LOCKED PLATING

Utku KANDEMIR, MD, FACS

Professor

Dept. of Orthopaedic Surgery

University of California San Francisco

Objectives

- Description and Types
- Why Locking plates needed
- Advantages
- Hybrid fixation
- Indications
- Biomechanics
- Pearls & Pitfalls
- Modifications

Definition

- Locking screw: screw possessing male threads on the head of the screw that engage matching female threads of plate hole and when coupled “lock” the screw into the plate
- Locking plate: a plate with screw holes possessing female threads that engage matching males threads of the screw head and when couple “lock” the plate to the screw head
- ***NOTE****: modern additions to this terminology includes plates with “tabs” or “flanges” inside plate hole (in place of threads) that will still engage threads of locking screw head but can allow for variable angle screw insertion*
- When coupled, a locking screw threads into a locking plate creating a FIXED ANGLE CONSTRUCT (i.e. preventing screw toggling)

Development

- **"Internal External Fixator"**: like an external fixator but applied internally
- 1886, Carl Hansman: Monocortical fixator
- 1916: Ernest Hey Groves
- 1931: Paul Reinhold
- 1974: Wolter system
- 1982: Zespol system
- 1994: Synthes, PC-fix
- 1995: AO, LISS plate
- 1998: Schuhli nut: allowed screws to lock into standard plate via threaded washer

Kolodziej et al. CORR 1998

Types of Locking Plates

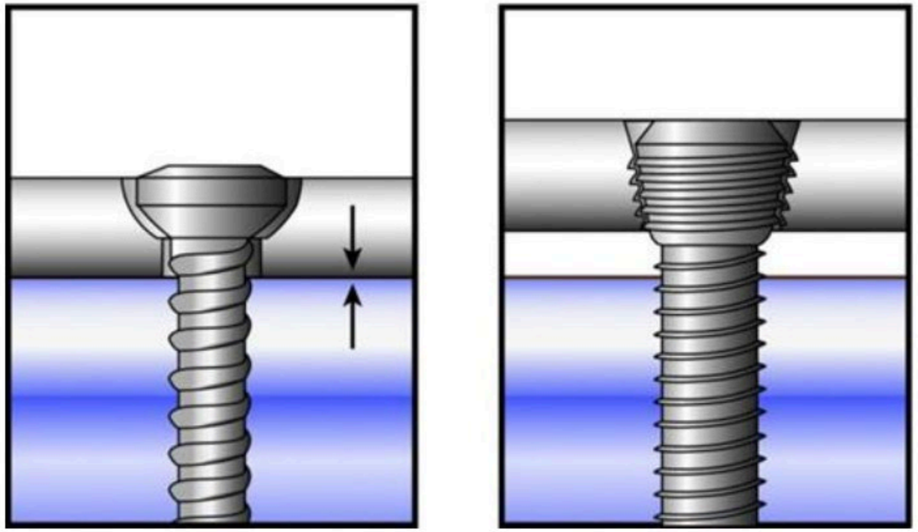
- Fixed Angle - Monoaxial
  - The screw can be locked to the plate only in one designed direction (guides threading into the hole is necessary for drilling)
- Variable Angle - Polyaxial
  - The screw can be locked within 10 ° -15° cone
- Other
  - A nonthreaded head screw is locked to the plate via a threaded locknut into the screw hole
  - A screw with threaded head is locked to the plate by creating threads in the hole as it is screwed in

Why Locking Plates are Beneficial ?

- In scenarios when <u>high rate of failure with non-locked fixation</u>
  - Poor Bone quality/Low bone density / Thin cortical bone (***Osteoporosis***)
  - Length/Area for fixation fixation is limited (***Periarticular fractures***)
  - Bridging Segmental comminution/Bone defects (***Long working length***)
  - Bicortical fixation not possible (***Articular Fractures***)

Comparison to Nonlocked plating

- ***Nonlocked** plating:*
  - Relies on FRICTION (generated by screws) between the plate and bone
  - Frictional force depends on torque generated by screw purchase
  - Screw purchase depends on Bone quality & Density
- ***Locked** plating:*
  - Relies on fixed angle construct, and NOT on friction between plate and bone

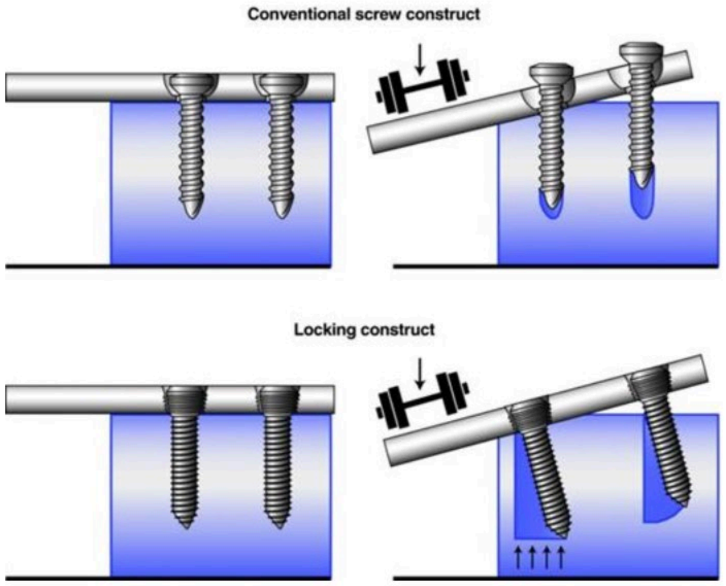


The conventional screw has a smooth screw head that allows for compression between the plate and bone. The locking screw has a threaded screw head that engages the plate and locks. It does not allow for compression between the plate and bone. The locking screw also has a finer screw pitch and a larger core diameter to increase resistance against bending forces.

Rockwood and Green's Fractures in Adults, 9e

Comparison to Nonlocked plating

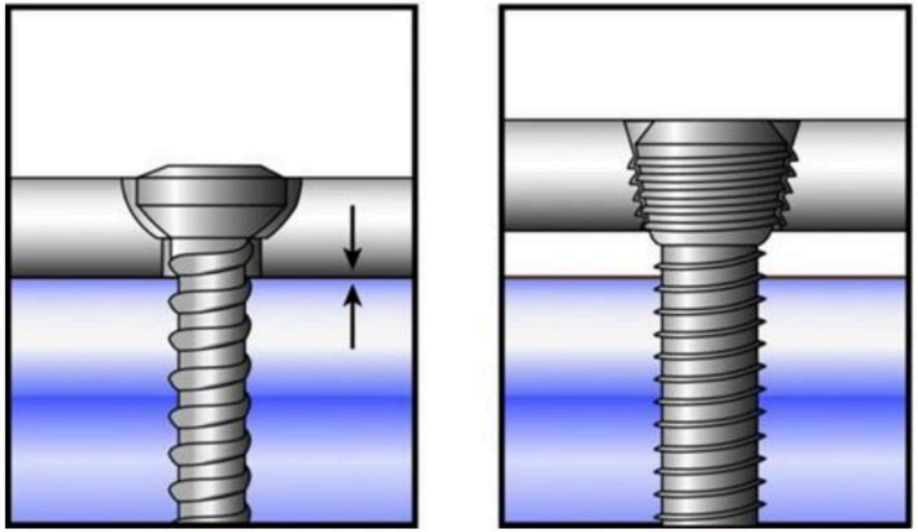
- **FAILURE** Mechanism Different
  - *Nonlocked plating:* Individual/sequential failure of screws with loosening (toggle) and pull out (each screw sustains loads individually)
  - *Locked plating:* All the screws fail in unison with cut through/pull out (loads are distributed evenly to all screws)
  - Locked Construct requires greater force to fail



