OTA Resident Core Curriculum: Locked Plating

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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

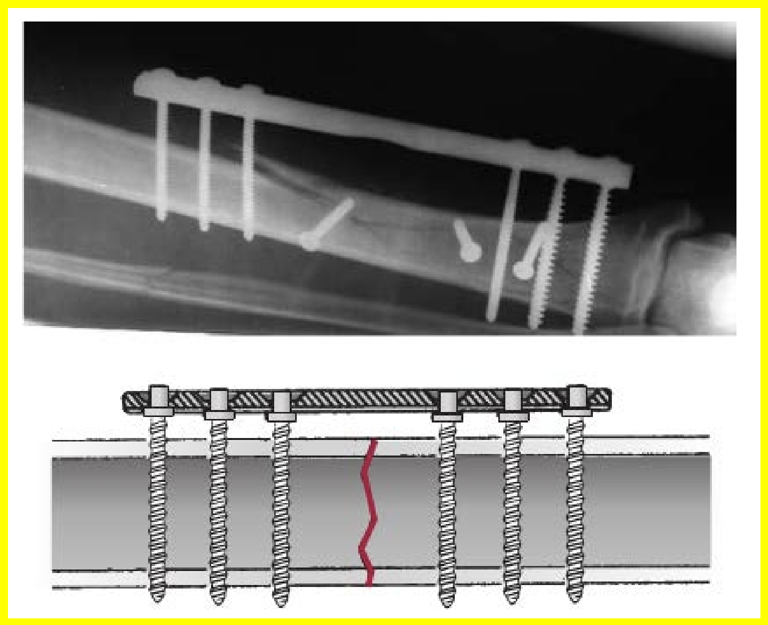
-Carl Hansman, 1886: monocortical fixator

-Ernest Hey Groves, 1916

-Paul Reinhold, 1931

-Wolter system, 1974

-Zespol system, 1982 →



-Synthes, PC-fix, 1994

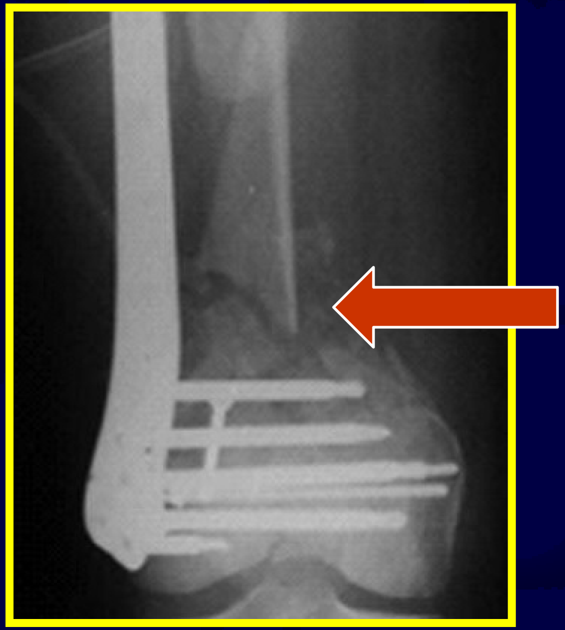
-AO, LISS plate, 1995

-Schuhli nut, 1998: allowed screws to lock into standard plate via threaded washer

Recently: Pubmed: ~800 papers, 50% in last 5 years

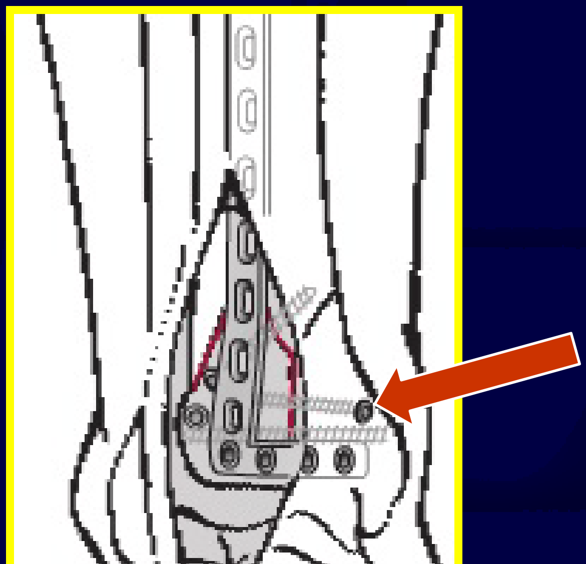
Why is locked plating important?

- 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

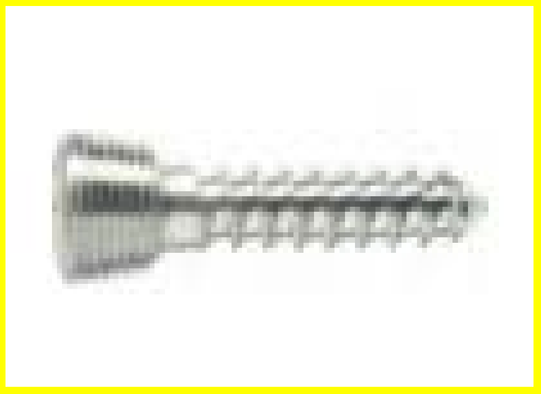
Why is locked plating important?

- 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



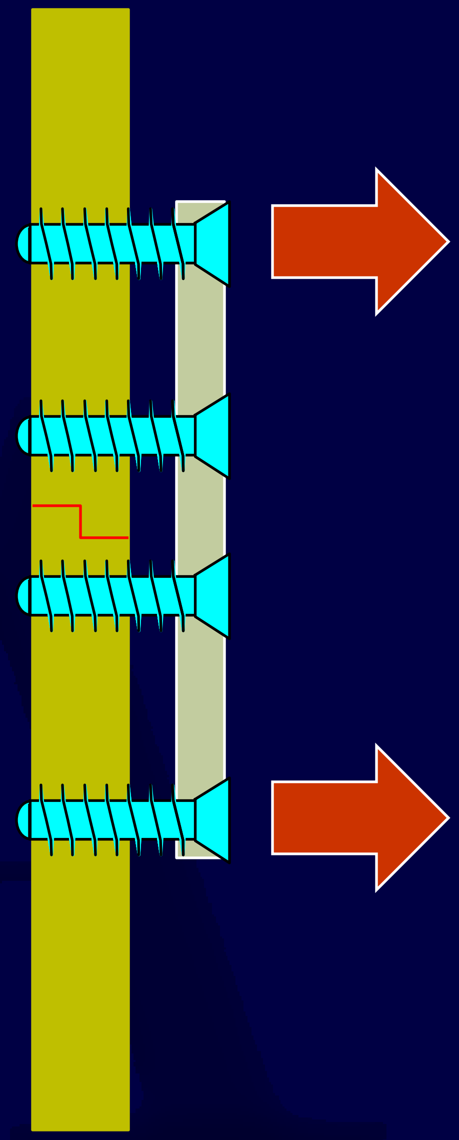
Images courtesy of Smith+Nephew

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



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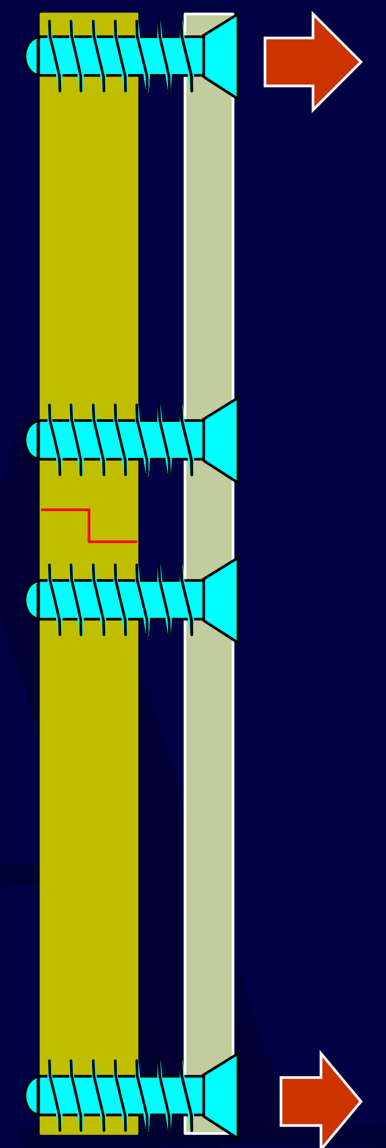

Biomechanics: Diaphysis

- 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

Ricci, Tornetta, et al OTA '06

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

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Injury, Int. J. Care Injured 34 (2003) S-B11–S-B19
INJURY
www.elsevier.com/locate/injury

Biomechanical testing of the LCP –
how can stability in locked internal fixators be controlled?

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

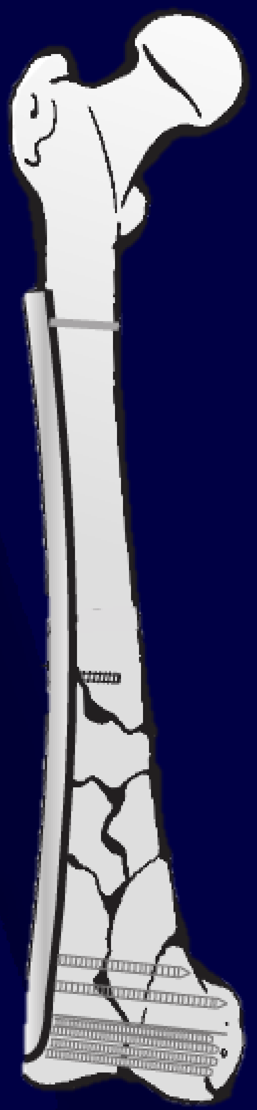
- Precontoured plates have locking and non-locking holes
- Locking screws support / raft subchondral bone

Biomechanics: Metaphysis

- Koval et al, 1997
  - Cadaver study, osteoporotic distal femur, 1 cm bone defect created
  - Condylar buttress place 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



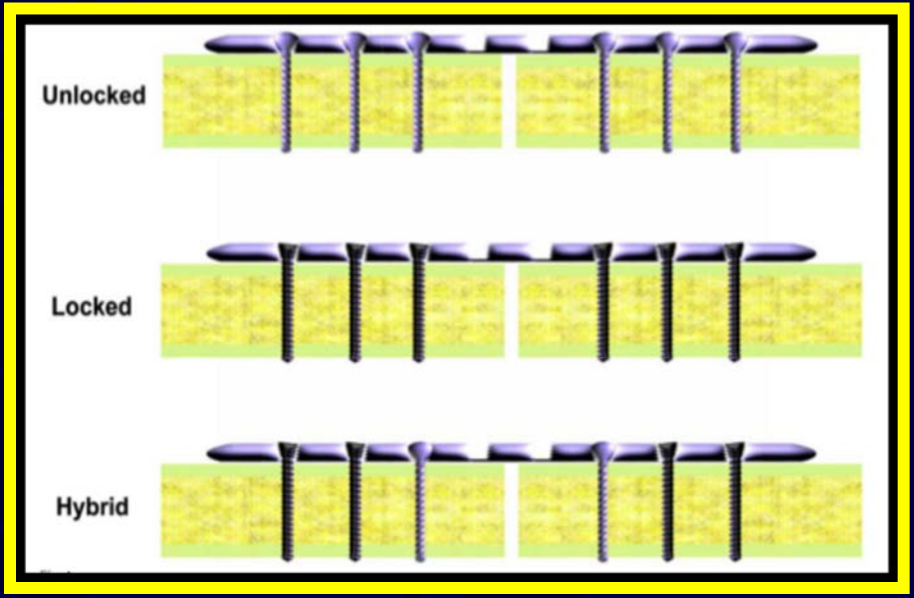
Hybrid Plating

- 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

Effects of Hybrid Plating With Locked and Nonlocked Screws on the Strength of Locked Plating Constructs in the Osteoporotic Diaphysis

