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CURRENT CONCEPT AND MANAGEMENT OF FEMORAL SHAFT FRACTURES

Konsep dan Manajemen Terkini Fraktur Shaft Femur

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ABSTRACT

Femoral shaft fractures are severe injuries and are often associated with a high impact trauma mechanism, frequently seen in multiple injured patients. In contrast an indirect trauma mechanism can lead to a complex femoral shaft fracture especially in elderly patients with minor bone stock quality. Hence management of femoral shaft fractures is often directed by co-morbidities, additional injuries and the medical condition of the patient. Timing of fracture stabilization is depended on the overall medical condition of the patient, but definite fracture fixation can often be implemented in the early total care concept in management of multiple injured patients. Femoral shaft fractures (FSF) typically occur in a bimodal distribution, high-energy trauma in the young population, and lower energy trauma in the elderly population. FSFs are also associated with other comorbidities necessitating a thorough advanced trauma life support (ATLS) assessment and interdisciplinary care. Intramedullary nailing (IMN) is the most common treatment of physiologically stable patients. The goal of fixation is early healing and long-term functional recovery. Treatment of modern-day femoral shaft fractures results in excellent outcomes.

KEYWORDS:
Femoral Shaft Fracture, Non-Operative Management, Operative Management

ABSTRAK

Fraktur Shaft Femur (FSF) merupakan cedera yang parah dan sering dikaitkan dengan mekanisme trauma high-impact, sering dijumpai pada pasien dengan cedera multipel. Sebaliknya mekanisme trauma tidak langsung dapat menyebabkan FSF yang kompleks terutama pada pasien usia lanjut dengan kualitas cadangan tulang yang minim. Oleh karena itu penatalaksanaan FSF sering disesuaikan dengan penyakit penyerta, cedera tambahan, dan kondisi medis pasien. Waktu dilakukannya stabilisasi fraktur bergantung pada kondisi medis pasien secara keseluruhan, tetapi fiksasi fraktur yang definitif sering kali dapat dilakukan dalam manajemen awal pasien dengan cedera multipel. FSF dapat terjadi pada dua kelompok usia. Pada usia muda, penyebabnya adalah trauma energy tinggi dan pada usia tua penyebabnya adalah trauma energy rendah. FSF juga dikaitkan dengan komorbiditas lain sehingga membutuhkan penilaian Advanced Trauma Life Support (ATLS) secara cermat dan perawatan interdisipliner. Intermedullary Nailing (IM) merupakan tatalaksana yang paling umum dilakukan pada penanganan pasien yang stabil secara fisiologis. Tujuan fiksasi adalah penyembuhan dini dan pemulihan fungsional jangka panjang. Pengobatan FSF masa kini memiliki hasil yang sangat baik.

KATA KUNCI:
Femoral Shaft Fracture, Non-Operative Management, Operative Management

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INTRODUCTION

The incidence of femoral shaft fractures ranges from of 9.5 to 18.9 per 100,000 annually and results from high-energy trauma, often associated with poly-trauma, comminuted fractures, and open fractures (Nikolaou *et al.*, 2011; Li *et al.*, 2016). Winquist, Hansen *et al.* (1984) classified femoral shaft fractures into four types (Baker and Whitehouse, 2017). This is based on fracture comminution. The shaft of the femur constitutes the portion of the femur that lies between 5cm from the lesser trochanter to 5cm proximal to the adductor tubercle (Reuling *et al.*, 2012). Various classification systems exist for shaft fractures, but the anatomic classification is used in this study for the simplicity it projects: proximal femoral shaft fractures, mid shaft fractures and distal femoral shaft fractures (Baker and Whitehouse, 2017).

Treatment of femoral shaft fractures has spanned centuries. The rich history of femoral shaft fracture management reflects the challenges of maintaining anatomic alignment while encouraging early functional rehabilitation (Rutkow, 1993). Most femur fractures are treated surgically. The goal of early surgical treatment is stable, anatomic fixation, allowing mobilization as soon as possible (Reuling *et al.*, 2012; Testa *et al.*, 2017). Surgical stabilization is also important for early extremity function, allowing both hip and knee motion and strengthening. Injuries and fractures of the femur may have significant short and long-term effects on gait kinematics and function if alignment is not restored. Today, shaft fractures are treated either non-operatively (with skeletal traction and cast brace) or operatively (Gansslen *et al.*, 2014).

