CHAPTER **37**

INNOVATIONS IN PLATE TECHNOLOGY: Synthes Locking Compression Plate

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PRINCIPLES OF INTERNAL FIXATION

In the 1950s, founders of the Swiss Association for the Study of Internal Fixation standardized the use of internal fixation. The AO group developed four principles of internal fixation: anatomic reduction, rigid internal fixation, preservation of blood supply, and early active mobilization. The goal of these principles was to increase rapid recovery of the injured limb.[1]

When following these principles, surgeons used a variety of plates and screws to obtain rigid internal fixation. Unfortunately, complications using plates occurred. These include delayed unions, nonunions, refractures after device removal, and infection. These complications were partly due to the inherent biomechanics of conventional plates. The locking plate technology was developed to improve screw and plate fixation.[2]

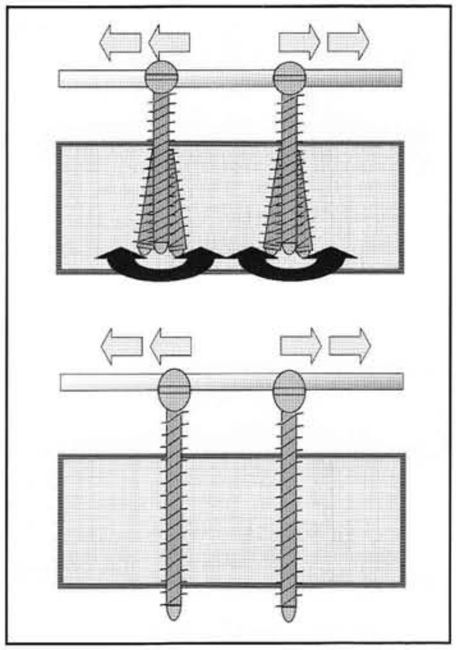

Figure 1. No stability until screw is advanced through far cortex.

CONVENTIONAL PLATE BIOMECHANICS

Conventional plates provide absolute stability. When placed properly, they resist axial, torsional, and bending loads. In order for plates to provide absolute stability, the bone stock must be healthy for good screw purchase.[3] Bicortical purchase of the screws is required for stability since the screws are free to toggle in the plate. In order for the plate and bone to act as one component, the screw must be inserted in the standard lag technique (Figure 1).[2]

When the screw purchases bone and compresses the plate onto the bone, the compression force between the plate and bone is converted into shear stress at the plate-bone interface. This shear stress is resisted by axial forces that are exerted on the bone (Figure 2).

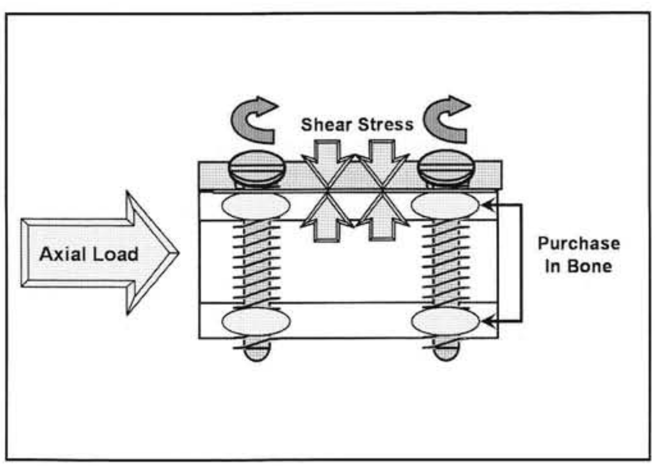

Figure 2. Conventional Plating Biomechanics – Theory. If Axial Load is less than the Shear Stress, the construct is stable.

Compression between the bone and plate is equal to the force generated by the torque applied to the screws fixing the plate to the bone.

Compression across the plate-bone interface demands not only sufficient screw torque to prevent motion, but also demands that the screw torque not exceed the shear resistance of the bone that would lead to screw stripping and loss of fixation. The screw with the greatest torque contributes the greatest amount of force and therefore bears the greatest load.

When resisting axial loads, conventional plates require the screw purchase to create shear force across the plate-bone interface to be greater than axial loads. When the axial load exceeds shear force, the screw head rotates about the far cortex and generates high stresses at the cortex nearest the plate. This leads to bone absorption and subsequent screw loosening.

