CHAPTER 4.1

A New Titanium Nail for the Femur: Concept and Design

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Introduction

Intramedullary nailing of the femur is an established and widely used technique in traumatologic and orthopedic surgery, with a broad spectrum of indications. It has become the preferred treatment for diaphyseal fractures due to good alignment at the fracture site, preservation of the periosteal blood supply and soft tissue, and the early restoration of function. Kuentcher’s basic principles of mechanical and biological fracture healing with closed reduction, preservation of the fracture hematoma, and fixation with an intramedullary nail according to the fracture pattern, is still valid today [37].

Fixation of the original intramedullary Kuentcher nail is based on the cylindrical reaming principle and transversal spring locking of the cloverleaf nail profile. The original idea, to obtain stability with a larger intramedullary blocked nail, was abandoned with the development of locking nails. With this remarkable development, the spectrum of indications expanded widely. However, to achieve axial and rotational stability, the new generation of intramedullary nails has to be interlocked proximally and distally [2, 9, 16, 34]. Using these technical principles, it has been demonstrated by numerous authors that intramedullary fixation of diaphyseal long bone fractures is more effective and mechanically superior to plate fixation [2, 20, 34, 52]. Conventionally, locked intramedullary nailing requires pre-reaming of the medullary canal for insertion of a larger diameter nail. Nevertheless, there are experimental and clinical data indicating that reaming may have adverse consequences of systemic embolization [55], pulmonary damage [45], hemostatic activation [27], reduction of bone strength [46] and destruction of the endosteal blood supply [50, 51]. Accordingly, the trend in nailing shaft fractures led to unreamed and limited-reamed techniques and the use of small-diameter nails. However, a high incidence of complications including implant failure, delayed unions, nonunions and malunions has been reported with the use of small-diameter nails and unreamed techniques [1, 5, 17, 26, 30, 53]. Many of the complications mentioned above are due to the poor primary stability of the osteosyntheses. Another disadvantage of unreamed nailing is the occasional appearance of distraction at the fracture site, due to endosteal resistance during the insertion process. The resulting fracture diastasis is a well-known cause of prolonged bone healing and nonunion.

Clear improvement concerning the aforementioned issues has been achieved with the development of new implant materials and different locking options, as well as the development of an integrated compression mechanism. With the same nail diameter, for the appropriate fracture, better primary stability can be achieved with the compression nail compared to other intramedullary locking nails [6, 7, 21, 39]. In addition, through the compression mechanism, which allows dispensed fragment apposition, a primary fracture diastasis can be avoided [43].

Instruments, Implants and Surgical Technique

The biomechanical concept of compressed or appositioned nailing consists in the use of an intramedullary device that is inserted into the medullary cavity without jamming and that allows, after proximal and distal locking, a relative movement of the fragments against each other. First, the implant is firmly attached to the distal main fragment (or the proximal fragment, if a retrograde technique is being employed), using fully threaded locking screws at the nail tip. Next, the other main fragment, which contains the nail entry portal, is fixed via a partially threaded locking screw (shaft screw) that has been placed in an oblong hole. The compression screw is inserted from the top of the nail, and is pushed against the shaft screw (Fig. 4.1.1), drawing either the distal or the proximal segment toward the fracture site, resulting in apposition or compression of the fracture gap (Fig. 4.1.2).
strength to transmit the forces applied via the compression screw into the bone, without undergoing major deformation. The former condition means that there is no need for a slot along the nail to obtain a tight intramedullary fit. This is also beneficial, since slotting would obviously, and unnecessarily, reduce the stiffness of the implant.

The T2 nails (T2 Nailing System, Stryker Trauma) are cannulated devices, with diameters that allow insertion without reaming or with limited reaming techniques. Typically used femoral nails are 9–13 mm in diameter. These nail diameters allow for the use of 5-mm locking screws, which with a core diameter of >4 mm are strong enough to withstand the compression applied without major bending. With this new generation of compression nails, we have titanium alloy implants (Ti6Al4V, anodization type II), which can be implanted using the ante- or retrograde technique with the same instruments and implants (Fig. 4.1.3) [43]. According to the fracture type, the system offers the option of different locking modes. In addition to static locking, a controlled dynamization with rotational stability is optional. Compression nailing can be performed using two different locking patterns: actively pre-compressed dynamic locking, and actively appositioned/pre-compressed static locking. The actively pre-com-

![Fig. 4.1.1. Cutaway view of compression mechanism at the proximal nail end (1). Compression screw (4) is tightened and its reaction against the transverse shaft screw (3) in the oblong hole (2) causes compression at the fracture/ostectomy site](image1)

Therefore, the devices used for compression nailing should be free to slide in the medullary canal, and should be of sufficient size and

![Fig. 4.1.2. a Persisting fracture gap of 5–7 mm after nailing with a locked GK-nail. b, c After nail exchange, sound apposition and compression is performed with the axially inserted compression screw](image2)