INTRODUCTION

Hip fractures are common and comprise about 20% of the operative workload of an orthopaedic trauma unit.[1] Intracapsular femoral neck fractures account for about 50% of all hip fractures. The lifetime risk of sustaining a hip fracture is high and lies within the range of 40% to 50% in women and 13% to 22% in men. Life expectancy is increasing worldwide, and these demographic changes can be expected to cause the number of hip fractures occurring worldwide to increase from 1.66 million in 1990 to 6.26 million in 2050.[2]

The estimated annual cost of treating these fractures is enormous and a significant burden to any healthcare system. There is very little debate about the management of the undisplaced intracapsular femoral neck fracture, which is almost invariably treated with internal fixation; however, only 15% of these fractures are undisplaced. The remainder are displaced and occur predominantly in elderly female patients. Despite the ubiquitous nature of these fractures there is still a surprising degree of variation in treatment. Options include reduction and fixation, unipolar arthroplasty, bipolar hemiarthroplasty, and total hip arthroplasty. Any of the arthroplasty options may be cemented or uncemented. Recent surveys of practice indicate widespread variation in the use of these options.[3,4,5,6]

In recent years, however, a number of randomized trials have been published that have provided better evidence on which to base treatment choices. As a generalization these trials have suggested that for the majority of patients with a displaced fracture an arthroplasty is the best choice, and that a modern design of arthroplasty is better than older designs of unipolar hemiarthroplasties.

Femoral neck fractures occur most frequently in elderly female patients. They are uncommon in patients under the age of 60 years. There is some racial variation in the incidence. They are less common in black races and more common in white females than males.[7,8]

Currently these fractures are most common in the white populations of Europe and North America.[9] The incidence increases exponentially with age.[10] The risk of a second hip fracture within 2 years approaches 10% in women and 5% in men.[11,12] In patients who sustain a second hip fracture it is the same type of hip fracture in more than 70%.[13] Epidemiologic studies have identified numerous risk factors associated with an increased risk of sustaining a hip fracture. These include, among other factors, a low BMI (less than 18.5), low sunlight exposure, low recreational activity, smoking, a history of previous osteoporotic fracture, family history of hip fracture, and corticosteroid treatment.[14,15,16,17,18]

In the past it was predicted that the worldwide incidence of these fractures would increase until 2050. More recent epidemiologic studies from Europe have reported that the incidence of osteoporotic fractures may have leveled off,[8,12] and there is even evidence that the incidence may be reducing.[12,19] One study has predicted that the risk factors for hip fractures can be divided into those that increase the risk of falls in the elderly and those that predispose to changes in bone mass.

Reduction in bone mass caused by osteoporosis has an unequivocal link with hip fracture and is present in more than 84% of patients with femoral neck fracture. A reduction of bone mass at the hip of one standard deviation doubles the risk of hip fracture.[20]The reduction in bone mass is caused by osteoporosis in most patients. Other metabolic disorders of bone such as osteomalacia and renal osteodystrophy also render the femoral neck more susceptible to fracture, but they are much less prevalent.[21] The risk of falling increases with age because of the increasing prevalance of risk factors for falling in older age groups. These include muscle weakness, abnormal gait or balance, neurologic disease, deteriorating eyesight, and medication with sedative or cardiovascular side effects.[22,23] The direction of the fall is also important. Older patients who are fitter tend to fall forward and are more likely to sustain distal radial fractures or other upper limb fractures. More infirm elderly patients are more likely to fall sideways, in which case the force of the fall is sustained directly on the trochanteric region.

The Hip joint can be approached in many ways and therefore many different exposures have been described. The choice of which approach to use depend on the type of surgery, what part of the hip needs to be exposed, age of the patient and surgeon's preference and expertise. [24]

Minimally invasive surgery of the hip seeks to eliminate some complications of traditional extensile exposure and also attempts to facilitate more rapid rehabilitation of patients after surgery. Traditional anterolateral approaches have divided the anterior portion of the gluteus medius and minimus and potentially jeopardized the superior gluteal nerve. These disadvantages have been associated with abductor weakness, prolonged limp and decreased patient satisfaction. To overcome these problems, a mini-incision approach was developed using the intermuscular plane between the gluteus medius and the tensor fascia lata. This intermuscular interval through a small incision provides good exposure for hip arthroplasty and preserves muscle integrity so that rehabilitation can be rapid and the posterior capsule remains intact so that posterior dislocation is less of an issue.[25]

Minimally invasive surgery (MIS) performed through the anterolateral approach potentially leads to a reduction in operative trauma through lower blood loss with a smaller soft tissue wound, a reduction in post-operative pain, and earlier mobilization accomplished by preserving muscle insertions. Theoretically, these improvements should result in a shorter hospitalization, convalescence, and rehabilitation period, as well as an enhanced cosmetic result through smaller skin incision and atraumatic wound closure. It is essential that any minimally invasive approach not lead to a reduction in the technical or long-term success of the procedure, including the post-operative position of the implanted components and restoration of the patient's leg length, and centre of rotation. With all of these requirements in mind, minimally invasive approach based on the anterolateral Watson-Jones approach was developed. [26]

To make this procedure minimally invasive, techniques were developed to preserve the insertions of the gluteal muscles on the greater trochanter while allowing bony preparation and component placement via a smaller skin incision. In choosing this approach, our aim was to allow the surgeon to perform the procedure under direct vision using the usual anatomic landmarks for orientation, while maintaining the ability to revert to conventional procedure by extending the skin incision. [27,28]

ANATOMY

The hip is a large synovial ball and socket joint. In the case of the femoral neck, the relationship to the femur and hip joint is characterized by anteversion of the femoral neck in the transverse plane and the femoral neck shaft angle in the coronal plane. The femoral neck subtends an angle with the femoral shaft of between 120 and 135 degrees in the normal hip. An angle less than this is referred to as coxa vara and an increased angle is termed coxa valga. Femoral neck anteversion describes the angle subtended by the femoral neck to the the transcondylar axis, which is usually between 10 and 25 degrees. In addition to these two angles, hip axis length and femoral neck width have also been shown to have an influence on the risk of femoral neck fracture. The hip axis length is the distance from the lateral aspect of the trochanteric region along the axis of the femoral neck to the inner table of the pelvis . An increase in hip axis length and femoral neck width and lower neck shaft angles are associated with an increased risk of femoral neck fracture.[29] Hip axis lengths are known to be longer in white females compared with those of Asian and black populations, which may partly explain the increased susceptibility to femoral neck fracture in this group.[30]

Femoral neck angle and anteversion have to be taken into consideration when reduction and fixation is selected as a method of treatment. Increased femoral anteversion may be present and occasionally coxa varus or valgus, which will influence implant placement.

Anatomy of the upper end of the femur

The proximal end of the femur consists of femoral head, neck, lesser and greater trochanters.

The head

The femoral head forms two third of a sphere, arising from the femoral neck. It is directed upwards medially and slightly forwards, and has an axis normally parallel to that of the neck.

The surface of the femoral head is covered with articular cartilage, about 4 mm in thickness over the superior portion and 3 mm at the equator.

The equatorial plane of the femoral head is virtually circular; however the radii of the meridians that are perpendicular to the equator are longer, differing in length according to their location. For example, the radius of the superior meridian is larger than the anterior and posterior meridians. This lack of roundness is greater in males than in females.[31]

The anatomic center of femoral head rotation in the hip joint is the center of the femoral head. It is usually located perpendicular to the axis of the femoral shaft on a line opposite the tip of the greater trochanter.[32] (Figure 1)

The neck

The neck is embryologically a continuation of the shaft. It has two rounded borders; the upper border is nearly horizontal and is gently concave upwards. The lower border is straight but oblique, and is directed downwards, laterally and backwards to meet the shaft near the lesser trochanter.[31]

The head of the femur overlaps the neck cortex but projects most prominently posteriorly as does the greater trochanter and its crest. The neck possesses a thick cortex anteriorly and laterally, posteriorly the calcar reinforces the neck, a thin fragile angulated cortex is left at the junction of the head and neck medially and laterally where the neck joins the trochanter crest these are classic sites for femoral neck fractures.

The longitudinal rotary axis of the femur passes from the center of the head to the region of the intercondylar notch when the proximal femur is intact, the course of the axis is outside the upper two thirds of the shaft. Dissolution of the femoral neck displaces the axis of rotation laterally into the marrow cavity of the shaft. This immediately converts all muscles passing from the pelvis to the linea aspra and lesser trochanter into uninhibited external rotators. They unwind the femoral shaft into external rotation. Compression forces on this axis, whether due to muscle action or direct contact will collapse and comminute the posterior cortex at its two weak areas (at the junction of the head and neck and laterally where the neck joins the trochanteric crest) after failure of the thick anterior cortex. [32]
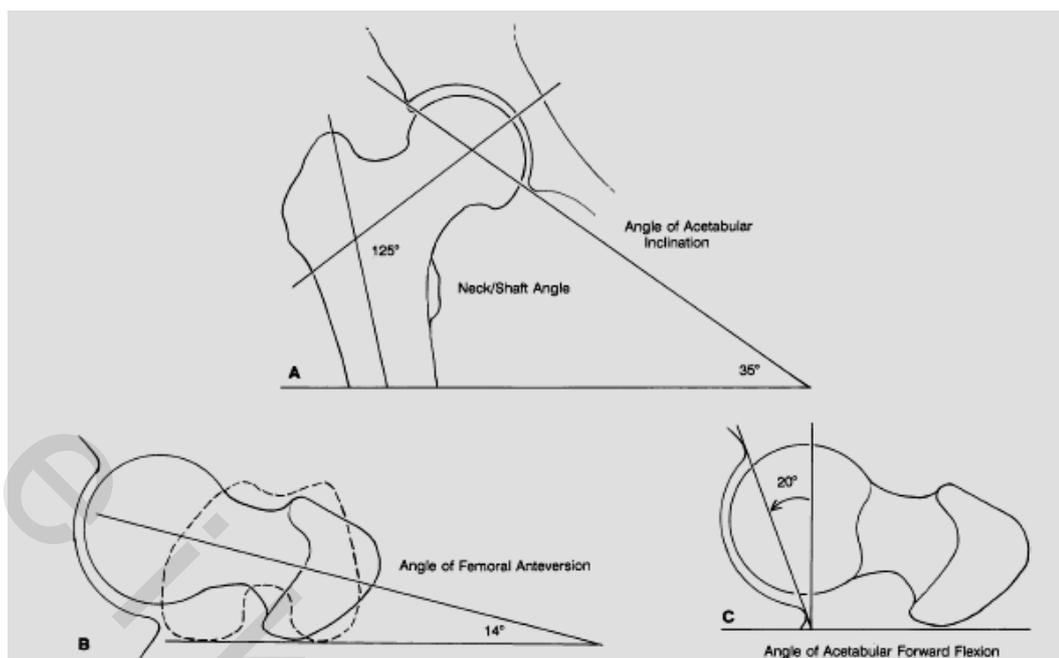
Figure 1:   A- Neck shaft angle and acetabular inclination. B- Angle of femoral anteversion. C- Acetabular anteversion. [33]

The greater trochanter

The greater trochanter is the site for insertion of the abductors. Both the femoral head and the greater trochanter are originally part of the same epiphyseal mass in which two separate secondary centers of ossification form. Growth disturbances at the capital femoral epiphysis cause a coxa vara, while growth arrest of the growing greater trochanter produces a coxa valga. [32]

It projects up and back from the convexity of the junction of the neck and shaft. Its upper border is projected into an apex posteriorly; this carries the upper part of the attachment of the gluteus medius. Piriformis is attached here and spreads forward along the upper border deep to gluteus medius. More anteriorly the medial surface of the upper border shows smooth facets for the tricipital tendon of the obturator internus and gemelli. The apex of the trochanter overlies a deep pit, the trochanteric fossa. The bottom of the pit is smooth for the attachment of obturator externus tendon. The anterior surface of the greater trochanter shows a J- shaped ridge for the gluteus minimus tendon. The lateral surface shows a smooth strip, 1 cm wide for the tendon of gluteus medius. Posteriorly the apex of the greater trochanter is continued down as the prominent trochanteric crest to the lesser trochanter. Quadratus femoris is attached here and vertically down to a level that bisects the lesser trochanter.

