Staying Out of Trouble with Limb Lengthening and Reconstruction

Thursday, July 13, 2023

Everline Resort & Spa – Grand Sierra Ballroom

Upon completion of this activity, physicians will be able to:

1. Discuss the basics of bone biology, nutritional factors, environmental factors which contribute to successful bone lengthening and deformity correction;
2. Demonstrate the application of a stable external fixator;
3. Demonstrate the application of a monorail external fixator;
4. Apply a foot frame to a complex deformity; and
5. Demonstrate the proper location of an osteotomy with an intramedullary lengthening device.

<u>Agenda</u>

Lectures will take place in **Grand Sierra B** unless otherwise noted

8:00–8:05 a.m.	Welcome, Disclosures, Introduction – *L. Reid Nichols, MD*
8:06–8:16 a.m.	Periosteum: Worth its Weight in Gold – *Jonathan Schoenecker, MD, PhD*
8:17–8:27 a.m.	Nutrition/Vitamin D – *L. Reid Nichols, MD*
8:28–8:38 a.m.	Basics of Distraction Osteogenesis – *Raymond W. Liu, MD*
8:39–8:49 a.m.	Regenerate Management – *Harold J.P. van Bosse, MD*
8:50–9:00 a.m.	Soft Tissue Management – *Jessica C. Rivera, MD, PhD*
9:01–9:11 a.m.	Management of Complications – *Mani Kahn, MD*
9:12–9:22 a.m.	Creating a Stable Frame/Demo Wire Stability Exercise *Alexander Cherkashin, MD*
9:23–9:33 a.m.	Building a Frame Around Bad Bone – *David Frumberg, MD*
9:35–10:25 a.m.	Hands–on Lab: Creating a Stable Frame – **Grand Sierra C** *Jaclyn F. Hill, MD; David Podeszwa, MD; Mikhail Samchukov, MD*
10:25–10:40 a.m.	Refreshment Break – **Grand Sierra A**
10:41–10:49 a.m.	Most Common Mistakes with Hexapod/Circular Fixators *Jessica C. Rivera, MD, PhD*
10:50–10:58 a.m.	Staying Out of Trouble with Cable Transport – *Stephen M. Quinnan, MD*
11:00–11:55 a.m.	Hands–on Lab: Staying out of Trouble with Cable Transport – **Grand Sierra D** *Paul E. Matuszewski, MD; Stephen M. Quinnan, MD; Jessica C. Rivera, MD*
12:00–12:10 p.m.	Most Common Mistakes with Rail Fixators – *Yasser Elbatrawy, MD*

12:12–12:58 p.m.	Hands–on Lab: Making It Perfect – How to Avoid Missing the Bone *Raymond W. Liu, MD; Yasser Elbatrawy, MD; Harold van Bosse, MD* **Grand Sierra C**
1:00–1:45 p.m.	Lunch/Discussion – **Grand Sierra A**
1:46–1:54 p.m.	Foot Frames in Peds and Adult Foot and Ankle: Indications – *L. Reid Nichols, MD*
1:55–2:02 p.m.	Foot Frames in Peds and Adult Foot and Ankle: How to Avoid the Crash *Scott Nelson, MD*
2:05–3:00 p.m.	Hands–on Lab: Building Butt and Miter Frames – **Grand Sierra D** *Scott Nelson, MD; L. Reid Nichols, MD*
3:01–3:11 p.m.	Most Common Mistakes with Internal Lengthening Nails *Christopher A. Iobst, MD*
3:12–3:22 p.m.	Acute Deformity Correction: Staying Out of Trouble when Using Nails and Plates *S. Robert Rozbruch, MD*
3:25 p.m.	Refreshments in Lab Room – **Grand Sierra C**
3:25–4:15 p.m.	Hands–on Lab: Internal Lengthening Nails – **Grand Sierra C** Choosing Osteotomies Levels Proximal or Distal Planning Deformity Correction with Nail *Jill C. Flanagan, MD; Christopher A. Iobst, MD*
4:16–4:30 p.m.	Discussion, Adjourn in Lab Room

Continuing Medical Education

This activity has been planned and implemented in accordance with the accreditation requirements and policies of the Accreditation Council for Continuing Medical Education (ACCME) through the joint providership of the American Academy of Orthopaedic Surgeons and the Limb Lengthening and Reconstruction Society. The American Academy of Orthopaedic Surgeons is accredited by the ACCME to provide continuing medical education for physicians.

The American Academy of Orthopaedic Surgeons designates this live activity for a maximum of 7 ***AMA PRA Category 1 Credits*™**. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Thank you to the following Partners for the generous grants and in–kind donations.

NuVasive Inc.

Orthofix Inc.

OrthoPediatrics

Smith & Nephew Inc.

DePuy Synthes

Disclosures

Program Committee
Christopher August Iobst, MD, FAAOS (Columbus, OH)
Submitted on: 04/07/2023
Metalogix: Paid consultant
Nuvasive: Paid consultant
Orthofix, Inc.: Paid consultant
Smith & Nephew: Paid consultant
Wishbone, Medical: Paid consultant

Reid Boyce Nichols, MD, FAAOS (Wilmington, DE)
Submitted on: 05/12/2023
AAOS: Board or committee member
Journal of Children's Orthopedics: Editorial or governing board
Journal of Pediatric Orthopedics: Editorial or governing board
Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid presenter or speaker
Orthopediatrics: Paid presenter or speaker
Pediatric Orthopaedic Society of North America: Board or committee member
Ruth Jackson Orthopaedic Society: Board or committee member
Smith & Nephew: Paid presenter or speaker

Stephen Matthew Quinnan, MD, FAAOS
Submitted on: 06/04/2023
Biocomposites: Paid consultant
Bone Support: Paid consultant
DePuy, A Johnson & Johnson Company: Paid consultant
Globus Medical: IP royalties; Paid consultant
Limb Lengthening and Reconstruction Society: Board or committee member
Microbion: Paid consultant
Nuvasive: Paid consultant
Smith & Nephew: Paid consultant
Stryker: Paid consultant

Karen R Syzdek – STAFF (Austin, TX)
(This individual reported nothing to disclose); Submitted on: 06/04/2023

Faculty

Alexander Cherkashin, MD (Dallas, TX)
Submitted on: 04/04/2023
Orthofix, Inc.: IP royalties; Paid consultant

Yasser Ali Elbatrawy Sr, MD, PhD
(This individual reported nothing to disclose); Submitted on: 04/17/2022

Jill C Flanagan, MD, FAAOS (Atlanta, GA)
Submitted on: 06/05/2023
AAOS: Board or committee member
Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid consultant
Orthofix, Inc.: Paid consultant

David B. Frumberg, MD, FAAOS (New Haven, CT)
Submitted on: 05/09/2023
American Academy for Cerebral Palsy and Developmental Medicine: Board or committee member
Limb Lengthening and Reconstruction Society: Board or committee member
Orthofix, Inc.: Paid consultant
Orthopediatrics: Paid consultant
Ultragenyx: Paid consultant

Jaclyn Faye Hill, MD, FAAOS (Houston, TX)
Submitted on: 04/07/2023
Limb Lengthening and Reconstruction Society: Board or committee member
Nuvasive: Paid presenter or speaker
Orthopediatrics: Paid presenter or speaker
Pediatric Orthopaedic Society of North America: Board or committee member
Stryker: Paid consultant

Christopher August Iobst, MD, FAAOS (Columbus, OH)
Submitted on: 04/07/2023
Metalogix: Paid consultant
Nuvasive: Paid consultant
Orthofix, Inc.: Paid consultant
Smith & Nephew: Paid consultant
Wishbone, Medical: Paid consultant

Mani D Kahn, MD, FAAOS
Submitted on: 06/04/2023
GE Healthcare: Paid consultant
Synthes: Paid consultant

Raymond W Liu, MD, FAAOS (Cleveland, OH)
Submitted on: 04/08/2023
AAOS: Board or committee member
Journal of Pediatric Orthopedics: Editorial or governing board; Publishing royalties, financial or material support
Limb Lengthening and Reconstruction Society (LLRS): Board or committee member
Orthopediatrics - Royalties paid to my university: IP royalties
Pediatric Orthopaedic Society of North America: Board or committee member

Paul Edward Matuszewski, MD, FAAOS (Lexington, KY)
Submitted on: 04/06/2023
AAOS: Board or committee member
BONESUPPORT: Paid consultant; Research support
Limb Lengthening and Reconstruction Society: Board or committee member
Orthopaedic Trauma Association: Board or committee member
Smith & Nephew: Paid consultant; Research support
Stryker: Paid consultant; Research support

Scott C Nelson, MD, FAAOS (Loma Linda, CA)
Submitted on: 01/06/2023
DePuy, A Johnson & Johnson Company: Paid consultant
Orthofix, Inc.: Paid consultant

David A Podeszwa, MD, FAAOS (Dallas, TX)
Submitted on: 04/04/2023
Elsevier: Publishing royalties, financial or material support
Limb Lengthening and Reconstruction Society: Board or committee member
Orthofix, Inc.: Paid consultant

Stephen Matthew Quinnan, MD, FAAOS
Submitted on: 06/04/2023
Biocomposites: Paid consultant
Bone Support: Paid consultant
DePuy, A Johnson & Johnson Company: Paid consultant
Globus Medical: IP royalties; Paid consultant
Limb Lengthening and Reconstruction Society: Board or committee member
Microbion: Paid consultant
Nuvasive: Paid consultant
Smith & Nephew: Paid consultant
Stryker: Paid consultant

Jessica C Rivera, MD, PhD, FAAOS
Submitted on: 04/14/2023
AAOS: Board or committee member
AAOS Now: Editorial or governing board
Bioventus: Paid consultant
Limb Lengthening and Reconstruction Society: Board or committee member
Orthopaedic Research Society: Board or committee member

