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Current Approaches to Distal Femur Fracture Management

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Abstract:

Distal femoral fractures are complex injuries that pose significant challenges in orthopedic practice due to their anatomical location, fracture patterns, and frequent association with severe soft tissue damage and osteoporosis. These fractures commonly result from high-energy trauma in young patients and low-energy falls in the elderly, leading to considerable morbidity and impaired knee function if not properly managed. Although operative fixation has become the standard of care, the optimal treatment strategy remains controversial because of the wide variety of fracture configurations and patient-related factors. Recent advances in surgical techniques and implant design have aimed to improve fracture stability, promote early mobilization, and enhance functional outcomes; however, complications such as nonunion, malalignment, infection, and knee stiffness continue to be reported. Therefore, evaluating current treatment modalities and their clinical outcomes is essential to guide optimal management of distal femoral fractures.

Keywords: Distal femur fracture; Femoral fractures; Locking plate; Retrograde intramedullary nail; Internal fixation; Functional outcome.

Introduction:

Distal femoral fractures represent a challenging subset of lower limb injuries, accounting for approximately 3–6% of all femoral fractures. They demonstrate a bimodal age distribution, occurring in young adults following high-energy trauma such as road traffic accidents, and in elderly patients as a result of low-energy falls in the presence of osteoporosis. These fractures are frequently associated with severe soft tissue injury, comminution, and intra-articular extension, which complicates management and adversely affects functional outcomes. In addition, distal femoral fractures are often accompanied by associated injuries and medical comorbidities, particularly in elderly patients, further increasing morbidity and mortality rates (1).

The primary goals in the treatment of distal femoral fractures are restoration of limb alignment, stable fixation, early mobilization, and preservation of knee function. Over the past decades, advances in surgical techniques and implant design have shifted management toward operative fixation in most cases. Locking compression plates and retrograde intramedullary nails have become the mainstay of treatment, offering improved biomechanical stability, especially in osteoporotic bone and comminuted fracture patterns. However, despite these advances, complications such as nonunion, malunion, infection, and knee stiffness remain common, and the optimal treatment strategy continues to be debated. Careful fracture assessment, appropriate implant selection, and adherence to sound surgical principles are essential to achieve favorable clinical and radiological outcomes (2).

i) Conservative treatment:

Conservative treatment is associated with unsatisfactory outcomes**.**(3)

Indications:

- o Medically unfit (e.g., severe cardiopulmonary risk) or expected death.
- o Non ambulatory patients (e.g., paraplegia)**.** (3)

Contraindications:

- Young active patient.
- Additional knee derangement.

Disadvantages:

- Weakening of extensor mechanism.
- Knee stiffness secondary to immobilization.
- Malunion / Nonunion.
- Deep venous thrombosis (DVT).
- Decubitus ulcers and generalized muscle atrophy**.** (3)

Advantages:

- Decrease the complications associated with surgery (no surgery).

The goals of conservative treatment are not anatomical reduction of fracture fragment, but reasonable restoration of overall length and axial alignment, as the proximity of the fracture to the knee joint, small degrees of malalignment may have adverse long-term effects on the joint mechanics. This can be done with upper tibia Steinman pin traction with a Thomas splint and Pearson knee attachment. Placement of a distal femoral pin not preferred because of significant soft tissue swelling, hemarthrosis, and fracture comminution**.** (3)

ii) Surgical treatment(4):

Initial resuscitation of patients in emergency room, splinting limb, appropriate radiographs and CT scan. In case of open fractures Intra-venous antibiotics (2nd generation cephalosporins, gentamycin) at admission, metronidazole and tetanus prophylaxis were also administered where anaerobic contamination was suspected. In cases which needed debridement, emergency debridement is done within 6–8 hours.

Pre-operative investigations were done consisting of complete blood count (CBC), prothrombin time (PT), international normalized ratio (INR), liver function tests, random blood sugar (RBS), kidney function tests, electrocardiogram (ECG) and echocardiogram (ECHO), Doppler ultrasound for high risk patients.

