# Feature:
# A Closer Look At Locking Plates In Podiatric Surgery

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Citing the drawbacks and increased risks of conventional plating techniques, these authors say new advances in locking plates can facilitate soft tissue preservation and improved bone healing.

Using plates and screws for bone fixation is a standard and successful technique. However, any fixation with plates and screws involves some amount of additional trauma and insult to the osseous blood supply of fracture fragments. These disturbances increase the risk of delayed union and infection.[1]

Indeed, reconstructive and trauma procedures of the foot and ankle present unique challenges for foot and ankle surgeons. As these cases grow in complexity, certain principles prevail in ensuring predictable and successful outcomes. These principles emphasize the protection of the soft tissue envelope and the importance of bone callus formation in uniting fractures and osteotomies. The technology of locking plates provides surgeons with an option that addresses both soft tissue preservation and bone callus formation.

As the technology progresses, we have also seen a growing number of indications and implications for locking plates in foot and ankle reconstruction and trauma procedures.

The ability to obtain a fixed angle and a rigid interface between the screw and plate is the basis behind locking plate technology (i.e. an internal–external fixator). This concept allows surgical approaches that protect the soft tissues while fostering an environment that is prime for secondary bone healing and preservation of the local osseous vascular supply.[2] Given the traditional plating options that involve compressing the plate to the bone at the expense of extensive soft tissue exposure, the interest in alternative locking plate technology continues to grow. In an attempt to decrease the risks associated with wound and fracture healing, surgeons are finding locking plate technology more favorable.

In order to achieve functional rehabilitation of the lower extremity following fracture, anatomic reduction, rigid internal fixation and early joint motion always remain the starting points for fracture and bone healing.[3] However, as delayed healing and other complications arose, there was an increased emphasis on limiting the extent of soft tissue dissection and bony devascularization. External fixators, distractors and other methods were introduced to preserve osseous perfusion and soft tissue integrity. Plates underwent redesigns to limit bone contact to further preserve bony vascularity.

Now locking plate technology offers a biologically friendly plating system that creates fixed angle plate screw constructs. Foot and ankle surgeons can use these constructs when considering surgical correction of complex deformities of the lower extremity.

## Understanding The Limitations Of Conventional Plates

Conventional plating techniques rely on friction as a means of ensuring primary bone healing. However, successful fixation only occurs when there is enough friction among plate, bone and fracture fragments held together in compression.[4] Conventional plating can resist axial, torsional and bending loads when no fracture gaps exist and the surgeon properly positions the plate. One can achieve increased resistance to screw pullout and increased torque at the bone plate interface in conventional plating with bicortical screw purchase.[5]

Unfortunately, screw pullout and available torque are related to the material into which the surgeon inserts them. Systemic diseases associated with bone demineralization or generalized osteopenia present the kind of deficient bone quality in pedal cases that can fail to resist the advancing torque or screw pullout forces one encounters in a typical postoperative period.

Conventional plating techniques create potential risks in foot and ankle surgical cases in which comminution, significant gaps in bone or inherent instability of non-anatomically reduced fractures are common.[5] Shortcomings in conventional plating methods lead to small amounts of motion at the plate's bone to screw interface. This motion can loosen fixation. Lost or failed fixation directly leads to nonunion as noted in Perren's "strain theory of bone."[3]

## What You Should Know About Bone Healing And The Strain Theory

Movement at the osteotomy site dictates bone healing. Bone heals primarily, secondarily or not at all, according to the amount of displacement.[6] When fracture displacement exceeds a certain threshold, bone healing can no longer occur and nonunion is inevitable. Conventional plating relies upon compression and rigidity at the union site, and this is associated with primary bone healing.[4] Locking plate technology ensures healing where relative motion leads to hematoma and callus formation, or secondary bone healing.

*This is a preoperative view of a weightbearing patient with calcaneal valgus deformity secondary to posterior tendon dysfunction.*

Secondary bone healing occurs in several phases. These phases include hematoma formation, the induction of pluripotent cells, the differentiation of inflammatory cytokines and ending in the endochondral ossification and remodeling. This process is referred to as callus formation.

Perren's "strain theory" defines and predicts whether bone heals primarily, secondarily or proceeds to nonunion.[3] The theory successfully shows how low fracture strain (less than 2 percent) results in no callus formation and primary healing whereas strain thresholds between 10 to 20 percent result in secondary healing with callus formation.[6] The loss of fixation creates strains exceeding 30 percent and subsequently yields nonunion results. Locking plates allow the amount of strain needed for bone healing through secondary intent while guarding against nonunion.