The lesser trochanter

Lies back on the lowest part of the neck. Its rounded surface facing medially is smooth for the reception of the psoas tendon. Iliacus is inserted into the front of the tendon and into the bone below the lesser trochanter.

Internal architecture of the upper end of the femur

It has long been recognized that the cancellous bone of the upper end of the femur is composed of bone trabeculae disposed into two arches intersecting each other at right angles. These trabeculae correspond in the position of the trajectories of maximum compression and tension stresses in Fairbank crane (a curved cantilever approximating the shape of the upper end of the femur).

The transmission of weight from the head of the femur to the shaft determined the arrangement of trabeculae in the upper end of the femur. Thus it can be concluded that the trabeculae in the upper end of the femur of a normal individual are arranged along lines of compression and tension stresses produced in the bone during weight bearing. This arrangement ensures maximum strength with the available material. [32]

The trabeculae are divided into the following five groups (Figure 2):

1. Principle compression group

The upper most compression trabeculae that extend from the medial cortex of the shaft to the upper portion of the head of femur, in slightly curved radial lines these are some of the thickest and most closely packed trabeculae in the upper end of the femur.

2. Secondary compressive group

The rest of the compression trabeculae that arise from the medial cortex of the shaft. These arise below the principal compressive group and curve upwards and laterally towards the greater trochanter and the upper position of the neck. The trabeculae of this group are thin and widely spaced.

3. Greater trochanter group

Some slender and poorly defined tensile trabeculae which arise from lateral cortex just below the greater trochanter and sweep upwards to and near its superior surface.

4. Principal tensile group

Trabeculae which spring from the lateral cortex immediately below the greater trochanter group. These trabeculae, which are the thickest amongest tensile group, curve upwards and inwards across the neck of the femur, to end in the inferior portion of the femoral head.

5. Secondary tensile group

Trabeculae which arise from the lateral cortex below the principal tensile trabeculae. The trabeculae of this group arch upwards and medially across the upper end of the femur and end more or less irregularly after crossing the mid line. [34]
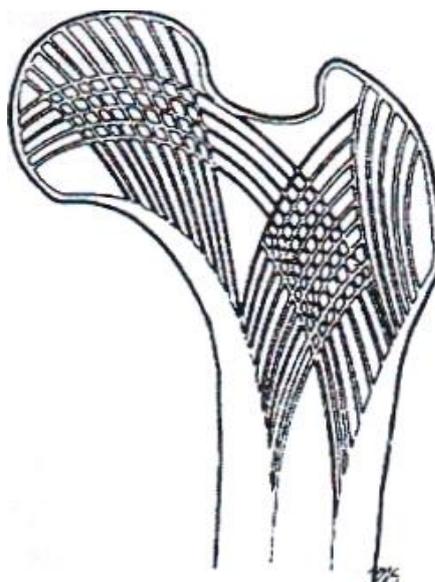
Figure 2: Trabeculae of proximal end of the femur. [34]

In the neck of the femur, the principal compressive, the secondary compressive, and the tensile trabeculae enclose an area containing some thin and loosely arranged trabeculae, this is called Ward's triangle.

Other two triangles are underneath the superior and inferior head-neck junctions respectively. These two triangles are part of the circular subcapital tunnel that houses a vascular anastomosis. [35]

The calcar femorale

It is a laminated vertical plate of condensed bone fanning laterally from the medial cortex toward the gluteal tubercle. Proximally it blends with the posterior cortex of the neck, and distally beyond the lesser trochanter it fuses with the posteromedial shaft. The thick walled tubular shaft pattern is interrupted by the posterior projection of the thin walled lesser trochanter and trochanter crest. The calcar femorale represents the original cylindrical shaft, strives to maintain the tubular outline and counteract the postero-inferior forces of the external rotators. [36]

X-ray films taken at right angle to the neutral axis of the femoral neck best portray the calcar femorale, which stands out like a solid bone spur. It appears that the calcar femoral is best developed during early adulthood and then gradually atrophies, however, it always remains present. (Figure 3)
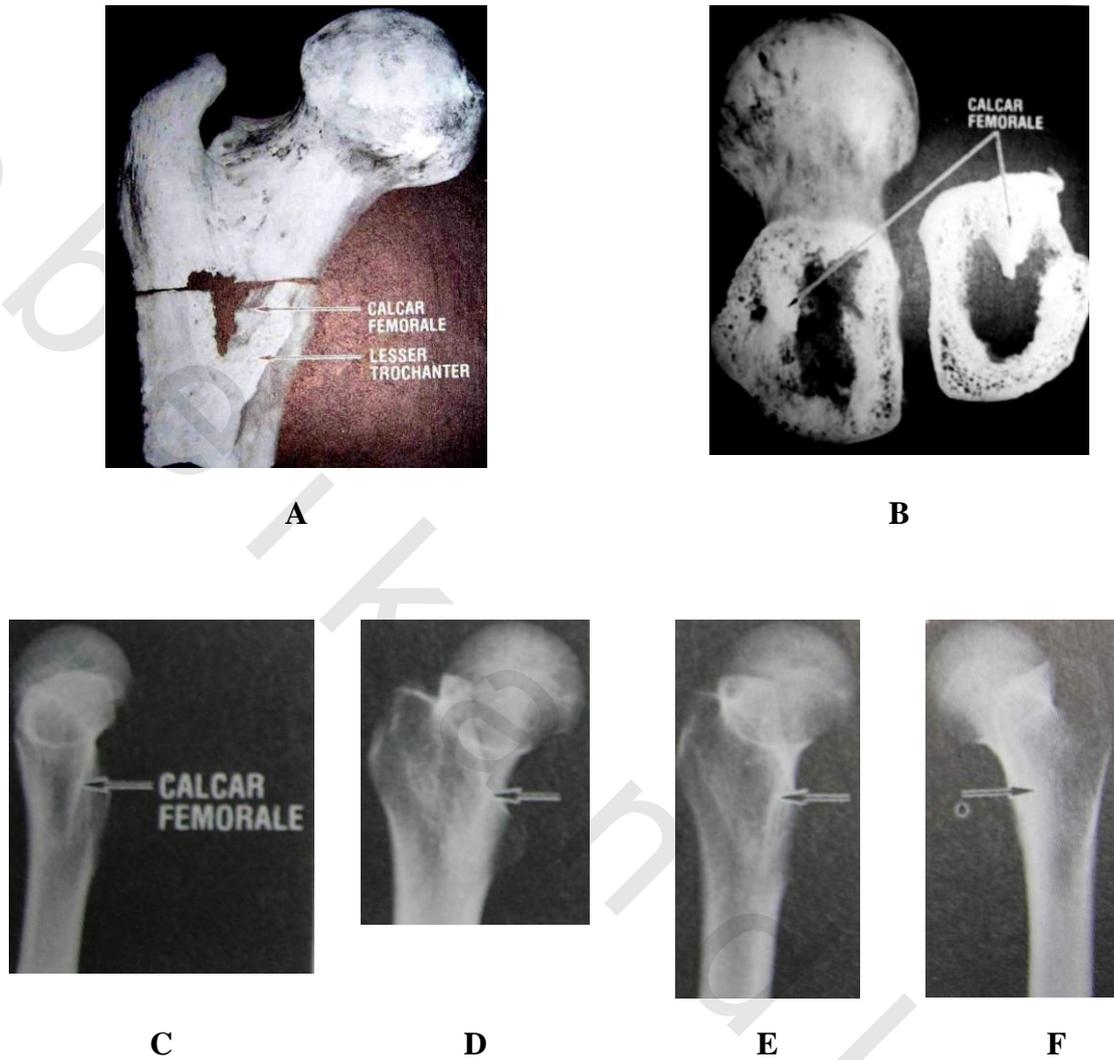
A   **B**

C   **D**   **E**   **F**

Figure 3:   Calcar femorale A: Posteroanterior view of the femur with the lesser trochanter and calcar lying deep to it. B: Transverse section of the femur at the level of the lesser trochanter. C-F: X-rays showing calcar femorale with different degree of neck rotation [37]

Muscles

Hip flexion is produced by the iliopsoas, which inserts into the lesser trochanter. When the femoral neck is intact, contraction of this muscle also produces internal rotation. If the femoral neck is fractured the muscle pull will result in external rotation of the femoral shaft. External rotation of the hip is also caused by the action of piriformis, the gemelli and obturator internus. Abduction is produced by the gluteal muscles, which are supplied by the superior gluteal nerve. Damage to this nerve, and particularly to the inferior division of the nerve, may occur in the direct lateral approach to the hip. This may contribute to the development of a Trendelenberg gait after arthroplasty for fracture.

Adduction of the hip is produced by the muscles in the adductor compartment, which are supplied by the obturator nerve. These include adductor longus, adductor magnus, and adductor brevis. These muscles are not of particular importance in femoral neck fractures, but may contribute to the characteristic leg shortening of the leg seen with a displaced intracapsular fracture.

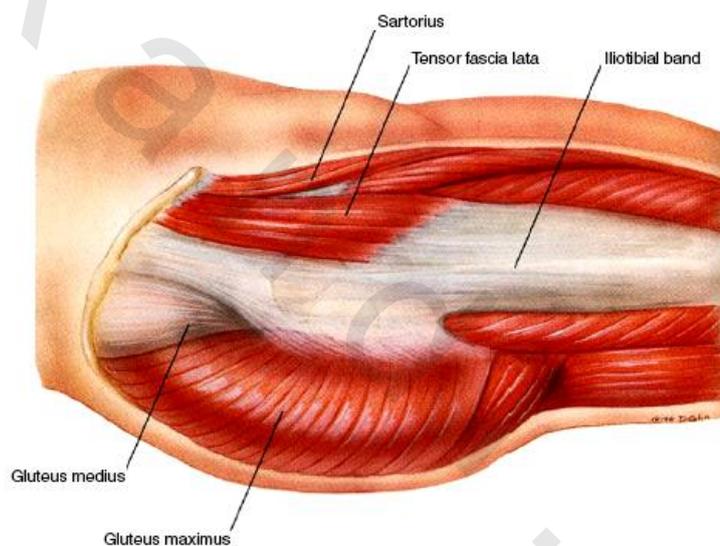The superficial and the deep muscular layers of the hip are shown in figure 4 and 5.

