CHAPTER **15**

LOCKING PLATE TECHNIQUES FOR FRACTURE STABILITY

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INTRODUCTION

Dynamic osteosynthesis techniques have been popularized for their biological and biomechanical advancements over rigid internal plate fixation in certain fractures. Conventional plating techniques rely on principles such as anatomical reduction of a fracture after wide visualization through periosteal stripping, followed by pre-contouring of the plate to allow friction and compression between the bone and plate system. In addition to a lower complication rate than conventional internal fixation, locking plate techniques allow better biological preservation by maintaining blood supply to the fracture site and less soft tissue disruption (1-9). Locking plates may also be used in a similar manner to conventional plating with certain added benefits.

Locking plates allow a screw to engage and lock into a plate, which minimizes compressive forces between the bone and plate (Figure 1). This may eliminate the need for the contouring of the plate to the bone and allows for minimally invasive techniques for fixation if desired. In many respects, these plating systems can be thought of as "internal" external fixators as described by the internal fixator principle whereby fracture fragments are bridged with a locking plate. The Locking Compression Plate (LCP) can allow semi-flexible and elastic internal fixation for indirect bone healing, or if desired the plate may also be applied utilizing compression plate principles or in combination with the internal fixator principle (10).

With the widespread use of these plating systems, it is important to understand the concepts by which they function. The aim of this update is to examine mechanical factors influencing LCP techniques and to review guidelines for their successful utilization.

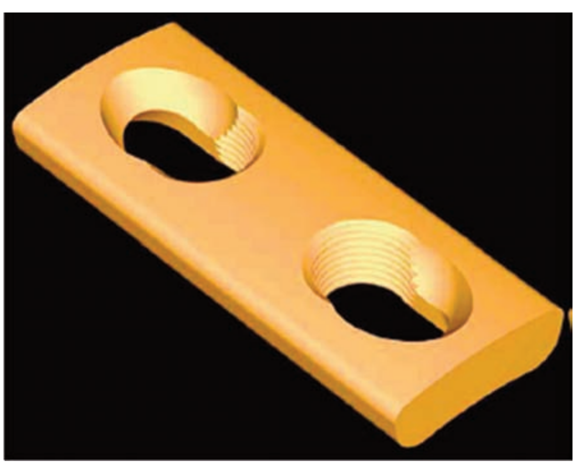

Figure 1A. Locking plate.

RESULTS

Indications

From a clinical perspective, the choice of using an LCP by conventional technique or minimally invasive percutaneous osteosynthesis (MIPO) is based on fracture location and configuration, soft tissue conditions, and patient condition. A conventional LCP technique with absolute stability is advised for most simple fractures, articular fractures, and delayed or nonunion repair. The MIPO technique for relative stability is advised in multifragmentary fractures, simple fractures if non-precise reduction is enough for functional outcome, peri-prosthetic fractures, secondary fractures after intramedullary nailing, and delayed change from external fixator to definitive internal fixation. Combination techniques are only advised for articular fractures with multifragmentary components and segmental fractures with 2 different fracture patterns (10).

Screw Selection

The type of screw (standard cortical, standard cancellous, self-drilling, self-tapping) used with the LCP are a key concept to understand for proper application. First, it is important to realize that because the screw threads into the plate, the plate itself is treated as the first cortex. As an example, if a bicortical screw is placed through an LCP, it would be considered to have 3 cortices of purchase.

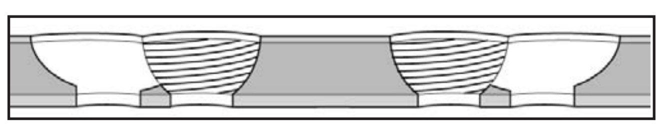

Figure 1B. Locking plates allow a screw to engage and lock into the threaded portion of the plate.

With insertion of a monocortical self-tapping screw, the tip of the screw should not contact the opposite bone cortex. If the screw tip contacts the far cortex, the near cortex bone threads are disrupted and anchorage of the screw may be lost (Figure 2).

