INTRODUCTION

Trochanteric fracture is common in elderly population. Ninety percent of trochanteric fractures in the elderly patients result from a simple fall. [(1)]

Hip fractures have a bimodal age distribution: Approximately 97% occur in patients over 50 years of age usually occur in alcoholics or patients with multiple medical diseases, whose fractures are related to osteoporosis, and only 3% in patients under 50 years, due to high-energy trauma.[(2)]

Approximately 50-60% of all trochanteric fractures are classified as unstable. This represents a great challenge to the operating surgeon, as the rate of failure for these kinds of fractures vary from 8 to 25 %.[(3)]

The goal of treating hip fracture is to return patients to their pre-fracture level of function without long-term disability and avoiding medical complications.[(4)]

Treatment options include nonoperative treatment and operative treatment. Operative options include closed reduction and internal fixation with dynamic hip screws, dynamic condylar screws and intramedullary fixation devices.[(4)]

Early operative intervention can shorten the time confined to bed, reduce the morbidity and mortality. Closed reduction and internal fixation is indicated for all trochanteric fractures, unless the patient's medical condition is such that any anesthesia, general or spinal, is contraindicated.[5]

Since its introduction in the late 1970's, the dynamic hip screw (DHS) had become a standard device for the fixation of all trochanteric fractures of the femur.[6]

However, in unstable fractures the DHS has performed less well with substantial rates of fixation failure, poor functional outcome and associated morbidity.[7]

DHS has been reported to involve high failure rates in cases of unstable pertrochanteric or subtrochanteric fractures.[8]

The DHS has several modes of failure, the most common being cutting-out of the lag screw from the femoral head. It is due to increase bending moment across the implant-fracture construct.[9]

To overcome the difficulties encountered in the treatment of unstable fractures, trochanteric-entry intramedullary nails have been developed. The main principle of trochanteric-entry nail fixation is based on a sliding screw in the femoral neck-head fragment, attached to an intramedullary nail. The nail has major advantages over a DHS from the bio-mechanical point of view; including a semi-closed procedure and a shorter lever arm giving greater stability and allowing rapid rehabilitation.[4]

The Gamma nail was the first trochanteric-entry nail introduced in 1988, and was designed specifically for the treatment of unstable fractures. However, the Gamma nail has been implicated with serious implant related complications such as iatrogenic femoral shaft fractures during nail impaction and, therefore, other intramedullary fixation devices has been introduced. The proximal femoral nail (PFN) was developed in 1997 with a redesigned tip that decreases resistance during insertion and reduces bone stress significantly thereby decreasing the risk of intra and post-operative fractures of the femoral shaft. It also incorporates two proximal screws to improve the rotational stability of the proximal fracture fragment.[10]

Nailing has shorter lever arm with reduction in bending stress and lower implant failure rate and makes no dissection at the fracture site. The nail occupies the medullary canal, preventing excessive sliding and medialization of the shaft. It also covers all the other fracture patterns like reverse obliquity and trochanteric fracture with subtrochanteric extension effectively.[11]

The short proximal femoral nail is a superior implant for stable and unstable trochanteric fractures in terms of operating time, surgical exposure, blood loss, and complications, especially for patients with relatively small femora.[12]

The biggest advantage of intramedullary implants is the early full weight-bearing ability. Intramedullary fixation remains the treatment of choice for proximal femoral fracture, because of its biomechanical superiorities in regard to axial loading. This rigid structure provides a good purchase, even in osteoporotic bone, for preventing the screws from sliding and pull-out.[(13)]

It is recommended that subtrochanteric fractures and hip fractures with associated femoral shaft fractures and pathological extracapsular fractures should be treated by intramedullary fixation.[(14)]

In patients with unstable trochanteric fractures treated with proximal femoral nailing, technical or mechanical complications seem to be related to the fracture type, operating technique, and time to weight bearing rather than the implant itself. Screw migration is attributed to fracture instability, presence of osteoporotic bones, and impaction at the fracture site.[(15)]

AIM OF THE STUDY

This essay aims at giving spotlight on the proximal femoral nail in the treatment of unstable trochanteric fractures as it`s a minimal invasive technique.

