

Treatment of the late complications of hip and femur fractures

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**UNIVERSITY OF ZAGREB
SCHOOL OF MEDICINE**

Thomas de Sousa

**Treatment of the late complications of
hip and femur fractures**

GRADUATION PAPER



Zagreb, 2014

This graduation paper was made at the Department of Orthopedic Surgery - University of Zagreb School of Medicine - under supervision of Goran Bicanic MD, PhD, and it was submitted for evaluation in the academic year 2013/2014

Graduation paper was made at the Department of Orthopedic Surgery – University of Zagreb School of Medicine.

Mentor: Goran Bicanic MD, PhD

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Thomas de Sousa

INTRODUCTION

Orthopedic surgeons deal with deformities, diseases of bones and joints, and injuries to the musculoskeletal system.

Orthopedic injuries are injuries to the skeletal system which consists of bones, joints and supporting structures like muscles, cartilage, ligaments and tendons. The term "orthopedic injury" includes fractures (broken bones), dislocated joints (dislocation) and torn or ruptured tendons, muscles or ligaments. Any of these injuries can result from trauma such as that encountered in automobile accidents, falls or contact sports.

The term "**fracture**" is defined as the disruption in the integrity of a bone often called a break or crack. This may involve injury to the bone marrow, periosteum, and adjacent soft tissues. Fractures may be categorized into various types, and descriptions of fractures are generally based on 1) which bone is involved and where in the bone the break has occurred, 2) how the bone fragments are aligned, and; 3) the existence of any complications.

Fractures can be **caused** in several ways: direct violence (a direct blow), indirect violence (usually a closed, twisting fracture), pathological (though bone tumors, cysts, osteoporotic bone...), fatigue fractures (repeated bending stresses, classically, military recruits who walked excessive distances, so called the "march fracture", or long distance runners).

Fractures can be **classified** in many ways but the most practical was the classification of the old military surgeons who regarded all fractures as "*simple*" (fractures with overlying intact skin), or "*compound*" (soft tissue damage and open wound). Those two terms have been replaced by the more modern terms

“closed” and “open” afterward. The degree of open or closed soft-tissue injury has been included in the Gustilo and Anderson Classification of open fracture¹(see Table 1.)

Table 1. Gustilo and Anderson Classification²

Gustilo Grade	Definition
I	Open fracture, clean wound, wound <1 cm in length
II	Open fracture, wound > 1 cm in length without extensive soft-tissue damage, flaps, avulsions
III	Open fracture with extensive soft-tissue laceration, damage, or loss or an open segmental fracture. This type also includes open fractures caused by farm injuries, fractures requiring vascular repair, or fractures that have been open for 8 hr prior to treatment
IIIA	Type III fracture with adequate periosteal coverage of the fracture bone despite the extensive soft-tissue laceration or damage
IIIB	Type III fracture with extensive soft-tissue loss and periosteal stripping and bone damage. Usually associated with massive contamination. Will often need further soft-tissue coverage procedure (i.e. free or rotational flap)
IIIC	Type III fracture associated with an arterial injury requiring repair, irrespective of degree of soft-tissue injury.

Describing a fracture involves a description of the fracture line, namely the “**shape**”. A *transverse fracture* is one where the fracture line goes across the bone, and tends to stay aligned more easily than fractures which do not fit together so nearly. An *oblique fracture* is one where the fracture line crosses the bone at an angle. A *spiral fracture*, also called a torsion fracture, is one where the bone has been twisted apart. A *comminuted fracture* is where the bone is splintered into more than two fragments, meaning that the exact anatomical reconstitution is difficult or impossible. *Crush, or compression fractures* are those encountered when cancellous bone (typically in the lumbar vertebrae, tibial plateau, and calcaneum) is squashed or crushed. Some of the more common fracture types include *greenstick fractures* (where the bone bends so that the cortical bone buckles while the other remain *fractures, compound fractures, avulsion fractures and transverse fractures.*

The **alignment** of the fracture fragments is characterized as either *displaced* or *non-displaced* meaning that they are in their normal anatomic position. Other

terms may be seen such as *segmental fractures* (long bone broken in two places creating a free segment), *stable fractures* (where two bones are lying in a position from which they cannot move), *complicated fractures* (infected fractures or any other complication...), *multiple fractures* (several separate fractures in the same patient), and *epiphyseal injury* (in growing bone, described by Salter and Harris who gave their name to the classification of epiphyseal injuries).

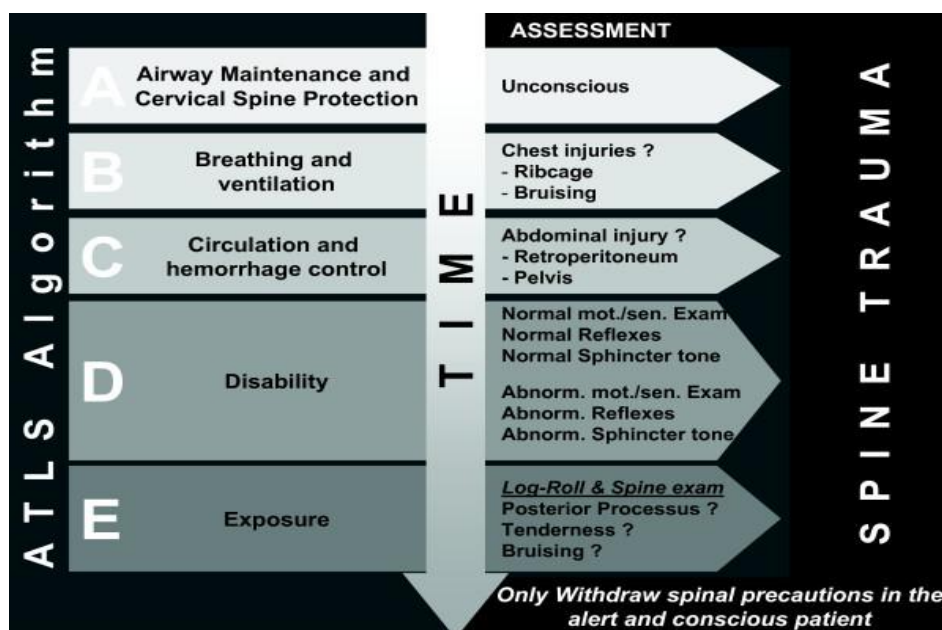
Fracture healing includes those fractures which may unite perfectly, or may be slow to unite (*delayed union*), fail to unite (*non-union*), or unite in the wrong position (*malunion*). In *delayed union*; the fracture takes longer to unite but eventually does so. *Non-union* describes a healing process that failed, and in which the bones end remain separated. *Non-union* and *delayed union* need to be differentiated, as delayed union only requires time and surveillance, and non-union may need operative intervention in order to allow the bones ends to unite. Malunion is applied to a bone that has united but in the wrong position. It is not always a problem, as clavicle fractures; for example, almost always unite with some degree of overlap, which does not affect the functional result, except when the fragments are pulled apart by muscles.

It is important to note that traumas and fractures are not the same thing. When a limb is broken, every tissue in it is damaged. The fact that the bony injury is the only one visible on x-ray does not make it the most serious. Radiographs do not show severed nerves, crushed muscles, ruptured blood vessels or torn ligaments, any more than they tell whether a wound is contaminated, how the injury occurred or how it should be treated.

Trauma is the “neglected disease”. It is the leading cause of death for people age 1 to 44 years of all races and socioeconomic levels, and the third leading cause of death for all age group³. The leading cause of traumatic death is blunt trauma, motor vehicle accidents and falling accidents. The use of drugs such as alcohol or illicit drugs such as cocaine increases the risk of trauma, by making traffic collisions, violence, and abuse more likely.

The assessment of polytrauma patients allows establishing priorities according to the type of injury, stability of vital signs, and the mechanism of injury. In life-threatening patients, the priority is to save life, and preserve the major functions of the body. The process is schematized by the ABC Sequence of Trauma Care, or Advanced Trauma Life Support (ATLS, see Figure 1.). It aims at identifying and treating life-threatening conditions by maintaining the patency of airways (A) and securing the cervical spine with a Shantz collar if necessary, monitoring breathing (B) and providing ventilation, checking the adequacy of blood circulation (C) along with hemorrhage control, assessing disabilities (D), i.e. assess the neurological status with the Glasgow Coma Scale, and controlling environment and possible exposure (E) by undressing the patient but preventing hypothermia at the same time.

Figure 1. ATLS Protocol⁴



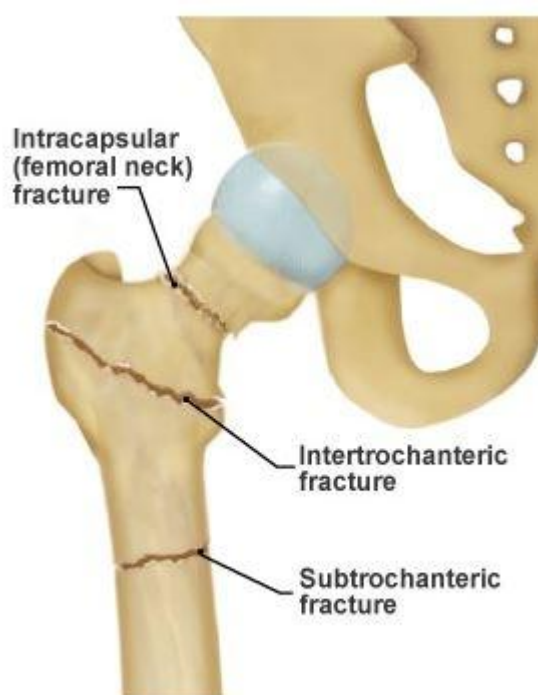
The orthopedic injuries on the polytrauma are seldom truly emergency situations, except those involving neural or vascular compromise. Also, it is short-sighted to treat only the area of injury revealed on radiograph, as the soft-tissue around is essential to fracture healing.

Also, as lower limb trauma is in the scope of this paper, there is one fundamental rule to apply, that is NOT to let those injuries, however dramatic in appearance, distract the clinician from less visible but life-threatening problems such as airway obstruction, compromised breathing, poor perfusion and spinal injury.

Fractures of the hip (see Figure 2) are relatively common in adults and often lead to devastating consequences. Disability frequently results from persistent pain and limited physical mobility. Hip fractures are associated with substantial morbidity and mortality; approximately 15-20% of patients die within 1 year of fracture. Most hip fractures occur in elderly individuals as a result of minimal

trauma, such as a fall from standing height. In young, healthy patients, these fractures usually result from high-velocity injuries, such as motor vehicle collisions or falls from significant heights. Despite comparable fracture locations, the differences in low- and high-velocity injuries in older versus younger patients outweigh their similarities. High-velocity injuries are more difficult to treat and are associated with more complications than minor trauma injuries. Complications of these injuries may be infections, nonunion, avascular necrosis, chronic pain, and gait disturbance.

Figure 2. Common Hip Fractures⁵



Hip dislocations (see Figure 3) are relatively uncommon during athletic events⁶. Injuries to small joints (i.e., finger, wrist, ankle, and knee) are much more common. However, serious morbidity can be associated with hip dislocations^{7,8}, making careful and expedient diagnosis and treatment important for the sports medicine physician. Large-force trauma such as motor vehicle

accidents, pedestrians struck by automobiles is the most common causes of hip dislocations. This type of injury is also associated with high-energy impact athletic events encountered in American football, rugby, water skiing, alpine skiing/snowboarding, gymnastics, running, basketball, race car driving, equestrian sports^{9,10,11}. Diagnosing and correctly treating these injuries to avoid late complications of avascular necrosis and osteoarthritis is imperative.

Figure 3. X-Ray - Hip dislocation¹²



Subtrochanteric fractures (see Figure 2) account for approximately 10-30% of all hip fractures, and they affect persons of all ages. Most frequently, these fractures are seen in 2 patient populations, namely older osteopenic patients after a low-energy fall¹³ and younger patients involved in high-energy trauma. A newer population of patients experience subtrochanteric fractures after bisphosphonate use. These so-called atypical fractures have a transverse or short oblique pattern with cortical thickening and medial cortical "beak."

Common complications include nonunion, malunion, failure of fixation, and wound infection^{14,15}.

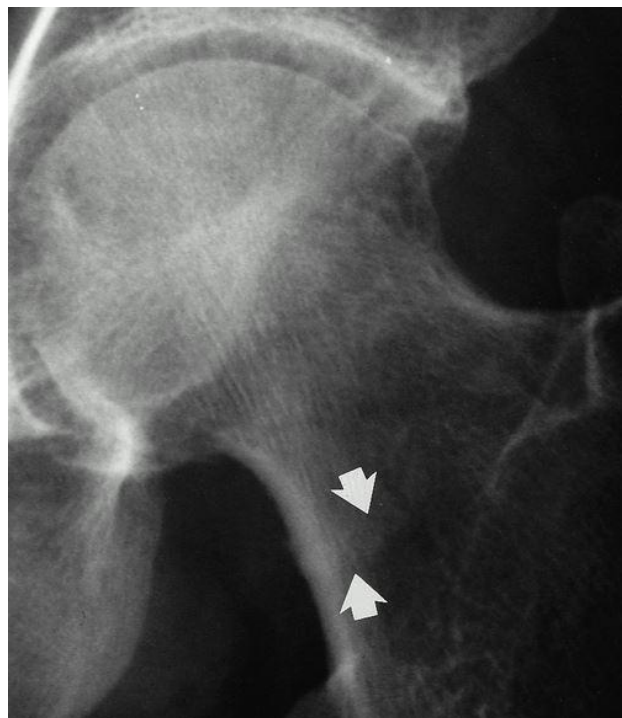
Femoral shaft fractures (see Figure 4) are generally caused by high-energy forces and are often associated with multisystem trauma. The spectrum of femoral shaft fractures is wide and ranges from non displaced femoral stress fractures, to fractures associated with severe comminuted fractures and significant soft-tissue injury. The femur is the largest and strongest bone and has a good blood supply. Because of this and its protective surrounding muscle, the shaft requires a large amount of force to fracture. Once a fracture does occur, this same protective musculature usually is the cause of displacement, which commonly occurs with femoral shaft fractures¹⁶. Isolated injuries can occur with repetitive stress and may occur in the presence metabolic bone diseases, metastatic disease, or primary bone tumors. The late complications may be delayed union, non-union, malunion, knee joint stiffness, and refracture and implant failure.

Figure 4. X-Ray - Femoral Shaft Fracture¹⁷



Stress fractures of the femoral neck are uncommon injuries. In general, these injuries occur in 2 distinct populations, (1) young, active individuals with unaccustomed strenuous activity or changes in activity, such as runners or endurance athletes¹⁸, and (2) elderly individuals with osteoporosis. Femoral neck fractures in young patients are usually caused by high-energy trauma. These fractures are often associated with multiple injuries and high rates of avascular necrosis and nonunion. Results of this injury depend on (1) the extent of injury (i.e., amount of displacement, amount of comminution, whether circulation has been disturbed), (2) the adequacy of the reduction, and (3) the adequacy of fixation. Recognition of the disabling complications of femoral neck fractures requires meticulous attention to detail in their management.

Figure 5. X-Ray - Femoral Neck Stress Fracture¹⁹



An **intertrochanteric fracture** (see **Figure 2**) occurs between the greater trochanter, where the gluteus medius and minimus muscles (hip extensors and

abductors) attach, and the lesser trochanter, where the ilio-psoas muscle (hip flexor) attaches²⁰: therefore, they are, by definition, extra-capsular. As with femoral neck fractures, they are common in elderly, and osteoporotic people, most of the patients being women in their 8th decade. Intertrochanteric hip fractures have significant complication rates including nonunion, infection, and failed fixation.

Supracondylar femur fractures (see Figure 6) usually occur as a result of low-energy trauma in osteoporotic bone in elderly persons, or high-energy trauma in young patients. The fracture line is just above the condyles, but may extend between them. In the worst cases the fracture is severely comminuted and especially difficult to treat properly²¹. Late complications may include knee stiffness, malunion, and non-union²².

Figure 6. X-Ray - Supracondylar Femoral Fracture²³



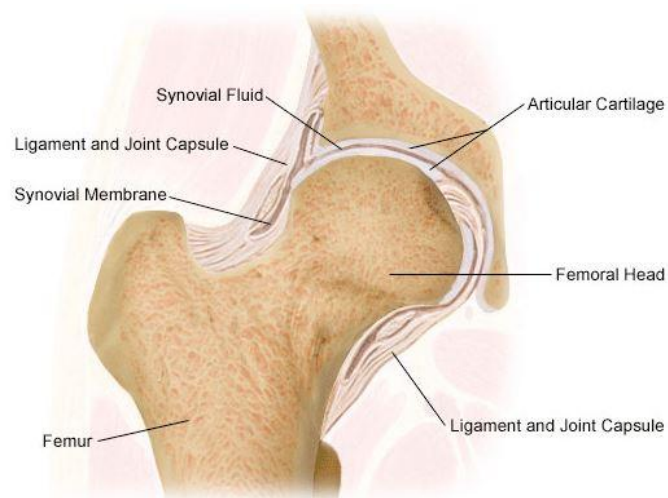
Late complications of all these conditions will be described further in different sub-sections, along with their treatments which represent the core of this review.

1. PELVIC INJURIES AND THEIR TREATMENTS

1.1. HIP DISLOCATIONS

The hip is a modified ball-socket joint (Figure 7). The femoral head is situated deep within the acetabular socket, which is further enhanced by a cartilaginous labrum. The hip is also bolstered by a fibrous joint capsule, the ischiofemoral ligament, and many strong muscles of the upper thigh and gluteal region. Because of this anatomic configuration, the hip is stable. Therefore, force needed to dislocate the hip is so great that the dislocation is often associated with fractures. If there is a major fragment, the injury is regarded as a fracture-dislocation.

Figure 7. Hip Joint²⁴



High-speed, high-impact sports are the most common setting for hip dislocations. The typical history of a hip dislocation during an athletic event involves 1 of 2 mechanisms:

- Most commonly, an athlete is running and lands on the feet or flexed knees, striking the ground while the hip is flexed, adducted, and internally rotated. This type of injury has been well documented in contact sports in which participants are tackled at high speeds and land out of control with other players piling on top of them (i.e., football, rugby). A similar injury may occur during high-speed racecar driving accidents.
- The second mechanism involves an athlete landing in the splits, with the hip flexed, abducted, and externally rotated. This type of injury is more likely to be seen during sports involving jumping and landing (i.e., basketball, gymnastics).
- The mechanism in skiing and snowboarding injuries is not well described and complex, due to high speeds and additional equipment, but it is likely similar to the aforementioned mechanisms.

