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Malalignment in plate osteosynthesis

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KEYWORDS

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ABSTRACT

The aim for this review is to present general considerations in relation to malalignment after osteosynthesis with plate fixation and its consequences after fractures in adults in each of the following anatomical locations: humerus, forearm, femur, tibia. Recommendations for accepted malalignment in humerus diaphyseal fracture is varus <20 degrees, valgus <15 degrees, sagittal deformity <5 degrees and rotation <30 degrees. Recommendations when treating fractures of the forearm is anatomical reduction. Varus of ulna leads to loss of pronation. Valgus of ulna leads to loss of both pronation and supination. Recommendations for acceptable malalignment in femoral fractures is rotational deformity <15 degrees, increasing varus deformity in intertrochanteric fractures increases load on implant. Cortical-step-sign, profile of lesser trochanter, evaluation of ipsilateral neck anteversion are intraoperative methods to avoid rotational malalignment. Recommendations for accepted malalignment in the tibia is shortening <10 mm, varus/valgus <5 degrees, sagittal deformity <10 degrees. Fixation of fibula leads to less rotational and valgus malalignment, but not enough to affect union rate of tibia, complications rate or functional score at 12 months. To avoid malalignment in plating, pre-contoured anatomical plates are available from most manufactures. Being aware that most such plates fit a 50-percentile Caucasian population is important in pre-surgical planning. Evaluation of the contralateral bone and the characteristics of the plate may help in planning additional bending of pre-shaped plates and bending tools should always be available when applying a plate, even a so-called anatomical one.

Introduction

The function of diaphyseal bone is to bear its joints in a fixed distance and to function as punctum fixum for the muscles that moves them. These functions are compromised by fracture and the goal of treatment is to recreate the pre-trauma state with a stable, pain free bone and adjacent joints.

> *"Restoration of length, axial alignment, and rotation is essential, but anatomical reduction of every fracture fragment is not necessary for normal limb function."* (Piet de Boer) [1]

To obtain this goal it is important to be aware of bone biology and the characteristics of the implant to add the stability and alignment necessary for the duration of bone healing. The bone biology is dependent on the patient's physiological state, comorbidities and the blood supply, before and after the implant has been applied. The implant can function as a surrogate cortex, but should not be relied on as compensation for inadequate fracture reduction. A plate osteosynthesis has a finite number of load cycles to failure and the goal is to obtain uneventful healing before this occurs [2].

To obtain pre-trauma alignment of a fractured bone and hence optimal function of the limb the surgeon must be aware of the pitfalls in different anatomical areas and the consequences of malalignment.

Considering timing, malalignment can be divided into *Primary* Malalignment that exists as soon as the patient leaves the operating room and *Secondary* Malalignment that occurs in the postoperative period until fracture healing occurs.

Primary malalignment is dependent on the surgeon's skills and knowledge and on the complexity of the fracture.

Secondary malalignment is caused by a change in fracture reduction and alignment at some point during the postoperative period. This may be due to several factors:

- Loss of fixation in poor bone quality.
- Inadequate fixation in combination with an unstable fracture pattern.
- Premature dynamization or non-compliance to postoperative regimen.
- Construct failure due to inadequate osteosynthesis or prolonged healing.

Malalignment can also be studied after the characteristics of the deformity:

1. Angulation
   a. Varus/valgus
   b. Anterior/posterior
2. Rotation
   a. Internal
   b. External

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3. Translation
   a. Medial/lateral
   b. Lengthening/shortening
   c. Anterior/posterior
4. Component in one, two or three planes
   a. Oblique plane deformity

When evaluating postoperative radiographs even little changes can be signs of pending failure. Slight loss of fracture reduction, halo around screws or slight change in screw position. Slightly change in fracture reduction is often optimistically interpreted as "settling". One should wary of this consideration. Expect the appropriate callus formation and bone healing response, direct or indirect, for the type of osteosynthesis obtained, absolute or relative stability, respectively.

