1 Principles of Internal Fixation

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1.1 Introduction

1.1.1 Mechanical Properties of Bone

The principal mechanical function of bone is to act as a supporting structure and transmit load. The loads which bone has to withstand are those of pure compression, those of bending, which result in one cortex being loaded in tension and the other in compression, and those of torque, or twisting. Bone is strongest in compression and weakest in tension. Fractures as a result of pure compression are therefore rare and occur only in areas of cancellous bone with a thin cortical shell. Thus, we find pure compression fractures in such areas as the metaphyses, vertebral bodies, and the calcaneus. Transverse, oblique, and spiral are the fracture patterns commonly seen in tubular bone.

Transverse fractures are the result of a bending force (Fig. 1.1). They are associated with a small extrusion wedge that is always found on the compression side of the bone. If this extrusion wedge comprises less than 10% of the circumference, the fracture is considered a simple transverse fracture. If the extruded fragment is larger, the fracture is considered a wedge fracture, and the fragment a bending or extrusion wedge. Because it is extruded from bone under load, it retains little of its soft tissue attachment and has therefore, at best, a precarious blood supply. This must be kept in mind when planning an internal fixation. Attempts to secure fixation with lag screws of such extruded fragments may result in their being rendered totally avascular. If the extruded wedge is very small, as in fractures of the radius and ulna, they may be ignored. If larger, as in fractures of larger tubular bones, it is best to leave them alone and use indirect reduction techniques to preserve whatever blood supply remains, and either use a locked intramedullary nail for fixation, or if this is not possible, a bridge plate.

Oblique fractures are also the result of a bending force. The extrusion wedge remains attached to one of the main fragments. The fissure between it and the main fragment is not visible on X-ray. If looked for at the time of an open reduction, it can often be found. During closed intramedullary nailing this undisplaced extrusion wedge is often dislodged and becomes apparent on X-ray.

Spiral fractures are the result of an indirect twisting force (Fig. 1.1). They often occur in combination with spiral wedge fragments of corresponding configuration. These fragments are larger and retain their soft tissue attachment. It is frequently possible to secure them with lag screws without disrupting their blood supply.

Fig. 1.1a–e. Types of fracture patterns. A lateral bending force can result in transverse fracture (a), extrusion or bending wedge fractures (b), or oblique fractures (c) in which the extrusion wedge remains attached to one of the main fragments. A twisting or torsional force may result in a spiral fracture (d) or one with a single or multiple spiral wedge fragments (e).
supply. These differences in the degree of soft tissue attachment and preserved blood supply are important to consider in the choice of internal fixation. If one is dealing with a spiral wedge or a very large extrusion wedge, then their soft tissue attachment and blood supply will likely be preserved, and an attempt at absolutely stable fixation with lag screws would not render them avascular. If on the other hand the extrusion wedge is small or if the wedge is fragmented or if one is dealing with a complex fracture, it is best not to attempt absolutely stable fixation but resort to splinting and secure the fracture with a bridge plate. These remarks apply, of course, to fractures in metaphyseal areas. Diaphyseal fractures are nailed by preference except in the forearm and humerus.

1.1.2 Types of Load and Fracture Patterns

Bone is a viscoelastic material. Fractures are therefore related not only to the force but also to the rate of force application. Much less force is required to break the bone if the force is applied slowly and over a long period of time than if it is applied rapidly: bone is better able to withstand the rapid application of a much greater force. This force is stored, however, and when the bone can no longer withstand it and finally breaks, it is dissipated in an explosive and implosive fashion, causing considerable damage to the soft tissue envelope. A good example of this is the skier who walks away from a spectacular tumble, only to break his leg in a slow, twisting fall. The amount of energy and the rate of force application are important factors since they determine the degree of associated damage to the soft tissue envelope. We therefore distinguish between low- and high-velocity injuries.

Low-velocity injuries have a better prognosis. They are more commonly the result of an indirect force application such as a twist, and the associated fractures are spiral and the comminution is rarely excessive. In high-velocity injuries the fractures are not only more fragmented but also associated with a much greater damage to the enveloping soft tissues, because of the higher energy dissipation and because of the direct application of force.

1.1.3 Classification of Fractures

The classification of fractures followed in this book is based on the Comprehensive Classification of Fractures of Long Bones (Müller et al. 1990). The unique feature of this system of classification is that the principles of the classification and the classification itself are not based on the regional features of a bone and its fracture patterns nor are they bound by convention of usage or the popularity of an eponym. They are generic and apply to the whole skeleton. The philosophy guiding the classification is that a classification is worthwhile only if it helps in evolving the rationale of treatment and if it helps in the evaluation of the outcome of the treatment (Müller et al. 1990). Therefore the classification must indicate the severity of the fracture, which in this classification indicates the morphological complexity of the fracture, the difficulties to be anticipated in treatment, and its prognosis. This has been accomplished by formulating the classification on the basis of repeating triads of fracture types, their groups and subgroups, and by arranging the triads and the fractures in each triad in an ascending order of severity. Thus there are three fracture types A, B, and C in ascending order of severity. Each fracture type has three groups, A1, A2, and A3, B1, B2, and B3, and C1, C2, and C3, and each group three subgroups, A1.1, A1.2, etc. The groups and the subgroups are also organized in an ascending order of severity (please see Fig. 1.2). This organization of fractures in the classification in an ascending order of severity has introduced great clinical significance to the recognition of a fracture type. The identification of the Type indicates immediately the severity.

The classification considers a long bone to have a diaphyseal segment and two end segments (Figs. 1.3, 1.4). Because the distinction between the diaphysis and the metaphysis is rarely well defined anatomically, the classification makes use of the rule of squares to define the end segments with great precision (Fig. 1.4). The location of the fracture has also been simplified by noting the relationship that the center of the fracture bears to the segment.

The authors of the Comprehensive Classification of Fractures of Long Bones have also developed a new terminology that is so precise that it is now possible to describe a fracture verbally with such accuracy that its pictorial representation is superfluous. The new precise terminology divides fractures into simple and multifragmentary (Fig. 1.5). The multifragmentary fractures are further subdivided into wedge and complex fractures, not on the basis of the number of fragments, but rather on the key issue of whether after reduction the main fragments have retained contact or not. In treatment this is, indeed, the essence of severity. Thus, a multifragmentary fracture with some contact between the main frag-