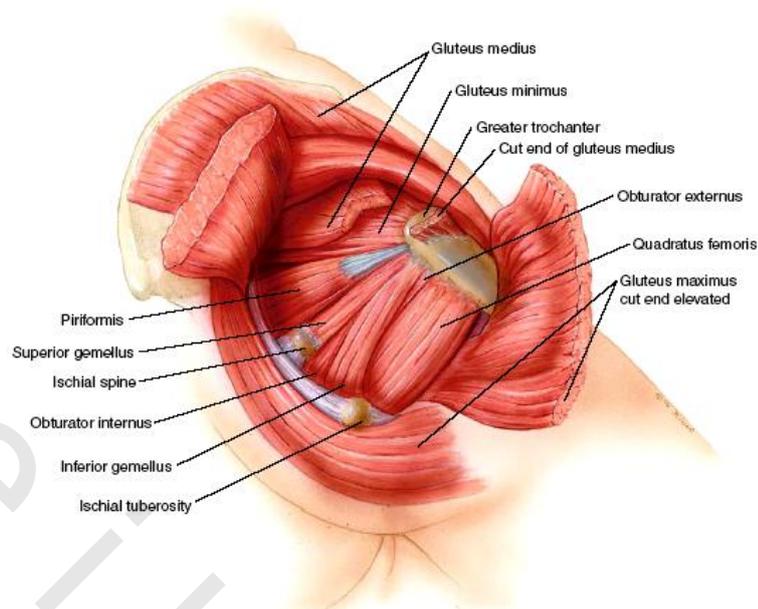**Figure 4:** The superficial muscular layer of the hip. [38]

Figure 5: The deep muscular layer (posterior View)[38]

Ligaments

The hip joint is a constrained ball-and-socket joint. The head rotates within the acetabulum and is incompletely covered. The depth of the acetabulum is supplemented by the fibrous labrum, which makes the joint functionally deeper and more stable. The labrum adds more than 10% to the coverage of the femoral head, creating a situation that keeps the head more than 50% covered during motion.[39,40,41,42,43] It takes more than 400 N of force just to distract the hip joint.[44] The capsule of the hip is strong and extends from the rim of the acetabulum to the intertrochanteric line anteriorly and the femoral neck posteriorly. The longitudinal fibers are supported by spiral capsular thickenings called ligaments.

Anteriorly, the iliofemoral or Y ligament originates from the superior aspect of the joint at the ilium and anterior inferior iliac spine. It runs in two bands inserting along the intertrochanteric line superiorly and just superior to the lesser trochanter inferiorly. The lateral arm of the iliofemoral ligament has dual control of external rotation in flexion and both internal and external rotation in extension. Increased tension in the iliofemoral ligament is considered to have a role in both the pathogenesis of femoral neck fractures and the posterior neck comminution characteristic of the injury.

The inferior capsule is further supported by the pubofemoral ligament, which takes its origin from the superolateral superior ramus and inserts on the intertrochanteric line deep to the Y ligament.[40,45] The pubofemoral ligament controls external rotation in extension with contributions from the medial and lateral arms of the iliofemoral ligament.[46]

Posteriorly, the capsule inserts on the femoral neck just inferior to the head medially and extends to the base of the greater trochanter laterally. The ischiofemoral ligament within the capsule posteriorly originates at the junction of the inferior posterior wall with the ischium. It runs obliquely lateral and superior to insert on the femoral neck with the

capsule.[40,45] The ischiofemoral ligament controls internal rotation in flexion and extension. In addition to these ligaments, the short external rotators lie on the posterior capsule, providing additional support. (Figure 6)
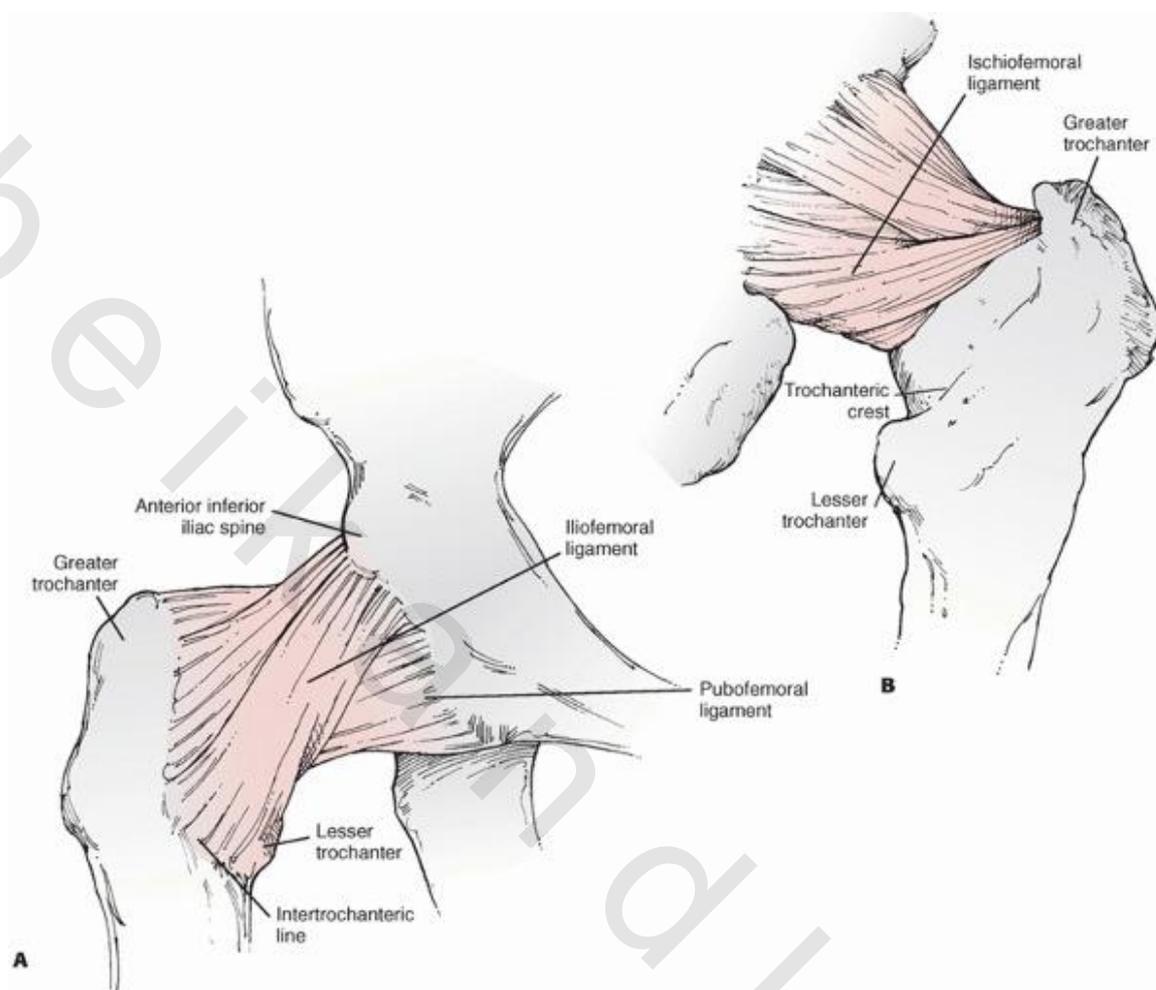

Figure 6: The hip capsule and its thickenings (ligaments) as visualized from anteriorly (A) and posteriorly(B).[40]

Blood Supply

The blood supply of the hip joint is of particular relevance when considering intracapsular hip fractures. There are three sources: capsular vessels, intramedullary vessels, and a contribution from the ligamentum teres.

In the adult the most important source of femoral head blood supply is derived from the capsular vessels. These vessels arise from the medial and lateral circumflex femoral arteries. These are in turn branches of the profunda femoris in 79% of patients. In 20% of patients one or other of these vessels arises from the femoral artery, and in the remaining 1% both vessels arise from the femoral artery.[47] The medial and lateral femoral circumflex arteries form an extracapsular circular anastomosis at the base of the femoral neck, and the ascending cervical capsular vessels arise from this. They penetrate the anterior capsule at the base of the neck at the level of the intertrochanteric line. On the posterior aspect of the neck they pass beneath the orbicular fibers of the capsule to run up

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the neck under the synovial reflection to reach the articular surface. Within the capsule these are referred to as retinacular vessels. There are four main groups (anterior, medial, lateral, and posterior), of which the lateral group is the largest contributor to femoral head blood supply. The most important retinacular vessels arise from the deep branch of the medial femoral circumflex artery.[48,49,50,51] These vessels supply the main weight-bearing area of the femoral head. The contributions of the lateral femoral circumflex artery and metaphyseal vessels are much less important by comparison.[49,50,51,52,53] At the junction of the articular surface of the head with the femoral neck there is a second ring anastomosis termed the subsynovial intra-articular ring.[54] The terminal branches of the deep branch of the medial femoral circumflex artery penetrate the femoral head 2 to 4 mm proximal to the articular surface on its postero-superior aspect.[55]

These capsular vessels are vulnerable to damage in displaced subcapital fractures.[56,57,58] They enter the femoral head just below the articular margin. Displacement of the femoral head because of a fracture in this area will damage these vessels, jeopardizing the blood supply to the femoral head and resulting in an increased risk of avascular necrosis if the head is retained.[59] Claffey[60] has shown that the risk of avascular necrosis is greatly increased if the important lateral retinacular vessels are damaged.

