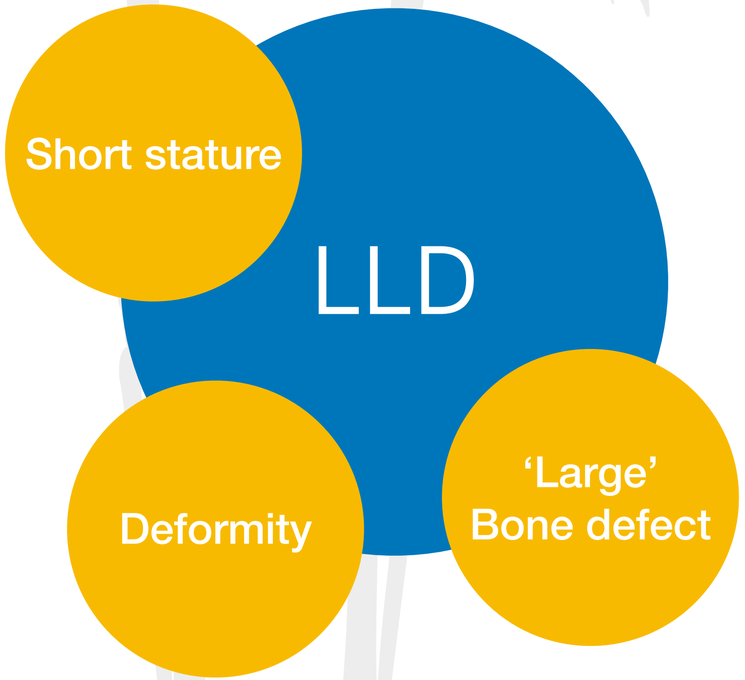
BONE LENGTHENING

Nisalak Upho MD,PhD (BMS, Biomaterials)

Department of Orthopedics - Faculty of Medicine - Prince of Songkla University

กระดูกเด็กมอ.
ยอมงอ...ไม่ยอมหัก

Problems



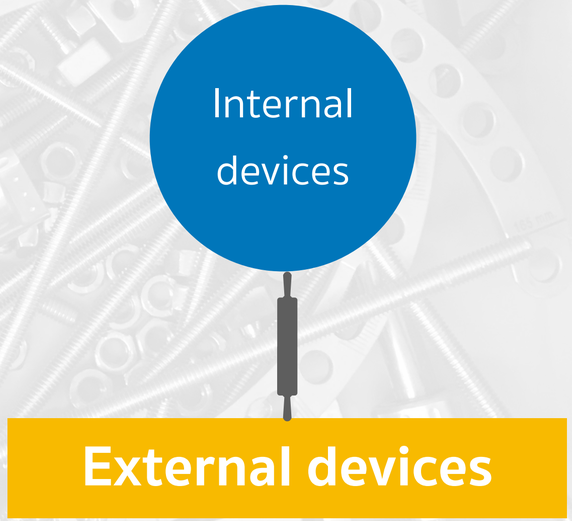
Methods

Bone lengthening

Bone transport

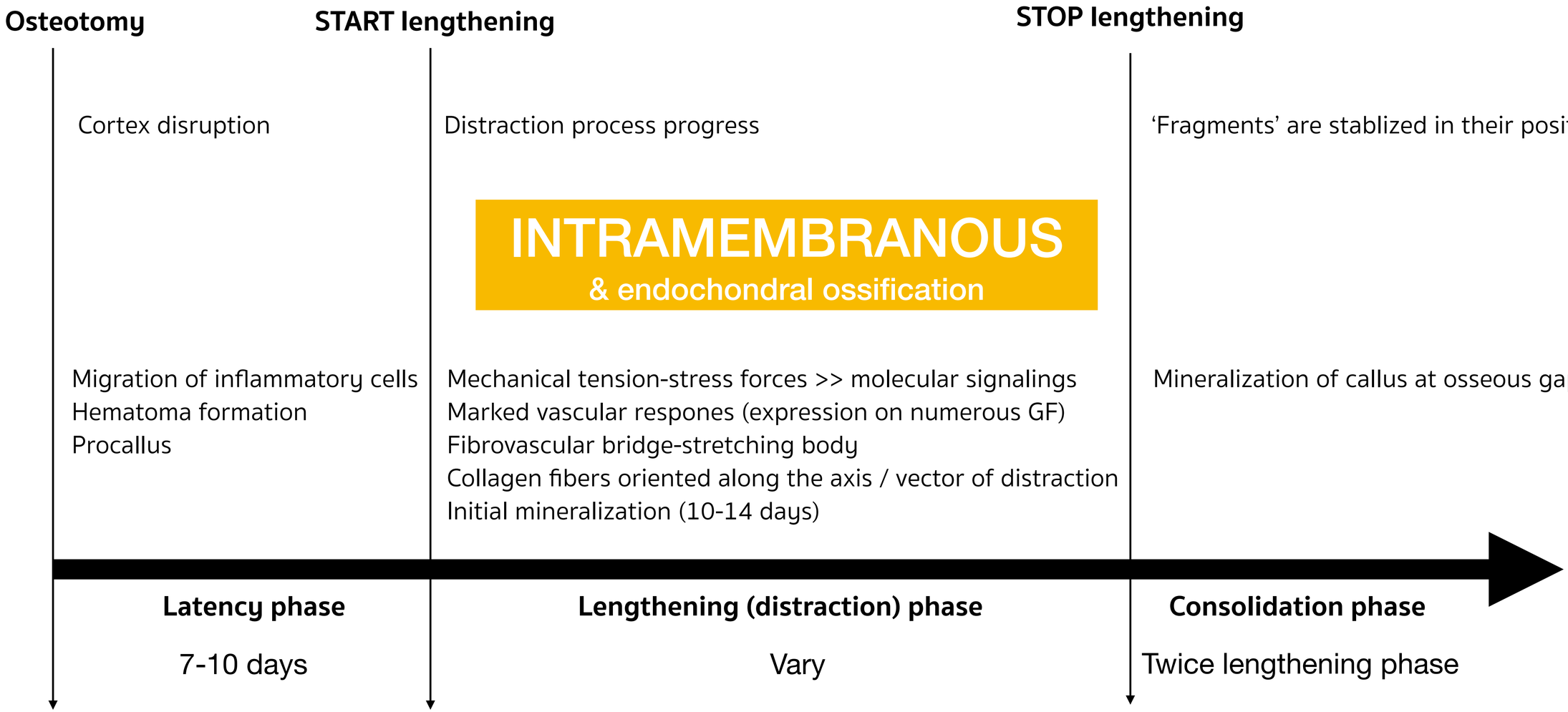
Distraction osteogenesis

Equipment



Ilizarov, 1992

Distraction Osteogenesis: Biology



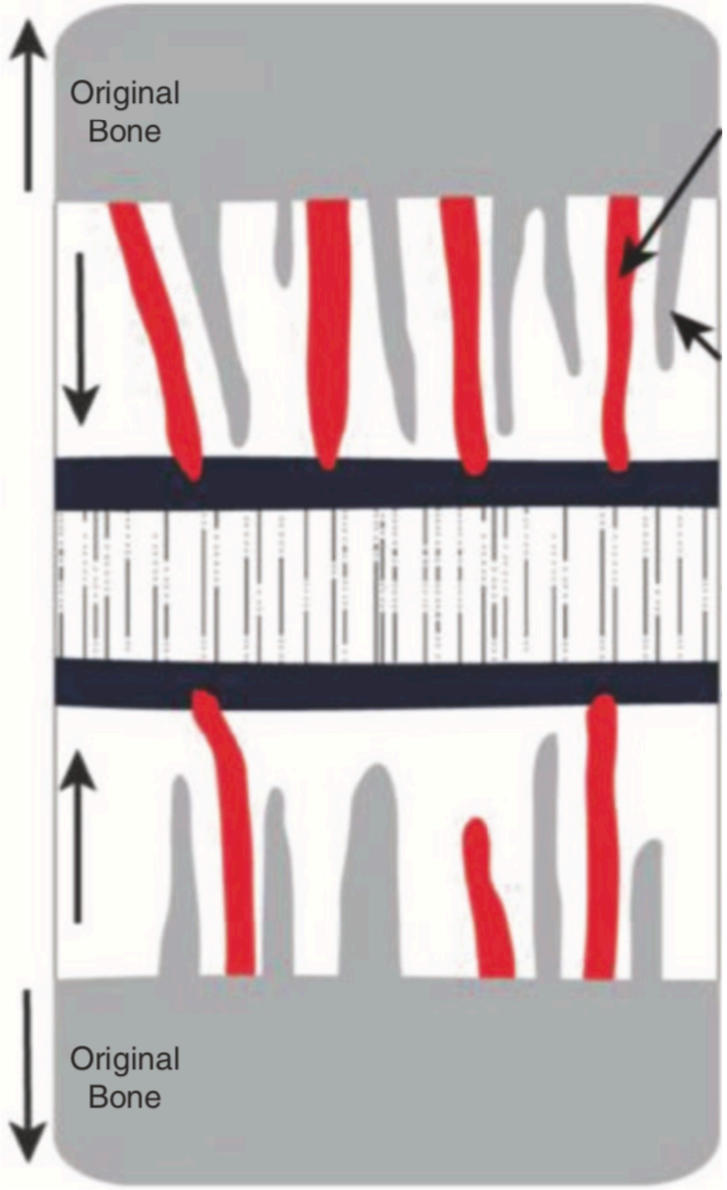
Ilizarov, 1988

Table 2: Recent experimental work implications to promote regeneration, formation and maturation in distraction osteogenesis

Cell therapy: Transplantation of osteoblast like cells to the distracted callus	Enhances angiogenesis and mineralization
Grafting with demineralized bone matrix	Bone healing at a faster rate than normal
Application of resorbable calcium sulfate	Increases rate of osteogenesis and consolidation
Application of bisphosphonate	Improves BMD,BMC and mechanical properties of bone undergoing distraction osteogenesis
Application of hormones: Recombinant growth hormone; 2 β-(3-hydrox-ypropoxy)-1α, 25 dihydroxyvitamin D3 (ED-71)	Stimulating effect on regenerate bone healing without changing the callus microstructure
Growth factors: Fibroblast Growth Factor; Insulin-like Growth Factor; VEGF	Stimulates bone formation, stimulates proliferation of Osteoblasts and Chondrocytes
Low intensity pulsed ultrasound	Regenerates bone formation in distraction osteogenesis
Electrical stimulation; Direct current, Capacitively coupled electromagnetic field	Regenerates bone formation in distraction osteogenesis
Osteonectin[29]	A glycoprotein that binds to calcium, hydroxyapatite, and collagen, suggesting that it is a nucleator for matrix mineralization.
Alkaline phosphatise[29,30]	A cell-linked polypeptide secreted from osteoblasts. It is thought to promote crystal formation in matrix vesicles by removing nucleation inhibitors.
Thrombospondin[30]	A trimeric glycoprotein secreted by connective tissue cells. It binds calcium, hydroxyapatite, and osteonectin. Organize extracellular matrix components or act as a growth factor
Bone morphogenic proteins (BMP)[31,32]	A family of cytokines that stimulates proliferation of both chondrocytes and osteoblasts and causes increased matrix production in each cell type.
Platelet-derived growth factor (PDGF)[31,32]	A growth factor, it stimulates proliferation of chondrocytes and osteoblasts.
Transforming growth factor-β (TGF-β)[31-33]	A growth factor, it causes differentiation of Mesenchymal Stem Cell's to chondrocytes, and may also induce chondrocyte and osteoblast proliferation
Estrogen[31]	A hormone, it has a complex effect on bone, with the final outcome being decreased bone resorption by osteoclasts.