S Robert Rozbruch, MD, FAAOS (New York, NY)
Submitted on: 04/01/2023
Informa: Publishing royalties, financial or material support
Johnson & Johnson: Paid consultant; Paid presenter or speaker
Nuvasive: IP royalties; Paid consultant; Paid presenter or speaker
Osteosys: Stock or stock Options
Springer: Publishing royalties, financial or material support

Mikhail Samchukov, MD (Dallas, TX)
Submitted on: 04/02/2023
Orthofix, Inc.: IP royalties; Paid consultant

Jonathan G Schoenecker, MD, FAAOS
Submitted on: 05/24/2023
Ionis Pharmaceuticals: Research support
Orthopediatrics: Research support
Pediatric Orthopaedic Society of North America: Board or committee member
PXE International: Research support
Rock Lake: Editorial or governing board

Harold J P Van Bosse, MD, FAAOS
Submitted on: 10/07/2022
AAOS: Board or committee member
Limb Lengthening and Reconstruction Society: Board or committee member
Pediatric Orthopaedic Society of North America: Board or committee member
Scoliosis Research Society: Board or committee member

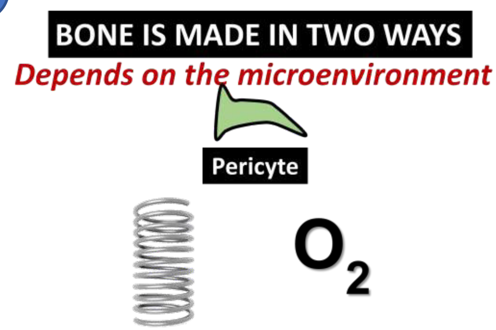
PERIOSTEUM

Worth its Weight in Gold – Jon Schoenecker MD PhD

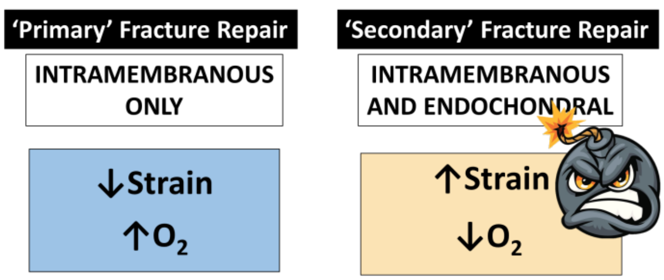
1

A Fracture or Osteotomy Create 2 Problems

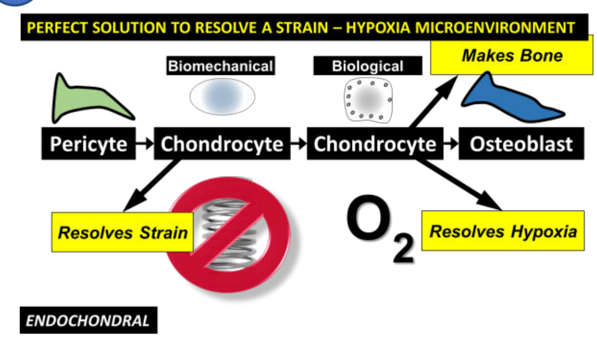
2



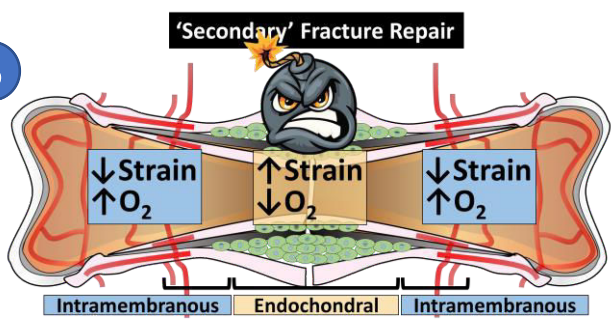
3



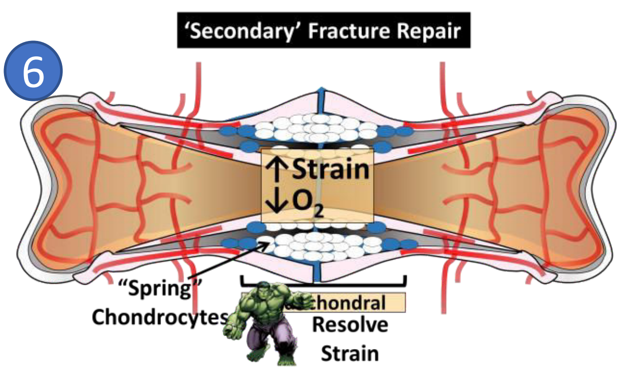
4



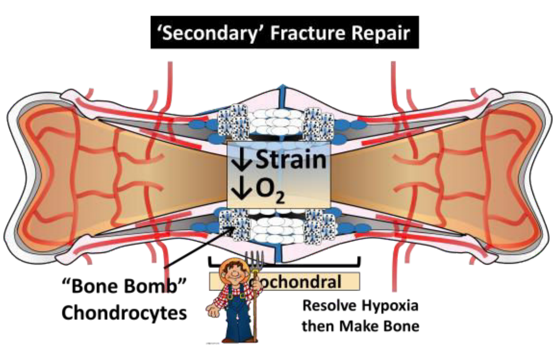
5



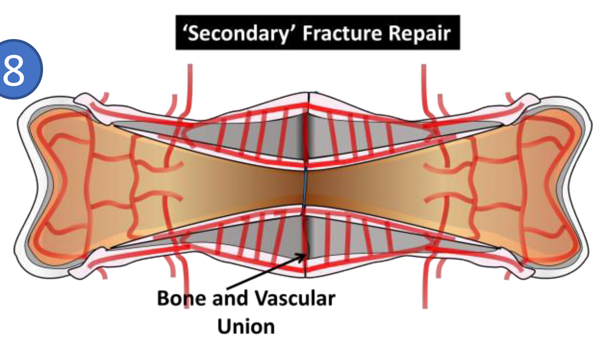
6



7



8



Clin Rev Bone Miner Metab. 2018;16(4):142-158. PMID: 30930699

Basics of Distraction Osteogenesis

Raymond W. Liu, M.D.

Distraction Osteogenesis: gradual mechanical distraction of a low energy osteotomy spontaneously produces new bone

Ideal conditions for intramembranous ossification

1. Stable fixation (malunion and nonunion with unstable)
2. Low energy osteotomy ideally metaphyseal (worse results with diaphyseal)
3. Latency 5-7 days (2-3 week latency risks premature consolidation)
4. Distraction up to 1mm/day 2-4x per day (worse bone formation with daily movement, less blood flow and worse mineralization with 2mm/day)
5. Minimal initial bone gap (large gap of 1cm or more leads to islands of cartilage)
6. Limb use: weightbearing in lower extremities, and functional use of upper extremities

Histologic and radiologic findings in distraction osteogenesis

1. Central radiolucent fibrous interzone
    - A. Histologically parallel collagen bundles
    - B. Very little blood flow crosses the interzone
2. Radiodense bone visualization
    - A. Lags the histiologic formation of microcolumns by about a week
    - B. Generally seen starting at 3 weeks
    - C. Radiolucent fibrous interzone persists with distraction
3. Increase in blood flow
    - A. Several factors above contralateral limb
    - B. Matches that seen in normal fracture healing
    - C. Likely the limiting factor when increased distraction rates are attempted

Regenerate Management and Stimulation Techniques

Or

C'mon, c'mon, heal up already!

Limb Lengthening and Reconstruction Society/ASAMI-NA

2023 Pre-course: Staying Out of Trouble in Limb Lengthening and Reconstruction

Bone formation

- Endochondral ossification
  - Cartilaginous precursor serves as model
    - Primary ossification center in mid diaphysis
    - Secondary centers in the epiphysis
    - Physeal plate develops inbetween two ossification centers
  - Initial bone development
    - Chondrocytes produce unossified cartilage
    - Chondrocytes secrete alkaline phosphatase to stimulate mineralization
    - Osteoblasts lay down bone on the calcified cartilaginous framework
    - Osteoclasts absorb the calcified cartilage
  - This is also the primary form of bone formation in typical fracture healing
- Intramembranous Ossification
  - Membranous sheets of mesenchymal tissue
    - Osteoblasts create peripheral lining (periosteum)
      - New bone develops underneath periosteum
    - No cartilaginous model
  - Growth occurs appositionally
    - Same process leads to increasing long bone girth
  - This is also the primary form of bone formation during distraction osteogenesis

Bone formation in distraction osteogenesis

- Pro-inflammatory cytokines
  - Interleukin (IL)-1, IL-6, tumor necrosis factor (TNF)-α
  - Stimulate intramembranous ossification
  - Leads to further differentiation of cells within osteoblastic lineage
- Members of transforming growth factor (TGF)-ß superfamily
  - Regulate cell differentiation
  - Stimulate osteoprogenitor cells
  - Inhibit osteoclasts
  - Include bone morphogenic proteins (BMP)-2 and BMP-4
- Angiogenic factors
  - Vascular endothelial growth factor (VEGF)
    - Stimulates new vessel formation

- Stem cells
    - Mesenchymal stem cells (MSC)
    - Skeletal stem and progenitor cells (SSPC)
    - Undifferentiated cells
        - Self-renewal of vital cell lineages
        - Differentiate into committed cell lines
    - These processes occur within “stem cell niches”
- Stem cell niche
    - Described by Ohlstein in 2004
        - “A specific location in a tissue where stem cells reside for an indefinite period of time and produce progeny while self-renewing”
        - Undifferentiated cells
    - Stimulus to behavior change (more rapid differentiation)
        - Mechanical perturbations
        - Altered extracellular matrix (ECM) stiffness
        - Altered cell stiffness
    - External mechanical forces converted into intracellular signals
        - Causes alterations in extracellular matrix
        - These are modulated by cell surface matrix proteins, principally integrins