The artery of the ligamentum teres is a branch of the obturator or medial femoral circumflex artery.[61] Some additional blood supply in the adult reaches the head via the medullary bone in the neck. Clearly these latter vessels will be as vulnerable to disruption in any displaced fractures as are the retinacular vessels. Although the vessels entering the head through the ligamentum teres contribute to femoral head blood supply, their contribution is generally not sufficient to maintain complete vascularity of the entire head.[52]

After a displaced fracture, revascularization of the femoral head occurs by revascularization from areas of the head with retained blood supply and ingrowth of vessels from the metaphysis.[56,57,60] The portion of the femoral neck within the hip joint capsule has no cambial layer in its fibrous covering to participate in callus formation during fracture healing. Fracture union depends on endosteal healing alone, which is one of the reasons prolonged union times are commonly seen in these fractures. (Figure 7)
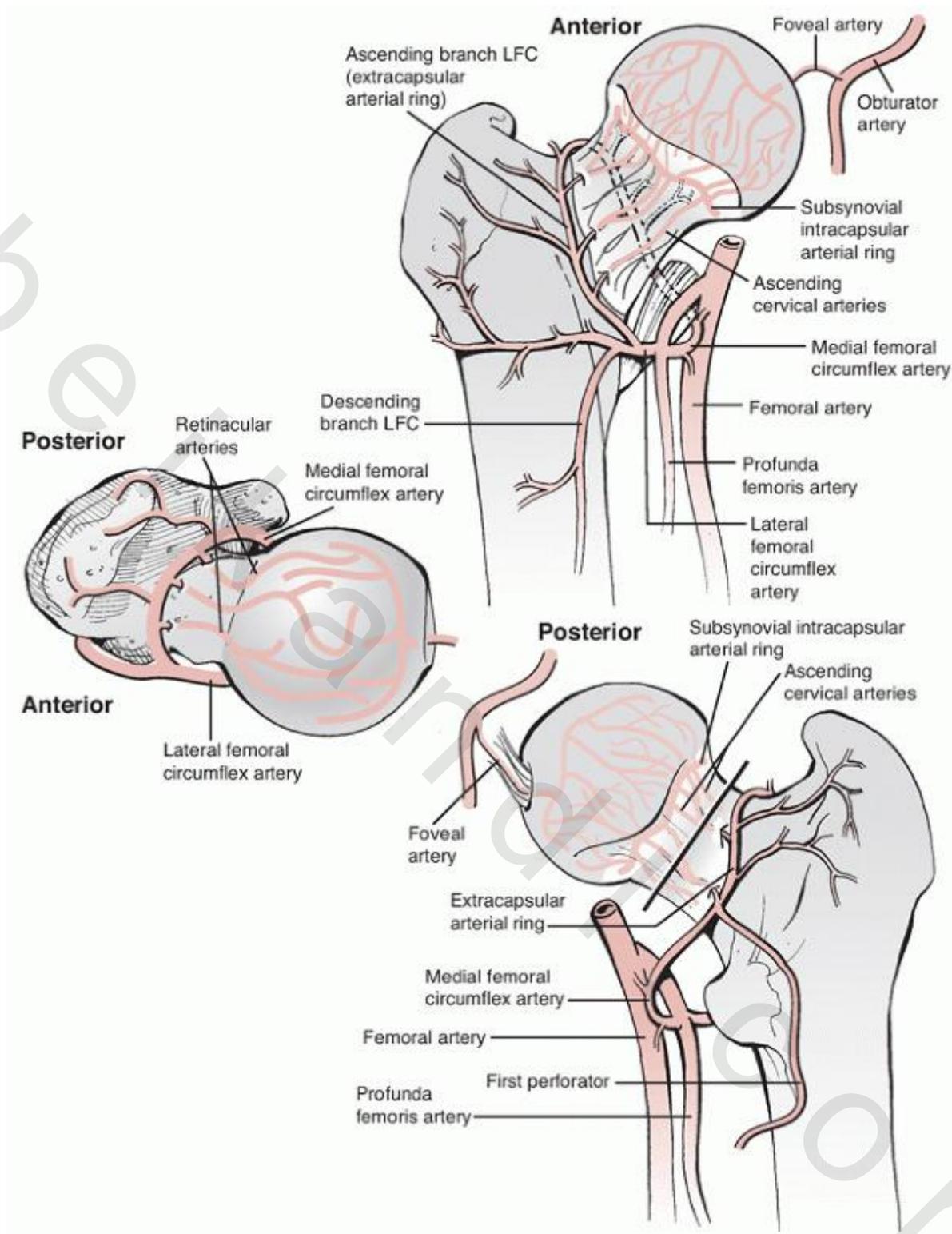
Figure 7: The vascular supply to the femoral head[62]

Sensory Supply

The hip joint derives sensation from the obturator, femoral, sciatic, and superior gluteal nerves. The anteromedial part of the joint is supplied by the obturator nerve. The anterior capsule receives sensory innervation from the femoral nerve. The posterior aspect of the joint is supplied by the sciatic nerve and there is a contribution to the posterolateral capsule from the superior gluteal nerve. This has some relevance for pain control after hip fracture.

Femoral nerve blockade is commonly used, but this produces incomplete pain relief. Much of the pain relief derived from femoral nerve blockade is secondary to the reduction of muscle spasm.

APPLIED ANATOMY

Vascular anatomy

The superior gluteal artery is the largest branch from the internal iliac artery and exits the pelvis through the greater sciatic notch in a position superior to the Piriformis muscle. A superficial division supplies the gluteus maximus, and a deep branch supplies the gluteus medius, gluteus minimus, and tensor fascia muscles. Small branches of the superior and inferior arteries communicate between the deep side of the maximus and the superficial side of the medius, and are at risk during dissection between these two muscles in a variety of hip approaches. The deep portion of the superior gluteal artery courses deep to the gluteus medius and runs along the proximal border of the gluteus minimus to anastomose at the ASIS with the ascending branch of the lateral circumflex and the deep iliac circumflex artery. An inferior division of the deep branch extends across the gluteus minimus toward the trochanter where it anastomoses with branches of the lateral circumflex artery.

The obturator artery branches from the internal iliac artery and is closely approximated to the lateral wall of the pelvis on the obturator fascia. The artery lies between the obturator nerve and vein. The close proximity of these neurovascular structures to the inner wall of the acetabulum places them at risk to injury from penetration through the acetabulum such as from screw placement during hip replacement, or fracture fixation. The obturator artery penetrates the obturator membrane and exits the pelvis through the obturator foramen. After exiting the foramen, the obturator artery divides into anterior and posterior branches. The anterior branch anastomoses with the posterior branch and the medial circumflex artery, and supplies the obturator externus, pectineus, adductors, and gracilis muscles. The posterior branch anastomoses with the anterior branch and also branches to the inferior gluteal supply.

An acetabular branch penetrates the acetabular fossa beneath the transverse acetabular ligament to enter into the ligamentum teres to provide one of the three major sources of blood to the femoral head.

The inferior gluteal artery branches from the internal iliac artery and exits the pelvis inferior to the Piriformis to supply the gluteus maximus. Posterior branches of the inferior gluteal artery pass along the lower border of the Piriformis across the sciatic nerve which receives a branch from this artery and is named the arteria comitans nervi ischiadici. The inferior gluteal artery continues in a distal direction to provide arterial branches to the short rotator muscle. In fracture work, these muscular branches may be important to maintain adequate circulation to bone fragments. [63]

Fracture neck of femur interrupt the blood supply to the head leading to avascular necrosis and non union.

Neuro-Anatomy

All the nerves to the lower extremity pass close to the hip joint. The sciatic nerve warrants the most attention, as it is most at risk. This nerve runs posteriorly to the joint, emerging from the greater sciatic notch deep to the piriformis and superficial to the obturator internis and gemelli muscles. In 85% of people, the nerve is a singular structure located in the normal position. In 12%, it divides prior to exiting the greater sciatic notch, and the peroneal division passes through, rather than deep to, the piriformis muscle.[64] In 3%, the nerve divisions surround the piriformis, and in 1%, the entire nerve passes through the piriformis. With posterior dislocation, the nerve may be stretched or directly compressed. The obturator nerve passes through the superolateral obturator foramen with the obturator artery. The femoral nerve lies medial to the psoas in the same sheath.

BIOMECHANICS

A basic knowledge of the biomechanics of the hip and the hip arthroplasty is necessary to properly perform the procedure, to successfully manage the problems that may arise during and after surgery, to intelligently select the components, and to counsel patients concerning their physical activities. Bipolar hemiarthroplasty is an example of the ability of the musculoskeletal system to react favorably to sound biomechanical design and its capacity to reveal early evidence of mechanical failure, usually before the onset of pain and loss of function. [65]

Biomechanics of the normal hip joint

Investigations in biomechanics of the hip joint have been performed to clarify the relationship between forces and motion and to develop an understanding of the mechanical characteristic of the joint structure.

A logical way to study the biomechanics of any area is to divide the study into four domains.

The first is that of the mechanical properties of the tissues, this concerns itself with the basic tissues of the cartilage, cancellous bone, cortical bone and joint capsule. It is necessary to have an understanding of not only the mechanical behavior of these tissues but also of their action in composite form as substructures are evolved.

The study of the substructures forms the second domain, a substructure can be any definitive unite, e.g. the upper end of the femur and the acetabulum.

Kinematics, the third domain, may be descriptive either of the motion of the whole joint, both as its range of motion and acceleration during activity, or of the motion on and about the joint surface. The fourth domain is concerned with loading surface in use, one sees the effect of loading of the hip joint. [32]

Biomechanical properties of tissues

When compared to cast iron, bone is three times as light and ten times more flexible, but both materials have the same tensile strength.

Bone is two phase material consisting of matrix, which is mostly collagen, and bone mineral. Bone mineral (hydroxyapatite) is more rigid than bone with a modulus of 114 giganewtons/m2 compared to 18 giganewtons/m2 (giganewtons = 1 billion Newton) and is stronger in compression than in tension. Bone collagen, on the other hand, offers no resistance to compression, but have a tensile strength five times that of bone. It would seem that this composite owes its tensile strength to its collagen and its rigidity and resistance to compression to its mineral content. Bone has a tensile strength of 140MN/m2 and a compression of 200MN/m2. [66]

A stress-strain curve for bone shows it is ductile, but being anisotropic, its tensile strength and modulus of elasticity (Young's modulus) are greater when bone is loaded in its longitudinal axis than in other directions. Bone can be strained 0.75% before plastic

deformity occurs, and the breaking strains are 2%to 4%. During plastic deformation it can absorb six times as much energy prior to fracture than during the elastic phase (strain is the change in linear dimension of a body as a result of force or load and expressed as percentage of starting length). As bone elongates the cross section diminishes, this is known as the poisson's ratio, change in diameter over change in length (d/1) is said to be 0.2 to 0.3. (Figure 8)
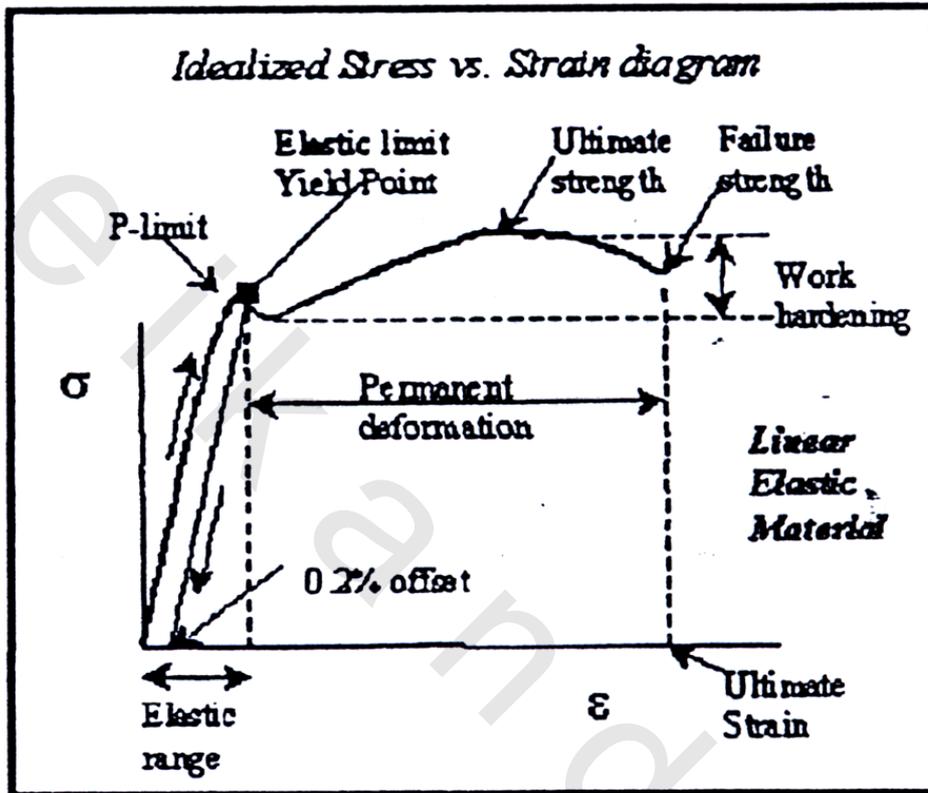

Figure 8: Stress-strain curve

Substructure behavior

In determining the properties of the substructures making up the hip joint, realistic loading configuration must be applied in laboratory study.