Indications:

- Displaced intra-articular fractures.
- Young active patient.
- Associated derangement of the knee.
- Pathological fractures.

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- Fractures in polytraumatized patient.

Contraindications:

- Patient unfit for surgery.

The goals of operative treatment of distal femur fractures are:

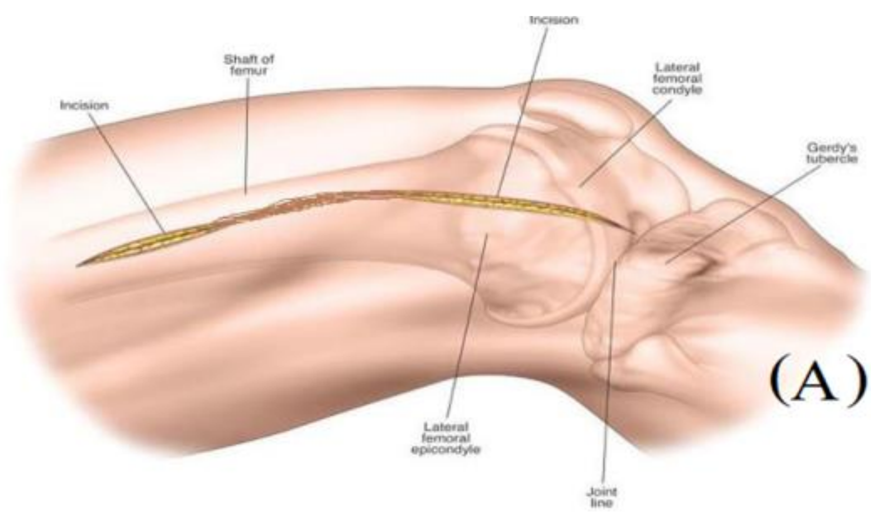
- Anatomical realignment of fractures.
- Stable fixation of the fractures.
- Rapid mobilization of the knee joint.
- Early functional rehabilitation of joint by physiotherapy.

Surgical approaches:

i) Lateral Approach: (Standard Technique):

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 of fractures in this area **(Fig. 1)**. The skin incision is longitudinal and distally centered over the lateral epicondyle. It should be long enough to allow gentle soft tissue retraction. The length of the incision should be determined based on the preoperative plan. The fascia lata is incised in line with its fibers exposing the vastus lateralis, which is reflected off the intermuscular septum along the linea aspera in an anterior direction. Perforators are identified and ligated or cauterized. This careful dissection is started distally and carried proximally**.** (5)

Wide soft tissue stripping is avoided to prevent devitalization of bone fragments. Visualization of the articular surface of the lateral condyle is satisfactory, but exposure of the intercondylar notch and medial condyle are more limited. When more access to the joint is needed, the incision can be extended distally and curved medially to allow for greater patellar subluxation. A tibial tubercle osteotomy can be performed (rare) to allow for reflection of the extensor mechanism and wide articular exposure. Knee flexion must be restricted for a period of time after tibial tubercle osteotomy; thus its use has been limited**.** (5)



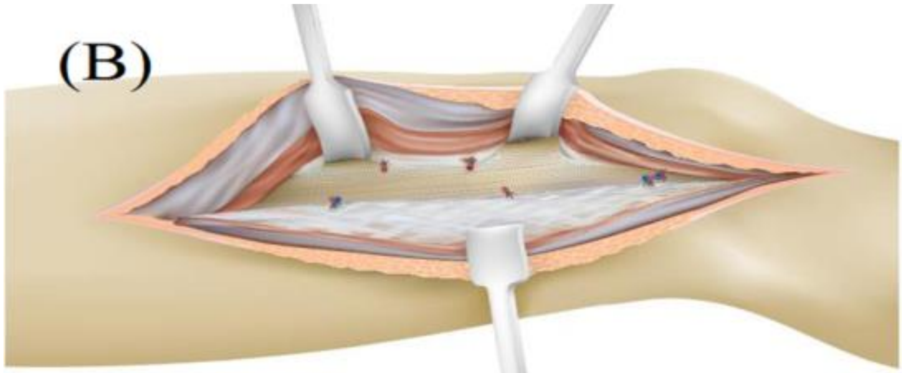


Figure (1): Lateral open approach to the distal femur. A: Lateral skin incision. B: The plane of incision is through the lateral iliotibial band and between the vastus lateralis and the lateral intermuscular septum to the bone. (5)

ii) Swashbuckler approach (modified anterior approach):

