OTA Resident Core Curriculum: Locked Plating

Yelena Bogdan, MD & Paul Tornetta III, MD

December 2015
Outline

- Definition of Locked Plating
- Development
- Types of Locking Plates
- Biomechanics
- Advantages + Disadvantages
- Indications
- Technique
- Pearls and Pitfalls
- New Applications
- Summary
Definition of Locked Plating

An implant that acts as an “internal fixator”
- derived from concept of external fixation
- screws lock into plate
- stability in a locked plate does not depend on bone-plate friction
Development of Locked Plating

- Carl Hansman, 1886: monocortical fixator
- Ernest Hey Groves, 1916
- Paul Reinhold, 1931
- Wolter system, 1974
- Zespol system, 1982
- Synthes, PC-fix, 1994
- AO, LISS plate, 1995
- Schuhli nut, 1998: allowed screws to lock into standard plate via threaded washer

Recently: Pubmed: ~800 papers, 50% in last 5 years
Why is locked plating important?

- Increased interest in combining multiple fixation methods
  - Metaphyseal fractures
    » Prone to comminution and not enough cortical bone for screw purchase
Why is locked plating important?

- Increased interest in combining multiple fixation methods
  - Metaphyseal fractures
    » Locked plates can be combined with absolute stability principles to achieve articular surface fixation (example: lag screws, red arrow)
Why is locked plating important?

- Increased interest in combining multiple fixation methods
  - Metaphyseal fractures
    » Fixed angle device with multiple rather than one point of fixation in periarticular fractures
Why is locked plating important?

- Increased interest in combining multiple fixation methods
  - Diaphyseal fractures
    » Locked screws can protect unlocked screws in the diaphysis
    » Helpful in poor quality bone

- Increase in periprosthetic fractures

- Increase in elderly osteoporotic fractures
  - Difficult to achieve absolute stability
  - Poor resistance to shear and pullout
Types of Locking Plates

- **Fixed Angle**
  - Only one way screw engages plate without cross-threading

- **Variable Angle**
  - Screw can be locked within a cone, clearance angle up to 15°

- **Screw Locking Mechanisms**
  - Screw head locked via threaded locknut
  - Screw head is threaded and screws into plate

Images courtesy of Smith+Nephew
Biomechanics of Locked Plating

- Stability via standard plates achieved via screw torque
  - Bone quality and comminution affect purchase of screws
- Stability in a locked plate depends on amount of load, plate properties
- Ask yourself: what does the locking screw add to the construct, and do I need it?
Biomechanics of Locked Plating

- Larger working length of plate distributes forces (Gautier et al, 2003)
  - longer lever arm for screws to counteract bending moments
Biomechanics of Locked Plating

- Larger working length of plate distributes forces (Gautier et al., 2003)
  - longer lever arm for screws to counteract bending moments
Biomechanics: Diaphysis

◆ Normal bone
  – Locked 6% - 31% less stiff
  – Failure 273 vs 303 lbf
  – No advantage to locked screws: most diaphyseal fx should undergo conventional plating

◆ Osteoporotic bone
  – Locked 21% - 74% more stiff
  – Failure 260 vs 223 lbf
  – Locking is an advantage
Biomechanics: Diaphysis

- Stoffel et al, 2003
  - LCP plate analysis: FEA + composites
  - Axial stiffness and torsional rigidity influenced by working length
  - Plateau of stability: 3 screws each side for axial, 4 screws for torsional
  - In comminuted fx, screws near fx site → less failure
  - Eliminating closest screw → 2x flexible in axial and torsion
Biomechanics: Metaphysis

- Relative stability with angular fixation for metadiaphyseal fractures
- Deforming forces distributed over large surface area of fracture, unfilled holes provide flexibility for secondary healing
**Biomechanics: Metaphysis**

- Precontoured plates have locking and non-locking holes
- Locking screws support / raft subchondral bone
Biomechanics: Metaphysis

Koval et al, 1997

- Cadaver study, osteoporotic distal femur, 1 cm bone defect created
- Condylar buttress plate vs custom locked plate vs 95 deg blade plate
- Tested in axial compression and bending/torsional loading
- Locked plate more stable in axial compression
- Similar to blade plate (fixed angle) but more points of fixation and distributed screw purchase into bone
Biomechanics: Metaphysis