In conventional plating, bending load resistance is equal to the resistance shear stress of the bone trapped within the threads of the screw (pull-out strength). This occurs because, in conventional plating, the screws align in the direction of the applied force. The weakest link in the plate-screw-bone construct is the shear interface between screw and bone (Figure 3).[2,3]

CONVENTIONAL DISADVANTAGES

Unfortunately, even with proper rigid internal plate fixation, complications do occur with conventional plates. These include delayed union, nonunions, refracture after device removal, and infection. There are inherent weaknesses in the plate-screw-bone construct. Studies have shown that the necessary normal force between the plate and bone, in order to prevent plate motion, generates compressive forces under the plate that prevent periosteal perfusion. This can cause bone necrosis deep to the plate, which leads to localized bone resportion at the screw threads and thus, result in loosening of the plate.[4] The necrotic bone can contribute to a potential nidus for infection. Because the screws are free to toggle in the plate, stability requires bicortical purchase of the screws. In osteoporotic bone or pathologic bone, the compression force between plate and bone is not sufficient enough to develop enough shear force to resist axial loading. This leads to plate and fracture motion.[3,4]

LOCKING PLATE BIOMECHANICS

The Synthes Locking Compression plate was developed in 1998 (Figure 4). The locking plate is a single beam construct. The screw head has threads that match the threads in the plate holes. When the screws are placed into the bone, the screw engages both the bone and plate. Unlike conventional plates, there is no toggling effect. This creates a single beam construct where there is no motion between the components. Studies have shown that this construct is four times stronger than conventional plating.[7]

With the Locking Compression plate, the plate holes can be filled with a conventional cortex screw or an angular-stable screw (locking head screw). A conventional screw can be used as a

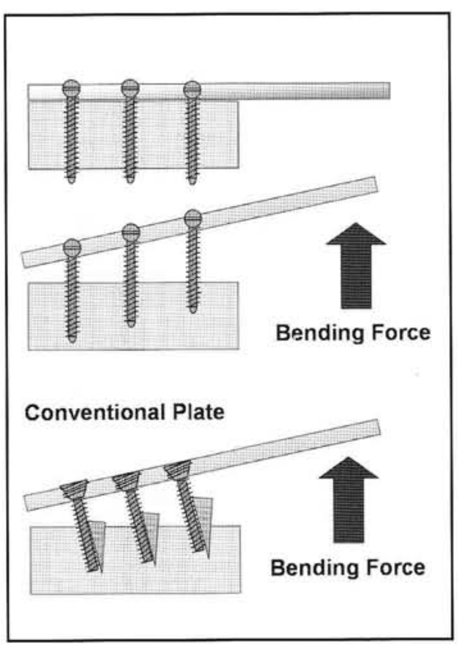

Figure 3.

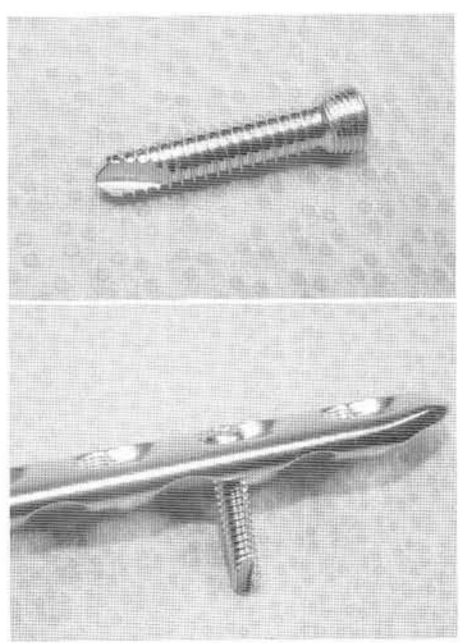

Figure 4. Locking Compression Plate.

reduction screw. Also, conventional screws can be inserted eccentrically to compress across fracture or fusion sites (Figure 5).[5]

Because the screws are locked into the plate, the locking plate converts shear stress (pull-out strength) to compressive stress at the screw-bone interface. This improves fixation since bone has a higher resistance to compressive stress than shear stress. Therefore, in order for the locking plate to fail, the bone encompassing the screw must fracture (Figure 6). The strength of the locking plate is equal to the sum of all screw-bone interfaces while conventional plates are equal to a single screw's axial stiffness or pullout resistance as seen in the unlocked plates (Figure 3). Bicortical screw purchase is not required to maintain stability for locking plates. Because the screw securely locks into the plate, this acts as the second cortex[2] (Figure 7).

