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JINJ 7184 No. of Pages 5

ARTICLE IN PRESS

Injury, Int. J. Care Injured xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Technical considerations to avoid delayed and non-union

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ARTICLE INFO

Keywords:
Intramedullary nailing
Non-union
Reduction
Malalignment
Entry point

ABSTRACT

For many years intramedullary nails have been a well accepted and successful method of diaphyseal fracture fixation. However, delayed and non unions with this technique do still occur and are associated with significant patient morbidity. The reason for this can be multi-factorial. We discuss a number of technical considerations to maximise fracture reduction, fracture stability and fracture vascularity in order to achieve bony union.

Introduction

The delayed or non union of fractures is typically the result of a number of influencing factors. Most commonly these include infection, metabolic or endocrine abnormalities, impaired vascularity, and inadequate biomechanical stability at the fracture site. Certain factors are patient specific and somewhat out of the control of the operating surgeon, however, others can be addressed through a careful and focused surgical approach. This article is aimed on the intra-operative technical considerations of intramedullary nail (IMN) fixation, their influence, and provide insight and alternatives to achieving an optimal surgical result. Specifically, we will focus on fracture reduction, improving fracture stability where IMN fixation used in isolation provides inadequate stability and fracture vascularity.

Fracture reduction

A fractures capacity to unite decreases with increasing distance between the fracture surfaces. Large fracture gaps between bony fragments have been shown to directly affect healing [1]. Furthermore, research by Bhandari et al. showed the presence of a post-reduction fracture gap to be a major risk factor for reoperation ($p < 0.0001$) [2]. Placement of an IMN alone does not result in adequate, anatomical fracture reduction. A common pitfall in intramedullary (IM) fixation is proceeding with fixation prior to achieving anatomical alignment and regardless of advances in implants and implant design, surgical technique remains of paramount importance.

Ideally, fracture reduction is achieved indirectly, thereby not disturbing the fracture haematoma. This is largely achieved through the application of longitudinal traction together with rotational adjustment, and is most commonly performed on the traction table for fractures of the femur although free hand methods are popular of IM nailing of the tibia, and humerus. Within our unit, we prefer to perform intramedullary fixation of the tibia, with the leg free, flexed over a radiolucent bolster and the application of manual traction as and when it is required. This permits complete control of the limb intra-operatively and ease of imaging, however this technique relies heavily on the skill of the surgeon and his assistant to achieve and maintain reduction. In both setups, direct external pressure can be applied to assist neutralisation of the fracture deforming forces. In some circumstances, this alone is insufficient to achieve the desired reduction. In such cases, percutaneous bone reduction clamps, supplementary Poller (blocking) screws or temporary blocking wires or a percutaneous pin (joystick) can be utilised. Despite these percutaneous techniques, on occasions the fracture site needs to be opened for direct reduction and held temporarily with clamps or plates clamped over the fracture site during the insertion of the IMN. Once reduced, some surgeons prefer to hold certain femoral fracture configurations by using cerclage wire fixation and or the addition of a plate applied over the fracture using unicortical screws so as to avoid impeding IMN insertion.

The approach and entry for tibial nails can be challenging due to the influence of the patellar tendon and patella. Conventionally, a parapatellar approach using either medial or lateral approaches, or a midline *trans*-tendinous approach, with the knee in approximately 90°of flexion is performed. With proximal fractures, the pull of the extensor mechanism on the tibial tuberosity resulting in

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http://dx.doi.org/10.1016/j.injury.2017.04.019
0020-1383/

Please cite this article in press as: T.E. McMillan, A.J. Johnstone, Technical considerations to avoid delayed and non-union, Injury (2017), http://dx.doi.org/10.1016/j.injury.2017.04.019

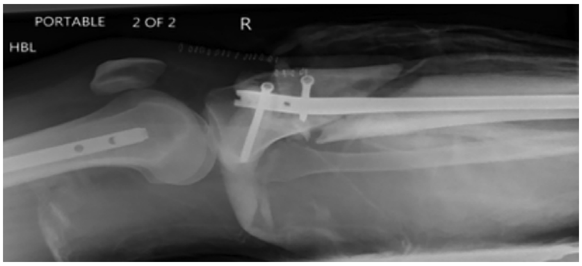

Fig. 1. Radiograph of a proximal tibial fracture, fixed with an IMN through an infra-patellar approach, with a residual apex anterior flexion deformity.

an apex anterior flexion and anterior translation deformity is exaggerated with flexion of the knee. This is demonstrated in Fig. 1.

However, within the last decade, interest has been growing in the use of a semi-extended supra-patellar approach, particularly for fractures involving the proximal tibia [3]. To date, our centre's experience, as part of a multicentre randomised control trial, has been extremely positive and to date is the only RCT comparing infrapatellar with suprapatellar nail insertion. Preliminary results have found this approach to achieve a statistically more accurate nail entry point and a statistically significant improvement in IMN position within the tibia resulting in an improvement in fracture alignment, when compared to the standard medial parapatellar approach where the knee in flexed during IMN insertion [4]. Furthermore, the semi-extended suprapatellar approach leads to significant improvements in the incidence and severity of anterior knee pain and anterior knee discomfort when kneeling compared with the infrapatellar approach.

