Dynamic plate osteosynthesis for fracture stabilization: how to do it

Juerg Sonderegger,[1] Karl R. Grob,[2] Markus S. Kuster[2,3]

[1]Department of Hand-, Plastic-, and Reconstructive Surgery, Kantonsspital, St. Gallen, Switzerland;
[2]Department of Orthopaedic Surgery, Kantonsspital, St. Gallen, Switzerland;
[3]The University of Western Australia, Perth, Australia

Abstract

Plate osteosynthesis is one treatment option for the stabilization of long bones. It is widely accepted to achieve bone healing with a dynamic and biological fixation where the perfusion of the bone is left intact and micromotion at the fracture gap is allowed. The indications for a dynamic plate osteosynthesis include distal tibial and femoral fractures, some midshaft fractures, and adolescent tibial and femoral fractures with not fully closed growth plates. Although many lower limb shaft fractures are managed successfully with intramedullary nails, there are some important advantages of open-reduction-and-plate fixation: the risk of malalignment, anterior knee pain, or nonunion seems to be lower. The surgeon performing a plate osteosynthesis has the possibility to influence fixation strength and micromotion at the fracture gap. Long plates and oblique screws at the plate ends increase fixation strength. However, the number of screws does influence stiffness and stability. Lag screws and screws close to the fracture site reduce micromotion dramatically.

Dynamic plate osteosynthesis can be achieved by applying some simple rules: long plates with only a few screws should be used. Oblique screws at the plate ends increase the pullout strength. Two or three holes at the fracture site should be omitted. Lag screws, especially through the plate, must be avoided whenever possible. Compression is not required. Locking plates are recommended only in fractures close to the joint. When respecting these basic concepts, dynamic plate osteosynthesis is a safe procedure with a high healing and a low complication rate.

From a rigid to a dynamic plate osteosynthesis

For many years the goal for fracture stabilization of long bones was an exact reduction of all fracture fragments in combination with a rigid osteosynthesis (Figure 1). Lag screws were used to obtain compression at the fracture site. Periosteum and muscle tissue had to be removed to obtain an anatomical reduction of all fragments. This kind of osteosynthesis resulted not only in lack of callus formation but also in decreased bone perfusion. Furthermore, it was difficult to monitor fracture healing by radiographs. Bone healing was delayed in many cases and hardware failures were often the result.

The goal in modern fracture stabilization, using either a plate or nail osteosynthesis, is to maintain the fracture hematoma and the perfusion of the bone, a so-called biological osteosynthesis.[1] The AO (Arbeitsgemeinschaft für Osteosynthesefragen, Switzerland) proposed the need for biological fracture management.[2] An intact perfusion of bone and soft tissue is more important for fracture healing than high primary mechanical stability (Figure 2). In a biological osteosynthesis the periosteum is preserved where possible, an indirect reduction is performed, and small fracture fragments are left in place. The goal is to restore the length, axis, and rotation of the bone without altering bone perfusion. It was recognized that callus formation is not a sign of instability but a natural and important process in fracture healing. Micromotion at the fracture gap is necessary in order to obtain callus formation. "Dynamic plate osteosynthesis" refers to plate fixation that allows such micromotion.

The biology of fracture healing

In addition to the biological factors, many mechanical conditions have to be met for a broken bone to heal. The size of the fracture gap and the amount of fracture motion are important criteria that can improve or delay fracture healing. Aro and Chao described the principles for understanding bone healing.[3] The authors distinguished between osteonal and non-osteonal bone healing (Figure 3). In non-osteonal fracture healing abundant callus formation is observed owing to periosteal and endosteal healing processes. No primary healing of the bone cortex is observed and remodeling processes are slow. This type of fracture is observed after cast immobilization, for example, where the fracture gap and the motion between the fragments are large. Abundant callus is needed to reduce motion at the fracture site, which finally allows remodeling and bone healing.