Risk factors for poor bone formation during distraction osteogenesis

- Host related factors
    - Non-steriodal anti-inflammatory drugs (NSAIDs)
    - Congenital bone conditions
    - Systemic illnesses
        - Hypophosphatemic rickets
        - Diabetes
        - Mal nutrition
    - Local factors
        - Scarring
        - Radiation treatment
        - Infection
    - Iatrogenic factors
        - Compromised soft tissue coverage
        - Suboptimal osteotomy technique
            - Oscillating saw thermal necrosis
        - Latency gap >1cm
        - Unstable fixation (frame)
        - Short latency (<5 days)
        - Rapid distraction (>2mm/day)

Regenerate stimulation techniques

- Mechanical modulation
    - Distraction rate
        - Fractionate distractions over the course of the day
        - Mizuta 2004
            - Study on high tibial osteotomies, 1mm lengthening per day
            - Studied fractionated distraction, either 4 or 8 intervals
            - Greater fractionation (8 times per day)
                - Increased bone density
                - Shorter frame time
        - Motorized distractors – nearly continuous distraction
            - Ilizarov 1989 – studied dogs, found faster healing
            - Korzinek 1990 – dogs, faster healing
            - Welch 1998 – studied goats, no difference in healing rates
            - Wiltfang 2001 – studied pigs, faster healing
            - Bright 2014 – his own patients for tibial lengthenings, no difference
    - Accordioning technique
        - Definition – repeated compression and distraction of healing bone
        - Used for both fractures and distraction osteogenesis
        - Many different strategies, but only a few studies
        - Makhdom 2015
            - 4 patients with absent/delayed callus formation in distraction gap
                - 0.25mm distraction in the morning
                - 0.25mm compression in the afternoon
                - 0.25mm distraction in the evening
            - Started the routine about 4.5 weeks after surgery, after the planned distraction osteogenesis for lengthening
            - Protocol sped healing in 3 of 4 patients with delayed/absent callus
        - Other strategies once final distraction reached
            - Compression followed by distraction
            - Cyclic compression-distraction
        - Why is accordioning hypothesized to work?
            - Compression – stimulates fibrogenesis, osteogenesis, intramembranous bone formation
            - Distraction – stimulates chondrogenesis and endochondral bone formation
        - My anecdotal strategy
            - Compress 1mm per day x 5 days
            - Distract 1mm per day x 5 days
            - Repeat until frame no longer compressible

- Dynamization
  - Used in fracture healing
    - Unstimulated callus with minimal loading does not heal
    - Dilatational strain (volumetric strain) - essentially axial force across healing bone
      - Causing a change in volume by applying an external force
      - Increase or decrease in volume per unit volume
      - Promotes bone healing
    - Deviatoric strain (distortional strains such as shear or torsion)
      - Retard bone formation
  - Weight bearing in frame
  - Destabilization of frame
    - Allow linear (axial) micromotion
    - Do not allow torsional or bending motion
    - Mostly anecdotal evidence

- Non-pharmacological treatments
  - Low intensity pulsed ultrasound (LIPUS)
    - High frequency mechanical waves induce regeneration of biologic tissues
    - Mechanism unclear
      - Possible microbubbles and microjets cause mechanical stimulation
    - El-Mowafi and Mohsen 2005
      - Applied LIPUS at the start of the consolidation phase
      - Healing index 30 days/cm in group with LIPUS vs 48 days/cm without
    - Raza 2016
      - Meta-analysis of 4 randomized controlled trials of LIPUS for tibial distraction osteogenesis
      - Study "suggests" LIPUS may provide reduction in overall treatment time
    - Current FDA approval limited to
      - Established non-unions
      - To speed healing of fresh distal radius or tibia fractures in adults
      - Pressure to change FDA designation from Class III to Class II medical device
        - Class II - devices for which special controls, combined with general controls, are necessary to provide reasonable assurance of safety and effectiveness.
        - Class III - "usually sustain or support life, are implanted or present a potential unreasonable risk of illness or injury"
  - Pulsed electromagnetic fields (PEMF)
    - Low field magnetic stimulation
      - Stimulates signal transduction through cell membrane via adenosine receptors
        - Increases new bone formation
        - Inhibits osteoclast differentiation

            - Causes both osteoinductive and angiogenic effects
                - Stimulates growth factors and cytokines
                - TGF-ß gene family, including BMP
            - Promotes extracellular matrix synthesis
        - Luna Gonzalez 2005
            - Bilateral humeral lengthenings, one with and one without
            - Faster callus formation and greater bone density on side with PEMF
        - Current FDA approval limited to
            - Established non-unions
            - To speed healing of lumbar and cervical spine fusions
            - Pressure to change FDA designation from Class III to Class II medical device
    - Meta-analysis of LIPUS and PEMF
        - Jauregui 2016
        - 7 studies included
            - 63 limbs with LIPUS
            - 40 limbs with PEMF
            - Most used during the distraction phase
            - Mean distraction of treatment and controls was ~8cm
            - Healing index 33.7 days/cm compared to 45.4 days/cm in control group
        - Did not compare/contrast modalities
- Biologic Stimulation
    - Bone marrow cells and platelet rich plasma (BMC-PRP)
        - Kitoh 2004, 2007
        - Harvested 40ml of bone marrow aspirate
            - Osteoblast progenitor cells cultured over 3 weeks
        - Centrifuged 200ml venous blood
            - 10ml of concentrated platelets
            - Used within 48 hours
        - Combined and injected into distraction osteogenesis site
        - 2 patients with achondroplasia (self as control)
            - 10cm lengthening vs. 8.7cm for controls
            - Healing index 22 days/cm vs. 38 days/cm for controls
    - Bone marrow cell concentrate and platelet rich plasma (BMAC-PRP)
        - Lee 2014
        - Harvest 50ml of bone marrow aspirate
            - Centrifuge for 15 minutes (separate layers: BMAC and PRP layers)
        - BMAC 3ml and PRP 3ml aspirated from centrifuge tube
        - Inject into osteotomy site at time of surgery
        - 22 patients bilateral (self as control) tibial lengthenings
            - 58mm lengthening vs. 66mm for control side
            - Healing index 1.14 month/cm vs. 1.47 month/cm for control side

- Bisphosphonates
  - Anticatabolic agents (poison or inhibit osteoclasts)
  - Kiely 2007
    - 7 patients undergoing limb lengthening with poor regenerate, average length 4.8cm
    - Parenteral zoledronic acid or pamindronate at mean 170 days after index surgery
    - 6 of 7 patients "responded"
    - Healing index 80 days/cm
  - No other literature
- Parathyroid hormone (PTH)
  - Stimulation of osteoblastic activity over osteoclastic activity
  - Teriparatide
    - Active fragment of human PTH
    - Once daily subcutaneous injection
    - Good results in osteopenic fracture healing
  - Wagner 2019
    - 16 patients, tibial bone transport
    - 8 weeks of Teriparatide injections
      - Early vs late treatment group cross over study design
    - Bone mineral density (BMD) increased 0.33gm/cm^2 during 8 weeks treatment, vs. 0.14gm/cm^2 during 8 weeks off treatment
  - Teriparatide has an FDA black box warning, caused osteosarcoma in rats
- BMP-2
  - Part of the TGF-ß superfamily of genes
  - Stimulates undifferentiated mesenchymal stem cells to proliferate and differentiate down the osteoblastic pathway
  - Promising early results, but only in animal studies
- Vitamin E
  - Acts as an antioxidant
  - Bone formation creates oxygen derived free radicals
    - Free radicals promote osteoclast production
  - Vitamin E theoretically dampens antioxidant properties
  - Akcay 2019
    - Dog study, mandibular lengthening
    - 7 days daily vitamin E injections after surgery
    - Statistically higher BMD and bone mineral content in the experimental group

- Biometals
  - Lengthening over intramedullary rods/wires
    - Popkov 2019
      - Hydroxyappetite (HA) coated wire
      - Dog study, tibial lengthening at 3mm/day for 10 days
      - Consolidation 14 days in HA wire group, 34 days in control

        - Magnesium
            - Cofactor for 300+ enzymes
            - Magnesium ions are generated during magnesium metal degradation, stimulates osteogenic differentiation of stem cells
            - Only in vitro studies thus far

Summary: Stimulation of bone regenerates

- Mechanical methods
    - Best known, few unwanted side effects
- LIPUS and PEMF
    - Research lacking, but appear to be useful
    - Off-label usage
- Bone marrow cells/platelet rich plasma
    - Promising technology
    - BMAC easier than BMC culture
- Pharmacologics
    - Vitamin E – relatively easy and low risk
    - Bisphosphonates – for severe cases
    - Parathyroid hormone – effective but with risks
- Future - Biometals

Complications in Limb Lengthening and Reconstruction Surgery - Mani Kahn

Limb reconstruction has a significant patient burden with spectrum of expected and unexpected complications

Paley classification – differentiate between “distraction” or “fixation” period

- Problem – transient, no return to OR
- Obstacle – transient, requires return to OR
- Complication – Long lasting

Intraoperative

Corticotomy propagation

*Pro-tip - place peri-corticotomy fixation pins after corticotomy

Acute neurovascular injuries

*Pro-tip - For patients with prior trauma to the area consider CTA to localize vascular structures

Early

Compartment syndrome

*Pro-tip - consider prophylactic fasciotomy or intra-compartmental monitoring

Wound complications

*Pro-tip - consider soft tissues on concave side of deformity as a structure at risk

Nerve traction injury

*Pro-tip - Frequent followup during late distraction phase

Pin site infections

*Pro-tip - Train patients to identify and manage these before they progress

Premature consolidation

*Pro-tip - frequent early radiographic monitoring and distraction rate modulation

Late

Nonunion

Persistent malunion

Stiffness and contracture

*Pro-tip - Prophylactic tendon release/lengthening, judicious use of bracing

Psychosocial dysfunction

*Pro-tip - engage family and support network prior to surgery. Judicious use of social work and psychiatric services. Frequent screening for depression during treatment.