In a recent analysis comparing different treatment options in femoral shaft fractures, it could be clearly stated that intramedullary fixation of femoral shaft fractures was associated with the lowest complication rates and loss of reduction rates compared to external fixation or plating strategies (Ramseier *et al.*, 2010). Therefore, femoral nailing is the overall "gold standard" in treating femoral shaft fractures (Koh *et al.*, 2011).

This paper reviewed the anatomy, classification, investigations, and the current treatment options for femoral shaft fractures to complement and enhance our understanding of managing these types of fracture.

EPIDEMIOLOGY AND ETIOLOGY

The worldwide incidence of femoral shaft fractures ranges between 10 and 21 per 100,000 per year. Two percent of these fractures are open fractures (Enninghorst *et al.*, 2013; Dim, Ugwoegbulem and Ugbeye, 2016). The rate of atypical femur fractures as defined by the American Society for Bone and Mineral Research (ASBMR) Task Force 2013 ranges between 3.5% to 16% (Oliveira *et al.*, 2012).

FSFs demonstrate a bimodal distribution. Men are more likely to sustain a fracture between the ages of 15 to 35 while women begin to show a steady increase starting at age 60. Men are more likely to sustain FSFs from automobile accidents or other high-energy mechanisms. Women are more likely to sustain an FSF from ground-level falls. Automobile accidents are more prevalent in the younger population, while ground-level falls are more common in the elderly population, which is attributed to osteoporosis (Enninghorst *et al.*, 2013).

Femoral shaft fractures can result from high or low energy mechanisms and are often associated with other serious injuries. The most common causes include automobile accidents, falls from heights, ground-level falls in individuals with osteoporosis, and gunshots. A study from Finland found that 75% of FSFs were caused by high energy mechanisms, 87% of which occurred in MVCs (65% of all fractures). Other less common causes of FSFs are atypical fractures from bisphosphonate use, pathologic fractures through a bone lesion, insufficiency fractures from osteoporosis, and stress fractures from overuse in athletes and military recruits (Saita, *et al.*, 2015; Oliveira *et al.*, 2012; Enninghorst *et al.*, 2013).

ANATOMY CONSIDERATION

Proximally, the femur is composed of a specialized metaphyseal region consisting of the head, neck, and greater and lesser trochanters. Distally, the femur comprises the metaphyseal flare, which continues into the medial and lateral femoral condyles, separated by the intercondylar notch. The shaft, or diaphysis, is the segment inferior to the lesser and ending at the metaphyseal flair and condyles. Classically the first 5 cm distal to the lesser trochanter is termed the sub-trochanteric region and is considered a separate fracture pattern. These fractures are challenging to manage secondary to the muscular deforming forces. They will not be discussed in this article (Nikolaou *et al.*, 2011). According to the *Arbeitsgemeinschaft für Osteosynthesefragen (*AO) classification of fractures, the femoral shaft begins at the inferior border of the lesser trochanter. It ends proximal to the condyles at a distance equal to the greatest width of the femoral condyles (Li *et al.*, 2016). The diaphysis is a smooth cylinder with differences in cortical thickness throughout its length, which may aid in assessing intraoperative femoral rotation. The femur is bowed anteriorly with an average radius of curvature 120 cm (+/- 36 cm); the shorter the radius, the greater the bow (Baker and Whitehouse, 2017). The linea aspera is the major cortical thickening along the posterior aspect of the femur and is an attachment site for muscles and the medial and lateral intermuscular septa and acts as a compressive cortical strut (Reuling *et al.*, 2012).

