Comparative Study Between Methods of Pre-Operative Measurement of Intramedullary Nail Length in Fracture Shaft of Femur

BY

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Abstrak

Pengenalan

Kepatahan batang tulang femur adalah di antara jenis kepatahan yang kerap berlaku di dalam bidang ortopedik. Cara merawat kepatahan femur memerlukan keseimbangan di antara susunan lurus secara anatomi dan rehabilitasi awal fungsi anggota badan. Paku dalam medulari berkunci bagi tulang femur telah diterima pakai sebagai teknik rawatan pilihan bagi kebanyakkan kes kepatahan batang tulang femur. Walau bagaimana pun, kebanyakkan simpanan bilik bedah di sini tidak mempunyai pilihan saiz dan panjang paku dalam medulari yang mencukupi. Oleh itu, kebanyakkan pakar bedah ortopedik akan menilai saiz dan panjang paku dalam medulari sebelum pembedahan dengan menggunakan pelbagai kaedah dan menyediakan satu saiz yang lebih kecil dan satu saiz yang lebih besar berbanding ukuran yang diperolehi untuk pembedahan yang dirancang.

Objektif

Objektif utama kajian ini adalah untuk mengkaji ketepatan dan kesahihan ukuran klinikal panjang paku dalam medulari sebelum pembedahan bagi kepatahan batang tulang femur. Kami juga mengkaji kebolehpercayaan antara pengkaji bagi setiap teknik yang diuji.

Metodologi

Kajian ini adalah kajian rawak prospektif yang melibatkan analisa data klinikal dan juga radiografi biasa. Kajian ini dijalankan secara penilaian klinikal. Sebanyak seratus tiga puluh pesakit yang datang ke klinik pesakit luar Jabatan Ortopedik HRPZ II untuk sebarang masalah diambil sebagai sampel dan ukuran batang tulang

femur dilakukan menggunakan ketiga-tiga teknik yang diuji oleh tiga orang penilai yang berbeza tanpa mengetahui ukuran satu sama lain.

Keputusan

Analisis menunjukkan terdapat perbezaan yang jelas di antara penyelidik bagi ukuran yang diambil menggunakan Kaedah 1 ($p = 0.0001$) dan Kaedah 2 ($p = 0.0001$) tetapi tiada perbezaan yang nyata bagi Kaedah 3 ($p = 0.763$). Kesemua kaedah adalah berkadaran dengan ukuran radiologi. Purata ukuran panjang untuk Kaedah 3 adalah 1.7 sm lebih panjang bagi pesakit wanita dan 2.5 sm lebih panjang bagi pesakit lelaki jika dibandingkan dengan ukuran purata radiologi.

Kesimpulan

Kaedah 3 senang untuk dilakukan, bebas radiasi dan boleh digunakan untuk amalan harian tanpa sebarang kerumitan. Ia juga boleh digunakan bagi pesakit yang mengalami kepatahan kedua-dua belah tulang femur. Ukuran pra pembedahan yang tepat boleh diperolehi dengan menolak sebanyak 1.7 sm daripada ukuran yang diperolehi bagi pesakit wanita atau sebanyak 2.5 sm bagi pesakit lelaki.

Abstract

Introduction

Fractures shaft of the femur are among the most common fractures encountered in orthopaedic practice. Locked femoral intramedullary nailing is accepted as the standard treatment of choice for most femoral shaft fractures. As most of operation room inventory in our setup does not have a complete range of the intramedullary nails, most surgeons estimate the size and length of the intramedullary nail pre-operatively by various methods and keep a size bigger and smaller the assessed length for the planned surgery.

Objective

The main objective was to study the accuracy and validity of pre-operative clinical measurement of intramedullary nail length in fracture shaft of femur. We also studied the inter-observer reliability of each method tested.

Methodology

This research was a prospective randomized study that involved analysis of data taken clinically as well from plain radiograph. This study was done as a clinical assessment. One hundred and thirty patients were enrolled. Measurement of femoral shaft was performed by using three different methods, which were tested by three investigators from different level of medical background. Method 1 was measurement taken from the tip of greater trochanter to the lateral knee joint line of the opposite limb minus 2 centimeters (standard AO), Method 2 was measurement taken from the tip of the greater trochanter to the upper pole of patella on the

opposite limb (alternative AO) and Method 3 was measurement taken from the tip of the olecranon process to the tip of the little finger on any side (the “tip-to-tip” method).