A high suspicion for hip dislocation must be present whenever evaluating a patient involved in a major trauma such as a road accident, significant fall, or an athletic injury.

Patients with a hip dislocation will be in severe pain. They may complain of pain to the lower extremities, back, or pelvic areas, will have difficulty moving the

lower extremity on the affected side and may complain of numbness or paresthesias.

Frequently, patients will be a victim of multiple traumas and may not refer the pain to the hip as a result of altered mental status or distracting injuries.

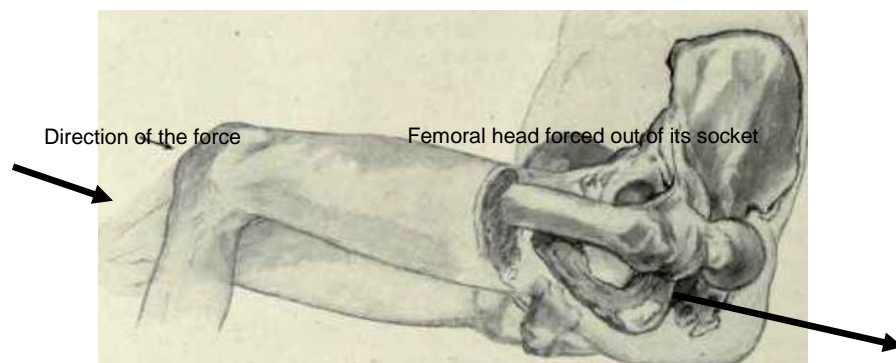
As with any major trauma victim, assessment of the airway, breathing, and circulation are of primary importance. During the secondary survey, an examination of the pelvic girdle and hip are mandatory. Examination should consist of inspection, palpation, active/passive range of motion, and a neurovascular examination.

Hip dislocations are classified according to the directing of the femoral head displacement: *posterior* (the commonest), *anterior* and *central*.

1.1.1. POSTERIOR DISLOCATION.

Posterior dislocations make up 80-95% of traumatic hip dislocations. It usually occurs in road accident when someone seated in a car is thrown forward, striking the knee against the dashboard (see Figure 8). The femur is thrust upward, and the femoral head is forced out of its socket. Often a piece of bone at the back of the acetabulum is sheared off, making it a fracture-dislocation.

Figure 8. Mechanism of Posterior Hip Dislocation²⁵



The incidence of this injury has increased in recent decades because of high-velocity motor vehicle use²⁶.

Posterior hip dislocations are also seen following total hip arthroplasty. Relatively minor forces, such as flexing the hip to pick an item up from the floor, can result in post-operative hip dislocation. Recent studies indicate that slight alterations in surgical technique (slightly larger femoral head and slightly more acetabular component anteversion) may decrease post-operative dislocation rates^{27,28}.

Clinically, the diagnosis is fairly easy. Typically, the patient with a posterior traumatic hip dislocation presents with a notably shortened lower limb held in a position of hip flexion, adduction, and internal rotation²⁹. The presence of the femoral head may sometimes be palpable at the ipsilateral buttock. A conjoint fracture of the ipsilateral femur may delay the diagnosis, as the limb may adopt any position.

The rule in severe injury is to perform an x-ray of the pelvis (Figure 9) and the knee, as these can be performed and evaluated in a very short amount of time. An anteroposterior (AP) view of the pelvis, including adequate views of the bilateral hips, is commonly the only film acquired before the diagnosis is confirmed³⁰. An additional lateral or Judet oblique view of the pelvis may add more information about the presence and direction of the dislocation and may be obtained provided that it does not interfere with the acute resuscitation of the patient. A CT scan of the hip can also be used to diagnose and describe the anatomy of the dislocation and identify small fracture fragments.

Figure 9. X-Ray - Subtle Posterior Hip dislocation of the right hip.³¹



Several classification systems are used to describe posterior hip dislocations.

- The Thompson-Epstein classification³² is based on radiographic findings:
 - Type 1 – With or without minor fracture
 - Type 2 – With large, single fracture of posterior acetabular rim
 - Type 3 – With comminution of rim of acetabulum, with or without major fragments
 - Type 4 – With fracture of the acetabular floor
 - Type 5 – With fracture of the femoral head

- The Stewart and Milford's classification^{33, 34} is based on functional hip stability:

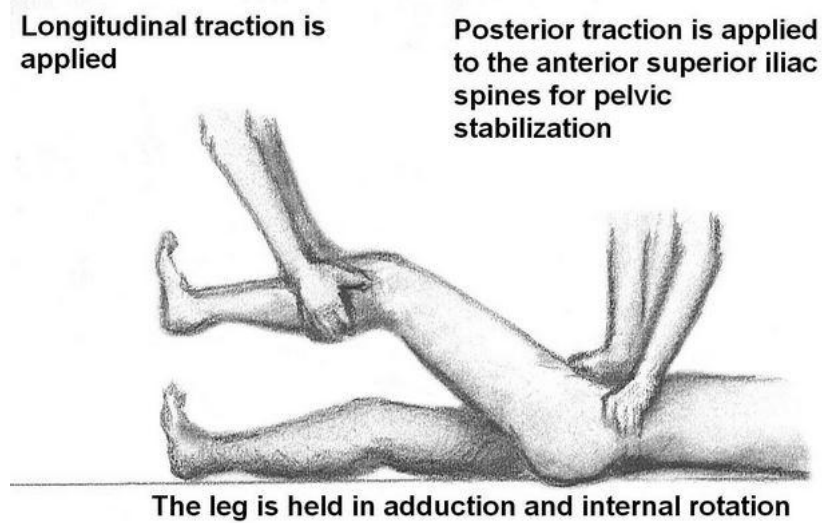
- Type 1 – No fracture or insignificant fracture
- Type 2 – Associated with a single or comminuted posterior wall fragment, but the hip remains stable through a functional range of motion
- Type 3 – Associated with gross instability of the hip joint secondary to loss of structural support
- Type 4 – Associated with femoral head fracture (further classified according to Pipkin's classification.)

Those classifications can be helpful in planning treatment.

The dislocation must be reduced as soon as possible under general anaesthesia. If hip dislocation is detected in the field, the patient should be placed on a backboard and allowed to assume the leg position that is most comfortable (i.e. hip slightly flexed, leg adducted). However, patients with hip dislocations often have life-threatening injuries that take precedence. Once life-threatening injuries have been stabilized or ruled out, the hip dislocation can be addressed. A proper neurovascular examination should be performed. If a neurovascular deficit exists, there is even more urgency to reduce the dislocation.

Reduction (Figure 9) is greatly facilitated by the use of procedural sedation. A combination of agents with muscle relaxant and analgesic properties is optimal. Once this has been achieved, the hip may be reduced.

Figure 10. Reduction of Posterior Hip Dislocation³⁵



Reducing a hip usually takes a significant amount of space and resources. Usually, one person applies traction and one or two people supply counter traction. A nurse or other physician provides sedation. More than 3 attempts at closed reduction in the ED are not recommended as the incidence of avascular necrosis increases with multiple attempts. If the dislocation cannot be reduced, an emergent CT scan (Figure 10) is indicated to visualize any bony or soft tissue fragments that may hinder reduction. Closed reduction may be attempted in the operating room under general anesthesia. However, a majority of these patients may require open reduction.

After closed reduction, a confirmation of the placement with a repeat radiograph is indicated. A CT scan or MRI of the hip can provide valuable information about further treatment and prognosis.

Figure 11. CT Scan - Posterior Dislocation of the right hip.³⁶



If relocation of the hip is successful, immobilization of the legs in slight abduction by using a pad between the legs to prevent adduction is ensured, until skeletal traction can be instituted. Pain will be significant, even after reduction, and patients may require parenteral narcotics.

The duration of traction and non-weight-bearing immobilization is controversial. Evidence suggests that early weight bearing (i.e. 2 weeks after relocation) may increase the severity of aseptic necrosis when it occurs, while decreasing the incidence of other complications (i.e. venous thromboembolism).

Open reduction is indicated when the dislocation is irreducible (~10%), when instability of the joint is persistent following reduction (i.e. fracture-dislocations), when a fracture of the femoral head or shaft is associated, or when a neurovascular deficit occurs after closed reduction.

Progression of weightbearing should be graduated and the hip joint monitored by x-ray.

The prognosis of the patient with a hip dislocation varies with the type of dislocation, with the associated fractures of the femoral head or acetabulum, and the presence of other injuries. Overall, good-to-excellent results are obtained in the great majority of patients.

Briefly, early complications of posterior hip dislocations include:

- Injury to the sciatic nerve which occurs in 10-14% of posterior dislocations during the initial trauma or during relocation. Function of the sciatic nerve should be verified before and after relocation to detect this complication. The finding of sciatic nerve dysfunction mandates surgical exploration to release or repair the nerve.
- Vascular injuries, usually the superior gluteal artery, which can create a profuse bleeding. When suspected, an arteriogram should be performed.
- An associated fracture of the femoral shaft, which can delay the diagnosis of the dislocation. It should be a rule to palpate buttock and trochanter, and to obtain a clear image of the hip on x-ray. A prompt open reduction of the hip followed by internal fixation of the shaft fracture should be undertaken.

1.1.1.1. LATE COMPLICATIONS OF POSTERIOR HIP DISLOCATIONS AND THEIR TREATMENTS.

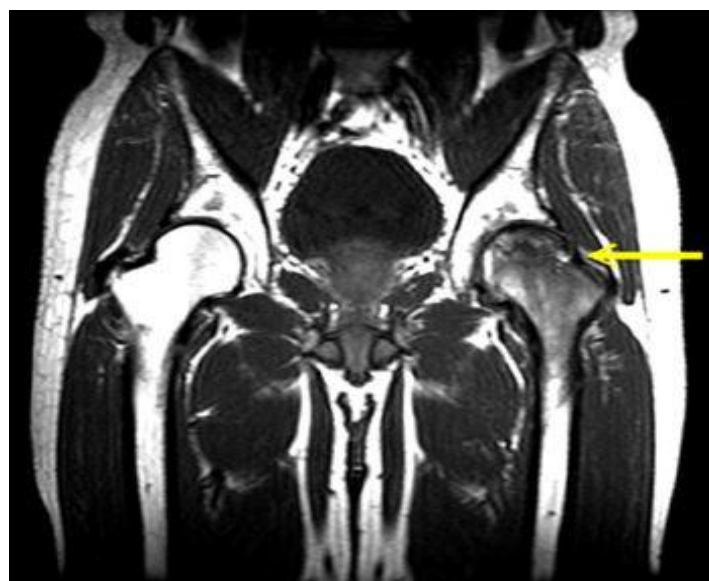
Late complications of posterior hip dislocations include avascular necrosis, myositis ossificans, unreduced dislocation and osteoarthritis.

Avascular necrosis of the femoral head is found in 10% of traumatic hip dislocations. Early diagnosis (less than 6 hours) and treatment of dislocations decreases the incidence of avascular necrosis. In fact, the incidence is increased with delayed reduction, repeated attempts at reduction, and open reduction (40% vs 15.5% with closed reduction).

The effect of early weight bearing on the occurrence of avascular necrosis is controversial. Most studies have shown that early weight bearing after reduction is associated with more severe situations, but it does not appear to increase the incidence.

Avascular necrosis may not become apparent on plain radiographs for several months. Early diagnosis can be made with MRI (Figure 12) or nuclear scanning, and these modalities should be considered in a patient who develops late and persistent pain after a dislocation.

Figure 12. Avascular necrosis of the left femoral head on T1-weighted MRI.³⁷



The most commonly performed prophylactic surgical intervention is core decompression, whereby one or more cores of necrotic femoral head bone is removed in order to stimulate repair³⁸. Core decompression is often supplemented with bone grafting (cancellous autograft or structural allograft) to enhance mechanical support and augment healing. Biologic augmentation of core decompression includes the addition of demineralized bone matrix, or electric/electromagnetic stimulation³⁹. These agents enhance bone formation or decrease bone resorption in the hope of maintaining the structural integrity of the femoral head.

The clinical results of core decompression alone deteriorate with more advanced lesions²⁶. The addition of cancellous bone grafting appears to slightly enhance clinical outcomes if subchondral fracture is present²⁶. The addition of demineralized bone matrix to core decompression confers little clinical response. The supplemental implementation of electrical stimulation with core decompression has provided disappointing results²⁶.

Osteotomies are performed in attempt to move necrotic bone away from primary weight-bearing areas in the hip joint. This technique may delay arthroplasty, but it is best suited for small precollapse or early postcollapse of the femoral head in patients who don't have an ongoing cause of avascular necrosis. However, osteotomies make subsequent arthroplasty more challenging and, unfortunately, these procedures are associated with an appreciable risk of nonunion.

The role of arthroscopy to better stage the extent of disease has emerged and is still experimental. Arthroscopic evaluation of the joint can help better define

the extent of chondral flaps, joint degeneration and even joint collapse and may help with the temporary relief of synovitis⁴⁰.

Despite aggressive management, most hips that undergo collapse ultimately require reconstruction (i.e. replacement). Prosthetic replacement offers the most predictable means of pain relief in advanced avascular necrosis.

Resurfacing arthroplasty, where both the femoral head and acetabulum are "resurfaced" with metal indicating minimal bone resection, remains a controversial procedure that likely will not last a patient's lifetime. Current recommendations are that resurfacing is contraindicated if the avascular area exceeds one third of the femoral head.

Bipolar arthroplasty theoretically decreases shear stress and impact load on acetabular cartilage, although this concept has not been born out clinically⁴¹.

Total hip arthroplasty is perhaps the most commonly performed and successful surgery for advanced avascular necrosis of the hip. However, clinical outcomes are inferior to those of total hip arthroplasty that is performed for osteoarthritis. Cementless prostheses with an improved design may afford increased longevity relative to cemented counterparts. Despite recent improvements in prosthetic replacement, replacement arthroplasty precludes further participation in impact activities (e.g. running, jogging) because these activities may greatly decrease implant longevity.

Other treatments include injections of cortisone into the hip joint that may temporarily alleviate the symptoms. However, these injections are not generally recommended because of their invasiveness and short-lasting effects.

Myositis ossificans (or heterotopic ossification) is an uncommon complication, probably related to the severity of the injury. During recovery, movements should never be forced and in severe injuries the period of rest and non-weightbearing may need to be prolonged. Small areas of ossification seen on x-ray usually bear no clinical significance. Anatomically, heterotopic ossification occurs outside the joint capsule without disrupting it. It often develops in patients with traumatic brain or spinal cord injuries, other severe neurologic disorders or severe burns, most commonly around the hips. The mechanism is unknown. This may account for the clinical impression that traumatic brain injuries cause accelerated fracture healing. The new bone can be contiguous with the skeleton but generally does not involve the periosteum. Three-phase technetium-99m (^{99m}Tc) methylene diphosphonate bone scan is the most sensitive imaging modality for early detection and assessing the maturity of heterotopic ossification⁴². Nonsurgical treatment with indomethacin (150 mg daily) and radiation therapy is appropriate for prophylaxis or early treatment of heterotopic ossification. Although bisphosphonate is effective prophylaxis if initiated shortly after the trauma, mineralization of the bone matrix resumes after drug discontinuation. During the acute inflammatory stage, the patient should rest the involved joint in a functional position, and once acute inflammatory signs subside, passive range of motion exercises and continued mobilization are indicated. Surgical indications for excision of heterotopic ossification include improvement of function, standing posture, sitting or ambulation, independent dressing, feeding and hygiene, and repeated pressure sores from underlying bone mass. The optimal timing of surgery has

been suggested to be a delay of 12 to 18 months until radiographic evidence of heterotopic ossification maturation and maximal recovery after neurological injury.

Unreduced dislocation can seldom be reduced by closed manipulation. Open reduction will be needed, and reconstructive surgery may have to be performed as several studies proved this procedure was more efficient⁴³.

Secondary osteoarthritis is not uncommon and is due to cartilage damage at the time of dislocation, the presence of retained fragments in the joint or ischemic necrosis of the femoral head. Treatment is the one of classic osteoarthritis. Nonpharmacologic interventions are to be instituted in first intention, and then a referral to an orthopedic surgeon may be necessary if the osteoarthritis fails to respond to a medical management plan. Surgical procedures for osteoarthritis include osteotomy, and arthroplasty.

1.1.2. ANTERIOR DISLOCATIONS

Anterior dislocations comprise 10-15% of traumatic dislocations of the hip, and thus are much rarer compared with posterior dislocations. Moreover, while posterior dislocation may be associated with fractures, anterior dislocations are mostly an isolated injury⁴⁴. They occur when the knee strikes a dashboard with the thigh abducted, a fall from height or from a blow to the back while in squatted position. Nowadays, the usual cause is a road accident or air crash. The neck of femur or greater trochanter impinges on rim of the acetabulum and thereby levers the head of femur out of acetabulum through a tear in the anterior hip capsule. Thus, the femoral head can occasionally be palpated. The

degree of hip flexion determines the position of the femoral head, which can be either superior (or pubic), presenting with the affected hip extended and externally rotated, or inferior (or obturator) presenting with the affected hip flexed, abducted, and externally rotated.

Clinically, the leg will not be shortened, as the rectus femoris attachment prevent the head from displacing upwards. Sometimes, the leg is abducted almost to a right angle. From the side, the anterior bulge of the dislocated head is unmistakable, and can be felt anteriorly (if superior), or in the groin (if inferior).

The basic workup is the same as with posterior dislocation. Lateral pelvic x-ray should be obtained. Whereas inferior anterior hip dislocation is easily recognized on an anteroposterior radiograph of the pelvis (figure 13), the radiographic appearance of superior anterior hip dislocation is less straightforward, often leading to an initial misdiagnosis of posterior hip dislocation. Misdiagnosis of the direction of a hip dislocation can result in failed closed reduction or an improper surgical approach to open reduction. In addition, recognition of associated impaction fractures is important, as patients with this finding have a greater tendency to develop traumatic arthritis⁴⁵.

Figure 13. X-ray - Inferior Anterior Hip Dislocation of the left hip.⁴⁶



The treatment of anterior dislocations includes maneuvers similar to those used in posterior dislocations, except that while the flexed knee is being pulled and the hip gently flexed upwards, it should be kept adducted. Then an assistant helps by applying lateral pressure to the inside of the thigh, until the point of reduction is heard and felt. The subsequent treatment is similar to that employed for posterior dislocation.

1.1.2.1. LATE COMPLICATION OF ANTERIOR HIP DISLOCATIONS AND TREATMENT.

Avascular necrosis is the main late complication of anterior dislocation of the hip. It occurs in less than 10% of cases, and is managed in the same manner as in posterior dislocation.