Three abundant muscular compartments envelop the femur. The anterior or extensor compartment is responsible for knee extension and houses the femoral nerve. The posterior or flexor compartment is responsible for knee flexion and houses the sciatic nerve. The medial compartment houses the adductor muscles. In FSF, the sciatic nerve and specifically the peroneal division are at the highest risk to injury because they lay close to the femoral shaft. The adductor compartment houses the obturator nerve. The gluteal muscles also surround and attach to the proximal femur and shaft; they include the gluteus maximus, medius, and minimus and cover the superior and inferior gluteal nerves. In FSF, the muscles are deforming forces on the fracture fragments depending on the location of the fracture. Generally, the proximal segment is flexed, abducted, and externally rotated by the iliopsoas and hip abductors. The distal segment is pulled proximally (shortened) by the quadriceps and hamstrings and adducted by the adductor muscles. The main blood supply to the femur derives from the femoral artery, a continuation of the external iliac artery. The femoral artery passes under the mid-portion of the inguinal ligament and divides into the superficial femoral artery (SFA) and deep femoral artery (DFA), also known as the profunda femoris. The SFA supplies the tissues below the knee, and the DFA supplies the femoral shaft and the surrounding soft tissues (Ramseier *et al.*, 2010; Rutkow, 1993; Testa *et al.*, 2017; Gansslen *et al.*, 2014; Koh *et al.*, 2011; Koczewski and Shadi, 2013).

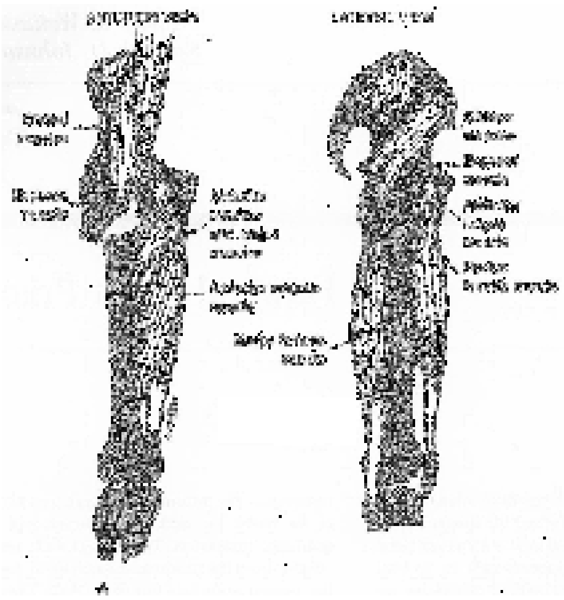

Figure 1. Anatomy of the femoral.

Multiple branches arise from the DFA, most notably the perforating arteries that encircle the femur. One or multiple nutrient arteries arise from the DFA or its branches to supply the inner 2/3 of the cortex and bone marrow. They anastomose with the metaphyseal-epiphyseal system. The periosteal blood supply supplies the outer one-third of the cortex (Koh *et al.*, 2011; Koczewski and Shadi, 2013).

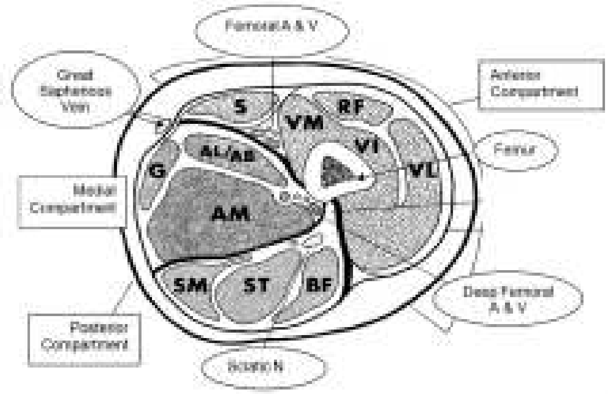

Figure 2. Anterior compartment of the femoral.

INITIAL EXAMINATION

Physical Examination

The life support protocols must be initiated for every traumatized patient, even those sustaining a ground-level fall to rule out associated morbidities that may preclude early definitive care. Clinically, shaft fractures manifest as pain, bruising, swelling, deformity, shortening, and instability around the thigh. In the poly-traumatized individual, injuries are frequently masked by more severe or painful injuries; therefore, a complete examination is imperative (Kajja *et al.*, 2010).