In a mechanically stable situation, as is the case in a rigid osteosynthesis, primary osteonal fracture healing will take place. Regenerating osteones will migrate directly from one fragment through the fracture gap to the opposite fragment. No remodeling will take place and no callus will be seen. This kind of fracture healing is possible only when the fragments are in direct contact. It does occur after rigid plate osteosynthesis with anatomical reduction and interfragmentary compression. Less rigid osteosynthesis results in micromotion at the fracture site. In this case, fracture healing is initiated by periosteal and endosteal callus formation, followed by osteonal fracture healing. This is called "secondary osteonal fracture healing" (Figure 4). Remodeling processes are fast as long as the bone fragments are in direct contact or with only a small fracture gap. Today fracture healing is attempted to be achieved by secondary osteonal fracture healing. It is important for a surgeon to know in what way he can influence the amount of micromotion at the fracture site and consequently the speed of fracture healing.

Correspondence: Juerg Sonderegger, Department of Hand-, Plastic-, and Reconstructive Surgery, Kantonsspital, CH-9000 St. Gallen, Switzerland.
E-mail: juerg.sonderegger@kssg.ch

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The choice of the implant

Several surgical options such as plate osteosynthesis, intramedullary nailing, or external fixation are available for the treatment of fractures of long bones. The choice can be difficult. In an animal model fracture healing after four different types of osteosynthesis was compared.[4] Comminuted tibial shaft fractures were treated by (i) rigid plate osteosynthesis using lag screws, (ii) bridging osteosynthesis, (iii) external fixation, and (iv) intramedullary nailing. Of all procedures, the rigid, anatomically reduced plate osteosynthesis showed the highest mechanical stability initially, but the worst course of fracture healing. The best results were obtained with the bridging osteosynthesis and external fixation. For successful fracture healing primary mechanical stability seems less important than a biological osteosynthesis with an intact endosteal and periosteal perfusion.

Intramedullary nailing is often the preferred treatment option, especially in shaft fractures of the tibia or femur. Open-reduction-and plate-osteosynthesis was brought into disrepute for its rigidness, long skin incisions, and soft tissue damage. However, biological plating techniques have improved and therefore plate osteosynthesis has regained popularity.[5] Nailing certainly offers many important advantages: incisions are small, blood loss is minimal usually, and a dynamic stabilization can be achieved. The surgical technique is simple and full weight bearing for mobilization is possible. Nevertheless, the disadvantages of nailing also have to be considered: reaming can produce fat embolism and compromises the endosteal perfusion. Furthermore, the risk of rotational malalignment is increased in intramedullary nailing of distal femoral and tibial fractures.[6,7] In a systematic review of distal tibial fractures rotational malalignment appeared more commonly in the intramedullary nailing group than in the plating group.[8] The incidence of rotational malalignment after intramedullary nailing of femoral shaft fractures seems to be as high as 30%.[9,10] It seems obvious that rotational malalignment can best be avoided by open reduction. It remains a problem in comminuted fractures if minimal invasive plating techniques are performed.

Anterior knee pain is another common complication after intramedullary nailing of the tibia.[11] In a prospective, randomized study 67% of the patients complained about anterior knee pain after transpatellar and 71% after paratendinous nailing.[12] Plate osteosynthesis, especially in distal tibial fractures, offers some well-established advantages. The risk for rotational malalignment and anterior knee pain can be neglected in simple fracture patterns, the fracture gap is usually small, and the endosteal perfusion can be preserved largely, even if open reduction is necessary. Furthermore, plate osteosynthesis is technically possible in metaphyseal fractures close to the joint, where intramedullary nailing reaches its limitations.

Possibilities for the surgeon to influence fracture healing

The surgeon performing a plate osteosynthesis has different possibilities to influence fracture healing. He can control micromotion at the fracture gap and fixation strength of the plate. It has been demonstrated that lag screws reduce motion at the fracture gap dramatically.[13] Axial stiffness and torsional rigidity are influenced mainly by the bridging length; for example, the distance of the first screw from the fracture site.[14] Micromotion increases exponentially with increasing bridging length

Figure 1. Rigid plate osteosynthesis of the femur. All fracture fragments are anatomically reduced. Many screws and lag screws are used. No callus formation is observed.

Figure 2. Biological plate osteosynthesis. Preoperative (left) and postoperative (right) radiographs of a comminuted femoral fracture are shown. There are only a limited number of screws. Lag screws and screws in the fracture area are avoided. The unicortical screw in the middle serves to hold one big fragment in place.