Results

Analysis showed that there were significant differences in inter-observer variability in the measurement taken using Method 1 ($p = 0.0001$) and Method 2 ($p = 0.0001$) but not in Method 3 ($p = 0.763$). All methods were well correlated with radiology measurements. The average length of measurement for Method 3 were 1.7 cm longer in female patients and 2.5 cm longer in male patients than average length of measurement by radiograph.

Conclusions

Method 3 is valid and can be applied in clinical practice with accuracy by subtracting 1.7 cm from the measurement in a female patient and 2.5 cm from the measurement in a male patient. It also has significant inter-observer reliability. It is simple to perform, radiation-free and can be applied in a patient with bilateral femur fractures.

1. Introduction

The foundation of the modern era treatment of intramedullary nailing of femoral shaft fracture was based on initially described technique by Kuntscher in 1940, where he first published the successful nailing of this fracture.[1] During the following 100 years the clinical diagnostics were further developed. Femoral nailing has advanced continuously over the past 60 years. The transition from open nailing techniques to closed techniques using a remote entry site at the proximal femur paralleled the availability of image intensification.[2] Intramedullary reaming allowed placement of larger implants, allowing improved rotational control and resistance to bending.[3] The introduction and increased popularity of interlocking nails allowed for improved rotational control, better maintenance of femoral length, early weight bearing, the use of smaller implants, and improved control of comminuted and segmental fractures.[4] Biomechanical improvements in nail designs and instrumentation have further expanded the indications for nailing. Cephalomedullary nails and retrograde nails have seen similar improvements in design and instrumentation, increasing the ease of insertion and further expanding the use of nailing techniques for some particularly difficult fractures. More recently, the use of alternative starting points such as the tip of the greater trochanter has been introduced.[5, 6, 7]

Femoral shaft fracture is associated with high energy injuries frequently associated with life-threatening conditions. The incidence involved about 37.1 per 100,000 person-years in United State.[1, 2, 3] It has a bimodal distribution, with a peak incidence occurring in younger persons aged 18-25 years and a second peak in older persons aged more than 65 years.[4, 6] Due to the strength of the tubular bone shape, it is usually fractured because of a high-energy mechanism in younger individual, usually involving road traffic accident, a fall from high or gun-shot injury. In elderly population, a low-energy such as a fall from standing positions maybe the cause. It is commonly associated with ipsilateral femoral neck fracture in about 2-6% of the incidence, which most of the time it is basicervical, vertical, and nondisplaced. Involvement of bilateral femur fractures carries a significant risk of pulmonary complications and has increased rate of mortality as compared to unilateral fractures. [3, 4]

Generally, shaft of femur fracture can be divided anatomically as proximal 1/3, midshaft or distal 1/3 based on total length of the shaft. The types of immobilization applied preoperatively are based on this division. To understand better of the effect and outcome of the treatment for femoral fracture, one should know in detail the anatomy, radiographic evaluation and also classification of the fractures in order to be able to offer the best treatment option.[20, 21, 22]

The art of femoral fracture care involves a balancing act between anatomic alignment and early functional rehabilitation of the limb.[7, 14] Locked femoral intramedullary nailing is accepted as the standard treatment of choice for most femoral shaft fractures.[12, 13, 15, 16, 17] However, most of operation room inventory in our setup does not have the complete range of the intramedullary nail sizes and length. Thus, most orthopaedic surgeons assess the size and length of the intramedullary nail pre-operatively by various methods and keep one size above and below the assessed length for the planned surgery. Option of methods to be used to achieve this purpose are multiple and variable. Usually, the well accepted methods was either the measurement taken from the opposite thigh from the tip of the greater trochanter to the lateral knee joint line minus 2 centimeters or the alternate measurement is done by measuring the distance from the tip of the greater trochanter to the upper pole of patella on the opposite side in a supine position.[5, 8, 9, 10, 11, 20] A recently proposed technique was the distance between the tip of olecranon process to the tip of the little finger on any side ("tip to tip" distance).[9, 10, 12] These methods however have their own pros and cons. This study was conducted to determine the accuracy and validity of pre-operative clinical measurement of intramedullary nail length in fracture shaft of femur.[5]

