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Surgical treatment of osteoporotic fractures: An update on the principles of management

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ABSTRACT

The treatment of osteoporotic fractures continues to challenge orthopedic surgeon. The fragility of the underlying bone in conjunction with the need for specific implants led to the development of explicit surgical techniques in order to minimize implant failure related complications, morbidity and mortality. From the patient's perspective, the existence of frailty, dementia and other medical related co-morbidities induce a complex situation necessitating high vigilance during the perioperative and post-operative period. This update reviews current principles and techniques essential to successful surgical treatment of these injuries.

Introduction

The population worldwide is ageing as both the number of individuals over 65 years of age and life expectancy continue to increase. This demographic transition raises concerns about the growing incidence of age-related diseases, including osteoporosis. Approximately 200 million people worldwide are affected with osteoporosis [1]. This disease is characterized by a decrease in bone density and quality, making it prone to sustaining fractures with low-energy injuries (i.e. osteoporotic fractures) and almost 90% of these occur as consequence of a fall from a standing height [2].

Each year approximately 9 million osteoporotic fractures occur worldwide and by 2040 this number is expected to double [3]. This poses a significant burden on the healthcare systems as osteoporotic fractures are associated with high rates of morbidity and mortality and the overall cost of treatment is estimated to reach $18 billion globally [3]. The role of the orthopedic surgeon becomes paramount as the main goal of treatment is to provide stable fixation that allows early weight bearing and mobilization. For this to be achieved, surgeons must acknowledge and be prepared to overcome the challenges of treating patients with osteoporotic bone. In this article our aim is to highlight the different surgical techniques that can be applied to optimize fixation of the fractures in patients suffering from osteoporosis.

The problem of bone with osteoporosis

Most difficulties faced when treating osteoporotic fractures are due to the changes the bone tissue undergoes with ageing. Bone has unique biomechanical characteristics; its elastic properties allow for a certain degree of deformation under loading and its strength permits it to withstand different amounts of stress before failing [2,4]. In addition to its intrinsic material properties, these characteristics are dependent on the bone's density and distribution, all of which is affected by osteoporosis [4]. Cortical bone consists of dense, parallel lamellar units. When compared to trabecular bone, it has a higher strength but a small carrying capacity when loaded beyond its range of elastic deformation [2]. In osteoporosis, as the balance between bone reabsorption and formation becomes more negative, cortical bone becomes porous, cortices get thinner and become more homogenously mineralized, therefore reducing its strength and making it more brittle [2,5,6]. Trabecular bone, on the other hand, consists of a network of less organized lamellae with variable density which allows it to have anisotropic biomechanical properties, it tolerates higher compressive forces but its carrying capacity under tension is limited. The biomechanical properties of trabecular bone are highly dependent on its density. With osteoporosis, the bone's strength and stiffness are altered in a nonlinear fashion, making it even more susceptible to mechanical failure [4]. This likely explains why most osteoporotic fractures occur in metaphyseal regions [5].

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Surgical strategy

The success of surgical treatment depends on the patient's characteristics, type of fracture, soft tissue envelope and a thorough understanding of the biomechanical factors affecting fixation of osteoporotic fractures [4]. The patient's physiology, pre-injury functional status, comorbidities and medications might affect bone healing and could help determine which surgical technique and implant is more appropriate. Preserving the soft tissues maintains an adequate biologic environment to enhance bone healing. However, biomechanical problems include unstable and comminuted fracture patterns in metaphyseal regions, short epiphyseal fragments that complicate fracture fixation, impaired healing by building constructs that are either too unstable or too rigid, decreased holding power of screws in the osteoporotic bone and early implant-bone fatigue which leads to implant loosening and loss of fixation [3,5,6]. Fixation techniques that can be considered include:

Plate fixation

Failure of internal fixation in osteoporotic bone typically results from bone failure rather than implant breakage [41]. The holding power of the plate-screw construct to the bone is affected by the changes the bone undergoes with ageing and osteoporosis resulting in a reduced strength of internal fixation. A decrease in cortical thickness of 1 mm leads to a 50% (1000 N) reduction of the screw's holding power [42,43].

The major difference between locking and conventional plate constructs is the way load is transferred between the implant and fracture fragments. Conventional plates rely on frictional load transfer between the plate and the bone. Thus, loads are transferred from the bone to the plate across the fracture area and back to the bone again. Friction in conventional plating is produced by compressing the plate on to the bone by tightening the screws. This compression induces a considerable amount of preload on the bone around the screws which further increases the risk of screw pull out [44].