A fresh human cadaver was instrumented in such a way that to determine the stress of the neck of the femur with various loading conditions, also gravitational and muscular load can be calculated, and the force acting on the femur is recorded electrically.[67] (Figure 9)
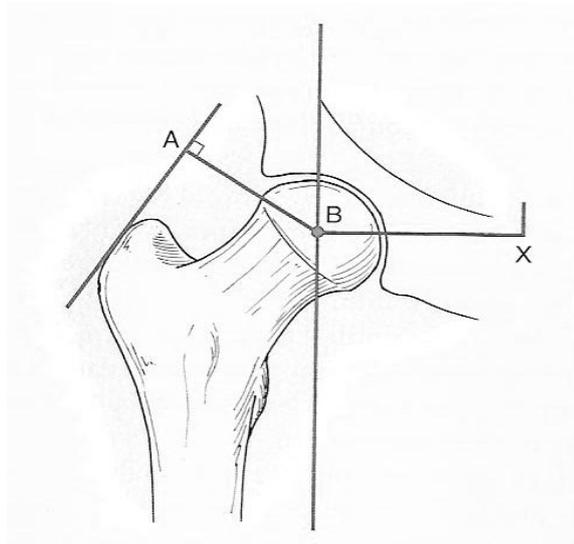
18

Figure 9: Lever arms acting on hip joint. Moment produced by body weight applied at body's center of gravity (x), acting on lever arm (B-X), must be counterbalanced by moment produced by abductors (A), acting on shorter lever arm (A-B).[68]

These calculations revealed that in normal activities essentially no tension stress is developed in the neck of the femur while increasing amounts of compressive stress are found as the inferior cortex of the neck is approached. If the loading conditions are modified by decreasing the abductor muscles force and allowing the hip to be supported in an unbalanced position. In this case large tensile strains are seen in the superior cortex. One may speculate that in certain conditions alterations of the resultant direction may result in pathological changes. In fatigue fractures of the neck of the femur muscular forces may be important. If the abductor muscle fatigue and soldiers keep marching, the loading configuration will exist. Here the high tensile strains on the superior cortex may lead to overload fracture "fatigue fracture" of the bone.[67] (Figure 10)
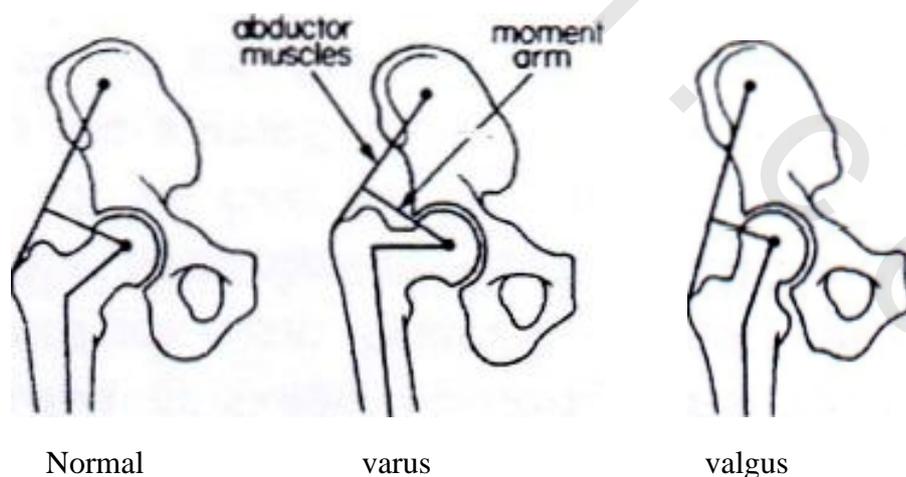

Normal   varus   valgus

Figure 10: Changes of the abductor mechanism with neck shaft angle. [32]

There is a question as the amount of torsion present in the femoral neck, attempts to produce fractures of the femoral neck by compressing it into the acetabulum and then twisting were impossible. This is due to slipperiness of the hip joint. It would seem that torsional loading of the femoral neck is insignificant. [32]

The above theories have been applied for determination of the fracture mechanisms by loading cadaver specimens with varying resultant load directions. The load direction has components acting axially and perpendicular to the neck. By varying the proportions of axial and bending components. Three types of fractures were represented;

- Typical subcapital fractures result with high N/P ratios (1/70) or above.

- Transcervical fractures occur with N/P ratio (1/60).

- The subcapital fractures with spike, occur in the middle range ratios [67]

The average energy absorption to failure is 60 Kg.f.cm for bone. The average female femoral neck fracture requires 600 Kg.f. for failure; the average male neck is 990 Kg.f.

If the energetic of a fracture of the neck of the femur is investigated, two mechanisms of the fracture are evident; in one type in which the patient slips but dose not fall, enough muscle force must be exerted to fracture the neck. Since the average elder's femoral neck requires 600 to 990 Kg.f. acting on the femoral head to produce fracture, it is of interest to calculate the amount of muscle tissue that must contract simultaneously to produce the fracture.

A physiological cross section of 1 cm of muscle tissue can produce 2 to 5 Kg. of force during maximal exertion. There is enough muscle tissue (120 to 300 Cm.2) spanning the hip joint to produce the required fracture force if it acts simultaneously. It is possible that such fractures in the elder do not represent a deficit in the bone strength but are due to aging of the neuromuscular apparatus; overloading of bone occurs because of lack of inhibitory impulses to the muscle during a slip. Femoral neck fractures occurring during falls do not require the postulation of weak bone.

When an elderly patient falls he must dissipate the potential energy possessed by his body in the example shown 3700 kg.f.cm of energy must be dissipated. If the neck can absorb only 60 kg.cm of energy before failure, obviously other mechanisms of energy absorption and dissipation are of importance. Most of energy in a fall is absorbed by active muscle contraction. [67]

Failure criteria for internal fixation devices and prosthesis are a part of substructure studies and serve as measures for strength of the appliances. After osteosynthesis of experimentally created femoral neck fractures, the bone absorbs as much as 75% of load applied to the femoral head and implants take 25%. This force can be resolved further into components creates a bending moment in the screw. The force component parallel to the screw is the component that produces sliding of the screw, if it is a sliding one or backing out if it of the fixed length type, when the parallel component exceeds the maximum static frictional force between the screw and its barrel. [67]

Three types of failure are usually considered; brittle, plastic and fatigue failures:

The brittle type of failure occurs when a stress raiser is present and the device behaves as though it was made of a brittle material such as glass instead of a material that deform a great deal without fracture.

The screw on the other hand may deform plastically without fracturing. Surgical material are ductile (undergoes plastic deformation and do not fail soon after the yield point). A small amount of yielding is permissible. Large deformations will obviously alter function of the hip joint.

The third type of failure occurs when a material is cyclically loaded. A small crack may start. Multiple small cracks form and coalesce. Finally the remaining material is not enough to support the load and device breaks, with a resultant fatigue failure. [69]

Kinematics

In considering kinematics of the hip joint, it is useful to view the femoral head as essentially a ball. Motion of the ball in the socket pivoting around the center of rotation of the femoral head will produce sliding of the particles at the joint surface. If for any reason the center of rotation of the femoral head is displaced, as with incongruity of the femoral head or malreduced fracture neck, sliding may not occur in a manner to minimize friction and the surface particles will tend to have a plow like action.

Data on the gross kinematics of the joint have been collected involving the displacement, velocities, and accelerations of the femur in relation to the pelvis. This information is useful in several ways. When correlated with phasic muscle activity it helps to demonstrate the function of the muscle in gait. The action of muscle which produce acceleration about the hip joint. Variations in these accelerations will be perceived as a limp. The acceleration rate is a key of information if the joint reaction force is to be calculated. [70]

Loading on substructures Forces acting on the hip joint

Theoretical calculations of forces acting on the femoral head started long ago. Most analyses are made as simple force diagrams. It is simple, by means of a force to calculate rough values of these forces, but it is very difficult to achieve precise figures.

To analyze the force pattern of the hip joint under vital conditions, a prosthetic device was implanted in a human subject. This prosthetic device was provided by strain gauges, by means of which forces acting on the hip could be determined as to their magnitude and direction. Furthermore, the coefficient of friction between steel and cartilage could be measured. [70]

The simplest situation in which forces of the hip joint could be analyzed is, in two leg support. Theoretically, slightly more than the superimposed body weight should be carried by the two hip joints, half of it by each. Measurement with the above described prosthesis gave exactly this result. One leg support is also a rather easy situation to analyze. Here also

theoretical calculation and direct measurements agree. It seems that standing on one leg creates force on the hip of about 2.5 times body weight. The direction of this force measured under vital conditions came out almost exactly to fit the anatomical design. The resulting force is parallel to the long axis of the elliptical cross section of the neck, and almost parallel to the trabecular system of the femoral head.

While walking, the force on the hip joint in the stance phase does not increase to extent which might be expected from theoretical calculation. In the swing phase the force acting on the hip joint is large than expected. The explanation is that, during the stance phase the body rolls over the femoral head so the abductors do not have to work as hard as in one leg support. A force peak occurs shortly after stance phase, when the leg is accelerated. This will decrease the magnitude of force in stance phase and make the force pattern more even during the gait cycle.