APPLIED ANATOMY AND BIOMECHANICS

1) Osseous Anatomy

The neck shaft angle of the adult femur in both sexes averages 130 degrees with a standard deviation of 7 degrees ***fig.(1)***. Average femoral anteversion is 10 degrees with a standard deviation of 7 degrees ***fig.(2)***. There is moderate interracial and intergender variations in these averages.[16]

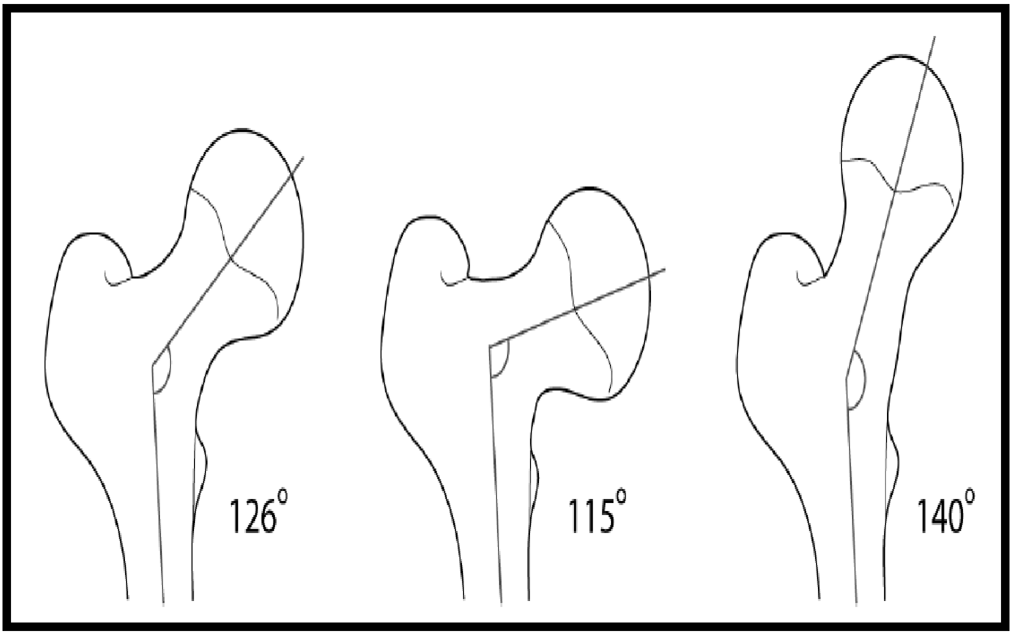

Fig. (1). (**a**) Normal femoral neck angle, (**b**) a decreased femoral neck angle (coxa vara), and (**c**) an increased femoral neck angle (coxa valga).[17]