References

Checketts R, MacEachem A, Otterbum M: Pin tract infection and the principles of pin site care, in DeBastiani A, Graham Apley A, Goldberg D, eds: Orthofix External Fixation in Trauma and Orthopaedics. Berlin, Springer, 2000, pp 97-103

Degen N, Randeu T, Wolf F, Fürmetz J, Euler E, Böcker W, Thaller PH. Prophylaktische Fasziotomie bei Tibia-Osteotomien: funktionelle Ergebnisse [Prophylactic fasciotomy in tibial osteotomies: functional results]. Unfallchirurgie (Heidelb). 2022 Sep;125(9):716-722. German.

Ferner F, Lutter C, Schubert I, Schenke M, Strecker W, Dickschas J. Perioperative complications in osteotomies around the knee: a study in 858 cases. Arch Orthop Trauma Surg. 2022 May;142(5):769-775.

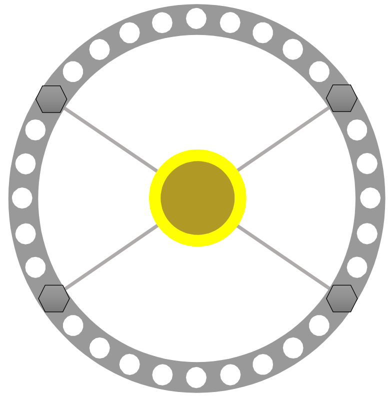
Green, Stuart A. M.D. Complications of External Skeletal Fixation, Clinical Orthopaedics and Related Research: November 1983 - Volume 180 - Issue - p 109-116

McQueen MM, Duckworth AD, Aitken SA, Court-Brown CM. The estimated sensitivity and specificity of compartment pressure monitoring for acute compartment syndrome. *J Bone Joint Surg Am*. 2013;95(8):673-677. doi:10.2106/JBJS.K.01731

Nogueira MP, Paley D, Bhave A, Herbert A, Nocente C, Herzenberg JE. Nerve lesions associated with limb-lengthening. J Bone Joint Surg Am. 2003 Aug;85(8):1502-10.
Oostenbroek HJ, Brand R, van Roermund PM. Lower limb deformity due to failed trauma treatment corrected with the Ilizarov technique: factors affecting the complication rate in 52 patients. Acta Orthop. 2009 Aug;80(4):435-9

Paley D. Problems, obstacles, and complications of limb lengthening by the Ilizarov technique. Clin Orthop Relat Res. 1990 Jan;(250):81-104.

SCOTTISH RITE HOSPITAL FOR CHILDREN



Essentials of Frame Biomechanics

DO's and DON'Ts in Circular Fixation

Alexander Cherkashin, MD

I choose a lazy person to do a hard job. Because a lazy person will find an easy way to do it.

Bill Gates

TrueLok designers

Lazy surgeon!

TrueLok Birthday: 1993

30th TRUELOK™ ANNIVERSARY 1993 - 2023

TrueLok Family

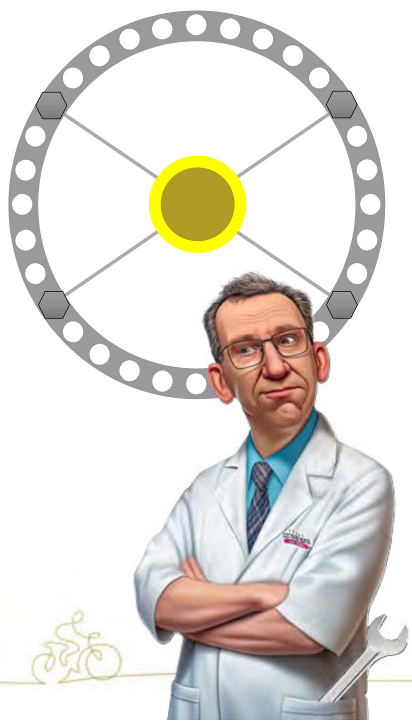
TrueLok™ Plus

TL-HEX

TL-HEX Trauma

TL-EVO

TEXAS SCOTTISH RITE HOSPITAL FOR CHILDREN



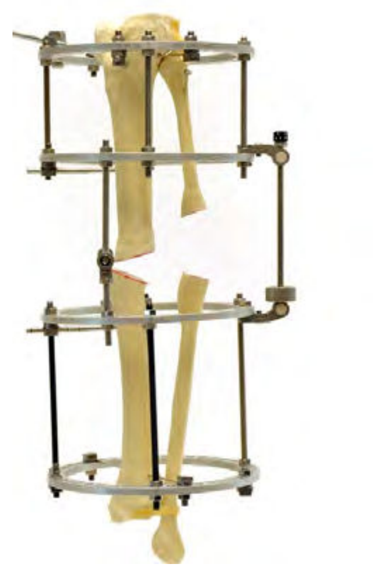
Essentials of Frame Biomechanics

DO's and DON'Ts in Circular Fixation

Alexander Cherkashin, MD

External fixation goal: control bone fragments

- Hold bone fragments
- Move fragments
- Provide optimal healing conditions



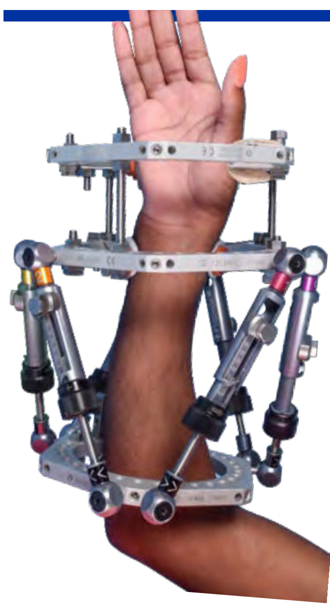
Fixation Blocks

SCOTTISH RITE FOR CHILDREN

Fixation blocks

- Fixation blocks increase frame stability
- Fixation block can span a joint to ad to small fragment fixation
- When tensioned wires are used double-ring block decreases ring deformation

SCOTTISH RITE FOR CHILDREN



Fixation blocks

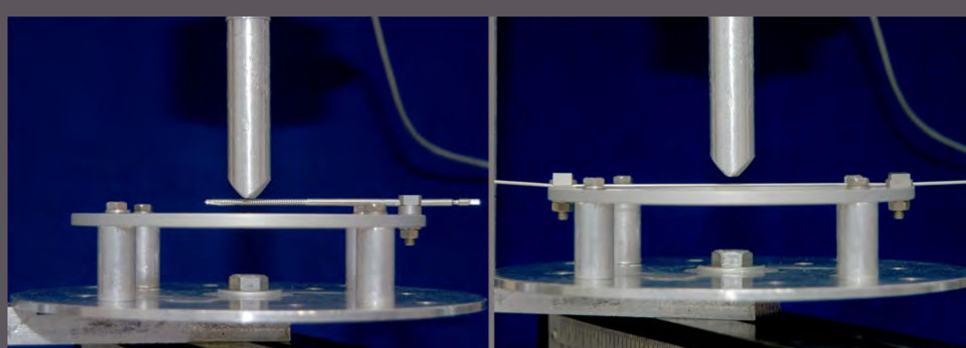
- Fixation blocks increase frame stability
- Fixation block can span a joint to ad to small fragment fixation
- When tensioned wires are used double-ring block decreases ring deformation