Natu, 2013

Distraction Osteogenesis: zone of distraction



Runyan et.al., 2017, Hvid 2016

Zone of mineralized microcolums formation (MCF)

Primary mineralized/matrix front (PMF)

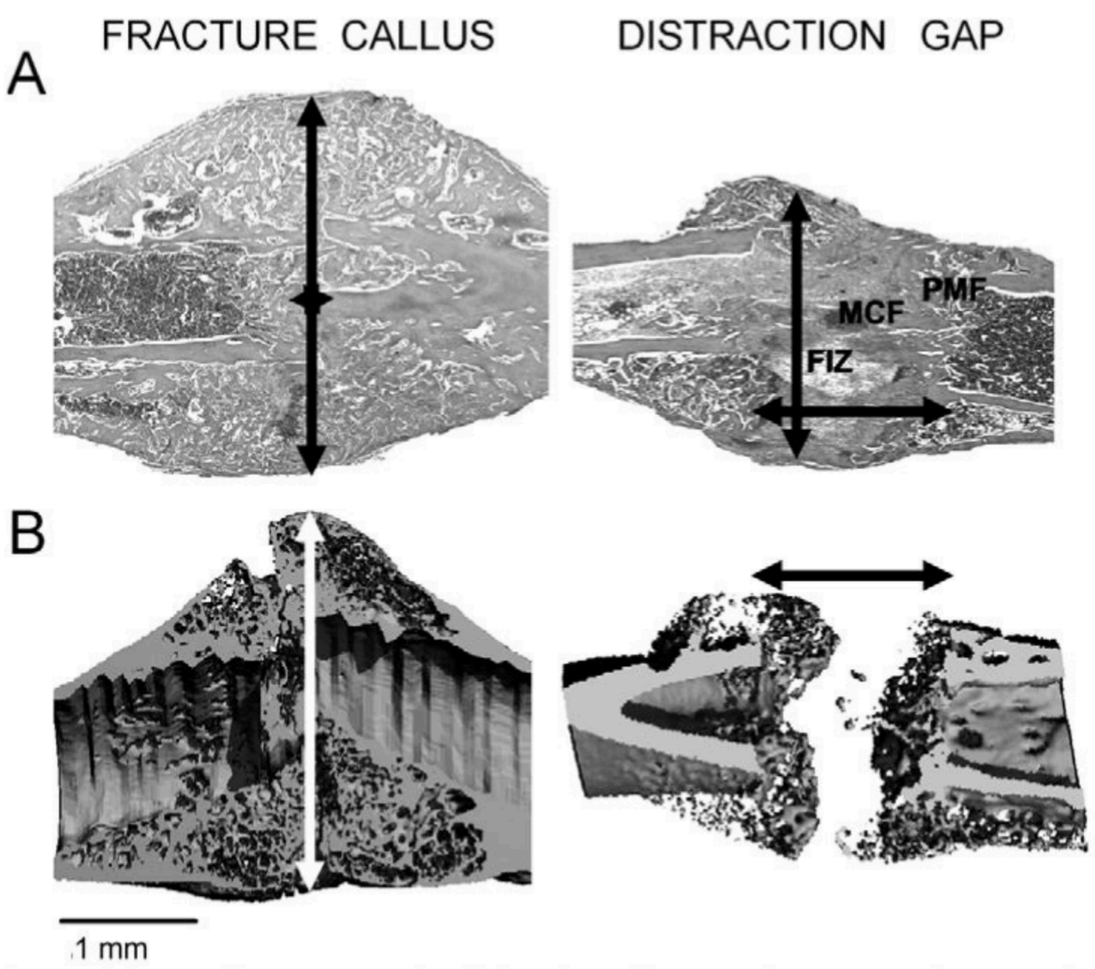
Fibrous interzone (FIZ)

Primary mineralized/matrix front (PMF)

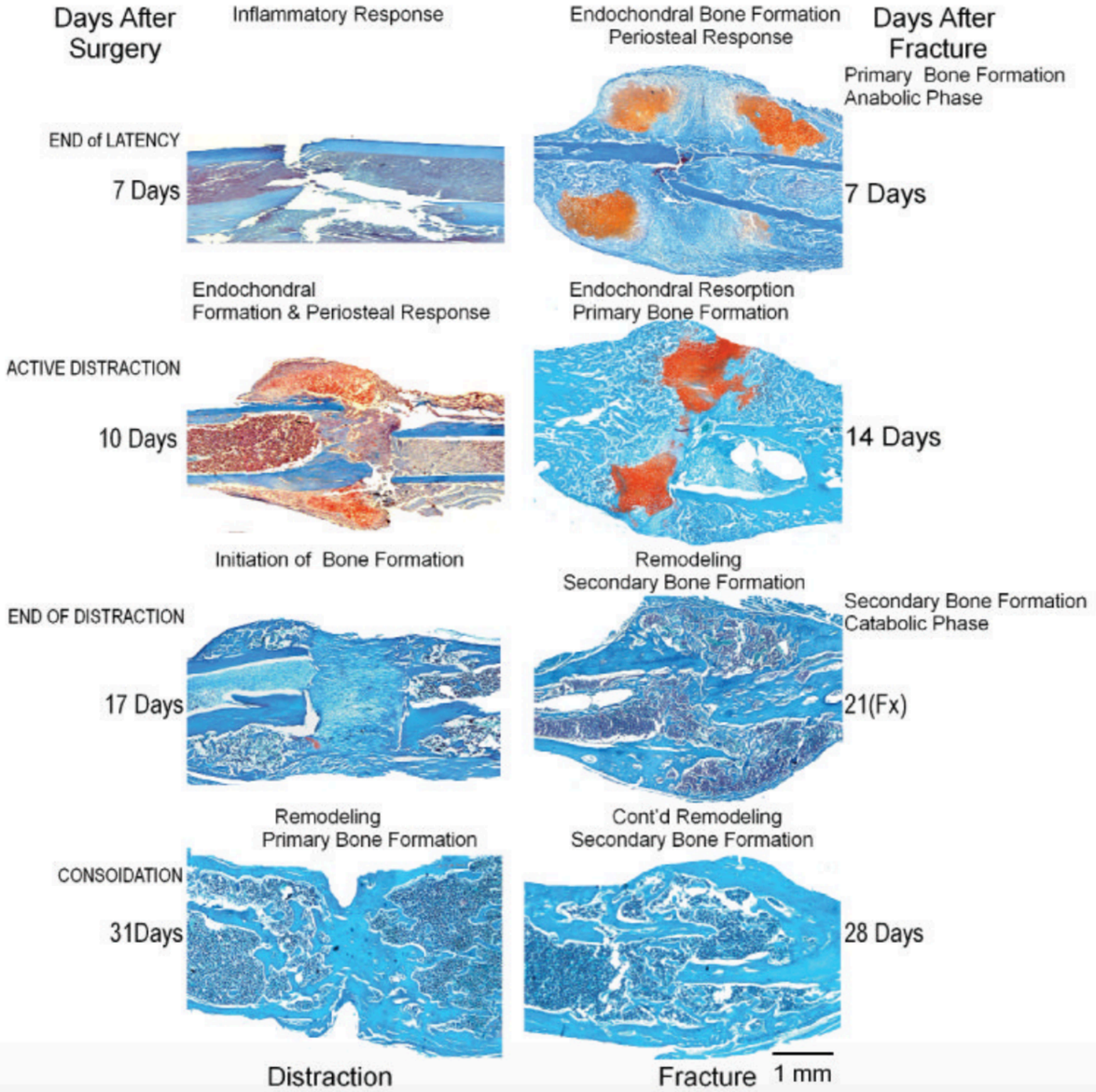
Zone of mineralized microcolums formation (MCF)



Distraction gap vs fracture gap



Al-Alq et.al., 2008

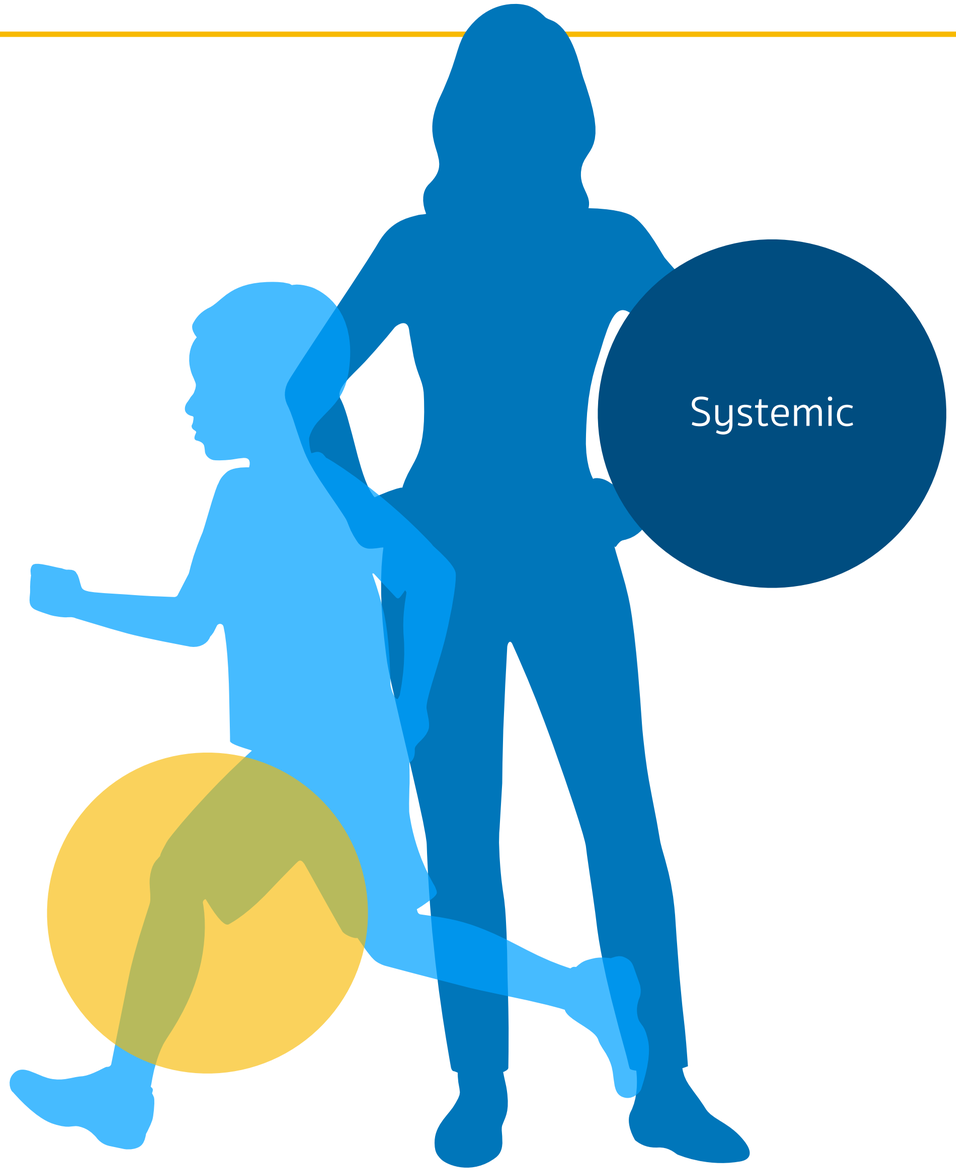


Runyan et.al., 2017

Factors affecting new bone formation and healing

Local

- Osteoprogenitor supply
- Blood supply
- Infection
- Soft tissue scarring
- Bone stock
- Prior radiation therapy