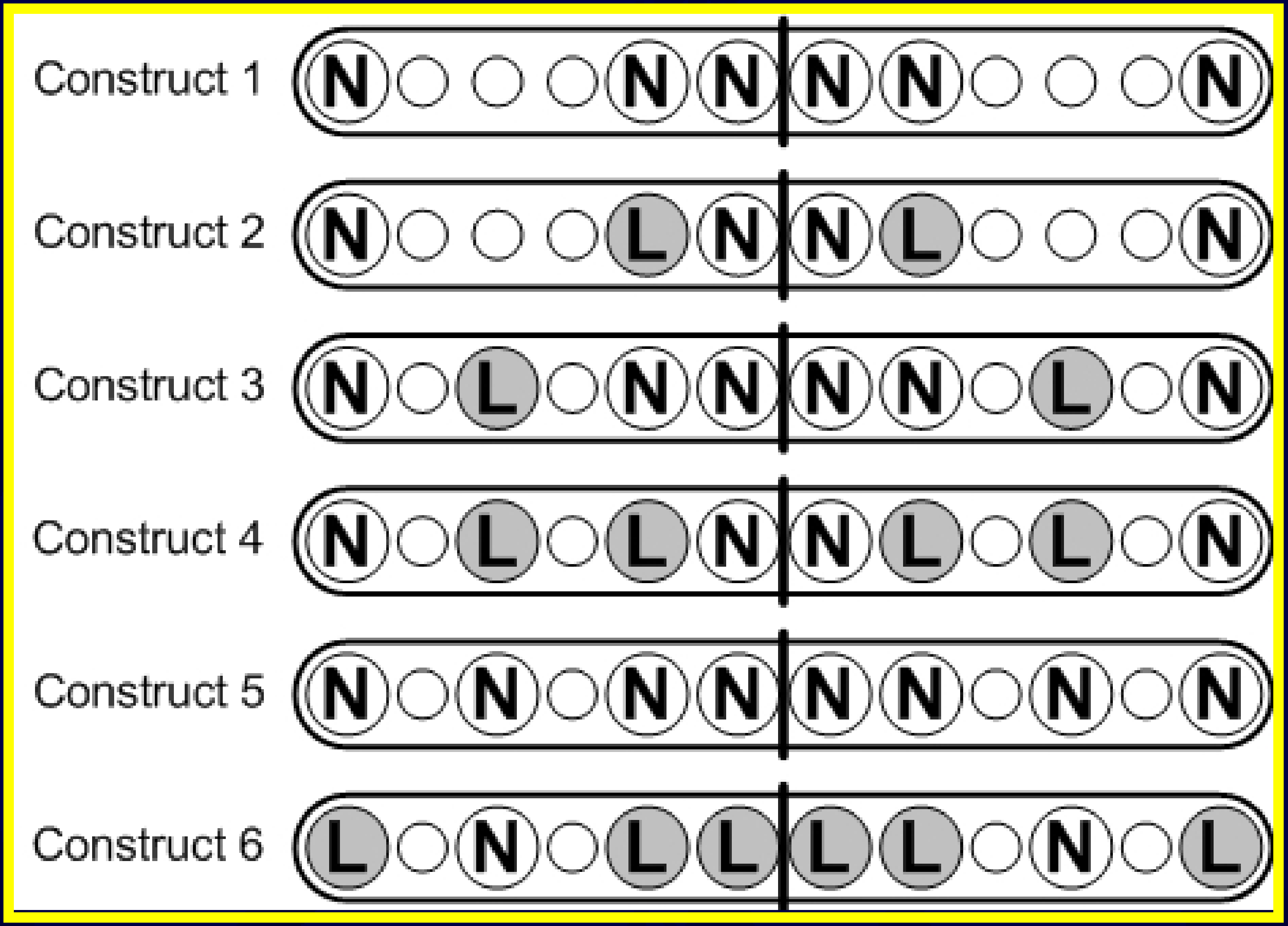
Josef Doornink, MS, Dan C. Fitzpatrick, MD, Sebastian Boldhaus, BS, Steven M. Madey, MD, and Michael Bottlang, PhD