SCOTTISH RITE FOR CHILDREN

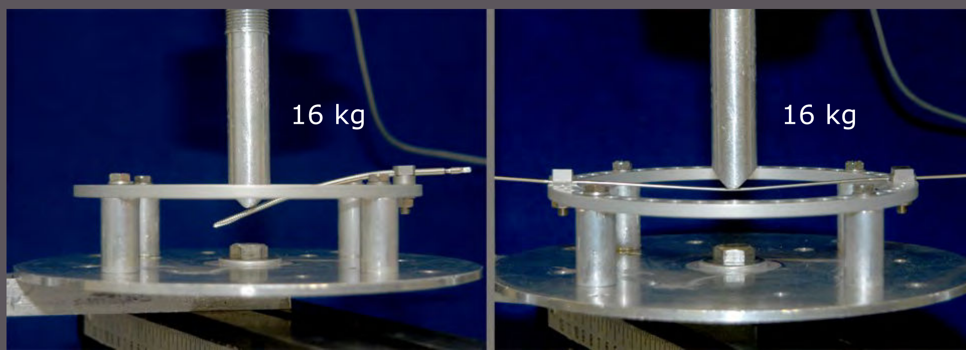
Applied forces

- Weight bearing
- Muscle tension
- Joint motion
- Compression/distraction

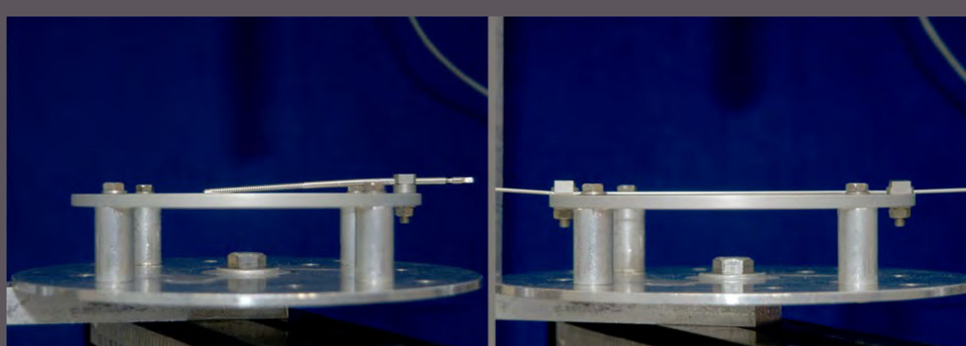
Wires vs. Pins



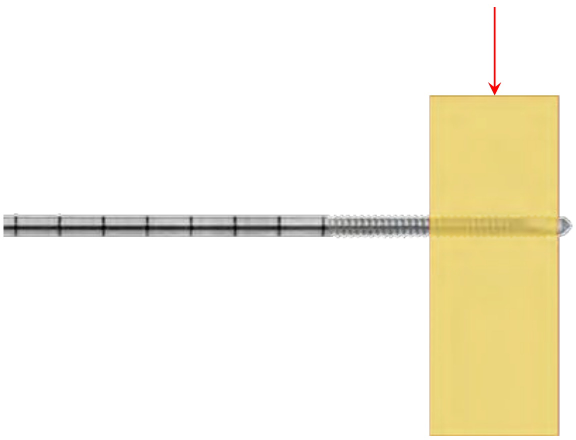
Wires vs. Pins



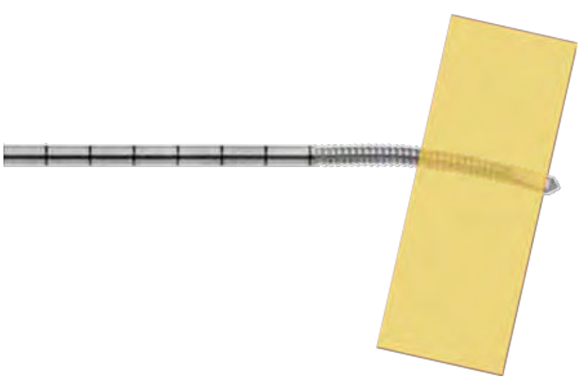
Wires vs. Pins



Pins under load

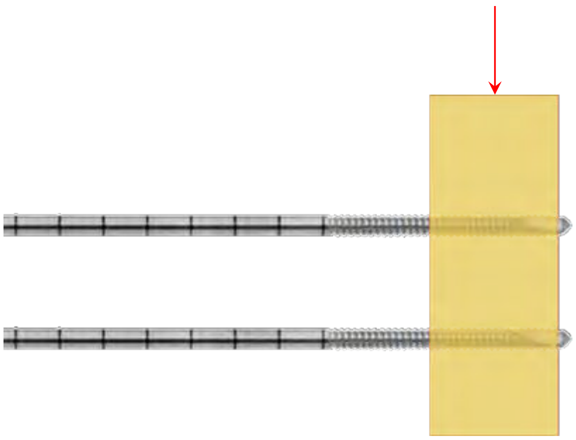


Pins under load



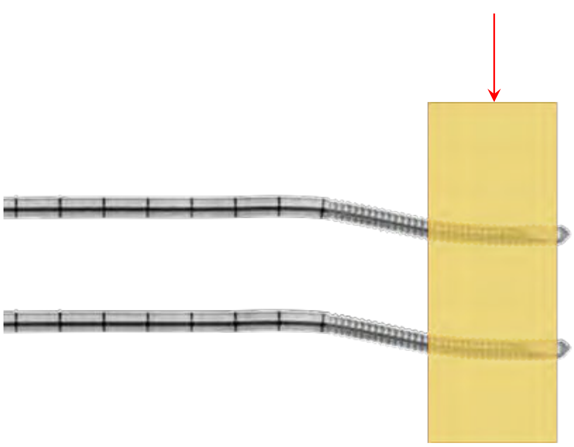
Cantilever bending

Pins under load



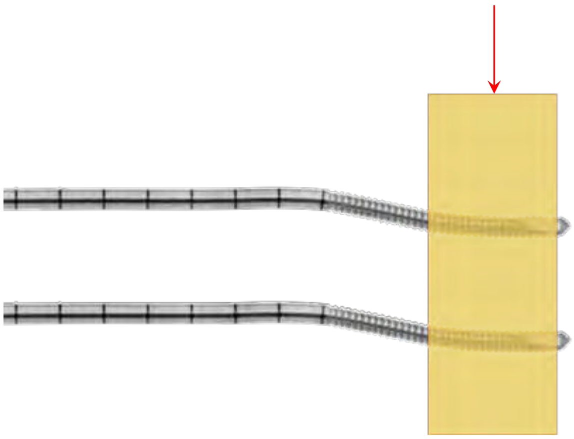
SCOTTISH RITE FOR CHILDREN

Pins under load



SCOTTISH RITE FOR CHILDREN

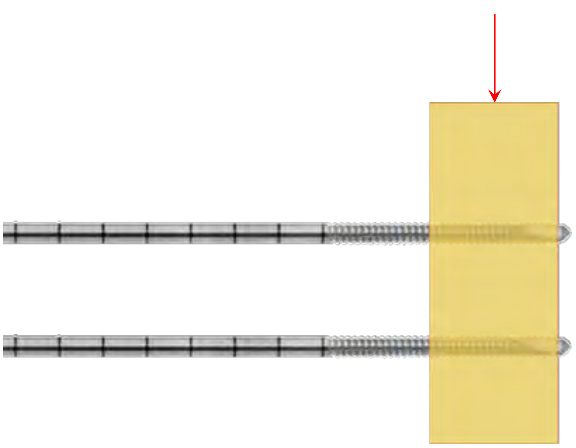
Pins under load



No!

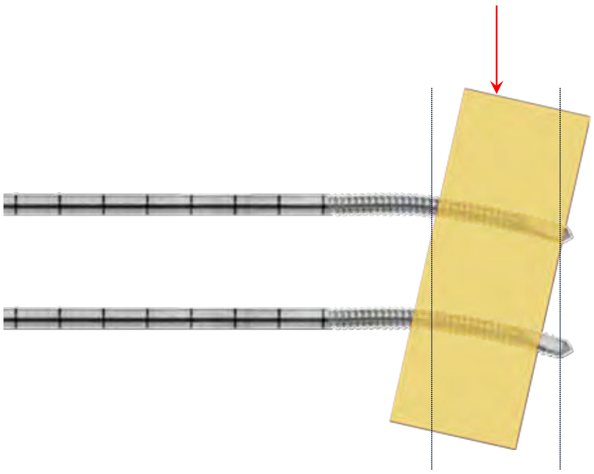
SCOTTISH RITE FOR CHILDREN

Pins under load

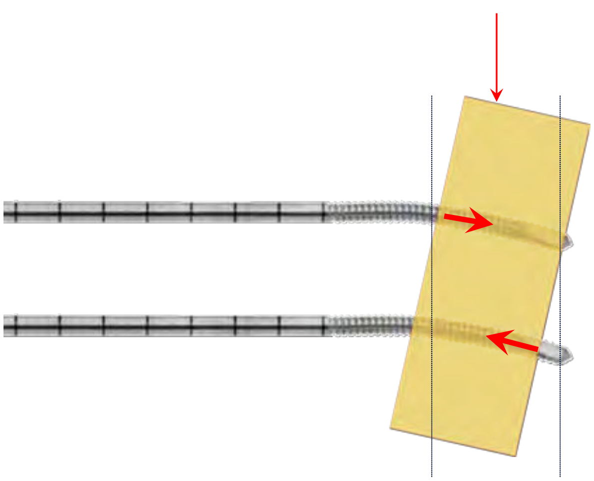


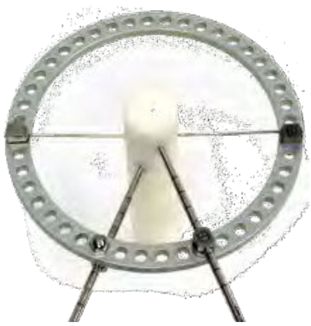
SCOTTISH RITE FOR CHILDREN

Pins under load



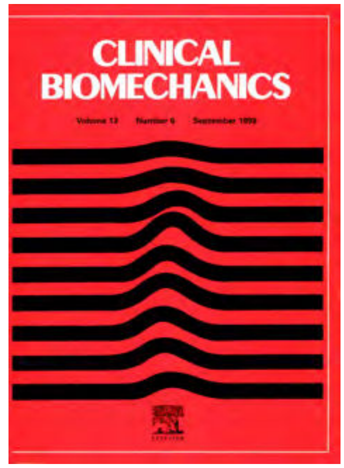
Pins under load





Biomechanics of the

CIRCULAR FRAME

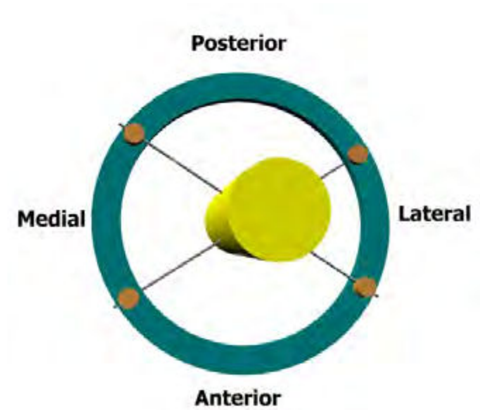


Bronson DG, Samchukov ML, Birch JG, Brown RH, Ashman RB. Stability of external circular fixation: A multi-variable biomechanical analysis. Clin Biomechanics 13:441-448, 1998

SCOTTISH RITE

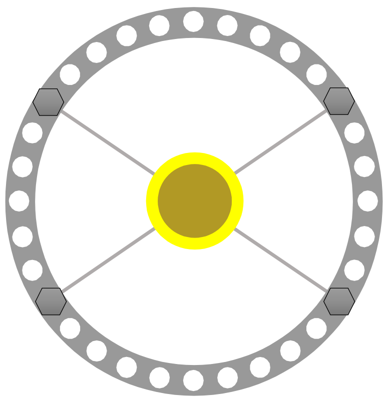
Circular external fixation stability

- Axial compression
- A-P translation
- M-L translation
- A-P bending
- M-L bending
- Torsion