2. Literature Review

2.1 Anatomy of Shaft of Femur *

2.1.1 Osseous Anatomy

The shaft of the femur is slightly bowed (convex) anteriorly. This convexity may increase markedly, proceeding laterally as well as anteriorly, if the shaft is weakened by a loss of calcium, as occurs in rickets (a disease attributable to vitamin D deficiency). Most of the shaft is smoothly rounded, providing fleshy origin to extensors of the knee, except posteriorly where a broad, rough line, the linea aspera, provides aponeurotic attachment for adductors of the thigh. This vertical ridge is especially prominent in the middle third of the femoral shaft, where it has medial and lateral lips (margins). Superiorly, the lateral lip blends with the broad, rough gluteal tuberosity, and the medial lip continues as a narrow, rough spiral line. The spiral line extends toward the lesser trochanter but then passes to the anterior surface of the femur, where it is continuous with the intertrochanteric line. A prominent intermediate ridge, the pectineal line, extends from the central part of the linea aspera to the base of the lesser trochanter. Inferiorly, the linea aspera divides into medial and lateral supracondylar lines, which lead to the medial and lateral femoral condyles.

** This chapter is a condensation from Clinically Oriented Anatomy, Seventh Edition by Keith L. Moore, Arthur F. Dalley, Anne M.R. Agur (2014), and Rockwood and Green's Fracture in Adults Sixth Edition, Lippincott Williams and Wilkins (2006) unless other references were mentioned.*

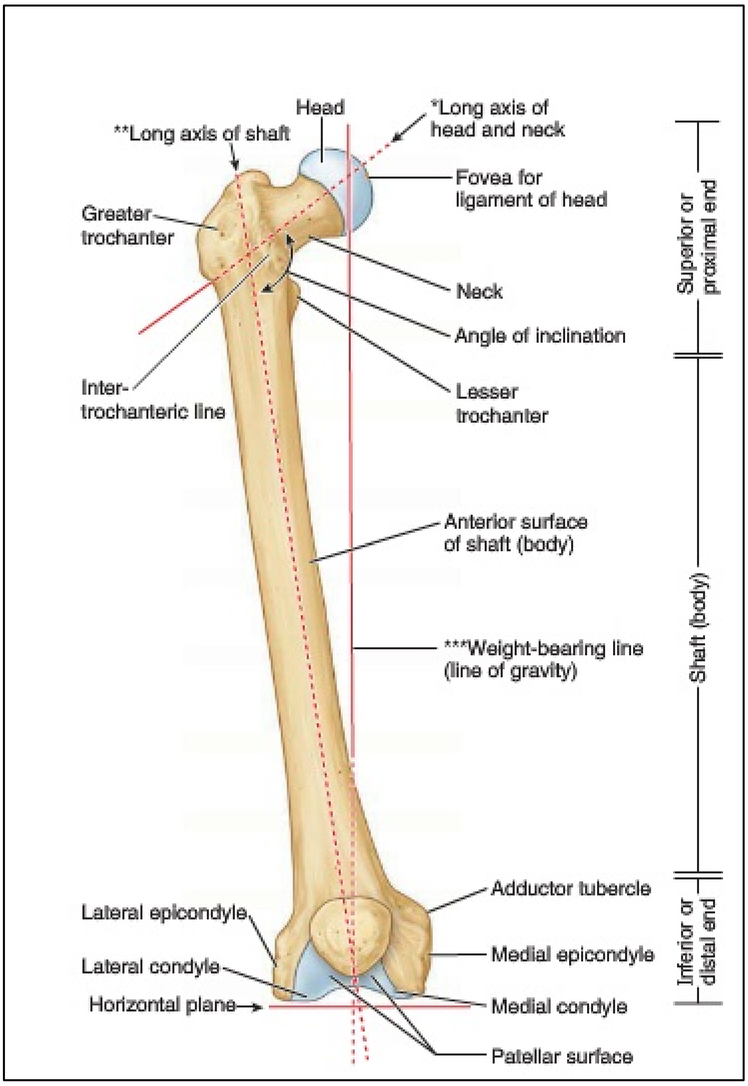

Fig 1: Anterior view of right femur. The bony features of an adult femur are shown.