Open fractures of the femoral shaft are exceptionally severe injuries and occur in about 2% in all femoral shaft fractures (Kajja *et al.*, 2010). A thorough exam is essential to rule out open fractures, and if present, prompt administration of antibiotics and tetanus is imperative to reduce the risk of infection. Any gross debris should be removed in the acute setting, and the wound and bone covered in sterile saline-soaked dressing. Formal irrigation and debridement should follow in the operating room. Open fractures are classified according to the Gustillo-Anderson (GA) or the Oestern and Tscherne classification. Communication with the outside world can lead to significant uncontained bleeding and an increased risk of infection (Makridis, Tosounidis and Giannoudis, 2013). A study demonstrated an infection rate of 2.3% for GA type I and II vs. 17.6% for GA type III (Walmsley, Axelrod and Rodriguez-Elizalde, 2014). Open fractures do not preclude compartment syndrome that can develop as a result of blunt trauma and the violent motion of the femur moving through the surrounding tissues. A retrospective study of thigh compartment syndrome identified FSF in 48% of patients, of these 5 were open (Rodriguez-Merchan, Moraleda and Gomez-Cardero, 2013).

Documentation of neurovascular status is imperative. Although rare, a vascular injury may occur with femoral shaft fractures up to 2% of the time, particularly with gunshots and penetrating trauma (Keeney *et al.*, 2009). Damage to the deep femoral artery (DFA) and its branches is the most common and typically results in significant hemorrhage rather than ischemia due to abundant collateral flow. Because the thigh can hold around 1.5 L of blood, vascular injuries can contribute significantly to the shock state in a poly-traumatized patient (Makridis, Tosounidis and Giannoudis, 2013).

Injury to the SFA, on the other hand, causes ischemia to the leg and foot as its first branches arise in the popliteal fossa. The superficial femoral artery (SFA) is a conduit throughout the thigh. If vascular compromise is suspected, which is characterized by pulselessness, enlarging pulsatile hematoma, bruit, thrill, hemorrhage, and acute ischemia, the extremity should be placed in traction and ABIs obtained. If the ankle-brachial index is <0.9, a computed tomography (CT) angiogram and vascular surgery consultation are merited (Keeney *et al.*, 2009; Kumar *et al.*, 2019).

Typically, femoral shaft fractures are readily identified injuries due to thigh deformity and instability; however, on occasion, these injuries are not evident, and further assessment and imaging are required, such as radiographs and computed tomography (CT) scanning. Obtunded patients may necessitate more imaging to identify their injuries (Kumar *et al.*, 2019).

Imaging

X-rays of the chest and pelvis are obtained as part of the ATLS protocol. When the patient is stabilized, orthogonal radiographs of the suspected injured extremity, including the ipsilateral joints proximal and distal to the injury, should be obtained to characterize the fracture. These images help identify potential fractures to the acetabulum, proximal femur, proximal tibia, and patella and help identify a possible floating knee injury (Testa *et al.*, 2017; Canton *et al.*, 2017).

CT is typically not the initial imaging modality of the femur, but it is often the first form of imaging obtained in a poly-traumatized individual. It has utility in identifying occult injuries and characterizing the fracture for operative planning. Thin cut imaging can help identify occult femoral neck fractures not seen on standard radiographs. Combined with contrast, vascular lesions can be identified and expeditiously treated (Testa *et al.*, 2017).

CLASSIFICATION

Classification systems should guide the surgeon in his treatment options and predict outcome. Femoral shaft fractures are generally classified to the alphanumeric coding system of the AO (Gansslen *et al.*, 2014), (see Fig. 3).

1. A type: simple fracture, with 2 fragments
   A1: spiral, A2: oblique, A3: transverse
2. B type: more than 2 fracture fragments, but the main parts are still in contact
   B1: spiral, B2: oblique, B3: transverse.
3. C type: complex fracture type, the fracture fragments are not in contact to each other
   C1: 1 or 2 spiral wedges, C2: oblique or transverse, multi étagère, C3: complex, comminuted, with segmental bone defect.