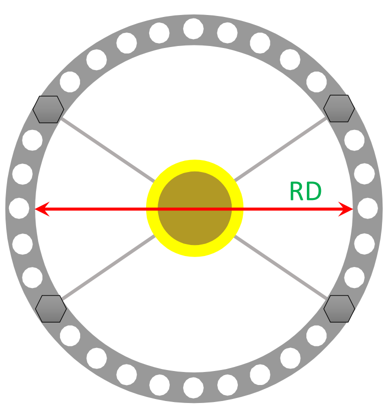
SCOTTISH RITE

Two Wires in a Ring



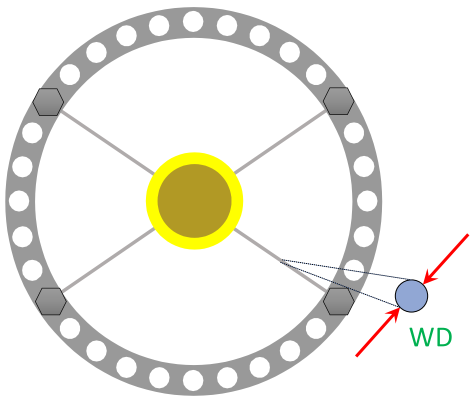
The effect of two cross tensioned wires stabilized on a single ring

Two Wires in a Ring



- Ring diameter (RD)
  120, 160, 200 mm

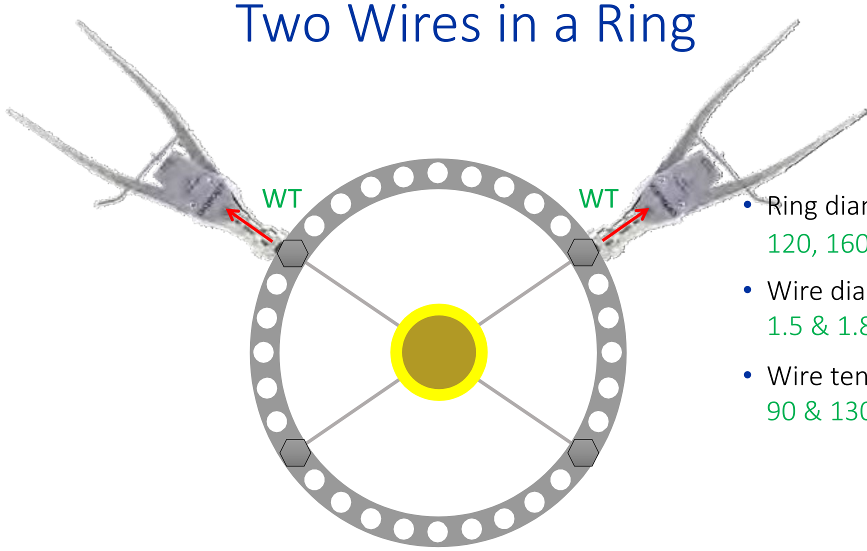
Two Wires in a Ring



- Ring diameter (RD)
  120, 160, 200 mm
- Wire diameter (WD)
  1.5 & 1.8 mm

SCOTTISH RITE FOR CHILDREN

Two Wires in a Ring



- Ring diameter (RD)
  120, 160, 200 mm
- Wire diameter (WD)
  1.5 & 1.8 mm
- Wire tension (WT)
  90 & 130 kg

SCOTTISH RITE FOR CHILDREN

LLRS Pre-Course 2023

Building a Frame around Bad Bone

David B. Frumberg, MD

What makes bone "bad?"

- Osteopenia
- Infection
- Soft tissue defects
- Limited real estate

Strategies for fixation

- Add more wires
- Add washers to olive wires
- Span adjacent joints

STAYING OUT OF TROUBLE WITH CABLE TRANSPORT

Balanced Cable Transport has become widely recognized as a useful option to address bone segmental bone loss in many situations. Despite this, the principles and technical details are still much less familiar than those of classic external fixation. This session will highlight some of the key tips to prevent common pitfalls that new users frequently encounter. It will also provide guidance on how to avoid and address complications that can occur during transport. In addition, it will cover some advanced tips and tricks to facilitate success in difficult cases for the more experienced surgeon.

How I do LRS monolateral fixator for long bone lengthening and be out of troubles ?

10 min Presentation and 50 min. Demonstration and workshop

By

Yasser Elbatrawy (MD)

Professor of Orthopedic surgery

Al-Azhar university, Cairo, Egypt

LLRS member since 1998 and previous fellow in Baltimore, MD

In this short presentation and workshop, I am going to show photos of some common mistakes that should be avoided to be out of troubles when applying any monolateral fixator to use for lengthening.

Pre-operative: It start by choosing the proper patient:

A- Good new bone quality.

B- Patient weight in relation to choosing the fixator type. If heavy weight then choose hybrid or ring fixator rather than mono lateral.

C-Planning, instrumentations & choosing pins diameter.

Intra-operative:

A- Technique of reference pins: Which pin to insert first ?

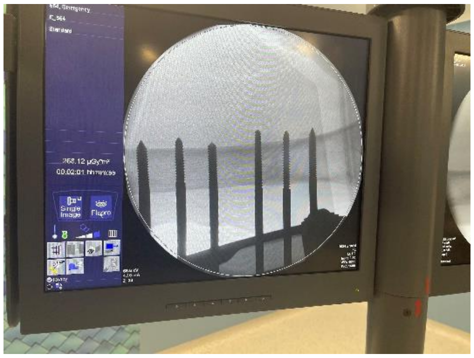
B- Technique of drilling using cannulated drill bit over wire Perpendicular to the mechanical axes of the bone.
C- Choosing the proper diameter and design of the drill bit.
D- How the Pins should be parallel in AP and all are in one line together without being Diverging or converging to each others.
E- Consider Soft tissue release and knee free range of motion to avoid knee stiffness and get the maximum possible lengthening if needed without trouble during the follow up.

Post Operative Care of the pins and the device and motor change with a longer one if needed.

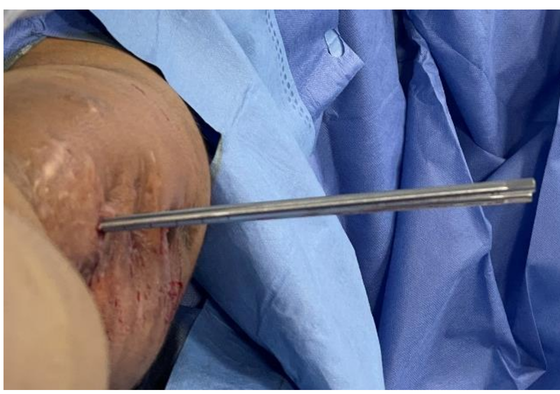
Leave at least 3 cm of pins outside of the fixator as you may need this to apply another fixator and exchange the original clamps or to dynamize the original fixator.

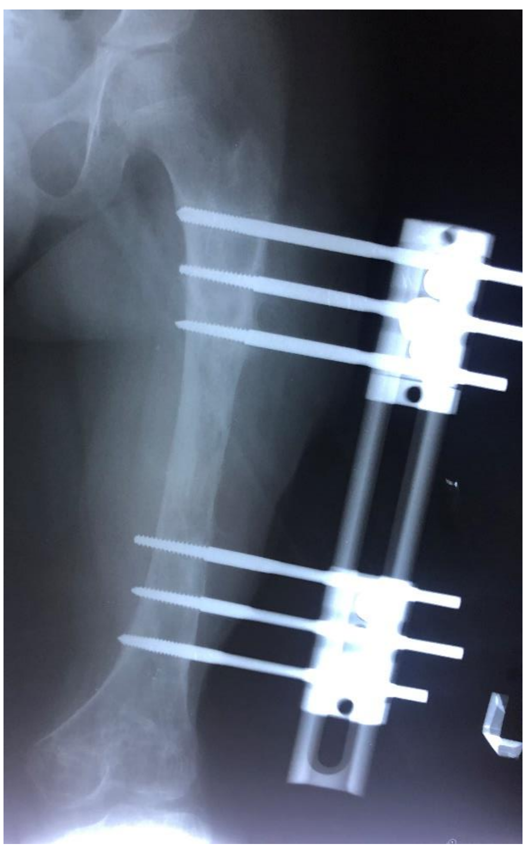
Start with the fixator as near to the bone as possible to have a stable rigid stiff fixator.

Here are some of the photos that I will explain the purpose of each one:







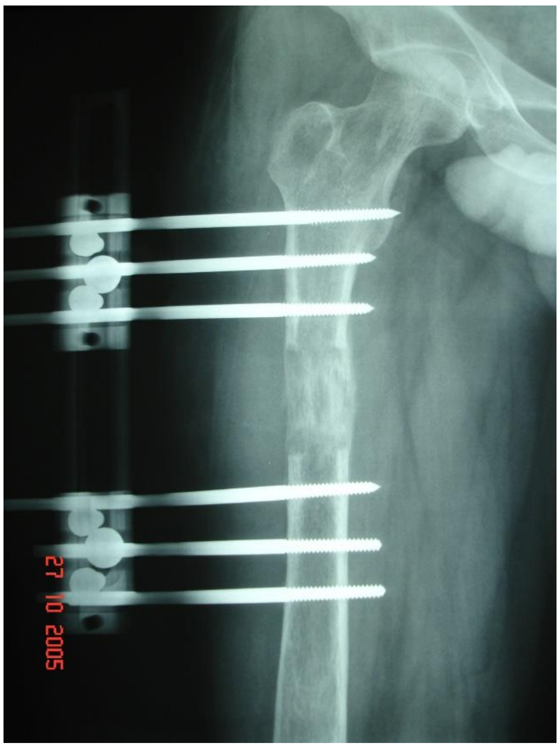



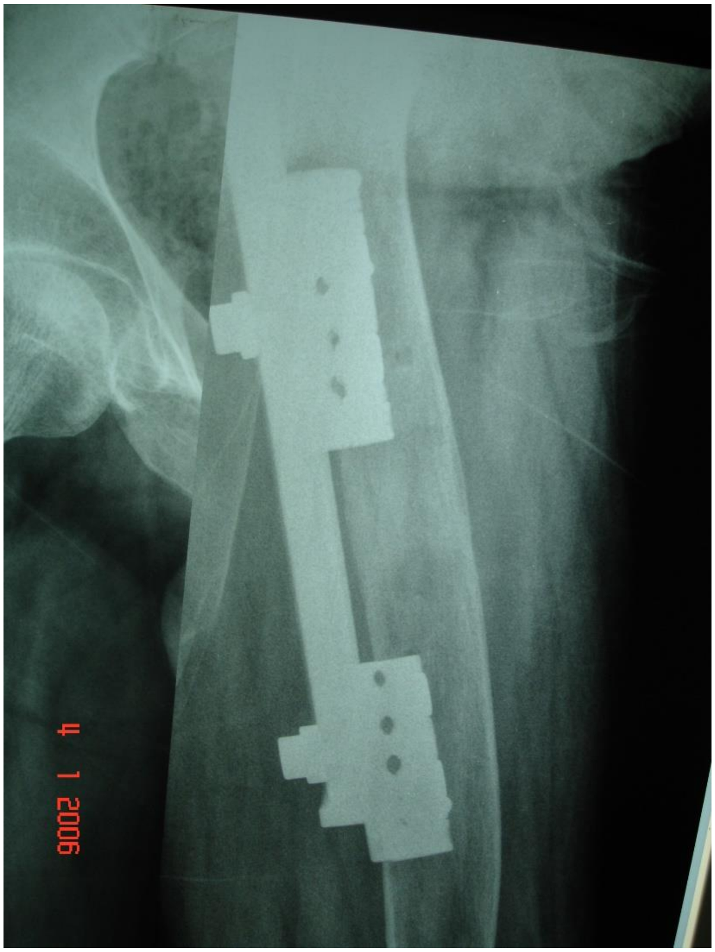

You can achieve 5 to 7 cm of lengthening safely with good consolidation specially in Children.

Keep an eyes to knee range of motion and to the pins signs of loosening on the X rays.

If any happened then must exchange or deal with the situation seriously.

Dynamize the frame by removing the closing pins to the osteotomy site first and leave the patient for few more weeks.





Check the quality of the regenerate in all views before deciding the frame removal time.

Check always in every visit the range of motion of the nearby joints and document it to compare.




Always dynamize the frame enough time before removal of the fixator.

Possible to do percutaneous gigli saw osteotomy

Sequale of Erb’s palsy after 8 cm lengthening.

Big problems could be solved easily with monolateral

Conclusion: The Unilateral frame is comfort to the patient but needs attention to the details from the surgeon: Pre., Intra. And post operative.

Using monolateral fixator is techniqually more demanding than circular fixator.

It needs skills and some very important tricks during its application to guarantee a successful procedure with much less problems or obstacles during the whole procedure time.

The pins must be perpendicular to the mechanical axis during femoral lengthening.

The pins must be exactly parallel to each others in AP and in Axial view: No any degree of divergence or convergence is allowed.

This Guarantee better longevity of your device and pins without any stress to the bone.

Make sure that no soft tissue tethering and deal with any.

Foot frames in pediatrics and adult foot and ankle:

How to avoid the crash

Scott Nelson MD
Loma Linda University
Hôpital Adventiste d'Haiti

1

Disclosures

- Consultant Orthofix
- Consultant Johnson and Johnson

2

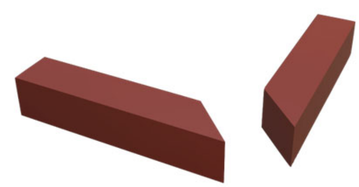
Objectives

- Know when to use a miter frame
- Make it easy
- Stay out of trouble

Patient photos used with permission

3

What is a miter joint



4

Indications

- Combination of:
  - Stiffness
  - Severe equinus
  - Severe midfoot deformity

16 y/o female with B clubfoot never treated

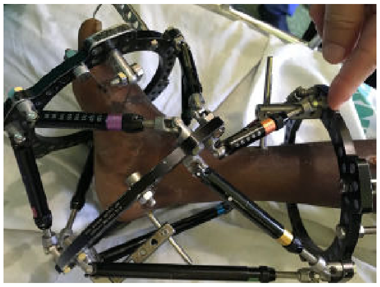
5

Final Goal

- Full correction of deformity
- No struts bottomed out
- No crash of components
- Angles not too great between rings

6

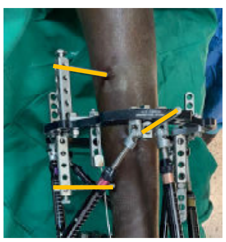
Final Goal



7

How to make it easy…

8



Proximal Ring

- "2+1" good points of fixation
- Make sure ring is proximal enough

Divide the operation into parts

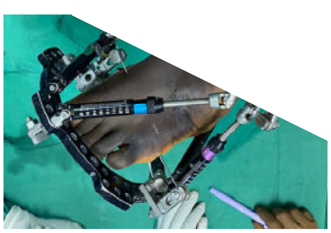
9

Hindfoot

- "2+1" points of fixation
- Wires before ring
- Big 2/3 ring (open anterior)
- Angle so that at end of program it is maximum 45° to prox ring

Divide the operation into parts

10



Forefoot

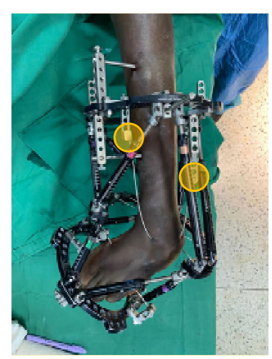
- Metatarsal wires
- Toe wires
- Wires before ring
- Ring should be distal

Divide the operation into parts

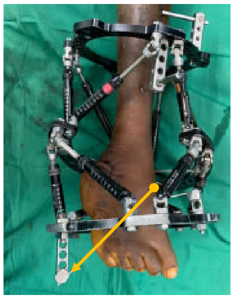
11

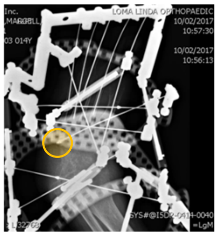
Special Fixation Tricks

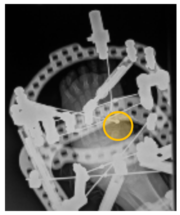
Stirrup Wire



12

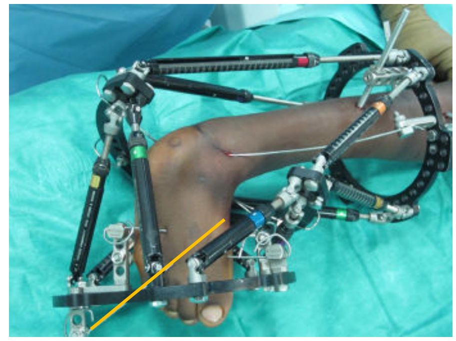




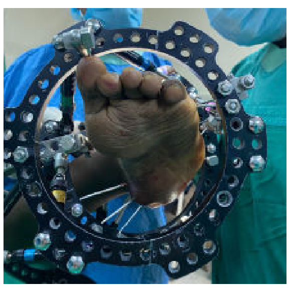


Single ended olive wires

13

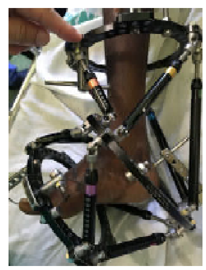


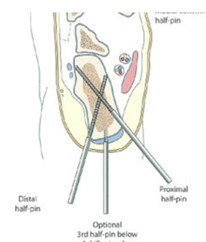
14



Toe wires

15





From The Art of Limb Alignment TSF:© 2018 Sinai Hospital of Baltimore

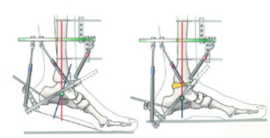
Calcaneal half pin(s)

16

The Kickstand

17

Programming Tips



From The Art of Limb Alignment TSF:© 2018 Sinai Hospital of Baltimore

- Proximal and distal ring references
- Distal frame 180° axial rotation
- Lateral process of the talus is axis of correction for proximal
- Center of TN rotation for distal if clubfoot

18

Avoid the Crash

Make sure your rings are far enough apart and angles are correct

19

Avoid the Crash

20

Most Common Mistakes with Internal Lengthening Nails

Christopher Iobst, MD, FAOA
LLRS Pre-Course
July 13, 2023

1

Disclosures

- Consultant: NuVasive, Orthofix, Wishbone Medical, Smith and Nephew
- I will not be discussing "off-label" or investigational uses for products or devices.

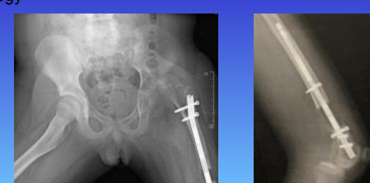
2

Pre-Operative

3

Pre-Operative

- Joint stability/morphology



4

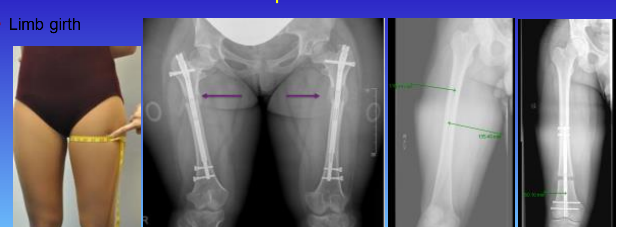
Pre-Operative

- Joint stability/morphology

5

Pre-Operative

- Limb girth



6

Pre-Operative

- Behavioral health evaluation
- Social support system evaluation
- Don't sign up for surgery at first visit

7

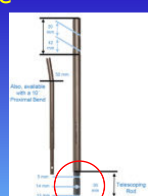
Pre-Operative

- Asking the nail to do too much
  - Size fit too tight
  - Large deformity corrections
  - Trauma applications

8

Pre-Operative

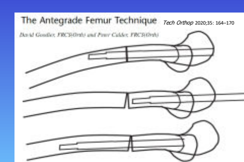
- Coronal Plane Planning
  - Nail size and diameter
  - 8 cm + desired lengthening