1.1.3. CENTRAL DISLOCATION

A fall on the side, or a blow over the greater trochanter, may force the femoral head medially through the floor of the acetabulum, leading to a fracture of the hip. An extensive degree of concomitant articular injury may occur, blurring the prognosis of this condition.

Also, a high incidence (~20%) of sciatic nerve injury is associated with central dislocations⁴⁷.

Although this is called “central dislocation”, it is really a fracture of the acetabulum, and then of the pelvic bone, which is beyond the scope of this paper.

1.2. FRACTURES OF THE HIP

Although sports injuries to the knee, ankle, and shoulder have been well documented, injuries to the pelvis, hip, and thigh get little attention because of their low prevalence. Unfortunately, severe consequences may result if these injuries are improperly managed^{48,49}.

In elderly patients, hip fracture most often results from a simple fall and in a small percentage, it occurs spontaneously, in the absence of any trauma.

Hip fractures can be classified based on their relation to the hip capsule (intracapsular and extracapsular), geographic location (head, neck, trochanteric, intertrochanteric, and subtrochanteric), and degree of displacement, so that fractures of the femoral head and neck are intracapsular, whereas those of the trochanteric, intertrochanteric, and subtrochanteric regions are extracapsular.

1.2.1. FEMORAL NECK FRACTURES

The femoral neck fracture is the commonest site of fractures in the elderly.

The vast majority of patients are Caucasian woman in the seventh and eighth decade, and the association with osteoporosis is so manifest that the incidence of femoral neck fractures has been used as a measure of age-related osteoporosis in population studies. Prevention of osteoporosis is the key to reducing the incidence of femoral neck fractures, as osteoporosis remains the single most important contributing factor to hip fractures.

A number of other factors predispose the elderly population to fractures, including malnutrition, decreased physical activity, impaired vision, neurologic disease, poor balance, and muscle atrophy.

Femoral neck fractures in young patients are usually caused by high-energy trauma. These fractures are often associated with multiple injuries and high rates of avascular necrosis and nonunion. Recognition of the disabling complications of femoral neck fractures requires meticulous attention to detail in their management.

Overall, patients with hip fractures may present in a variety of ways, ranging from an 80-year-old woman reporting hip pain after a trivial fall to a 30-year-old man in hemorrhagic shock after a high-speed motor vehicle accident.

Femoral neck stress fractures usually manifest more insidiously, with an otherwise healthy person reporting pain related to activity and not healing with the conservative treatments suggested by their primary care doctor. Those types of fractures were mainly seen in military recruits due to a triad of activity that is new, strenuous, and highly repetitive. However, as a result of self-imposed fitness regimens of recreational athletes, over the last 20 years the number of these injuries has been increasing in nonmilitary populations. Devas instituted, in 1965, a classification scheme for fatigue fractures, based on prognosis and radiographic appearance⁵⁰. His system split stress fractures into compression and transverse (or tension) types.

- *Compression fractures* are the less serious of the 2 and are seen most frequently in younger adults. These fractures are considered stable and may be treated with several days of rest followed by a period of protected weightbearing. Nonoperative management of these fractures necessitates frequent radiographs because late displacement, a potentially catastrophic complication, has been reported in the literature.
- *Transverse fractures*, by contrast, are more commonly seen in the elderly population and carry a 10-15% possibility of displacement, with subsequent avascular necrosis of the femoral head. A displaced femoral neck is one of the few true orthopedic

emergencies, owing to the disastrous outcomes associated with avascular necrosis. Transverse fractures appear on an internally rotated anteroposterior (AP) radiograph as a crack at the superior femoral neck. Over a period of days to weeks, these fractures may become complete, and callus formation may become evident over time.

Clinically, although the classic presentation of a hip fracture is an elderly patient who is in extreme pain, a young, healthy athlete usually has the same presentation.

The affected leg is externally rotated and may be shortened. The extremity shortening occurs because the muscles acting on the hip joint depend on the continuity of the femur to act, and when this continuity is disrupted, the result is a shorter-appearing leg. Assessing peripheral pulses and checking Doppler pressures to assure vascular patency is very important.

A patient with a stress fracture may present more subtly, reporting pain in the anterior groin or thigh. This pain increases with activity and can persist for hours afterward. Unless the form of the activity is modified, the pain gradually worsens over a few weeks to the point where the patient is unable to walk without pain..

Musculoskeletal testing reveals a painful hip with limited range of motion, especially in internal rotation. Pain is noted upon attempted passive hip motion. The heel percussion test and placing a tuning fork over the affected hip may also produce pain. An antalgic gait pattern may be present.

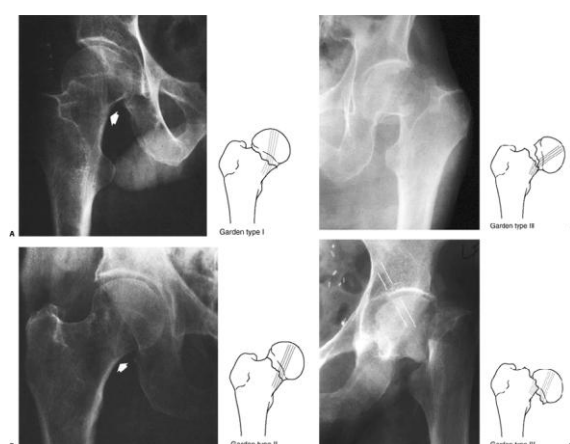
Deep palpation in the inguinal area produces discomfort. Tenderness to palpation is noted over the femoral neck, and may also be swollen.

Moreover, approximately 70% of patients with stress fractures of the femur demonstrate a positive hop test result (i.e. the hop test involves the patient hopping on the affected leg to reproduce symptoms).

Afterward, femoral neck fractures are classified based on the amount of displacement apparent in the pre-reduction x-ray (Figure 14). The most commonly used classification system is the *Garden classification*^{51,52}. This system gives guidance for treatment options and surgical implants.

- Garden type I (Figure14, A): Incomplete fracture with valgus impaction,
- Garden type II (Figure14, B): Complete fracture without displacement,
- Garden type III (Figure14, C): Complete fracture with partial displacement of the fracture fragments,
- Garden type IV (Figure14, D): Complete fracture with total displacement allowing the femoral head to rotate back to an anatomic position

Figure 14. X-Ray - The Garden classification of femoral neck fractures.⁵³



This classification can be further simplified into nondisplaced, Garden I and II, or displaced Garden III and IV fractures.

If the diagnosis of hip fracture is still under consideration after taking into account the patient's history and presentation, laboratory studies should be ordered based on the patient and the potential for surgery.

They include: CBC, electrolytes evaluation, serum urea nitrogen value, creatinemia, glucose level, urinalysis, PTT, APTT, arterial blood gas determination.

These studies are used to determine the patient's medical condition before surgery and to allow correction of any abnormalities before surgical intervention.

In addition to the recommended laboratory studies in a patient suspected of having a hip fracture, the physician should also obtain a chest x-ray film and an electrocardiogram (ECG) tracing to further assess the patient's medical condition before any surgical intervention.

X-ray films (Figure 15) are always indicated to determine which type of fracture, if any, is present. Anteroposterior (AP) views of the pelvis and hip and cross-table lateral x-ray films are usually sufficient to evaluate potential fractures. Rotating the affected leg internally or externally can increase the sensitivity of these radiographs.

Figure 15. X-Ray - Right femoral neck fracture.⁵⁴



If the clinical picture is highly suggestive of a fracture or stress fracture and the x-ray findings fail to demonstrate a fracture, magnetic resonance imaging (MRI), CT scan, or bone scanning can be useful in defining otherwise imperceptible fractures.

A bone scan displays a radiographically occult fracture 80% of the time 24 hours after an injury, and it also shows almost all fractures after 72 hours. Negative bone scan findings virtually exclude the diagnosis of a stress fracture.

The goals of the treatment are to promote healing, to prevent complications, and to return function. The treatment of femoral neck fractures and most tension femoral neck stress fractures requires surgical intervention.

If the nonoperative approach is taken, the patient should be mobilized as soon as possible to avoid the complications of prolonged immobilization.

The acute treatment principles of protection, rest, ice, compression, elevation, and medication are to be followed. This treatment regimen is most appropriate for *compression* (as opposed to *tension*) femoral neck stress fractures.

Consider low-dose nonsteroidal anti-inflammatory drugs (NSAIDs) for pain relief or narcotics if the patient has severe pain. NSAIDs should be given for as short a time as possible as they may interfere with bone healing⁵⁵.

Garden types I and II femoral neck fractures are surgically stabilized with closed reduction and internal fixation.

Garden types III and IV treatments are controversial in the type of implant used for treatment. In younger patients, closed or open reduction is recommended. In less active older patients, prosthetic replacement (Figure 16) is recommended.

Figure 16. X-Ray - Right modular arthroplasty in good position.⁵⁶



Young patient with high energy trauma may present with combined fractures of the neck and shaft of the femur. The femoral neck takes priority as complications are usually more difficult to address than those of the shaft fractures. The femoral neck is reduced closely or openly, and the fracture fixed with screws. The femoral shaft can then be managed with retrograde locked intramedullary nailing through the knee or lateral plate.

As far as stress fractures are concerned, surgical treatment is warranted for all stress fractures that have progressed to a *transverse fracture* of the femoral neck because of a high propensity for fracture displacement. The orthopedist may choose either internal fixation or arthroplasty. The decision-making process

should include consideration of the patient's bone quality, life expectancy, physiologic status, and overall activity level. However, the main factor in deciding which type of repair to undertake should be the likelihood of revision surgery being needed in the future for a failed arthroplasty. For younger individuals in otherwise good health, this means internal fixation of the fracture is warranted. Most authors recommend aggressive treatment with internal fixation with percutaneously placed cannulated screws.

Compression stress fractures are usually treated with conservative care, using MRI to identify the minority of patients who warrant internal fixation. If no fatigue line on MRI greater than 50% of the width of the neck is present, rest and crutch-assisted touch-down weight-bearing gait are initiated. Recommend interruption of all aggravating activities until the patient is free from pain. This is followed by gradual introduction of weight-bearing activities to the limit of pain, progressively increasing activity until the patient returns to his or her previous level of function. Weekly x-ray films are taken to monitor changes in fracture status, and any sign of fracture displacement requires surgical intervention.

Postoperative treatments include crutch-assisted touch-down weight-bearing ambulation for the first 6 weeks and partial weight bearing for the subsequent 6 weeks. Thereafter, a supervised physical therapy program is outlined for progressive activity, lower extremity strengthening, and full weight-bearing ambulation. In elderly individuals, physical therapy continues until the patient has reached his or her maximum potential with range of motion and strength and until he or she is able to independently complete all required activities of daily living.

Also, supplementation with high dose oral vitamin D (≥ 800 IU daily) may help prevent hip fractures and other nonvertebral fractures in patients ≥ 65 years of age⁵⁷, as well as oral contraceptives for amenorrheic women as such agents may aid in the recovery of bone mass in these women.

Patient education is an important factor in the prevention of stress fractures. Female athletes should decrease their risk of recurrent fractures by maintaining adequate muscle mass and bone density.

Most complications are associated with fracture displacement or a delay in diagnosis. Complications include delayed union, nonunion, refracture, osteonecrosis, and avascular necrosis.

1.2.1.1. LATE COMPLICATION OF FEMORAL NECK FRACTURE AND TREATMENT.

While femoral neck stress fractures are not particularly dangerous, delayed diagnosis of transverse-type injuries is associated with consequential potential for morbidity. Complications include delayed union, nonunion, malunion, and osteonecrosis or AVN.

In the active individuals who are at risk for this type of fracture, a missed or delayed diagnosis that results in displacement can lead to an operation with an increased risk of osteonecrosis and the need for reconstructive surgery.

Nonunion of the stress fracture site occurs 4-33% of the time after internal fixation. However, several studies suggest that the incidence of nonunion in a stably fixed fracture is largely determined by an individual's age and the degree of fracture displacement. Should a nonunion result, patients usually experience

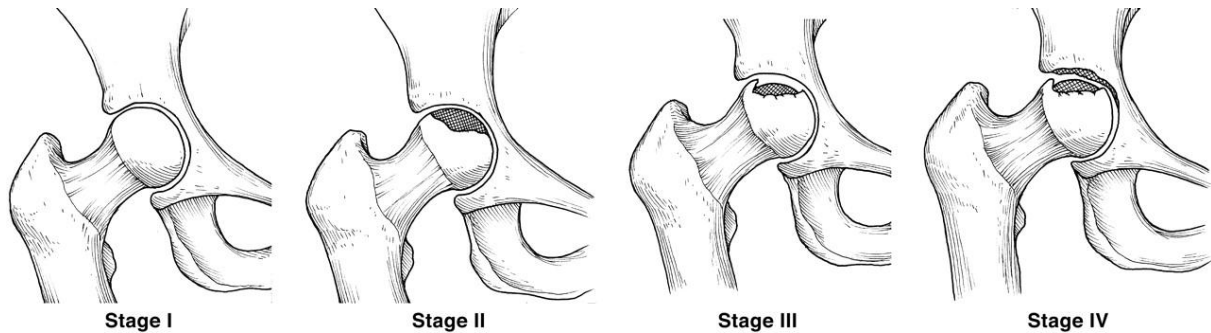
severe anterior thigh or groin pain and exhibit a classic Trendelenburg gait. The treatment for this complication is almost always reconstructive surgery.

The most important primary complications arising from femoral neck fractures are nonunion and avascular necrosis.

Ischemic necrosis of the femoral head occurs in about 30% of patients with displaced fractures. X-rays changes may not become apparent for months or even years. The most widely used classification system for avascular necrosis of the femoral head is the one created by Ficat and Arlet^{58,59} (Figure 17). This system is based on radiographic appearances.

- Stage 0: no radiographic findings. Diagnosed by means of magnetic resonance imaging (MRI) or bone scanning.
- Stage 1: slight osteoporosis on plain images. Clinical symptoms may be present, but sclerosis is not.
- Stage 2: diffuse osteoporosis and sclerosis at the region of the infarction. The infarcted area is well delineated due to a reactive shell of bone. The spherical shape of the femoral head is maintained.
- Stage 3: crescent sign, or radiolucency under the subchondral bone, which represents a fracture. The contour of the femoral head is abnormal. The joint space is preserved.
- Stage 4: femoral head collapse, joint-space narrowing, and subchondral sclerosis.

Figure 17. Ficat classification system.⁶⁰



The Ficat-Arlet classification is especially pertinent in Garden III and IV fractures in which there is a significant incidence of avascular necrosis.

In patients over 45 years, treatment is by total joint replacement.

In younger patients, the choice of treatment is controversial. Core decompression has no place in the management of traumatic osteonecrosis. Realignment or rotational osteotomy is suitable for those with a relatively small necrotic segment. Arthodesis is often mentioned in armchair discussions, but in practice it is seldom carried out. Joint replacement may be justifiable even in this group.

Non-union occurs in more than 30% of all femoral neck fractures. Many causes are found: poor blood supply, imperfect reduction, inadequate fixation, and late healing characteristic of intra-articular fractures. The bone at the fracture site is ground away, the fragment fall apart and the screw cuts out of the bone or is extruded laterally. The patient will complain of pain, shortening of the limb and difficulty with walking. The x-ray shows the blurred outcome.

The method of treatment depends on the cause of the non-union and the age of the patient. If young, 3 procedures are available:

- Subtrochanteric osteotomy with internal fixation if the fracture is nearly vertical but the head still alive,
- Remove the screws, reduce the fracture and insert fresh screws correctly and also apply a bone graft across the fracture if the reduction or fixation was faulty,
- Prosthetic replacement may be suitable if the head is avascular but the joint unaffected. Total replacement may be indicated if the joint is damaged or arthritic.

In the elderly, only 2 procedures are to be considered:

- Total hip replacement if the pain is unbearable.
- Raised heel and a stout stick or elbow crutch are sufficient if the patient is old and infirm and pain not unbearable.

Secondary osteoarthritis is to be mentioned as it may arise years after avascular necrosis or femoral head collapse. If there is marked loss of joint movement and widespread damage to the articular surface, total joint replacement will be needed.

1.2.2. INTERTROCHANTERIC FRACTURES

The anatomic site of this type of hip fracture is the proximal, upper part of the femur or thigh bone. The proximal femur consists of the femoral head, femoral neck, and the trochanteric region. An intertrochanteric hip fracture occurs between the greater trochanter, where the gluteus medius and minimus

muscles (hip extensors and abductors) attach, and the lesser trochanter, where the iliopsoas muscle (hip flexor) attaches.⁶¹ They are, by definition, extracapsular.

As with femoral neck fractures, they are more common in elderly, osteoporotic people, most of all are women in their 8th decade.

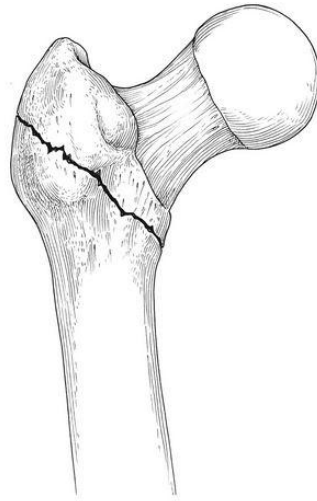
The etiology of intertrochanteric fractures is the combination of increased bone fragility of the intertrochanteric area of the femur associated with decreased agility and decreased muscle tone of the muscles in the area secondary to the aging process. The increasing bone fragility results from osteoporosis and osteomalacia secondary to a lack of adequate ambulation or antigravity activities, as well as decreased hormone levels, increased levels of demineralizing hormones, decreased intake of calcium and/or vitamin D, and other aging processes⁶².

Usually, the fracture is caused by a fall directly onto the greater trochanter or by an indirect twisting injury. The crack runs up between the lesser and the greater trochanter and the proximal fragment tend to displace in varus (Figure 18).

In contrast to intracapsular fractures, extracapsular fractures unite quite easily and seldom cause avascular necrosis.

Intertrochanteric fractures can be divided into *stable* and *unstable* varieties.