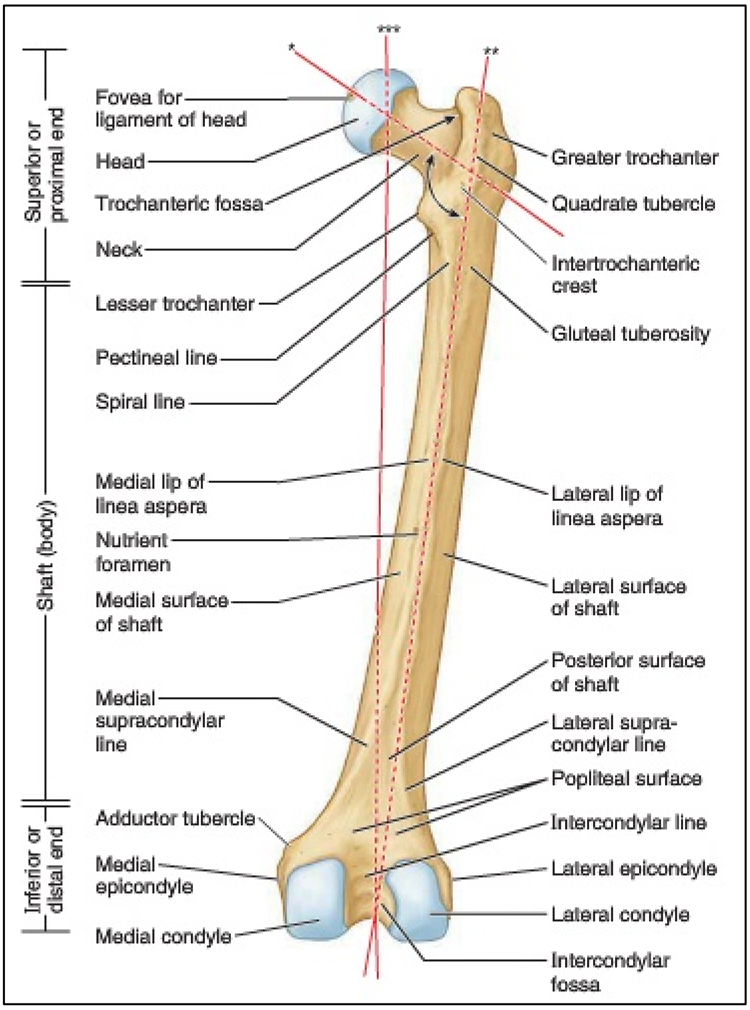

Fig 2: Anterior view of right femur. The bony features of an adult femur are shown.

2.1.2 Surface Anatomy of Femur

Bony landmarks are helpful during physical examinations and surgery because they can be used to evaluate normal development, detect and assess fractures and dislocations, and locate the sites of structures such as nerves and blood vessels. The greater trochanter forms a prominence anterior to the hollow on the lateral side of the buttocks. The prominences of the greater trochanters are normally responsible for the width of the adult pelvis. The posterior edge of the greater trochanter is relatively uncovered and most easily palpated when the limb is not weight-bearing. The anterior and lateral parts of the trochanter are not easy to palpate because they are covered by fascia and muscle. Because it lies close to the skin, the greater trochanter causes discomfort when you lie on your side on a hard surface. In the anatomical position, a line joining the tips of the greater trochanters normally passes through the pubic tubercles and the center of the femoral heads. The lesser trochanter is indistinctly palpable superior to the lateral end of the gluteal fold. The femoral condyles are subcutaneous and easily pal-pated when the knee is flexed or extended.

At the center of the lateral aspect of each condyle is a prominent epicondyle that is easily palpable. The patellar surface of the femur is where the patella slides during flexion and extension of the leg at the knee joint. The lateral and medial margins of the patellar surface can be palpated when the leg is flexed. The adductor tubercle, a small prominence of bone, may be felt at the superior part of the medial femoral condyle by pushing your thumb inferiorly along the medial side of the thigh until it encounters the tubercle.