Patient factors

- Age
- Cause for lengthening
- Metabolic disorders
- Vitamin D deficiency
- Connective tissue disease

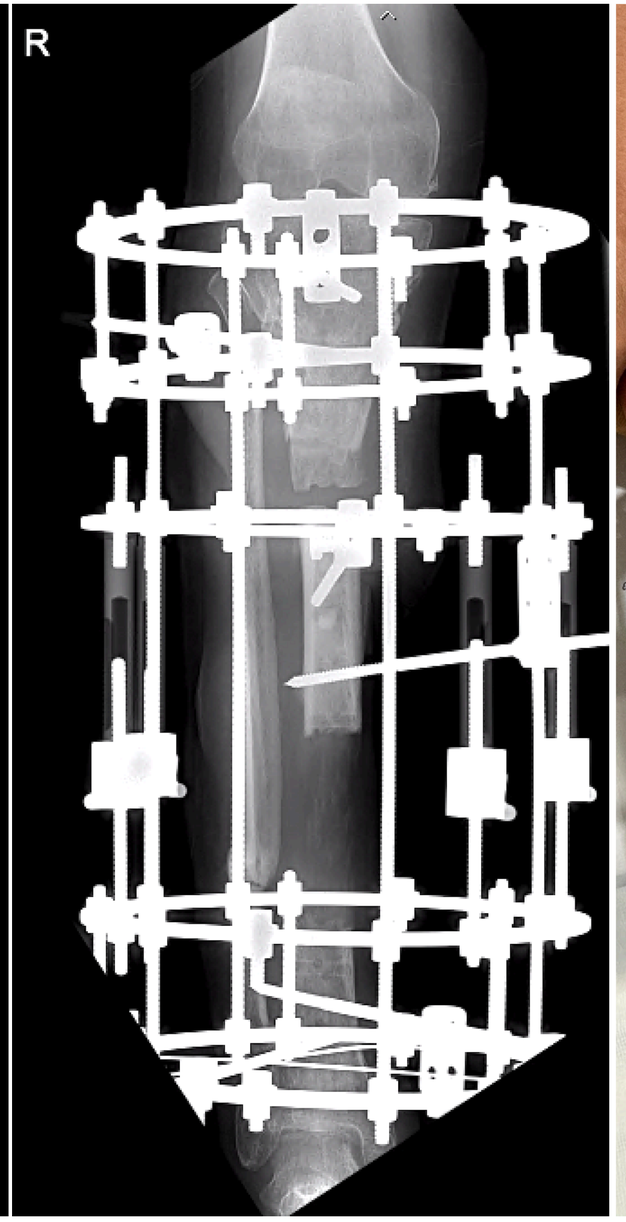
Medication

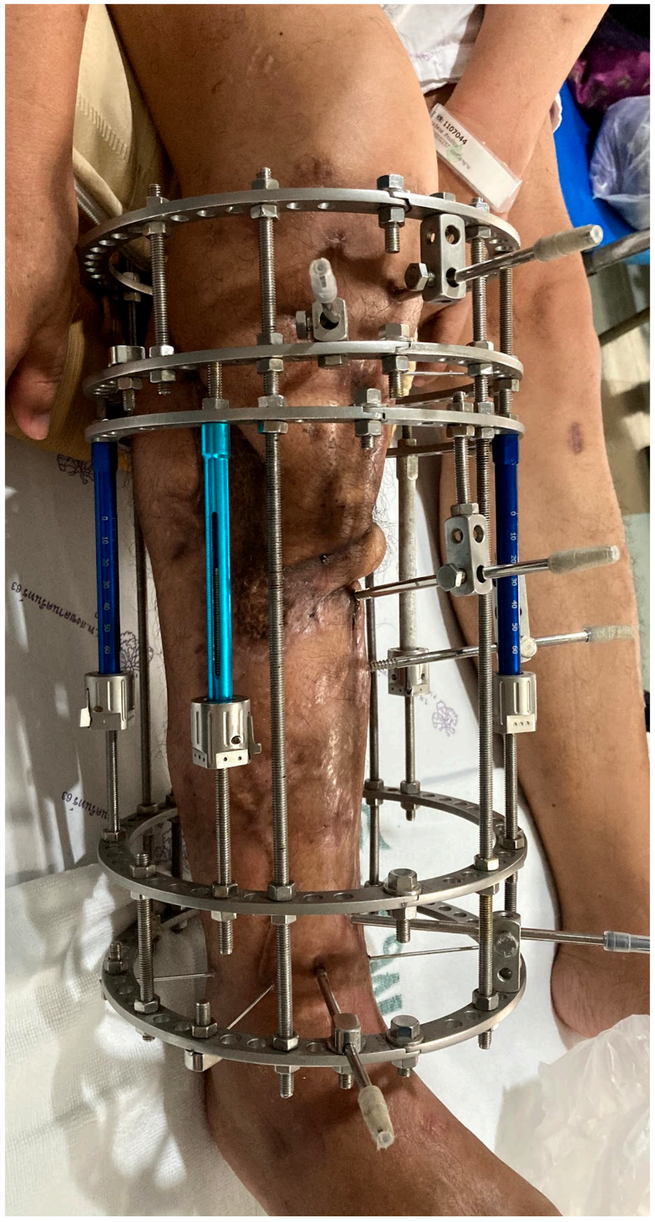
- Chemotherapy
- Corticosteroids
- Antibiotics
- LMWH
- NSAIDs

Imola et al. 2002,2008, Hvid et al. 2016









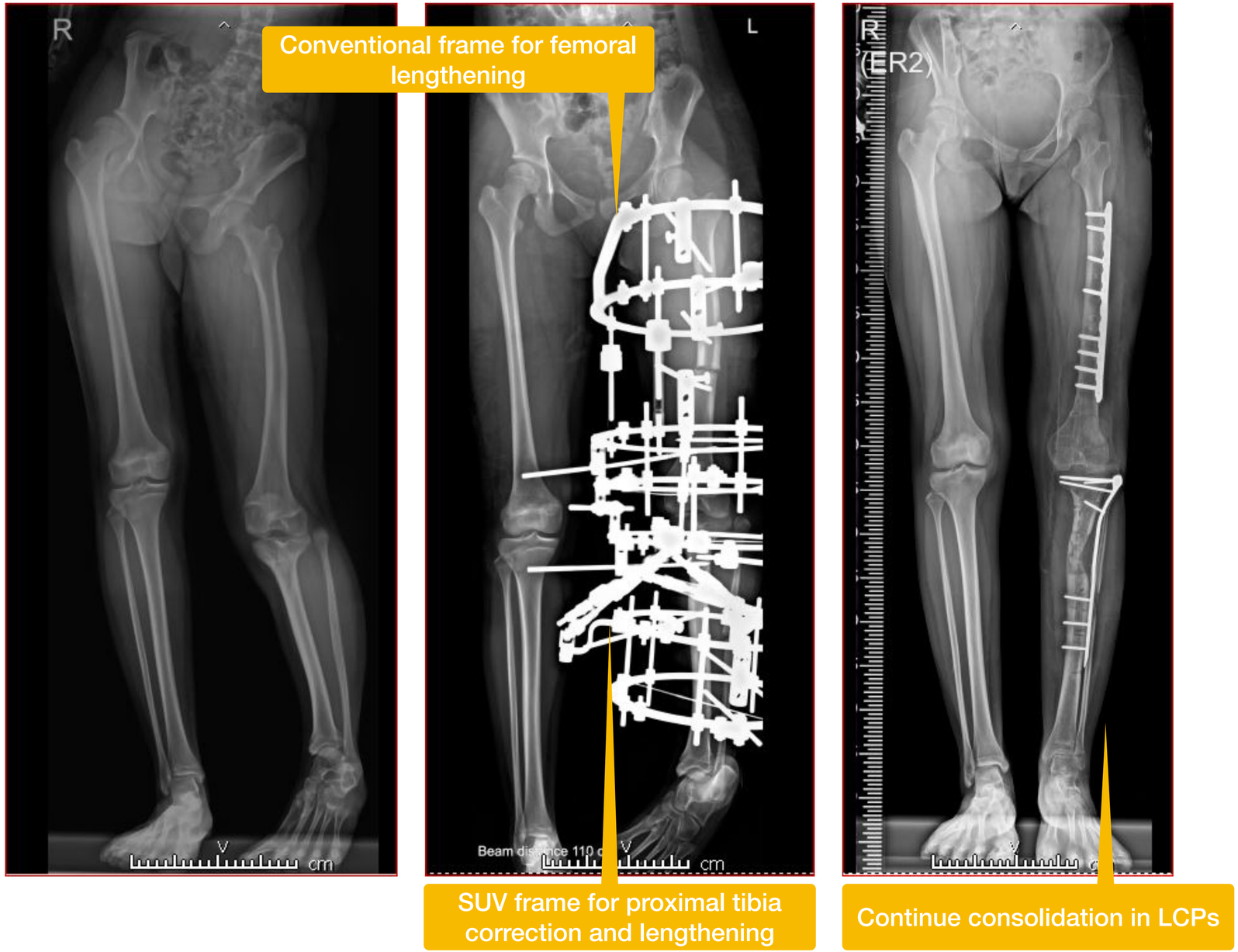
A 50-year-old man with large bone defect from open fracture and chronic osteomyelitis. Skin compromised Rt leg was noted.

Indications

Classic Rule of thumb: LLD > 4 cm

- **Congenital**
  - Congenital limb deficiency
  - Skeletal dysplasias with short stature
  - Cosmetic short stature
- **Developmental**
- **Bone defect from**
  - Trauma
  - Tumor
  - Infection

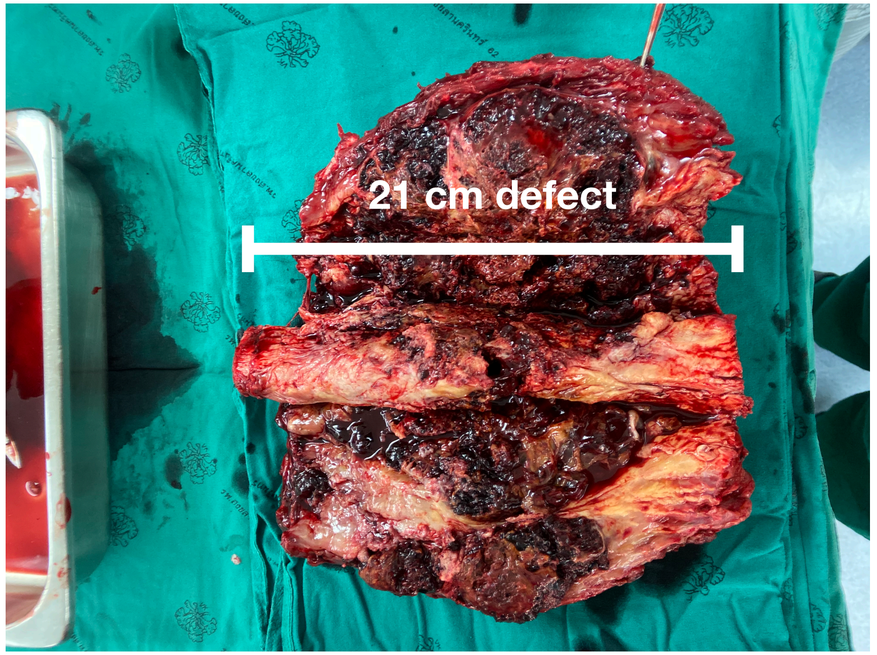
A 10-year-old girl with severe knee deformity and LLD from neonatal osteomyelitis since age of 4 months



Contraindication ?