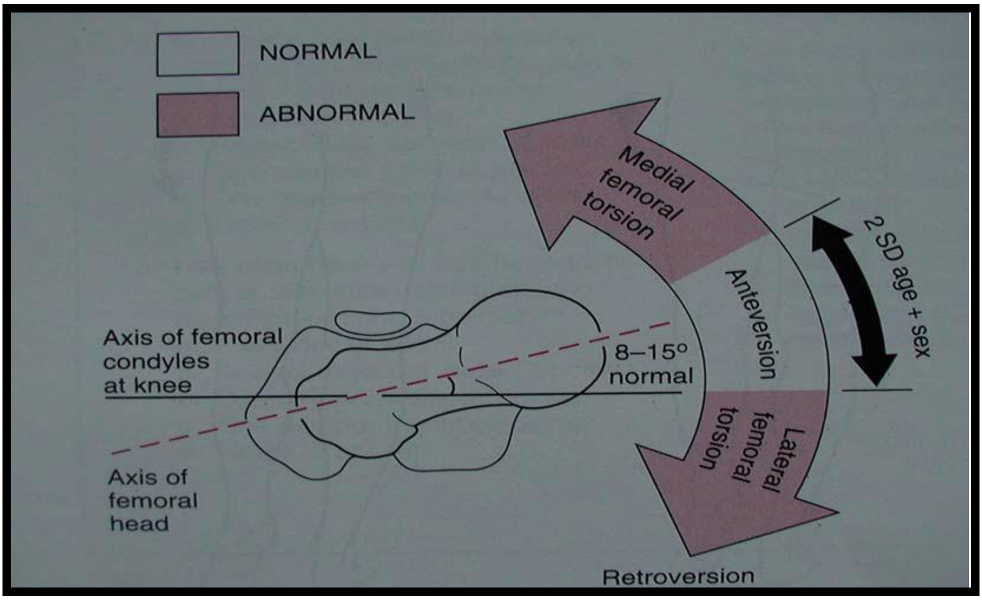

Fig (2): Normal range of anteversion and torsional deformity beyond.[18]

The trochanters project posteriorly to the neck, which originates slightly anteriorly to the midcoronal plane of the shaft. If the lesser trochanter appears in profile on radiographs, the femoral shaft is externally rotated. Understanding these relationships is critical to ensure correct assessment of the reduction and accurate placement of internal fixation. The internal trabecular structure of the proximal femur was first described by Ward in 1838. In accordance with Wolff's law, trabeculations arise along the lines of force to which the bone is exposed. In the femoral neck and trochanteric region cancellous trabeculations form from the transition of the shaft cortex into metaphyseal canellous bone. Primary compressive and tensile trabeculations pass through the neck and are separated by an area of sparse cancellous bone labeled Ward's triangle **Fig. (3)**. When mechanically tested in cross section, the cancellous bone of the hip has increased stiffness along these weight-bearing trabeculations and it is significantly reduced in Ward's triangle and in the trochanteric region.[19]