- 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

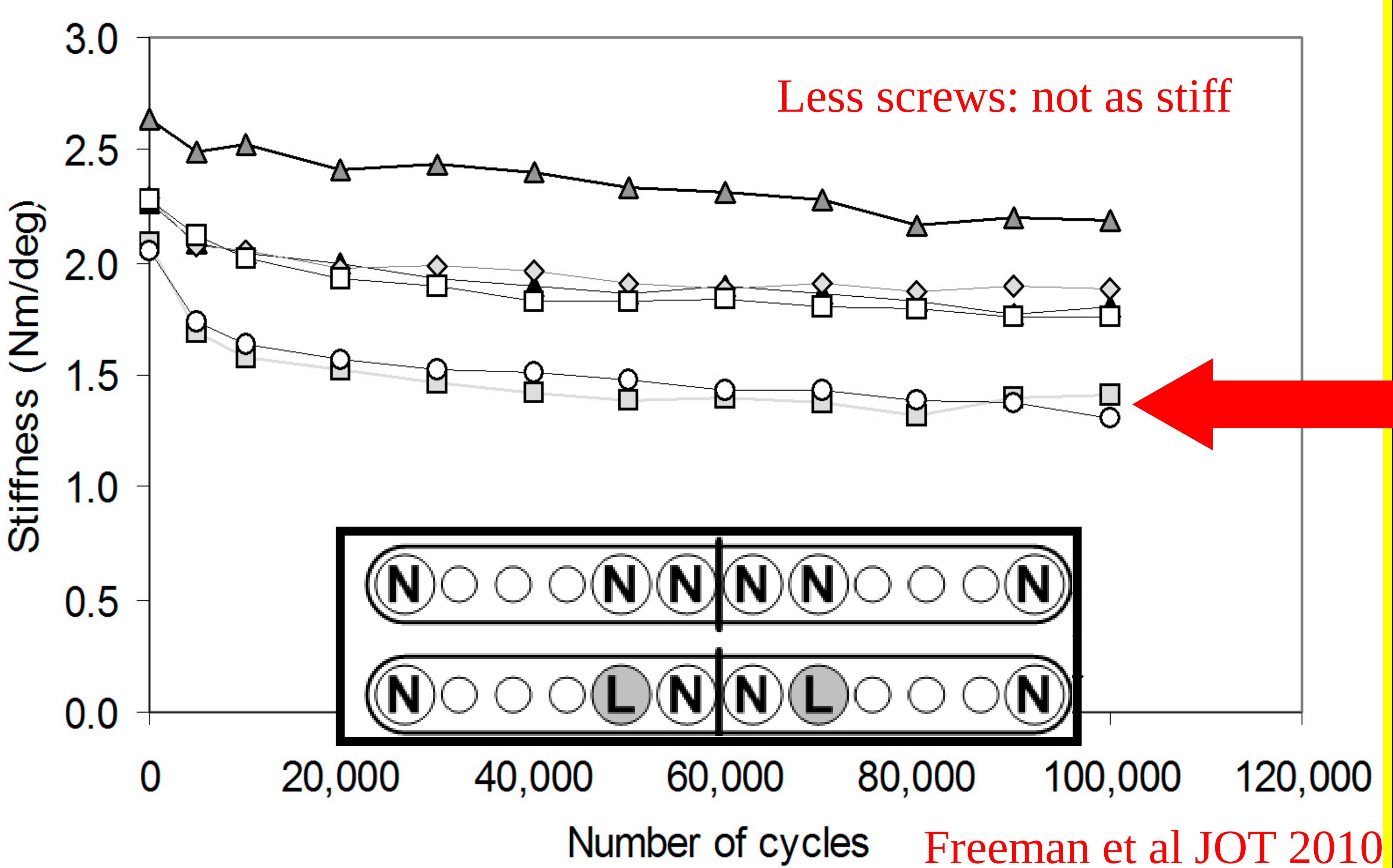
Biomechanics: Hybrid Plate

- 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

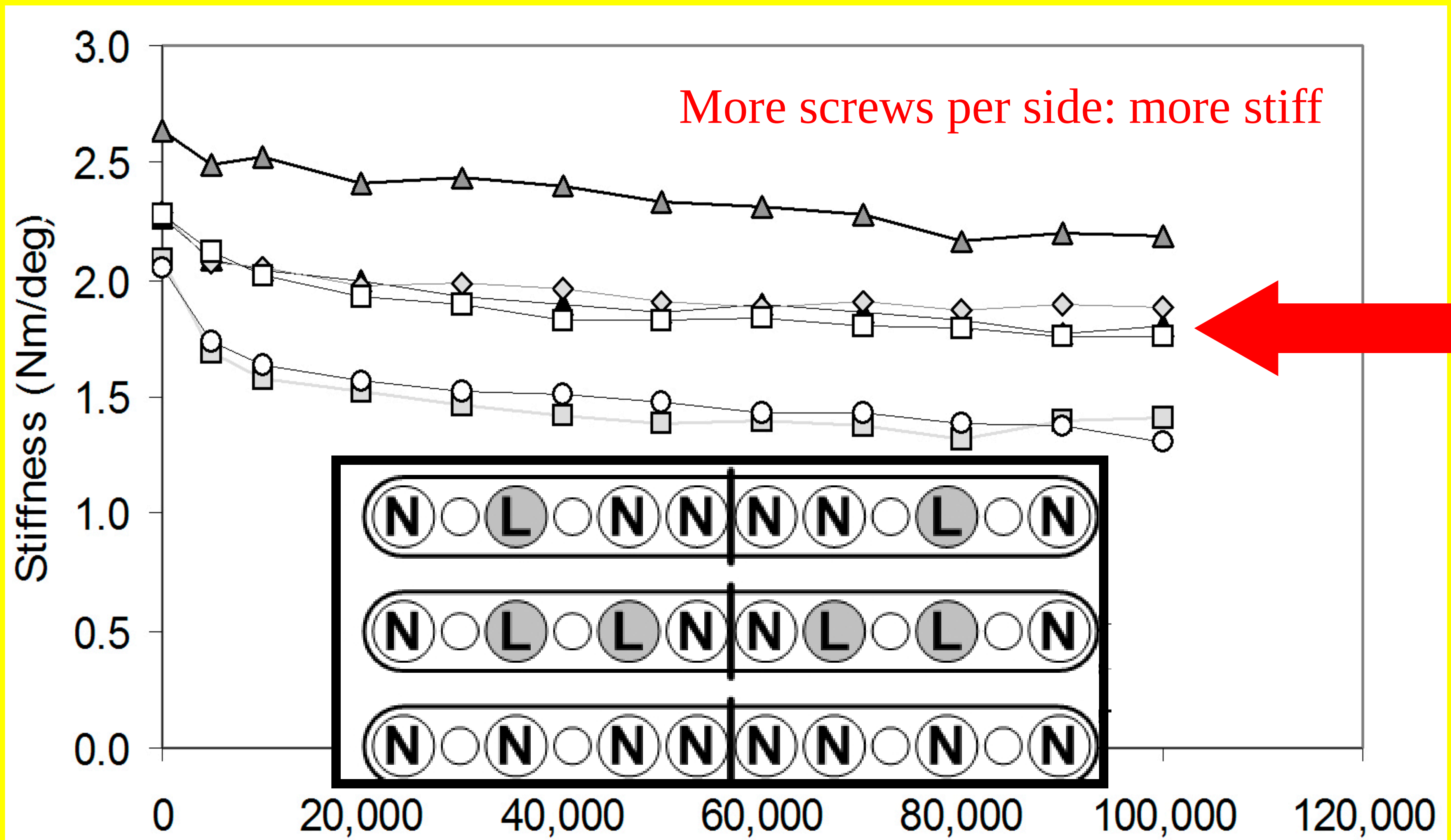


Results: Stiffness



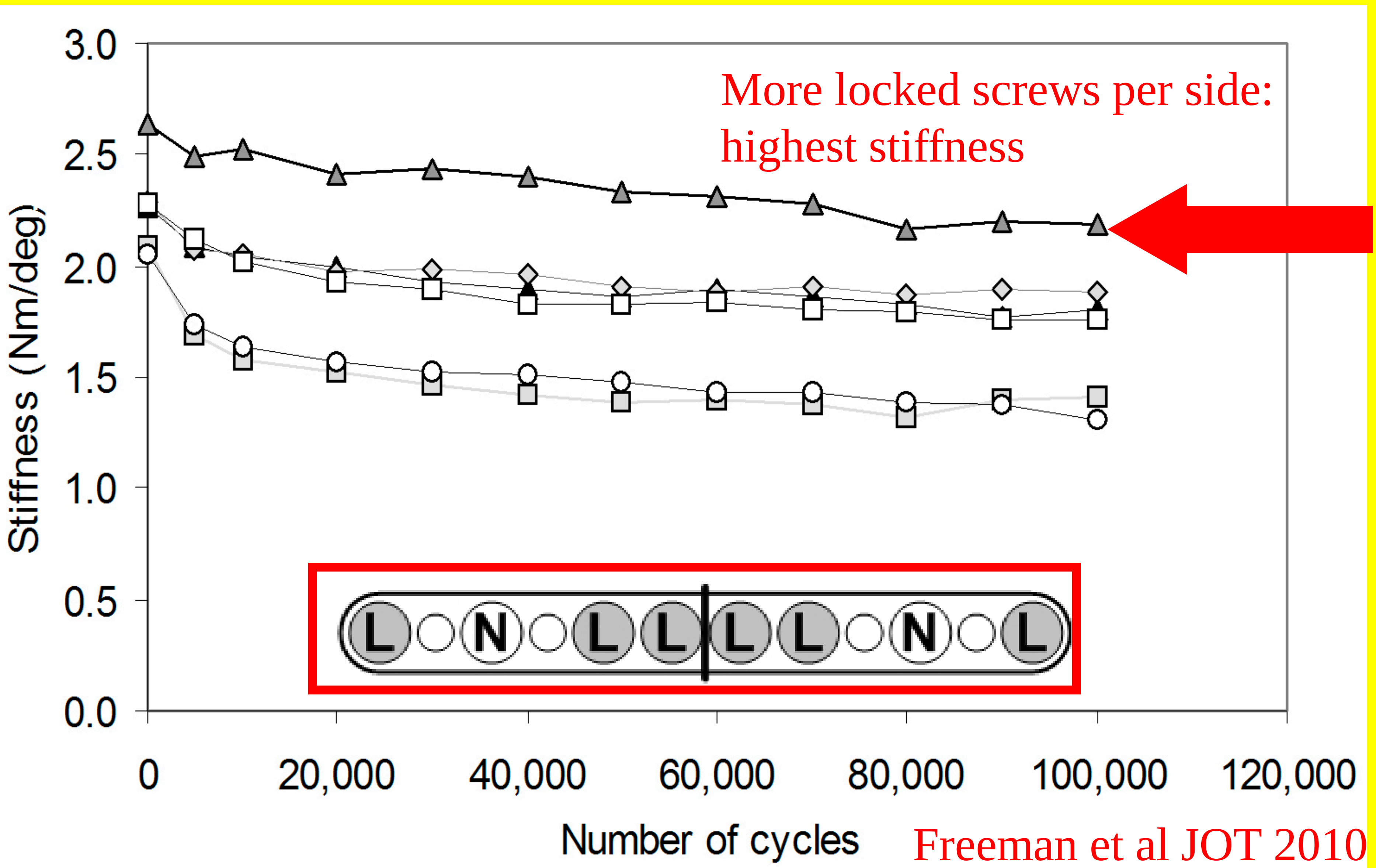
Freeman et al JOT 2010

Results: Stiffness



Freeman et al JOT 2010

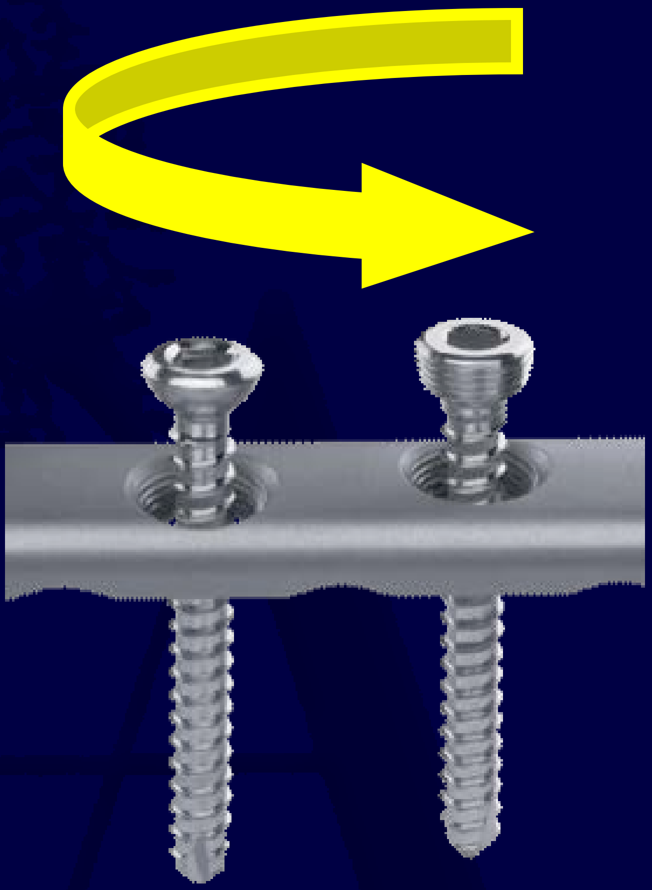
Results: Stiffness



Freeman et al JOT 2010

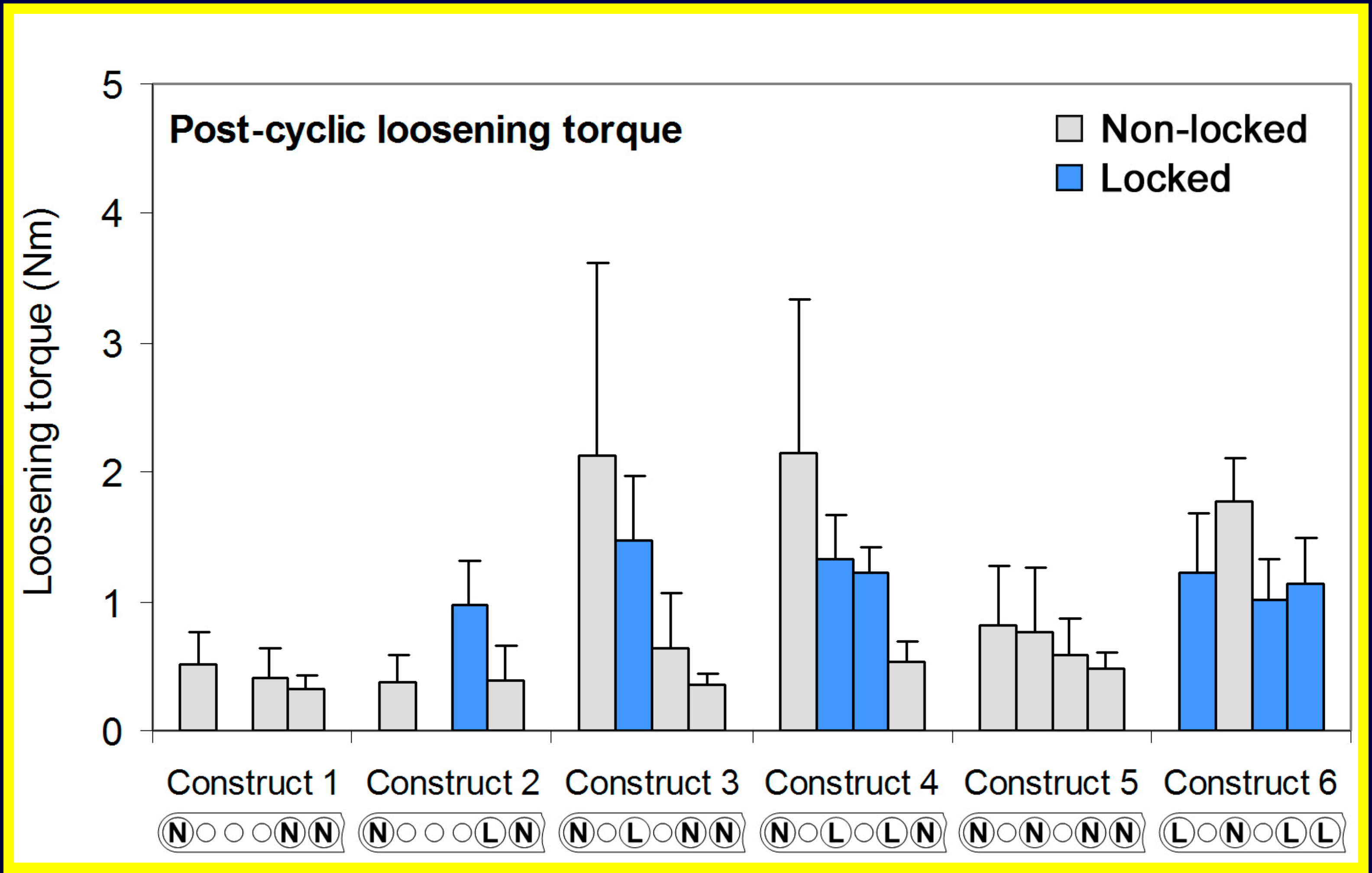
Removal Torque

- Locked screws
  - Not affected by position
  - Retained avg 50%
- Unlocked screws
  - Position dependent
  - Lost up to 90% (30% - 90%)



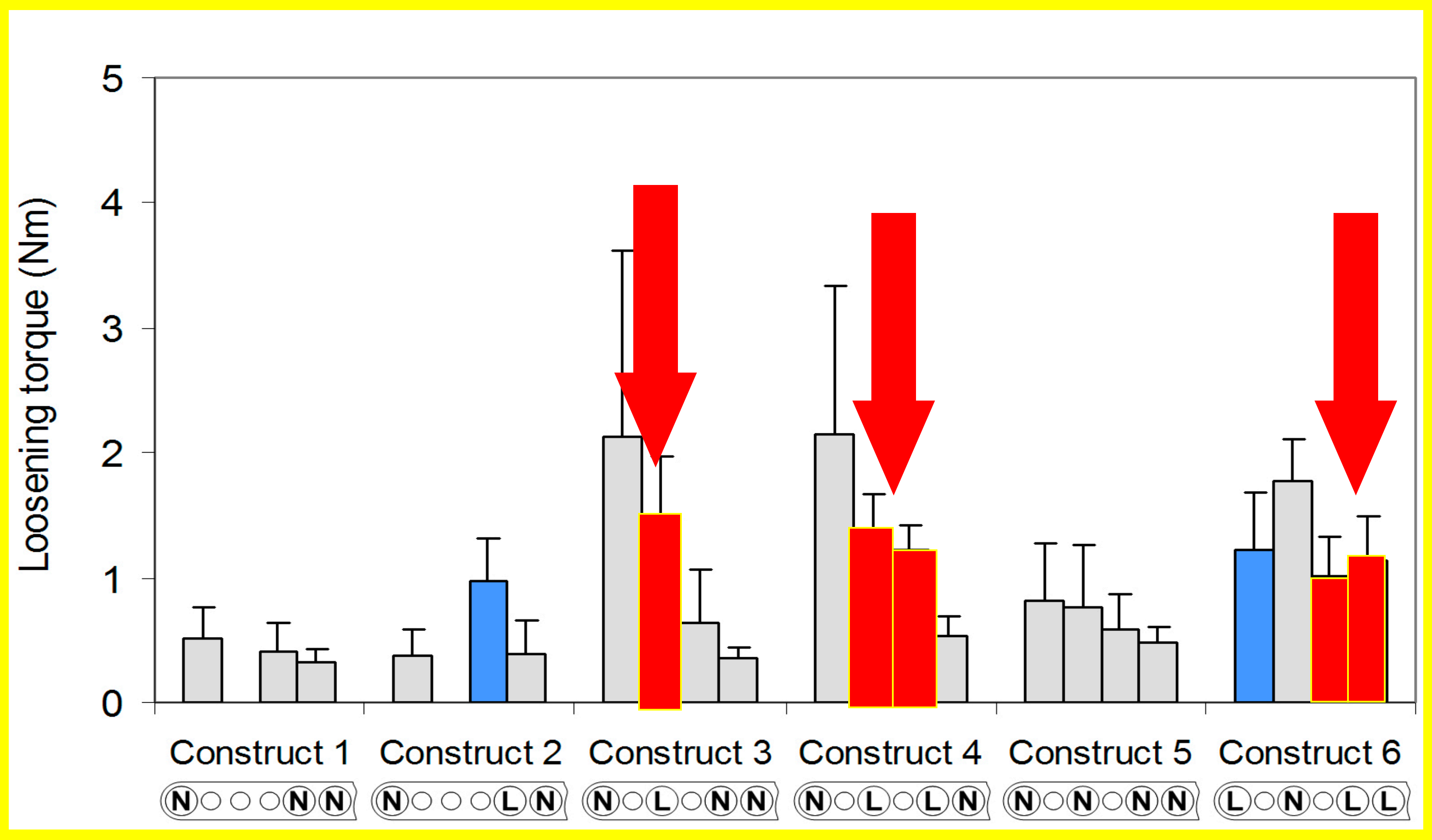
Freeman et al JOT 2010

Removal Torque



Freeman et al JOT 2010

Removal Torque

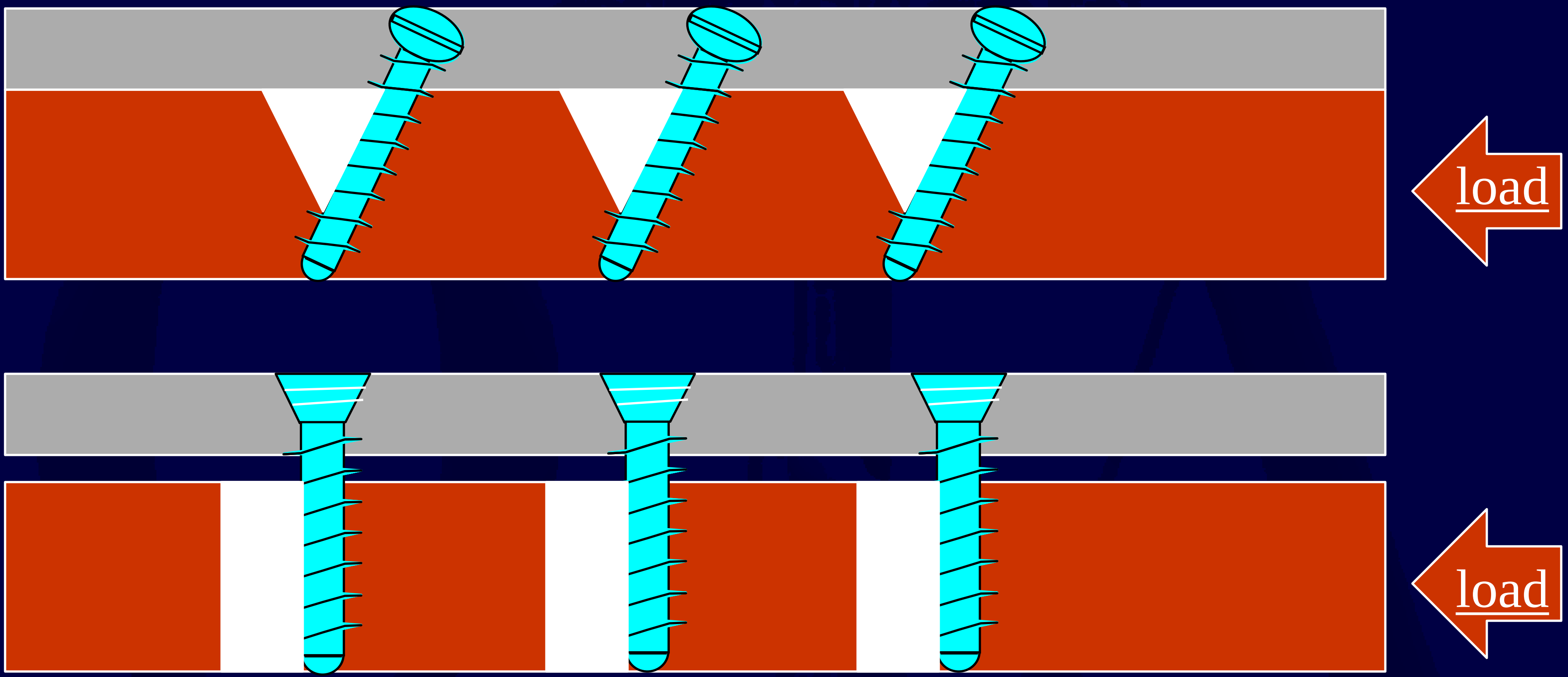


Locked Protects Unlocked (red arrows)

