less than 10% are used to treat femoral lesions, and a majority of these are used to treat pediatric lesions. Depending on the nature of the clinical condition, its location, and the specific mechanical demands, a wide variety of fixator frames[3,4] are used. These range from simple one plane unilateral frames to stabilize femoral shaft fractures, to multiplane and length adjustable devices to manage complex limb deformities and length discrepancies. This discussion of the current use of femoral fixators will focus on anatomic considerations, mechanical aspects, and preferred frame configurations.

## RELEVANT ANATOMY

The principal structures that surround the femur and are vulnerable to drill/pin injuries are the femoral vessels, the femoral nerve, the sciatic nerve and its divisions, and the hip and the knee joints.[12]

The femoral nerve and the superficial femoral artery, which enter the lower extremity through the inguinal canal, lie initially in an area that is rarely used for pin insertion. They quickly divide into several indistinct branches and are rarely injured during the application of the fixator frame. In the proximal thigh, the saphenous nerve joins the superficial femoral vessels. Together they take a course from a position anteromedial to the femoral shaft to a straight medial position in close adherence to the bone in Hunter's canal. Further distally, the saphenous nerve crosses toward the mid-aspect of the medial femoral condyle where the infrapatellar branch splits off in a lateral direction. After exiting from Hunter's canal, the femoral vessels continue to move posteriorly until they enter the popliteal fossa where they lie midway between the femoral condyles. Through much of their course through the thigh, the femoral vessels are covered and protected by the overlying sartorius muscle. Of all the neurovascular structures in the thigh, the deep femoral vessels and the saphenous nerve are potentially most vulnerable as they pass through Hunter's canal because, in this location, their position is essentially fixed and thus, they are easily injured by drill or pin tips that penetrate the medial femoral cortex. While the position and length of Hunter's canal are variable, it can extend, according to one reliable study[10] from about the mid-aspect of the femur to the distal one-sixth of its length.

In the trochanteric area, the sciatic nerve lies posteromedial to the femur. It soon splits into its femoral and peroneal branches, which assume a straight posterior position in the middle of the femur and then slightly diverge as they approach the knee joint. The sciatic nerve and its branches, however, are never in direct contact with the femur. They initially are separated from the bone by the gluteus maximus and further distally by the biceps femoris.

The capsule of the hip joint extends in front down to the base of the femoral neck and in the back to about half

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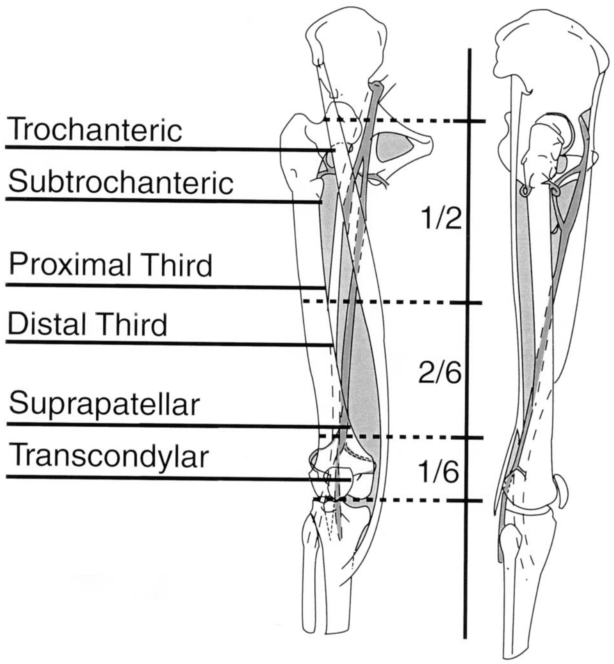


**FIG. 1.** Anterior-posterior and lateral diagrams of femur with key neurovascular structures and cross sectional levels.