Classic Rule of thumb: LLD / defect > 20 cm

- **Active diseases**
  - Infection
  - Malignancy
- **Medications**
  - Ongoing chemotherapy
  - Ongoing radiotherapy
  - Immunosuppressive drugs
- Others
  - Poor nutritional and health status
  - Psychosocial issues







Procedure

1. Lengthening device placement
2. Osteotomy
3. Adjunct procedures

Lengthening Devices

External device types

1. **Monolateral external fixator**
    1. OrthoFix
    2. DriveRail
    3. Simple monolateral external fixator
2. **Ring external fixator**
    1. Ilizarov system with telescoping rod
    2. SUV system
    3. Taylor Spatial frame (TSF)
    4. Vilex frame system



Internal device types

1. **IM nails**
    1. PRECISE nail
    2. Fitbone nail
2. **Plates**

Lengthening over nail (LON)

Pros and cons

1. Much more sheaper than the internal devices
2. Can correct multiple planar deformity
3. Risk of superficial and deep infections
4. Technical requirement



Pros and cons

1. Decrease infection rate
2. Easy to perform compared to complex ring fixator
3. Good compliance and satisfaction
4. Easy for rehabilitation program
5. **Very expensive**



Paley Institute

The PRECISE nail

The PRECISE plate

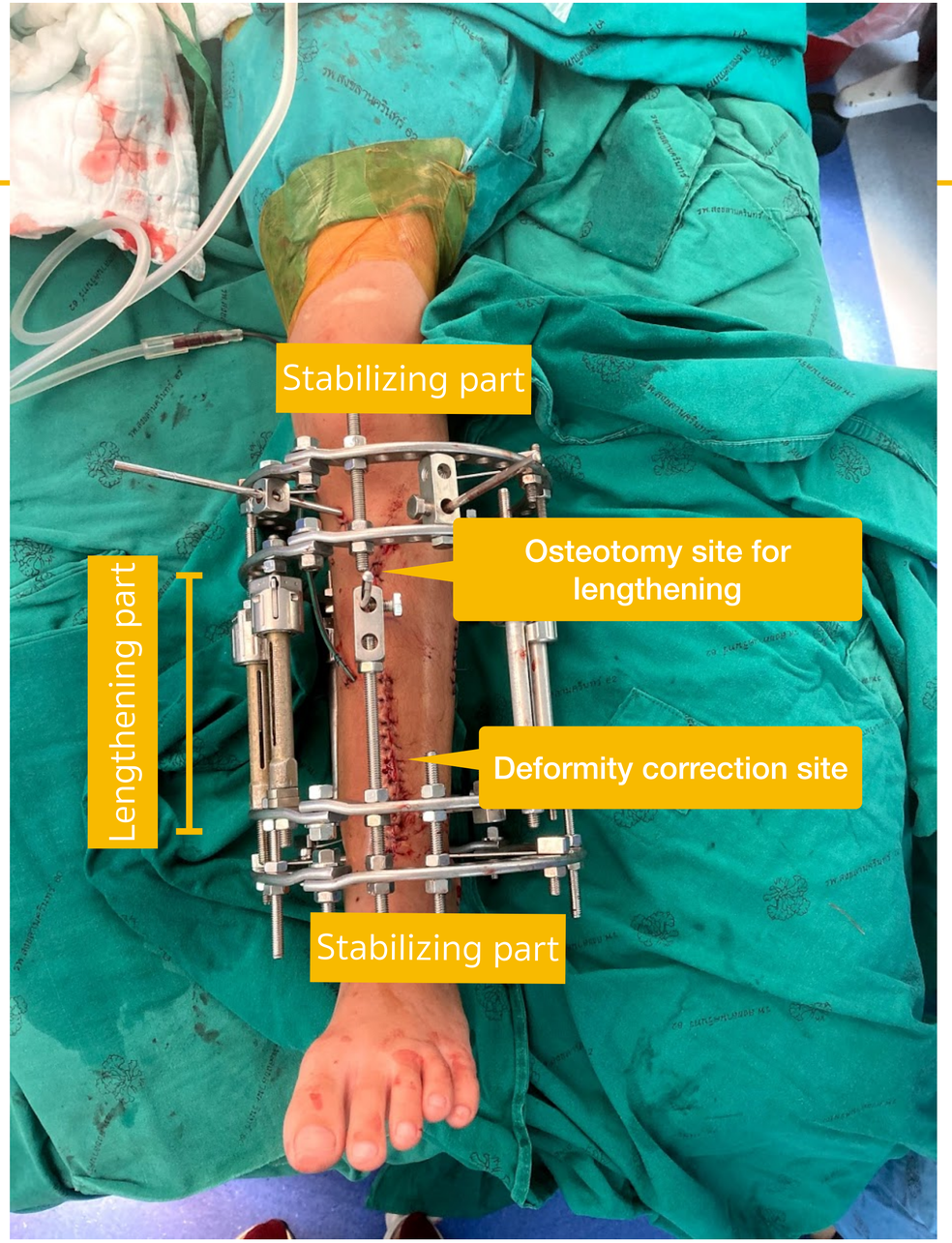


Ilizarov ring external fixator

1. **Lengthening - transport part:** cover the osteotomy site
2. **Stablizing part:** increase stability of proximal and distal fragment

Factors affecting healing and stability

1. Bone quality
2. Pin / wire sizes
3. Number of pin / wire
4. Location of pin / wire
5. Tension of wire
6. Number of ring and distance from bone
7. Overall system design

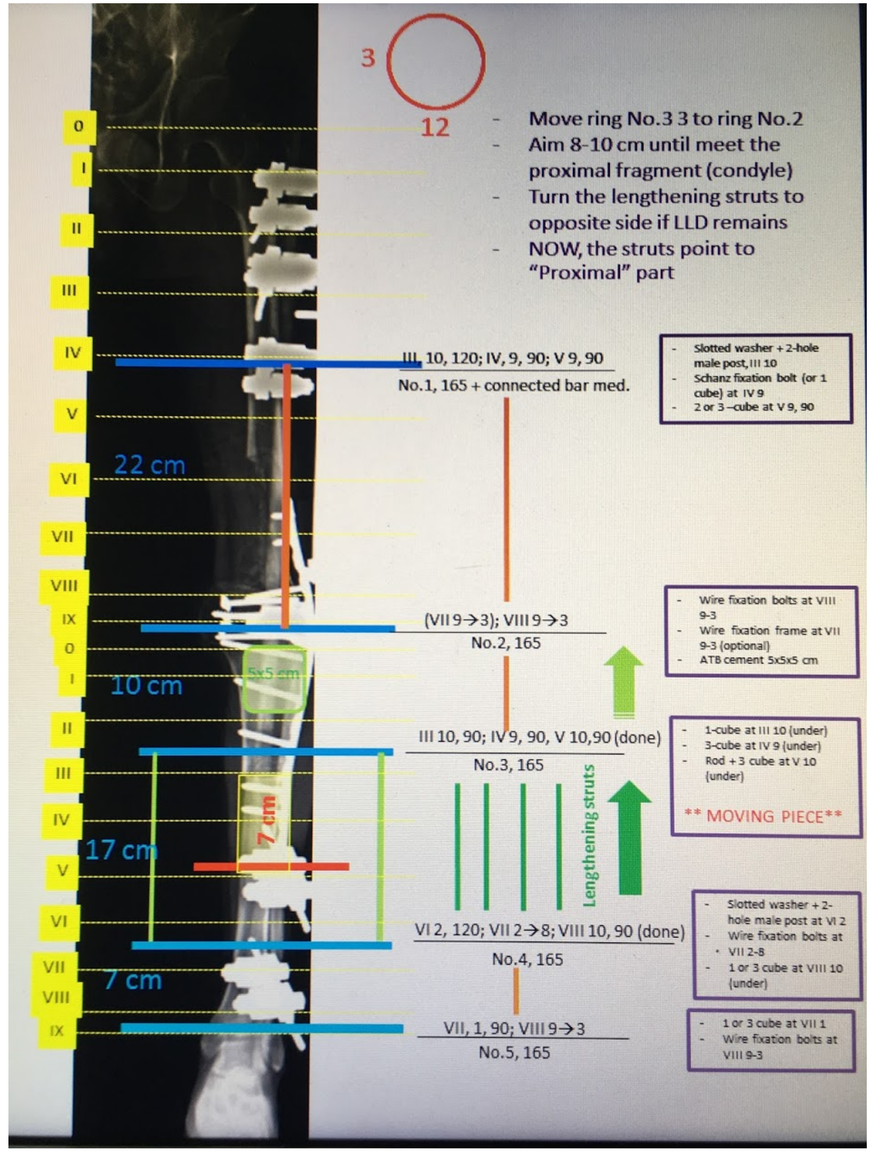


Pre-operative planning

Determine ‘Problem (s) ’ and availability of instruments

- LLD / defect alone
- LLD with deformity
  - One stage surgery: correct deformity and immediately lengthening in the same episode
  - Two stage surgery: correct deformity first then second stage for lengthening in the future