Rockwood and Green's Fractures in Adults, 9e

Advantages of Locked Plating

- BIOLOGICAL FIXATION
  - Blood supply to bone and fracture site is PRESERVED when applied with locked screws only as the periosteum under the plate is not compressed
- Does not rely on friction between plate and bone
  - Can be applied off the bone
- HOWEVER, if locking plate first secured with non-locking screw, this biological principle is lost



Conventional screw   Locking screw

The conventional screw has a smooth screw head that allows for compression between the plate and bone. The locking screw has a threaded screw head that engages the plate and locks. It does not allow for compression between the plate and bone. The locking screw also has a finer screw pitch and a larger core diameter to increase resistance against bending forces.

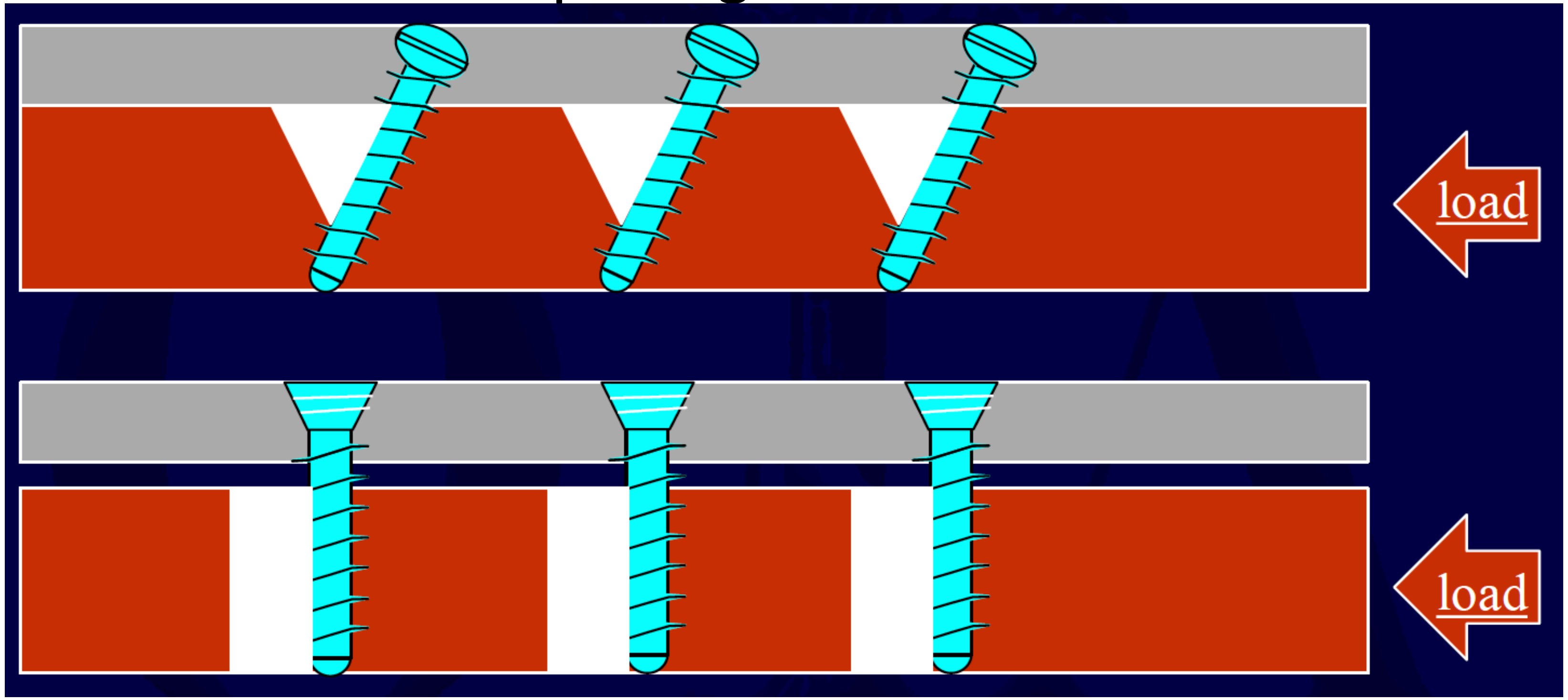
Rockwood and Green's Fractures in Adults, 9e

Advantages of Locked Plating

- Single beam construct
  - Axial load is converted to compression (as it is fixed angle) vs. shear in nonlocked plating

Nonlocked

Locked



Advantages of Locked Plating

- Improved Stability of fixation/Resistance to failure of fixation
  - In poor bone quality and low bone density
  - When the length/area for fixation is limited e.g. short periarticular fragment
  - When bridging Comminuted segments/Bone defects
  - In the setting of limited area of fixation In periprosthetic fractures (unicortical locked plating around stems)

Advantages of Locked Plating - Technical

- May FACILATATE Reduction (Length, Alignment, Rotation) especially in Periarticular fxs and Bridging constructs (Comminuted fxs, Segmental fxs, Bone defects)
- Does NOT need perfect contouring to the bone
- Can be applied with MINIMALLY INVASIVE approaches compared to other fixed angle implants (e.g. Blade plate, DCS)
- Fixed angle device with MULTIPLE points of fixation (compared to single point of fixation in Blade plate, DCS)

Disadvantages

- No tactile feedback of screw purchase & bone quality
- Locking Plates usually thicker vs nonlocking plates: May cause symptoms
- Cold welding makes removal problematic (an issue with some titanium alloys)
- More expensive than nonlocking plates: Should be used when beneficial

Hybrid plating

- Application:
  - Using locking screws in metaphyseal fragment and nonlocking screws in diaphyseal fragment
  - Using nonlocking and locking screws in the same fracture fragment
- Nonlocking screws should be used BEFORE locking screws in the same fracture fragment: facilitate reduction and apposition of plate to bone
- When applied in diaphyseal fracture fragment, Locking screws PROTECTS nonlocking screws from failure

Indications

- Poor Bone quality/Low bone density / Thin cortical bone (Osteoporosis)
- Length/Area for fixation is limited (Periarticular fractures)
- Bridging Comminution & Bone defects (Long working length)
- Bicortical fixation not possible (e.g. proximal humerus, periprosthetic fractures)

Biomechanics

Plate Length

- The LONGER the plate is, the longer the leverage arm and the LESS bending force is acting on the screws
- Therefore, longer construct requires greater load to failure

Plate Length (PL)

- Plate Working Length (WL) is defined as the distance between the 2 screws closest to each end of the fracture

- Screw working length (SL) is defined as the distance within the bone that is traversed by a screw

- In general, the greater the PL/WL ratio, the greater the stability of the construct

Stability of Locked plating Diaphysis

- AXIAL STIFFNESS and TORSIONAL RIGIDITY was mainly influenced by **working length**

- By omitting one screw hole on either side of fracture, the construct became almost twice as flexible in both compression and torsion

Stoffel et al. Injury 2003

Stability of Locked plating Diaphysis

- The closer an additional screw is positioned towards fracture gap, the stiffer the construct becomes under COMPRESSION.