It is also important to realize the extrusion length of self-drilling versus self-tapping screws. The self-tapping screw will have a shorter extrusion length than self-drilling because it lacks a cutting tip; therefore adjustments in length must be appreciated to allow proper engagement of the far cortex (Figure 3).

In osteoporotic bone with thinning cortices, the purchase length of cortical bone is diminished along with anchorage of the screw. It is therefore recommended to use bicortical self-tapping screws in this patient population (11) (Figure 4).

If utilizing the LCP by conventional or combination techniques, standard screws may be placed in an eccentric position to gain compression. Additionally, standard screws may be used to contour the plate to the bone. Once locking screws have been placed, these options are no longer available; therefore all standard screws must first be placed. If desired, the standard screws may be replaced with locking screws (Figure 5).

Plate Selection

Plate length was previously confined by the desired length of skin incision and prevention of extensive soft tissue disruption. With the MIPO technique, this is no longer a factor and plates can be chosen based on mechanical demand (discussed below). MIPO techniques for indirect reduction do not mandate exact adaptation of the plate to the bone. If the LCP is used by a conventional technique, then accurate shaping is still necessary (10).

Construct Stability

Axial Stiffness and Torsional Rigidity. The proper determination of plate length, number of screws, and screw location within the plate are vital for a stable fixation construct. Axial stiffness and torsional rigidity are primarily influenced by distance from the first screw to the fracture site, while plate length will secondarily benefit axial stiffness.

Stability is affected by the number of screws per fracture fragment. More than 3 screws per fragment do not significantly increase axial stiffness, while more than 4 screws do not significantly increase torsional rigidity. Mechanical testing has been performed to examine these parameters (Figure 6). With 3 screws per main fracture fragment, approximately 95% of the fracture axial stability and 70% of torsional rigidity are obtained. However, the position of the 3rd screw will affect axial stiffness with little influence on torsion. With 2 screws placed nearest and farthest to the fracture, the closer the 3rd screw is placed to the fracture, the stiffer the construct is under compression (Figure 7).

Using the MIPO technique, in a simple fracture with less than 2 mm gapping it has been recommended to place 2 or 3 screws per main fragment, while omitting the first 1 or 2 plate holes near the fracture gap. This construct will allow fracture motion and bone contact to occur with indirect bone healing. In comminuted fractures, it is recommended to have 3 screws on either side of the fracture with 2 screws as close to the fracture as possible for added stability (10) (Figure 8).

Plate to Bone Distance. The distance between plate and bone is another factor influencing overall stability (Figure 9). An increase in this distance will decrease construct stability. When short and long plates with equal number of screws are compared, the short plate will have reduced axial stiffness but

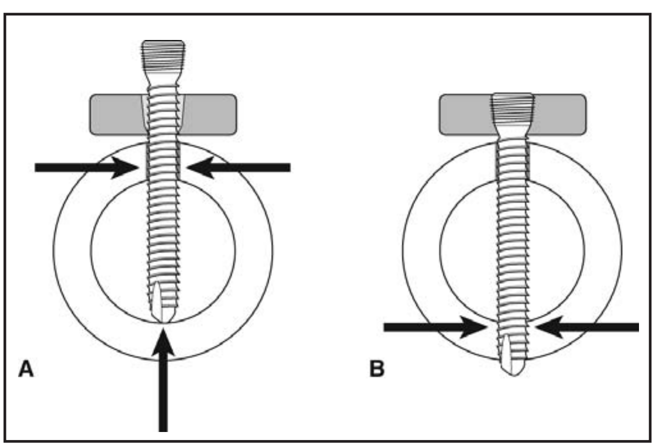

Figure 2. Insertion of a monocortical locking screw. The tip of the screw (A) should not contact the far bone cortex or the near cortex threads are disrupted and anchorage of the screw may be lost. This is prevented by shortening a monocortical screw or placing the screw bicortical (B).