Freeman et al JOT 2010

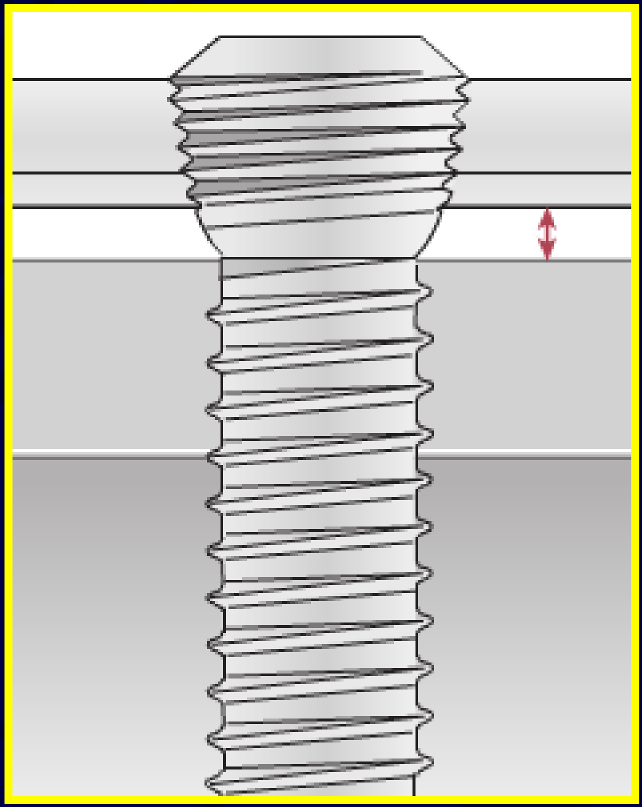
Advantages of Locked Plating

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



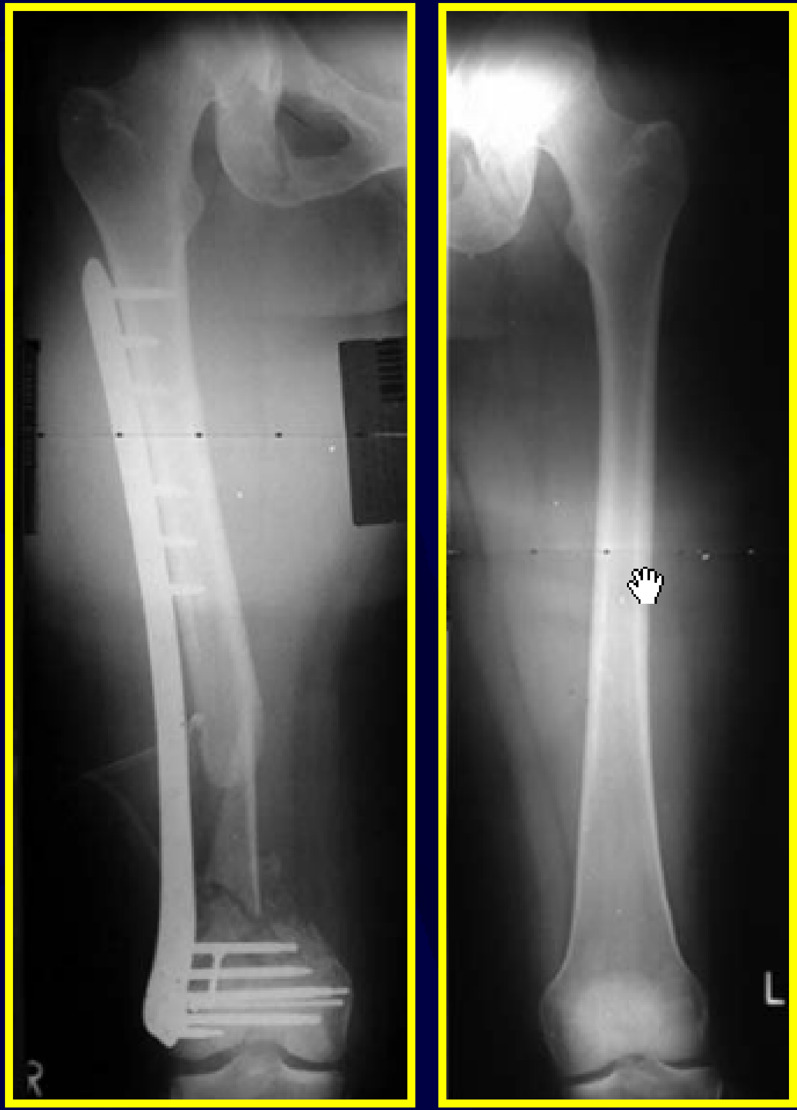
Advantages of Locked Plating

- 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



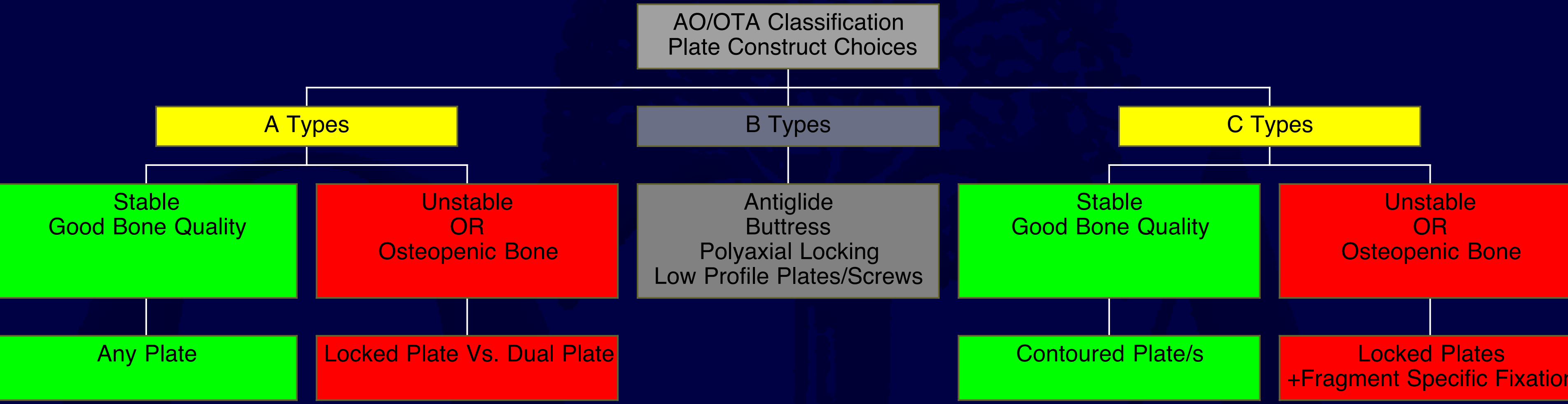
Disadvantages of Locked Plating

- 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

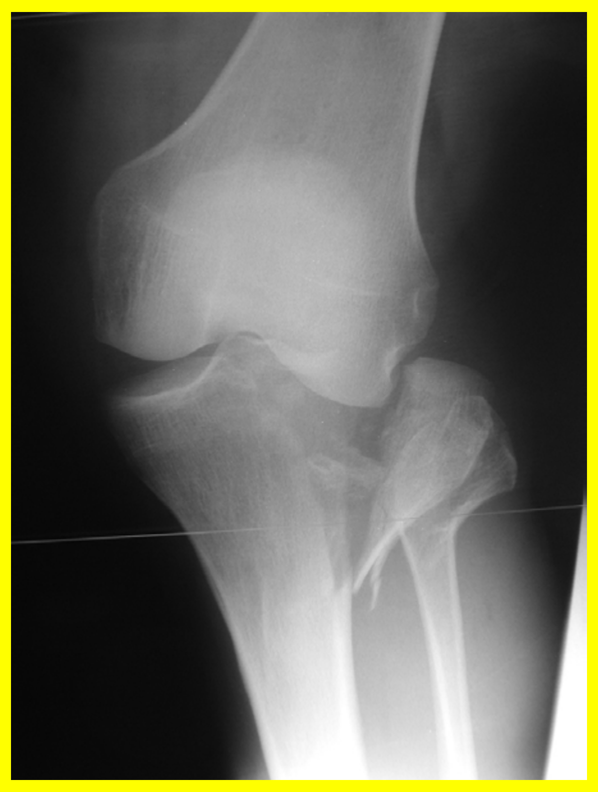
Russell Tornetta Algorithm
2007



Courtesy of Dr. Tornetta

NOT an indication

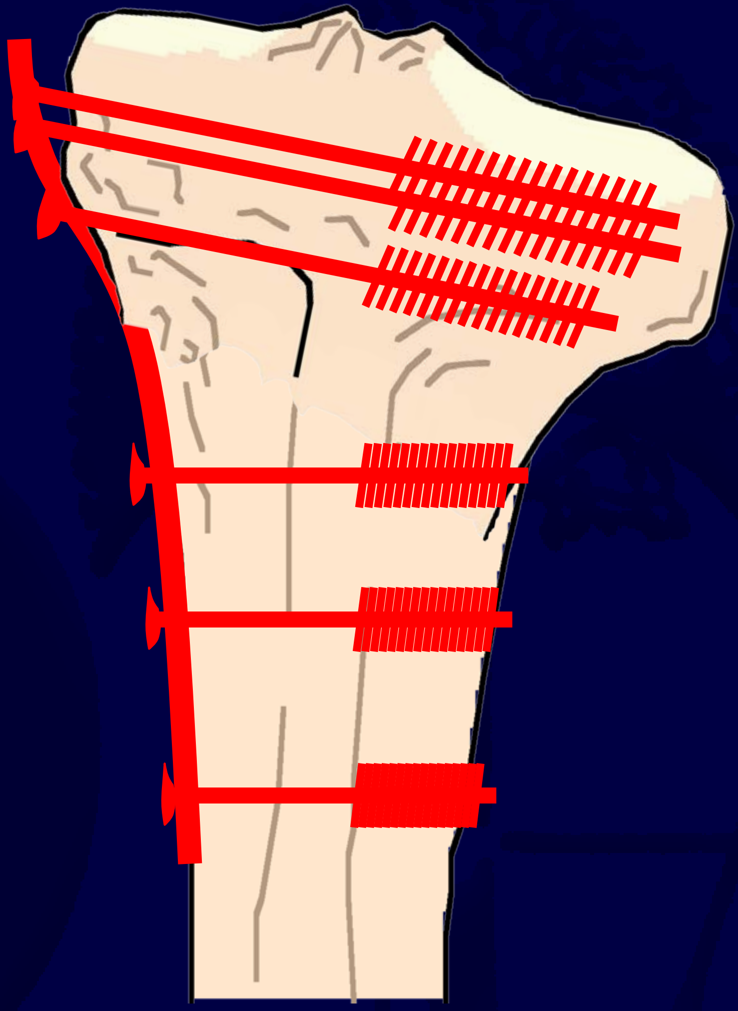
- Partial articular injury
  - "B" types….in good bone