This approach can be used as an alternative to the standard lateral approach **(Fig. 2)**. 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. Extend the incision directly down to the fascia of the quadriceps. Incise the quadriceps fascia in line with the skin incision. Sharply dissect the quadriceps fascia off the vastus lateralis muscle laterally to its inclusion with the iliotibial band. Retract the iliotibial band and fascia laterally, continuing the dissection down to the linea aspera. Incise the lateral parapatellar retinaculum, separating it from the vastus lateralis. Make a lateral parapatellar arthrotomy to expose the femoral condyles. Place a retractor under the vastus lateralis and medialis, exposing the distal femur and displacing the patella medially. Ligate the perforating vessels, and elevate the vastus lateralis, exposing the entire distal femur**.** (6)

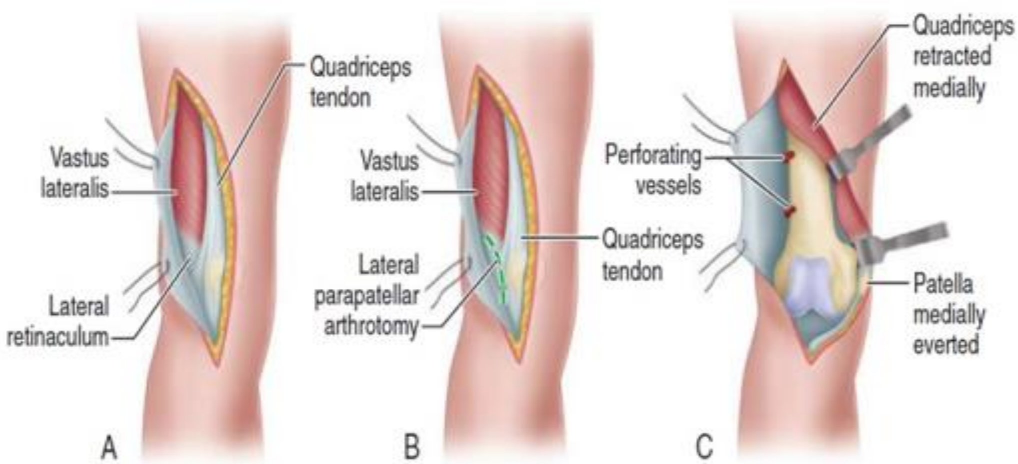


Figure (2): Swashbuckler technique. A, Fascia overlying quadriceps is incised longitudinally and lifted laterally off underlying muscle. B, Farther laterally, fascia over quadriceps becomes confluent with iliotibial band. Lateral parapatellar arthrotomy is performed. Proximally, arthrotomy incision is made between vastus lateralis muscle and lateral retinaculum of knee. C, Proximal release of vastus lateralis fibers from lateral intermuscular septum allows further mobilization of quadriceps. Perforating vessels can be controlled with cautery. (6)

iii) Medial Approach:

The medial approach to the distal femur is used for ORIF of displaced medial condyle fractures (B2 and B3) or to repair other unstable injuries not well repaired from the lateral side. Approach along the posterior border of the vastus medialis obliquus (VMO) muscle is recommended, the so called “sub-VMO approach” **(Fig. 3)**. A straight medial skin incision is made over the adductor tubercle and extended proximally into the distal thigh. Proximal extension with this approach should be performed carefully, as the femoral vessels pierce the adductor magnus 10 to 12 cm above the knee joint. The fascia over the VMO is incised longitudinally and the muscle belly retracted proximally and anteriorly, then the VMO tendon is incised transversely in the anterior direction toward the patella where the tenotomy is extended distally as a medial parapatellar arthrotomy, while leaving a cuff to repair to. Care should be taken to protect the medial collateral ligament and medial meniscus. If a surgeon is using a medial approach to supplement lateral fixation, stripping to soft tissue should be minimized to avoid problems with healing and/or infection**.** (7)

