

Biomechanics and clinical application principles of locking plates

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1 Introduction

The introduction some 10 years ago of the combination of biological bridge plating with indirect reduction techniques was considered by some to be an important and welcome evolution, but by others (2,5,6) as a revolution against rigid AO principles. It had become evident that in the cortex directly underneath a plate, and to a lesser extent in the vicinity of an intramedullary nail, considerable structural changes occur. These changes were first attributed to so-called stress protection by a metallic implant much more rigid than bone. Further research (1,3) gave rise to the theory that disturbed blood flow within the cortical bone was responsible for the intense remodeling processes that could be observed underneath every plate that was pressed against bone by screws (figure 1).

Reducing the area of contact between plate and bone, as achieved by the LC-DCP design, significantly reduced the vascular changes caused by pressure



Figure 1. A conventional plate pressed against the bone surface interferes with the cortical blood flow and induces structural changes underneath the plate.

on the cortex. However, the LC-DCP also has to be pressed against the bone in order to create the friction needed to fulfill its function.

In order to abolish the ill effects of any plate to bone contact, a completely different approach had to be chosen. With the introduction of screws or bolts that rigidly lock into the plate hole when driven home, the plate is no longer pressed against the underlying bone (4). Furthermore, the use of unicortical self-tapping screws seemed, in in vitro experiments, equally as effective as external fixation in obtaining a stable construct (4). In a way similar in principle to the external fixator this new and quite different technique of applying a plate has been termed the internal fixator system, as the implant functions more like a fixator than a plate, while the whole construct is covered by soft tissues and skin.

Such devices, since they are designed to avoid the ill effects of conventional plating, might be expected to offer a higher resistance to infection and other complications.

The first implant designed to fulfill the new requirements was the small PC-Fix for forearm bones. The PC-Fix was a narrow plate-like implant with a specially designed undersurface having only small points that come into contact with bone. The screws were self-tapping, unicortical and were available in one length only. The screw head locked firmly in the plate hole with a fine thread.

The Point Contact Fixator was the forerunner of the Less Invasive Stabilization System (LISS) and the Locked Compression Plate (LCP) whereby the latter implant offers both technologies in a more familiar plate design than the first internal fixator, PC-Fix.

The locking head screws of those implants are designed to lock tightly in the plate (figure 2). This provides axial and angular stability of the screw relative to the plate (= internal fixator).

Bone fracture fixation with an internal fixator is

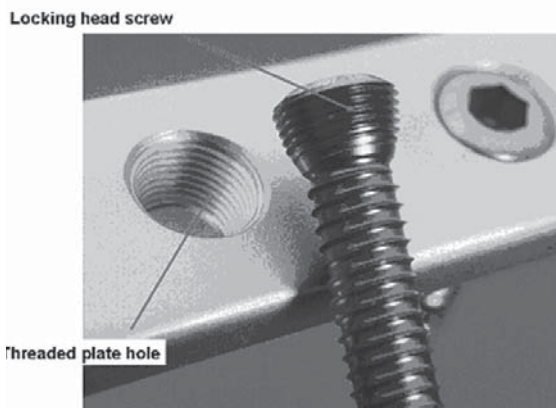


Figure 2 Locking Head Screws (LHS) of the LISS (Less Invasive Stabilisation System)

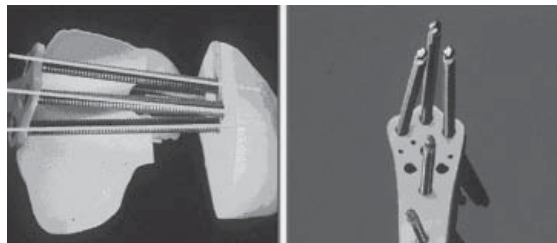


Figure 3 LISS for the distal femur (LISS DF) with the convergent screw directions in the metaphysis providing an ideal configuration to the condyles and an optimal anchorage even in osteoporotic bone.



Figure 4 Complex tibia plateau fracture AO 41-C2 with extension into the shaft. Stabilisation with a Tibia LISS with percutaneous insertion of the long plate.

not heavily dependent on the bone quality or the anatomic region of anchorage. Unlike the compression screw, this screw-plate combination does not require friction between the plate and the bone for the stable treatment of a fracture (non – contact plate). Therefore, the plate does not have to be adapted exactly to the shape of the bone. The position of the plate in relation to the bone remains unchanged during tightening of the locking head screws. Once this internal fixation has to bear the weight of the patient, the force will be transferred from one bone segment to another via the plate-screw construct. Unlike compression screws, the locking head screws are exposed more to bending loads than to tensile ones.