Figure 18. Intertrochanteric fracture.⁶³

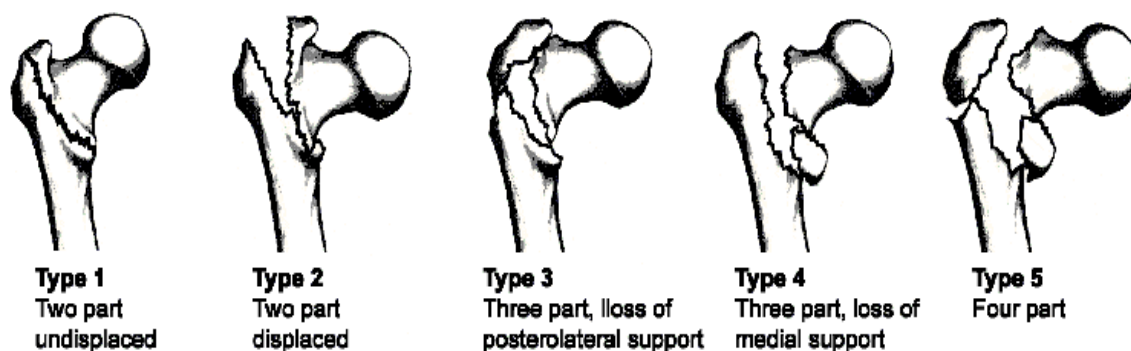


Unstable fractures are those where:

- there is poor contact between the fracture fragments, as in four-part intertrochanteric types (greater and lesser trochanter, proximal and distal femoral fragments), or if the posteromedial cortex is comminuted.
- the fracture pattern is such that forces of weightbearing continually displace the fragments further, as in those with a reverse oblique pattern or with a subtrochanteric extension.
- Osteoporosis leading to poor quality grip by the fixation implants.

The importance of fracture pattern is detailed in the classification by Jensen⁶⁴ (Figure 19) which distinguishes 5 basic patterns that reflect increasing instability and increasing difficulty at reduction and fixation.

Figure 19. Jensen classification of trochanteric fractures (Jensen & Michaelsen 1975)⁶⁵



The patient typically presents with a history of slipping on, falling on, or twisting of the lower extremity that is followed by severe pain in the affected hip area. Patients may be unable to stand or move their body or the affected extremity without pain. Local physical examination typically reveals the affected lower extremity in a position of hip extension with the leg externally rotated, with the patient experiencing pain on any active or passive motion of the hip or any part of the extremity.

The diagnosis of an intertrochanteric fracture is confirmed by the review of appropriate radiologic images, including an AP pelvic view and either a cross-table lateral view of the hip or a frog lateral view of the hip and a traction AP hip radiograph. A full-length radiograph of the involved femur is necessary to rule out any pathologic process or deformity that may exist distal to the fracture. These images also define the inherent stability or instability of the fracture, the need for a reduction of the fracture, and whether further manipulation is indicated to produce a reduction sufficiently stable to heal before the implant fixation is lost. The stability of the fracture is defined by the amount of contact between the proximal and distal main fragments. Two-part intertrochanteric

fractures are very stable, as there are only 2 fragments, which, once reduced, are impacted on each other and provide inherent stability for the implant.

Figure 20. X-Ray - Intertrochanteric fracture.⁶⁶



The fracture stability is inversely proportional to the size of the lesser trochanteric fragment (3-part fracture). Instability occurs when more than 50% of the calcar is affected, allowing the proximal fragment to collapse into varus position and shorten. Therefore, a fracture is considered unstable if there is a large lesser trochanteric fragment or if the greater and the lesser trochanter are separate fracture fragments (4-part fracture). The more unstable the fracture, the more difficult it is to reduce the fracture and the more likely it is that an implant, such as a cephalomedullary nail, will be needed to stabilize the fracture and prevent collapse⁶⁷.

The current treatment of intertrochanteric fractures is surgical intervention. Despite an acceptable healing rate with nonsurgical methods, surgical intervention for intertrochanteric fractures has replaced previous nonsurgical methods of prolonged bed rest, prolonged traction in bed, or prolonged immobilization in a full-body cast⁶⁸.

Dynamic hip screw (Figure 22), with Sliding Compression Screw Devices, is the gold standard for intertrochanteric fractures.

Figure 21. Assembled dynamic hip screw.⁶⁹

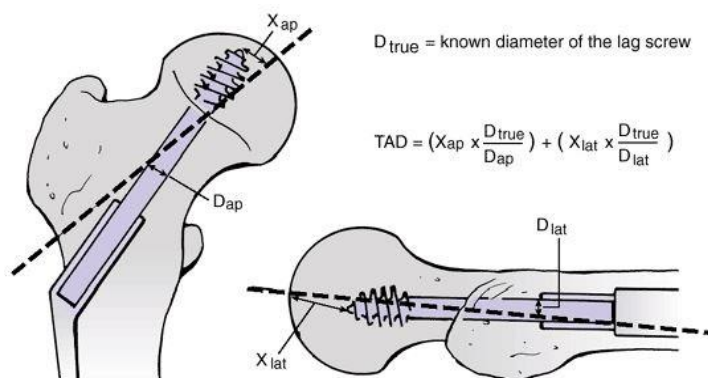


Patient is kept in supine position on a fracture table. It is reduced by traction, slight internal rotation (occasionally external rotation) and by rotating the proximal fragment with the help of guidewires or by lifting the distal fragment up with a bone lever. If there is a posterior sagging it is lifted upward by hohman spike. A crutch can be used to elevate the sagging femur. A slight valgus position is preferred. If closed reduction is not satisfactory, open reduction is performed.

Lateral incision is taken starting from the tip of the greater trochanter about 7cm downwards. While exposing the lateral surface, the vastus lateralis should not be split longitudinally. This maneuver denervates the posterior fibers and is associated with greater bleeding. Entire vastus is elevated subperiosteally. A guidewire is passed in the dead center of head and neck in anteroposterior and lateral views, the so-called "bull's eye" or center-center placement which is the optimal position.

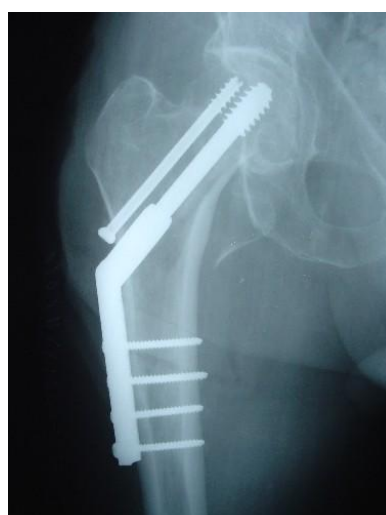
The sliding screw is placed with the tip within 10mm of the sub-chondral border. A “tip-apex distance” (Figure 21) is described to identify a “sweet spot” for positioning this sliding screw: if within 25mm, there is a lower risk of the screw cutting out of the femoral head.

Figure 22. Tip-apex distance (TAD).⁷⁰



Tapping of the femoral head to cut screw threads prior to insertion of the screws is done in all but the most osteoporotic bone. The more the barrel covers the distal portion (at 2/3 of barrel) of screw, the better it is biomechanically.

Figure 23. X-Ray - Dynamic hip screw transfixing an intertrochanteric fracture of the right femur, with a cannulated cancellous screw to control rotation of the femoral head.⁷¹



Post operatively, most of the elderly patients are allowed immediate weight bearing as tolerated. If there is severe osteoporosis or if the implant is insecure,

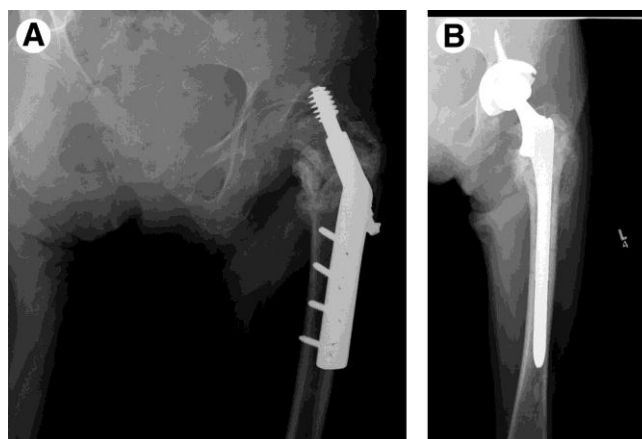
and in type IV fractures (with subtrochanteric extension), weight bearing is delayed.

Early complications are the same as with femoral neck fractures, reflecting the fact that most of these patients are in poor health. Other complications may include pulmonary complications of pneumonia resulting from inactivity, pulmonary embolism from deep vein thrombosis (DVT) caused by immobilization of an extremity, bedsores, loss of motion of the lower extremity joints and muscle atrophy due to prolonged immobilization, union of the fracture in an unacceptable position resulting in a deformity (malunion).

1.2.2.1. LATE COMPLICATION OF INTERTROCHANTERIC FRACTURE AND TREATMENT.

Failed fixation is one of the late complications that involve reoperation. Screws may cut out of the osteoporotic bone if reduction is poor or if the fixation device is incorrectly positioned. If union is delayed, the implant itself may break. (Figure 23)

Figure 24. X-Ray - A) Intertrochanteric fracture fixed with pin and plate. Fixation failed by screw cutout. B) Salvage with total hip replacement using a extensively porous coated prosthesis with shaft fixation.⁷²

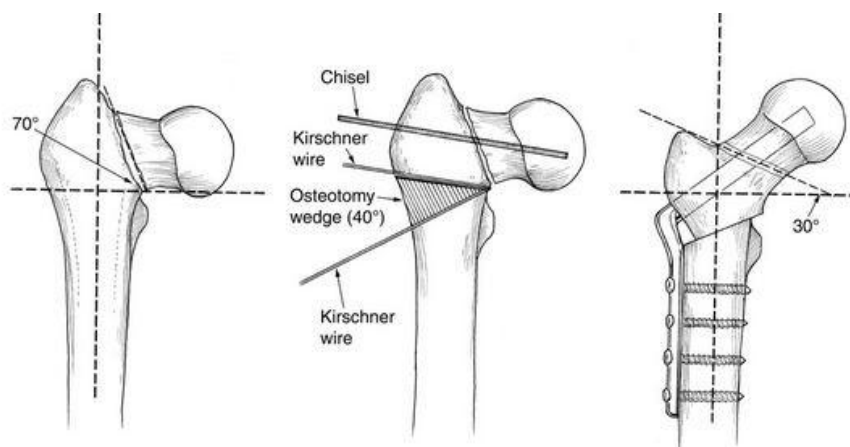


Malunion causing varus and external rotation deformities are common, but are seldom severe and rarely interfere with function.

Non-union is very rare⁷³. Intertrochanteric fractures seldom fail to unite. If healing is delayed (>6months) the fracture probably will not join and further operation is advisable. The fragments are repositioned as anatomically as is feasible, the fixation device is applied more securely and bone grafts are packed around the fracture.

It also appears that valgus intertrochanteric osteotomy (Figure 25) is an effective procedure that reliably restores hip function in trochanteric malunion or nonunion.⁷⁴

Figure 25. Principles of valgus-producing intertrochanteric osteotomy (with femoral neck fracture).⁷⁵



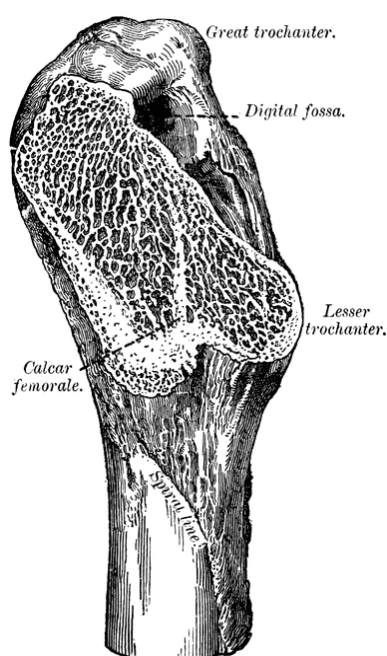
1.2.3. SUBTROCHANTERIC FRACTURES

The part of the femoral shaft around the lesser trochanter is substantially strengthened by a widening cortex and that stout pillar bone posteromedially, the calcar femorale (Figure 26).

Therefore, large forces are needed to cause fractures in this area, and that is the case when this injury is diagnosed in young adults.

By contrast, in the elderly, who are the second group who sustain this fracture quite frequently, the injury is relatively trivial due to weakening of the bone in this area by osteoporosis⁷⁶, osteomalacia, Paget's disease or a secondary deposit. Minor slips or falls that lead to direct lateral hip trauma are the most frequent mechanism of injury in this category of patients⁷⁷.

Figure 26. Femoral Spur of the Femur.⁷⁸

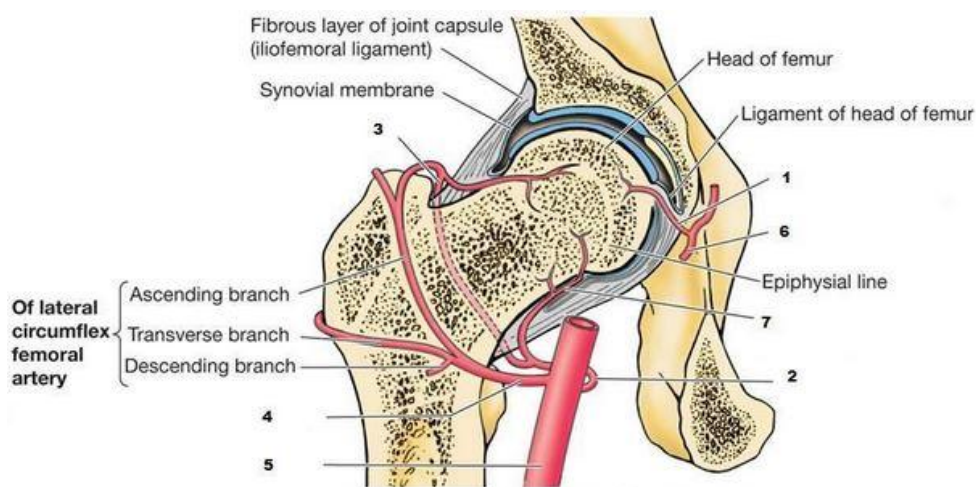


The subtrochanteric region of the femur, arbitrarily designated as the region between the lesser trochanter and a point 5 cm distal, consists predominantly of cortical bone. Healing in this region is predominantly through a primary cortical healing. Thus, the fracture is quite slow to consolidate.

In addition, this region is exposed to high stresses during activities of daily living: up to 6 times the body weight is transmitted across the subtrochanteric region of the femur⁷⁹.

Subtrochanteric fractures have several features that make them challenging to treat. The blood loss is greater than with femoral neck or trochanteric fractures, as the region is covered with anastomosing branched of the medial and lateral circumflex arteries which come off the profunda femoris trunk (Figure 27).

Figure 27. Anterior view of a coronally sectioned hip joint. 1. acetabular branch of obturator artery. 2,3. medial circumflex femoral artery. 4. lateral circumflex femoral artery. 5. profundus femoris artery. 6. obturator artery. 7. retinacular arteries.⁸⁰

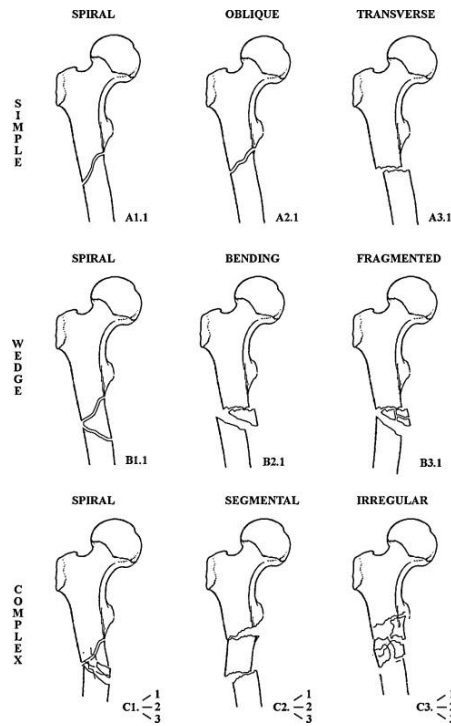


Also, there may be subtle extensions of the fracture into the intertrochanteric region, which may influence the manner in which internal fixation can be performed.

Moreover, the proximal part is abducted and externally rotated by the gluteal muscles, and flexed by the psoas. The shaft of the femur has to be brought into a position to match the proximal part or else a malunion is created by internal fixation.

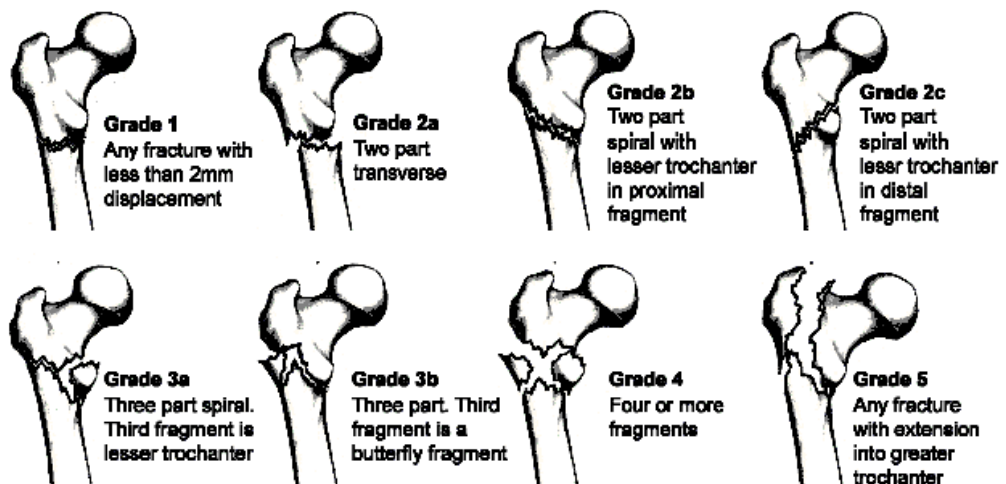
A universally accepted fracture classification does not exist for subtrochanteric femur fractures. The Association for the Study of Internal Fixation (AO-ASIF) has developed a complicated 3-part classification system with 10 subtypes that is most useful in research settings⁸¹.

Figure 28. The Association for the Study of Internal Fixation (AO-ASIF) classification of subtrochanteric femur fractures.⁸²



In 1978, Seinsheimer⁸³ presented an important classification with 8 subgroups that identified fractures with loss of medial cortical stability (Figure 29).