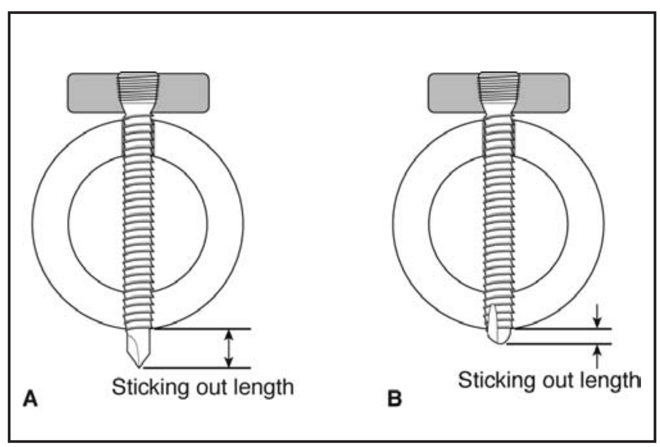

Figure 3. Extrusion length of self-drilling versus self-tapping screws. The self-drilling screw (A) will have a longer extrusion length than a self-tapping screw (B). Adjustments in length must be made for proper thread engagement of the far cortex.

no difference in torsional rigidity. Based on the number of screws and length of plate, other factors must be considered along with plate to bone distance, especially stress. Stress is diminished by increasing bone contact through greater bridging length; however an increased number of screws also lead to higher implant stress (1).

Fatigue Testing. In simple fractures with a 1 mm fracture gap and 2 screws per fragment, no construct failure was seen after 1 million cycles in testing performed by Stoffel et al. In comminuted fractures with a fracture gap of 6 mm, only the shortest working length was able to withstand 1 million cycles (Figure 10). This supports placement of fixation nearest to the fracture site (1).

CONCLUSION

Applying the above indications for LCP in conjunction with appropriate screw and plate selection allows for the best possible outcome in fracture stabilization. By precisely placing the screws based on the fracture type, construct stability can be maximized while limiting the amount of screws placed across the fracture site. Fewer screws placed allows for even less soft tissue disruption and stress forces.

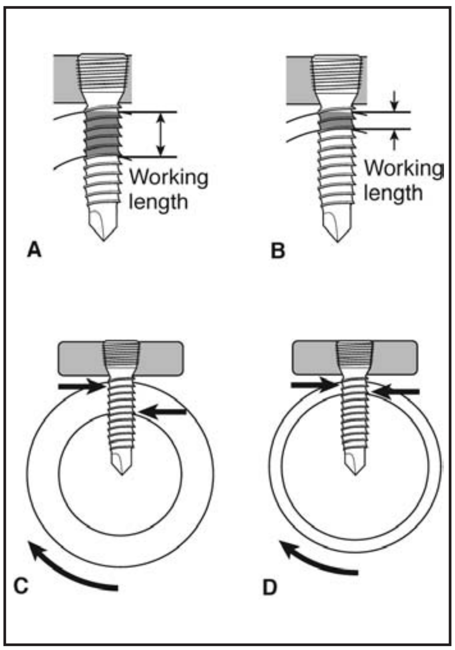

Figure 4. Osteoporotic bone and screw purchase. Thinning cortices cause diminshed purchase length of cortical bone. It is recommended to use bicortical self-tapping screws to increase anchorage.

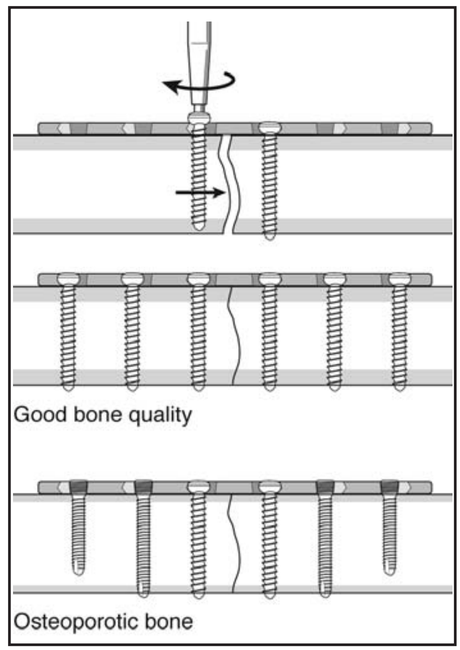

Figure 5A. LCP by conventional or combination techniques. Standard screws may be placed in an eccentric position to gain compression or contour the plate to the bone.