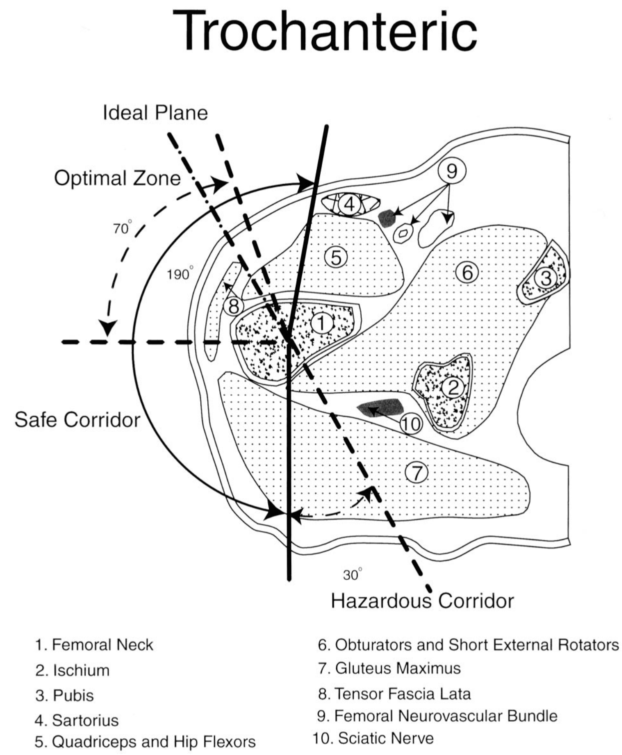


**FIG. 2.** Cross section at the intertrochanteric level.

way between the base of the neck and the subcapital area. The anterior extension of the knee joint, the suprapatellar pouch, extends on the average[10] to about 6.3 cm above the proximal pole of the patella. Further distally, the knee joint capsule inserts about 1 cm peripherally to the superior, lateral, medial, and posterior borders of the articular cartilage of the knee joint. In its most distal medial extension, it surrounds peripherally the origin of the medial collateral ligament, which remains extraarticular. The capsule forms a similar recess over the lateral femoral condyle. Practically speaking, this extraarticular area starts approximately 3 to 4 cm proximal to the most medial and most lateral extensions of the articular cartilage.

## SAFE CORRIDORS

In distinction from such bones as the tibia[6] and the ulna, the femur is surrounded by tendons, muscles, retinacular extensions, joint capsules, nerves, and vessels along its entire length. As it is essentially devoid of areas where the bone lies directly subcutaneous, most of the noted structures can be injured by an incautiously placed pin or wire.[12]

For the purpose of this review we shall define "safe corridors"[6] (Figs. 1,2,3,4,5,6,7), as areas through which pins and wires can be safely inserted without injuring major neurovascular structures. For all practical purposes, this corridor is delineated medially by a plane that extends from the center of the femur through the lateral border of the sartorius muscle, which protects the femoral neurovascular bundle throughout its course through the thigh. In the supine position, a good surface approximation of this landmark is represented by a straight line that extends from the most medial aspect of the medial femoral condyle to the anterior superior iliac spine. The posterior border of the safe corridor is delineated by a plane that proximally extends straight posterior from the mid-aspect of the intertrochanteric area and further distally corresponds to the intermuscular septum between the lateral and the posterior compartment. In the prone position, the surface projection of this plane is represented by a line that extends from the mid-aspect of the intertrochanteric area to the most lateral aspect of the lateral femoral condyle. Throughout its course, the sciatic nerve lies medial to this plane. The knee joint, however, is excluded from this wedge shape safe corridor. Within the safe corridor, inserting pins through the rectus femoris is undesirable because of a concern that this promotes soft tissue adhesions and thus leads to knee stiffness. It is important to remember that pins or wires inserted through the safe corridor may injure or penetrate