- The rigidity under TORSIONAL load was determined by the number of screws only

Stoffel et al. Injury 2003

Stability of Locked plating Diaphysis

- Plateau of stability
    - >3 screws /fragment added minimal AXIAL STIFFNESS
    - >4 screws /fragment added minimal TORSIONAL RIGIDITY
- In COMMINUTED fractures, placement of innermost screws as close as possible to the fracture → LESS failure
- ***REMINDER***: GOAL OF FIXATION is to achieve uncomplicated physiologic fracture healing while preserving alignment and motion(must base construct on fx pattern, bone quality, specific bone, etc)

Stoffel et al. Injury 2003

Normal vs Osteoporotic Bone Diaphysis

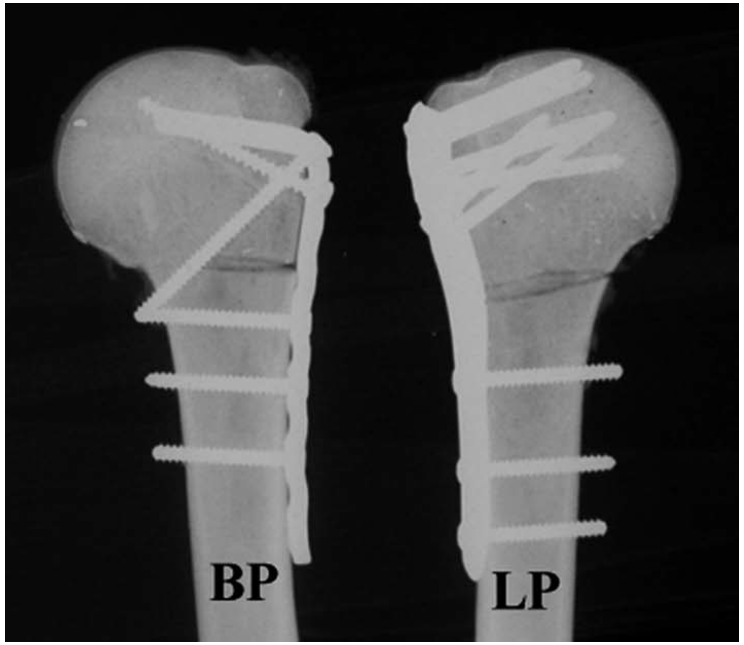
- NORMAL DIAPHYSEAL BONE
  - Locked 6-31% LESS stiff, Failure @273 vs 303 lbf (pound-force)
  - No advantage of locking screws
  - Diaphyseal Fractures with normal bone → Nonlocked Plating
- OSTEOPOROTIC DIAPHYSEAL BONE
  - Locked 21-74% STIFFER, Failure @260 vs 223 lbf
  - Diaphyseal Fractures with Osteoporotic bone → Locked Plating

Ricci et al. OTA 2006

Biomechanics
Metaphysis – Proximal Humerus

- high torsional and bending loads at proximal humerus
- 2-part comminuted surgical neck fracture model
- Locking plate vs 90° blade plate
- Cyclic loading in Bending and Torsion

- Locked plating construct
  - Greater torsional stability
  - Similar bending stability



Siffri et al. J Orthop Trauma 2006 Sep; 20(8):547-54.

Biomechanics
Metaphysis – Proximal Humerus

- 2-part comminuted surgical neck fracture model in cadaveric bone
- Locking plate vs Proximal humeral nail
- Cyclic loading in Varus bending and Torsion

- Locked plating construct
  - STIFFER
  - Less displacement in varus bending
  - Less rotation in Torsion

Edwards et al. JBJS 2006

Biomechanics
Metaphysis – Distal Radius

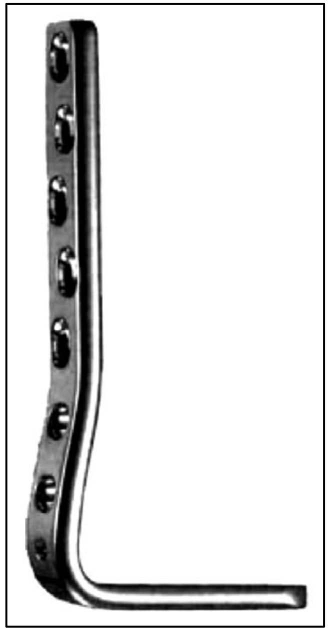
- Extraarticular Distal Radius fracture with dorsal comminution model in cadaveric bone
- <u>Volar Locking </u>plate vs <u>Dorsal Nonlocking </u>plate
- Cyclic Axial and Torsional loading

- Axial Stiffness, Torsional stiffness, Load to failure NOT significantly different. **Locked plating improved STABILITY in osteoporotic specimens**
- Volar Locked plating construct performed similarly, and application is *MORE* **soft tissue friendly**.
- Therefore, locked plating is **preferred**

Kandemir et al. JOT 2008

Biomechanics
Metaphysis – Distal Femur

- Distal Femur Extraarticular Comminuted Fracture (OTA/AO 33-A3) model in cadaver
- Condylar Buttress plate vs Locking Condylar Buttress plate vs Blade Plate
- Cyclic loading: axial and bending/torsion



- Locked plating construct
  - LESS displacement in axial loading vs Nonlocked plate or Blade plate
  - Resistance to Displacement similar to Blade Plate

Koval et al. J Orthop Trauma. 1997 Oct;11(7):521-4.