The magnitude of the peak resultant force generated during gait can vary from 1.6 to 4.3 BW and is affected by numerous factors especially stride length and the speed of ambulation. The most extensive studies to date were conducted recently by Bergmann et al. [71,72] During the stance phase of gait, the orientation of the load in the frontal plane is relatively constant and is medial and inferior, whereas in the sagittal plane, the orientation is more variable and is posterior during the first part of stance and anterior during the later part of stance.[73] (Figure 11)
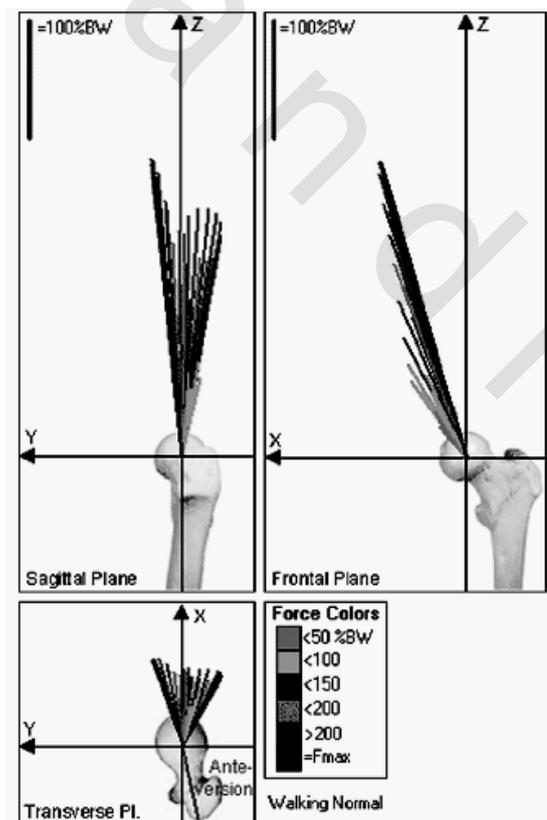

Figure 11:   Force vectors and points of load transfer on the prosthetic head during level walking for a patient [73]

Contact pressures from a Moore type of endoprostheses have been studied during activities of walking, jogging, stair climbing, and chair rising. Peak pressures during gait occur between heel strikes and early mid stance, and they relate to increases in both ground reaction forces and abductor muscle activity. During walking, the maximum pressures [5.5 MPa (megapascal)] occur on the superior anterior femoral surface, which corresponds to the superior acetabular dome. Chair rising triples pressures, up to 9 to 15 MPa on the apex of the femoral head or superior posterior aspects of the acetabulum. The sites of high acetabular pressure on the superior posterior region of the acetabulum correspond to sites of frequent degenerative changes observed in cadaver specimens.[70,71]

In running, however, dynamic effects will have greater influence and forces up to 4.5 to 5 times body weight were recorded, in spite of the fact that the abductors here work still less than in walking.

Normally the femoral head can be loaded up to 12 to 15 times body weight before fracture neck occurs. This is thus a safety margin in construction if the bone substance is normal. In one leg support, using cane in the opposite hand, the force acting on the hip is reduced to slightly more than the body weight. Theoretically the cane should completely substitute for the abductors and the force should be less than the body weight, but of course this is only the ideal situation. If the cane is used on the same side that is measured, the reduction of force is much less.

It is very difficult to reduce the force still further. Standing on the leg, the reduction of force acting on the hip when gradual load bearing is taken by the opposite leg has been studied. When the pressure on the ground is zero, which means that the weight on the leg is completely balanced by muscles of the leg, the force acting on the hip is about 1/3 of the body weight. Further unloading decreases the force on the hip a little more, with a minimum of 1/8 of the body weight but force increases with further unloading. When the leg is completely free from the floor, the force acting on the hip joint is about '/z of the body weight, but with 90 degrees flexion in the hip and the knee joint, the force acting on the hip joint is almost body weight.

A common procedure to unload the hip joint is to put the patient to bed, however, in a supine position flexion of the hip with straight knee will give rise to force about 1.5 times body weight in the other hip. Abduction of the hip will give rise to a force of almost body weight and abduction of the opposite hip will give force of about 0.2 times body weight. These result led to the conclusion that the most effective way to unload the hip is to give the patient a cane in the opposite hand. This decreases the load from more than two times body weight to about body weight. Further unloading is very difficult to achieve, if at all possible. The natural conclusion is that we should allow patient with prothesis after femoral neck fracture to get up on crutches the day after surgery. It has also been noted that sitting in an ordinary chair or in a deep chair creates a very small force on the hip and therefore not to be avoided by hip patients. The same is true for sitting in squatting position.

The effect of traction on the hip joint was determined, it was found that in the supine position when traction was applied to the leg with the knee and hip in flexed or extended position no force was recorded even after application of a load of 24kg. for 3 hours, which means that in traction the muscle pull is counterbalanced and no load will occur in the hip joint. However, if a load is applied suddenly a force will act for about 0.1 second.[74]

Walking downstairs creates a load in the hip of the same magnitude or slightly less than level walking. Walking upstairs, however, increase the load on the hip about three times the body weight. Therefore special care should be taken against walking upstairs, when reduction of weight bearing on the hip is needed.

The forces on the joint act not only in the coronal plane, but because the body's center of gravity (in the midline anterior to the second sacral vertebral body) is posterior and proximal to the axis of the hip joint, they also act in the sagittal plane to bend the stem posteriorly.

The forces acting in this direction are increased when the loaded hip is flexed, as when arising from a chair, ascending and descending stairs or lifting.[68] (Figure 12, 13)

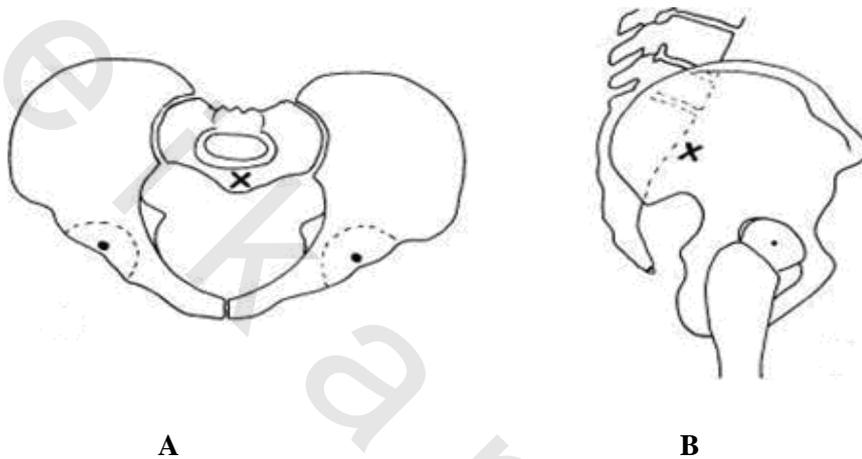**A**   **B**

Figure 12:   While standing, center of gravity is posterior to axis of the hip joint. **A,** View of pelvis from superior margin of symphysis pubis to level of sacral ala. Acetabula are outlined, and center of gravity is at (*X*). **B,** Center of gravity (*X*), is anterior to S2 vertebra, although center of gravity is not fixed and changes with movement of upper body with respect to pelvis. [68]

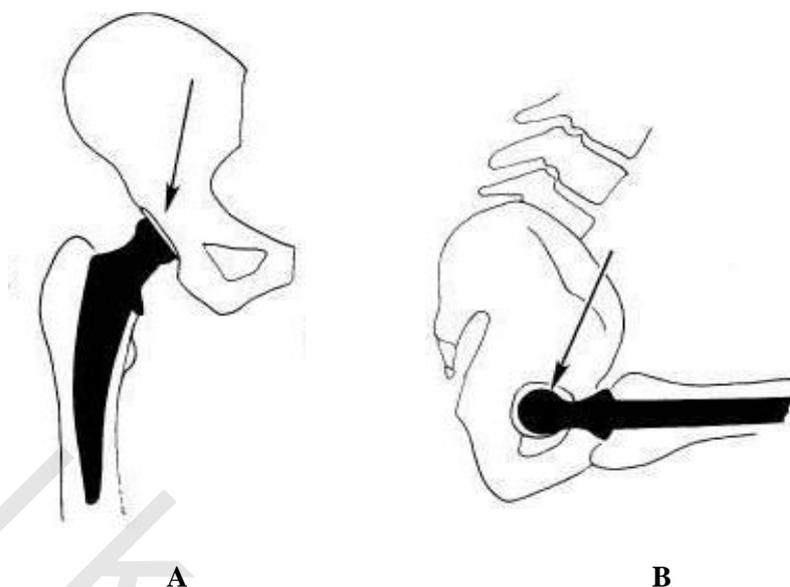**A**   **B**

Figure 13:   Forces producing torsion of stem. Forces acting on hip in coronal plane (**A**) tend to deflect stem medially, and forces acting in sagittal plane **(B)**, especially with hip flexed or when lifting, tend to deflect stem posteriorly. Combined they produce torsion of the stem. [68]

Valgus position of the proximal femoral prosthesis will decrease the moment of bending which tend to break the prosthesis and it will increase proportionally the axial loading of the prosthesis. A mild valgus is usually desirable, but it dose shorten the lever arm of abductors. [68]

In contrast, a varus position will increase the moment of bending and decrease the axial loading on stem, this position lengthen the abductor lever arm, but it should be avoided because it increases the risk of loosening and stem failure. Furthermore it shortens the femur and may result in hip dislocation. [68]

In prosthetic replacement it is important to preserve slight anteversion. A high femoral anteversion will lead to relevant reduction in the range of motion due to impingement of the neck of the stem to the rim of the socket and may cause dislocation. [75] The length of femoral neck should also be preserved. The greater the length of the neck the greater the lever arm or the moment of bending of forces that tends to break the prosthesis or dislocate the hip. [68]

Specific implant alloy

• Stainless Steels

Stainless steels are iron-carbon-based alloys. In general, these alloys contain approximately 18% to 22% Cr, 12% to 14% Ni, 2.5% Mo, and 0.03% to 0.08% C. The steels are used as surgical instruments rather than surgical implants and include both 300 series (austenitic) and 400 series (martensitic) steels. The latter steels are heat treatable steels (i.e., they will vary their mechanical properties with different heat treatment

25

procedures), whereas 300 series steels (e.g., 316) are not heat treatable but can be cold worked. The austenitic (316 series) alloys are typically used in fracture-fixation devices, such as bone plates, intramedullary rods, and bone screws. In the past, they have been used for total joint replacements, but they have been found to be less reliable than the current alloys used in these applications (cobalt-based and titanium-based alloys).[76]

- **Cobalt-Based Alloys**

The cobalt-based alloys typically contain chromium, molybdenum, carbon, and other elements such as nickel, silicon, and iron.

Cobalt-based alloys have several properties that make them excellent alloys for total joint prostheses. They are high-strength materials and have a high hardness (resistance to surface deformation). Furthermore, as a result of several factors, they work-harden very rapidly. That is, a small amount of plastic deformation results in a large increase in the strength. This property of cobalt-based alloys gives them a high wear resistance and makes them ideally suited for articulating surface applications.

These alloys are strengthened by solid-solution strengthening and, to some extent, precipitation hardening resulting from the precipitation of carbides. The chemistry and phase structure of Co-Cr-Mo alloys is not well understood. [76]

- **Titanium-Based Alloys**

There are several titanium-based alloy systems in use or under consideration. Titanium-based materials are among the most intensely studied implant alloy systems for orthopaedic applications. Titanium alloys are known to be highly biocompatible and have several other properties that make them suitable for implant applications, such as high strength and fatigue resistance.

Titanium has a very large affinity for oxygen and will absorb it in high concentrations at high temperatures. In small quantities, oxygen can serve as an interstitial solid-solution-strengthening element, and at very small concentrations, it can have a significant effect on mechanical properties.

One property of interest in titanium alloys is its low elastic modulus compared to other implant alloys. It is about one half the values found for Co-Cr-Mo or 316L stainless steel. This reduced modulus is thought to aid in stress transfer from implant to bone and to minimize the potential for stress shielding and bone resorption. [76]

Effect of osteoporosis on bone biomechanics:

The structural strength of bone is related not only to bone mass and its anatomical distribution but also to a concept known as connectivity. It refers to the degree of trabecular interconnectiveness within the bone. Osteoporosis involves thinning of the cortex as well as change in the structure of trabecular bone. Cortical bone has a low ratio of surface area to volume, while trabecular bone has a much greater surface area

Bones and bone regions rich in trabecular bone such as the vertebrae, calcaneus and the metaphyseal segments of the long bones are subjected to a loss of structural integrity during the aging process

The body accommodates for bone loss by redistribution. The diameter of the long bone gradually increases with age, and a concurrent increase in the medullary diameter leads to a net thinning of the cortical bone. This process of enlargement partially compensates for the decrease in the bone mass when bending and torque stresses are applied to the bone. However, this shift of bone mass provides no such protection when an axial loading is applied.