- Higgins et al, 2007
  - Cadaveric distal femur fracture model
  - Locked plate vs blade plate
  - Locked plate less subsidence and greater ultimate load to failure

- Edwards et al, 2006
  - Locked plate vs IMN for 2 part surgical neck fractures of proximal humerus
  - Locked plate less displacement in varus cantilever bending, torsion, overall more stiff construct
Hybrid Plating

- A way, but not the only way, of using locked plates
  - Plate is reduction tool
  - At least 3 bicortical locked screws on either side of fracture
  - Locking screws placed between fracture and unlocked screws
    » protect the latter from loosening

Image courtesy of Smith+Nephew
Biomechanics: Hybrid Plate

- Gardner et al, 2006
  - Three constructs tested
  - Osteoporotic Sawbone
  - Oscillating cyclic torsion
  - Results: at 1000 cycles, locked and hybrid retained 80% of original stiffness, while unlocked only 22%
Biomechanics: Hybrid Plate

Doornink et al, 2010
- Locked vs hybrid construct in osteoporotic sawbone
- Hybrid stronger in torsional testing
- In axial load, hybrid weaker in compression
- Hybrid may be inappropriate depending on loads experienced by specific bone
Biomechanics: Hybrid Plate

- Freeman et al, 2010
  - Tested contribution of number and location of locked screws in hybrid constructs
  - Osteoporotic model Fixed with 12 hole plate
  - Torsional Stiffness
  - Removal Torque
Freeman et al, 2010: Constructs Tested

Construct 1

Construct 2

Construct 3

Construct 4

Construct 5

Construct 6
Results: Stiffness

Less screws: not as stiff

Freeman et al JOT 2010
Results: Stiffness

More screws per side: more stiff

Freeman et al JOT 2010
Results: Stiffness

More locked screws per side: highest stiffness

Freeman et al. JOT 2010
Removal Torque

- **Locked screws**
  - Not affected by position
  - Retained avg 50%

- **Unlocked screws**
  - Position dependent
  - Lost up to 90% (30% - 90%)

Freeman et al JOT 2010
Removal Torque

Freeman et al JOT 2010
Removal Torque

Locked Protects Unlocked (red arrows)
Freeman et al JOT 2010
Advantages of Locked Plating

- Single-beam construct (diaphysis) – no toggle
  - Fixed angle device converts axial load to compression rather than shear (as in conventional plating)
Advantages of Locked Plating

- Biologically friendly
  - Plate is off the bone
    - Only if all locked screws
  - Minimal soft tissue stripping
  - No compression of periosteum, preserving blood supply
Advantages of Locked Plating

- Improved stability in osteopenic/poor quality bone
- No need for plate contouring
- Newer plates can combine locking and non-locking techniques
- Can facilitate reduction of difficult fractures
  - periarticular, segmental, bone loss, or comminution
Disadvantages of Locked Plating

- Expensive

- Misapplication
  - Inappropriate indications
  - Poor technique (locking before lagging)
  - No reduction prior to locking

- Lack of tactile feedback of screw purchase in bone

- Cold welding (titanium only): difficult removal

- Plate thickness can be symptomatic
Locking Plate Indications

Russell Tornetta Algorithm
2007

AO/OTA Classification Plate Construct Choices

A Types
- Stable
  Good Bone Quality
- Any Plate
  Locked Plate Vs. Dual Plate

B Types
- Unstable
  OR
  Osteopenic Bone
- Antiglide
  Buttress
  Polyaxial Locking
  Low Profile Plates/Screws

C Types
- Stable
  Good Bone Quality
- Contoured Plate/s
- Unstable
  OR
  Osteopenic Bone
- Locked Plates
  +Fragment Specific Fixation

Courtesy of Dr. Tornetta
NOT an indication

- Partial articular injury
  - “B” types...in good bone
Locking Plate Indications

- Short segment fixation
When far side support needed...
…Locking Helps

Fixed Angle!
If you did this with unlocked plate
Locking Plate Indications

- Osteoporotic Bone
Locking Plate Indications

- Periprosthetic Fracture
  - Short segment variant
Surgical Technique

- This technique is for hybrid plating, which is how most locked plates are utilized currently.
- Reduce the joint via compression (if applicable).
- Lag screws placed before locking screws.
- Reduce shaft to plate (if applicable), then lock.