2 LISS (less invasive stabilization system)

While the PC-Fix had limited applications in the metaphyseal and epiphyseal areas, the LISS (figure 3) was conceived for precisely these regions-initially for the distal femur and later for the proximal tibia. Its shape conforms to the anatomical contours of the specific area of the bone so separate implants are required for the right and left sides. Additional contouring is not required as the “plate” fixator does not necessarily need to touch the bone. In addition to the locked unicortical screws, this implant is designed and instrumented for application via a minimally invasive submuscular approach (7,8).

The fracture should be adequately reduced and aligned prior to the application of the LISS. This is especially true for the articular components of the distal femur or proximal tibia which must be anatomically reconstructed and held by plate-independent lag screws. The LISS can accommodate long, fully threaded self-tapping screws that are locked in plate holes when driven home, thereby providing the attributes of a fixed-angle device (figure 3).

The Less Invasive Stabilisation System for Distal Femur (LISS-DF) is indicated for the stabilisation of fractures of the distal femur.

These include:

- Distal shaft fractures
- Supracondylar fractures
- Intra-articular fractures

LISS also offers the possibility of stabilizing fractures in bones with implants already in situ, e.g. total knee replacements, whether they have a medullary stem or not. Since multiple screws can be inserted into

the distal portion of the implant, the LISS offers a high degree of stability and reliability in osteoporotic bone. No other currently available implant can achieve this wide range of application.

The Less Invasive Stabilization System for Proximal Lateral Tibia (LISS PLT) is indicated for the stabilization of fractures of the proximal tibia similar to the LISS for the distal femur (figure 4). These include:

- Meta-diaphyseal fractures
- Segmental shaft fractures
- Intra-articular fractures
- Fractures in osteoporotic bone
- Pathological fractures
- Periprosthetic fractures

Unilateral plate fixation with locking head screws has been seen to improve the treatment of complex fractures of the tibial plateau that present with concomitant soft tissue injury and extensive metaphyseal/diaphyseal comminution. The LISS PLT method may not replace open reduction and internal fixation as the standard treatment for these fractures, but it is an excellent option for their treatment due to its minimal infection rates, high union rates without bone grafting, and good functional results.

3 LCP (locking compression plate)

A further refinement of internal fixator systems, with screw heads locking firmly into the plate hole, has now been devised. This is a new plate hole configuration which brings to this most valuable innovation the advantages of conventional plating, for example, placement of a lag screw across the plate for certain fracture configurations. This is achieved through a new design, the “combination” plate hole which can accommodate either a conventional screw or the new “locking head

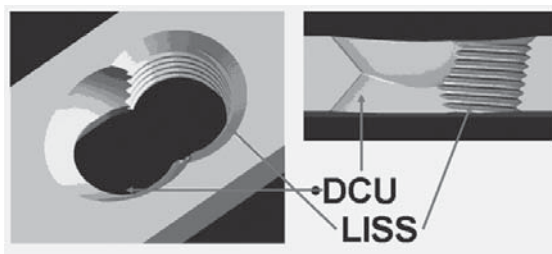


Figure 5 The combination hole of the LCP system consists of the conventional screw hole design (DCU) and the threaded new hole of the LISS.

screw (LHS)” which has a conical threaded head (figure 5).

The LHS comes in two forms; the self-tapping LHS has self-tapping grooves and is designed for use in sites such as the metaphysis where exact measurement of screw length is required. It can be bicortical or monocortical and predrilling is needed. The self-drilling and self-tapping LHS is of the same design but with the addition of a drilling tip of conventional design; it is for monocortical use only. The standard screw can be applied in the usual fashion. Alternatively, the combination design enables the new screw to be locked in any hole along the plate, so providing angular stability.

Depending on the desired function the locking compression plate (LCP) can be applied in three different ways:

1. As a conventional dynamic compression plate providing absolute stability (=compression technique) (figure 6):

With the use of an eccentric drill guide, axial compression can be obtained or a lag screw can be placed through a plate hole. This classical type of rigid fixation is still applicable in simple type A and B1 fractures in the meta-diaphyseal area, i.e. the forearm, where anatomical reduction may be required and can easily be achieved without wide exposure.

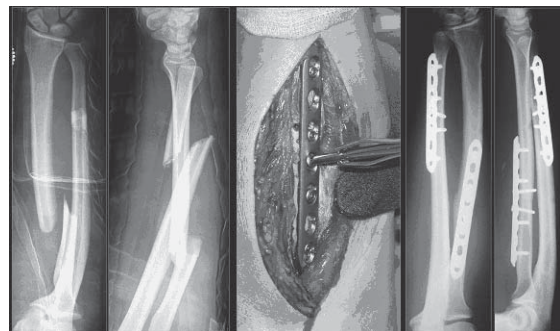


Figure 6 Forearm shaft fracture with simple fracture patterns (AO 22-A3), stabilised in traditional open technique, using two LCPs in compression technique.

