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# Distal femur: dynamization of plating

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ABSTRACT

With advances in osteosynthesis technology providing improved stability of fixation and better outcomes, surgical treatment has become the standard of care for distal femur fractures. Pre-contoured distal femoral locking plates are the most commonly used implants for fixation. However, healing problems such as delayed union, failure of fixation, and /or nonunion are not uncommon. The fixation construct being "too stiff" is a commonly quoted reason when nonunion/failure of fixation occurs on distal femur fractures fixed with a plate. A flexible fixation construct allowing controlled axial micromotion could help stimulate the bone healing. In order to achieve this goal, plating construct stiffness can be modified by several methods.



## Introduction

Distal femur fractures are relatively uncommon fractures, estimated to be about 0.4% of all fractures and 6% of all femur fractures [1,2]. More than half of all distal femur fractures occur in the elderly and this is expected to increase with the aging population [3]. With advances in osteosynthesis technology providing improved stability of fixation and better outcomes, surgical treatment of distal femur fractures has become the standard of care [4–6]. The primary goal of surgical treatment is to provide optimal mechanical fixation that allows for an early range of motion and to achieve healing without loss of alignment and fixation.

It has been noted that strain at the facture site is critical for a successful healing process. Excessive axial strains as well as shear strain between fracture fragments may both be detrimental to bone healing [7–9]. At the same time, a moderate amount of strain is necessary to stimulate callus formation [7–9]. Strain is related to fracture gap and interfragmentary motion which in turn depends on stiffness of fixation construct. While the ideal value of stiffness i.e. the balance between the stability and motion at fracture site, to achieve uneventful and timely fracture healing for a specific fracture pattern and bone characteristics is yet to be determined, it has been shown that construct stiffness can be modified by the surgeon by choosing implant material, screw type, position of screws or position of the plate [10]. In a simple fracture pattern with anatomic reduction a stiffer construct may be preferable (stainless steel implant with hybrid or locking screws) [8]. On the other hand, in a comminuted fracture pattern, a less stiff construct allowing for more micromotion with fatigue life long enough to for the plate to survive until fracture healing may provide better outcome (e.g. titanium implant with locking screws) [8,11–14].

Rigid fixation constructs aim to provide absolute stability at the fracture site. The healing occurs with primary/direct healing consisting intramembranous healing and osteonal /haversian remodeling without formation of callus. This is preferred type of healing for intraarticular fractures and may be for simple fractures patterns at the metaphysis and diaphysis.

Flexible fixation constructs provide relative stability. The healing occurs with secondary/indirect healing which consists of both intramembranous and endochondral ossification with formation of callus. This is commonly applied for comminuted fractures and fractures at the metaphysis and diaphysis.

In summary, stability at the fracture site dictates the type of healing. Regarding fixation with plates, compression plating and neutralization plating after anatomic reduction of simple fractures are examples of rigid fixation construct. On the other hand, bridge plating of a comminuted diaphyseal or metadiaphyseal fracture is an example of flexible fixation construct.

In the setting of distal femur fractures, if there is an extension of the fracture into the knee joint, anatomic reduction and rigid fixation of the intraarticular component of the fracture providing absolute stability is necessary [9]. The healing of the intraarticular component is usually not problematic. When the supracondylar metadiaphyseal component of the fracture is comminuted, plate fixation is a bridging construct providing relative stability. On the other hand, both rigid and flexible fixation constructs providing relative stability could be applied for simple fracture patterns at the metadiaphyseal part of the distal femur.

## Dynamic construct vs. static/fixed construct

Dynamic fixation construct usually refers to fixation with intramedullary nail when interlocking screws are placed in a

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dynamic hole through the nail in a length stable fracture pattern (such as transverse fracture pattern where the length will not change with loading) in contrast to static locking when interlocking screws are placed through round holes. Most of the contemporary femoral and tibial intramedullary nail designs have an oblong hole with an option of placing the interlocking screw in dynamic mode. All static nailing constructs and most of the plating constructs (except anatomic reduction and compression fixation) have some micromotion at the fracture site in torsional and bending stress. While nailing constructs are extremely stiff under axial loads, plating constructs tend to bend under axial loads due to their position outside the mechanical loading axis. This bending results in closing of the fracture gap at the far cortex and a lack of micromotion at the near cortex of the plate. The rationale behind dynamic plating constructs is that a more uniform motion along the longitudinal bone axis is introduced at the fracture site which in turn provides stimulation of bone healing.

The typical plating constructs are static and not dynamic in the longitudinal axis of the bone even when a bridging construct is applied for a comminuted fracture. Recently, dynamic constructs for plating were introduced with modifications of the bone-screw or plate screw interfaces [22,40–42]. These dynamic designs allow more and controlled motion at the fracture site without compromising the longitudinal stability of fracture fixation. Far locking screw, dynamic locking screw, active plates are examples of these modifications.