Attention should be paid when planning lateral plating in fractures with associated medial comminution. For example, distal femur fractures with medial comminution or proximal humeral fractures with medial metaphyseal comminution have a high rate of secondary varus malalignment when failing to ensure medial stability. Examples of means of stability are opposite site plates, graft or both [2].

The aim for this review is to present general considerations and available literature regarding malalignment and its consequences after fractures in adults. The field is illuminated by available relevant studies of typical and common fracture sites at the following anatomical locations: humerus, antebrachium, femur, tibia. This is a narrative review and fractures in children are not included.

Current evidence

Humerus shaft

Humerus shaft fractures are common and account for approximately 3–5% of fractures in adults [3]. The humerus has a rich blood supply with limited axial weight bearing demand, but external forces being predominately rotational. It is easy to immobilize. As a result, fractures to the humerus shaft has historically been categorized as benign with good response to conservative treatment with functional bracing and union rates of 90% and good functional and cosmetically outcome have been described [4,5].

Traditionally malalignment greater than 20 degrees in any planes and rotation greater than 30 degrees has been the considered indication for surgical fixation [3,6]. The limited studies available of non-operative treatment have shown good cosmetically and functional results when angulation was limited to this degree. Most historically studies, however, have used outcome measures like ROM of elbow or shoulder as measurement for upper extremity function. This must be taken into consideration when analyzing these results as ROM in both adjacent joints must be expected to be near-normal after a humeral shaft fracture, despite the malalignment of the shaft [3,4].

Crespo et al. [5] in 2016 challenged this existing paradigm. In an observational study, they developed a cadaver model and a 3D computerized model of humeral fractures with malalignment. Their measured outcome was the third metacarpals ability to reach 6 anatomical landmarks with the scapula immobilized. This was used as a surrogate for upper extremity function. They found that varus malalignment was better tolerated than valgus and sagittal malalignment. All landmarks were reached between 5–20 degrees of varus deformity. Only 2 of 6 landmarks were reached at a valgus deformity greater than 20 degrees and even declined drastically at 15 degrees (3/6). Valgus deformity was seen to impair the ability to reach posterior landmarks because of loss of internal rotation.

The function was severely affected by sagittal deformity. Both antecurvatum and recurvatum more than 5 degrees resulted in inability to reach the pubic symphysis and at 10 degrees the sacrum could not be reached. This was the case in both models.

Fig. 1. Humerus fracture with varus deformity after non-operative treatment.

This might add new knowledge to future decision making in the management of humeral fractures and the limits for acceptance of malalignment both in choosing primary treatment and when evaluating postoperative results (Fig. 1). No recent studies have evaluated the consequences of rotational malalignment of the humerus shaft and 30 degrees is still the generally accepted limit for operative indication [3,6].

Humerus shaft
Recommendations

Accepted malalignment:
- Varus <20 degrees
- Valgus <15 degrees
- Sagittal deformity <5 degrees
- Rotation <30 degrees

Forearm

Fractures of the forearm involves two bones, but they should be considered as one unit, as fracture and malalignment of one bone affects the alignment of the other. Anatomically and according to the AO classification the forearm fractures are divided into proximal, shaft and distal, and the fractures are distributed with a ratio as 1:2:5 [7].

Forearm fractures involve specific problems different from fractures of the diaphysis in other long bones. Failing to restore the correct anatomical relationship between the two bones is strongly related to loss of function [8]. This is illustrated by the high rates of complications in patients who sustained a Monteggia fracture [9]. They include loosening of fixation, malunion, non-union, radioulnar synostosis, ulnohumeral arthrosis, radiohumeral subluxation and ulnohumeral dislocation [9].

Snow et al. [10] conducted a cadaver study to quantify the impact of varus and valgus malalignment on forearm rotation after proximal ulna fractures. They used 8 cadaveric upper extremities and tested pronation and supination at low, medium and high torque values in varus/valgus malalignment at 5, 10 and 15 degrees. They showed that varus deformity resulted in decreased pronation with larger deformity leading to greater loss of pronation. Supination was not affected at 15 degrees of varus deformation.