Biomechanics
Metaphysis – Distal Femur

- Distal Femur Extraarticular Comminuted Fracture (OTA/AO 33-A3) model in cadaver
- Locking plate vs Blade Plate
- Cyclic loading

- Locked plating construct
  - Less displacement/subsidence
  - Higher Load to failure

Higgins et al. JOT 2007

Biomechanics
Metaphysis – Distal Femur

- Distal Femur Extraarticular Comminuted Fracture (OTA/AO 33-A3) model
- Fixation constructs in diaphysis: 1) Stainless steel hybrid, 2) Stainless steel locked, 3) Titanium locked, 4) Stainless steel locked with offset

- HIGHEST STIFFNESS and CYCLES to FAILURE: Stainless steel hybrid fixation, and Stainless steel locked constructs
- REDUCTION in STIFFNESS and CYCLES to FAILURE: Offset placement and Titanium

Kandemir et al. JOT 2017

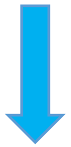
Hybrid Plating
Osteoporotic model

- Osteoporotic sawbone humerus
- Unlocked vs Locked vs Hybrid
- Cyclic torsion testing

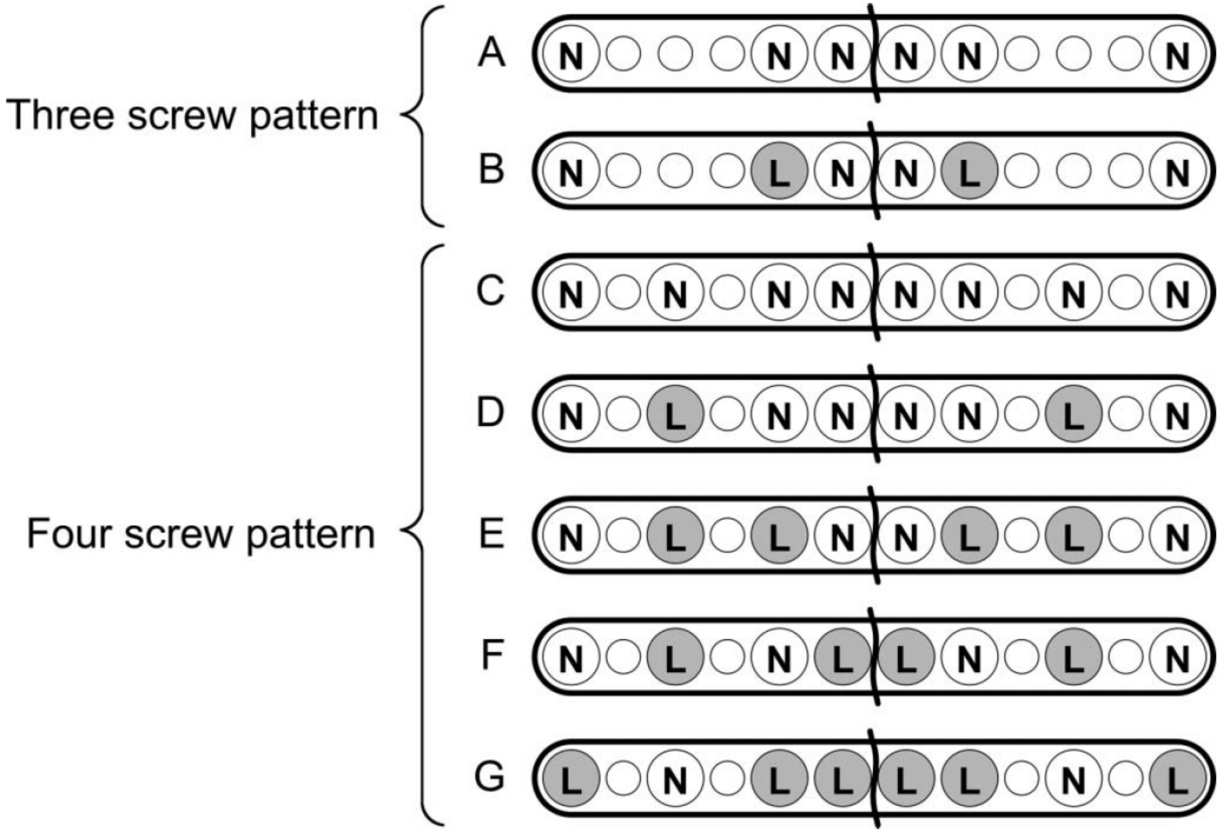
- Locked & Hybrid constructs retained 80% of original stiffness vs Unlocked only 20%
- Hybrid constructs are mechanically similar to locked constructs, and both are significantly MORE STABLE than unlocked constructs under torsional cyclic loading.

Hybrid Plating
Osteoporotic Model

- To determine the effect of number and location of locking screws
- 5 mm fracture gap
- Fixation with 12-hole plate
- Cyclic torsional loading



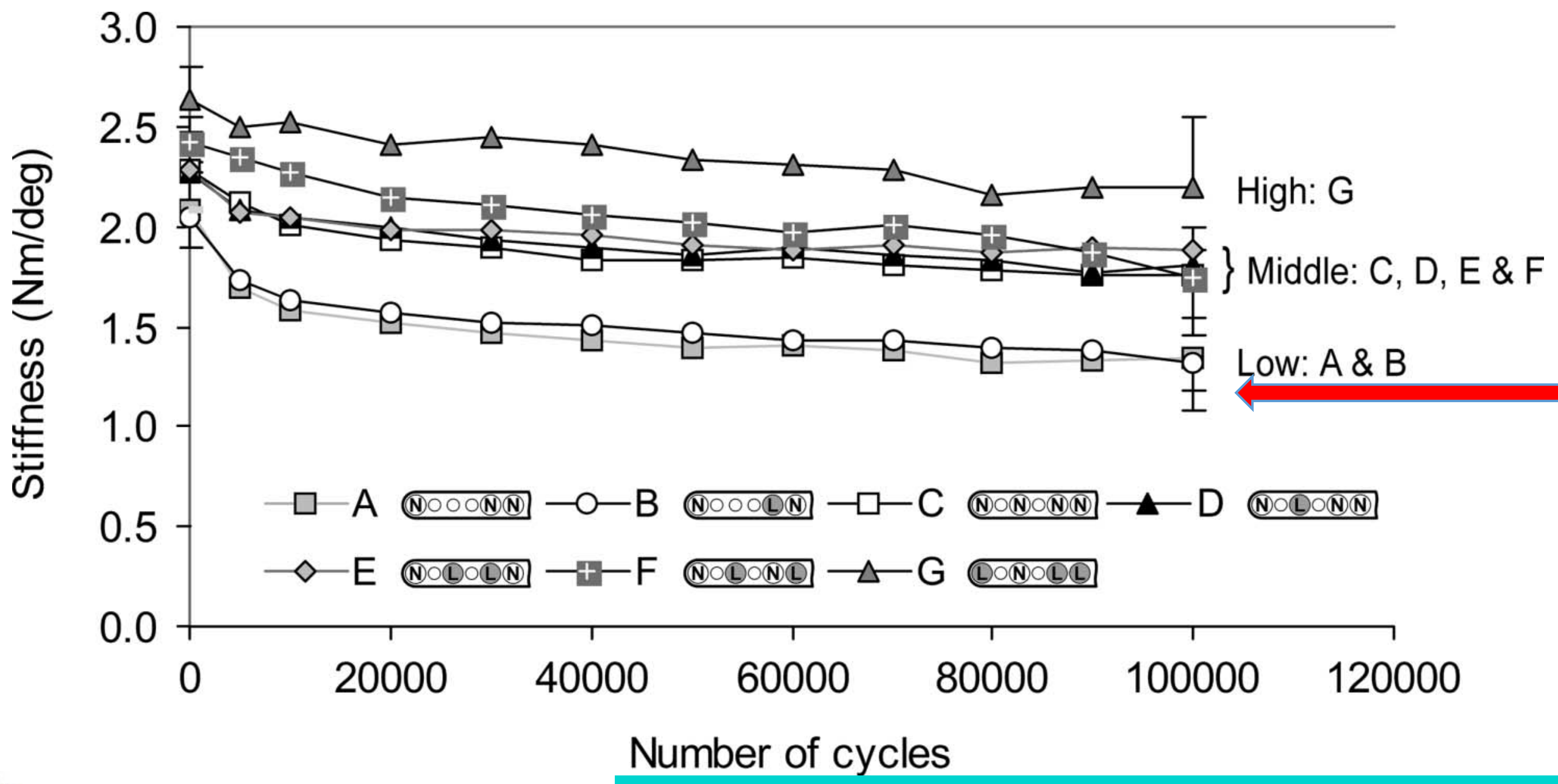
- Torsional Stiffness
- Removal torque of screws