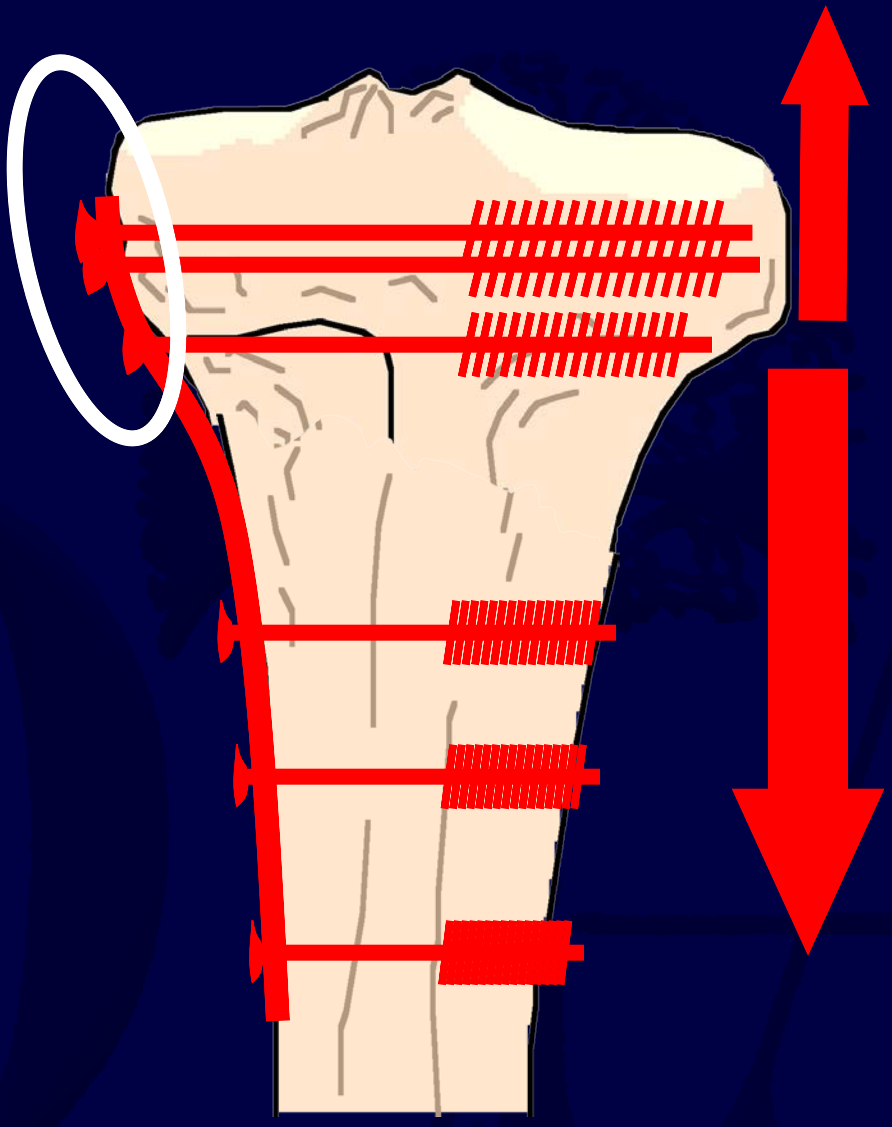
Locking Plate Indications

- Short segment fixation

When far side support needed…

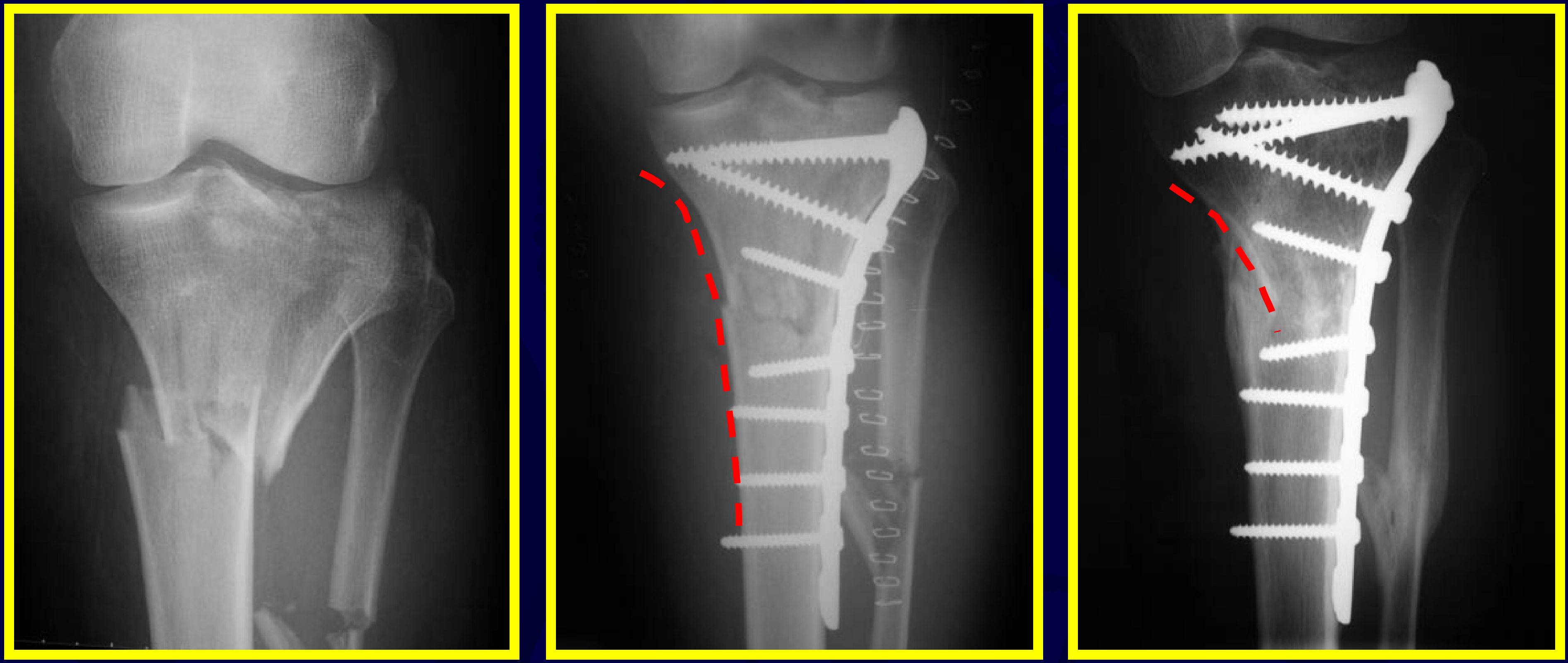


...Locking Helps



Fixed Angle !

If you did this with unlocked plate



Locking Plate Indications

- Osteoporotic Bone

Locking Plate Indications

- Periprosthetic Fracture
  - Short segment variant



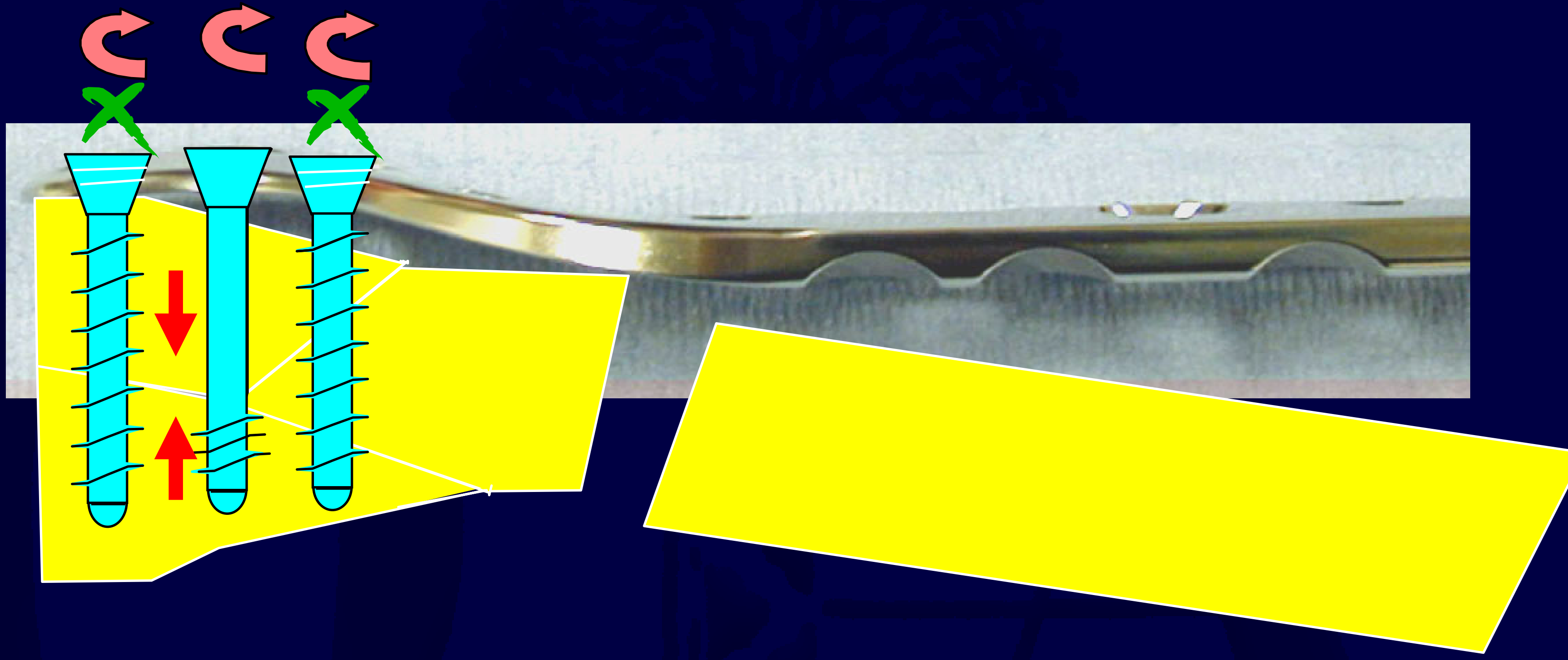

Surgical Technique

- 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)