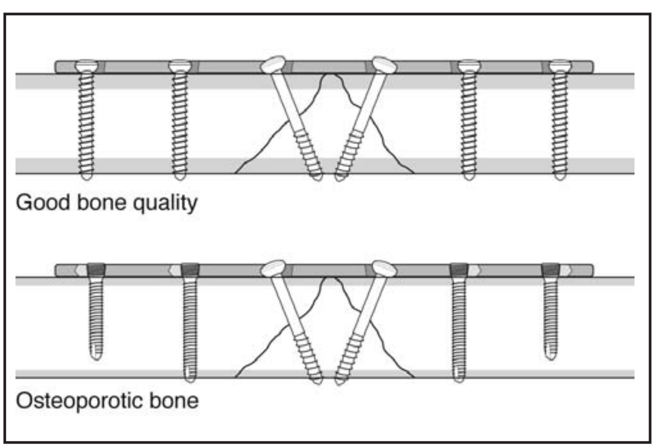

Figure 5B. Once locking screws have been placed, these options are no longer available; therefore all standard screws must first be placed. If desired, the standard screws may be replaced with locking screws. Similar principles apply in comminuted fractures.

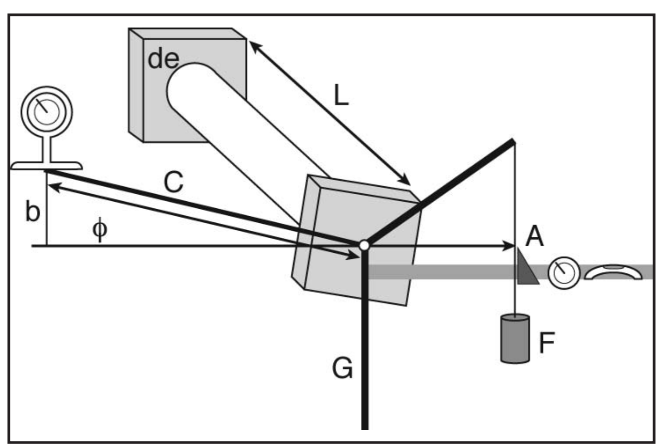

Figure 6. Forces acting on a fracture site. Axial stiffness and torsional rigidity can be measured by using bone and plate length, torque, load, and deflection.

Simple fractures are best fixated with the compression technique under direct reduction and partially open implant insertion. The plate should be conformed to the bone using both locking and standard screws. Bicortical screws are recommended when possible, with 2 or 3 screws per main fragment and at least 3 cortices per main fragment (11).

Comminuted fractures are best fixated with a bridge plating technique such as MIPO. Indirect reduction is performed along with minimally invasive plating. It is not necessary to contour the plate, and locking screws should be applied. At least 2 screws per main fragment should be utilized, with combinations of monocortical and bicortical screws. The fracture site should be spanned with a minimum of 3 holes left empty (11).

When advised, LCP allows minimal vascular and soft tissue disruption, eliminates need for bone compression, may eliminate the need for precise reduction (in certain fracture patterns), and allows usage in combination with conventional plating techniques while increasing overall stability (11).