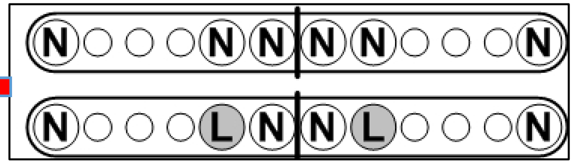


Freeman et al. J Orthop Trauma. 2010 Mar;24(3):163-9.

Hybrid Plating
Osteoporotic Model

- Less screws (3 vs 4 screws) → LOWEST torsional stiffness





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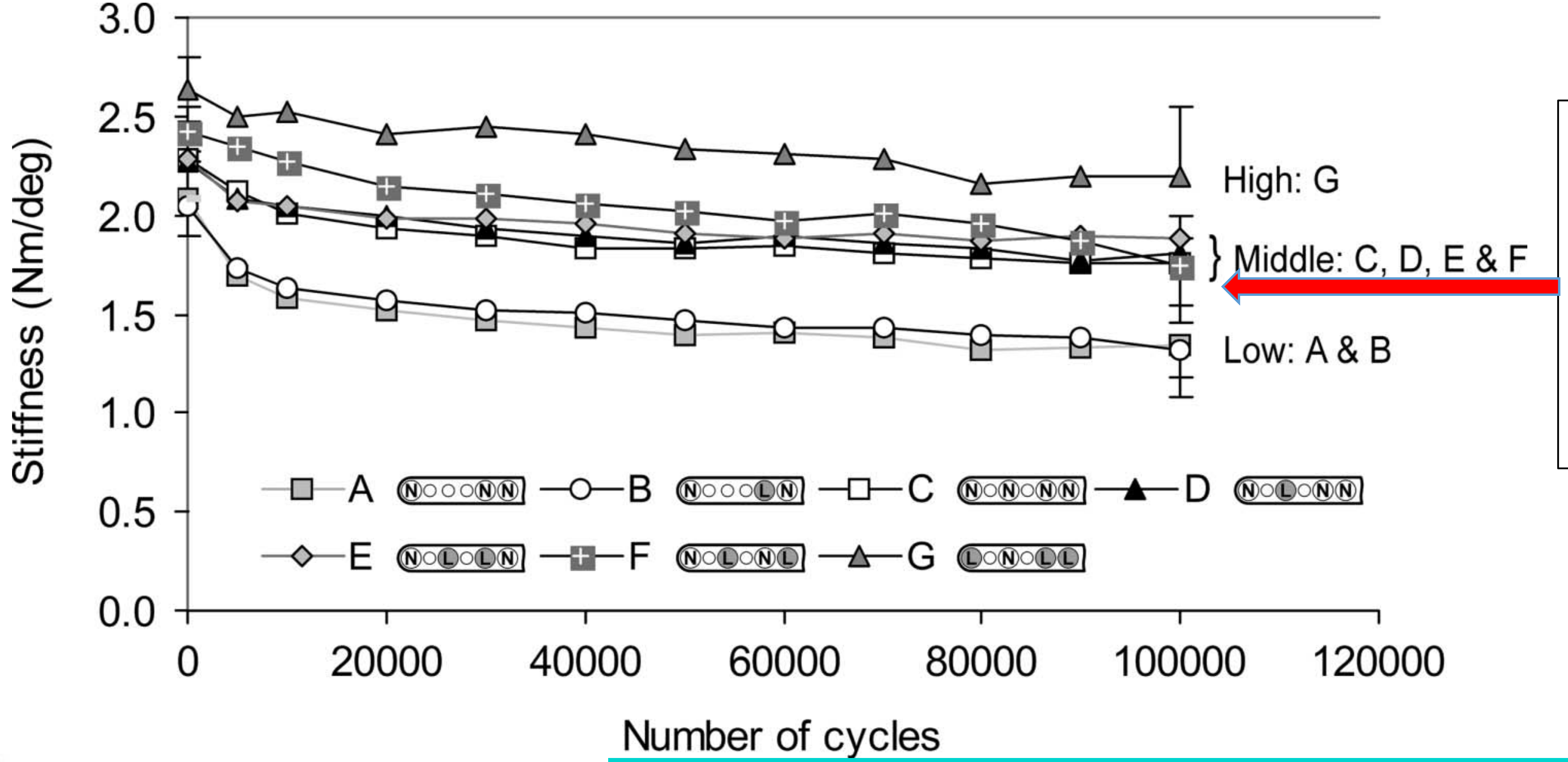
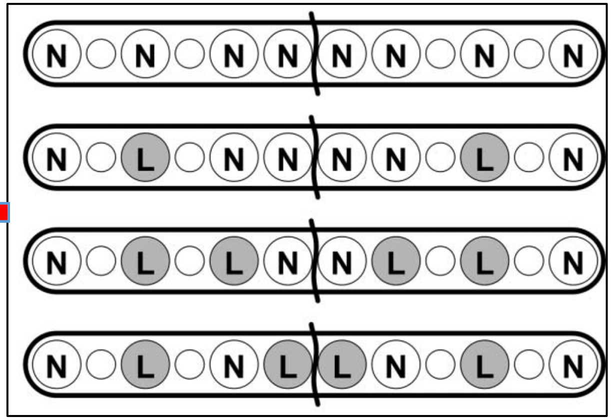
Hybrid Plating