LOCKING PLATE ADVANTAGES

Conventional plate and screws can be equivalent to the locking plate only when there is healthy bone to permit proper screw torques. Since locking plates do not require the force between the plate and bone to achieve compression and absolute stability, this allows the local blood supply under the plate to be preserved. Theoretically, this allows more rapid bone healing and decreased incidence of infection, bone resorption, delayed union, nonunion. Also, the LCP design reduces plate to bone contact by 50%[3] (Figure 8).

Locking plates do not require bicortical screw purchase. Theoretically, locking plate screws that are not bicortical minimizes further damage to the endosteal circulation and may decrease the risk of refracture after plate removal.[4]

LOCKING PLATE DISADVANTAGES

There are some disadvantages with the Locking Compression Plate that the surgeon must keep in mind when using the plate. When inserting the locking screws, there is no ability to alter the angle of the screw within the hole and still achieve a locked screw. Therefore, pre-planning screw placement is critical when inserting locked screws. It may potentially be more difficult to remove the locking plate if locked screws become cold-welded to the plate. When the screws are cold-welded to the plate, they become firmly attached to the plate. While fracture reduction may be aided with the application of conventional plates, with the locking plate the fracture must be reduced and the limb alignment, length, and rotation must be set properly before placement of any locked screws.[2,6]

CLINICAL APPLICATION

The Synthes locking plate can be used in a variety of surgical settings. First metatarsal phalangeal joint non-unions, Charcot mid-foot reconstructions, any fusion site with osteoporitic bone, and comminuted fractures are some examples where a LCP would be superior over conventional plates. When used properly, the LCP potentially can improve fusion rates.[10]

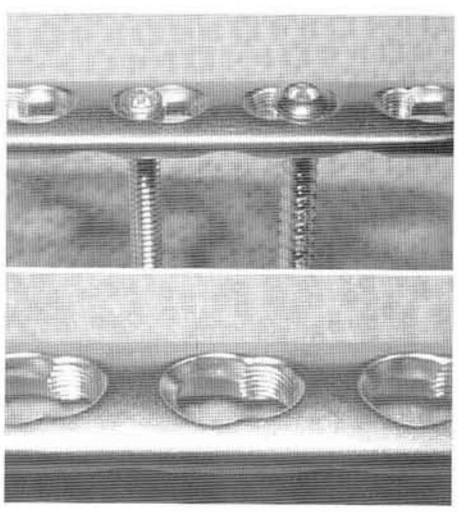

Figure 5. Locking Compression Plate – Note the DCP holes and the ability to use both conventional and locked screws.

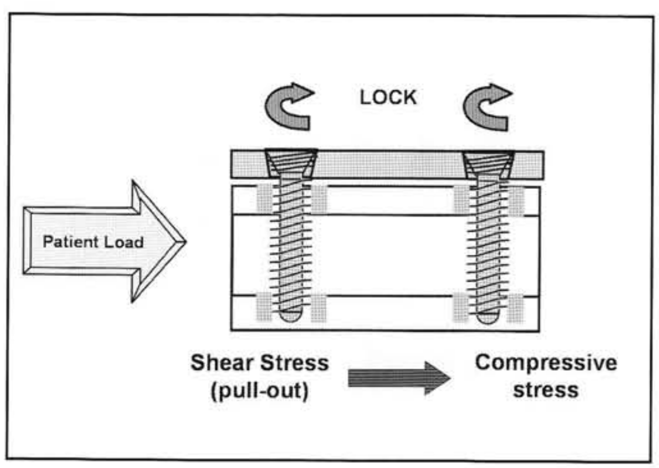

Figure 6. Locking Plate Biomechanics - Theory.