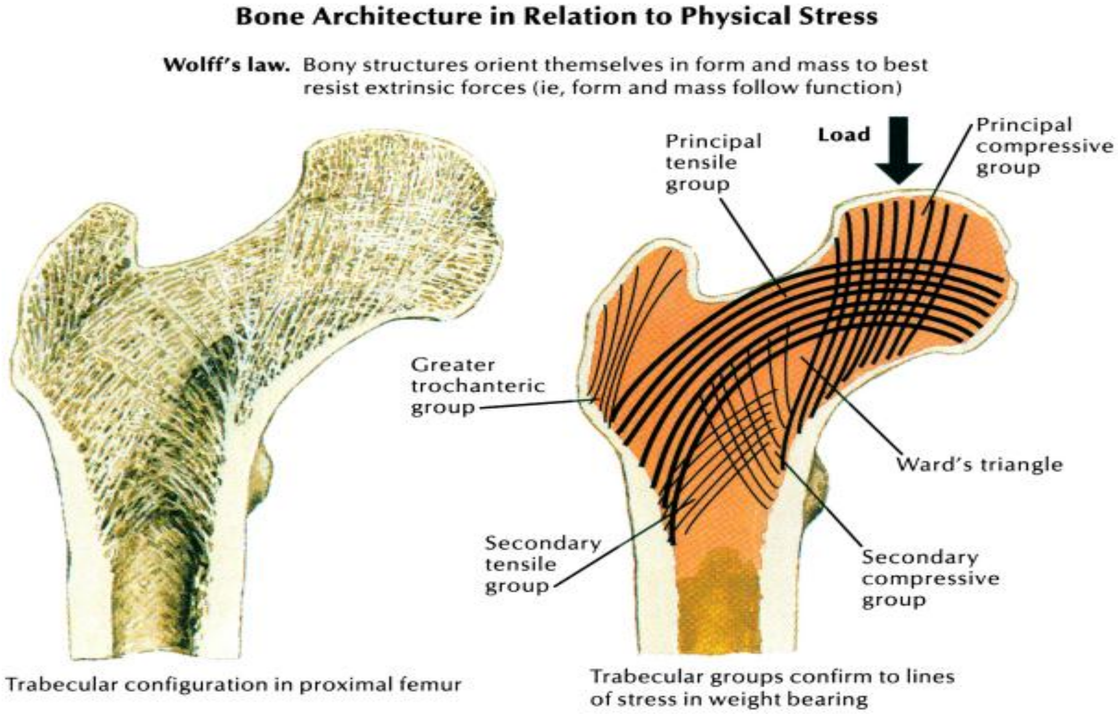

Fig. (3): Diagramatic representation of the major trabecular groups of the proximal femur. The markedly osteopenic area surrounded by the primary and secondary compressive trobeculae and the primary tension group is known as ward's triangle (w).[20]

This nonhomogenous pattern of bone density and stiffness is particularly apparent in the osteoportotic patient and is important to appreciate when trying to establish fixation.[16]

A dense buttress of bone in the coronal plane, the calcar femorale, extends proximally from the posteromedial portion of the femoral shaft distally and deep to the lesser trochanter ***Fig. (4).***[16]

The calcar is a key support in providing strength to the femoral neck, but does so from this vertical position at the shaft-neck transition. It has been frequently misidentified as the medial cortex at the intersection of the neck and shaft.[16]

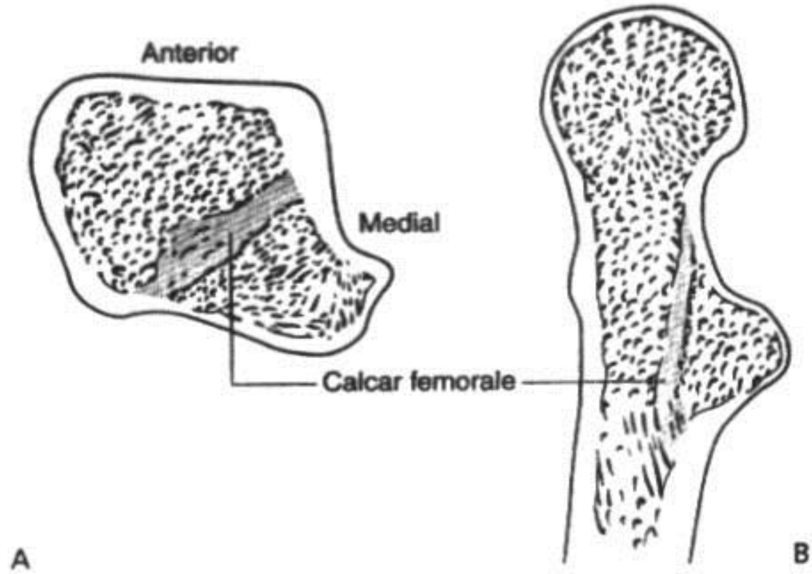

Fig. (4): A dense buttress of bone running in the coronal plane, the calcar femorale is seen in a transverse section at the level of the lesser trochanter (A) and in a sagittal section of the proximal femur (B).[21]

The trochanteric region of the hip, consisting of the area between the greater and lesser trochanters, represents a zone of transition from the femoral neck to the femoral shaft. This area is characterized primarily by dense trabecular bone that serves to transmit and distribute stress, similar to the cancellous bone of the femoral neck. The greater and lesser trochanters are the sites of insertion of the major muscles of the gluteal region: the gluteui medius and minimus, the lliopsoas, and short external rotators. The calcar femorale, a vertical wall of dense bone extending from the posteromedial aspect of the femoral shaft to the posterior portion of the femoral neck, forms an internal trabecular strut within the inferior portion of the femoral neck and trochanteric region and acts as a strong conduit for stress transfer.[22]

2) Muscles of the hip region:

The musculature of the hip region can be grouped according to function and location. The abductors of the gluteal region, the gluteus medius and gluteus minimus, which originate from the outer table of the ilium and insert onto the greater trochanter, function to control pelvic tilt in the frontal plane. The gluteus medius and gluteus minimus, along with the tensor fascia lata, are also internal rotators of the hip. The hip flexors are located in the anterior aspect of the thigh and include the sartorius, pectineus, iliopsoas, and rectus femoris. The iliopsoas inserts onto the lesser trochanter. The gracilis and the adductor muscles (longus, brevis, and magnus) are located in the medial aspect of the thigh. The short external rotators: the piriforrnis, obturator internus, obturator externus, superior and inferior gemelli, and quadratus femoris, all insert onto the posterior aspect of the greater trochanter. The gluteus maximus, originating from the ilium, sacrum, and coccyx, inserts onto the gluteal tuberosity along the linea aspera in the subtrochanteric region of the femur and the iliotibial tract. The gluteus maximus serves as an extensor and external rotator of the hip. The semitendinosus, semimembranosus, and biceps femoris, which originate from the ischium to form the hamstring muscles of the thigh, are responsible for knee flexion as well as hip extension.[(23)]

3) Vascular Anatomy

The extraosseous vascular anatomy of the proximal femur was well described in 1950 by Howe and co-workers after their dissection of 40 specimens **Fig. (5)**. The medial femoral circumflex artery usually originates from the profunda femoris and runs posteriorly between the iliopsoas and pectineus, along the base of the femoral neck, extracapsularly, proximal to the lesser trochanter. It supplies the obturator externus, running along its inferior border, deep to the quadratus femoris to reach the posterior femoral neck. It emerges in the interval between the quadratus and obturator externus and invariably gives off branches to the posterolateral surface of the greater trochanter at this level. The vessel passes superficial to the tendon of the obturator externus before diving deep to the tendinious insertions of the obturator internus and gemelli, where it is protected by the overhanging tip of the greater trochanter. The terminal branches of the medial femoral circumflex vessel (Trueta's lateral epiphyseal arteries) pierce the superolateral capsule and run deep to the synovial reflection before entering the femoral head just distal to the articular junction. The lateral femoral circumflex also originates from the profunda femoris, then runs laterally over the iliopsoas here it sends branches out to supply the anterolateral muscles as well as along the intertrochanteric line, nourishing the capsule, anterior femoral neck, and greater trochanter. There is little to no direct contribution to the femoral head blood supply from the lateral femoral circumflex artery.[24]

The nonunion and avascular necrosis rate in pertrochanteric fractures is less than 1% because of the ample blood supply in this region.[25]