## Weighing The Advantages Of Locking Plate Fixation

Locking plate fixation is advantageous when surgeons use it for osteopenic bone, comminuted fractures or in circumstances when anatomic reduction is not necessary or possible.[7] Screws that lock to plates eliminate screw toggle and create a fixed angle or a single beam construct. Conventional plating can only achieve the single beam effect, if at all, with screws that have solid bicortical purchase in dense healthy bone.

*This intraoperative AP view demonstrates a Variax polyaxial locking plate. Note the angular placement of the screw/plate interface.*

*Here one can see a post-op lateral radiograph with a Variax polyaxial locking plate. Note the ability to avoid â??hardware trafficâ?• (AO gymnastics).*

The strength of the locking plate single beam is related to the sum of all screw bone interfaces. A locking plate is strongest with multiple anchoring points or multiple screws. One might consider the locking plate construct as the ultimate external fixator in that it is a rigid structure one places extremely close to the mechanical axis of the bone.[8] This construct has demonstrated strength capacities four times that of conventional systems whereas screws tend to toggle.[5] The construct creates stable elastic fixation, allows strains of 2 to 10 percent and promotes callus formation, which leads to secondary bone healing.

Secondary bone healing requires some relative motion.[1,5,9] Locking plates allow that residual “strain” that inevitably occurs when fixating severely comminuted or osteoporotic bone.

Locking plates also

make anatomic reduction unnecessary. Anatomic reductions are paramount when employing traditional plating techniques. However, anatomic reduction comes at the high price of extensive surgical exposure and soft tissue stripping. When it comes to multifragmentary shaft fractures, precise anatomical reduction is often not possible without a great risk of iatrogenic soft tissue trauma.[10] Aggressive soft tissue dissection increases the likelihood for nonunion or infection. The recent shift toward minimally invasive surgical techniques encourages locking plate constructs. In cases that are difficult to reduce anatomically, one should consider using locking plates.

*Here one can see a post-op lateral radiograph with a Variax polyaxial locking plate. Note the ability to avoid â??hardware trafficâ?• (AO gymnastics).*

*This is a post-op lateral radiograph with a monoaxial locking plate.*

Current locking plate designs do not rely on friction force at the bone-plate interface. Therefore, locking designs do not impair periosteal blood flow to healing bone.[9] Although the foot does not allow the latitude of extensive soft tissue coverage, in particular when one considers dorsal incisions. The combination of mechanical superiority and their biologically friendly nature makes locking plate fixation appealing in the surgical correction of complex foot and ankle deformities.

**What Does The Future Hold For Locking Compression Plates And Polyaxial Locking Plates?**

The development of the locked internal fixator concept has opened the door to technological advances that one can apply to the fixation of bone fragments in lower extremity trauma or reconstruction. Locking compression plates (LCPs) and polyaxial locking plates are two such advances. Although they differ from early generation locking systems, they both still promote less soft tissue and blood supply damage while ensuring more rapid and predictable fracture healing.

Locking compression plates feature a combination of holes that can either be conventional (the compression principle) or locking (the internal fixator principle), or a combination of the two.[11] The polyaxial Variax system (Stryker) additionally allows eccentric loading in some of the plates in this locking system. This allows the surgeon to take advantage of many plating principles.

Surgeons may use this system to facilitate conventional compression of a solid, reducible area of a fracture or osteotomy while reserving the opportunity to lock and bridge an area of significant bone grafting or communition within the same plate. This "lag and lock" principle involves the combination of compressing the plate to bone while the locking screws are locked to the plate. Foot and ankle surgeons can use this principle in cases in which good bone quality and bicortical screw purchase coexists with osteoporotic bone or when there are no cortices within the same fixation zone. The LCP is a new development in locking plate technology that can maintain both angular stability and interfragmentary compression within one plate.

The polyaxial locking plate allows surgeons to apply the fixed angle concept in more than one axial relationship.[12] The advent of this concept allows foot and ankle surgeons to navigate the difficult shapes and contours of surgically reduced pedal bones. Previous locking constructs limited the option for screw plate locking to one 90-degree option. The polyaxial concept opens the door for screw placements in upward of a 15-degree divergence in any one direction or plane. This allows the surgeon to circumvent lag screws or locate denser bone for the placement of locking screws. We have coined this phrase as "AO gymnastics."

The advancement of the polyaxial concept makes it possible to introduce multiple locking screws with an independent axis of orientation. Studies have shown that surgeons can accomplish the polyaxial concept without compromising torque to failure or pullout strengths of the implant.[13]

**In Summary**

The basic principles of using a conventional plate and screw system are direct, anatomical reduction and stable internal fixation of the fracture. Wide exposure of the bone is necessary to gain access to and provide good visibility of the fixation zone in order to allow one to perform plate reduction and fixation. Pre-contouring of the plate as well as screw insertion can compress the plate onto bone. Friction between the plate and bone actually provides the stability required for proper fixation and primary bone union to occur.