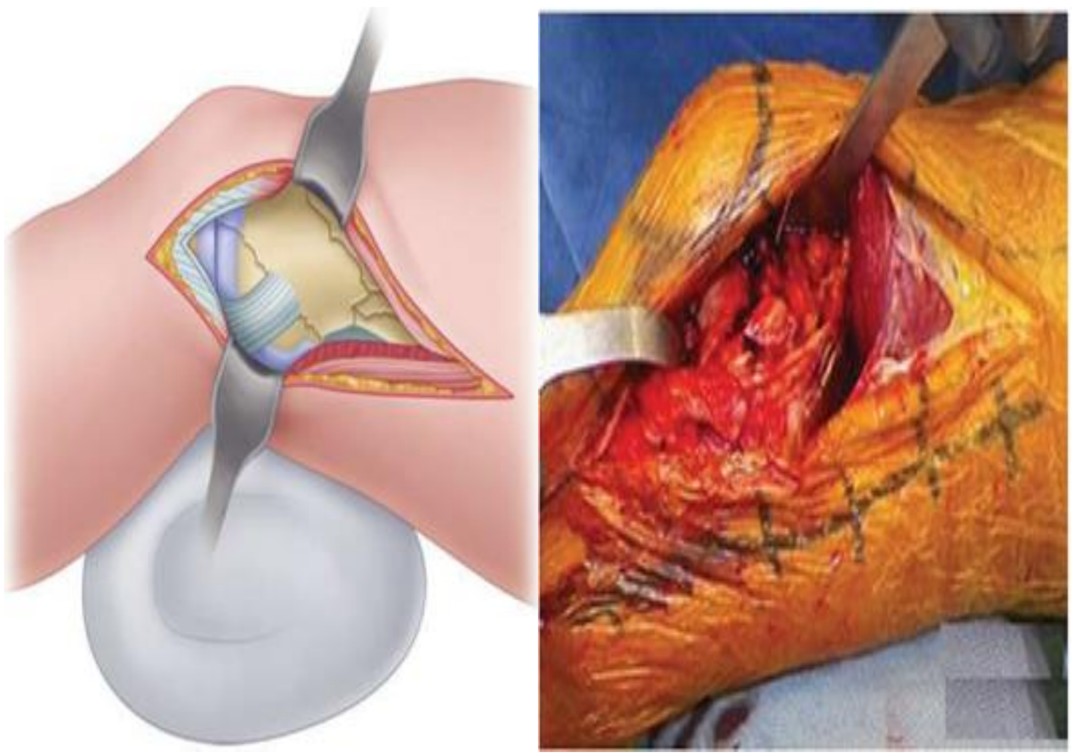


Figure (3): Medial approach to the distal femur is facilitated by a VMO sparing approach. The muscle is elevated proximally and an “L” shaped tenotomy is performed distally, which includes a medial parapatellar limb. (7)

Principles of internal fixation:

Sequences in the surgical management of supracondylar fracture includes:

- Anatomic reduction of articular surface.
- Restoration of limb alignment, length and rotation.
- Impaction of fracture in osteoporotic patients.
- Early mobilization of knee.

Methods of internal fixation of distal femoral fractures:

In operative treatment, various modalities include:

1. Open Reduction Internal Fixation (ORIF) with Dynamic Condylar Screw (DCS).
2. ORIF with Condylar Buttress plate.
3. ORIF with Cancellous screws.
4. Closed Reduction & Internal Fixation with supracondylar nail.
5. External fixation.
6. ORIF with Locking Compression Plate (LCP).