Figure 29. Seinsheimer classification of subtrochanteric fractures (Seinsheimer 1978).⁸⁴



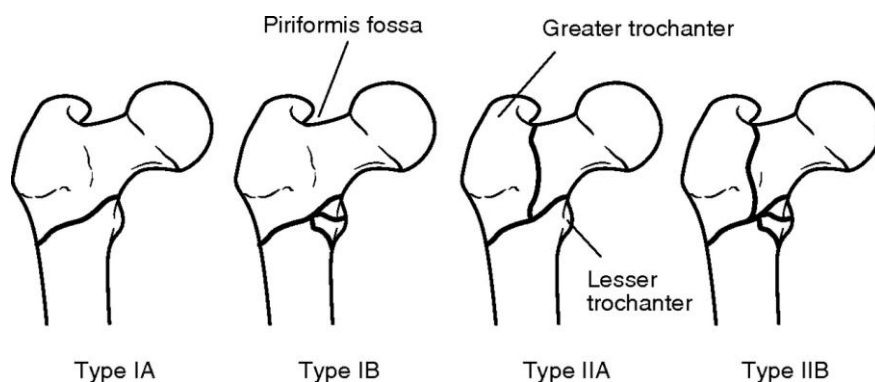
The Russell-Taylor classification system is helpful because it assists in determining the proper mode of treatment.

Type 1 fractures do not involve the piriformis fossa. They are subdivided into type A, for fractures below the lesser trochanter, and type B, for fractures involving the lesser trochanter.

Type 2 fractures involve the piriformis fossa. Type 2A fractures have a stable medial buttress. Type 2B has no stability of the medial femoral cortex.

Type 1 fractures can be treated with first- or second-generation intramedullary devices while type 2 fractures typically require open reduction and internal fixation (ORIF) with screw plate devices or fixed-angle implants.

Figure 30. Russell-Taylor classification of subtrochanteric femoral fracture.⁸⁵



Physical findings at the time of injury often include a shortened extremity on the fractured side. Significant swelling is frequently present, with tenderness to palpation in the proximal thigh region. The leg may lie in internal or external rotation. The patient cannot flex the hip or abduct the leg.

Hemorrhage into the injured thigh may be substantial, and the patient should be monitored for systemic shock and compartment syndrome.

In high-energy fractures, a complete system examination must be performed. Associated injuries to the cranium, thorax, and abdomen (Waddell triad) must be recognized⁸⁶.

Pelvic, spine, and long bone injuries are also common, especially on the ipsilateral side, and these should be identified early to optimize treatment and outcomes.

Biplanar plain radiography is the basic and essential imaging study for the diagnosis of subtrochanteric femur fractures (Figure 31). Full-length anteroposterior (AP) views of the femur from the hip to the knee should be obtained. A cross-table lateral view of the hip allows for evaluation of the femoral neck and an evaluation of the extent of the fracture. An AP view of the pelvis is also required, as well as views of the ipsilateral knee, because of the frequency of associated injuries.

Computed tomography scanning is not usually useful or necessary for surgical planning in these injuries.

Figure 31. X-Ray - Subtrochanteric Fracture.⁸⁷



When a pathologic fracture is suspected, screening studies such as technetium bone scanning or MRI may be indicated to rule out other sites of skeletal involvement. Screening chest radiography is also necessary to screen for possible pulmonary metastases.

During the past 25 years, treatment of subtrochanteric fractures in adults has become almost exclusively surgical. With increasing evidence of the morbidity of prolonged bed rest in elderly people or in patients with multiple traumatic injuries, nonoperative treatment methods are seldom nowadays.

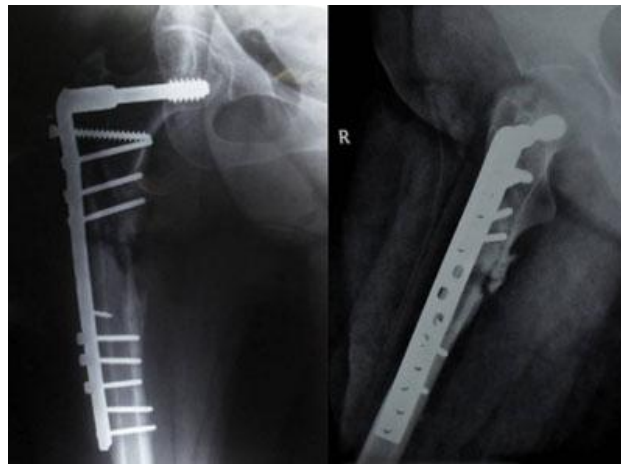
In selected patients with grossly contaminated fractures and in patients who are medically unstable for any surgical intervention, treatment with traction remains an option. It is important to realize that traction is associated with fracture malalignment problems and joint stiffness in the adult patient. However, in skeletally immature patients, traction followed by cast bracing is still a viable treatment option⁸⁸.

Surgical treatment can be divided into 3 main techniques: external fixation, open reduction with plates and screws, and intramedullary fixation. External fixation is rarely used but is indicated in severe open fractures. For most patients, external fixation is temporary, and conversion to internal fixation can be made if and when the soft tissues have healed sufficiently. External fixation becomes complicated when significant fracture comminution extends proximally, which may require more proximal stabilization to the iliac crest^{89,90,91}.

When plate fixation is chosen for fixation of subtrochanteric fractures, the traditional option is the AO-ASIF blade plate. However, high rates of complications were reported with this technique.

As a result of the complications and the technical difficulties inherent in the blade plate technique, the sliding hip screw (dynamic hip screw [DHS]) and the dynamic condylar screw (DCS, Figure 32) evolved as treatment options^{92,93}. These devices were believed to allow fracture impaction, and they had the biomechanical advantages of the blade plate but with a less complicated insertion technique. Several early reports suggested good rates of fracture union and low complication rates with both devices.

Figure 32. X-Ray - A subtrochanteric femur fracture treated with dynamic condylar screw and plate.⁹⁴



At the subtrochanteric level, most fractures are managed with a long intramedullary nail (Figure 33) together with a large lag screw or they are managed with screws that capture the neck and head of the femur or the area immediately underneath it, if it has remained intact.

Figure 33. X-Ray - Repair of subtrochanteric fracture with a long intramedullary nail.⁹⁵



In order to keep the bones from rotating around the nail or from shortening ("telescoping") on the nail, additional screws may be placed at the lower end of the nail in the area of the knee. These are called interlocking screws (Figure 34).

Figure 34. X-Ray - Interlocking screws at the end of the nail make the fixation more secure.⁹⁶



Essentially all subtrochanteric fractures below the level of the lesser trochanter can be nailed with a centromedullary locking nail. Most type 2A and 2B

fractures can be successfully treated with cephalomedullary nails (including those that affix to the femoral neck and head)⁹⁷.

Attention is given to the use of hip fracture implants (compression screw cephalomedullary nails) as they are not the ideal implant for most subtrochanteric fractures secondary to the large amount of bone that must be removed in the trochanteric and head areas and due to limited canal diameter options that do not allow for use of a canal fitting nail.

Following intramedullary nailing, if the bone quality and cortical contact is adequate, 50% partial weightbearing can be allowed immediately. With less stability, patients can perform touchdown weightbearing.

Close follow-up is required following fixation of subtrochanteric fractures. The patient should have monthly clinical evaluations and radiographs to monitor healing.

1.2.3.1. LATE COMPLICATION OF SUBTROCHANTERIC FRACTURE AND TREATMENT.

Common complications include nonunion, malunion, failure of fixation, and wound infection^{98,99}.

Nonunion is usually accompanied by significant pain after 4-6 months with the inability to bear full weight. If not obvious on plain radiography, tomography may help delineate nonunions. Occasionally, bone scanning can be helpful. In the presence of stable fixation, autogenous bone grafting can lead to successful fracture unions. In patients treated with intramedullary nails, exchange nailing with over-reaming is also appropriate with or without static locking of the new nail device.

Figure 35. X-Ray - A subtrochanteric nonunion with a broken plate is evident in this anteroposterior radiograph of an elderly woman.¹⁰⁰



Malunion is usually evident as a limp from shortening or rotational deformity with limitation of hip rotation. This can be prevented by careful attention to accurate reduction before internal fixation is applied. Late detection of malrotation may require a derotational osteotomy of the affected bone. Shortening is often secondary to varus at the neck shaft junction and can be addressed with a valgus osteotomy.

Failure of a screw plate device can be salvaged with a repeat plating and bone graft procedure or with second-generation nailing.

2. FEMORAL INJURIES AND THEIR TREATMENTS

2.1. FEMORAL SHAFT FRACTURES

The femoral shaft is circumferentially padded with large muscles (see Fig.36). It is the largest and strongest bone and has a good blood supply (see Fig.37-38). Because of this and its protective surrounding muscle, the shaft requires a large amount of force to fracture. Once a fracture does occur, this same

protective musculature usually is the cause of displacement, which commonly occurs with femoral shaft fractures¹⁰¹.

Figure 36. Cross-section through the middle of the thigh.¹⁰²

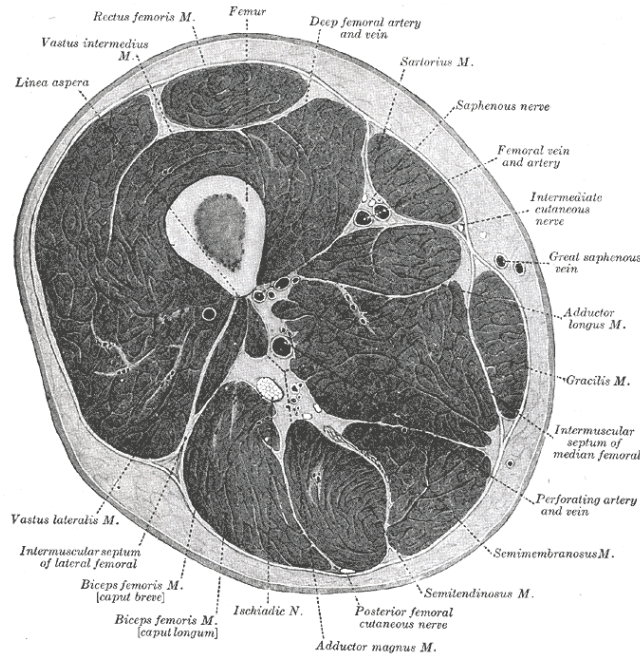


Figure 37. Right femur. Posterior/Anterior surface.¹⁰³

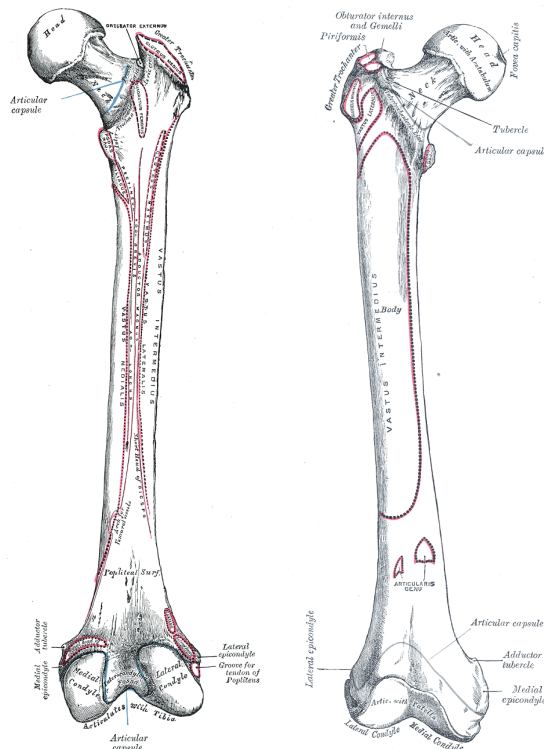
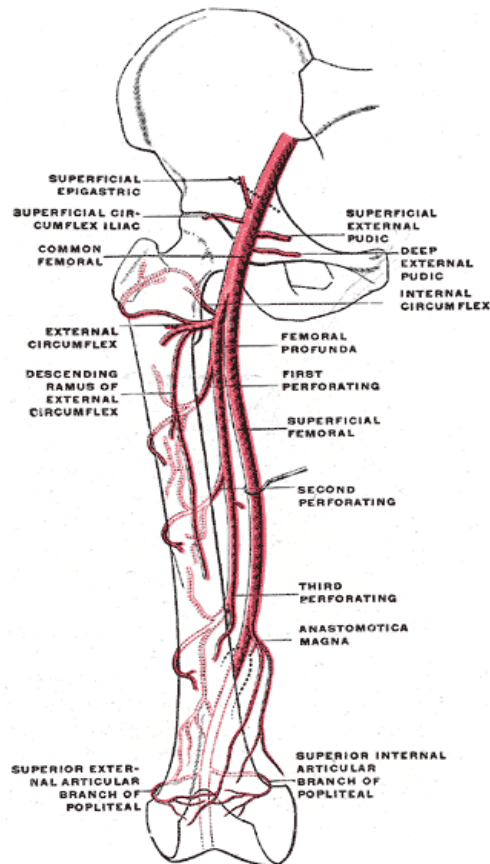


Figure 38. Scheme of the femoral artery.¹⁰⁴



This also causes a difficult reduction, while healing potential is improved by having this well-vascularized sleeve containing a source of mesenchymal stem cells. It allows open fractures to be managed with no more than split thickness skin grafts to obtain satisfactory cover.

The spectrum of femoral shaft fractures (Fig 39.) is wide and ranges from non-displaced femoral stress fractures to fractures associated with severe comminution and significant soft-tissue injury.

Figure 39. X-Ray - Femoral Fracture.¹⁰⁵



Femoral shaft fractures are most commonly the result of high-energy injuries, and are frequently accompanied by other injuries. The first priority in treatment is to rule out other life-threatening injuries and stabilize the patient. Advanced Trauma Life Support (ATLS) guidelines should be followed.

Isolated injuries can occur with repetitive stress and may occur in the presence of metabolic bone diseases, metastatic disease, or primary bone tumors. Also, diaphyseal fractures in elderly patients should be considered “pathological” until proved otherwise. In children under 4 years of age, child abuse should be kept in mind.

Generally, we can distinguish:

- Traumatic femoral fractures, where the history is not subtle, a high-velocity injury is customarily involved, pain and inability to bear weight are present, a shortening of one leg, swelling, and gross deformity may be noted, and other bony injuries, including tibial shaft fractures,

ipsilateral femoral neck fractures, and extension of the fracture into the distal femur may be associated.

- Femoral stress fractures, which are observed with increasing frequency in joggers^{106,107}, where a sudden increase in mileage, intensity, or frequency of training is recognized¹⁰⁸, a change in terrain or running surface may contribute, the onset of stress fractures is usually gradual (although it can be sudden and severe), groin or thigh pain may be reported, and symptoms may be aggravated by activity and relieved by rest.

As with many orthopedic injuries, neurovascular complications and pain management are the most consequential quandaries in patients who come to Emergency. The affluent blood supply can result in consequential bleeding and open fractures have a great potential for infection¹⁰⁹.

Fracture patterns are clues to the type of force that produced the break.

Three types of femoral shaft fractures are recognized:

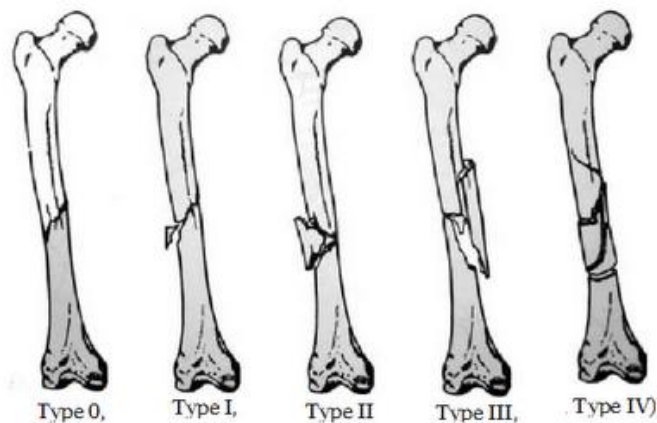
- Type 1 – Spiral or transverse (most common)
- Type 2 – Comminuted
- Type 3 – Open

Most fractures of the femoral shaft have some degree of comminution, although it is not always apparent on x-ray. Small fragments or a single large “butterfly” fragment may separate at the fracture line but usually remain attached to the

adjacent soft tissue and retain their blood supply. The fracture may become unstable with more extensive comminution and without point of contact.

This is the basis of a helpful classification of Winquist, which reflects the observation that the degrees of soft tissue damage and fracture instability increase with increasing grades of comminution.

Figure 40. Winquist's classification.¹¹⁰



In this classification we can distinguish:

- Type 0 – Frank break without fragment.
- Type 1 – Only a tiny cortical fragment is present.
- Type 2 – The butterfly fragment is larger but there is still at least 50% cortical contact between the main fragments.
- Type 3 – The butterfly fragment involves more than 50% of the bone width.
- Type 4 – Essentially a segmental fracture.

The Gustilo and Anderson classification of open fractures is also useful.

Fracture displacement often follows a predictable pattern dictated by the pull of muscles attached to each fragments:

- In proximal shaft fractures: the proximal fragment is flexed abducted and externally rotated.
- In mid-shaft fractures: the proximal fragment is again flexed and externally rotated but abduction is less marked.
- In lower third fractures: the proximal fragment is adducted and the distal fragment is tilted by gastrocnemius pull.

The soft tissues are almost always injured and bleeding from the perforators of the profunda femoris may be severe. Over one liter may be lost into the tissues, and the patient may become hypotensive quickly if bilateral femoral shaft fractures are encountered and not adequately resuscitated.

History conventionally is conspicuous in cases of femoral diaphyseal fractures. Typically, patients describe a consequential force applied to the extremity.

Clinically, there is a swelling and deformity of the limb and pain which can be excruciating on moving the limb. In case of both tibial and femoral fractures, a “floating” knee may be produced, signaling a high risk of multisystem injury in the patient.

In cases of diaphyseal femur fracture, laboratory studies felicitous for a trauma patient may need to be authoritatively mandated depending on the situation. The hemoglobin and hematocrit level should be monitored because of the peril of massive blood loss. The amount of blood lost with an isolated femur fracture should not cause clinically consequential hypotension. If this occurs, bleeding

from another site should be suspected. Culture and sensitivity results may be obtained in cases of open fractures to determine the optimal antibiotic treatment after empiric therapy.

In diaphyseal femur fracture, traction or splinting should be applied prior to radiographs to avert further soft tissue damage. It may be arduous to obtain a x-ray in emergency setting, so this may be deferred until more preponderant facilities are met, and more preponderant situating of the patient is possible. One should never forget to take radiograph of both the hip and the knee as well. A chest x-ray is withal utilizable as there is a peril of adult respiratory distress syndrome (ARDS) in those with multiple injuries. Baseline chest images may withal be needed to compare with later images to avail in the diagnosis of a fat embolism. The fracture pattern should be noted as this provides a form of guide to treatment.

In emergency settings, **skin traction** and a **Thomas' splint** are used in the field in emergent situations to provide comfort for the patient and to prevent any further soft tissue damage. The leg is pulled straight and threaded through the ring of the splint. The shod foot is tied to the cross-piece so as to maintain traction and the limb and splint are firmly bandaged together. This temporary stabilization helps control pain, reduces bleeding and makes transfer easier.