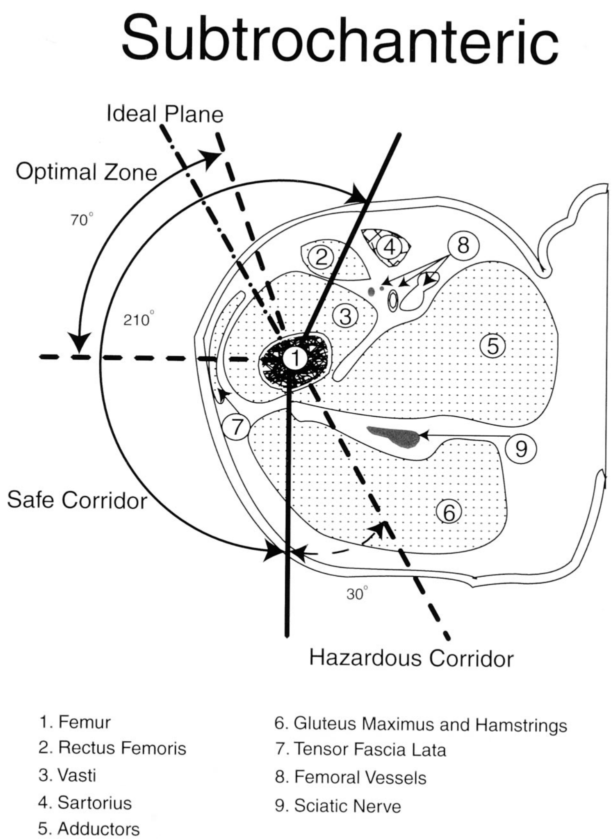


**FIG. 3.** Cross section at the subtrochanteric level.

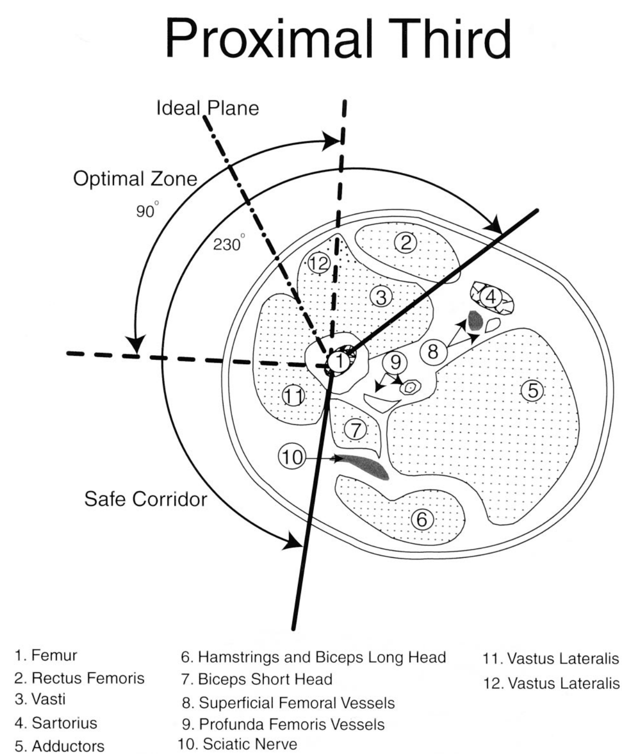


**FIG. 4.** Cross section through the proximal third of the femur.

vulnerable structures at the exit sites. This is particularly true for the hip joint, the knee joint, and Hunter's Canal.

Posteromedially adjacent to the safe corridor, we have included a "hazardous corridor," which diminishes in size from the intertrochanteric area where it measures 30° to the junction of the proximal and the mid-third of the femur where it terminates. This corridor may be used in rare occasions for the insertion of transfixion wires/pins. While in most patients, the sciatic nerve will lie medial to this plane, only open exposure of the pin/wire tracks, however, will assure that an injury to the sciatic nerve is being avoided.

The anterolateral entry level quadrant of the thigh represents an "optimal zone" for the placement of unilateral frames (Figs. 1,2,3,4,5,6,7). It is defined proximally by a plane that lies approximately 20° lateral to the sagittal plane. Distally, it coincides with a plane that extends from the center of the femur through the intramuscular septum between the vastus intermedius and the vastus lateralis and always lies lateral to the lateral border of the rectus femoris. Practically, the optimal zone is represented by a wedge that encompasses approximately 70° near the trochanteric area and progressively diminishes to approximately 10° at the lateral femoral condyle. Within the optimal zone we have outlined an "ideal plane for one plane unilateral frames" (Figs. 1,2,3,4,5,6,7). This plane extends from the center of the femur through the junction between the vastus intermedius and the vastus lateralis peripherally. A unilateral fixator placed along this plane allows the patient to lie in bed with a physiologically slightly externally rotated leg. It avoids pin interference with the abdomen proximally and is optimally placed to deal with the prevailing mechanical forces in the femur. By following the indistinct intramuscular septum between the vastus intermedius and the vastus lateralis (along the anterolateral approach to the thigh described by Henry), it minimizes pin/soft tissue irritation and, hopefully, quadriceps adhesions.