Osteoporotic Model

- More screws (3 vs 4 screws) → HIGHER torsional stiffness





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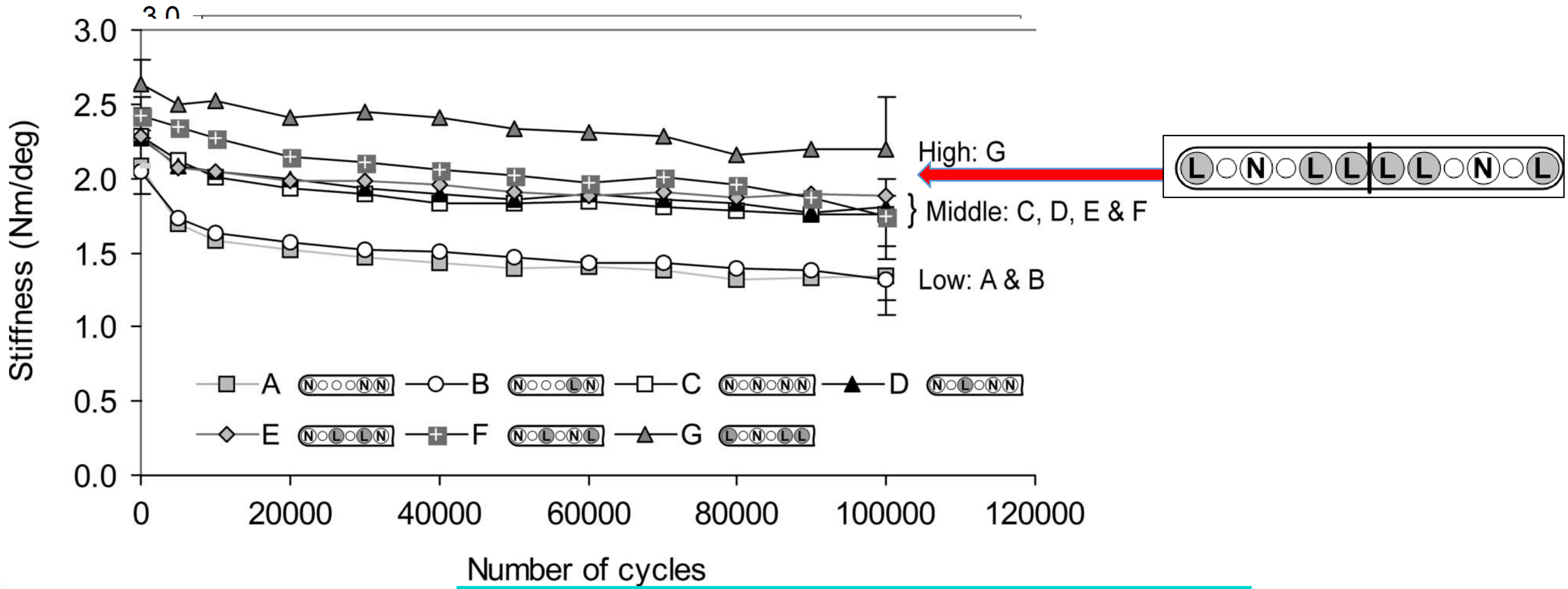
Hybrid Plating
Osteoporotic Model

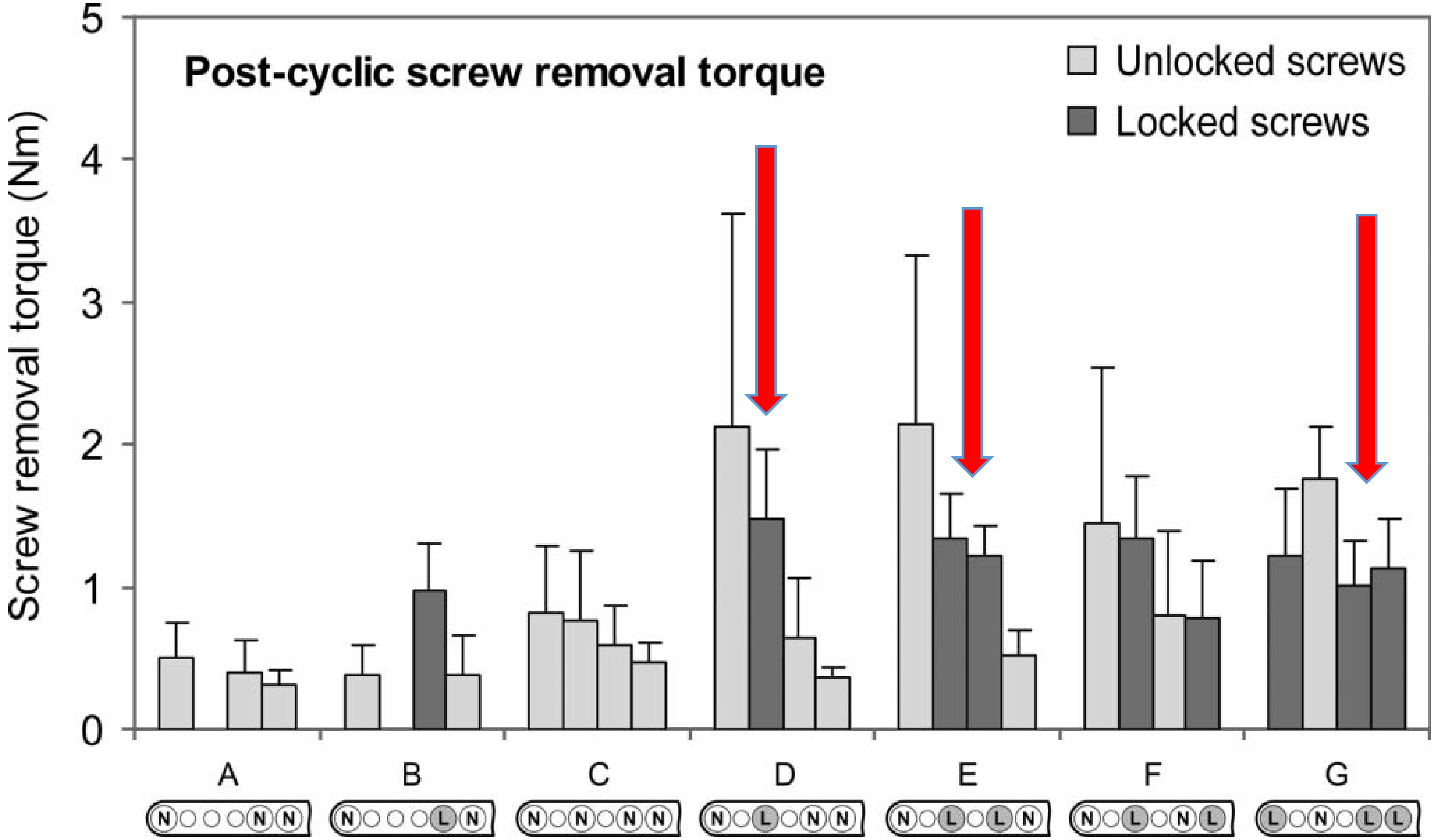
- More (3) locking screws ➡ HIGHEST torsional stiffness



Freeman et al. J Orthop Trauma. 2010 Mar;24(3):163-9.