Femoral fractures in children are classified following the alphanumeric system of the AO-PAEG (Joeris *et al.*, 2017). Sub-trochanteric fractures are described as 31-M/3.1-III, shaft fractures as 32-D/4 or 5. 70% of these juvenile fractures occur in the mid-shaft region, 22% are located proximally and 8% in the distal diaphysis (Rupp, Popp and Alt, 2020).

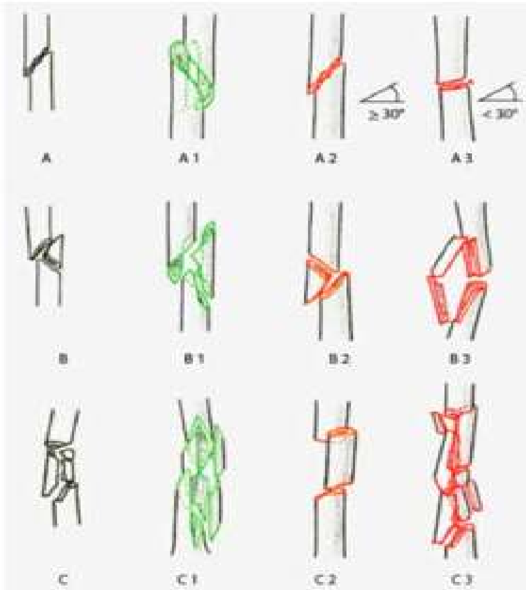

Figure 3. Graphic demonstration of the AO definition of femoral shaft fractures (Gansslen *et al.*, 2014).

For completion of sufficient description and classification of open femur fractures the soft tissue classification in open fractures is repeated: Gustilo and Anderson, originally designed to classify soft tissue injuries in tibial shaft fractures (Ibrahim *et al.*, 2017).

1. Grade I: clean skin opening of less than 1 cm, usually from inside to outside, minimal muscle contusion; simple transverse or short oblique fractures.

2. Grade II: laceration more than 1cm long, with extensive soft tissue damage; minimal to moderate crushing component; simple transverse or short oblique fractures with minimal comminution. – Grade III: Extensive soft tissue damage, including muscles, skin, and neurovascular structures; often a high-energy injury with a severe crushing component.
3. Grade III A: extensive soft tissue laceration, adequate bone coverage; segmental fractures, gunshot injuries; minimal periosteal stripping.
4. Grade III B: Extensive soft tissue injury with periosteal stripping and bone exposure requiring soft tissue flap closure; usually associated with massive contamination.
5. Grade III C: Vascular injury requiring repair.
6. Tscherne and Oestern classification (Ibrahim *et al.*, 2017) respects size of wound, level of contamination, and mechanism of fracture
7. Grade I: small puncture wound without associated contusion, negligible bacterial contamination, low- -energy mechanism of fracture.
8. Grade II: small laceration, skin and soft tissue contusions, moderate bacterial contamination, variable mechanisms of injury.
9. Grade III: large laceration with heavy bacterial contamination, extensive soft tissue damage, frequent associated arterial or neural injury.
10. Grade IV: incomplete or complete amputation with variable prognosis based on location of and nature of injury (e.g. cleanly amputate middle phalanx vs. crushed leg at proximal femoral level).

MANAGEMENT

Treatment of femoral shaft fractures can be operative or non-operative. Operative fixation with intramedullary nailing is the gold standard of treatment in the high-income countries. Other operative techniques include plate osteosynthesis and external fixation. Closed treatment with traction, splinting, and casting may be temporary treatment or definitive treatment in some third-world countries (Nahm and Vallier, 2012).

1. Non-operative Management

Conservative treatment of femoral shaft fractures in adults is only exceptional as surgical stabilization techniques offer significant advantages in terms of morbidity, mortality, and functional outcome (Kajja *et al.*, 2010). Only in presence of general contraindications for anesthesia and surgery traction treatment or even cast treatment can be initiated.