Basing findings on a number of the currently available anatomic and radiographic studies,[1,7,8,9,11] atlases, and textbooks of the lower extremity, we have further depicted the noted zones with the help of six cross sections (Fig. 1), through the thigh at the following levels: trochanteric (between the greater and lesser trochanter) (Fig. 2), (subtrochanteric just below the lesser trochanter) (Fig. 3), proximal third (Fig. 4), distal third (Fig. 5), suprapatellar (approximately 5 cm above the proximal

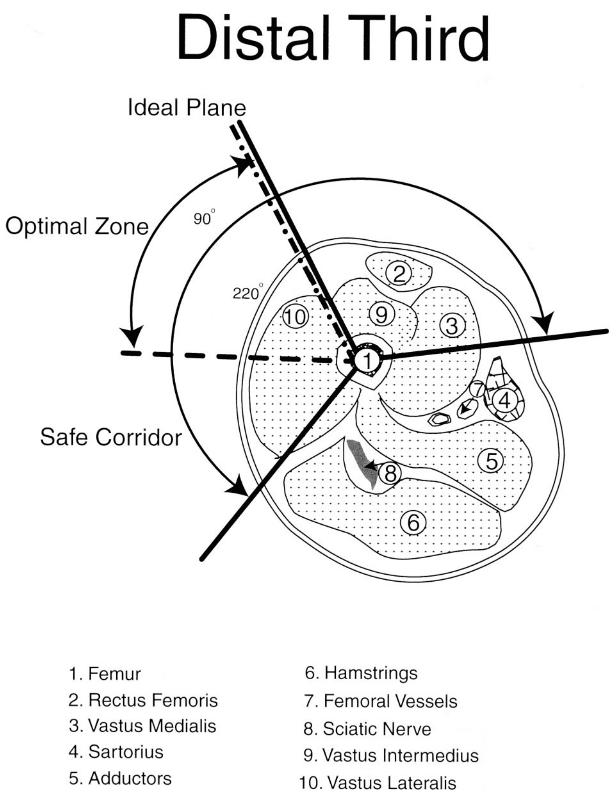


**FIG. 5.** Cross section through the distal third of the femur.

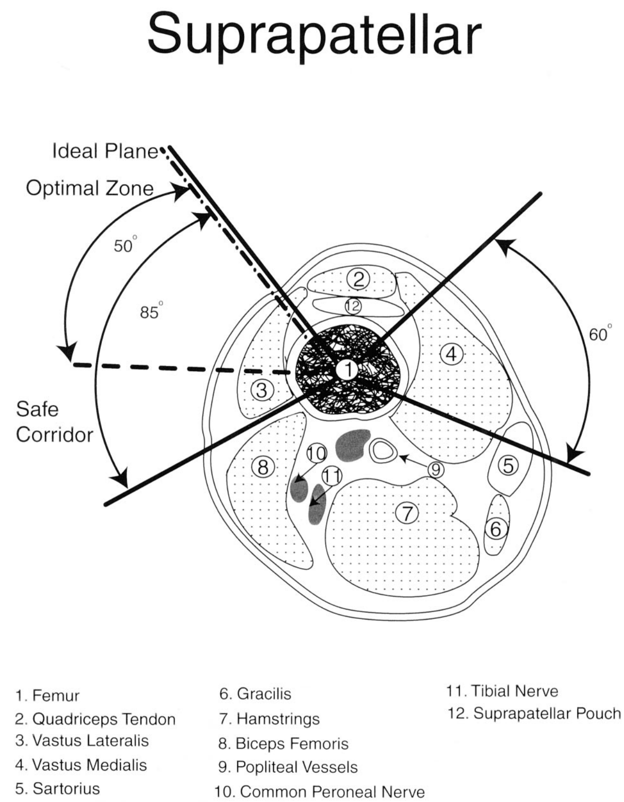


**FIG. 6.** Cross section above the patella.

pole of the patella) (Fig. 6), and transcondylar (just proximal to the superior pole of the patella) (Fig. 7). Due to the wide anatomic variations that exist, the delineated corridors and their sizes at the various cross sections can only represent a rough approximation.