Hybrid Plating
Osteoporotic Model

- Locking screws PROTECT nonlocking screws from loosening



Freeman et al. J Orthop Trauma. 2010 Mar;24(3):163-9.

Bone-to-Locking Plate Distance

- STRONGEST in compression and torsion when bone-to-plate distance is 2mm vs 6 mm

Stoffel et al. Injury 2003

- Strongest in compression and torsion when bone-to-plate distance is <2mm

Ahmad et al. Injury 2007

Pitfalls

- Application of Locking screws before nonlocking screws
- Misconception: Locking plate will reduce the fracture. While implants may facilitate achieving alignment if used with appropriate techniques, they do NOT reduce the fracture
- Utilization when no superiority over nonlocked plating e.g. simple pattern BBFF, partial articular fractures (requires buttress)

Valgus malredcuction, locking plate did NOT reduce the fracture

Pitfalls

- In simple fracture pattern very rigid fixation with gap at fracture site (Oh et al. AOTS 2011)
- Cross threading will make removal problematic
- Bending at locking holes may cause deformation and preclude locking
- Bending any periarticular plate before checking the reduction twice
- Once a locking plate is bent, it may NOT be used to guide the reduction of alignment

Pearls

- Reduction BEFORE fixation
- Application of Nonlocking screws (Lagging or approximation of bone plate interface) BEFORE locking screws
- Can exchange non-locked screw for locked screw after construct complete if need added stability in periarticular region
- NOT needed in good bone quality with large area/long segment for fixation
- NOT needed in most B-type articular fractures
- May need additional fixation if far cortex is comminuted/not well aligned
- Screw Density <0.5 to distribute forces (fill every other screw hole at most)
- Plate Length in comminuted fractures: Fracture Length X2-3
- Working length in simple fractures with non-anatomic reduction: Longer= improved stability
- Check the reduction twice before bending any periarticular plate

Modifications

- Stiffness of locked plating constructs (very stiff with inadequate micromotion at fracture site) is blamed for some of the failures
- As search for solution, modifications of locked plating are suggested.
- Modification of screw-bone or plate-screw interface at diaphysis induce axial motion without causing shear or failure of fixation i.e. controlled axial micromotion

- Far Cortical Locking
- Dynamic Locking Screw
- Active Locking Plates

Very stiff

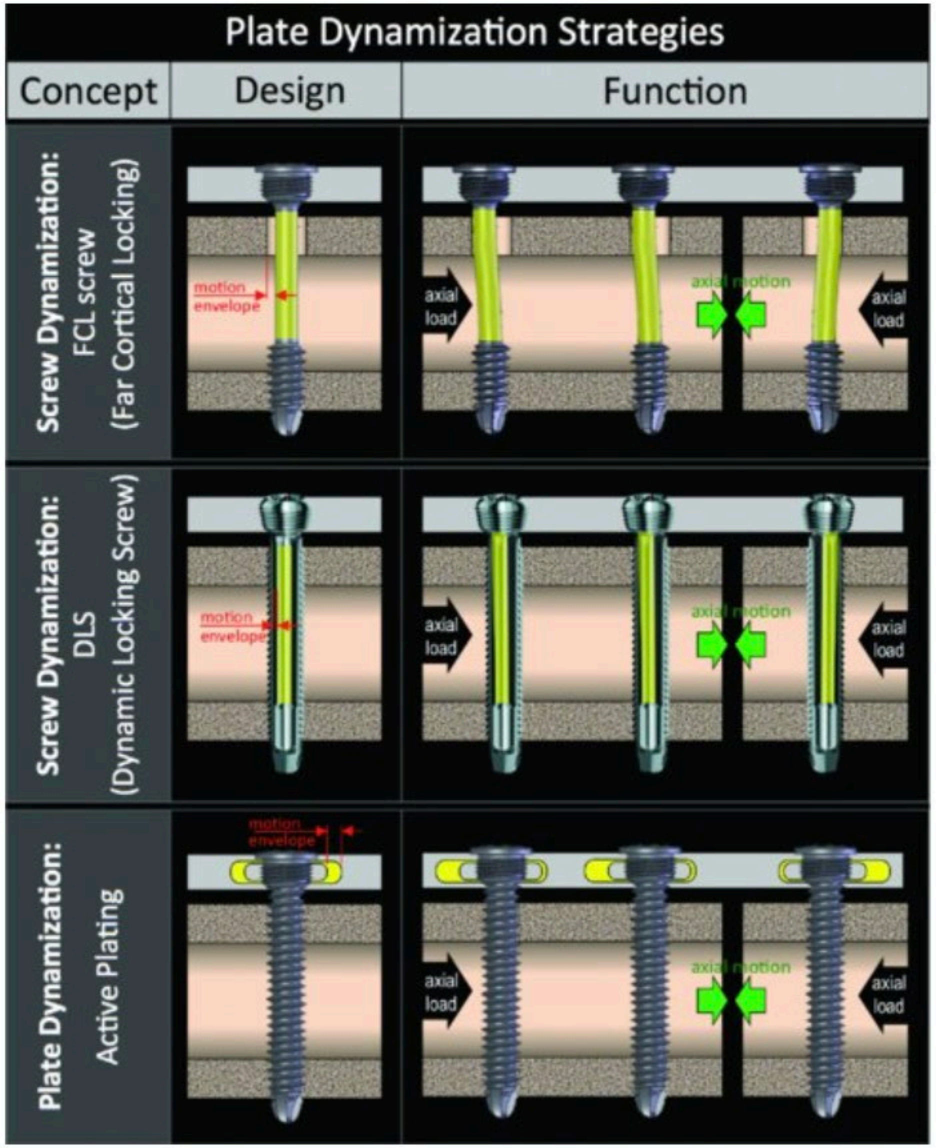
Kandemir. Injury 2018

Modification:
Far Cortical Locking

- Locking screws with smooth shaft with locking to plate and fixation to far cortex, larger hole at near cortex allows axial micromotion