Pre-assembly frame

Goal: decrease operative time



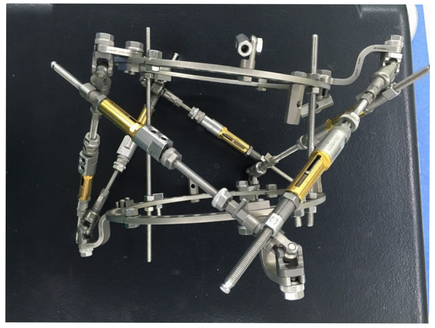


Frame assembly



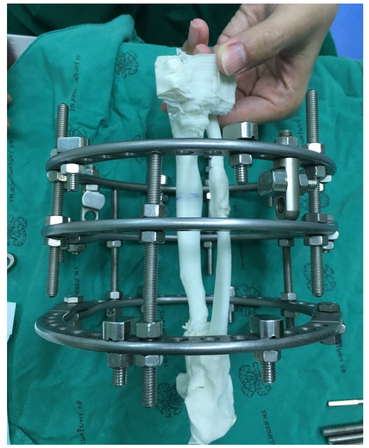




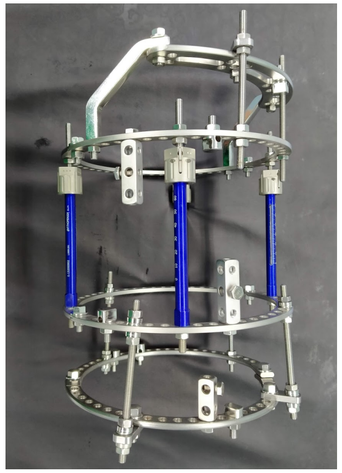




Some of
my frames



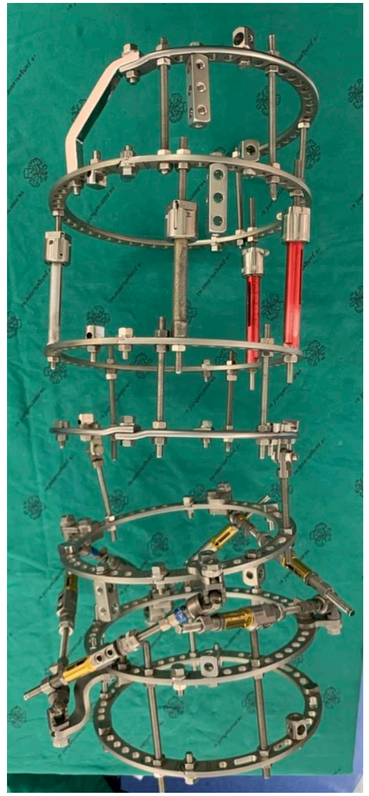






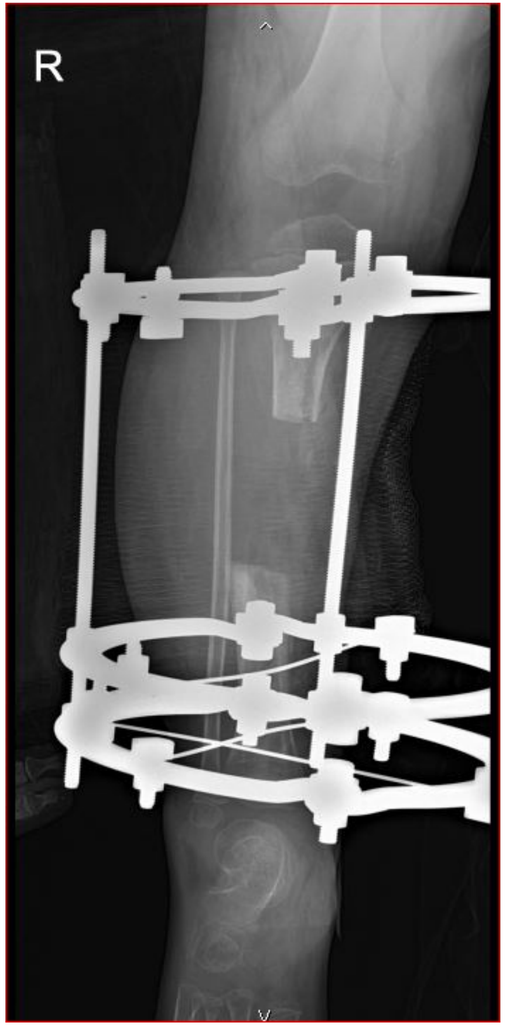




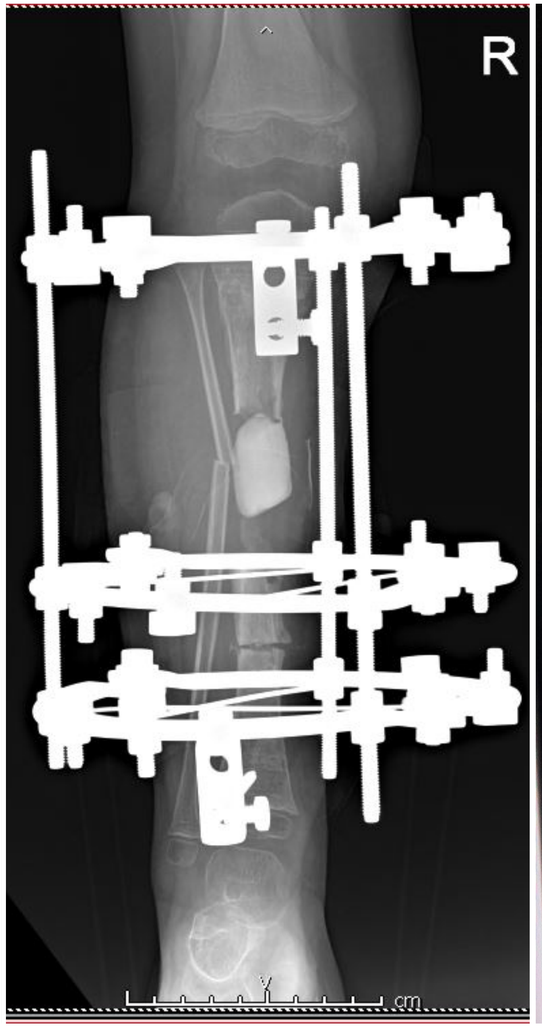


Emergency - unplanned frame











Osteotomy - Corticotomy - Osteoplasty

Make ‘complete’ bone gap while preserving the good ‘environment’

Techniques:

1. Classic open corticotomy
2. Percutaneous osteoplasty (osteotomy)

Factors

- Biological factors:
- Device factors

Complete osteotomy equally effective compared to corticotomy

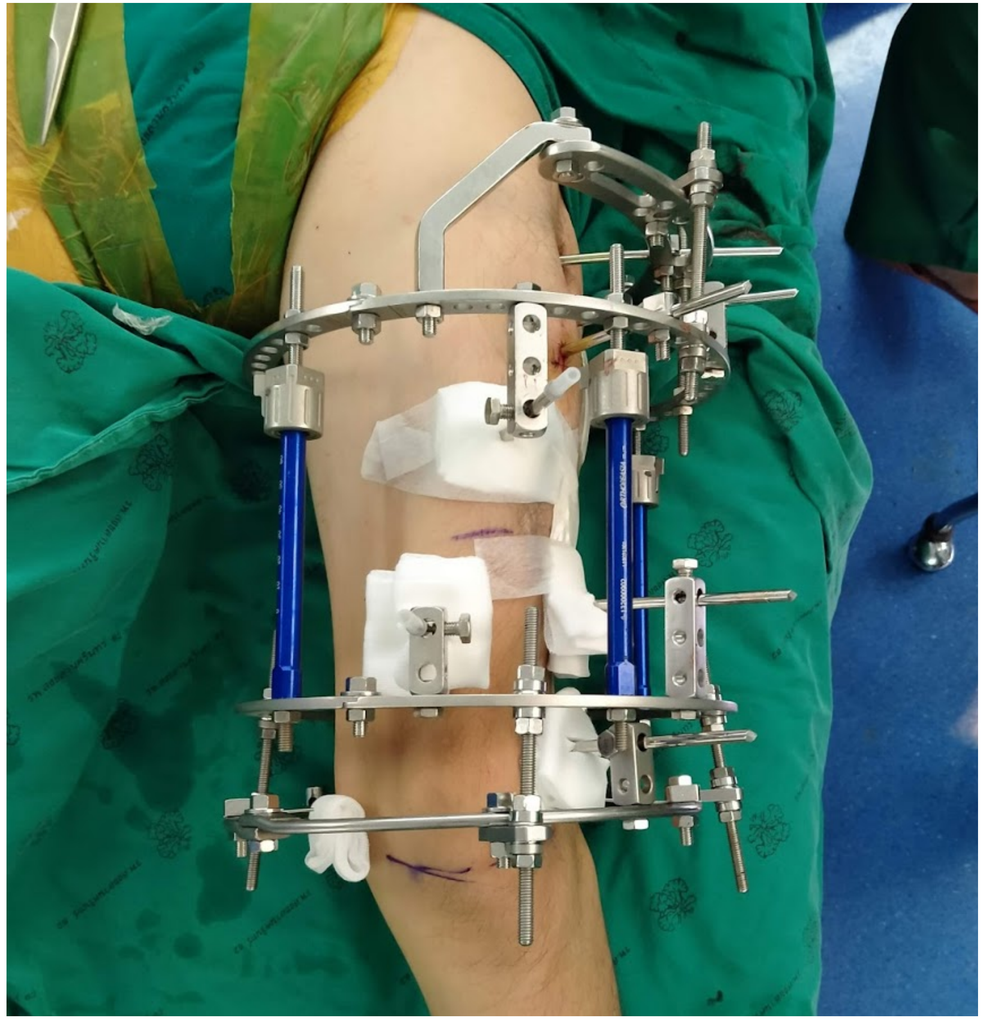
(Frierson 1994, Paley 1990)