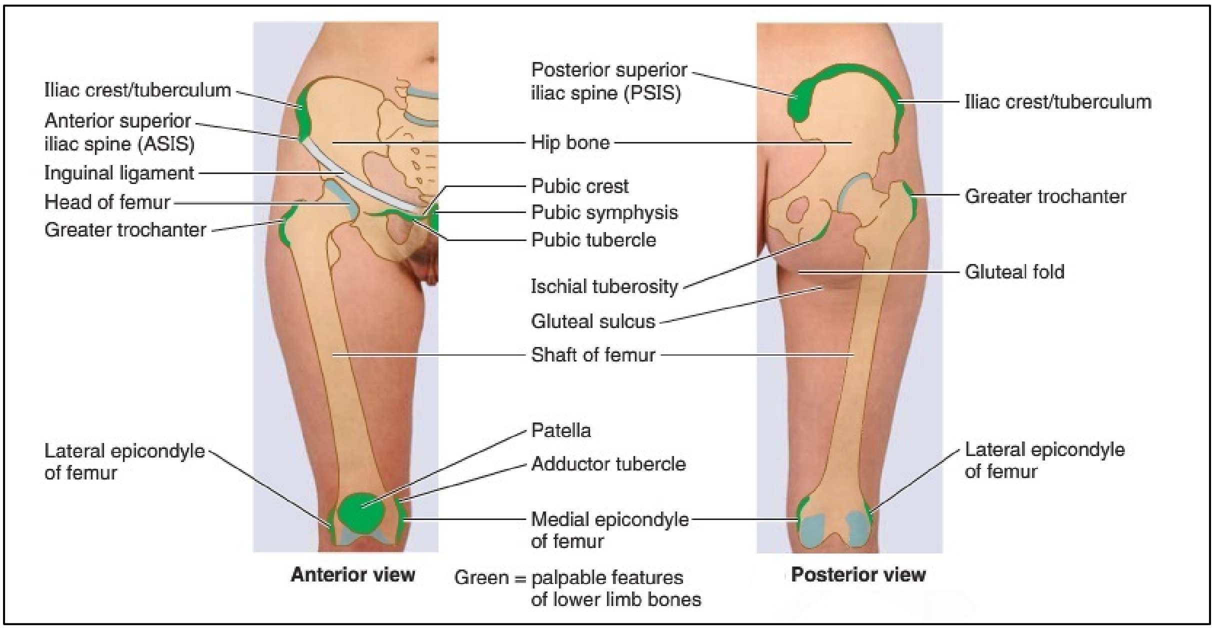

Fig 3: Surface projection and palpable features of hip bone and femur.

2.1.3 Muscles Relations

The femur is almost completely encased in muscles, most of which have attachments to the bone itself. Knowledge of these muscle attachments is important for performing atraumatic surgical dissections and for understanding the commonly observed deformity patterns associated with fractures of the femur. The proximal muscular attachments include the hip abductor and short external rotator insertions at the greater trochanter, gluteus maximus osseus insertion at the posterolateral proximal femur, and iliacus and psoas insertions on the lesser trochanter. The adductors insert on the posterior and medial aspects of the femur along its length. The vastus lateralis origin is proximal, just distal to the gluteus medius insertion. The anterior and lateral femur serves as the origin for the vastus intermedius along the majority of the diaphysis. On the medial and posteromedial portions of the femur is the origin of the vastus medialis. Distally, the gastrocnemius originates from the posterior aspect of the femoral condyles. The resting tones of the primary muscles attaching to and spanning the femur largely determine the observed deformities. Shortening is universally observed because of the pull of the hamstrings and quadriceps muscles. In proximal fractures (in the subtrochanteric region), the proximal segment is typically flexed, abducted, and externally rotated by the muscular pull of the hip abductors, external rotators, and iliopsoas. The distal fragment is usually medialized because of the pull of the adductors. In distal fractures, the gastrocnemius muscle origins at the femoral condyles are largely responsible for the commonly observed fracture extension deformity. The shaft of the femur is frequently medialized because of the attachments of the adductor muscles. Because of these largely unopposed muscle forces, the exercise of attempting to reduce proximal and distal fractures with an increasing distraction force is typically futile. Limb position, strategic bumps, and externally applied forces are much more helpful than brute strength in improving the angulatory and translational deformities that occur.