Achieving the desired entry point on the tibia is crucial, as and incorrect entry point can lead to loss of reduction at the fracture site post nail insertion as well as iatrogenic valgus malalignment due to the less than optimal alignment of the nail within the tibia. To obtain ideal nail placement it is essential that the surgical approach permits optimal placement of the guide-wire and subsequent centralised reaming of the canal prior to nail insertion. Good quality fluoroscopic images to confirm entry position on two planes is also essential. To some degree the exact tibial entry point varies depending upon the nail design and in particular the size of the Herzog bend in the proximal part of the nail. This said, in most modern tibial nails, the Herzog bend has been reduced considerably compared with earlier designs and therefore has little bearing upon final nail alignment although it must be emphasised that nail designs that have sizeable Herzog bends are not suitable for insertion using a supra-patellar, semi-extended approach. When an infra-patellar entry point is being used, the entry is most commonly used medial parapatellar approach commonly results in over medialisation of the starting point resulting in a valgus deformity of the tibia especially with proximal or segmental fractures. Although by using a lateral parapatellar approach malalignment is less likely, it is still well recognized that varus malalignment can occur at the fracture site. Finally, a more distal starting point on the tibia can cause procurvatum.

For fractures involving the proximal femur, and especially subtrochanteric fractures where the psoas muscle creates a strong flexion deforming force upon the proximal fragment, the most common mistake is to inert a nail when the fracture is inadequately reduced. In addition, an excessively lateral entry point precipitates a varus deformity at the fracture lateral cortex gapping and limited bone contact (Fig. 2) and subsequent delayed or non union with the potential for implant failure.

Fracture stability

Instability at the fracture site is the primary mechanical cause for aseptic delayed or non union, and results from excessive fracture motion that impairs fracture healing. IMN fixation provides load sharing characteristics and confers relative stability at the fracture site. However, the degree of stability is influenced significantly by the chosen intramedullary nail, its rigidity and the proximal and distal locking screw options available. This is directly influenced by materials used, nail diameter, wall thickness and the dimensions of the cross screws.

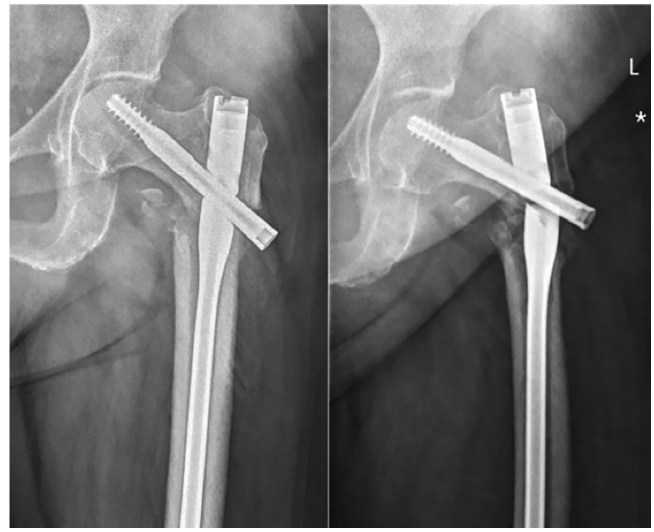

Fig. 2. Radiographs displaying varus deformity, lateral cortical gapping and subsequent fixation failure as a result of lateral nail entry in a subtrochanteric femoral fracture.

Intramedullary reaming is frequently used to increase the area of cortical contact and to allow for insertion of a larger diameter nail. This increase in diameter confers greater nail bending stiffness, with stiffness proportional to the radius to the power of 4. The other benefit of reaming is that the bone contact within the isthmus is increased that in turn reduces the working length of the nail both proximal and distal to the isthmus with an associated increase in stability. This said, surgeons should always remain conscious of the detrimental effects of reaming and the risk of osteocutaneus necrosis with over-reaming [5]. Additionally, proceeding with reaming prior to achieving optimal reduction, causes eccentric reaming and is likely to lead to further deterioration in the reduction when the nail is inserted.

In the evolution of intramedullary devices, the addition of locking screws, that limit rotational and axial movement, also improve fracture stability. Although surgeons and industry commonly focus upon the properties of the IMN, one cannot over emphasise the importance of the cross screws that essentially connect the IMN to the bone. In particular, the mechanical properties of the cross screws heavily influence the overall structural stability of the IMN combined with the bone. Biomechanical research has shown that cross screw length, core diameter and alloy from which the screws are manufactured greatly affects overall fracture stability. Shorter, thicker cross screws made form a more resilient alloy such as stainless steel add to the overall stability of the construct. Although additional screws do add to overall fracture stability, one should appreciate that long screws places at the extremes of bones, where the cortices are thinnest and therefore provide limited screw purchase, do not add significantly to the stability of the overall construct [6]. This increase in screw length is associated with increased deflection with loading, and a subsequent decrease in stability combined with a tendency to pull out from the cortical bone [7]. (Fig. 3). For this reason, in situations where increased fracture stability is required, the locking options that are closest to the midpoint of the

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