*The following technique slides are from prior version of this talk (created by Thomas F. Higgins, MD; Sean E. Nork, MD; James P. Stannard, MD; and Philip J. Kregor, MD).
-Green X in animation = locking screws.
Joint Reduction ➔ Locking Distally

Metaphyseal Fixation
Removal of non-locking screw

Metaphyseal Fixation
Replacement with locking screw

Metaphyseal Fixation
Improper Technique

Metaphyseal Fixation

Reduction of Shaft
Proper Technique

Metaphyseal Fixation

Reduction of Shaft
Proper Technique

Metaphyseal Fixation

Reduction of Shaft
Metaphyseal Fixation

Proper Technique

Reduction of Shaft
Proper Technique

Metaphyseal Fixation

Reduction of Shaft
Proper Technique

Metaphyseal Fixation

Reduction of Shaft
Proper Technique

Metaphyseal Fixation

Reduction of Shaft
Proper Technique

Metaphyseal Fixation          Axial Loading


Proper Technique

Metaphyseal Fixation

Additional locking screw to reduce toggle
Technique Pearls & Pitfalls

- **Epiphysis (Proximal Humerus)**
  - Err on shorter side to avoid joint penetration, try to reach within 5mm of subchondral bone
  - In variable angle locking plates, diverge screw directions to avoid collapse
Technique Pearls & Pitfalls

- **Metaphysis**
  - Avoid re-contouring the plate at locking screw holes, as they can be deformed
  - If plate allows, align screws parallel to joint to assist with alignment
  - Largest and as many metaphyseal screws as possible
Technique Pearls & Pitfalls

- **Metaphysis**
  - Beware of using locking plates for Type B (partial articular) fractures
    - better addressed with buttress plating and compression
  - Locking plate does not substitute for reduction!
Technique Pearls & Pitfalls

- **Diaphysis**
  - If you can nail it, do so (stresses closer to center of bone)
  - Avoid locked plates in healthy diaphyseal cortical bone (use unlocked compression plating)
Technique Pearls & Pitfalls

◆ Diaphysis
  
  – Keep a long working length
    » 2-3 x length of fracture
  
  – Do not place all the screws: too rigid (Scolaro et al 2011)
    » Screw density ratio
      
      ◆ #screws inserted / #holes in plate
      ◆ Ratio should be <0.5, meaning <1/2 of plate holes filled
Locking Plate Failures

- **Mechanical**
  - Screw-plate junctional failure
  - Plate bending stress

- **Biological**
  - Screw-bone interface
  - Collapse of osteoporotic bone
  - Periprosthetic fracture above plate

- **Sequential failure can also occur**
  - “Pullout of all screws together” is not the case
Locking Plate Failures

- Bottlang et al, 2010
  - High stiffness can reduce interfragmentsary motion
    - Can decrease strain too much and lead to nonunion
Locking Plate Failures

- Bottlang et al, 2010
  - High stiffness can reduce interfragmentary motion
    » Can decrease strain too much and lead to nonunion
  - Leaving holes empty decreases stiffness but can get too much motion on side opposite of plate
    » Can lead to asymmetric callus and/or plate breakage
What Really Happens

Junctional Failure
What Really Happens

Loosening
New Locking Plate Applications

- **Far Cortical Locking**
  - Overdrilling of near cortex *(red arrows)*
  - Motion provides less rigidity and more construct elasticity
    - Greater callus formation in bovine osteotomy model *(Bottlang et al, 2010)*
    - Encouraging results in several retrospective series in distal femur fractures
Summary

- Locked plating is useful addition to surgeon’s armamentarium
- Appropriate indications are important
- Avoid malreduction and over-rigid constructs
If you would like to volunteer as an author for the Resident Slide Project or recommend updates to any of the following slides, please send an e-mail to ota@ota.org
For questions or comments, please send to ota@ota.org