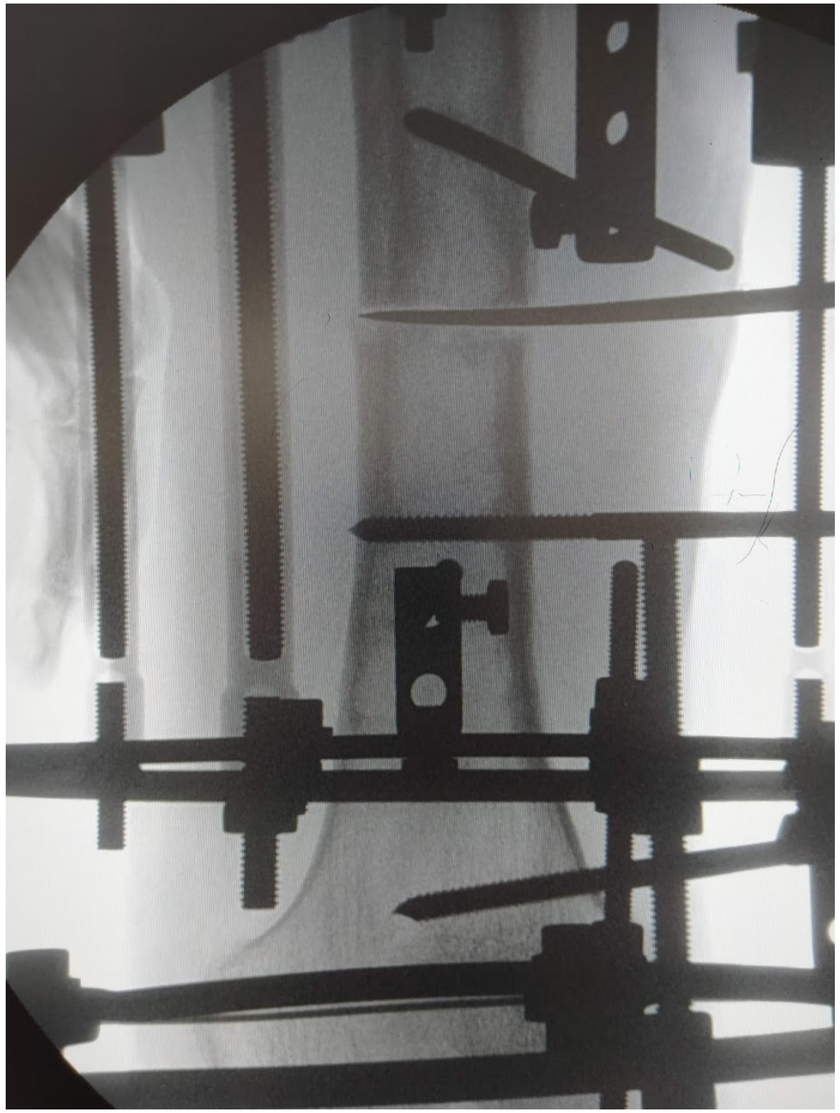
Location

1. Proximal metaphysis
2. Diaphysis
3. Distal metaphysis

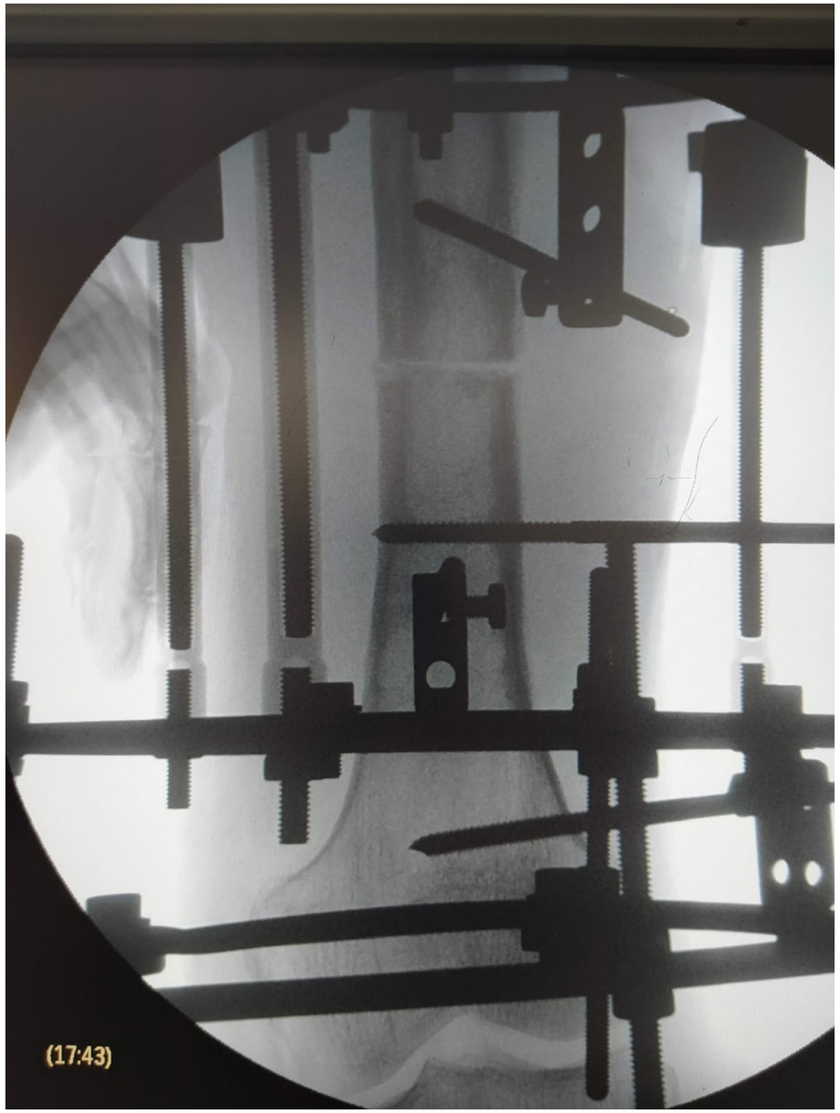
Factors

- Location of defect
- Sites of fixation





Percutaneous osteotomy through multiple drill holes



Complete osteotomy



Confirmation for complete osteotomy by immediate distraction around 3-5 mm

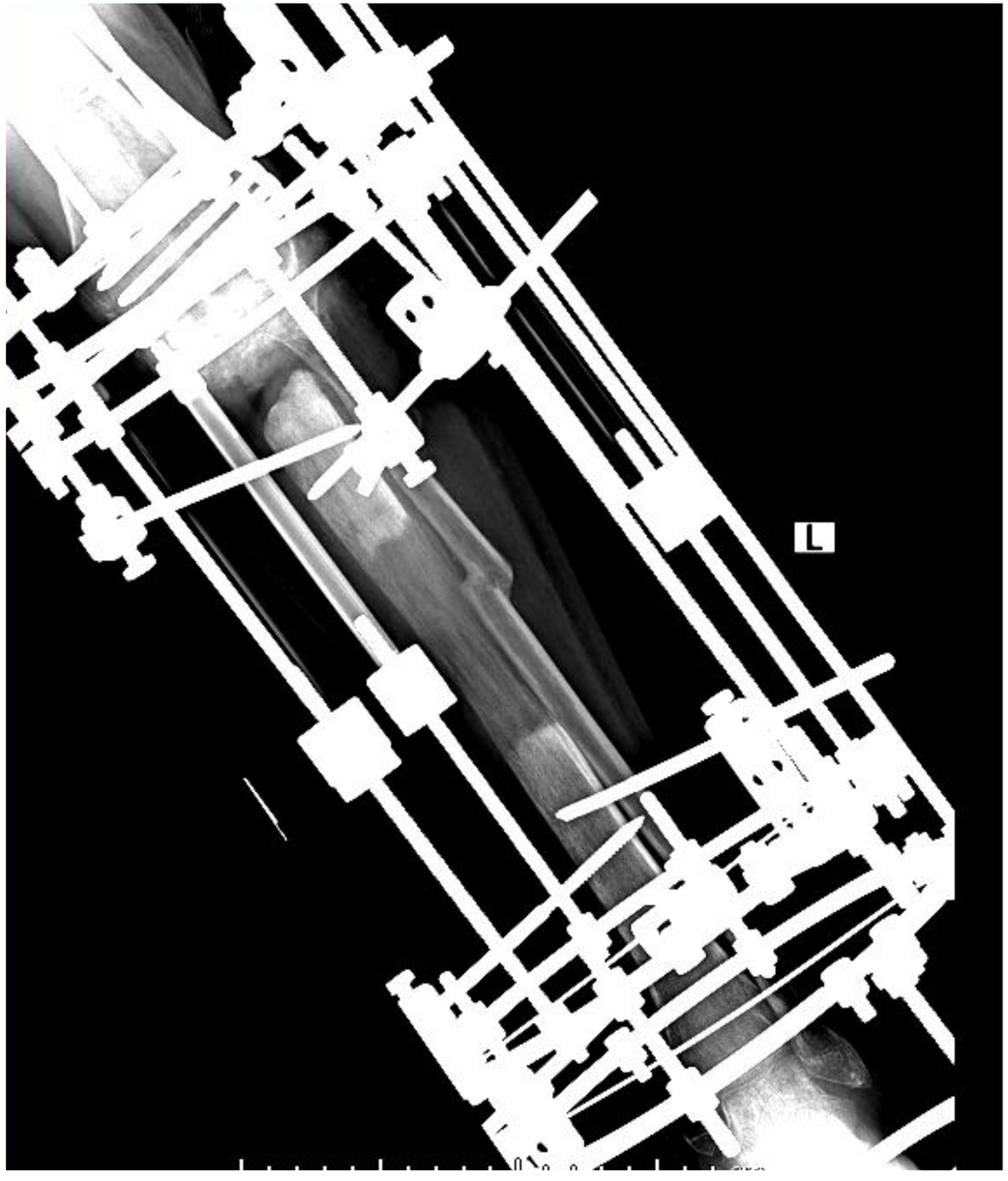
A 34-year-old man with previous giant cell tumor. No proximal tibial bone stock is noted.

Bone transport was performed. The osteotomy was done at middle to distal 1/3 shaft of tibia.

Consolidation in LCP (total transport 8 cm)

1 year after plating





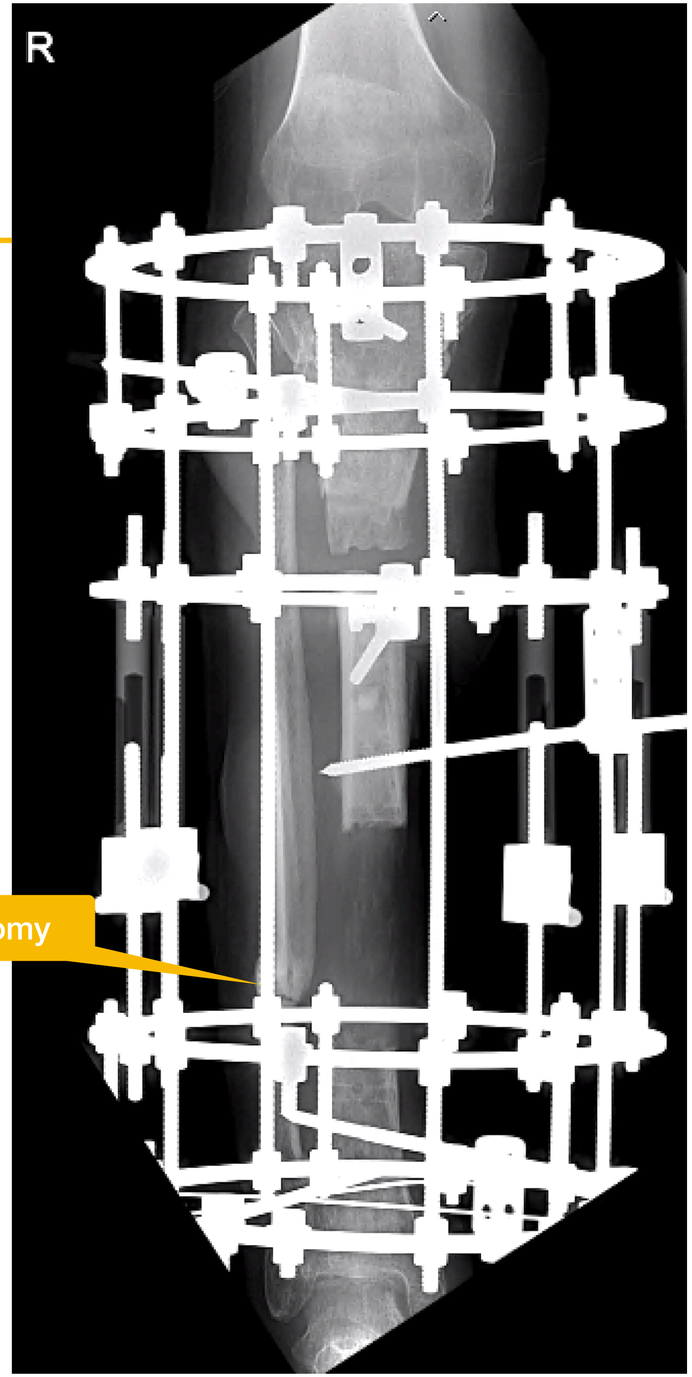




Adjunct procedure (s)

These procedures may be added;

- Fibular osteotomy
- Tensor fascia lata release: cutting the ‘enemy’ of lengthening
- Prophylaxis peroneal nerve decompression
- ‘Shoe’ frame for remaining LLD



Lengthening Protocol: ‘individual’

Rate

Premature healing

<

0.5-1 mm/day

>

Fibrous nonunion

Ilizarov, 1989

Rhythm

2-4 times/days

- Compliance
- Mechanical and biological properties of bone

Should not exceed **20%** of original bone length in lower extremity

Hosny, 2020

Time

- 4 times: 8.00, 12.00, 16.00 and 20.00
- 2 times: 8.00 and 20.00

- Compliance
- Avoid disturbance of growth hormone/endorphine

Lengthening Protocol: Upper extremity





A 10-year-old boy with MHE forearm. Progressive forearem angulation and radial head subluxation of Lt side were noted.