Shock should be treated, blood volume restored and maintained, and a definitive plan of action instituted as soon as the patient's condition has been fully assessed.

The association of femoral shaft fractures with other injuries increases the potential for developing fat embolism, ARDS and multi-organ failure. The peril of

complications can be significantly reduced by early stabilization of the fracture, conventionally by a locked intramedullary nail. The American College of Surgeons Committee on Trauma has recommended that femoral shaft fractures in polytrauma patients be treated within 2-12 hours after injury, provided they are hemodynamically stable¹¹¹. Patients with head and chest injuries had a lower morbidity and mortality rate when fixation was achieved in the first 24 hours^{112,113}. This is thought to be caused by inflammatory changes engendered by surgery and blood loss, which consequently increases both morbidity and mortality, a phenomenon called “the second hit” referring to a second episode of trauma, albeit surgical, on the patient. Each patient's treatment must be culled with clinical consideration of the patient's health status on presentation, the caliber of emergent treatment needed, the available materials, the patient's age, and the medico's personal experience. Therefore, internal fixation is still the treatment of cull for most closed injuries and some open because of the higher amalgamation rate, lower rate of complications, lower morbidity, earlier weight bearing, shorter hospital stay, and more preponderant control of alignment. However, in some situations, such as when the hardware is not available or the patient cannot undergo surgery relatively soon, ephemeral skeletal traction may be a viable choice, which may be exchanged for an intramedullary nailing later when the patient is stabilized. The timing of this second procedure is still problematic. Sometimes, the quantification of circulating levels of Interleukin-6, a pro-inflammatory cytokine, is utilized to decide whether it is safe or not to perform this “second hit” intervention, but this cannot be applicable to all patients. Additionally, the exchange for an intramedullary nail carries the

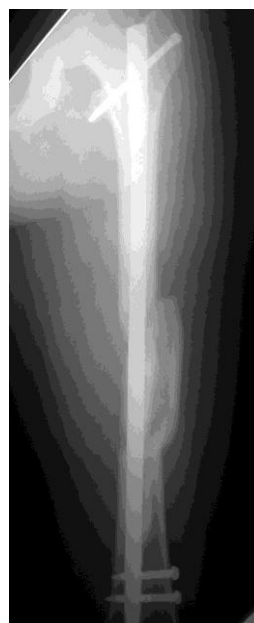
jeopardy of transferring contaminants from pin sites to the intramedullary nail: the earlier it is performed, the lower the risk.

Cast bracing is more of a historical treatment in light of the options available in modern orthopedics. They were usually applied after a period of traction, the advantage being an earlier return to motion. Only relative indications exist today, including distal-third fractures or comminuted fractures in patients who are not surgical candidates and as supplemental support for internal fixation.

Spica casting is not used often in adults or adolescents and is a treatment of choice in young children with isolated uncomplicated femoral-shaft fractures. The positive aspect of the spica cast is avoidance of primary and secondary surgery for hardware removal.

Currently, **antegrade reamed interlocked intramedullary nailing** (see Fig.41) is the treatment of choice for diaphyseal femur fractures¹¹⁴. The exposure is small, and soft tissue damage is limited¹¹⁵.

Figure 41. Anteroposterior radiograph of the femur shows an antegrade intramedullary nail with one proximal oblique and two distal interlocking screws that transfix a comminuted mid-diaphyseal femoral fracture.¹¹⁶



The nail itself has the advantage of being centrally located in the shaft and load sharing. Antegrade reamed locked nailing promotes rejuvenating through abundant callus formation. The fixation is solid and able to withstand extensive comminution. It allows early and, in some cases, immediate weight bearing. It is associated with more facile nursing care, shorter hospital stays, and lower morbidity. The results of treatment have been excellent, with a 99% rate of union and 1% incidence of infection. The fracture customarily heals within 20 weeks with a low rate of complication.

Retrograde intramedullary nailing of the femur (see Fig.42) has presented itself as an alternative to the antegrade nail^{117,118}. Fairly similar results have been achieved in some comparisons, but it lacks the long-term studies that have made antegrade nailing the criterion standard.

Figure 42. X-Ray - Retrograde nail on distal anteroposterior and lateral radiographs.¹¹⁹

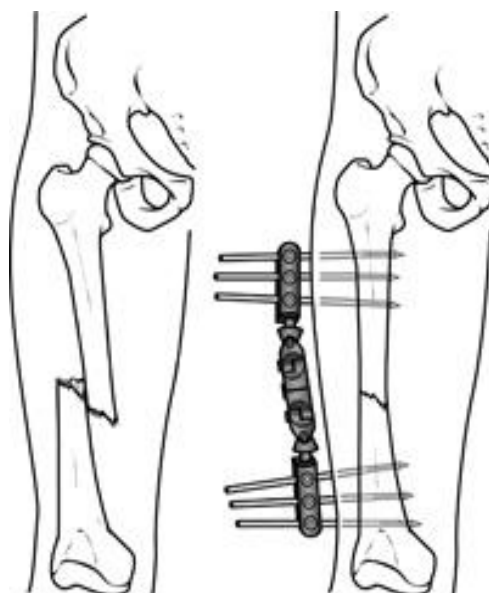


Advantages of retrograde nailing might include decreased operative time, decreased blood loss, and amenability to polytrauma situations. Retrograde nailing also allows separate treatment of femoral neck fractures and limits

heterotopic ossification formation. It may be ideal in floating knee injuries and ipsilateral supracondylar fractures and patients who are obese or pregnant, allowing easier starting point access and exposing the fetus to less radiation. Nevertheless, retrograde nailing should be avoided in Gustilo - IIIB open fractures, septic knees, subtrochanteric fractures, open physes, and knee injuries, and it is not as effective in very proximal shaft fractures.

External fixation (see Fig.43) is the treatment of choice for many patients with grade IIIB or IIIC open fractures, for patients with fractures in which vascular surgery is needed, for patients in unstable condition, and for those in whom definitive surgery cannot be performed relatively soon. Because of the relatively short operative time, the surgeon also may consider this a feasible option when time is lacking, as in a mass casualty situation¹²⁰.

Figure 43. External fixation.



Compression plating has been met with much less enthusiasm than intramedullary nailing¹²¹. The extensive approach, periosteal stripping, potential blood loss, load sparing, less aesthetic scar, and higher rate of complications

tend to favor other methods of treatment. Compression plating may be used in distal metaphyseal-diaphyseal junction fractures and in certain situations with ipsilateral femoral neck fractures.

More recently, **locked plating technology** has introduced the concept of relative stability to promote more rapid callus healing versus slower primary healing. It has also allowed bridge plating of comminuted areas and promoted the development of the **Minimally Invasive Plate Osteosynthesis (MIPO)** approach that spare the soft-tissues. It has made plating a more biologic friendly option for the orthopedic surgeon and patient and has led to better union rates. Its indications are fracture at either end of the femoral shaft, a shaft fracture in a growing child, and a fracture with a vascular injury.

Open fractures should be carefully assessed for skin loss, wound contamination, muscle ischemia and injury to blood vessels and nerves. Gustilo class I, II, and IIIA fractures treated with **standard reamed antegrade nailing** is supported by a lot of literature. Many authors still agree that grade IIIB and IIIC fractures should be treated with **external fixation after initial debridement**, which can be exchanged later. Debridement and delayed closure are required. If the surgeon believes that the intramedullary canal is grossly contaminated, intramedullary nailing should be avoided. Treatment initiated within the first 8 hours has shown to decrease the incidence of infection. Indeed, the patient is started on **intravenous antibiotics** as soon as immediate treatment is established: for grades I and II, the recommended treatment is with a first-generation cephalosporin, and for grade III injury, a first-generation cephalosporin and an aminoglycoside is required. Because of the higher rate of

infection in any open fracture that has gone untreated for longer than 8 hours, the injury should be treated as a grade III open fracture by using external fixation.

Fractures with associated vascular injuries must be sought at all moment. Warning signs are excessive bleeding or hematoma, paresthesias, pallor and/or pulselessness in the leg. One should not accept arterial spasm as a cause of absent pulses. The fracture level on x-ray will indicate the region of arterial damage and arteriography may only delay surgery to re-establish perfusion. When surgical intervention is delayed more than 4-6 hours, salvage of the limb may not be possible and the risk of amputation rises. The diagnosis must be prompt and re-establishing perfusion is a priority. Fracture stabilization becomes secondary.

The recommended sequence for treatment is to create a shunt from the femoral vessels in the groin to beyond the point of injury using plastic catheter, to stabilize the fracture by plating or external fixation and then carry out definitive vascular repair. This allows quick re-establishment of blood flow and permits fracture fixation and vascular repair to be carried out without pressure of time.

Femoral fractures are also frequently associated with injury to *the ligaments of the knee*. Direct blows to the knee from the dashboard of the car in an accident will damage knee ligaments as well as break the femoral shaft and femoral neck: this composes a triad that should be recognized. The knee injury is easily overlooked in rush of emergency, and re-emerge frequently as a persistent complaint weeks or months later. The knee should be examined as soon as the fracture is stabilized.

Ipsilateral fractures of the femur and tibia may leave the knee joint “floating” (see Fig.44). This is a very serious situation, and other injuries are often present. Both fractures will need immediate stabilization by an anterior approach to the knee joint allowing both fractures to be stabilized by **intramedullary nail**, retrograde for the femur, anterograde for the tibia. It is usual to fix the femur first (see Fig.45).

Figure 44. X-Ray - "Floating" of the left knee.¹²²

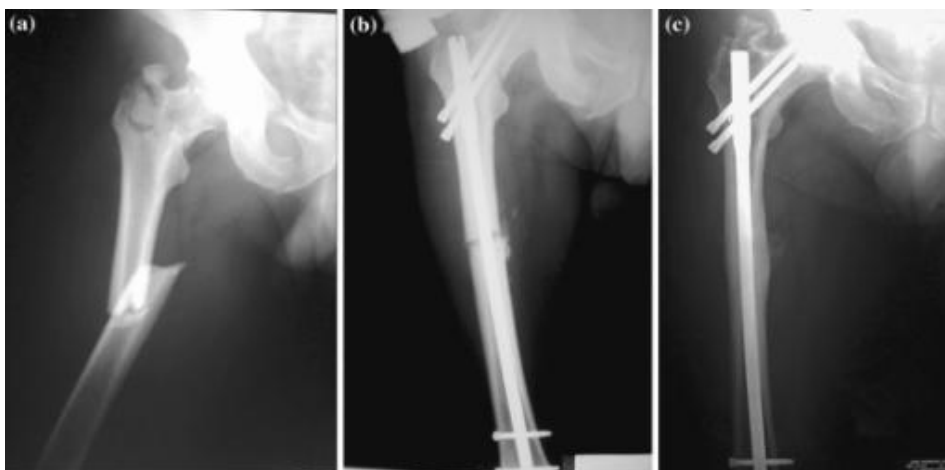


Figure 45. X-Ray - Intramedullary nailing in a "floating" left knee.¹²³



Combined neck and shaft fractures are an important diagnosis: always examine the hip and obtain an x-ray of the pelvis. Both sites must be stabilized, first the femoral neck and then the femur. **Parallel screw fixation** of the femoral neck followed by **retrograde femoral nailing** is a useful way to treat this problem.

Figure 46. X-Ray - Ipsilateral femoral neck and shaft fracture: a) pre-surgery, b) after reconstruction nailing and c) satisfactory union achieved after 8 months with evidence of heterotopic ossification at the tip of the great trochanter.¹²⁴



Fracture through metastatic lesions should be fixed by **intramedullary nailing**. Provided the patient is fit enough to tolerate the operation, a short life expectancy is not a contraindication. Prophylactic fixation is also indicated if a

lytic lesion is greater than half the diameter of the bone, longer than 3 cm on any view, or painful, irrespective of its size. Also, Paget's disease, fibrous dysplasia or rickets may present a problem. The femur is likely to be bowed and, in the case of Paget's disease, abnormally hard. An osteotomy to straighten the femur may be necessary to allow a nail to be inserted fully.

Periprosthetic fractures are uncommon. They may happen during primary hip surgery when reaming or preparing the medullary canal, or when forcing in an over-sized uncemented prosthesis, or during revision surgery while extracting cement or attempting to dislocate the hip if the soft tissue release has been insufficient. Sometimes the fracture occurs much later, and there are usually x-ray signs of osteolysis or implant loosening suggesting a reason for bone weakness.

Figure 47. X-Ray - Periprosthetic fracture.¹²⁵



If the prosthesis is worn or loose, it should be removed and replaced by one with a long stem, thereby treating both problems. If the primary implant is neither loose nor worn, it can be left in place and the fracture treated by **plate fixation** with **structural allografts** bridging the fracture.

Most femoral shaft fractures take 4 to 6 months to completely heal. Some take even longer, especially if the fracture was open or broken into several pieces. Strengthening of the quadriceps and hamstring muscles can begin almost immediately in the postoperative period. Hip, knee, and ankle range-of-motion (ROM) exercises should be started early. Patients treated with a 12-mm statically locked nail with 2 distal locking screws may even begin with immediate full weight bearing. In other treatments, progressive weight bearing is often used and graded with consideration to the method of treatment, the condition of the patient, and the extent of the fracture.

Prolonged supervised therapy is not often needed, since full ROM is usually attained within 4-6 weeks. Follow-up radiographs are obtained at 1, 3, 6, and 12 months to ensure that the fracture is healing in an acceptable position. If retained hardware removal is needed, it can usually be performed 1 year after union.

Early complications of femoral shaft fractures are several:

- One or two litres of blood can be lost even with a closed fracture, and if the injury is bilateral, **shock** may be severe. Because of the high rate of associated injuries, other sources of blood loss in patients with femur fractures and hypovolemic shock should be sought actively. Patient will require transfusion.
- **Fat embolism** and **adult respiratory distress syndrome (ARDS)** can occur. Femur fractures at a level one trauma center have been associated with double the risk of developing ARDS compared with

other patients admitted for musculoskeletal injury¹²⁶. The risk trends upward with delays in surgical repair greater than 24 hours.

- While open fractures are at high risk of soft-tissue and bony **infection**, postoperative infection is rare following repair of closed fractures. Prophylactic antibiotics and careful attention to the principles of fracture surgery should keep the incidence below 2%. If the bone does become infected, the patient should be treated as for an acute osteomyelitis (antibiotics, debridement and removal of any dead tissue if pus or sequestrum is present).
- Prolonged traction in bed predisposes to **thrombosis**. Movement and exercise are important in preventing this, but high-risk patients should be given prophylactic anticoagulants as well. Monitoring is advised with use of these medications.
- **Injuries to the neurovascular bundle** are rare because of the large cushion of muscle protecting neurovascular structures.
- **Compartment syndrome of the thigh** does not occur often, and peroneal nerve contusion is seen occasionally.

More delayed complications include permanent stiffness of the hip or knee, shortening of the extremity, or malrotation, resulting in permanent deformity and decreased performance.

Late complications are usually the result of surgical treatment. Complications directly related to repair include (in order of increasing frequency) breakage of fixator hardware, nonunion, **malunion**, or **delayed union**.

Finally, refracture can occur at the initial injury site.

2.1.1. LATE COMPLICATION OF FEMORAL SHAFT FRACTURES AND TREATMENT.

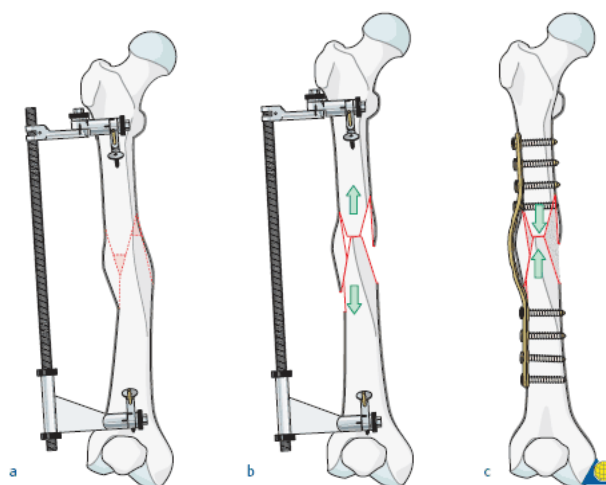
As far as **delayed union or non-union** are concerned, the time-scale for declaring their occurrence vary with the type of injury and the method of treatment. If there is failure to progress by 6 months, as judged by serial x-rays, then intervention may be needed. Usually the removal of locking screws from intramedullary nail to enable the fracture to dynamise is done. More often it fails and results in pain as rotational control of the fracture is lost. So exchange nailing is now a better alternative, placing a larger diameter nail. Bone graft may be added to the site if gaps remain.

Furthermore, the success of reamed intramedullary nails has made **nonunion** in treated femoral fractures rare. Reported nonunion rates range from approximately 3 percent to 5 percent. Several factors are associated with the development of a nonunion, the critical one probably being the degree of damage to the local soft tissues and the related damage to the local bone vascularity. Indeed, the success of intramedullary nailing is probably associated with the lack of additional damage to bone viability during the surgical procedure as opposed to that caused by conventional plating. Other factors play

a role, but recent evidence highlights the biological effect of NSAIDs, which, if administered during the healing period, significantly increase the nonunion rate. Fractures treated by traction and bracing often develop some deformity. Overall, no more than 15° of angulation should be accepted. Although initial reduction was satisfactory, the fracture is too insecure to permit weight bearing: bending will occur, and bowing ensue.

Diaphyseal **malunions** with serious angulation/rotation and shortening should be corrected at the level of the deformity. If there is major shortening, the plate is the implant of choice. Intramedullary nailing¹²⁷ of the sclerotic malunion is dangerous and reserved for minor correction.

Figure 48. Correction and lengthening osteotomy of a malunited femoral shaft fracture¹²⁸.



- a. Decortication of the region of shortening, especially on the posterior aspect and fixation of the distraction apparatus anterolateral, outside the area of future plating.
- b. Oblique osteotomy and distraction of the fragments until the desired length is achieved. Osteotomy of the tips of the fragments and adaptation on the level of the transverse osteotomy is obtained.

c. A tension band plate (wave plate) compressing the osteotomy with the articulated compression device. Autogenous bone is grafted if the contact area is small and the decorticated fragments do not provide a sufficient, vascularized, bony bridge.