Ideal indications for this compression technique are:

- Simple fractures in the diaphysis and metaphysis (if precise, “anatomical” reduction is necessary for the functional outcome; simple transverse or oblique fractures with low soft tissue compromise)
- Articular fractures (buttress plate).
- Delayed or non-union, osteotomies.
- Complete avascularity of bone fragments.

2. As a “pure” internal fixator providing relative stability by bridging the fracture zone according to LISS principles (=bridging technique) (figure. 7):

The complex type C fracture zone is bridged—without being exposed—by a long plate. This allows rapid indirect fracture healing with external callus formation. While the fractured bone must be appropriately aligned before the LCP is applied, little or no contouring is needed. Due to the locking mechanism the fragments are not pulled towards the plate.

The typical indications for this bridging technique are:

- Multifragmentary fractures in the diaphysis and metaphysis.
- Open-wedge osteotomies (e.g., proximal tibia: TomoFix).
- Periprosthetic fractures.
- Delayed change from external fixator to definitive internal fixation.
- Tumor surgery.

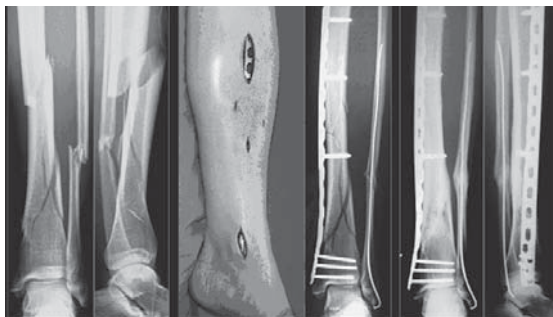


Figure 7 Complex distal tibia and fibula fracture AO 42-C2 with extension into the articular portion of the ankle joint, stabilised with a long LCP Metaphyseal-plate 3.5/4.5/5.0mm in a MIPO-technique (minimal invasive plate osteosynthesis).

3. In combined fashion where both techniques are employed (=combination technique) (figure 8), using conventional lag screws as well as locked screws:

In articular fractures requiring an anatomical reduction and fixation by interfragmentary compression lag screws may be essential for the reconstruction of any articular components. At the same time the locking head screw provides angular stability, helping to prevent secondary displacement in case of metaphyseal comminution or other bony deficiency.

The term “combination” describes the combination of the two described biomechanical principles: use of a combination of interfragmentary compression and the internal-fixator method (bridging). A combination technique does not mean combining different types of screws! This hybrid use of both types of screws (standard and locked screw) can be considered in the following situations (10): a) Reduction onto the plate in case of a residual axial malalignment of a fracture mostly in the frontal plain. b) Malalignment of the plate with respect to the long bone axis. When the plate is not ideally aligned to the axis of the diaphyseal segment the screw at the plate end may not meet the bone cortex when a locked screw with its predefined



Figure 8 Pilon fracture AO 43-C2 stabilised with a LCP 3.5 for the tibia in a combination-technique using 1) limited open reduction and lag screw fixation providing interfragmentary compression and absolute stability of the articular portion and 2) bridging the metadiaphyseal comminution by a partial MIPO-technique.

screw direction is used. Note: If for some reason a combination of different screw types is necessary, one should follow a simple rule for the fixation of each fragment - No placement of a cortical screw in a fragment in which a locking head screw has been already inserted!

There exists two indications for this combination technique:

- Articular fracture with a multifragmentary fracture extension into the diaphysis: anatomical reduction and interfragmentary compression of the articular component, bridging of the reconstructed joint block to the diaphysis (flexible fixation by the internal fixator method).
- Segmental fracture with two different fracture patterns (one simple and one multifragmentary): conventional technique with compression principle for the simple fracture, and bridging technique with internal fixator principle for the multifragmentary fracture.

Using these different principles of fracture treatment leads to different types of fracture healing. Under certain circumstances, the two different principles - absolute and relative stability - may be incompatible. Therefore, it is advisable to use only one of the two methods in one fracture zone, either in a compression method or as internal fixator. It is important to command knowledge of both methods and different techniques and their different features.

Choosing to use a LCP depends on bone quality, fracture situation, anatomical region and the surgeon's preference.

By making the correct decision in using the LCP in specific cases, one can significantly contribute to the improvement of the clinical outcome of the operative treatment of bone fractures. Promising early clinical results have already been published (11).

In summary, the existing benefits of the new internal fixator principles are enhanced by the combination hole concept in the following respects:

- Improvement in angular stability due to locking head screws (even if unicortical).
- Accurate plate contouring not required.
- Less damage to the periosteum and its blood supply.
- More options and greater versatility in fracture management, especially if complex epi-metaphyseal fractures or fractures with limited bone quality are present.

However, these new techniques demand very careful preoperative planning, especially in the sequence of applying the different types of screws, since this process requires a clear understanding of the principles governing each technique. The versatility of the system may increase the risk of application errors with disturbances to the fracture healing (12).

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