Corrective osteotomies and ulnar lengthening



Distraction rate: 0.5 >> 0.75 >> 1 mm/day



Total distraction = 3.2 cm in 4 month

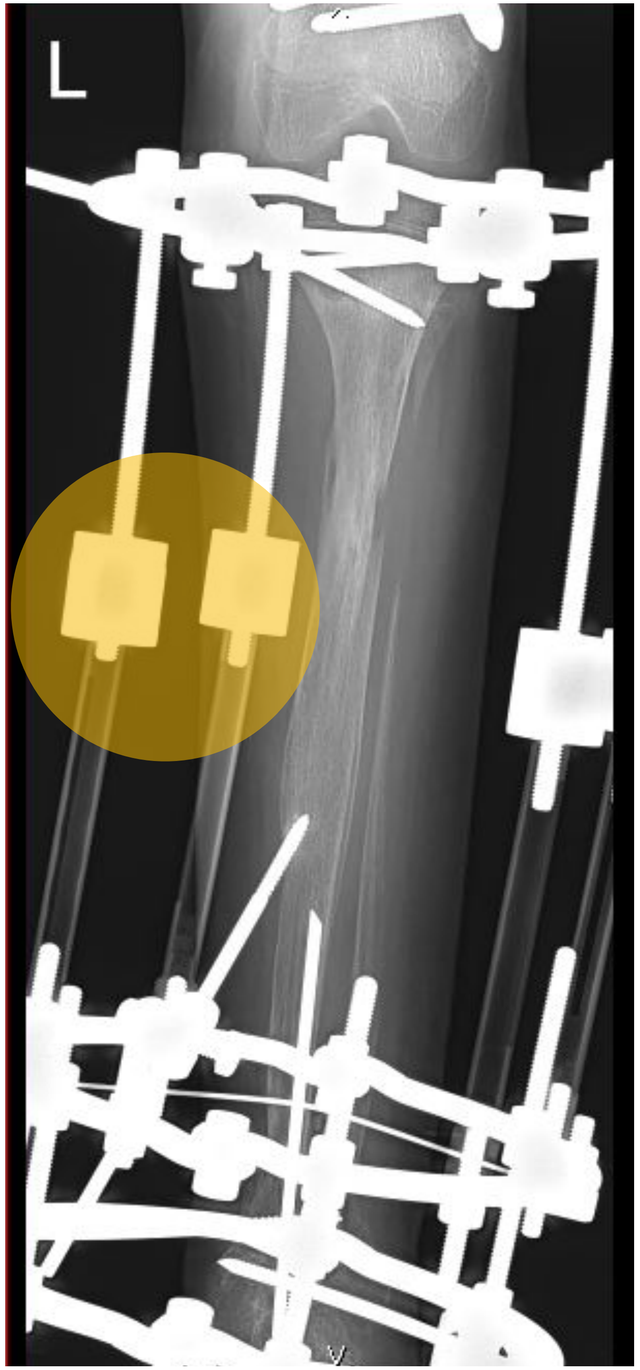
Follow Up:

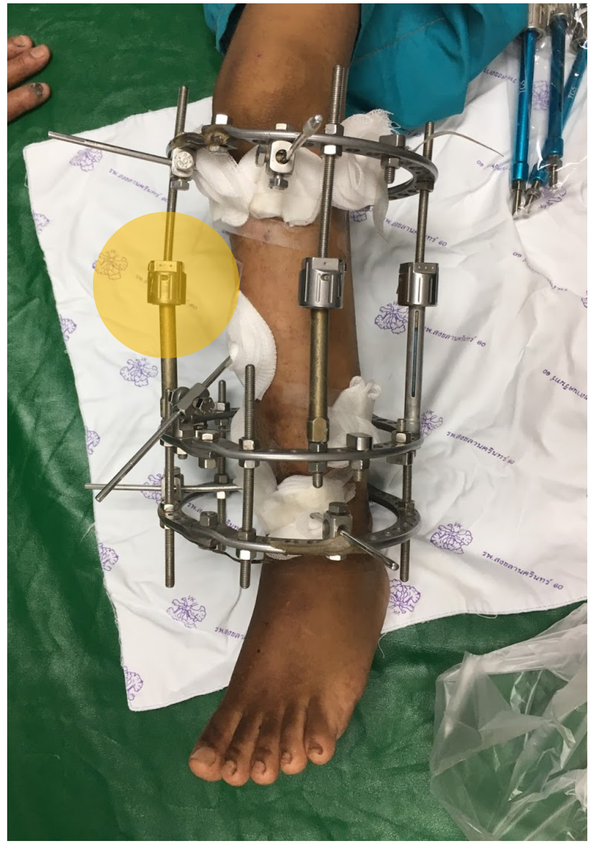
Depent on patient compliance and complexity of the system

- First visit: 10 mm
- Second visit: 20 mm
- Then monthly

Looking for:

- Infection
- Relation between radiographic lengthening distance and timing
- Quality of home dressing
- Length of struth: ending of telescoping rod
- Frame distance
- Sign of
  - neuropathy
  - contracture/stiffness
  - joint subluxation / dislocation









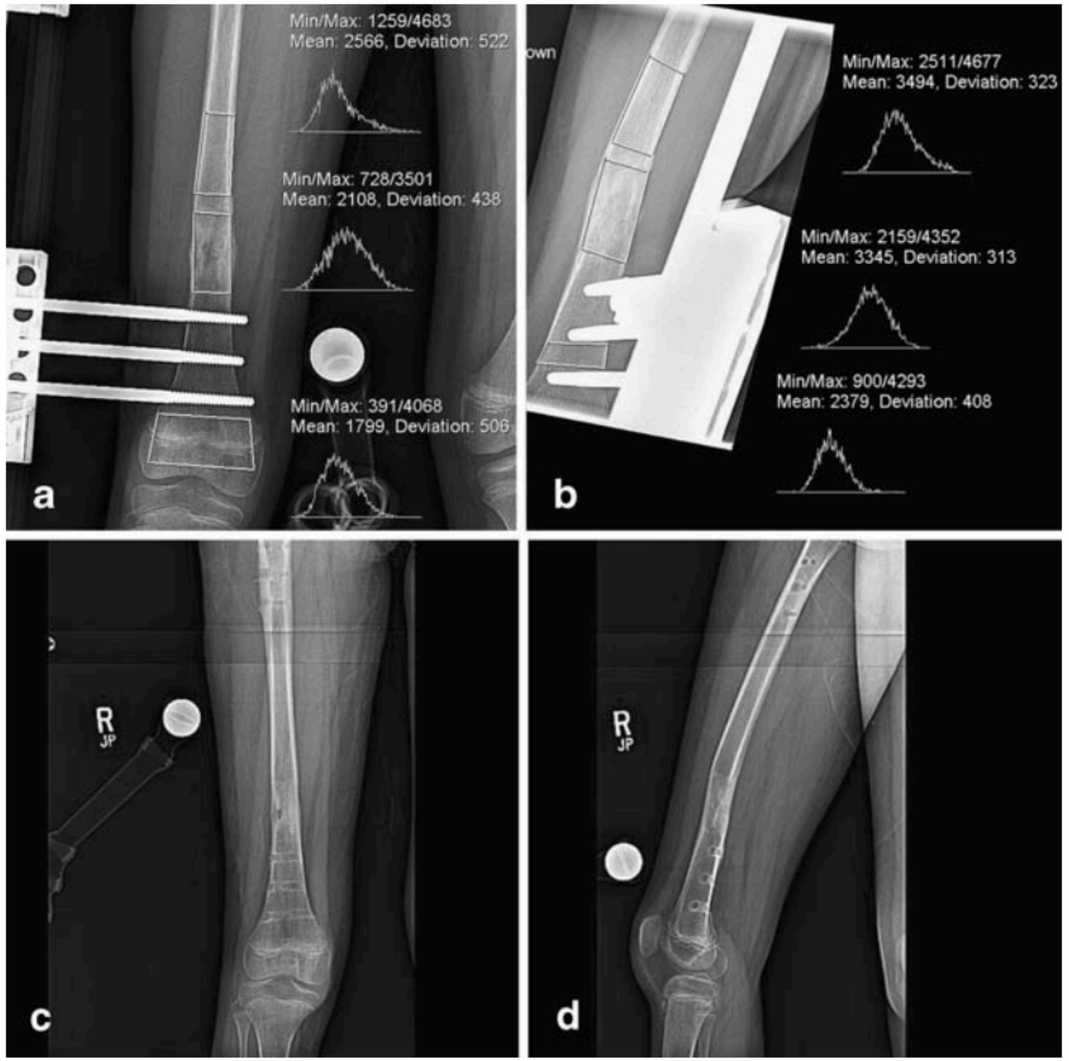
Assessment of new bone formation

These methods can be used;

- Physical examination
- X-ray: removal of fixation when
  - **Presence of 3/4 continuous cortices at least 2 mm on AP and lateral views**
- CT scan
- DEXA scans to assess BMD
- Pixel density technique

FOR

- Removal of fixation system
- Dynamization
- Growth acceleration
- Stop treatment



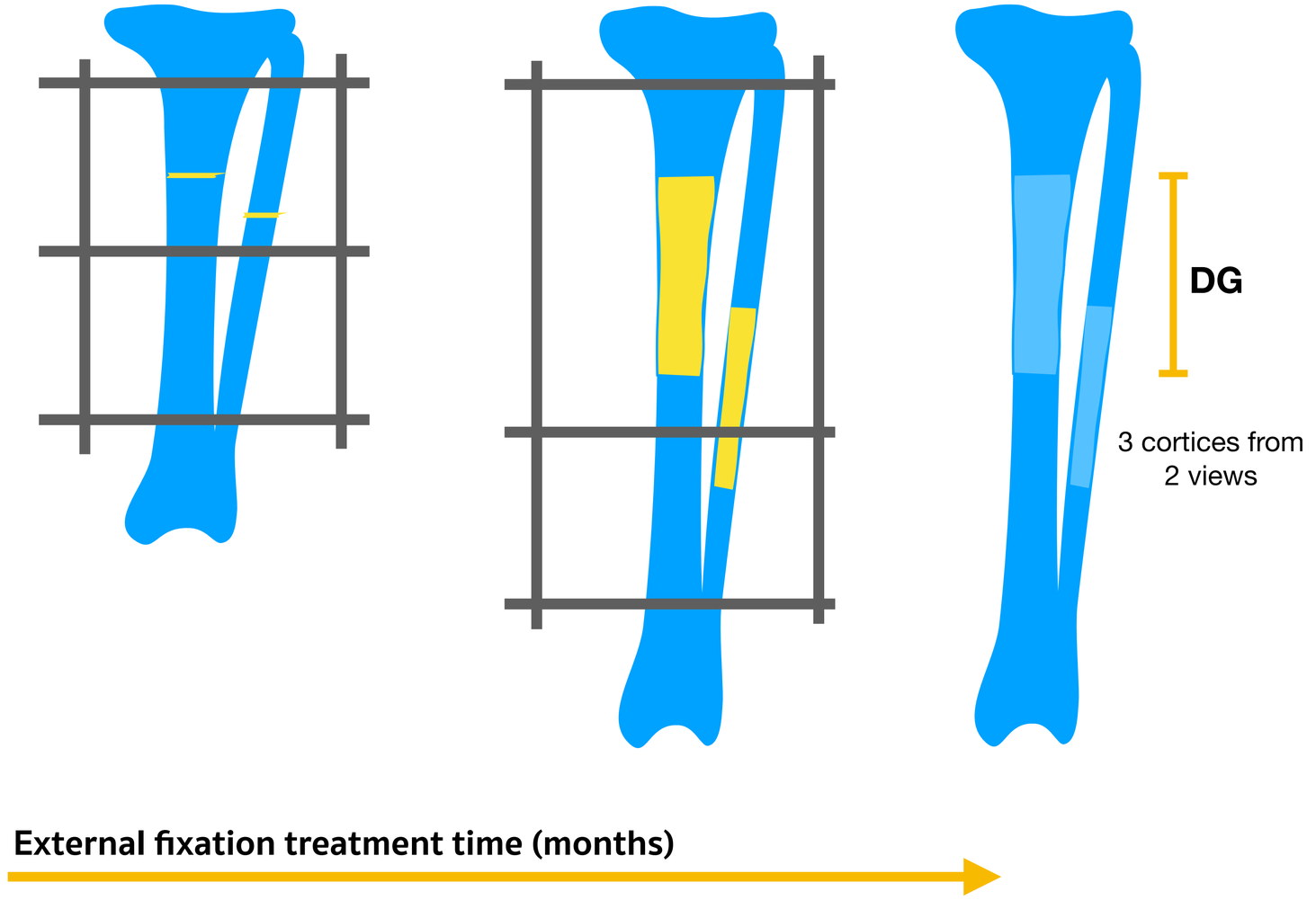
Babatunde 2010

Lengthening Index

Number of months of external fixation treatment per centimeter of elongating distraction gap (DG)