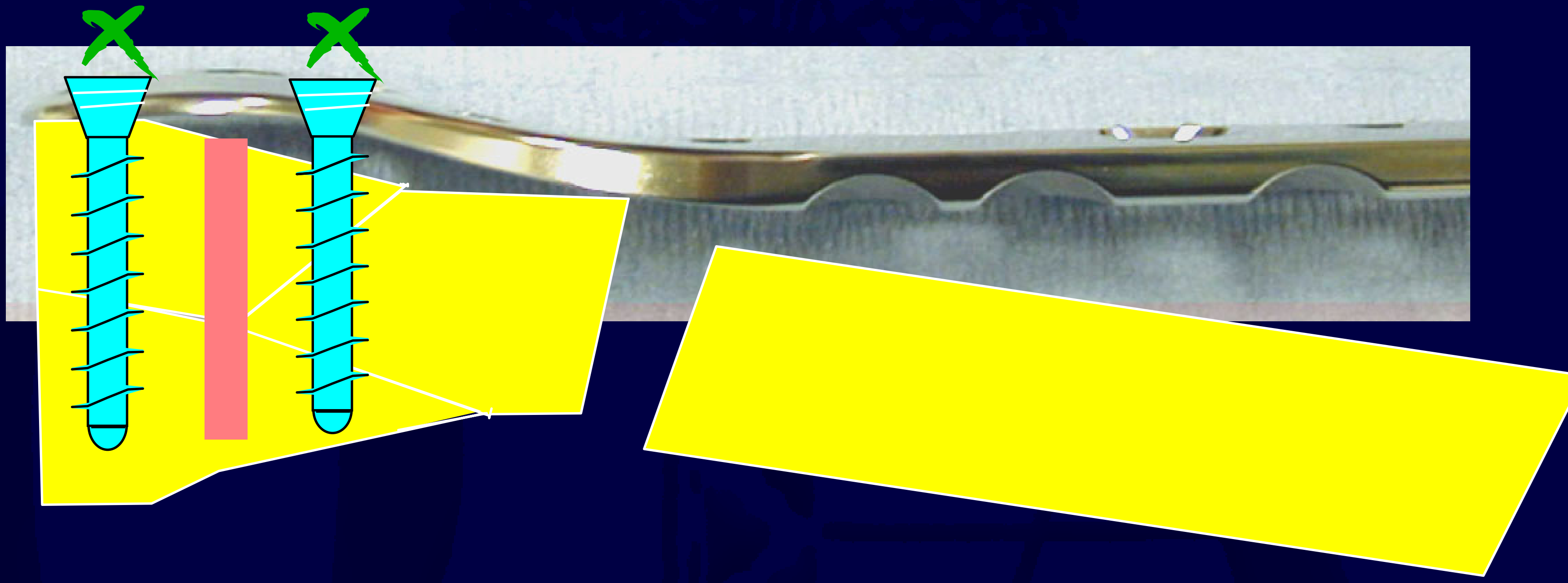
-Green X in animation = locking screws

Joint Reduction→Locking Distally



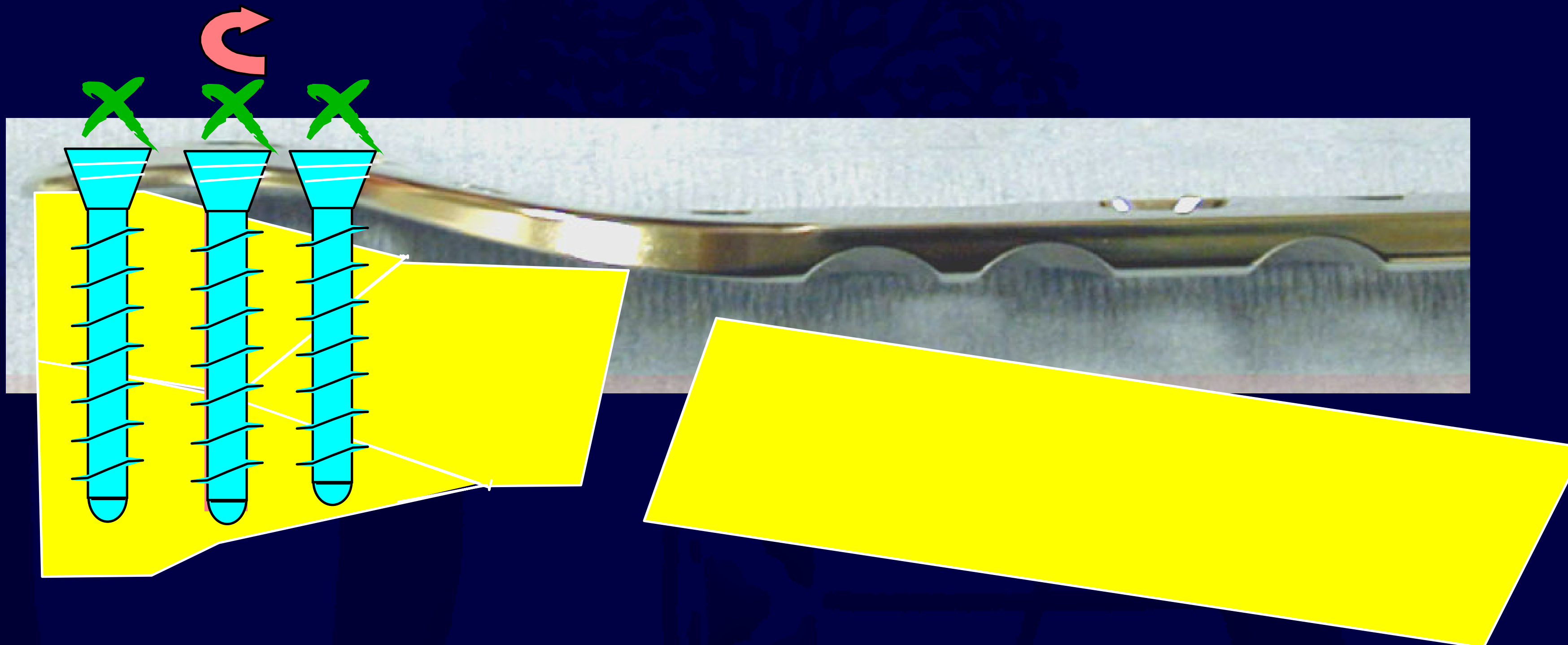
<u>Metaphyseal Fixation</u>

Removal of non-locking screw



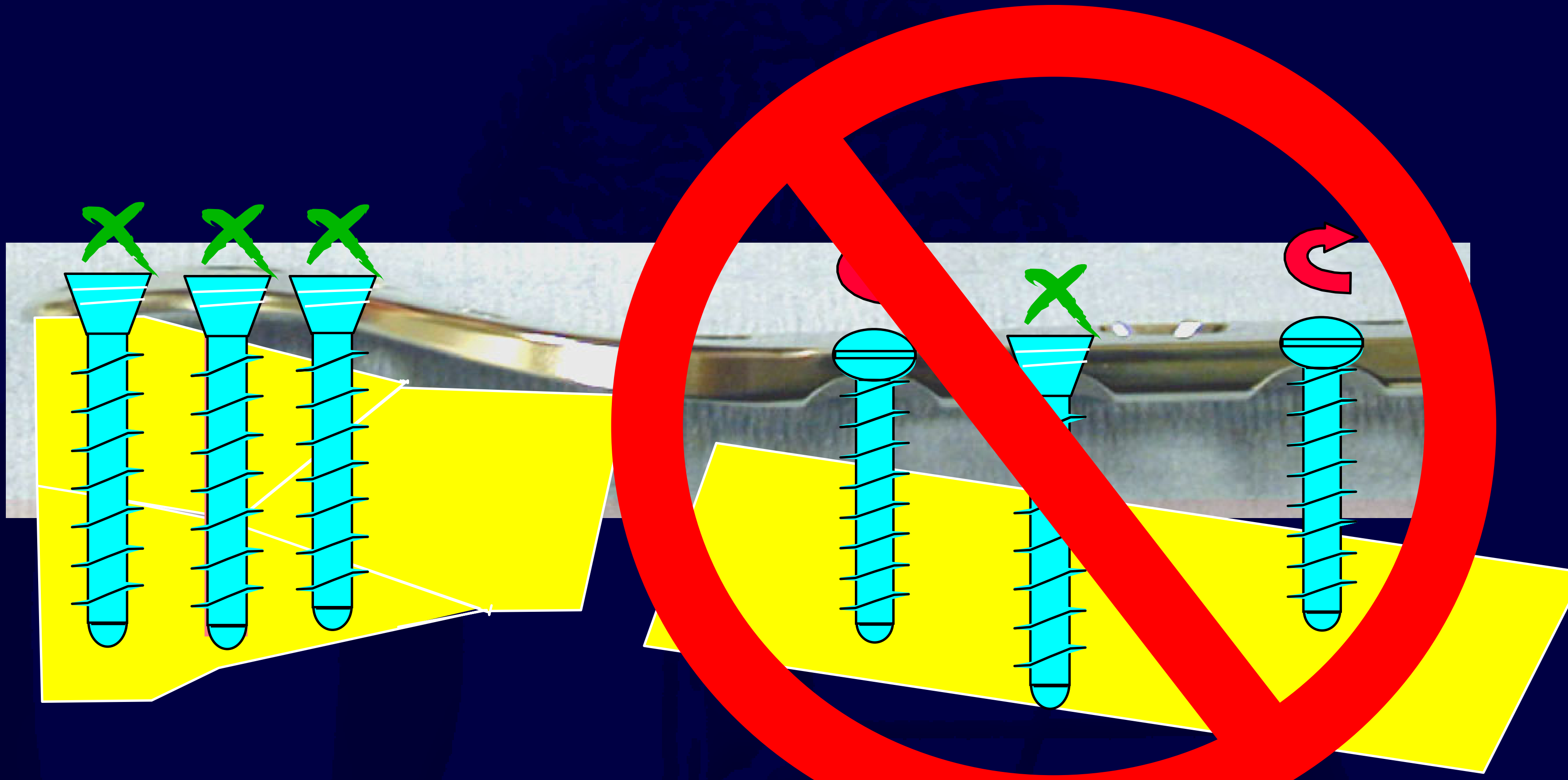
Metaphyseal Fixation

Replacement with locking screw



<u>Metaphyseal Fixation</u>

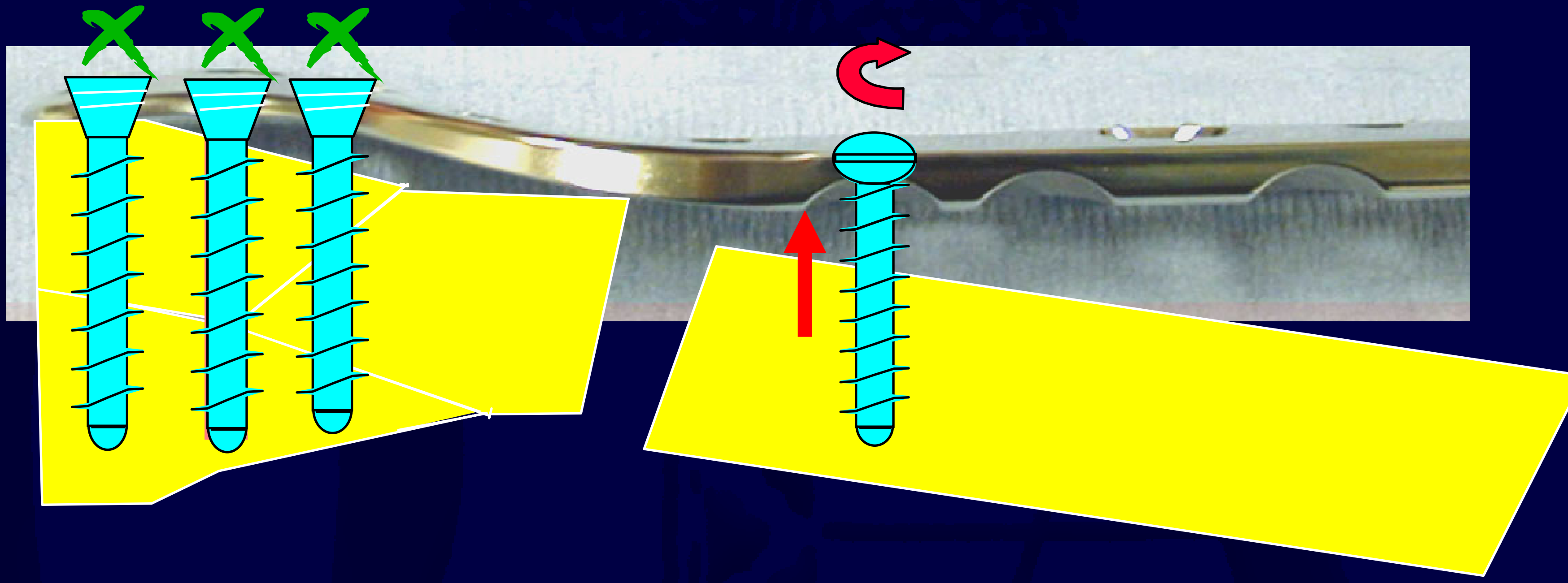
Improper Technique



Metaphyseal Fixation

Reduction of Shaft

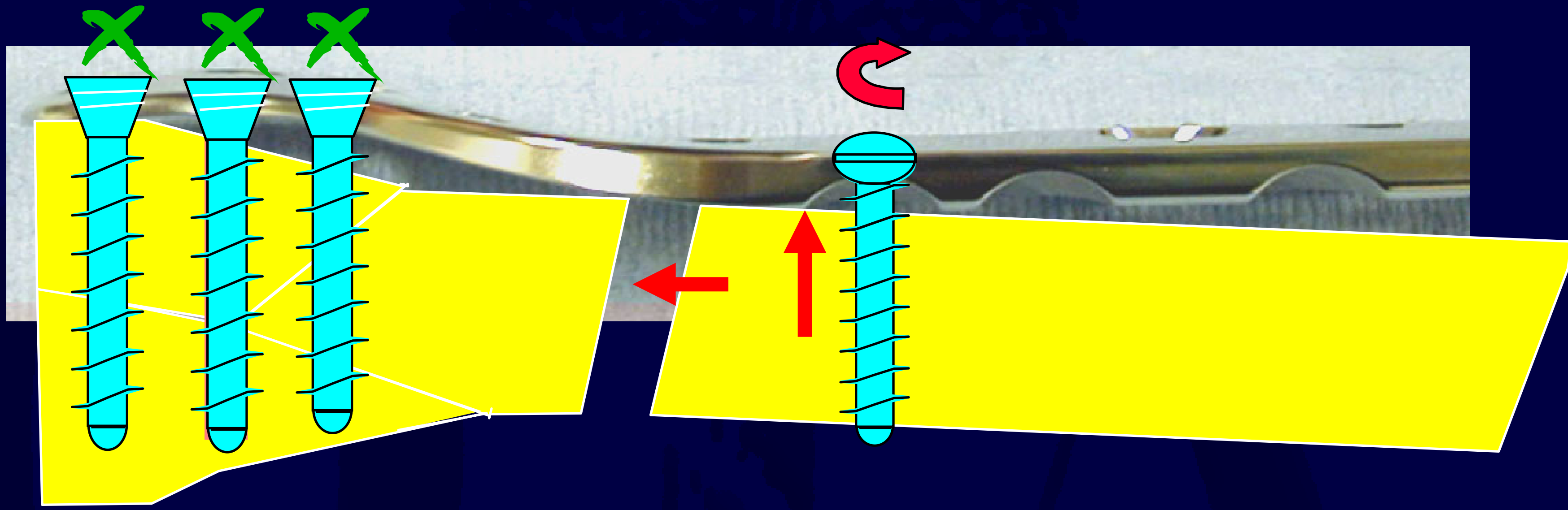
Proper Technique



Metaphyseal Fixation

Reduction of Shaft

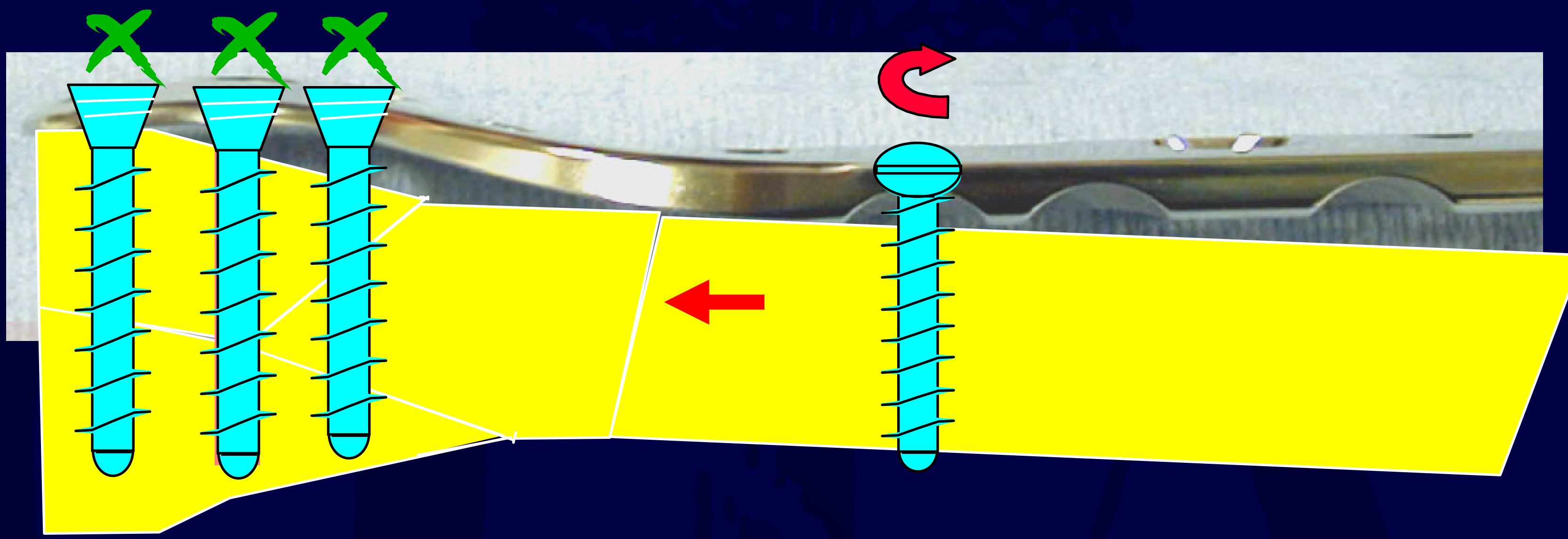
Proper Technique



<u>**Metaphyseal Fixation**</u>

<u>**Reduction of Shaft**</u>

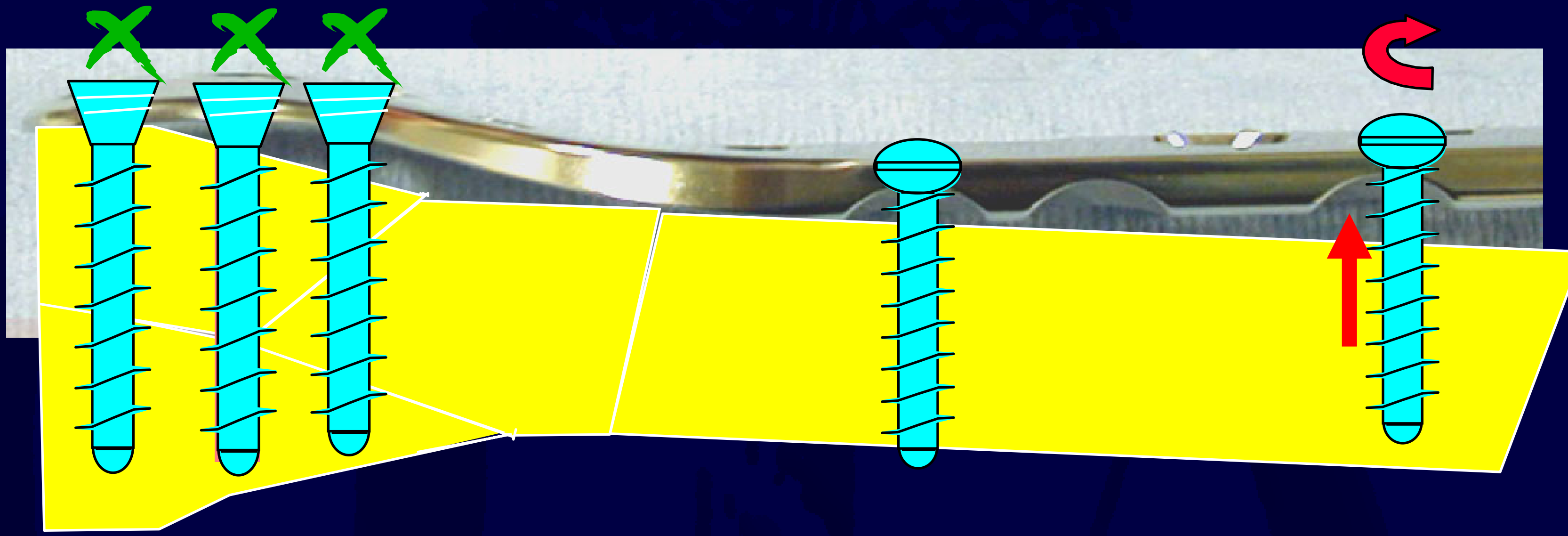
Proper Technique



Metaphyseal Fixation

Reduction of Shaft

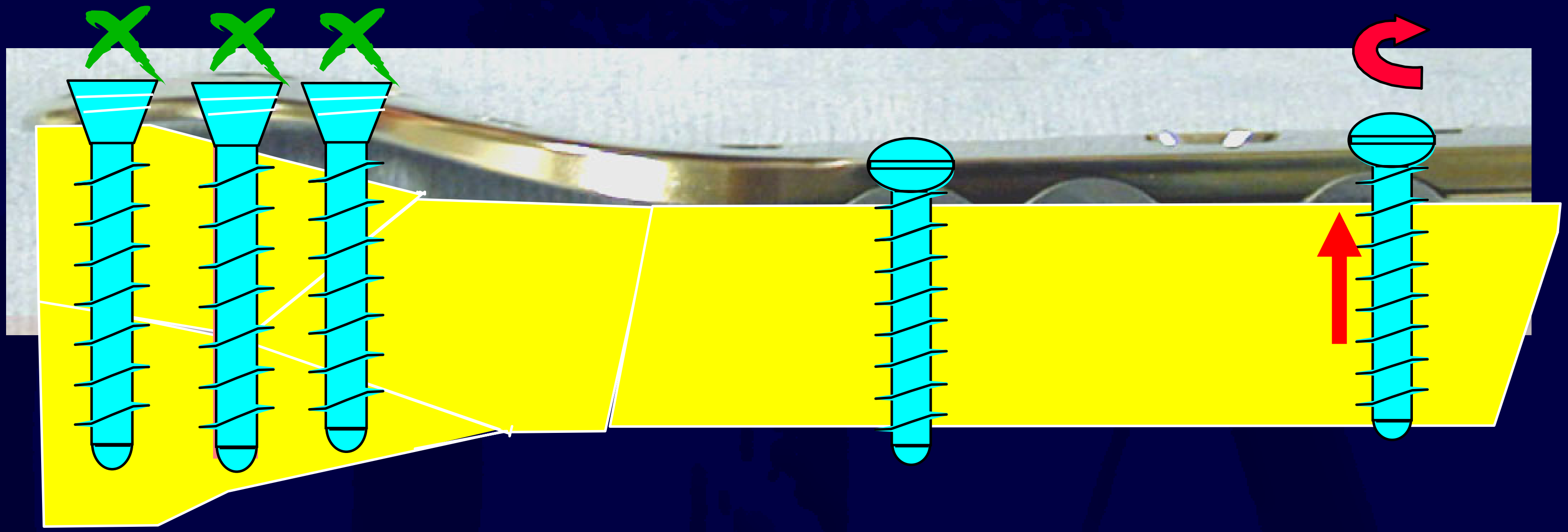
Proper Technique



<u>Metaphyseal Fixation</u>

<u>Reduction of Shaft</u>