In the trochanteric area (Fig. 2), the safe corridor encompasses approximately 190°. The hazardous posteromedial extension of this corridor is approximately 30° to 40° because the sciatic nerve at this level lies medial to the femur shaft. The medial limit of the optimal corridor is approximately 70° with the "ideal" unilateral pin placement at approximately 60° to 70°. While more medial pin placement is safe, it is not advised because it does interfere with hip flexion when the patient assumes a sitting position.

At the subtrochanteric (Fig. 3) level, the sartorius lies more medial. This extends the safe corridor to approximately 210°. Size and position of the optimal corridor and the ideal pin plane are unchanged.

At the junction of the proximal to the middle third (proximal third) (Fig. 4), the sartorius continues to move medially, the sciatic nerve now lies straight posterior to the femoral shaft, and the posterolateral intramuscular septum moves more laterally. The safe corridor measures approximately 230° with the optimal corridor being 90° and the ideal pin plane staying at approximately 70° anterior to the frontal plane.

At the level of the distal third (Fig. 5), the safe corridor continues to move medially but retracts to approximately 220°. The optimal corridor remains at 90° with the ideal pin plane approximately 60° to 70°, still lies in the interval between the vastus lateralis and the intermedius.

The appearance of the suprapatellar extension of the knee joint (suprapatellar) (Fig. 6), gives rise to an anterior unsafe corridor, which moves gradually in a lateral and posterior direction distally. At this level, the safe corridor is separated into a medial extension of approximately 60° and a lateral extension of approximately 80° to 90°. The optimal corridor is reduced to 50° with the ideal pin plane lying close to its anterior border.

In the condylar area (transcondylar) (Fig. 7), the medial and lateral safe recesses diminish to approximately 30° and the optimal corridor to approximately 20°. Medial and lateral corridors become obliterated approximately 4 cm above the medial and lateral articular cartilage.

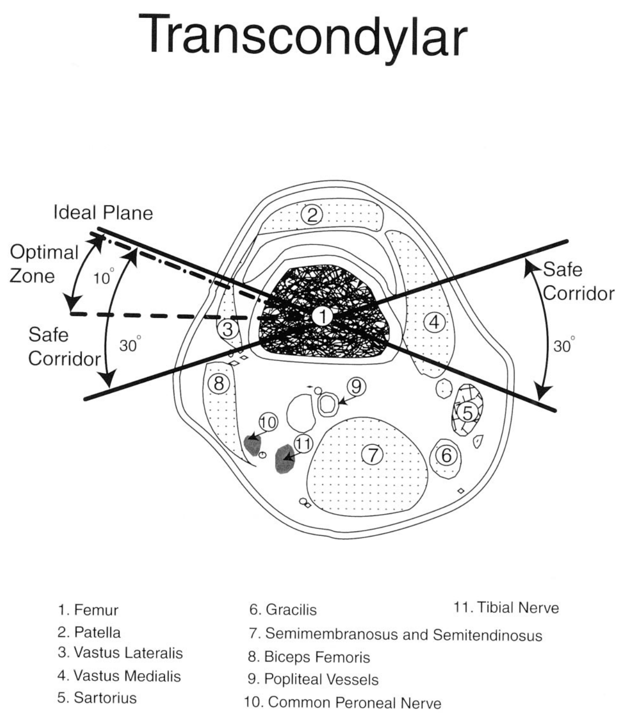


**FIG. 7.** Cross section at the transcondylar level.

## MECHANICAL CONSIDERATIONS

There are no mechanical studies that delineate the mechanical forces applying at each femoral cross section. Qualitative measures such as the size and configuration of the muscle centers around the femoral shaft and the fact that most thigh muscles activate the knee, a sagittal hinge joint, make it obvious that at most levels the preponderance of forces apply in the sagittal plane. In addition, the adductor muscles exert substantial medial pull on proximal fragments, while the action of the iliotibial band applies an external rotation moment to the distal femur.