*This patient sustained a complete rupture of the posterior tibal tendon.*

*Here is an intraoperative view using interfragmentation compression and a Variax polyaxial locking plate for a midfoot fusion. Note that there is less soft tissue dissection with periosteum intact.*

Anatomic reduction of the fracture is the prerequisite for conventional plating. However, gaps in bone, multifragmentary shaft fractures or osteopenia created the need for a technique for bridging plate osteosynthesis, which permits healing with callus formation and less soft tissue invasion with less emphasis on anatomic reduction. This is known as locking plate technology. Since the damage to soft tissue and blood supply is less extensive and fracture healing in difficult scenarios is likely, locking plate technology has gained momentum in its use for lower extremity reconstruction and trauma.

Indications for the use of locking plates in foot and ankle trauma or reconstruction are evolving. The biological and mechanical advantages of locking plates have distinguished and defined their surgical use. Foot and ankle surgeons have employed many of the advantages, first outlined in orthopedic literature, to pedal pathology. A thorough understanding of the properties of locking plates will allow their application to expand.

*This post-op lateral radiograph shows the use of a Variax polyaxial locking plate in a foot with severe rheumatoid arthritis.*

The biologically friendly nature of the locking plate technology is increasingly appealing to podiatric surgeons when one can combine predictable callus formation with locking internal fixator constructs. The literature further supports the use of locking plates in facilitating low nonunion rates in difficult fractures. Hybrid technology that merges the benefits of traditional, locking and polyaxial plate properties is most likely the future of internal fixation in foot and ankle reconstruction or trauma.

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**References**

1. Frigg R. Locking Compression Plate. An osteosynthesis plate based on Dynamic Compression Plate and the Point Contact Fixator. *Injury.* 2001; 32 (suppl 2): 63-66.
2. Hatchikewych G. Innovations in Locking Plate Technology. *Journal American Orthopedic Surgery.* 2004; 12: 205-212.
3. Perren SM, Schegel U. Surgical Aspects of Implants and Infections. *Arch Orthop Trauma Surg.* 1190; 109: 330-333.
4. Frigg R, Appenzeller A, Christensen R. The Development of the Distal Femur Less Invasive Stabilization System. *Injury* 2001; 32 (suppl 3) SC24-SC31.
5. Greiwe RM, Archdeacon MT. Locking Plate Technology. *Journal of Knee Surgery,* 2007; Vol 20 No 1. 50-55.

6. Perren SM. Physical and Biological Aspects of Fracture Healing with Special Reference to Internal Fixation. *Clinical Orthopedic Related Res.* 1979; 138: 175-196.
7. Egol KA, Kubiak EN, Fulkerson E. Biomechanics of Locked Plates and Screws. *Journal Orthopedic Trauma.* 2004; 18: 488-493.
8. Bolhofner BR, Carmen B, Clifford P. The Result of Open Reduction and Internal Fixation of Distal Femur Fractures Using a Biologic (Indirect) Reduction Technique. *J Orthop Trauma*. 1996; 10: 372-377.
9. Kolodziej P, Lee FS, Patel A. Biomechanical Eval of the Schuhli Nut. *Clinic Orthop Relate Res.* 1998; 347: 79-85.
10. Ruedi TP, Murphy WM, eds. AO Principles of Fracture Management. Stuttgart-New York: Thieme; 2000.
11. Wagner M. General Principles for the Clinical Use of the LCP. *Injury Int,* 2003; 34: S-B31-S-B42.
12. Zlowodzki M, Williamson S Zardiackas LD. Biomechanical Evaluation of the Less Invasive Stabilization System and the 95 degree Angled Plate For the Internal Fixation of Distal Femur Fractures in Human Cadaveric Bones with High Bone Mineral Density. *Journal of Trauma* 2006; 60: 836-840.
13. Olms, K. Gregor M, Gerber C. Biomechanical Performance of the VariAx Foot Plating System. *Stryker Internal Report,* Til446/07.
Additional Reference
14. Leunig M, Hertel R, Siebenrock KA, Ballmer FT. The evolution of indirect reduction techniques for the treatment of fractures. *Clin Orthop Rel Res* 2000; 375: 7-14.

**i***For related articles, see “Exploring New Advances In Internal Fixation” in the May 2005 issue of Podiatry Today and “Point-Counterpoint: Is External Fixation Overutilized?” in the June 2007 issue.*

**i***For other articles, visit the archives at* www.podiatrytoday.com.

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