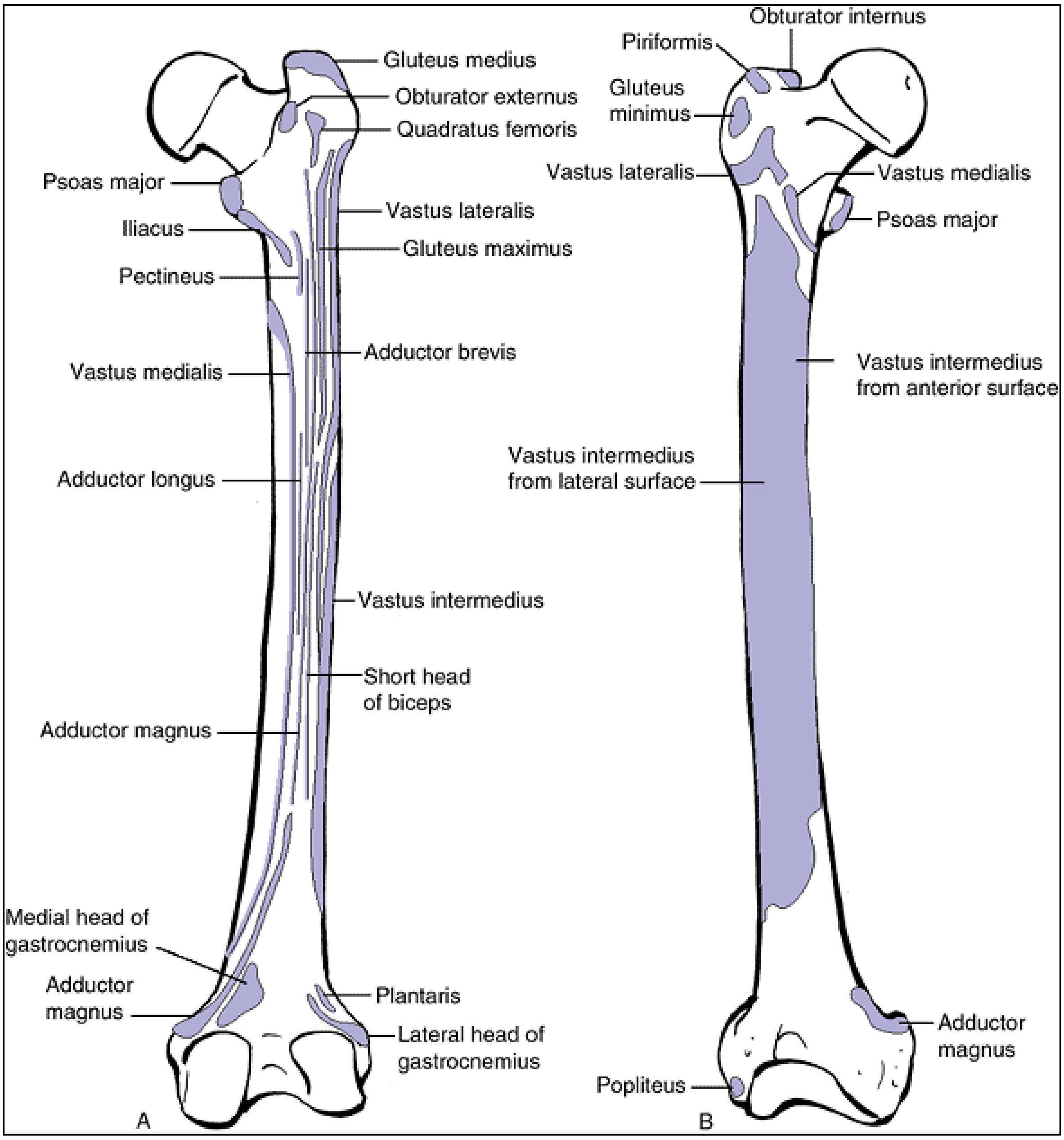

Fig 4: The primary muscular attachments on the anterior (A) and posterior aspects of the femur (B).