First responders at the scene of an accident must quickly assess for any potentially lifethreatening injuries. Special attention must be placed on the lower extremities where significant pooling of blood is possible, as discussed earlier. Temporary traction devices such as the Thomas, Hare, Sager, Kendrick, CT-6, Donway, and Slishman splints may be utilized to stabilize apparent femoral injuries. Longitudinal traction applied to the extremity stabilizes the fracture site, restoring the gross length, alignment, and rotation. Traction may also relieve pressure on neurovascular structures and tamponade bleeding by stabilizing the surrounding clot. These devices should be promptly exchanged for fiberglass vs. plaster splint or skin vs. skeletal traction in the hospital because prolonged use may cause pressure sores or compress neurovascular structures distally (Matullo, Gangavalli and Nwachuku, 2016).

More tolerable and effective traction systems include skin and skeletal traction that provide better distraction of the affected extremity. Skin traction, also called Bucks traction, is applied through a boot attached to the distal extremity with a counterweight. The problem specific to this technique is a shear injury to the underlying dermal tissue (Even *et al.*, 2012).

In skeletal traction, a pin is placed through the bone distal to the injury preventing the soft tissues from bearing the traction forces. Common sites of pin placement include the distal femur, proximal tibia, and calcaneus, with the distal femur as the preferred placement because of the superior force vector, better control, and ability to range the knee. In rare cases, skeletal traction may serve as a prolonged treatment in medically unstable patients or as definitive treatment in certain parts of the world. Complications of skeletal traction include pin site infections, iatrogenic neurovascular injury, muscle wasting, immobility, mal-union, deep vein thrombosis, and pulmonary embolism (Even *et al.*, 2012). In high-income countries, the preferred treatment is operative fixation resulting in superior outcomes and less morbidity and mortality compared to traction (Eman *et al.*, 2015).

2. Surgical Treatment

a. *Intramedullary Nailing*

Intramedullary nailing (IMN) is the gold standard of treatment for femoral shaft fractures. Early definitive treatment in systemically stable patients within 24 to 48 hours reduces the incidence of pulmonary complications, infection rates, and mortality. Hemodynamically stable patients with multiple injuries received the most benefit from early fixation. Delayed treatment increases pulmonary complications in up to 56% of patients compared to only 16% of patients treated early (Kumar and Narayan, 2014; Lefaivre *et al.*, 2010).

The insertion site of an IMN is outside the zone of injury, preserving the surrounding blood flow and retains the hematoma that contains beneficial bone growth factors. Intramedullary nailing also has the benefits of early weight-bearing that helps maintain muscle mass, function, strength, and mobility (Kumar and Narayan, 2014).

b. *Antegrade Nailing*

Antegrade nailing is the gold standard treatment of femoral shaft fractures with excellent outcomes if patients are treated within the first 24 hours. Early fixation decreases pulmonary complications, improved rehabilitation, reduced length of stay, and lower healthcare costs (Byrne *et al.*, 2017).

There is debate about the benefits of early fixation in patients with closed head injuries, with some studies demonstrating an increased incidence of pulmonary complications and CNS function with early treatment secondary to a second hit phenomenon of hypoxia and hypotension. Other studies have shown that early fixation does not increase CNS complications, rather it is the head injury itself that increased the risk of both CNS and pulmonary complications. However, it is advised to avoid hypoxia and hypotension in these individuals and to consider less invasive treatments in the acute phase of treatment (Byrne *et al.*, 2017; Harvin *et al.*, 2012; Hussain *et al.*, 2017).

Approaches include the piriformis, trochanteric, and lateral entry. In the piriformis entry approach, the nail trajectory is along the long axis of the femur, and a straight design nail is used. Disadvantages of this approach include injury to the abductor muscles with resultant Trendelenburg gait and damage to the blood supply to the femoral head. The trochanteric entry technique spares the abductors to a greater degree, and it is easier to establish the starting point. The anterior and lateral bow of the nail accommodates the curvature of the femur. Using a straight nail in this approach risks perforation of the anterior cortex or when the starting point on the greater trochanter is too posterior. The trochanteric entry technique has a reduced operative and fluoroscopic time compared to the piriformis entry technique. Long term functional outcomes are equivalent between the approaches (Hussain *et al.*, 2017; Sheth *et al.*, 2016; Zhang *et al.*, 2015).