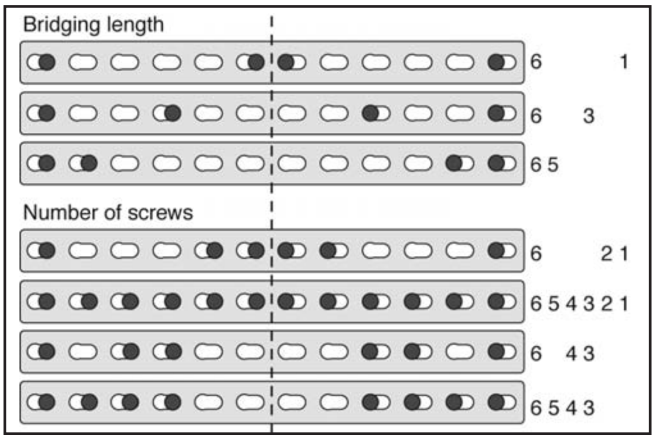

Figure 7. Bridging length and number of screws. With 3 screws per main fracture fragment, 95% of the fracture axial stability and 70% of torsional rigidity are obtained. The position of the 3rd screw will affect axial stiffness. With 2 screws placed nearest and farthest to the fracture, the closer the 3rd screw is placed to the fracture, the stiffer the construct is under compression. More than 3 screws per fragment do not increase axial stiffness, while more than 4 screws do not significantly increase torsional rigidity.

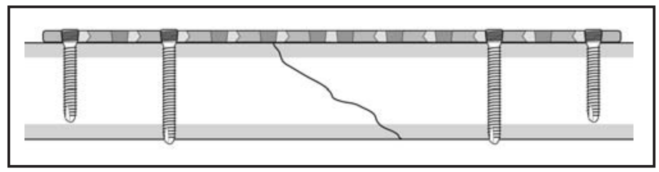

Figure 8A. MIPO technique. In simple fractures with less than 2 mm gapping, it is recommended to place 2 or 3 screws per main fragment, while omitting the first 1 or 2 plate holes near the fracture gap.

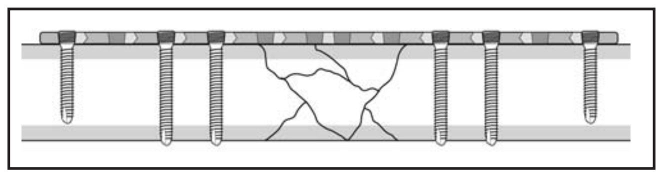

Figure 8B. In comminuted fractures, it is recommended to have 3 screws on either side of the fracture with 2 screws as close to the fracture as possible for added stability.

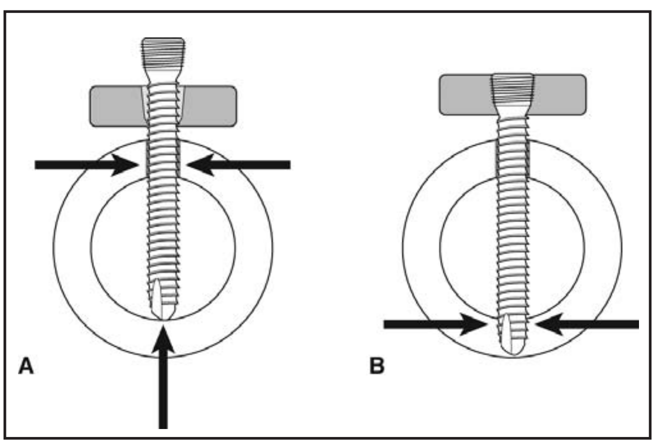

Figure 9. Plate to bone distance for fracture stability. An increase in plate to bone distance will decrease construct stability.

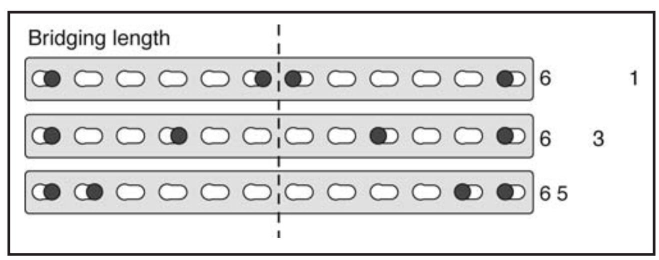

Figure 10. Screw and plate fatigue testing. In simple fractures with a 1 mm fracture gap and 2 screws per fragment, no construct failure was seen after 1 million cycles in testing performed. In comminuted fractures with a fracture gap of 6 mm, only the shortest working length was able to withstand 1 million cycles. This supports placement of fixation nearest to the fracture site.

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