In locking plates the loads are transferred through the screws and the interface between the screw and plate which prevents individual screws from toggling and cutting through the bone in cycling fatigue [45].

A recent study compared the stresses in the bone-screw interface between locking plates and conventional plates both in osteoporotic and healthy bone. It showed a significantly lower strain at the screw-bone interface when locking plates were used in osteoporotic bone [44]. This provides a mechanical explanation for the improved performance of locking plates in poorer bone quality and explains previously reported higher incidence of screw loosening using conventional plates.

The early clinical experience with locking plates, especially for the distal femur and proximal tibia, showed excellent results with the LISS system (less invasive stabilization system, Synthes, Paoli PA) especially in the settings of osteoporotic and periprosthetic fractures [50]. In addition there were reports of good outcomes using locking plates in the treatment of diaphyseal fractures and non-unions [51].

There are still some limitations and complications associated with the use of locking plates. The knowledge and experience using them correctly is extremely important. Locking plates could create a construct that can be too rigid leading to non-unions [46]. Additionally, and especially in highly comminuted fractures, leaving fracture gaps or the absence of a far cortex will increase the risk of bending at the site of the fracture and eventually failure of fixation, thus some author's recommend deliberate shortening in order to eliminate gaps [47]. To increase the bending resistance and increase flexibility it is recommended using longer plates with fewer screws spread over a longer working distance from the fracture [47,48].

There are new innovations and techniques emerging to overcome the limitations of locking plate and screw systems. The concepts of "far cortical locking" and "near cortical slots" have been proposed to help reduce the construct's stiffness by using locked screws with unicortical fixation in the distal cortex [19,20,21,23]. Some screws designed for "far cortical locking" have a smaller midshaft diameter to increase flexibility and prevent excessive stress at the distal cortices but, because of their reduced diameter they may be prone to premature fatigue [21,22]. For "near cortical slots", conventional locking screws can be used but the proximal cortices must be overdrilled [20]. Although in biomechanical studies these new techniques appear promising, their clinical use is still limited by the lack of strong clinical studies.

Clinical examples of plating in different osteoporotic fractures are seen in Fig. 1.

Intramedullary nailing

Intramedullary nails are load sharing devices, they allow forces to be more equally distributed between the implant and the bone, and because they are located closer to the bone's mechanical axis, they have a high resistance to bending forces [7]. As a result, internal fixation of osteoporotic fractures using intramedullary nailing, in most cases, allows the patient to start early weight bearing and protects the soft tissues around the fracture site. The weakest regions of intramedullary nail fixation are the metaphyseal areas where the interlocking screws are placed [5,6,8]. Here the medullary canal is wider, the nail is not in contact with the cortices, and therefore the construct's stability relies on the screw-nail interface [9]. This should be considered when nailing osteoporotic bone as the strength of interlocking screw fixation is hindered by poor bone quality.

Intramedullary nails were initially best suited for fixation of diaphyseal fractures and their use for treating osteoporotic fractures was limited. These fractures usually occur in the bone's metaphysis and have small epiphyseal fragments that are subjected to significant displacement because of the different muscular insertions. Therefore, interlocking screws were not able to provide sufficient fracture stability, resulting in loss of fixation or rotational deformities [7].

New generations of intramedullary nails have changed their design and different techniques have emerged allowing surgeons to extend the indications of intramedullary nail fixation for treating osteoporotic metaphyseal fractures [7,9]. Nails with the option of using interlocking screws in multiple planes helped improve fracture stability and decrease the risk of malunion [3,5]. Different interlocking devices such as helical blades have been designed to provide more load bearing surface area to distribute the forces over a larger volume of bone and reduce stress on the construct [8]. A biomechanical study by Ito et al. showed that under axial loading, a blade-like interlocking device created a construct that was 41% stiffer and 20% stronger than constructs with conventional interlocking screws [8]. Based on the biomechanical properties of locking plates, nails with fixed angle interlocking capabilities have been designed to achieve a more rigid fixation by reducing the toggling of the interlocking screw within the nail [10].

Although from a biomechanical point of view these new designs are appealing and may improve the strength and stiffness of the bone-implant constructs, more thorough investigations are needed. Although many studies show improved results under axial loading, most of them fail to assess stability under rotational or more physiologic loading [10–12]. Additionally, the clinical

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