## Dynamization

While the term *dynamic* describes the condition at the time of fixation, *dynamization* is usually reserved for the modification of original fixation on follow up. When there is delayed healing or nonunion, dynamization may help in order to stimulate bone healing through an increase of compressive axial motion and loading of the bone. Dynamization of nailing constructs has been previously described and applied [15,16]. The goal is to convert a static construct into a dynamic construct which can be achieved either by exchanging static interlocking screws with an interlocking screw in dynamic mode or removing all interlocking screws on one side of the fracture altogether if there is no concern of rotational instability.

Dynamization of a plating construct may be helpful to achieve bone healing before failure of fixation occurs in cases of delayed healing and nonunion. This can be achieved by modifying the fixation construct from a stiff construct to a more flexible construct. The stiffness can be modified to allow more motion at the fracture site by removing screws close to fracture site and/or exchanging locking screws with nonlocking screws as much as possible without compromising the overall construct stability. Evaluation of the cause(s) of delayed healing or nonunion is critical. Dynamization is obviously not a good option when the cause of the delayed healing or nonunion is instability of the fixation construct and may results in catastrophic failure.

## Fixation constructs in distal femur fractures

Implant choices available for the fixation of distal femur fractures include intramedullary nails and plates [17]. Pre-contoured distal femoral locking plates are the most commonly used implants [4,11,18,19] allowing for locking, non-locking or hybrid (combination of locking and non-locking) screw fixation. However, healing problems such as delayed union, failure of fixation, and/or nonunion occur in up to 23% of patients [12,20,21].

Numerous, previous studies clearly demonstrated that type of implant and fixation construct influence biomechanical performance [2,6,12,17,22–29]. While it is not exactly clear how rigidity of implant or fixation construct affects failure, the amount of rigidity of the fixation construct has been associated with healing problems and failure of fixation [4,12,13,30–32]. Multiple factors influence the mechanical strength of a distal femoral locking plate construct including the fracture pattern, bone quality, quality of reduction, implant design (number of periarticular screws, geometrical shape, thickness of plate), implant material, length of plate, the position of plate (offset vs. contact to bone), screw type (size, locking vs. non-locking, unicortical vs. bicortical), and screw configuration. Other than the fracture pattern and bone quality, the rest of the factors are under the surgeon's control and can be modulated [4,10,33].

## Dynamic construct or dynamization as a solution to nonunion/failure of fixation of distal femur fractures

The evaluation of any delayed healing and nonunion should include a detailed investigation of the host and biological factors such as smoking and metabolic and endocrine abnormalities [34,35] in addition to the detailed analysis of fixation mechanics. The restoration of the mechanical axis and alignment is of utmost importance in order to achieve the best outcome [30].

The fixation construct being "too stiff" is a commonly quoted reason when nonunion/failure of fixation occurs on distal femur fractures fixed with a plate [4,12,13,30–32]. Stiffness of a plating construct is the amount of displacement in response to applied force. A stiffer construct will have less motion at the fracture site compared to a more flexible construct. A flexible fixation construct allowing axial micromotion will help stimulate the bone healing. On the other hand, a fixation construct too flexible allowing too much axial motion or bending, torsional, or shear motion at fracture site will prevent bone healing and result in delayed union or nonunion [36]. It should be noted that, while a stiffer construct may not seem to help for healing, it might provide a longer fatigue life before failure, which translates into more time for healing. Strain levels should also be considered while choosing screw configuration in a given fixation construct [37]. Increased strain levels in the bone around the screws, specifically the screws closer to the fracture site, are critical in failure of fixation with loosening. In healthy bone under axial loading, decreased working length and increased plate rigidity are associated with lower strain levels. In osteoporotic bone, spacing of screws within the plate on each side of fracture decreases strain levels. In case of no load sharing contact at fracture site such as significant comminution, increasing working length to make the construct more flexible increases the strain levels around the screws [37].

### *Options to modify the plating construct stiffness*

Options for modifying plating construct stiffness are shown in Table 1.

#### *Implant design*

The specific shape of the implant is associated with construct stiffness. This has been reported in biomechanical studies comparing different types of locking plates used for fixation of distal femur fractures [17]. The thickness and the width of the plate are correlated with stiffness. All other parameters being equal, a thicker distal femoral locking plate will result in a stiffer fixation construct.

#### *Implant material*

Most of the currently used plates are alloys of stainless steel or titanium. As modulus of elasticity of titanium is lower, the same design stainless steel plate will provide stiffer fixation construct compared to the titanium plate of the same design. Not all stainless steel alloys and titanium alloys used for manufacturing the plates are the same. The ingredients of alloy may be modified to achieve a stiffer or less stiff plate.