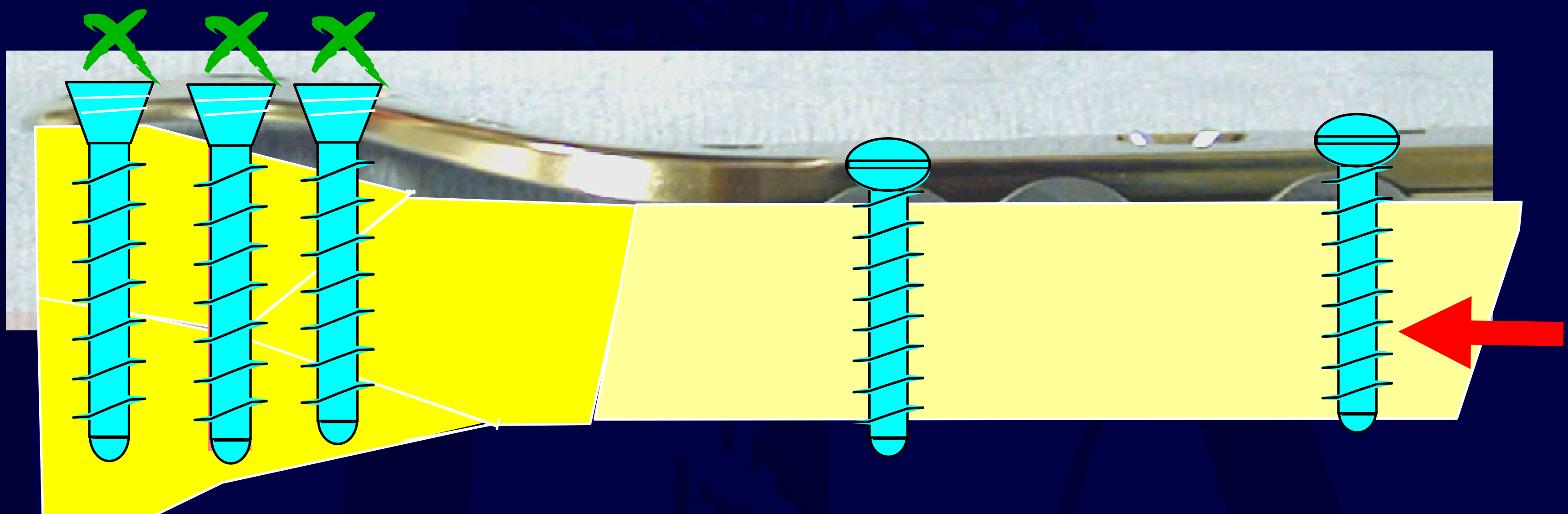
Proper Technique



<u>Metaphyseal Fixation</u>

<u>Reduction of Shaft</u>

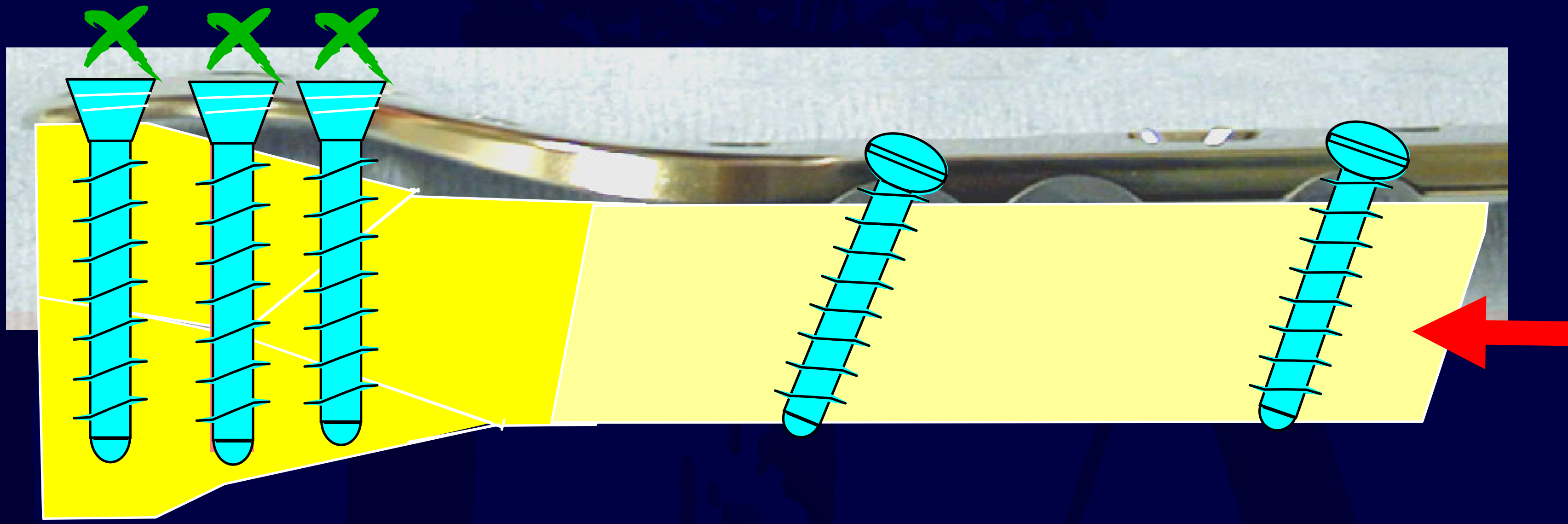
Proper Technique



Metaphyseal Fixation

Reduction of Shaft

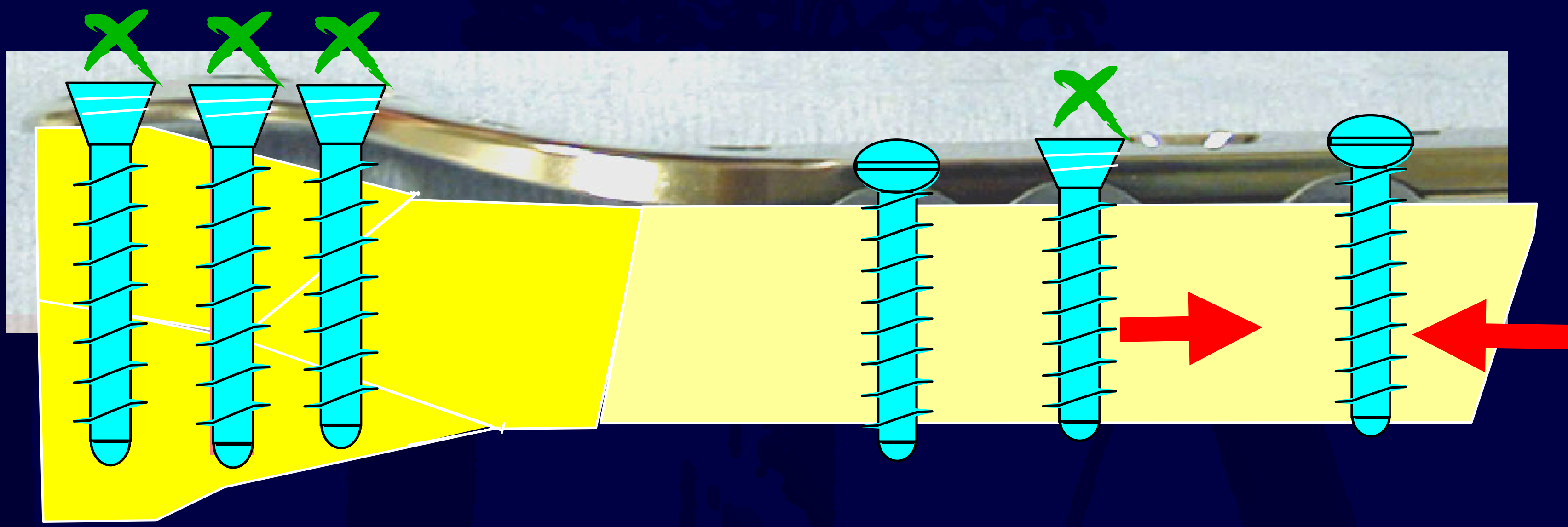
Proper Technique



Metaphyseal Fixation

Axial Loading

Proper Technique

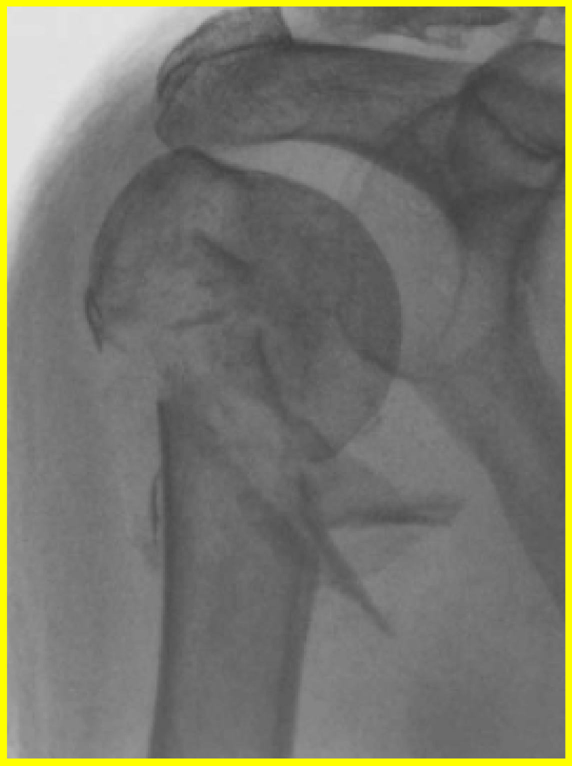


Metaphyseal Fixation

Additional locking screw to reduce toggle

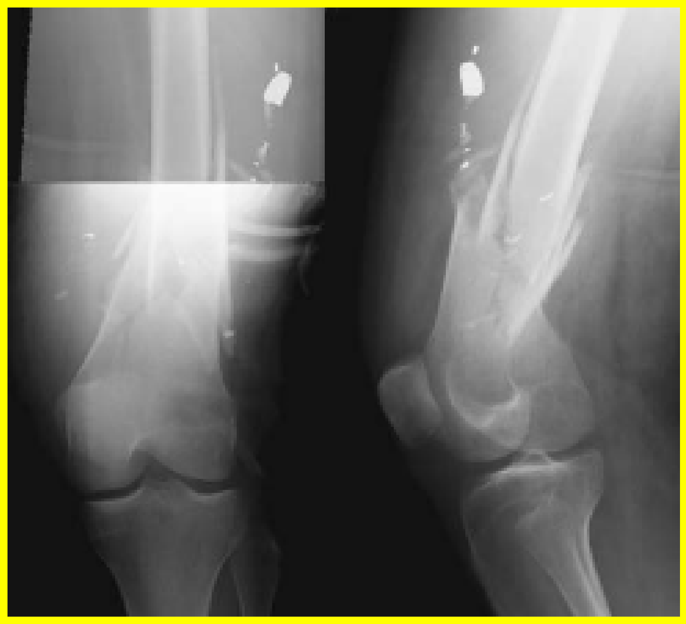
Technique Pearls & Pitfalls

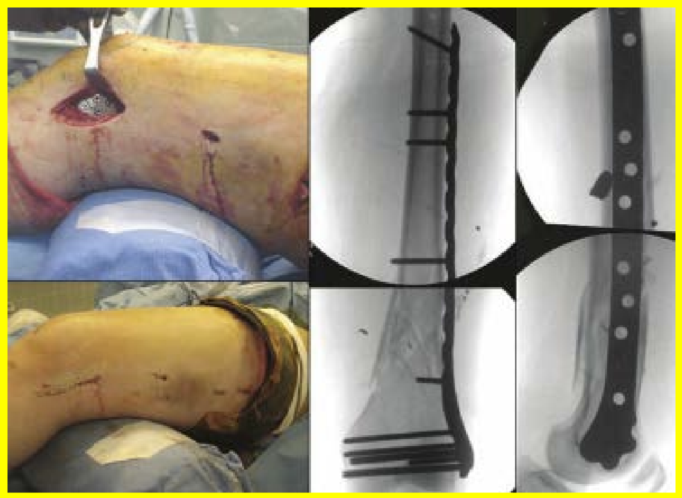
- Epiphysis (Proximal Humerus)
  - Err on shorter side to avoid joint penetration, try to reach within 5mm of subchondral bone
  - In variable angle locking plates, diverge screw directions to avoid collapse



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

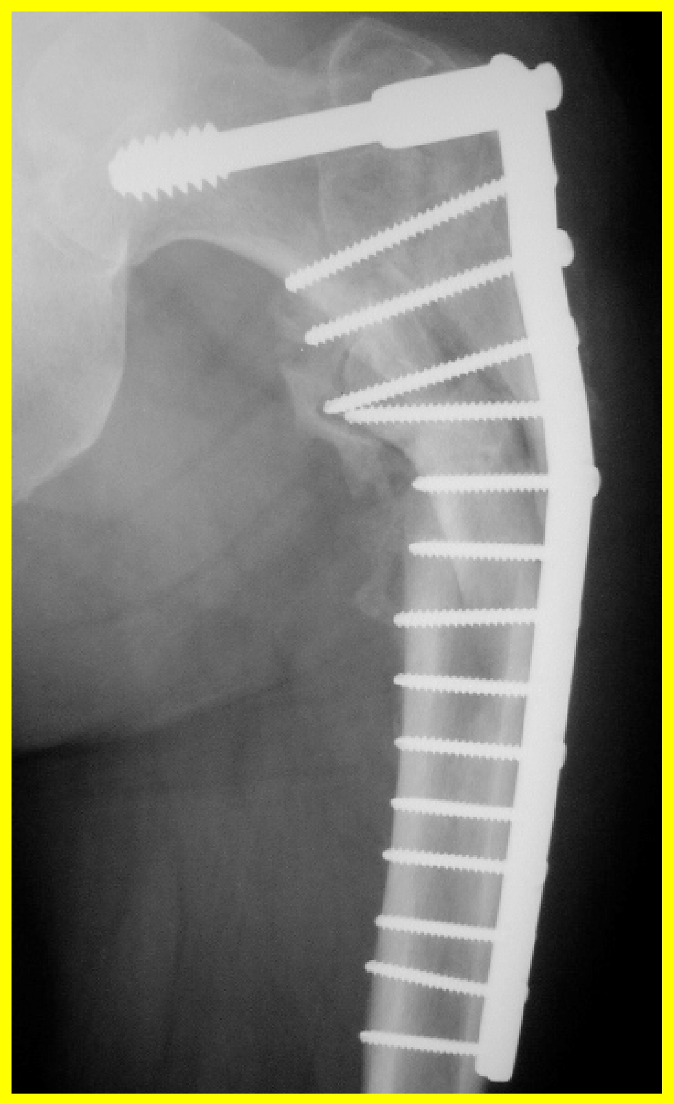
- Metaphysis
  - Beware of using locking plates for Type B (partial articular) fractures