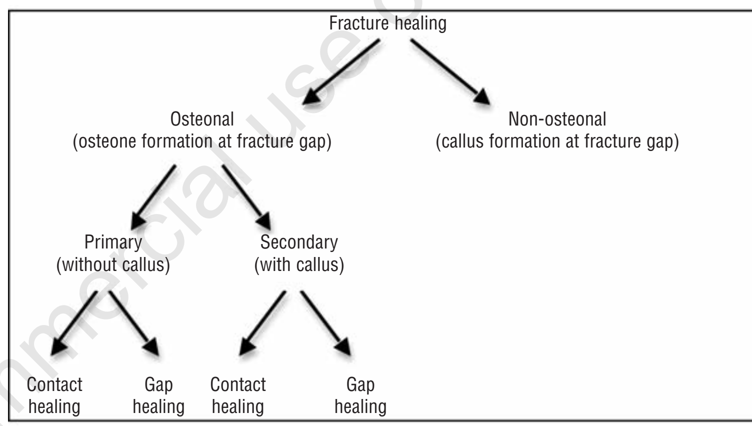

Figure 3. Two different patterns of fracture healing: in osteonal fracture healing the fracture gap is bridged by osteones. In non-osteonal fracture healing the fracture gap is bridged by callus.

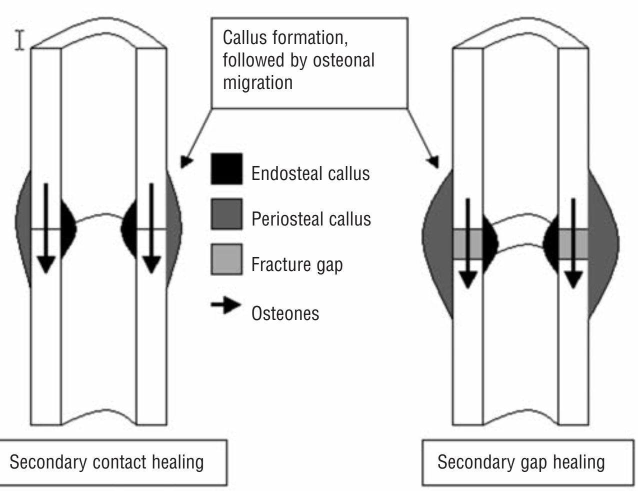

Figure 4. Secondary osteonal fracture healing. First, callus formation is observed followed by osteone migration. The fracture fragments are in direct contact (secondary contact healing, left) or separated by only a small fracture gap (secondary gap healing, right).

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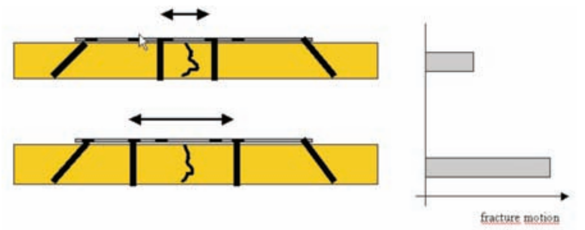

Figure 5. Influence of bridging length on fracture motion: micromotion at the fracture gap increases exponentially with increasing distance of the screws from the fracture site.

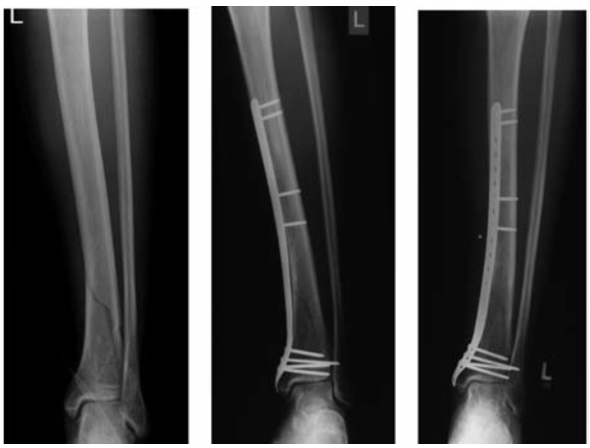

Figure 6. Example of a dynamic plate osteosynthesis in a distal tibial fracture. Preoperative (left), postoperative (middle), and radiographs after fracture healing (right) are shown. A long plate with a limited number of screws is used. Screws close to the fracture site and lag screws are avoided.