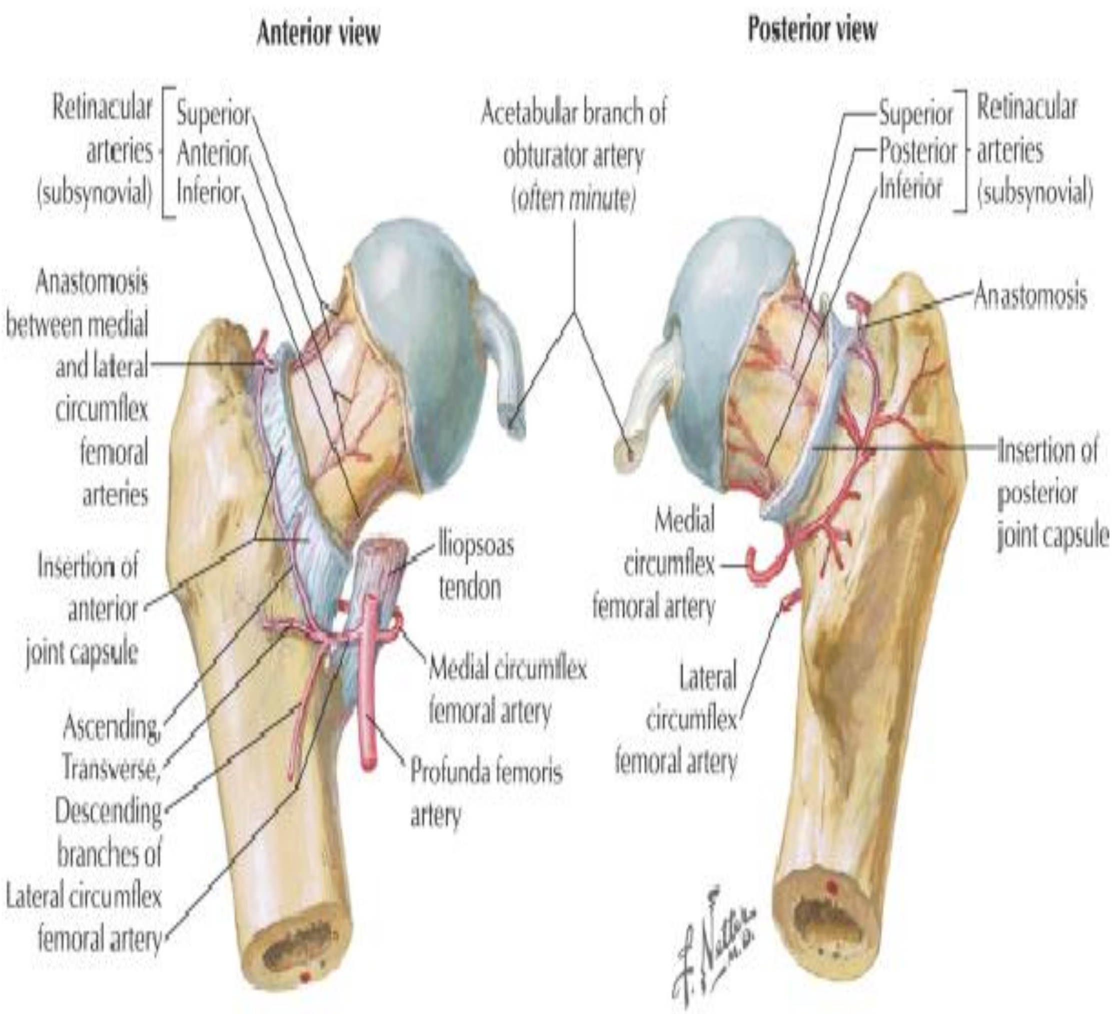

Fig. (5). Blood Supply to Femoral Head.[20]

Biomechanics

Extracapsular fractures (trochanteric and subtrochanteric fractures) primarily involve cortical and compact cancellous bone. Because of the complex stress configuration in this region and its nonhomogeneous osseous structure and geometry, fractures occur along the path of least resistance through the proximal femur. The amount of energy absorbed by the bone determines whether the fracture is a simple (two-part) fracture or is characterized by a more extensively comminuted pattern. Bone is stronger in compression than in tension, cyclic or repetitive loading of bone at loads lower than its tensile strength can cause a fatigue fracture. Each load causes microscopic damage to the osseous structure, essentially forming microscopic cracks that can coalesce into a single macroscopic crack, which in turn functions as a stress riser. Failure can thus occur if healing of these microfractures does not take place. In repetitive loading, the fatigue process is affected by the frequency of loading as well as by the magnitude of the load and the number of repetitions.[16]

Muscle forces play a major role in the biomechanics of the hip joint. During gait or stance, bending moments are applied to the femoral neck by the weight of the body, resulting in tensile stress and strain on the superior cortex. The contraction of the gluteus medius, however, generates an axial compressive stress and strain in the femoral neck that acts as a counterbalance to the tensile stress and strain. When the gluteus medius is fatigued, unopposed tensile stress arises in the femoral neck. Stress fractures are usually sustained as a result of continuous strenuous physical activity that causes the muscles gradually to fatigue and lose their ability to contract and neutralize stress on the bone.[26]

The proximal femur and hip are very familiar to most orthopaedic surgeons. An understanding of the forces about this area of the skeleton is a must prior to attempting subtrochanteric fracture reduction and internal fixation. Koch described weight-bearing forces at 1,200 pounds per square inch in the femur of a 200-pound man **fig.(6).** In the medial cortex region, this force may be exceeded 1 to 3 inches below the lesser trochanter. The force is usually somewhat less just opposite on the lateral cortex. This is the reason medial comminution plays an important role in destabilizing reconstruction in this area of the femur.[27]