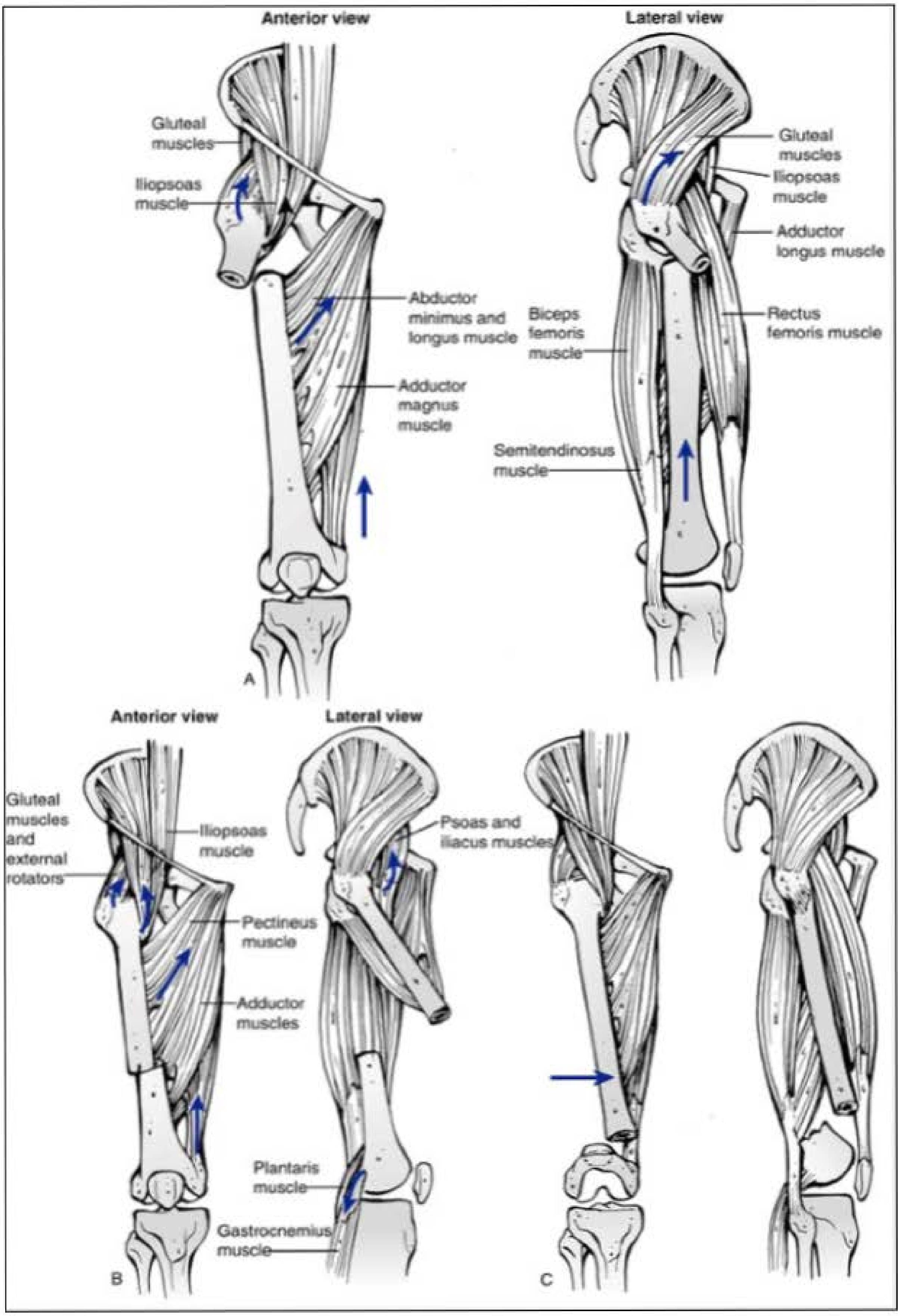

Fig 5: Muscular attachments and fracture location determine the observed deformities and displacements.

2.1.4 Intramedullary Fixation

Internal fixation of fractures of the femoral shaft became popular after World War II, when open intramedullary nailing was introduced.[20, 21] It is applied in the narrowest portion of the medullary canal using an intramedullary nail. Successful intramedullary nailing results in a short hospital stay, a rapid return of motion in all joints, prompt return to walking, and a relatively short total disability time. However, fractures in the proximal or distal thirds of the shaft or fractures with severe comminution are less suitable.

Although Kuntscher introduced closed intramedullary nailing in the 1940s, it did not gain popularity in North America until the 1970s.[20, 21] With improvements in technique and the availability of image intensifiers, closed nailings have almost replaced the open technique. Still, problems with severely comminuted fractures and fractures in the proximal and distal thirds remained for unlocked nails. Fractures of these types more recently have been treated with intramedullary appliance modifications, for example, interlocking intramedullary nails and “reconstruction” or cephalomedullary nails, which have transfixation screws to control length and rotational alignment.

Knee ligament injuries frequently occur with femoral fractures. Walling et al. (1982) noted a 33% incidence of knee ligament injury by manual examination. De Campos et al. (1994) arthroscopically examined 30 knees with the patients under anesthesia immediately after intramedullary nailing of femoral fractures. They noted some laxity (grade I) in 52% of the patients. Arthroscopic findings were noted in 55% of the patients, including 19 partial and two complete anterior cruciate tears and two partial and one complete posterior cruciate tear. There also were five medial and eight lateral meniscal tears.

