

Physiological principles of intramedullary nailing

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Abstract

Locking screws provide controlled dynamic compression effects, but never static-compression among fragments. The advantage of nonreamed nailing is in better preservation of blood supply that enables early callus formation. Intramedullary nailing is used in the diaphyseal and metaphyseal fractures of long bones. In the polytraumatized patients and patients with several long bones fractures the primary external fixation that is later converted to intramedullary fixation is recommended.

Introduction

The evolution of osteosynthesis with screws and plates headed towards rigid compression among fragments and primary healing. The ideal of primary healing is the overgrowth of the fracture with the lamellar bone without any callus formation. Callus in the X-ray films was actually considered proof of inefficient compression (stabilization) and a sign of movement among fragments.

Fracture reparation and intramedullary nailing

Intramedullary nailing does not provide complete immobilization among fragments or static compression among them, therefore this method cannot result in primary bone reparation. Despite the introduction of various forms of nails, reaming of the medullary canal and locking screws, intramedullary nailing could never reach the effects of primary reparation. Reaming of the medullary canal multiplies the contact surface between the nail and the medullary canal, but it does not prevent the fragments to move when the movement was not preliminary prevented by the form of fracture itself. Slight movement of the fragments leads to bone resorption at the butted ends of fragments and at the abutting wall between the bone and the metal nail. This slight movement – dynamic compression – can easily cause resorption on the surface of the bone and the screw and by that eliminate friction between the bone and the screw even in the direction of rotation. Even the special highly elastic nail with the along-side gap, which allows the placement of an over-calibrated nail, cannot completely prevent the along-side torsion between fragments. Locking screws prevent this movement of the metaphyseal fragments, but cannot provide compression because of the disability of the metaphysis to provide enough support to the screws. Non-reamed under-calibrated nail with two locking screws at each of the two larger fragments prevents any rotation of the fragments and any along-side movement, but it cannot prevent slight oscillation of fragments.

Intramedullary fixation can therefore not result in primary bone reparation, but this does not necessarily mean the healing process will last any longer. It takes as much time for the lamellar bone to reconstruct under pressure as it does for callus to form. The advantage of intra-

medullary fixation is in the early allowed burdening by the almost neutral position of the nail regarding to the axis of the weight burdened bone. On the contrary, in cases of fixation with plates and screws, the plate is placed in an eccentric position and thus only neutralizes the pulling force. The contact force at the other end is neutralized by the contact between fragments, but as that is not necessarily true in all cases, we must sometimes wait for the sufficient amount of callus to form, which can naturally delay the beginning of full weight burdening on the bone.

In rigid and compressive osteosynthesis the formed lamellas of the bone bridge over the fracture line if fragments on both sides of the fracture line are well supplied with blood. The process of primary bone reparation (primary healing) can be understood as a balanced activity of osteoblasts and osteoclasts in incomplete fracture, where a part of the long bone is not fractured, whereas the fragments nearest to the fracture line are completely rigid and the crack is less than 1 mm wide. After the fracture line has been overcome with lamellas, the re-arrangement of those lamellas can be achieved by burdening. This re-arrangement is the second part of the same process of osteolysis and osteogenesis (3). Not all authors support S. Perren's thesis on primary healing.

Primary healing is – along with regeneration – a part of a universal reparatory mechanism. Like in all other tissues, it consists of the neurogenic, destructive and constructive phase; it is unique in the zone of maturation, where first cartilage and then bone callus substitute the fibrous tissue. The duration of the formation of callus depends on the partial oxygen pressure in the maturation zone. If it is above 12 mmHg, the osteoblasts will be active, if it is lower than 12 mmHg, the chondroblasts will multiply. The critical oxygen pressure is ensured within the radius of $50 \cdot 10^{-6}$ m around the capillary in the tissue. When the capillaries sprout quickly into the fracture area and create a dense capillary net, callus will ossify faster, whereas when the sprout is slow due to an infection, inefficient immobilization, age, etc., callus will need more time to ossify.

The amount of callus depends only on the movement of fragments and not on the size of the haematoma above the fracture. The slighter is the movement, the lesser the amount of callus. Each type of callus (fibroid, cartilaginous, or bony) neutralizes the movement of the fragments at its own time. The relation between stability and the size of callus remains dynamic almost all through maturation; if stability increases at a certain point during maturation, the originally large fibroid or cartilaginous callus will result in a small bony callus and vice-versa.

When to decide on intramedullary fixation

Intramedullary nailing is not the optimal method in all fractures of long bones, currently it is only a method with certain advantages in certain types of fractures, of course in the hands of an experienced surgeon. Its advantages are most obvious in cases of diaphyseal femoral and tibial fractures, where it can replace plates and screws of any kind. In tibial diaphyseal fractures the greatest advantage is in sparing of soft tissue envelope. Where femoral fractures treatment stands today, intramedullary fixation is superior in comparison to angular, condylar or DHS plate in cases of comminute, unstable and subtrochanteric fractures, because it provides more mechanic stability, which is crucial in cases of senior patients who cannot always walk after the operation without bearing weight. Retrograde intramedullary nails for condylar and supra-condylar fractures still have some limitations and lack of proven studies to be declared as completely superior

to DCS and condylar (particularly angular stable) plates. It seems but very effective, particularly in cases of type 33A and many 33C (according to AO classification) fractures.

As the mechanical advantages of the intramedullary nail in cases of humeral fractures are less obvious, it appears to be asserting more slowly. But taking into consideration the possible damage on soft tissues and nerves when inserting plates, it is safe to say that the tip on the scale will eventually point towards intramedullary nailing. Intramedullary nailing of the forearm is still problematic; we will have to find a completely new solution for nailing the radius and the ulna, both in the sense of new materials as well as the method of placing the intramedullary nail.

The use of intramedullary nails, especially with reaming, affects the whole organism, particularly with the embolization of the medullary cavity content through the circulation, release of mediators etc. Therefore this method can aggravate the already critical condition of a poly-traumatized patient. The non-reamed nail naturally causes less damage and provokes far less distant side effects, but its use is questionable because of the complicated surgical procedure and technical demands. It appears that the manufacturers tend to sell thinner, but firm nails with locking screws. As the locking screws are not as firm as the nail itself they break easily and they serve as a kind of "protection" if the bone is over-burdened. It is namely still easier to remove the locking screws than a broken distal remaining of the nail in the medullary canal.

Taking in the consideration all the mentioned facts we must be aware that placement of intramedullary nails is a demandable procedure that could last long (for example, placement of four intramedullary nails to fixate two femoral and two humeral fractures would last approximately three to four hours), the patient is largely exposed to cold, with the complex instrumentation and a large surgical team needed, the blood loss could be high with a lot of mediators released, etc.. Therefore, in cases of poly-traumatized patients with more than one diaphyseal long bone fractures it is best to place an external fixator first, and then when the patient is optimally conditioned – regularly within three weeks later – convert it to intramedullary fixation.

Conclusion

Intramedullary nailing is a dynamic or a static method of osteosynthesis, but it can never provide rigid compression among fragments. Because of the central position of the nail, it allows early burdening on the bone even before bony callus completely bridges over the fracture line. This method is the most appropriate for the fixation of diaphyseal tibial and humeral fractures and of diaphyseal and metaphyseal femoral fractures. It is to be considered whether to be used for urgent fixation in poly-traumatized patients, but it can be certainly used after a time of patient's stabilization period to replace temporary osteosynthesis with an external fixator.

References

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