    - » better addressed with buttress plating and compression
  - Locking plate does not substitute for reduction!

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

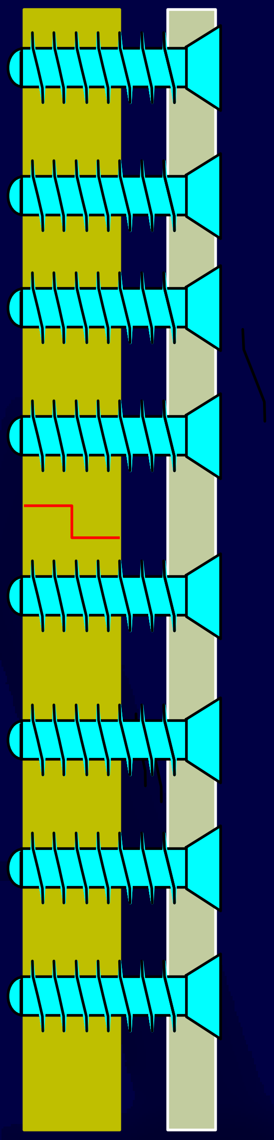


Locking Plate Failures

- 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

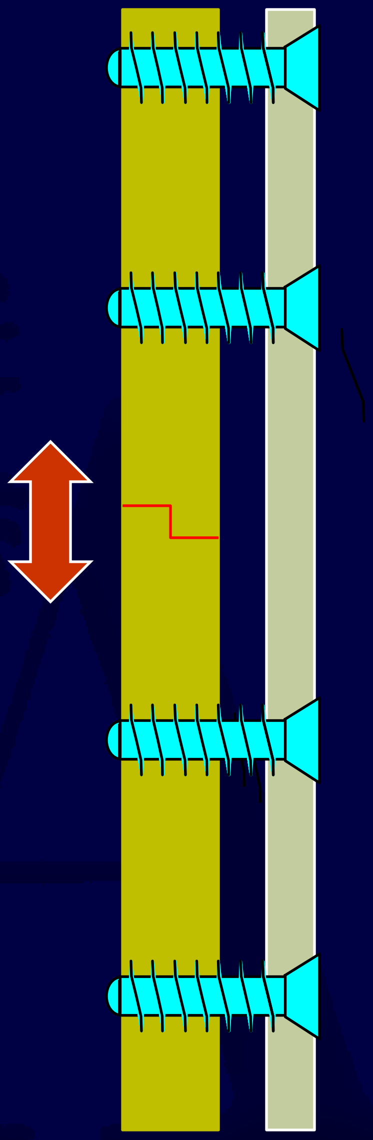
Locking Plate Failures

- Bottlang et al, 2010
  - High stiffness can reduce interfragmentary motion
    - » Can decrease strain too much and lead to nonunion

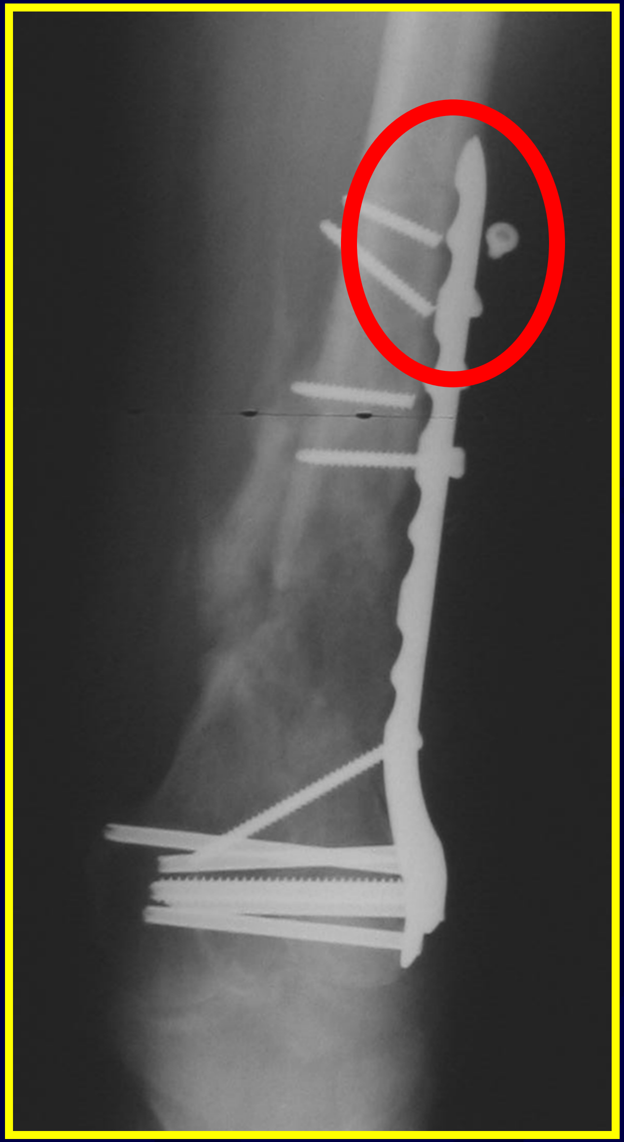


Locking Plate Failures

- 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

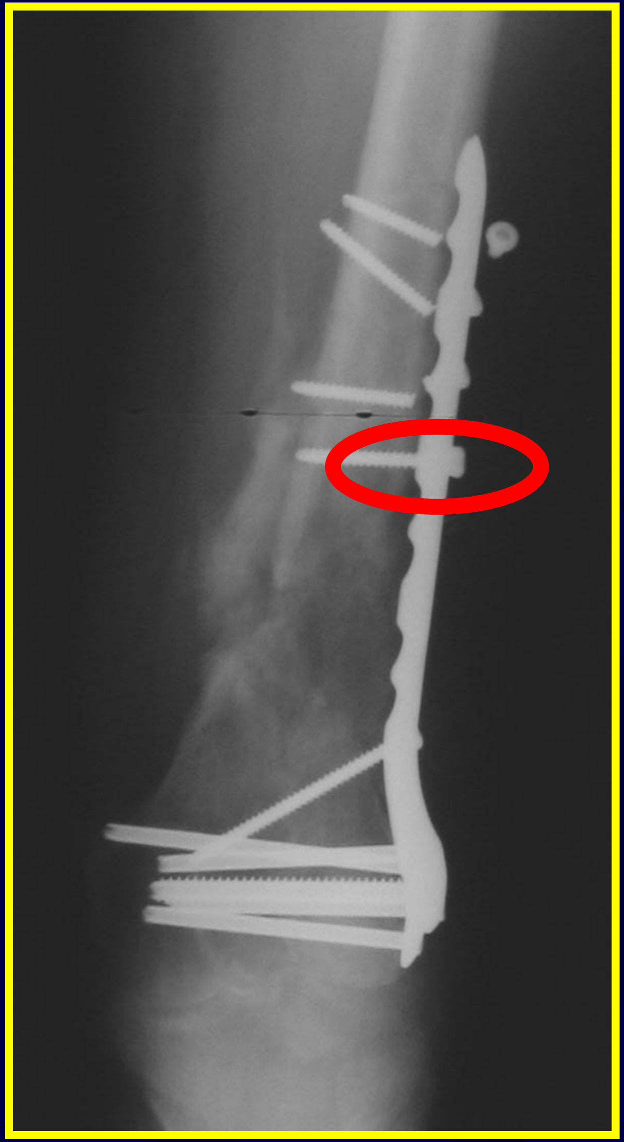


What Really Happens



Junctional Failure

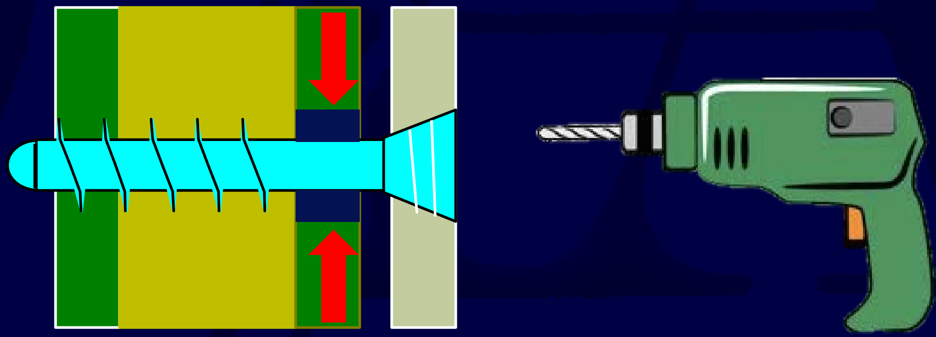
What Really Happens



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

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