Dynamic Condylar screw (8)**:**

DCS has a 95 degree angle between the screw and side plate, and both the screw and side plate are available in a variable lengths **(Fig. 4)**. The condylar screw must be introduced parallel joint line on the both AP and Lateral view of femoral condyles, so that the plate will sit flat on the lateral mid femur and the threaded portion should cross fracture site. This causes compression at the fracture when the screw is tightened. The large diameter threads of DCS lag screw firmly grip the cancellous bone. The round and oval holes of the DCS side plate when used in compression mode causes compression at the extra articular portion (shaft and metaphysis) of the fracture site. A condylar screw inserted in a valgus position will force the knee into varus when the side plate is attached to the shaft, conversely when inserted in varus, a valgus position of the knee will result.

The advantages of DCS include the ability to apply interfragmentary compression through femoral condyles which can be obtained by a lag screw and provides better purchase in osteoporotic bone. The main disadvantages are the bulky shoulder which interfere with the free movement of iliotibial band and the difficulty to apply this device in extremely distal fractures (at least 4 cm of intact lateral cortex above the intercondylar notch of femur is needed to apply it). (8)

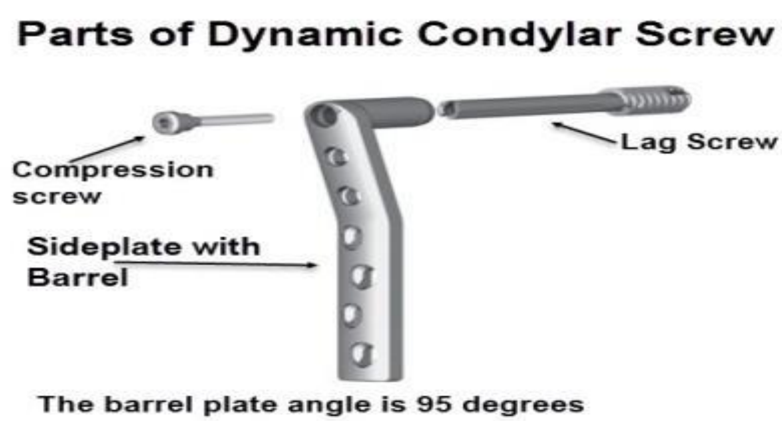


Figure (4): DCS has a 95 degree angle between the screw and side plate. **(8)**

Condylar Buttress plate (9)**:**

Condylar buttress plates have been designed to be used for C3 fractures of distal femur (complete articular fracture multifragmentary) according to the AO classification **(Fig. 5)**. They come in a right and a left version. The plate has a cloverleaf-shaped distal portion which allows the placement of up to six cancellous screws, these cancellous screws are helpful in the presence of multiple intraarticular fractures in the coronal or sagittal plane. Mechanically it is not as strong as a blade plate or condylar screw with side plate and therefore should not be substituted for these implants.

The disadvantage of this plate is that there is no fixed angle between screws and the distal holes as is seen in a locking plate. With indirect reduction techniques the screws may shift relative to the plate producing varus deformity or valgus deformity, so its use should be restricted to cases in which the lateral femoral condyle is comminuted or there are multiple intraarticular fractures in the coronal or sagittal plane. In cases with extensive medial comminution a second medial plate needs to be used to prevent varus deformity. (9)

Figure (5): Right and a left version of condylar buttress plate. (9)

Intramedullary Supracondylar Nail (10)**:**

These nails have been developed specifically for retrograde insertion through the intercondylar notch **(Fig. 6)**. It was developed by Green Seligson and Henry and hence was called GSH nail. It is a cannulated closed section stainless steel intramedullary device designed specifically to provide fixation for supracondylar fracture. It is available in 10mm, 11mm, 12mm, or 13mm outer diameter. It has many advantages as minimizing soft tissue and periosteal damage, thus preserving vascularity of the fracture site. Less surgical dissection is required resulting in less blood loss, less muscle damage and less postoperative discomfort. It can also be used in cases of floating knee, for simultaneously fixing femoral or tibial fractures. also it is associated with potential disadvantages as well, the intra-articular portion may lead to knee stiffness, sepsis, patello-femoral pain and synovial metallosis. The proximal tip of the nail generally lies in the mid or distal femoral shaft creating a stress riser in this area.