2.1.5 Biomechanics of Fracture and Nailing

The femur is subjected to significant bending, axial, and torsional forces that can exceed three to four times body weight during normal activities.[20, 21] The commonly observed fracture patterns are determined by the magnitude of the applied load, rate of load application, and strength of the femur. A purely torsional force results in the spiral fracture pattern typically seen in elderly patients. In younger patients, a combination of bending and axial loading produces the commonly observed transverse and bending wedge fractures. As the applied force increases, so does the diaphyseal comminution. The necessary bending force to produce a femoral shaft fracture in the normal adult has been estimated at 250 Nm. However, in purely axial compression, the loads necessary to produce a fracture may exceed 8000 Nm.[20, 21]

The tubular anatomy of the femur makes intramedullary nailing an ideal treatment biomechanically and practically. An intramedullary nail is a strong device in axial loading and bending given its centrally located cross-sectional moment and the symmetry in its design. Thus, a nail can support loads equally in all directions.[20, 21]
The torsional rigidity of a femur fracture treated with an intramedullary nail is determined by a combination of nail characteristics and fracture characteristics. Important nail characteristics include the presence or absence of an open section or slot, the wall thickness, the cross-sectional shape, and the presence or absence of interlocking screws.

The presence of a slot, or an open section, significantly decreases the torsional rigidity of the nail. Similarly, increasing the wall thickness of the nail will result in an increase in the nail's torsional stiffness. Therefore, with slotted and/or thin-walled nails, torsional loads may result in rotational changes in the fractured femur-nail construct, despite interlocking.

Bending stiffness is primarily determined by the outer diameter of the implant and the material (stainless steel vs titanium). The modulus of elasticity of 316L stainless steel is approximately twice that of titanium. The ultimate strength of titanium is approximately 1.6 times that of stainless steel.[20]

Resistance to axial loading of the implant bone construct is primarily determined by the presence of interlocking screws and the bone contact at the fracture if applicable. It becomes obvious that multiple factors determine the final construct stiffness, all of which should be understood and considered when choosing a particular intramedullary nail. Location, angulation, number, and size of interlocking screws are variable, depending on the manufacturer.[20]

Bone healing after intramedullary nailing is usually predictable. Closed intramedullary nailing in closed fractures has the advantage of maintaining both the fracture hematoma and the attached periosteum. In addition, if reaming is performed, these elements provide a combination of osteoinductive and osteoconductive materials to the site of the fracture. Finally, reaming may produce a periosteal vascular response that increases the local blood flow. As a result, secondary bone healing with abundant fracture callus formation is expected in most femur fractures treated with intramedullary nailing. This leads to the ability to weight bear early after intramedullary nailing and a low refracture rate after nail removal in clinically indicated cases.

2.2 Radiology Evaluation

The radiographic evaluation begins with full-length anteroposterior (AP) and lateral radiographs of the entire femur. More information can be obtained if these are performed with the femur at length, preferably after traction is applied. Traction can be accomplished with either a Thomas splint or an appropriately placed distal femoral or proximal tibial traction pin. Ideally, the entire femur should be present on a single radiographic cassette. The x-rays should be critically evaluated to determine the fracture pattern, bone quality, presence of bone loss, associated comminution, presence of air in the soft tissues, and amount of shortening. The length of the femur can be estimated using digital films or with rulers appropriately corrected for magnification. Contralateral extremity femoral films in two planes are useful for determining the normal femoral bow and the normal femoral length. The diameter of the medullary canal at the isthmus can be measured as part of the preoperative plan if nailing is anticipated. The presence of osteopenia, metastases, or cortical irregularities in the region of the fracture or remote in the femur should be identified.

Other x-rays that should remain a part of the routine evaluation include dedicated films of the hip and knee. Although an internal rotation x-ray of the hip is ideal for evaluation of the femoral neck, this may be difficult in a patient with a femoral shaft fracture. The knee x-rays should be reviewed to determine whether there is associated joint widening or associated fractures. If a computed tomography (CT) scan of the abdomen and/or pelvis is obtained for other reasons, this should be reviewed because it may provide evidence of injury to the ipsilateral acetabulum or femoral neck. To minimize the incidence of a missed femoral neck fracture in association with a fracture of the femoral shaft, a number of additional radiographic