Singh's index (Figure 14):

This index grades patterns of trabecular loss into six grades:

Grade 6: All trabecular groups are visible, this represents normal skeleton.

Grade 5: This is an apparent accentuation of the structure of the principal compressive and tensile trabeculae groups. The trochanter group is not visible. The secondary compressive trabeculae are hardly demarcated, thus wards triangle looks more prominent.

Grade 4: The tensile trabeculae are markedly reduced in number but still intact laterally while the secondary compressive trabeculae are not visible, thus Wards triangle opens laterally. This represents borderline between normal and porotic bone.

Grade 3: Thinned out trabeculae with a break in the principal tensile group. This represents definite osteoporosis.

Grade 2: The primary compressive trabeculae are the only prominent group while all other groups are more or less completely resorbed. This represents moderately advanced osteoporosis.

Grade 1: Only the primary compressive trabeculae are visible but they are reduced, this represents severe osteoporosis. [77]
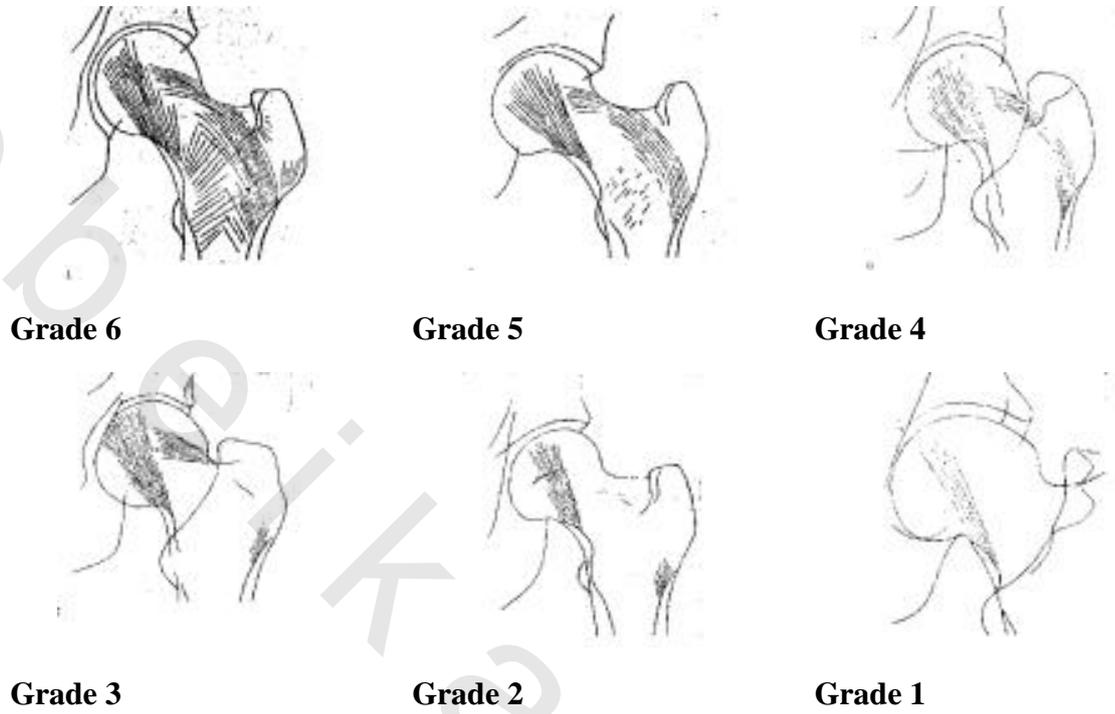
Grade 6   **Grade 5**   **Grade 4**

Grade 3   **Grade 2**   **Grade 1**

Figure 14: Singh's index [77]

CLASSIFICATION OF FEMORAL NECK FRACTURES

I. Based on patient characteristics: [78]

1. The elderly individual who complains of hip pain.

2. Patients with distracting injuries (other fractures such as a femoral shaft).

3. Young adult less than 40 years of age with repetitive strain injuries (stress fracture).

4. Patients with Paget's disease.

5. Patients with Parkinson's disease.

6. Patients with spastic hemiplegia.

7. Post-radiation of the pelvis.

8. Metastatic disease of the bone.

9. Patients with hyperparathyroidism.

II. Based on fracture classification:

The four common classifications of femoral neck fractures are those based on:

1. Anatomic Location (Watson Jones classification): [79]

i. Subcapital fractures: that occurs immediately beneath the articular surface of the femoral head along the old epiphyseal plate.

ii. Transcervical fractures: that passes across the femoral neck between the femoral head and the greater trochanter.

2. Fracture Angle (Pauwel's classification): [78]

Pauwel's divided femoral neck fractures into three types based on the direction of the fracture line across the femoral neck:

Type I   The fracture line orientation< 30 degree from horizontal.

Type II   30 to 50 degrees from horizontal.

Type III   >50 to70 degrees from horizontal. (Figure 15)

As fracture progress from type I to type III, the obliquity of the fracture line increases and, theoretically, the shear forces at the fracture site also increase. [79]
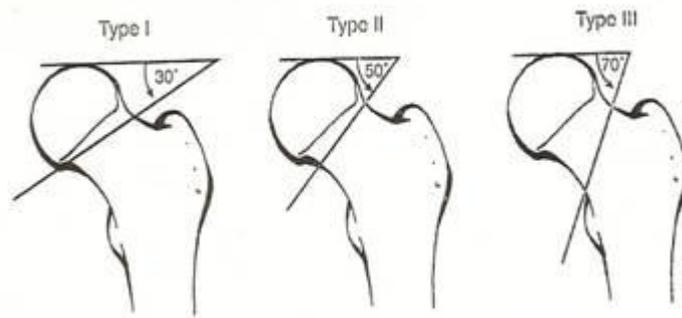
Figure 15: The pauwel's classification of femoral neck fractures is based on the angle the fracture forms with the horizontal plane. [78]

3. Fracture Displacement (Garden classification): [80,81]

Garden classification system is based on the degree of displacement of the fracture noted on pre-reduction anteroposterior x-ray:

Garden I fracture*:* is an incomplete or impacted fracture; in this fracture the trabeculae of the inferior neck are still intact. This group includes the abducted impaction fracture.

Garden II fracture*:* is a complete fracture without displacement. The x-ray demonstrates that the weight bearing trabeculae are interrupted by a fracture line across the entire neck of the femur.

Garden III fracture*:* is a complete with partial displacement. In this fracture there is frequently shortening and external rotation of the distal fragment and the trabecular pattern of the femoral head dose not line up with that of the acetabulum, demonstrating incomplete displacement between the femoral fracture fragments.

Garden IV fracture*:* is a complete fracture with total displacement of the fracture fragments. In this fracture, all continuity between the proximal and distal fragments is disrupted. The femoral head assumes its normal relationship in the acetabulum.Therefore, the trabecular pattern of the femoral head lines up with the trabecular pattern of the acetabulum. (Figure 16)
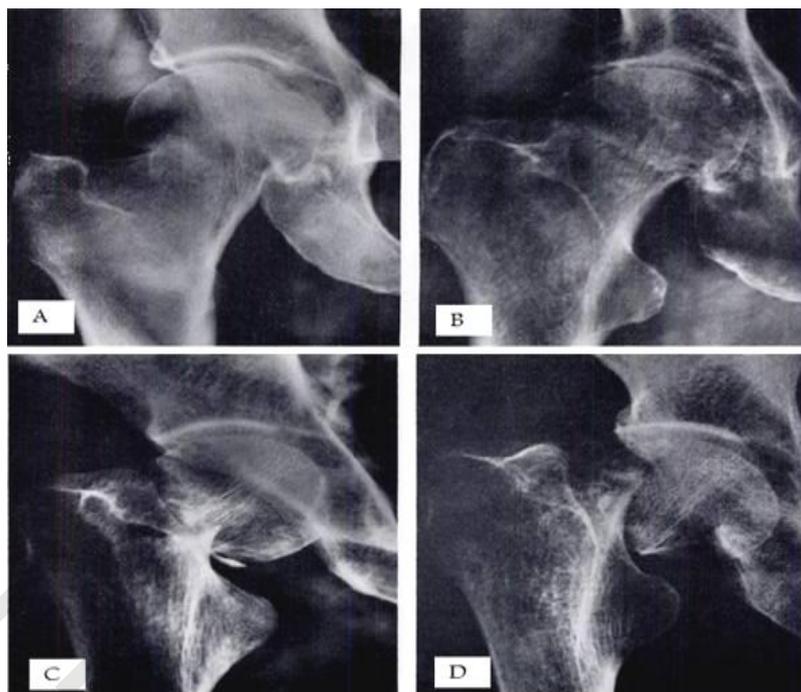
Figure 16: Garden classification. (**A**) *Garden I*- Incomplete fracture. The medial group of trabeculae in the femoral neck shows a greenstick fracture in a valgus position. (**B**) *Garden II*- Complete fracture without displacement. The line of the medial trabecular group is undisturbed. (**C**) *Garden III*-Complete fracture with partial displacement. The capital fragment is tilted into a varus position, and its medial trabeculae are out of line with their fellows in the pelvis. (**D**) *Garden IV*- Complete fracture with full displacement. The capital fragment has returned to its normal position in the acetabulum, and its medial trabeculae are in line with their pelvic projections. [82]

4. Orthopaedic Trauma Association (OTA) Classification: [83]

In orthopedic trauma association alphanumeric fracture classification, femoral neck fractures are designated type 31-B, in which 31 is the proximal femur group and B the femoral neck subgroup. Sub categorical codes further describe the fracture pattern and amount of fracture displacement. (Figure 17)

B1   Fractures are subcapital fractures with slight displacement.

B1.1 impacted in valgus of 15 degrees or more

B1.2 impacted in valgus of less than 15 degrees

B1.3 non impacted

B2   Fractures are transcervical fractures.

B2.1 basicervical

B2.2 midcervical with adduction

31

B2.3 mid cervical with shear

B3   Fractures are displaced subcapital fractures.