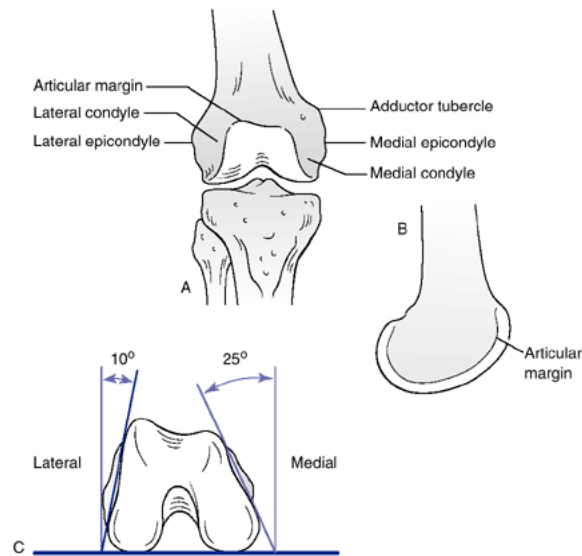
The knee joint may also be affected and injured at the same time as the femur. It may stiffen due to soft tissue adhesions during treatment. Physiotherapy is preponderant for prevention.

Ultimately, fractures which heal with abundant callus are unlikely to recur. By contrast, in those treated by internal fixation, callus formation is often slow. If a comminuted fracture is plated, bone grafts should be added and weightbearing delayed so as to protect the plate from reaching its fatigue limit too soon. Intramedullary nails are less prone to **break**, but sometimes they do. When this occurs, the usual site is through the screw-hole closest to the fracture. The treatment is to replace the nail and adding bone grafts. Sometimes, the fracture may need excision followed by distraction osteogenesis which stabilizes the limb and deals with the length discrepancy.

2.2. FEMORAL SUPRACONDYLAR FRACTURES.

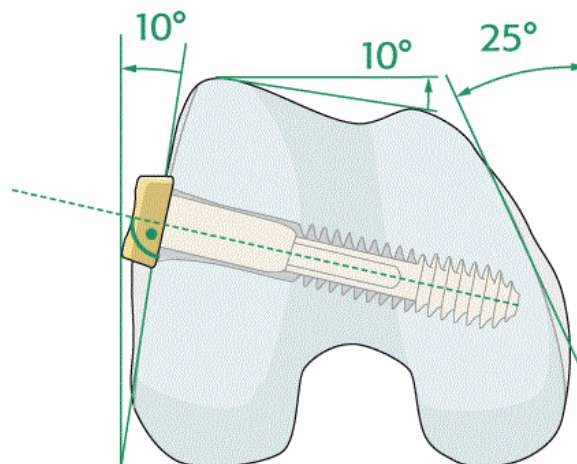
The distal femur has a unique anatomical shape. Seen from an end-on view, the distal femur is trapezoidal and the lateral surface has a 10° inclination from the vertical, while the medial surface has a 20–25° slope (see Fig. 49).

Figure 49 - Anatomy of the distal femur. A. Anterior view. B. Lateral view. The shaft of the femur is aligned with the anterior half of the lateral condyle. C. Axial view.¹²⁹



A line drawn from the anterior aspect of the lateral femoral condyle to the anterior aspect of the medial femoral condyle (patella-femoral inclination) slopes approximately 10°. These anatomical details are important when inserting screws, or blade plates. In order to avoid joint penetration, these devices should be placed parallel to both the patella-femoral and femoro-tibial joints planes (see Fig.50).

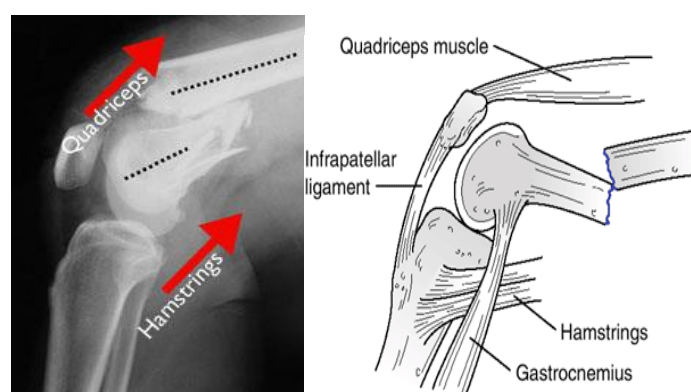
Figure 50 - Distal femur angles and screw positioned.¹³⁰



Distal femur fractures occur at approximately one-tenth the rate of proximal femur fractures and make up 6% of all femur fractures¹³¹. There is a bimodal distribution of fractures based on age and gender. Most high-energy distal femur fractures occur in males between 15 and 50 years, while most low-energy fractures occur in osteoporotic women >50 years. The most common high-energy mechanism of injury is a traffic accident (53%) and the most common low-energy mechanism is a fall at home (33%).

Those fractures involve the femoral condyles and the metaphysis. As with all fractures, understanding the deforming forces involved is critical for successful operative management. Shortening of the fracture with varus and extension of the distal articular segment is the typical deformity¹³². Shortening is caused by the quadriceps and hamstrings. The varus and extension deformities are due to the unopposed pull of the hip adductors and gastrocnemius muscles respectively (see Fig.51).

Figure 51 - Lateral view showing muscle attachments and resulting deforming forces.^{133, 134}



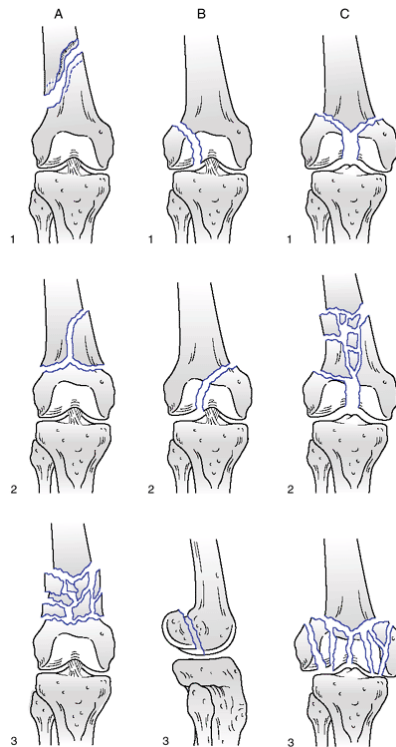
The fracture line is just above the condyles, but may extend between them. In the worst case the fracture is severely comminuted. The ability to recognize the normal anterior bow of the distal femur is important in fractures with metaphyseal comminution. Also, reducing the extension deformity can be

challenging when using an intramedullary device, and the reduction can be difficult to evaluate when using a laterally-based plate construct, because the device obstructs fluoroscopic visualization.

The most common classification system used for distal femur fractures is the AO/OTA system (see Fig.51). Type 33-A is an extra-articular fracture. Type 33-B is a partial articular fracture involving one of the femoral condyles. Type 33-C is a complete articular fracture. Each of the letter designations is further classified into 1, 2, or 3 based on the amount and location of comminution:

- Extra-articular fracture
 - A1 - Simple
 - A2 - Metaphyseal, wedge
 - A3 - Metaphyseal, complex
- Partial articular fracture
 - B1 - Lateral condyle (sagittal fracture line)
 - B2 - Medial condyle (sagittal fracture line)
 - B3 - Frontal (coronal fracture line)
- Complete articular fracture
 - C1 - Articular and metaphyseal segments, simple fractures
 - C2 - Articular simple, but metaphyseal multifragmentary fractures
 - C3 - Articular and metaphyseal segments, multifragmentary fractures

Figure 52 - AO-ASIF classification of supracondylar femur fractures.¹³⁵



Supracondylar fractures of the femur are often the result of high-energy trauma. Therefore, a complete evaluation of the whole patient should be performed. The presence of other injuries to the same extremity needs to be ruled out, with particular attention to the hip and the leg below the fracture site. The vascular supply to the limb should be assessed by examining for the presence of a pulse at the popliteal, dorsalis pedis, and posterior tibial arteries. Motor and sensory function to the leg and foot must be assessed.

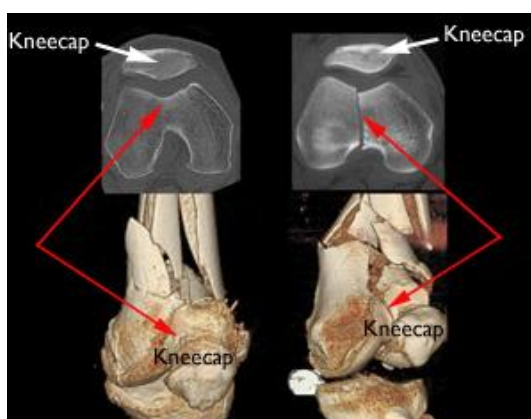
Inspection usually shows swelling and deformity around the distal femur and knee. The presence of an open wound in the case of open fractures should be identified. Although manipulation of the injured limb demonstrates motion and crepitus, this maneuver causes unnecessary pain and should be precluded by the x-ray evaluation.

As a part of and immediately after the physical examination, the injured extremity should be gently realigned (if necessary) and splinted before x-ray evaluation.

Routine x-ray evaluation of the distal femur and knee includes standard anteroposterior and lateral x-rays. X-rays of the pelvis, the ipsilateral hip, and the complete femoral shaft should also be obtained to rule out the presence of associated injuries.

Complex intra-articular fractures of the supracondylar area may be visualized better with additional 45-degree oblique x-rays. Gentle application of manual traction to the distal extremity may also help in obtaining a x-ray that can be more easily interpreted. Both techniques may be helpful to avoid missing an undisplaced or minimally displaced intercondylar fracture, an injury that is easily missed on plain x-rays. Complex intra-articular fractures and osteochondral lesions may require additional imaging with computed tomography to assist in completing the diagnostic assessment and preoperative planning. Computed tomography (CT) scans are therefore indicated for essentially all intra-articular fracture patterns (see Fig.53).

Figure 53 - CT scan providing cross-sectional and 3-D images. Left: no intra-articular fracture. Right: Joint surface fracture.¹³⁶



Arteriography should be performed when the history or physical examination has shown that an associated dislocation of the knee has occurred. Arteriography is indicated when the physical examination has demonstrated a diminished or absent pulse, expanding hematoma, persistent arterial bleeding through an open wound, or injury to the adjacent tibial nerve.

Once diagnosed, treatment decisions are based on both the characteristics of the fracture and patient factors. Treatment challenges are presented by patients with osteoporotic bone, open fractures with significant bone loss, and fractures with short articular segments¹³⁷.

Nonoperative treatment may be chosen for non- or minimally-displaced fractures in low-demand elderly patients. Nonoperative treatment may consist of either skeletal traction or initial splinting and mobilization with limited weight bearing and eventual transition to either a cast or functional brace. Radiographs are typically obtained at weekly to biweekly intervals for the first 6 weeks to ensure that the fracture reduction is maintained. Gradual progressive weight bearing and joint mobilization are allowed based on the clinical and radiographic progression of fracture healing.

However, it has been clearly demonstrated in studies that nonoperative treatment does not work well for displaced fractures, and therefore is reserved for those patients who cannot tolerate surgery¹³⁸.

Operative treatment is indicated for displaced fractures, open fractures, and those associated with a vascular injury. In open fractures and in polytraumatized patients, these injuries need to be dealt with as soon as possible, either definitively or with wound management and temporary skeletal

stabilization using a bridging external fixator. In the case of closed, isolated injuries, timing of management is not as pressing.

Treatment goals include anatomical reduction of the articular surface, restoration of limb alignment, early postoperative knee range of motion (important for articular cartilage nutrition), and early patient mobilization.

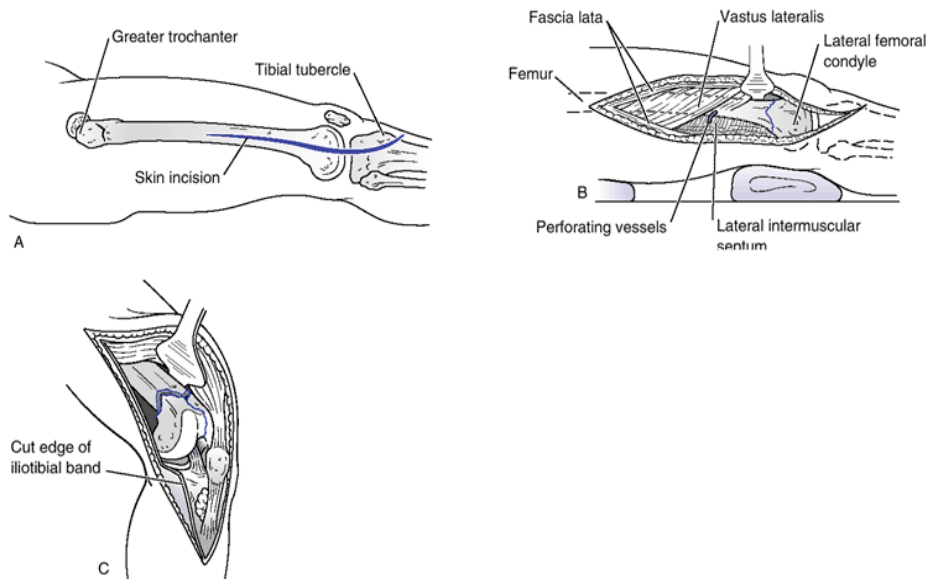
Initial management of distal femur fractures typically includes a well-padded long leg splint to improve patient comfort and prevent further soft tissue injury.

In high-energy closed and open distal femur fractures, particularly in polytraumatized patients, some surgeons may temporarily stabilize the fracture with a knee-spanning external fixator until definitive management is possible.

Not only does this restore crude overall alignment, prevent further soft tissue injury, and improve patient comfort and mobility, but it also allows a CT scan to be obtained for preoperative planning that is more useful as discussed above.

A lateral approach to the distal femoral shaft and supracondylar region of the femur is the most commonly used exposure for open reduction and internal fixation (ORIF) of fractures in this area (see Fig.54). Most supracondylar fractures (with the exception of fractures limited to the medial condyle), when treated with ORIF, can be managed with this approach.

Figure 54 - Lateral approach to the distal femur. A. Lateral skin incision. B. The plane of dissection is through iliotal band and between the vastus lateralis and the lateral intermuscular septum to the bone. C. Visualization of the lateral femoral condyle¹³⁹.



A radiolucent operating table facilitates use of an image intensifier during the procedure, and it is recommended because it allows rapid intraoperative evaluation of reduction and implant placement for this technically demanding procedure. A fracture table (and traction) should not be used, because the resulting muscle tension will make exposure and reduction more difficult. The patient is positioned supine with the ipsilateral hip elevated to allow slight internal rotation of the leg. Alternatively, the patient may be placed in the lateral position. A single straight lateral incision is made along the thigh. The incision should start as proximal as necessary; distally, it should extend across the midpoint of the lateral condyle anterior to the fibular collateral ligament, across the knee joint, and then gently curve anteriorly to end distal and lateral to the tibial tubercle. The fascia lata is incised in line with the skin incision. At the knee, the iliotal tract will need to be incised, and the incision will continue down through the joint capsule and synovium to expose the lateral femoral

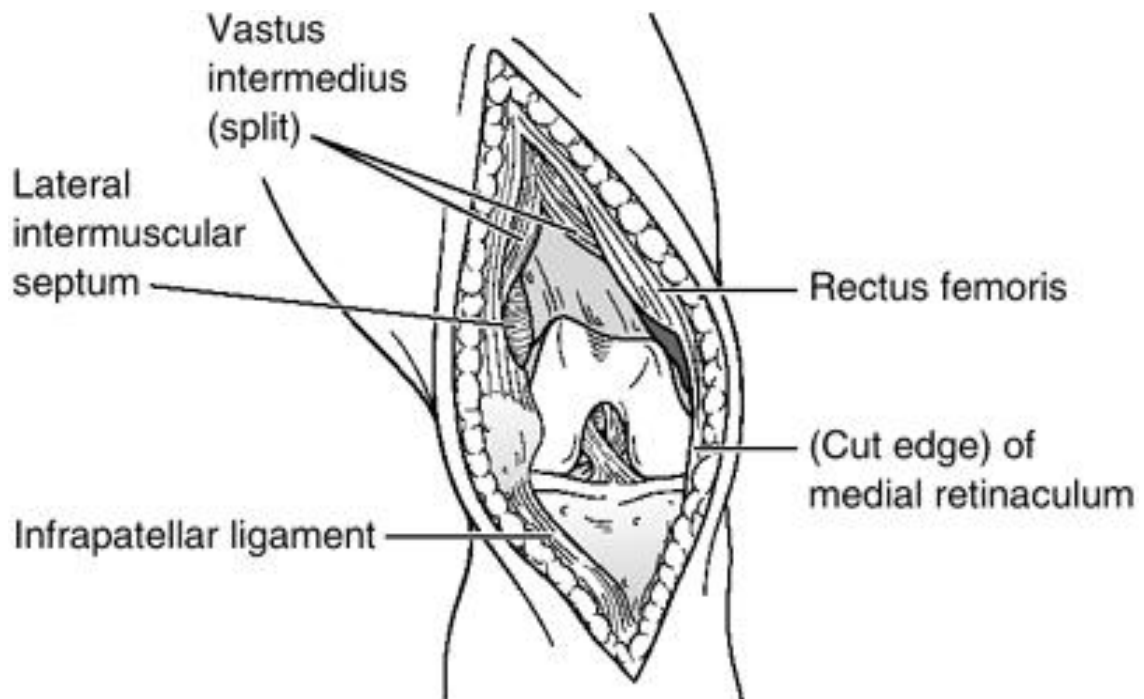
condyle. The superior geniculate artery will need to be identified and ligated. Care must be taken not to incise the lateral meniscus at the lateral joint margin. The vastus lateralis muscle is carefully elevated from the intermuscular septum and is retracted anteriorly and medially. The perforating vessels will need to be identified, ligated, and then cut. Stripping of soft tissues from the anterior, medial, and posterior surfaces of the femoral shaft and supracondylar regions is unnecessary and should be avoided, to prevent devitalization of bone fragments.

In the case of complex intra-articular (type C3) fractures, it may be necessary to increase the exposure of the articular area of the distal femur beyond what is possible with the standard lateral technique alone.

Minimally invasive approach avoids direct exposure of the non-articular portion of the fracture site and minimizes soft tissue stripping, but has several features that limit its applicability (limited to certain fixation devices, the access of extra-articular fracture is only possible percutaneously, requires a skilled surgeon...).

The anterolateral approach can be used as an alternative to the standard lateral approach (see Fig.55). It offers the advantage of better exposure of the articular surface of both condyles than the lateral approach, without the need for an osteotomy of the tibial tubercle. The disadvantage of this approach is that intramuscular splitting of the vastus intermedius muscle is required, and this may lead to adhesions between this muscle and the femur. This may then lead to loss of knee flexion.