c. *Retrograde Nailing*

Retrograde nailing has recently become more popular. Indications for this technique include the ipsilateral femoral neck, acetabular, and tibia fractures (floating knee injuries), bilateral femur fractures, pregnancy, and morbidly obese individuals. Studies have demonstrated comparable outcomes to antegrade nailing. Union (100% vs 99%), mal-union (11% vs 13%), and non-union rates (6% vs 6%) are similar for retrograde and antegrade approaches. A common complaint of retrograde nailing is knee pain, while for anterograde nailing, it is hip pain and stiffness (Kim *et al.*, 2018; El Moumni *et al.*, 2010).

The starting point in this approach is in the middle of the intercondylar notch and 2 to 4 mm anterior to the distal tip of Blumensaat's line. Despite entering the knee joint, there is no increase in septic knees. Long term, patients may report anterior knee pain or screw irritation distally. Iatrogenic injury to the cartilage and ligaments of the knee is possible (Kim *et al.*, 2018; Tomlinson and Silva, 2013).

d. *Plate Osteosynthesis*

Open reduction internal fixation (ORIF) techniques developed in the 1960s were the first operative techniques utilized for fracture fixation. Over time, a better understanding of biologic and mechanical processes in fracture fixation was established. ORIF is typically not the primary treatment of femoral shaft fractures unless there is extension to the proximal or distal femur, which may be a contraindication to intramedullary nail fixation. Plates are used in recalcitrant non-unions, peri-prosthetic and peri-implant fractures, narrow femoral canals, and open fractures with vascular injury. Open plating techniques require fracture site visualization and significant soft tissue stripping around the fracture site, resulting in interruption of blood flow to the bone, especially the periosteum (Andalib *et al.*, 2017). Extensive soft tissue dissection may also increase an individual's inflammatory response to surgery, further complicating care, and tissue healing. Minimally invasive techniques such as minimally invasive plate osteosynthesis (MIPO) avoid exposure of the fracture site. The plate is introduced away from the fracture site, positioned sub-muscularly but above the periosteum, and fixed percutaneously. Bridge plating is a technique that spans an area of comminution with fixation proximal and distal to the affected area (Testa *et al.*, 2017).

e. *External Fixation*

External fixation is indicated for patients with open fractures, vascular injuries, poly-trauma, stabilization for transfer, and those unstable for early definitive care. External fixators can be applied with minimal effect on the trauma patient's disease burden. Fixator constructs can vary from surgeon to surgeon, but the governing principles are stable fixation with the relative restoration of length, alignment, and rotation. Neurovascular structures can be avoided by placing pins laterally into the femur rather than from anterior to posterior. Proximal pins can be placed into the femoral neck and head, while distal pins may be placed in the distal femur or proximal tibia. Infrequently external fixators can be used as definitive treatment if conversion to internal fixation is contraindicated because of medical or other orthopedic problems. Definitive treatment with external fixation has a relatively high complication rate, such as loss of reduction, mal-union, pin site infections, osteomyelitis, non-union, and joint stiffness. Treatment with an external fixator is rare because of the successful early treatment with intramedullary nailing (Pairon *et al.*, 2015).

CONCLUSION

Femoral shaft fractures have a high incidence in multiple injured patients. Management of the fracture under these circumstances depends on the overall medical condition of the patient. No evidence has been proven yet for a definite treatment scheme but a trend is found for early definite care for patients in clinically stable conditions. This is mainly due to the further development of modern intramedullary nailing devices which handling and insertion are facilitated by design and fixation options. Median surgical time and blood loss could have been reduced and hence risk of thromboembolism is minimized. Individual cases can be challenging in management, especially peri-prosthetic femoral fractures, and plate fixation might be the more suitable fixation method. Beside general postoperative complications mal-rotation still is the most frequent one. Perioperative radiographic control of the projection of the lesser trochanter, the width of the cortex in the aligning fragments or the cross-section dimension of the intramedullary space are not reliable parameters for intraoperative control of the rotation. Postoperative CT-scan assessment evaluates definite leg axis and rotation.

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