It appears that a two plane fixator frame[3,6] with a principal pin plane in the sagittal plane and the lesser in the lateral aspect of the frontal plane, would ideally neutralize the noted mechanical forces, while a mechanical optimal one plane unilateral frame would lie close to what is identified as the ideal plane.

Because the mechanical forces that apply to femoral fragments are substantial, and because most unilateral femoral frames are applied from a lateral direction, all means available to increase the mechanical properties of a femoral fixator,[5] particularly if applied in an adult, should be used to strengthen the frame. This includes large pin sizes, wide pin spread in each fragment, the use of stacked bars and finally, the erection of a principal pin plane as close to the ideal plane as possible.

## FIXATOR CONFIGURATIONS

### Ring Fixators/Hybrid Frames

From the trochanteric area to the knee, the safe corridor permits the use of transfixion pins or wires at each level.[3,4] Due to its narrowness, the spread angle between transfixion implants is minimal. Proximally, the transfixion implants have to be inserted close to the sagittal plane, while around the knee they usually lie within a few degrees of the frontal plane. Because of the limited mechanical effectiveness of close angle transfixion implants, most ring/hybrid frames in the femur are established with a combination of transfixion implants and half pins. Although ring/hybrid frames can be most versatile and mechanically quite effective, they tend to be time consuming to apply and can be uncomfortable for the patient.

### Two Plane Unilateral Frames

These frames usually consist of a pin plane applied from a straight lateral direction and an anterolateral pin plane that is placed close to the anterior border of the optimal corridor. The pins can be connected to longitudinal rods or be part of a circular or hemicircular construct. The use of a second pin plane is particularly important in fractures with small proximal fragments and in osteopenic patients.

### One Plane Unilateral Frames

Such frames are frequently used for the treatment of femoral fractures in children and for the temporary immobilization of femoral fractures in adults, mostly in open fractures. Most unilateral frames are applied from a straight lateral position, possibly because of habit and because it may be easier with this approach to maintain anatomic orientation. As this pin plane is mechanically not very effective, pin size and spread should be maximized and in heavier adult patients or when faced with small fragments, a double rod should be used.[5] Applying the frame 20° anterior to a straight lateral position is better tolerated by bedridden patients because a frame in this position does not interfere with the physiological external rotation of the lower extremity.

In the authors' view, the most effective one plane unilateral frames are applied in what is called the ideal pin plane, which extends from the center of the femur through the indistinct musculoskeletal septum between the vastus intermedius and the vastus lateralis so noted approximately 70° anterior to the frontal plane in the intertrochanteric area and approximately 10° anterior to this plane near the knee joint. This pin plane lies in an anatomically ideal interval and mechanically neutralizes effectively the knee flexors and extensors, as well as the adductor muscle groups.

The stabilization of small distal femoral fragments may require pin placement close to the knee joint.[12] Empirically, it appears that when the most distal pin is inserted directly opposite the origin of the medial collateral ligament, pin placement will remain extraarticular and will not injure the growth plate in a child. When faced with small fracture fragments, a large leg, or advanced osteopenia, the most distal fragment may have to be stabilized with transfixion pins or transfixion wires connected to a full or partial ring of a hybrid fixator.[2]

## SUMMARY

The circumferential soft tissue sleeve, the presence of the hip joint, and even more limiting, the extensive synovial space surrounding the knee complicate external fixation of the femur. Bilateral fixation using transfixion pins or transfixion wires is possible proximally but may require the entry into hazardous territory. Ring and hybrid frames are usually established with a combination of transfixion pins/wires and half pins. Two-plane fixation is possible proximally within the anterolateral quadrant of the thigh but not distal to the suprapatellar pouch, which extends 6 to 7 cm proximal to the upper pole of the patella. With the exception of the most complex, most proximal, and most distal lesions, external fixators in the femur are applied within the optimal corridor, which encompasses an anterolateral segment of approximately 70° proximally and gradually diminishes in size to a few degrees approximately 4 cm proximal to the knee joint. The ideal pin plane for one-plane unilateral frames is anterolateral between the vastus intermedius and the vastus lateralis in the proximal three-fourths of the femur and moves close to the frontal plane distally. Mechanically, most femoral frames should be optimized by using large pins, maximal pin spreads, double stacked connecting bars, and one pin plane as close as possible to the sagittal plane.

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