Figure 55 - Anterolateral approach to the distal femur. At the knee is a medial parapatellar arthrotomy and lateral dislocation of the patella¹⁴⁰.



When treating fractures of the distal femur operatively, the surgeon should follow the principles of fracture care developed by the AO and Association for the Study of Internal Fixation (ASIF): anatomic reduction, stable fixation, preservation of blood supply to bone, and early range of motion with functional rehabilitation.

Various strategies can be used for the different fracture patterns.

Type A fractures are extra-articular fractures of the distal femoral metaphysis.

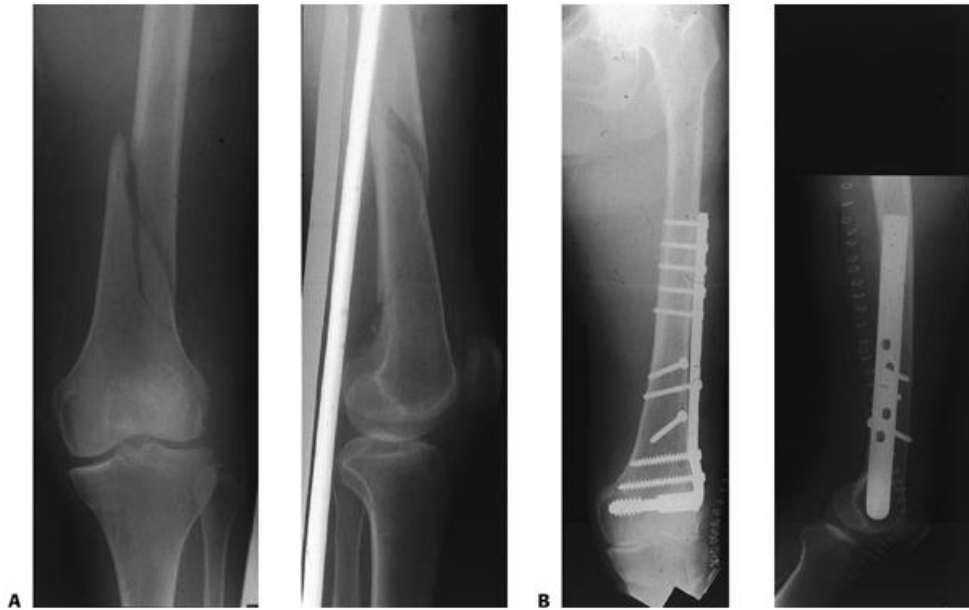
Type A1 fractures are not comminuted, type A2 fractures have a metaphyseal wedge and therefore are minimally comminuted, and type A3 fractures have significant comminution of the metaphyseal bone. The principles for treatment of these extra-articular fractures are to restore length, alignment, and rotation to the femur and then to provide relatively stable fixation to allow the bone to heal in the correct position. Open direct reduction can be considered in type A1

fracture patterns, followed by absolutely stable internal fixation with interfragmentary lag screws and a neutralization plate. Either a 95-degree blade plate or a Dynamic Condylar Screw would be appropriate as a neutralization plate in this application. Blood supply to bone is preserved because of the sound soft tissue envelope, and given that there are no small comminuted fragments, careful dissection of the fracture will leave ample soft tissue attachment to bone (see Fig.56).

Open indirect reduction and relatively stable internal fixation are appropriate for many type A2 and A3 fractures. For minimally comminuted fractures (type A2), the articulated tension device applied in a distraction mode works well for indirect reduction. In more comminuted fractures (type A3), the femoral distractor should be used because of its superior mechanical strength. Using a biologic bridge plate can then provide relative stability. Again, either the 95-degree blade plate or the Dynamic Condylar Screw will work well in this application. Bone grafting is not necessary if the indirect reduction technique is used.

The so-called minimally invasive plate osteosynthesis has been described and advocated by some surgeons. Although some basic science research has indicated that submuscular plate insertion and percutaneous insertion of the screws are associated with less disturbance of femoral perfusion, no clinical studies have documented improved outcomes¹⁴¹. These techniques remain controversial in the treatment of type A distal femur fractures.

Figure 56 - A. Type A1 distal femur fracture. B. Direct open reduction and internal fixation with interfragmentary lag screws and a dynamic condylar screw¹⁴².



Closed reduction and intramedullary nail fixation comprise a useful technique for many type A1, A2, and A3 distal femur fractures. The closed nailing technique has the biologic advantage of not disturbing the fracture hematoma or the remaining soft tissue attachments to bone. Intramedullary nailing of type A distal femur fractures can be accomplished either through an antegrade or a retrograde approach. For rigid interlocking nails, it is imperative to ensure that two distal locking screws are used to secure the distal fragment. Using only one screw will not provide sufficient stability to protect against angular deformity in the sagittal plane. Antegrade femoral intramedullary nailing using standard techniques is a good option for management of many type A distal femur fractures (see Fig.57)

Figure 57 - A. Type A distal femur fracture. B. Postoperative films after closed reduction and static locked reamed antegrade intramedullary nailing¹⁴³.



Type B partial articular fractures of the distal femur are classified as those that involve the lateral condyle (type B1), the medial condyle (type B2), and those that occur in the coronal plane (type B3 or Hoffa's fracture). For those fractures, a 4.5-mm T buttress plate is recommended¹⁴⁴.

Figure 58 - A. Type B1 distal femur fracture. B. Postoperative after open reduction and internal fixation using interfragmentary lag screws and a 4.5-mm dynamic compression plate as a buttress plate. C. In strong bone, a buttress screw (arrow) may be used¹⁴⁵.



The principles used for **type C fractures** (extra-articular and unicondylar intra-articular fractures of the distal femur) are combined when managing the more complex complete articular fractures. The first step is anatomic reconstruction of the articular surface using the techniques described for intraarticular fractures and is of prime importance. The second step is equally important and involves reduction and fixation of the extra-articular component of the fracture by using the same techniques described for treating type A fractures.

Type C1 fractures are not comminuted on either the joint surface or in the extra-articular portion. The surgical approach depends on the type of fixation to be used. Adequate exposure of the joint surface is imperative. Anatomic reduction of the intraarticular component is maintained by lag screw fixation. Reduction of

the extra-articular component can then be accomplished by open direct reduction, open indirect reduction, or closed reduction, as previously described. The fixation of the supracondylar segment can then be accomplished with a 95-degree condylar blade plate, a condylar screw, a locking plate, an antegrade interlocking femoral nail, a retrograde supracondylar nail, or a full-length retrograde femoral nail.

Type C2 fractures are not comminuted on the joint surface, but they are comminuted in the supracondylar area. Management follows the same guidelines as for type C1 fractures. The reduction of the comminuted supracondylar area ideally would avoid open direct reduction and is more appropriately accomplished using indirect reduction methods or closed reduction techniques. The fixation choices then include the 95-degree blade plate, the condylar screw, a locking plate, an antegrade interlocking femoral nail, a retrograde full-length femoral nail, or a retrograde supracondylar nail (see Fig.59).

Figure 59 - A. Type C2 distal femur fracture. B. Postoperative, lag screw fixation of the articular component and indirect reduction and bridge plate fixation using the 95-degree blade plate for the extra-articular part. C, D. Healing progression¹⁴⁶.



The type C3 fracture pattern is not only the most complex distal femur fracture; it is the most common in our experience (59 of 119 type C fractures were C3). These fractures are comminuted both at the articular surface and in the supracondylar region. The joint surface comminution complicates the surgical treatment and increases the risk of poor outcome from posttraumatic osteoarthritis. The surgical approach must provide exposure of joint surface so all articular fragments can be reduced and fixed. Temporary fixation with K-wires, followed by permanent fixation using lag screws, is the usual strategy. When there is significant intercondylar comminution, it is important not to narrow the distal femoral articular surface. Screws placed across comminuted

areas of the joint should not be inserted as lag screws, to avoid narrowing the joint surface. Ideally, all screws should be inserted from a non-articular position. If the screws must be inserted from an intraarticular site, then they must be countersunk to bury the head, or Herbert-type screws can be used. Reduction and fixation of the non-articular component follow the same principles as for type A3 fractures; however, intramedullary devices are rarely appropriate. A fixed-angle device such as the 95-degree condylar blade plate or a condylar screw may be an option. It may not be possible to use either of those implants if the supracondylar fracture is close to the joint surface because there may not be enough bone to accept the implant. Fractures with marked articular comminution that have required multiple AP screws for fixation of coronal plane fractures may also preclude the use of either of the fixed-angle devices. In both those situations, the condylar buttress plate has been used in the past. Because it is not a fixed-angle device, it cannot be used to assist in the reduction of the supracondylar component of the fracture in the same way that the blade plate or the condylar screw devices can be used (see Fig.60)

Figure 60 - A. Type C3 distal femur fracture. B. Postoperative films after open reduction and internal fixation with lag screw fixation of the articular components and a dynamic condylar screw¹⁴⁷.



During fixation of supracondylar femur fractures, the surgeon must assess the stability of fixation and quality of the bone. If the fixation is solid and bone quality good, some patients can be allowed early weight bearing and motion, especially when intramedullary fixation is used. If bone quality is good but not enough to allow early weight bearing, the patient may be placed in a hinged knee brace to allow early motion but kept off full weight bearing until radiographs show bone healing (at about 12 wk). If bone quality is poor, more rigid splinting may be required for about 6 weeks and then switched to a hinged brace. Postoperative physical therapy is usually required. Patients need to be monitored until the bone is healed.

With stable fixation, anatomic alignment, and restoration of intra-articular congruency, most patients do well. The more comminuted the fracture and the poorer the quality of bone, fixation, or reduction, the worse the prognosis. Severe comminuted type C3 fractures are expected to develop significant stiffness and posttraumatic arthritis. Patients with open fractures fair worse than closed fractures.

Periprosthetic fractures and dementia, heart failure, advanced renal disease, and metastasis lead to reduced survival. Surgical delay greater than 4 days increases the 6-month and 1-year mortality risks. Mortality after native fractures of the distal femur in the geriatric population is high and similar to mortality after hip fractures¹⁴⁸.

2.2.1. LATE COMPLICATION OF SUPRACONDYLAR FEMORAL FRACTURES AND TREATMENT.

Late complications are often the persistence of early ones. Infection may persist and may become chronic osteomyelitis. Reduction and fixation problems may result in malunion, nonunion, or both. A less than anatomic joint surface may result in the development of early arthritis in the knee. Similarly, infection in the knee, which is often subtle, can lead to early arthritis of the knee.

Late infection can be in the form of osteomyelitis, chronic septic arthritis, infected nonunion, or some combination of these. This section deals with posttraumatic osteomyelitis of the distal femur. Infected nonunion is considered later in the discussion of nonunion.

The chronic bony infection rate after a fracture of the distal femur treated operatively is probably about 5%. Many of these infections can be treated after the fracture is healed by removal of the internal fixation, debridement of the obvious infected soft tissue and bone, and administration of local (antibiotic beads) and systemic antibiotics. Unless the infection is persistent and dangerous, the internal fixation should not be removed until the bone has undergone sufficient remodeling to have inherent mechanical stability. This may take 18 to 24 months if the fracture has extended up into the diaphyseal bone of the femur, which does remodel quickly after rigid fixation. A period of restricted weightbearing may be in order if the bone removed is of sufficient volume to undermine the mechanical integrity of the bone or if there has not been enough time for bone remodeling. Failure to restrict weightbearing may result in a

refracture through infected bone and soft tissue, a difficult problem that is best avoided.

Proper debridement of the soft tissue leaves a defect. If the defect is small, the wound can be closed over the antibiotic-loaded beads. If the defect is large, the beads should be left in place in a sealed bead pouch for up to 6 weeks, at which time they can be removed, and the wound may be closed by whatever means possible.

Fortunately, the femur is a bone that heals readily, and **nonunion** is not common. Even more fortunately, the epiphyseal (joint surface) portions of the bone heal frequently, and nonunion is rare. The exceptions to this rule are the partial articular fractures (type B fractures). These fractures often have vertical fracture lines subject to high shearing forces. It is often difficult to design fixation that adequately resists these high shearing forces. Furthermore, the distal fracture fragments are often poorly vascularized.

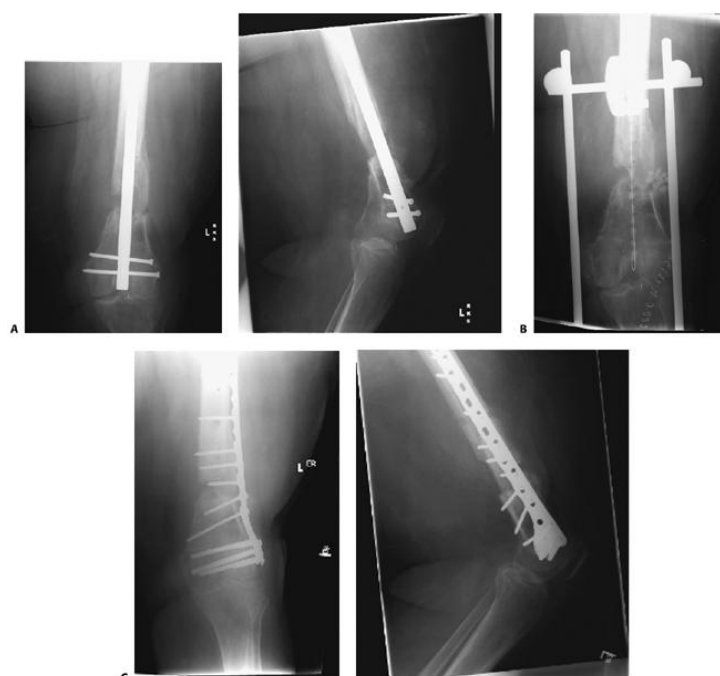
The principle of treating a **nonunion of a partial articular fracture** is to gain rigid fixation through the use of compression, to buttress against inevitable shear forces, and to prevent unnecessary stress by enforcing non-weightbearing. Ideally, fixation will avoid the joint surface, but transarticular surface fixation may be necessary, either with Herbert's screws or conventionally headed screws. The screws should be strong, should ensure good fixation of the distal fragment, and should be capable of high compression.

Nonunions of the metaphyseal portion of a supracondylar fracture are usually accompanied by already healed articular pieces, so they become type A fractures instead of type C fractures. Again, the establishment of rigid fixation is

most important. The construct most often used to establish this fixation is the 95-degree condylar blade plate with interfragmental screws¹⁴⁹.

If rigidity is not accomplished with this device, a second short medial plate, again under compression, should be applied. It is preferable to use the compression device instead of the “dynamic” compression built into the sloped holes of dynamic compression-type plates (see Fig.61).

Figure 61 - A. Infected metaphyseal nonunion with retrograde intramedullary nail in place. B. Removal of fixation, debridement, insertion of antibiotic beads, spanning external fixation, and antibiotic therapy. C. Later, locking compression plate¹⁵⁰.



Malunions occur as a result of failure of reduction or failure of fixation. Many of these complications can be prevented. However, the vagaries of bone strength, bone behavior, and patient behavior are such that the surgeon should feel guilty only about failure and preventable errors in preoperative planning.

Malunion most often occurs with the distal fragment in varus. Distal femur fractures fixed with an intramedullary nail placed while the patient is in the lateral position will, if they develop a malunion, have valgus of the distal

fragment. Flexion of the distal fragment seems to be more common when the fracture is treated with a nail and extension than when it is treated with a plate or blade plate. Rotation can occur with either technique, but it is usually of greater magnitude when a nail is used. Malunion in shortening is more common than in lengthening, but both situations are possible. Again, lengthening is more common with intramedullary techniques.

Patients with a pure rotational malunion may be managed by a minimally invasive osteotomy with an intramedullary saw, followed by fixation with a locked nail.

Fortunately, intraarticular malunions are rare unless the patient has been treated conservatively. These malunions do occur in type B fractures. Intraarticular osteotomies are difficult to perform and to stabilize, and they often result in a fragment with little or no blood supply.

The more common malunions are those that have angular deformity at the fracture site in either or both of the AP or medio-lateral planes. These malunions should be treated with an osteotomy directly at the fracture site. The final length in a closing wedge osteotomy will be the sum of the proximal and distal fragments as measured on the concave side. If this length is not acceptable, an opening wedge osteotomy with the insertion of a tricortical bone graft can be done. An opening wedge osteotomy will result in length equal to that measured on the convex side of the fracture. If this measurement is not satisfactory, then one should consider doing a slow distraction over a nail to gain appropriate length. All lengthening procedures have potential or real problems with postoperative knee flexion, and the surgeon may have to use

judgment about whether the lack of knee flexion or the shortening is the lesser of the two evils before embarking on a lengthening procedure.

Painful internal fixation is so common after internal fixation of distal femur fractures that it is as much a necessary evil as a complication. Screws that are too long and protrude out the medial side are particularly troublesome for the patient; these should be avoided in the index operation. When present, these devices can be removed and replaced or left out, depending on the stage of fracture healing.

Most of the time, removal of the painful fixation is a simple matter of reopening the previous incision and removing the offending metal. One must use great caution, however, in removing a plate from the medial femur. These plates are much easier to put in than to remove.

Knee stiffness in one form or another is a not too uncommon sequel of having a fracture of the femur into or just above the knee. The patient may have a fixed flexion deformity or limited range of flexion or both. Knee stiffness can have intraarticular and extra-articular components. It is often difficult to tell preoperatively which of the components is the major one. If the affected knee has more flexion with the hip flexed, then the quadriceps (rectus at least) plays a role.

Of course, the best approach to knee stiffness is to prevent it when possible.

Once it is determined that a knee is stiff and no amount of physical therapy is going to improve it, a surgical plan is made. This may include gentle manipulation while the patient is under anesthesia, which rarely works. Vigorous manipulation may disrupt the fixation or may cause a new fracture. Surgically

loosening the knee follows a failed attempt at gentle manipulation. Often, it is helpful to consult a plastic surgeon if the patient has areas of scars, split skin grafts, or flaps. It has occurred that knee motion has been established but skin closure has not.

Posttraumatic arthrosis may accompany any intraarticular fracture. It can also occur in extra-articular fractures, which are held in misalignment, particularly varus. Prevention of this complication, at least for many years, is at least theoretically possible by anatomic reduction of the distal femoral joint surface, correct alignment, and maintenance of knee motion.

Radiologic development of osteoarthrosis is common but often minimally symptomatic. Symptomatic osteoarthrosis should be treated like osteoarthrosis of other causes. Both intraarticular and extra-articular osteotomies can be used to attempt to obtain a smoother joint surface and better weight-bearing mechanics. End-stage arthrosis is best managed by either knee arthrodesis or knee arthroplasty.

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