9

Pre-Operative

- Sagittal Plane Planning
  - Straight nail in a curved bone

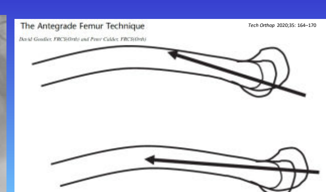


10

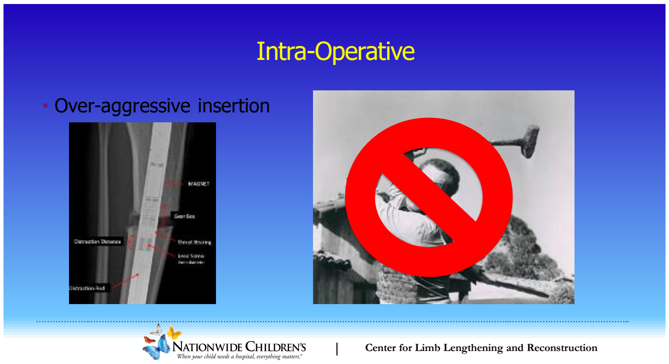
Intra-Operative

11

Intra-Operative
Starting point



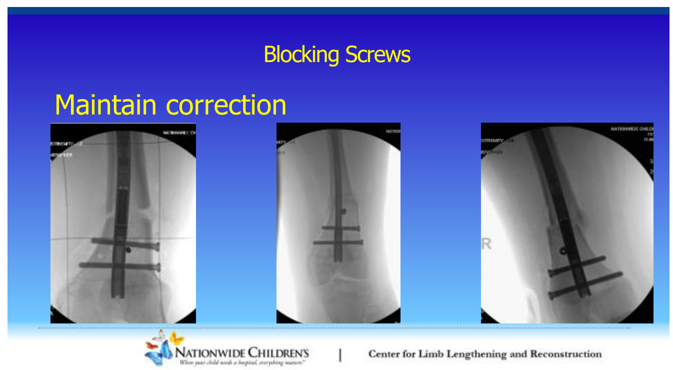
12



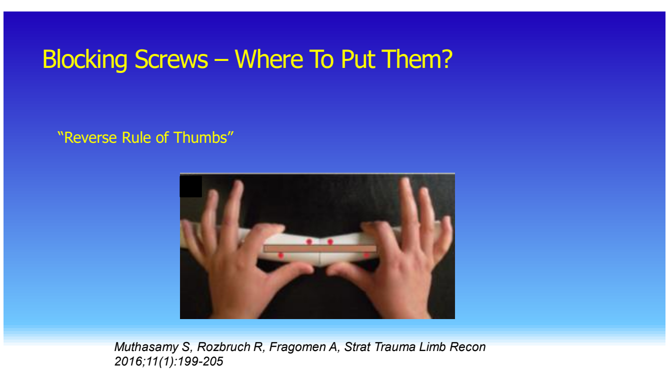
13

14

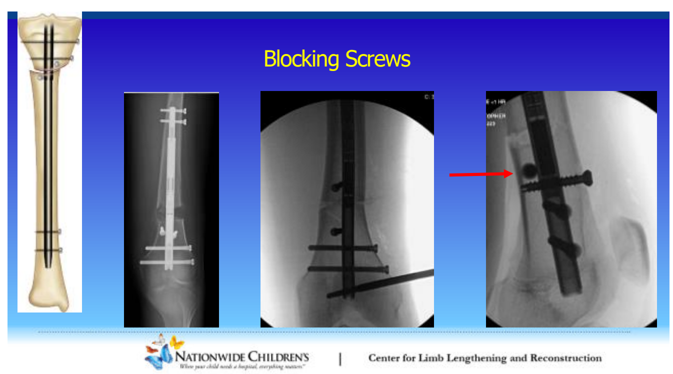
15



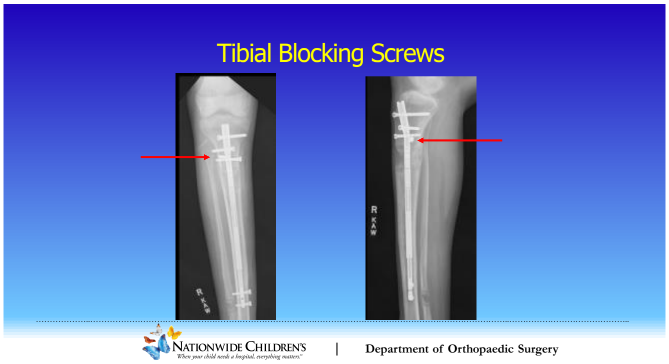
16



17

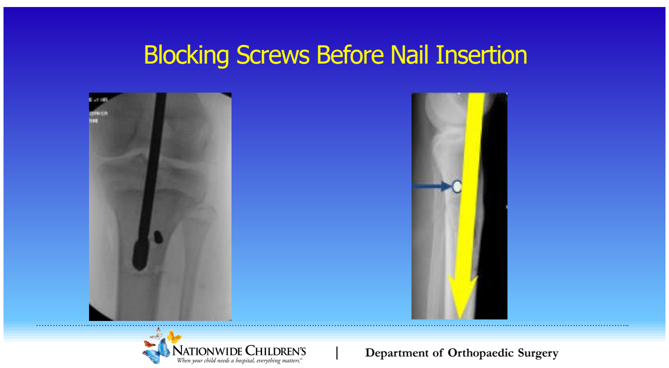


18

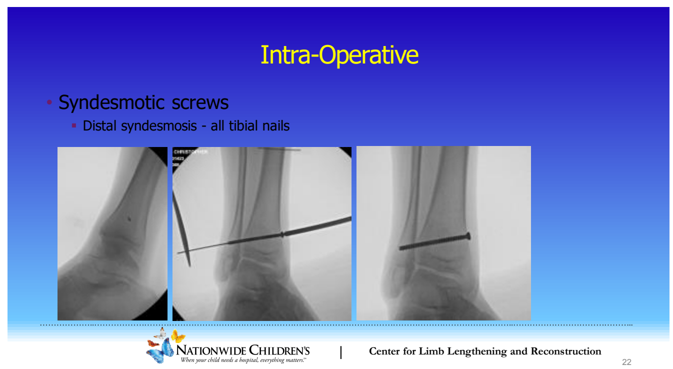


19

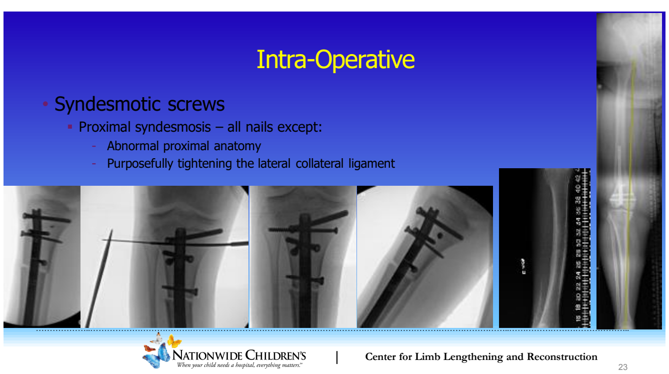
20



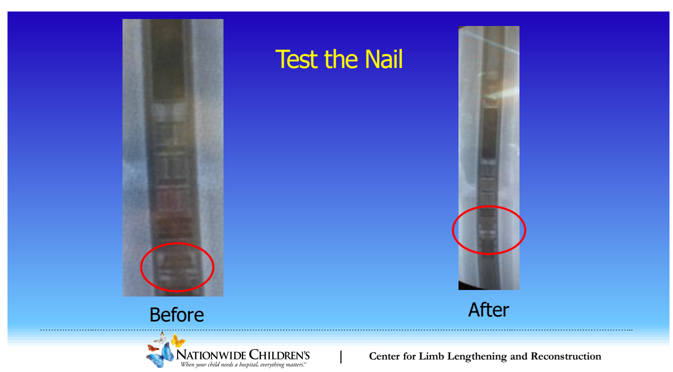
21



22



23



24

Post-Operative

25

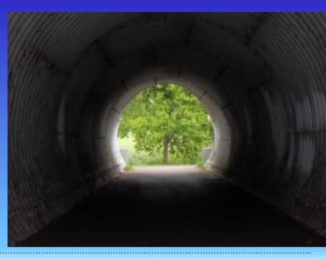
Post-Operative

- Poor regenerate
  - Appropriate latency
  - Rate and rhythm
    - Mechanobiology is different than external fixation
    - Start conservatively
    - Small increments
    - Don't sacrifice patient convenience for healthy regenerate
    - Constantly massage the rate and rhythm – don't blindly use the same rate the entire time
    - Don't create a black hole

26

Post-Operative

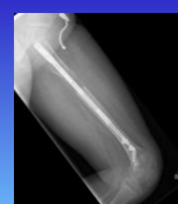
- Lengthening goal tunnel vision

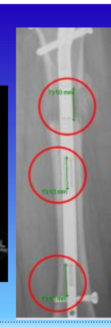


27

Post-Operative

- Train yourself to evaluate radiographs closely and comprehensively
- 1) Regenerate quality
- 2) Nail distracting appropriately
- 3) Length of regenerate as expected

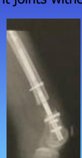




28

Post-Operative

- Train yourself to evaluate radiographs closely and comprehensively
- 4) Adjacent joints without subluxation/dislocation



29

Thank You For Your Attention
For Questions or Comments:
christopher.iobst@nationwidechildrens.org

30

Avoiding Complications During Acute Deformity Correction

S. Robert Rozbruch, MD

A. What can go wrong
    a. Compartment syndrome
    b. Nerve injury
    c. Nonunion
    d. Inaccurate correction
B. Principles
C. Examples and tips
    a. Opening wedge osteotomy
    b. Closing wedge osteotomy
    c. Fixator assisted IM nailing with Blocking screws
    d. Soft tissue release
    e. Nerve decompression
    f. Fasciotomy