- Improved fracture healing with more abundant callus

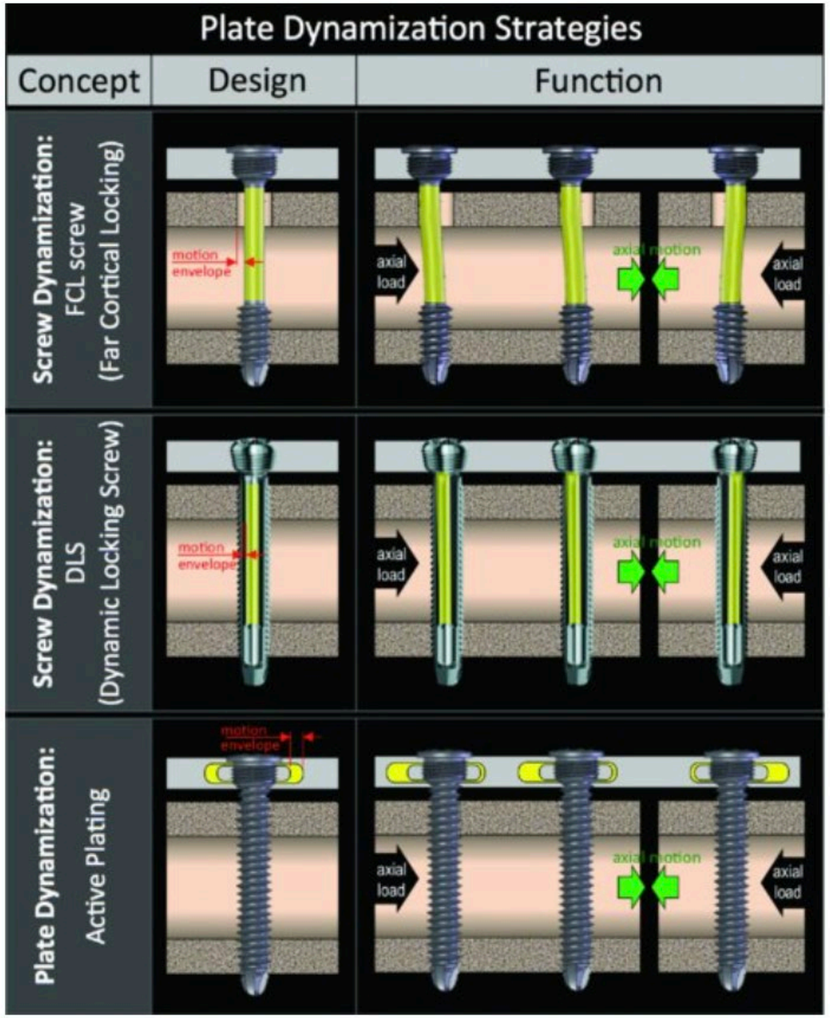
Bottlang et al. JBJS 2010



Rockwood and Green's Fractures in Adults, 9e

Modification:
Dynamic Locking Screw

- Consists of
  - Sleeve with bonethread
  - pin with locking head
- Both are connected in a way allowing the movement within the screw without movement in bone screw interface or at plate-screw interface
- DLS reduces stiffness → increased interfragmentary motion without compromising angular stability and strength



Rockwood and Green's Fractures in Adults, 9e

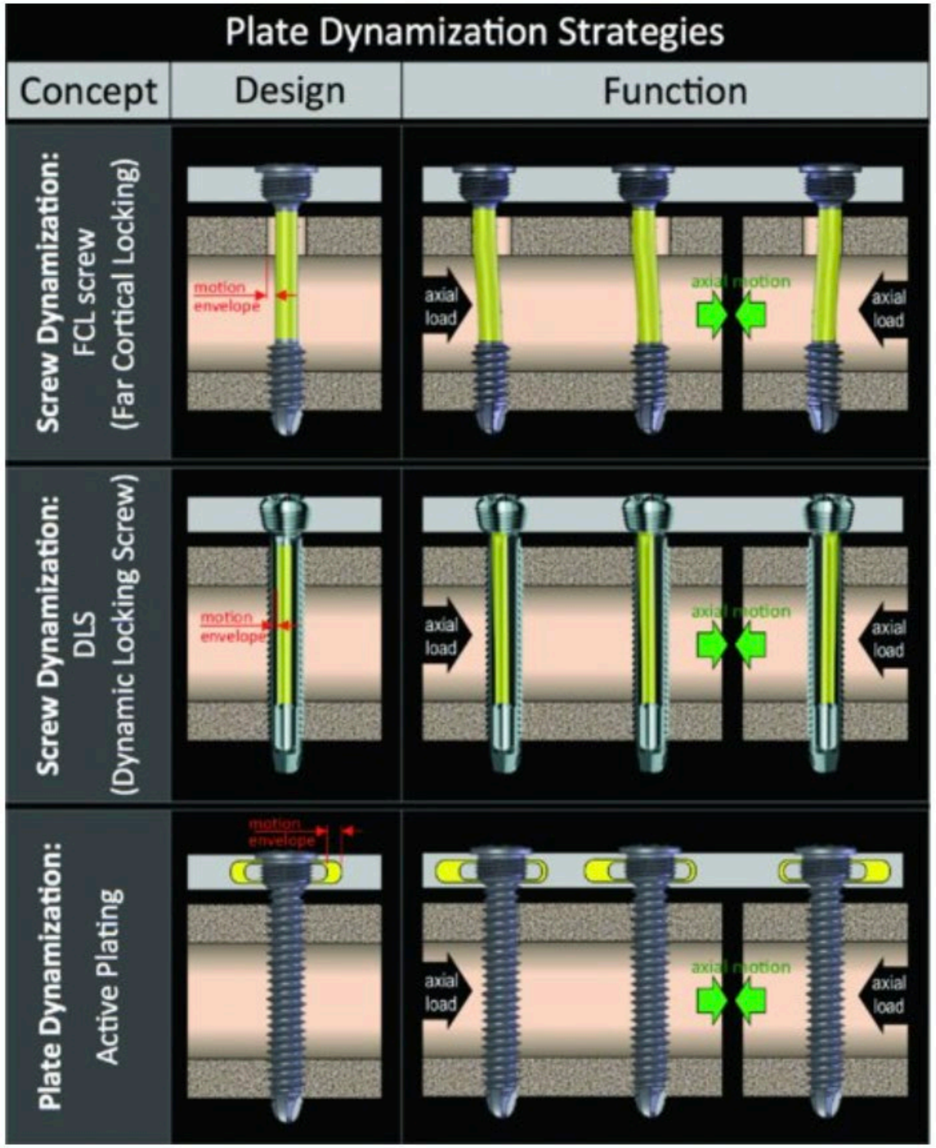
Dobele et al. LAS 2010

Modifications: Active Locking Plate

- Controlled axial dynamization by elastic suspension of locking holes within the plate

- Symmetric, stronger and faster callus formation compared to standard locking plates

Bottlang et al. JBJS 2016



Rockwood and Green’s Fractures in Adults, 9e

Summary

- Locked plating is indicated
  - Poor bone quality/Low bone density/Thin cortices (Osteoporosis)
  - Length/Area for fixation is limited (Periarticular fractures)
  - Bridging Comminution & Bone defects
  - Bicortical fixation not possible (e.g. proximal humerus fxs, periprosthetic fractures)
- The construct (length of plate, location and number of screws, all locking vs hybrid fixation) should be decided based on the goals of fixation for specific fracture pattern
- Creates greater stability / rigidity:
  - can improve chance for union when need greater stability
  - can be less forgiving on fracture reduction and increase risk on non-union when greater than needed rigidity

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THANK YOU

Utku.Kandemir@ucsf.edu