Figure (6): Retrograde supracondylar nail I for treating supracondylar fractures. (10)

External fixation (11)**:**

External fixation can be used in supracondylar femoral fracture, especially in sever open fractures with significant bone and/or soft tissue loss, fractures associated with vascular or nerve injuries and in supracondylar fractures in polytraumatized patient **(Fig. 7)**. Other indications for external fixation are infected fractures, nonunions and malunions where use the ring fixator give satisfactory results. The external fixator can be used as a temporary device for initial management of the fracture and soft tissues. Once soft-tissue control is achieved, delayed internal fixation should be considered. External fixation with minimal internal fixation another alternative in the treatment of supracondylar fractures of the femur. The femoral condyles are first reduced percutaneously or via a medial arthrotomy and stabilized with 6.5 mm cannulated screws. Fixator pins are placed in the condyles and in the shaft above the fracture. The advantages of the external fixation include adequate alignment, the ability to maintain length, nursing care to the wound, minimal soft-tissue dissection, and the possibility of early ambulation of the patient. The disadvantages include pin-track infection with subsequent loosening of the device and loss of reduction, loss of knee motion secondary to adhesions in the quadriceps mechanism, and increased risk of delayed union or non-union. (11)

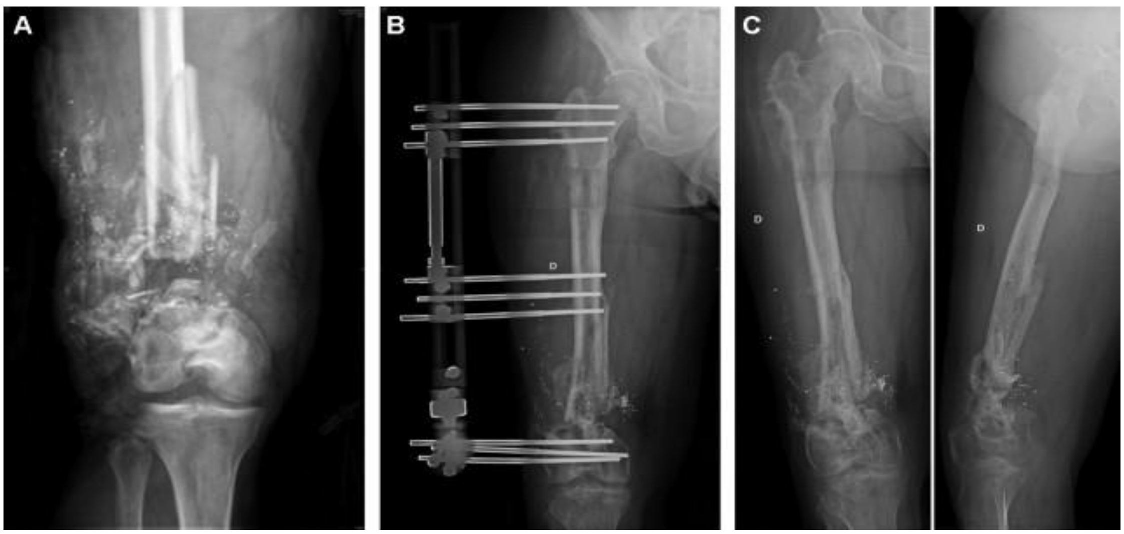


Figure (7): (A) Gustilo IIIC fracture due to a gunshot wound. (B) stabilization of the fracture by external fixation. (C) Final radiological results. (11)

Cancellous screws (12)**:**

The least complex injury of the distal femur that requires surgical treatment is the unicondylar fracture. Fixation of these fractures can usually be achieved with 6.5mm cancellous screws. The tips of these screws should just penetrate the opposite cortex to give more stable fixation. In most cases, washers are used with these screws to prevent the heads from sinking into the cortex. (12)

Locking compression plate:

- Biomechanics of the Implant:

In standard plates, screw head compresses against plate and there is potential for movement of screw relative to plate. This leads to relative angular movement of screws allows plate to fail. Construct rigidity depends on plate compression against bone, therefore screws must compress the plate against bone and compression periosteal blood supply which affects healing. Locking plates is considered as anatomically precontoured low profile plate which have minimal implant-to-bone contact, long-span bridging and fewer screws for fixation **(Fig. 8)**. Locking Plate System is a biological internal fixation system that was designed from the beginning to protect the bone with minimal contact, provide stability and rigidity that depends on screw head fixation to plate and promote rapid healing by minimal periosteum compression**.** (13,14)

Designers assumed that, preservation of the blood supply to bone, it would be possible to reduce or avoid refracture after plate removal, development of infection and forming sequestrum under the deep surface of the plate, delayed union, and nonunion. (15,16) Locked plates show promise for fixation of malunions, previously fractured bone, and pathological bone**.** (17,18)

An additional theoretical advantage of the locked plate construct is the avoidance of stress shielding below the plate. (18) Locked plates have become an attractive alternative to conventional plates as mentioned above and as they can be used as “bridge plates” to preserve fragmentary blood supply. (18)

Figure (8): Distal femur locking compression plate. (19)

The locking plate acts as an external fixator but without the disadvantages of an external system not only in the transfixion of the soft tissues, but also in terms of its mechanics and Increased resistance to infection. In Locking plates, screw head is fixed to the plate and creating a fixed angle device, thus if the plate went to fail all screws have to fail simultaneously and offers improved purchase in osteoporotic bone and once the screw is locked into the plate, the fixed angle stable design, converts shear stress into compressive stress at the screw-bone interface. Locking screws are preferred as if the cortex thickness is insufficient or near the joints. (20)

First-generation locked plate implant systems use unicortical screw fixation. Unicortical screw fixation has the following benefits over bicortical screw fixation as ease of measuring screw lengths percutaneously when employing minimally invasive plate osteosynthesis techniques, decreased damage to the endosteal blood supply; and there is no need to generate high axial forces to compress the plate to the bone. However, monocortical screws require secure purchase in the near cortex and will have insufficient purchase to provide stable fixation in metaphyseal bone with a thinner cortex**.** (20)

Screws characteristics:

A screw is a tool that capable of converting torque (rotary force) which applied to its head into compressive force between the two surfaces it has engaged. locked plates system characterized by the presence of combi – holes that have additional dynamic compression holes providing options for axial compression in addition to locking mechanism.

(21) It combines the advantages of the dynamic compression plate principle with the locking screw head principle, giving the surgeons great flexibility of choice within a single implant. The screw holes in plate have been specially designed to accept either a standard cortical screw with a hemi spherical head or a locking screw with a threaded head. (22)

The conventional screw characterized by having a wide, asymmetrical thread to resist pullout. While the locking screw characterized by having symmetrical thread, so that it forces equally in pullout and advancement. For advancing into the bone, the locking screw designed to have a fine-pitched thread **(Fig. 9)**.

The screw's pullout strength in trabecular bone relies on its outside diameter, its length of engagement, the density of bone into which it is embedded, and its thread shape and for very small screws, the material from which it is made **(Fig. 10 a,b)**. (22)

Figure (9): Locking screw vs conventional screw. (23)

(A) **(B)**

Figure (10): (A): Sequential pullout of conventionnal screws and **(B):** Pullout of an interlocking screw system. (24)

The locking screws are designed to tolerate the shear loads resulting from angle stable fixation. The core (diameter of the screw between threads) is larger than standard bone screws, with a smaller thread profile. In addition, the pitch of the screw is smaller and matches the pitch of the thread on the head of the screw. (24,25)

The plate-screw-bone construct must resist physiological loads to allow fracture union by limiting fracture gap stress, provide sufficient stability to permit early limb motion and not fail before fracture union occurs. When locked plates are used in a bridging mode, they should be pre dynamized by allowing at least two empty screw holes over the fracture gap **(Fig. 11)**. (26) This increases the working length of the plate and decreases internal stress in the plate, in order to increase the working length three or four plate holes should be left empty at the level of the fracture and so that strain and stress concentration on the plate is decreased. But when working length is short there is increased stress and strain concentration with loading and torsional forces, which results in implant failure by placing too many screws. (26)