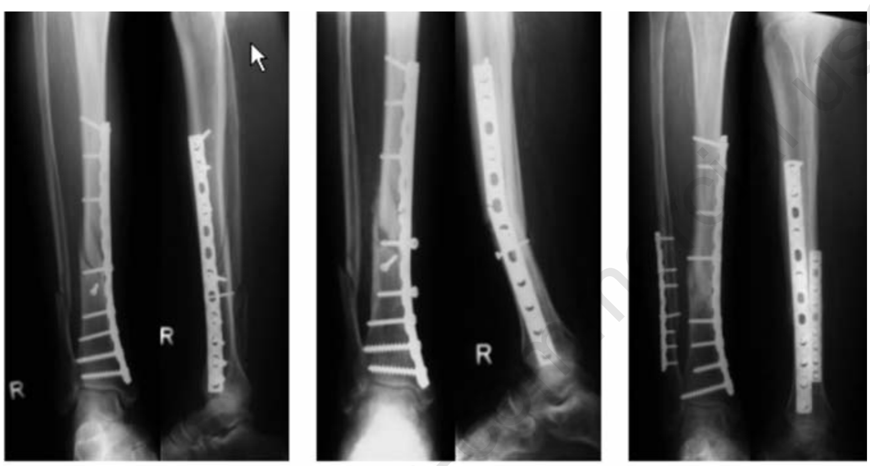

Figure 7. Plate failure: postoperative radiographs (left), at six weeks (middle), and after revision surgery (right). Note that the principles of dynamic plate osteosynthesis were not respected during the primary procedure by inserting a lag screw through the plate. Plate breakage was recorded at six weeks. Fracture healing was achieved after revision surgery with replacement of the plate, additional osteosynthesis of the fibula to provide lateral support, and removal of the lag screw to allow micromotion.

(Figure 5). Omitting two or three plate holes at the fracture gap and avoiding lag screws, especially through the plate, allows sufficient micromotion and therefore fast bone healing.

The most important factor to improve pullout strength of the screws in long bones is the length of the plate.[14] Oblique screws at the plate ends also increase pullout strength.[15] Another factor is the choice of the plate material. A titanium plate is twice as elastic as a steel plate and therefore allows more micromotion with the same plate configuration. The surgeon can influence fracture healing by the number of screws used. Drilling many screw holes may provoke local heat necrosis and the local endosteal blood flow may be disturbed without improving fixation strength. Hence, only few screws should be used for fracture fixation.

Our experience: a clinical study

The effects of dynamic plate osteosynthesis on fracture healing were studied in a case series of 47 patients with a mid- or distal tibial shaft fracture. All the patients were treated with a dynamic plate osteosynthesis. The mean age was 46 years. There were six open and 41 closed fractures. Nine- to 16-hole titanium LCDC plates were used. In ten cases an additional osteosynthesis of the fibula was performed. In four cases a fasciotomy and in two open fractures a local flap for soft tissue coverage was necessary. Bone union was achieved in all cases (Figure 6). There were no wound infections and no rotational malalignment. Screw breakage was recorded in three cases. However, the broken screws had no influence on stability and fracture healing. One plate failure occurred six weeks postoperatively. In this case the patient initially had undergone a rigid plate osteosynthesis with a lag screw through the plate. Fracture healing was achieved after revision surgery with removal of the lag screw, replacement of the plate, and additional osteosynthesis of the fibula (Figure 7).

A few easy steps toward a dynamic plate osteosynthesis

For successful dynamic plating we recommend the following principles:

- Use long plates.
- Use a few screws only.
- Omit two or three plate holes at the fracture site.
- Avoid drilling near the fracture site.
- Avoid lag screws whenever possible. When a lag screw is indicated for technical reasons, for example in the case of a spiral fracture, never place it through a plate hole.
- Place oblique screws at the plate ends.
- Treat the periosteum with care. Never strip it from the bone. Keep bone fragments covered with muscle and soft tissue.
- Consider the fact that a steel plate is twice as rigid as a titanium plate. Hence, for comminuted fractures where the bridging length is large owing to missing bone fragments a steel plate might be the better choice.

Dynamic plate osteosynthesis is a good choice for the stabilization of certain tibial and femoral fractures. It is a valuable alternative to intramedullary nailing, especially for distal fractures close to the joint.

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