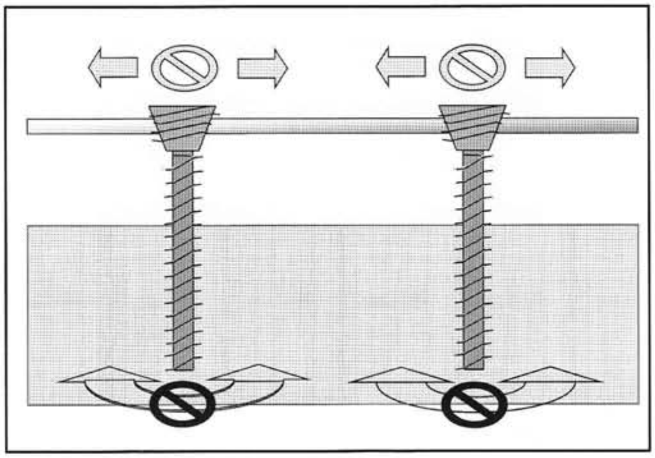

Figure 7. Locking Compression Plate requires monocortical screw purchase. Stability: Locked construct acts like a second cortex.

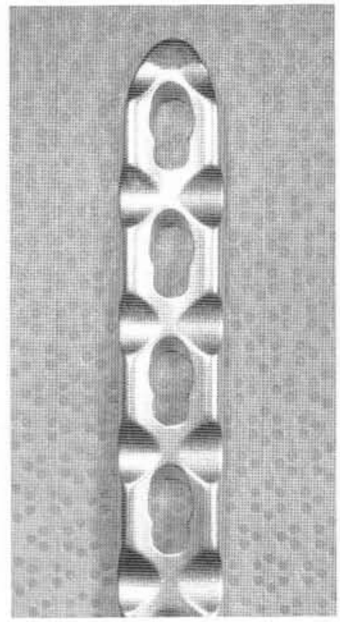

Figure 8. Locking Compression Plate design: 50% Reduction in plate to bone contact.

CASE STUDIES

The following case studies compare a Charcot mid-foot reconstruction with convention screws and plates and the Synthes Locking Compression Plate:

Case Presentation 1: A 62-year-old patient with long standing diabetes, presented with a Charcot Mid-foot collapse. The patient elected to have surgical intervention to correct the deformity. Surgical intervention included talo-navicular joint, navicular–cuneiform joint, Medial Lisfranc joint, and calcaneal cuboid fusion with conventional screws and plates. The following are preoperative, immediate postoperative, and 1 year postoperative. Note the gradual internal fixation failure and bony resorption around the screw (Figures 9-11).

Figure 9. Preoperative view.

Figure 10. Immediate postoperative view.

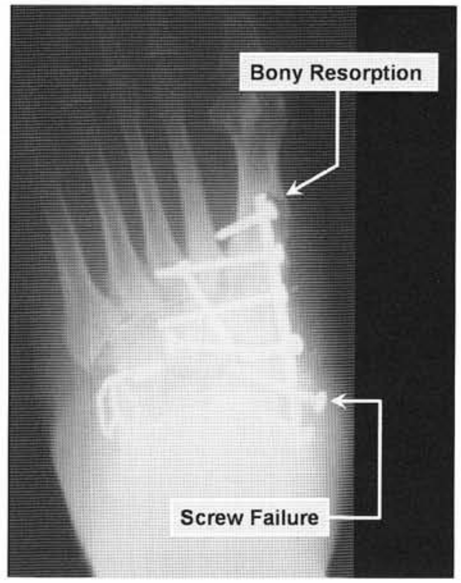

Figure 11. 1 year postoperative view.

Case Presentation 2: A 49-year-old female with Insulin Dependent diabetes mellitus, presented with a Charcot mid-foot collapse. Prior treatment included first metatarsal–cuneiform and navicular-cuneiform fusion that resulted in inadequate correction. As with Case presentation 1, the patient elected to have surgical reconstruction of the medial column. Surgery included navicular-cuneiform joint and first-third Lisfranc joint fusion with combination of conventional screws and the Synthes Compression Locking Plate. The following are preoperative, immediate postoperative, 3 months postoperative, and 9 months postoperative. Note the intact internal fixation and complete consolidation (Figures 12-15).

Figure 12. Preoperative view.

Figure 13. Immediate postoperative.

Figure 14. 3 months postoperative.

Figure 15. 9 months postoperative: Complete consolidation.

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