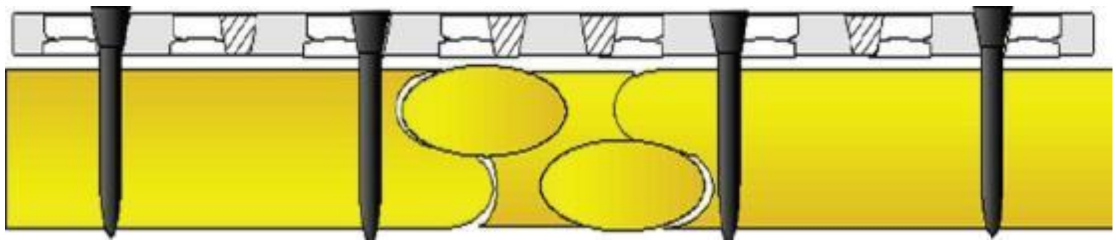


Figure (11): Locked screws are used when a bridge-plate technique is applied to span an area of comminution. (27)

In conventional plate, screws require secure purchase in far cortex to provide stable fixation, but this way seems to be harmful to surrounding soft tissues as tendons, ligaments. In contrast locking screw has no need to achieve good purchase in the opposite cortical bone as there is no pullout force. As from practical field the locking screw, never has to be offset and a slightly short screw would be better than an excessively long screw and avoiding a number of potential problems. (28)

Length of the plate:

The ideal length of the plate can be determined by the plate span width and plate screw density.

Plate span width = $\frac{\text{plate length}}{\text{overall fracture length}}$

This should generally be more than 2-3 for comminuted fractures.(29)

The second factor is the plate screw density and the value should be below 0.5, indicating that less than half of the plate holes are occupied by screws **(Fig. 12).** (29)

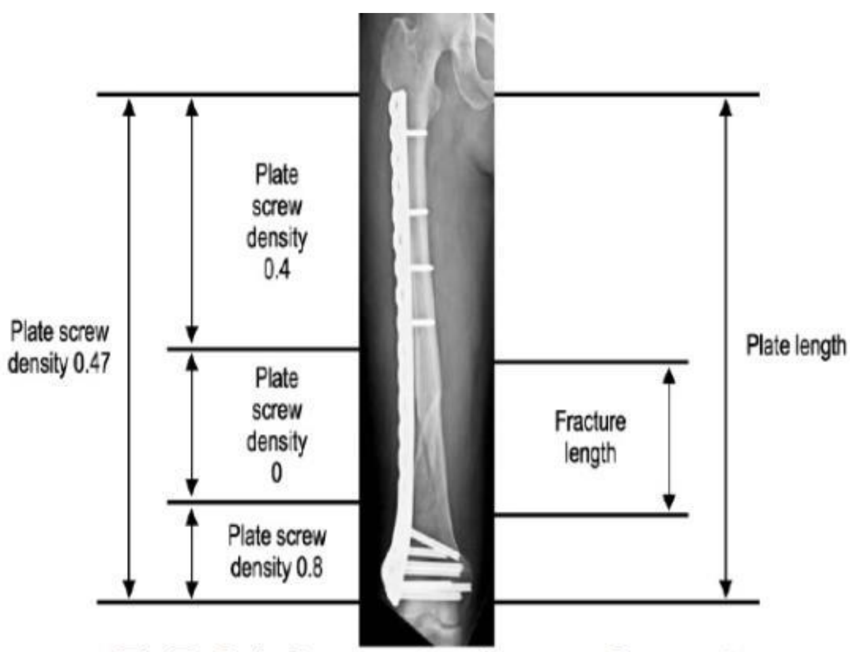


Figure (12): Technical parameters in screw placement. (29)

Number of screws:

Screw density = $\frac{\text{Number of screws inserted}}{\text{Number of plate holes}}$

Ideally this value should be under 0.4-0.5. For example, the screw density for a twelve-hole plate with five screws is 0.4 indicating that less than half of the plate holes are occupied by screws. (29)

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