B3.1 moderately displaced in varus and external rotation

B3.2 moderately displaced with vertical translation and external rotation
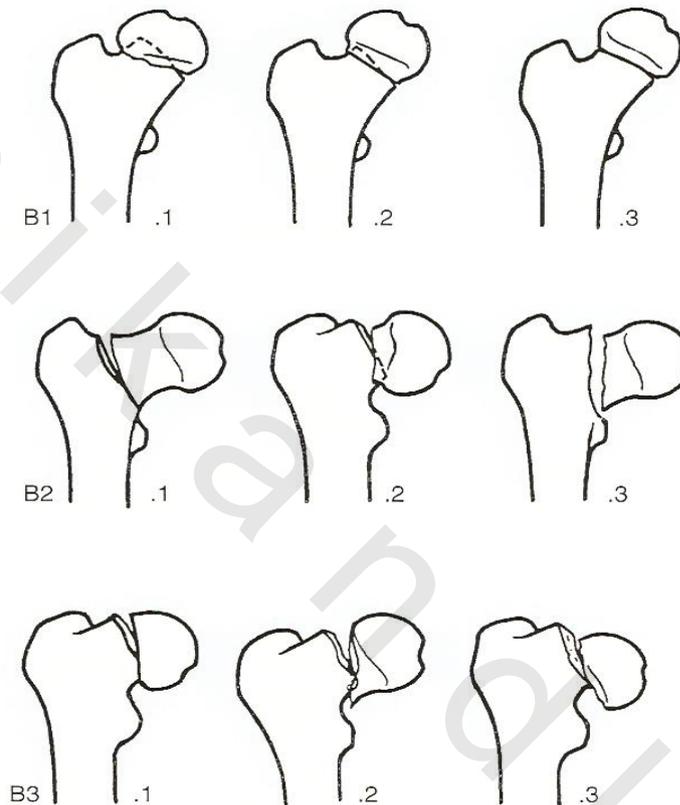
B3.3 markedly displaced

Figure 17: The OTA classification of femoral neck fractures.[83]

Management of femoral neck fractures in elderly

For more than a hundred years the optimal treatment of femoral neck fractures has been sought. The first surgical treatment is attributed to Langenbeck, who used a silver pin for internal fixation in 1850, it failed due to infection. Non operative treatment was preferred until the modern era of surgical fracture treatment started in the 1930s with open reduction and internal fixation using the Smith-Peterson nail. [84] Afterwards the term "The unsolved fracture" was introduced by Speed in 1935 and is still alive due to ongoing controversy concerning the ideal treatment. [85]

The goal of modern fracture treatment is to enable the patient to return to the original activity level and living conditions as soon as possible, with a minimum of risks and pain and with the least expenses for society. [85]

The treatment of femoral neck fracture depends primarily on the activity of the patient, the severity of fracture displacement, the age of the fracture, and the degree of osteoporosis present. The management of fresh femoral neck fractures continues to be a major challenge to the Orthopaedic surgeons. Garden I and II fractures with no displacement present no problem in the planning of their treatment as they are stable fractures and union can occur after internal fixation. [86]

Among patients with displaced fractures (Garden III, IV) the rate of fracture healing complications after internal fixation is considerably high, being in most studies with an at least two years follow up in the range of 35-50%. [87,88]

The alternative treatment is a primary hip arthroplasty (unipolar hemiarthroplasty, bipolar hemiarthroplasty or total hip replacement). [89]

In a recently published international survey of the operative management of displaced femoral neck fractures in elderly patients, there was some consensus that younger patients should be treated with internal fixation and older patients with arthroplasty. The preferred method for the most elderly patients was hemiarthroplasty (unipolar or bipolar), but there was significant disagreement regarding the optimal approach to the management of the active elderly patients between 60 and 80 years of age. [89]

Treatment options:

A. Internal fixation

Several authors support urgent reduction and internal fixation of femoral neck fractures to minimize the risks of healing complications. When more than 6- 12 hours have elapsed from injury; there is a progressive increase in the risk of healing complications after internal fixation of displaced intracapsular fractures. [90]

Because elderly patients will achieve the best functional result when a femoral neck fracture heals without osteonecrosis after reduction and internal fixation, this treatment option also may be considered for undisplaced intracapsular fractures in the elderly. [90]

Methods of internal fixation:

Over the years, many fixation devices have been used to treat fractures of the femoral neck.   It is accepted that virtually any method of fixation will give satisfactory results for undisplaced fractures. [91]

In general terms there are now two accepted methods of fixation in use: [92]

. A lateral plate with an integral sliding pin or screw. (Figure 18)

. Multiple pins or screws. (Figure 19)

Figure 18: Internal fixation of the subcapital femoral neck fracture with a screw and short side plate with an additional derotational screw above.

Figure 19: Internal fixation of subcapital fracture neck of femur with multiple screws.

B. Arthroplasty

Before the 1950s, treatment of hip fractures in the elderly typically consisted of fracture reduction and surgical fixation. Historically, attempts at closed or open reduction of displaced femoral neck fractures and internal fixation were met with a high incidence of complications. [93]

The most common complications included nonunion, loss of fixation, and avascular necrosis of the femoral head. The use of prosthetic implants for displaced femoral neck fractures was introduced in the 1950s by Moore as a salvage of failed internal fixation. [93]

Prosthetic options following femoral neck fracture can be divided into: [94]

1. Unipolar hemiarthroplasty.

2. Modular unipolar hemiarthroplasty

3. Bipolar hemiarthroplasty.

4. Total hip arthroplasty.

34

1- Unipolar hemiarthroplasty

The original design of the unipolar hemiarthroplasty used for femoral neck fractures had the following features: a solid polished unipolar head with a collared, straight, fenestrated stem designed for noncemented use. The best known design of this type was the Austin Moore prosthesis. A second design was the Thompson prosthesis, characterized by a solid unipolar head and a collared, shorter, curved, nonfenestrated stem. The original design was for use without cement, the cement fixation was developed in the late 1960s was applied to the Thompson prosthesis because of its curved, nonfenestrated stem. [94]

Figure 20: Austin Moore prosthesis   **Figure 21:** Thompson prosthesis

2- Modular unipolar hemiarthroplasty

Modular unipolar hemiarthroplasty in management of femoral neck fractures was found to be better than other unipolar prosthesis as it allows the possibility of revision to total hip arthroplasty in case of occurrence of acetabular complications like acetabular erosions and acetabular protrusion. [95]

These models consist of two parts:

- A femoral head of varying size
- A femoral stem

Figure 22: Modular unipolar hemiarthroplasty

3- Bipolar hemiarthroplasty

The development of the bipolar hemiarthroplasty was based on the clinical experience with unipolar prosthesis in which success was limited by progressive acetabular wear and concomitant pain. [95] Over time, this erosion/migration often resulted in acetabular protrusio. Two bipolar designs emerged in the early 1970s: the Bateman and the Giliberty prostheses. [93]

Figure 23: Bipolar hemiarthroplasty

These dual bearing models consisted of three parts: [95]

- A femoral head and stem unit, with varying size heads.

- An ultrahigh molecular weight polyethylene bearing insert, which locks over the femoral head component.

- An outer metallic head that press fits onto the inner bearing surface and articulates with the acetabulum. The bipolar hemiarthroplasty allow for easier conversion to total hip arthroplasty when necessary.

4- Total hip arthroplasty

With hemiarthroplasty becoming popular for the treatment of intracapsular hip fractures, it was logical to expand the operation to include an acetabular component. The primary treatment of acute displaced femoral neck fractures by total hip arthroplasty remains a topic of debate. [94]

It is generally accepted that primary total hip arthroplasty may be done after displaced intracapsular fracture of the proximal femur, but this procedure should be reserved for patients with preexisting symptomatic acetabular disease (osteoarthritis, rheumatoid arthritis, degenerative arthritis secondary to a previous pathology). [96]

Figure 24: Total hip arthroplasty

Common Surgical Approaches

Anterior Approach (Smith-Petersen)

The Smith-Petersen approach is the standard anterior approach to the hip. It involves making an incision along the iliac crest, which is then extended inferiorly from the anterior superior iliac spine. The gluteal muscles are detached from the external wing of the ileum and a plane is developed between tensor fascia lata and sartorius. This allows access to the anterior aspect of the hip joint. The reflected head of rectus femoris is detached to gain direct access to the capsule. This surgical approach is useful for fixation of femoral head fractures, but is not routinely used in the management of femoral neck fractures.

Anterolateral Approach (Watson Jones)

This is an anterolateral approach to the hip that gains access to the hip joint via an intermuscular plane. A lateral incision is made in line with the femur that extends up to the iliac crest. It angulates in a posterior direction to finish 8 to 10 cm anterior to the posterior superior iliac spine. The fascia is divided in line with the incision. A plane is developed between the anterior edge of the gluteal muscles and tensor fascia lata that allows access to the anterior capsule of the hip joint. This approach has most commonly been used in femoral neck fractures when open reduction is necessary. It can be used for hip arthroplasty or hemiarthroplasty, but access is limited and in particular it is not ideal for femoral stem placement.

Direct Lateral Approach (Hardinge)

This approach is popular for arthroplasty of the hip after a displaced intracapsular fracture. There is a higher rate of dislocation associated with total hip arthroplasty following hip fracture than with total arthroplasty performed for primary osteoarthritis of the hip. The direct lateral exposure is associated with a lower rate of dislocation after arthroplasty than the posterior approach and it is the preferred approach for hip fracture patients if total hip arthroplasty is being carried out. Variations on this approach have been described by a number of authors. In general the patient is placed in the lateral position and a longitudinal incision is made centered on the greater trochanter. After division of the fascia the trochanteric bursa is excised. An incision can then be made through the tendon of gluteus medius extending distally to reflect the vastus lateralis off the femur. At the proximal end of the trochanter the gluteal muscles are split in line with their fibers. Care should be taken not to carry this split too proximally or injury to the superior gluteal nerve is a risk. This risk is increased if dissection is performed more than 5 cm proximal to the trochanter. The approach can then be developed by dissecting down to bone and then reflecting the tissues in an anterior direction until the capsule is incised around the base of the neck. The alternative is to divide the gluteus medius and minimus tendons separately, which exposes the hip joint capsule, which is then incised separately. The hip can then be exposed by flexion and external rotation of the femur, which delivers the fractured femoral neck out of the joint, thereby allowing access to the fractured head in the acetabulum. Once this is removed, hemiarthroplasty or total arthroplasty can be carried out.

Posterior Approach

The posterior exposure to the hip may be performed with the patient in the prone or lateral position. The former position is popular for acetabular fracture surgery, but for arthroplasty the lateral position is preferable to facilitate correct positioning of the components. The approach is made through an incision centered on the greater trochanter, which extends distally down the shaft and proximally toward the posterior superior iliac spine. The more proximal part of the approach, which provides access to the sciatic notch and posterior column of the acetabulum, is not routinely required for femoral neck surgery. The fascia is divided in line with the incision. Above the level of the trochanter the gluteus maximus is split. More distally the exposure is facilitated by partial division of the gluteus maximus insertion into the linea aspera. The sciatic nerve should be indentified and protected. The short external rotators of the hip are divided starting proximally with piriformis. The obturator internus and the gemelli are then divided and reflected posteriorly, where they lie over the sciatic nerve. The capsule can then be incised to expose the femoral head and neck. The neck is accessed by flexing the knee to 90 degrees and internally rotating the femur.

This approach provides excellent access to the hip joint for both hemiarthroplasty or total hip arthroplasty. It also has the advantage of being extensile both proximally and distally. None-theless this facility is not often required during femoral neck fracture surgery. The main disadvantage of this approach is that it is associated with a higher rate of dislocation than the anterior or anterolateral approaches. Although the risk is acceptably low in osteoarthritic patients, it is much higher in patients undergoing total arthroplasty for femoral neck fracture and this is a significant drawback of this approach.