Paley 1990, Fischgrund et al. 1994

For example, DG = 4 cm in 4 months
>> LI = 4/4 = 1 month per 1 centimeter



How to ‘Decrease’ lengthening index

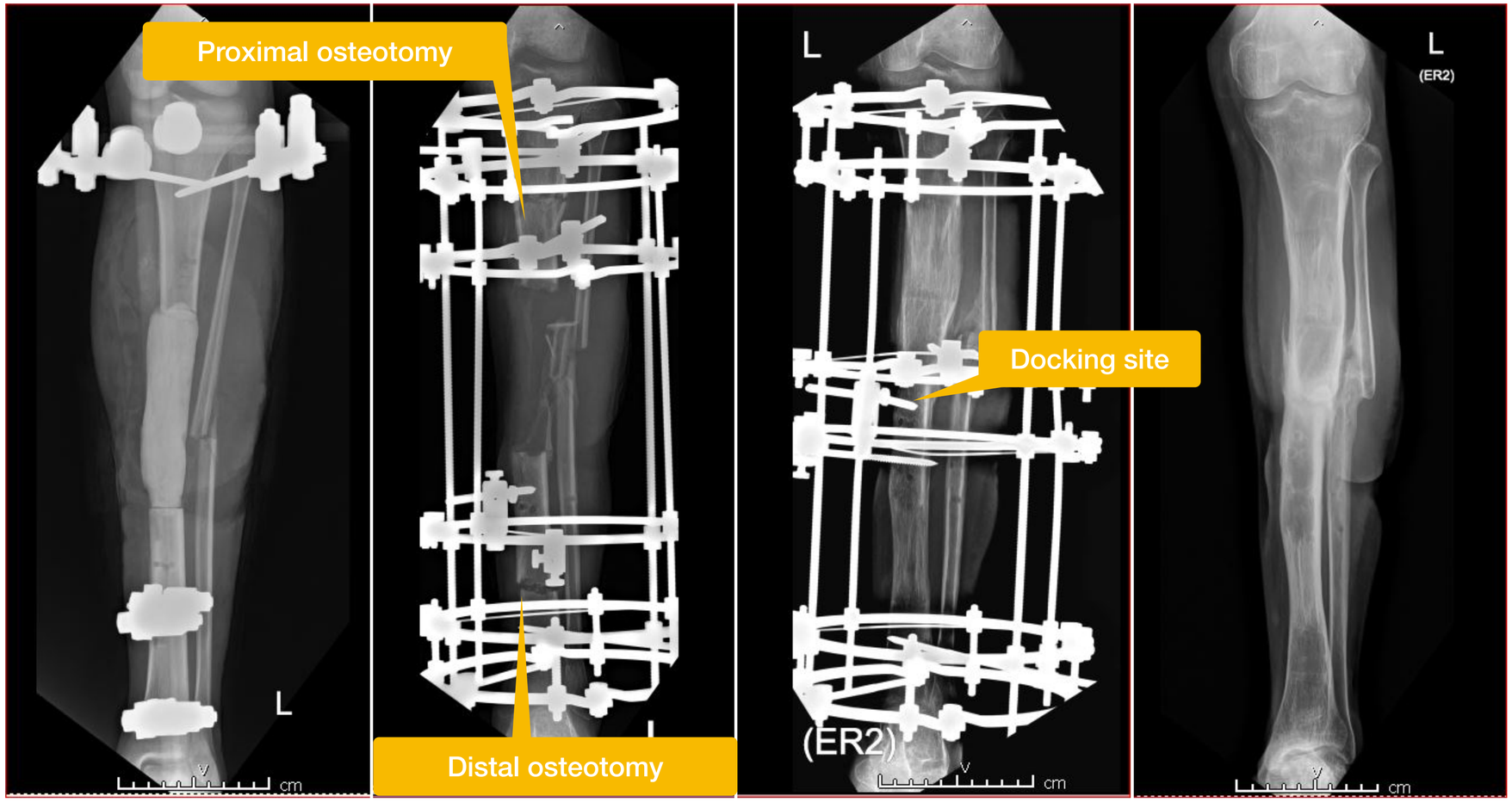
i.e., decrease time of fixation while maintaing the expected lengthening distance

These procedures might be combinded with each other;

- Increase osteotomy site : Biofocal / trifocal osteotomy
- Frame dynamization
- Using internal device for consolidation
- Acceleration of bone formation:
  - BMPs
  - Bone marrow injection
  - Bone graft

A 19-year-old man with previous open fracture and osteomyelitis

Procedures: Bifocal bone transport with bone marrow injection



Lengthenin index: around 0.5 month/cm

A 8-year-old girl with MHE forearm





Ulnar lengthening to correct radial head dislocation



Deep pin tract infection

Lytic lesion and pin loosening

Complications

- **Infection**: might be 100%
  - Superficial
  - Deep: osteomyelitis, pin loosening
- Aseptic loosening
- Fracture through lengthening site
- Joint problems
  - Stiffness
  - Subluxation/dislocation
- Disuse osteopenia
- Neurovascular issues
- Others: MRI issue

Table 1 Overall complication rate during lengthening

Study	Procedure	No. of patients	Period of study	Complication rate	No. of surgeons
Bukva et al. [38]	IEF or IEF& IA	73	14 years	83.6%	Single
Lascombes et al. [36]	Multiple	32	3 years	75%	Multiple
Lee et al. [68]	ISKD	35	2 years	74%	Single
	PRECICE 1	34	Not available	17.4%	Single
	PRECICE 2	64	Not available	50%	Single
Castelein and Decquer [39]		39	14 years	84%	Multiple
Reitenbach et al. [40]	TSF & IEF	43	16 years	TSF 12.1% IEF 50%	Multiple
Manggala et al. [41]	TSF & IEF	14	4 years	TSF 28.6% IEF 71.4%	Multiple
Guerreschi and Tsibidakis [43]	IEF	63	25 years	81%	Multiple
Novikov et al. [42]	IEF	138	23 years	37%	Multiple

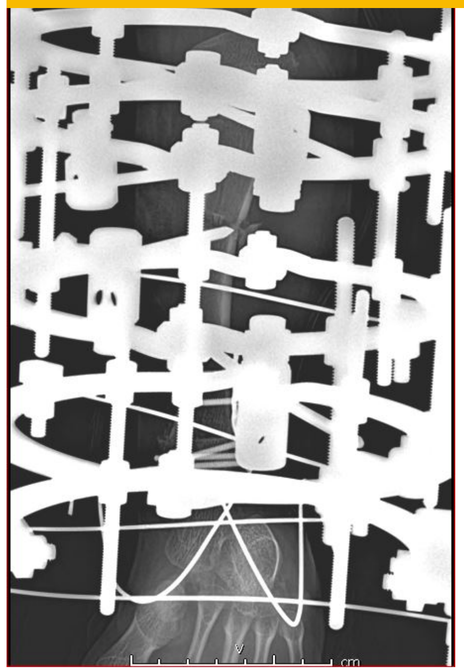
IEF Ilizarov external fixator, *IA* intramedullary alignment, *ISKD* Intramedullary Skeletal Kinetic Distractor, *TSF* Taylor Spatial Frame

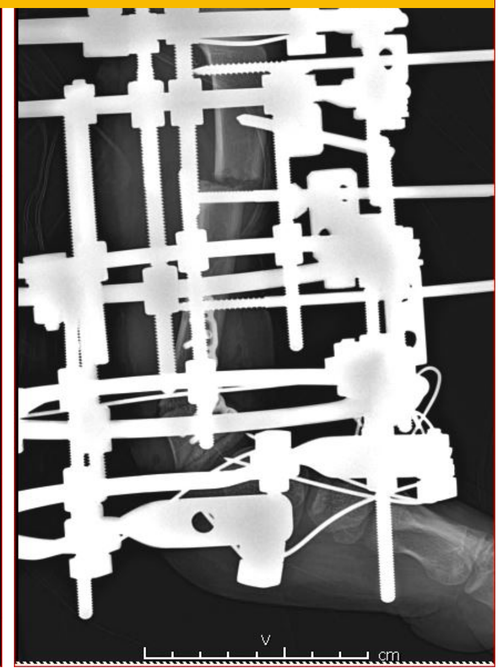
Hosny, 2020

A 3-year-old girl with fibular hemimelia Lt side

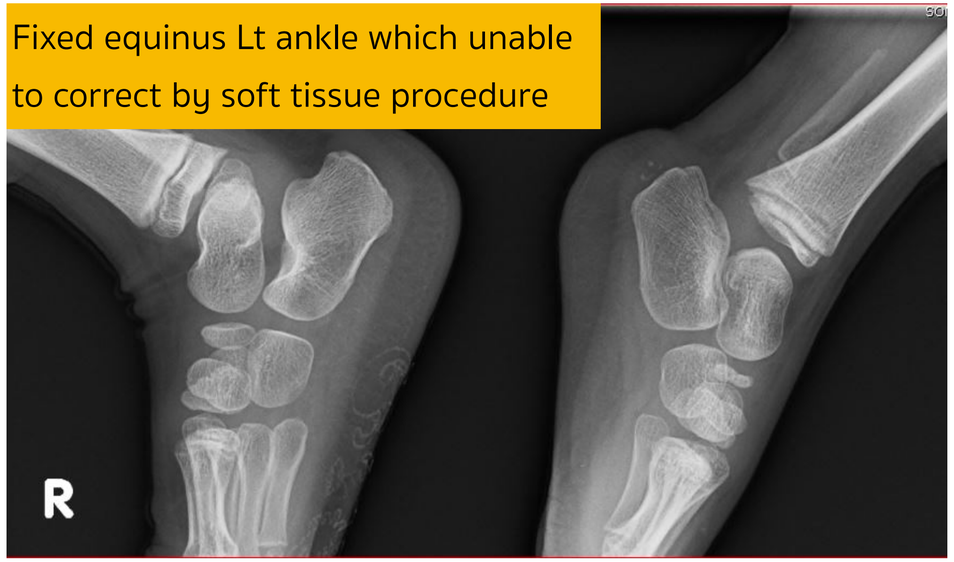


SUPERankle procedure and immediate Lt leg lengthening





Fixed equinus Lt ankle which unable to correct by soft tissue procedure





Fracture through lengthening site after falling



ORIF with recon locking plate

Fracture at distraction site

A 58-year-old woman with previous open fracture and bone loss. Ilizarov was applied for bone transport



She accidentally had MRI for fatty liver f/u. Pin loosening and burn were documented.

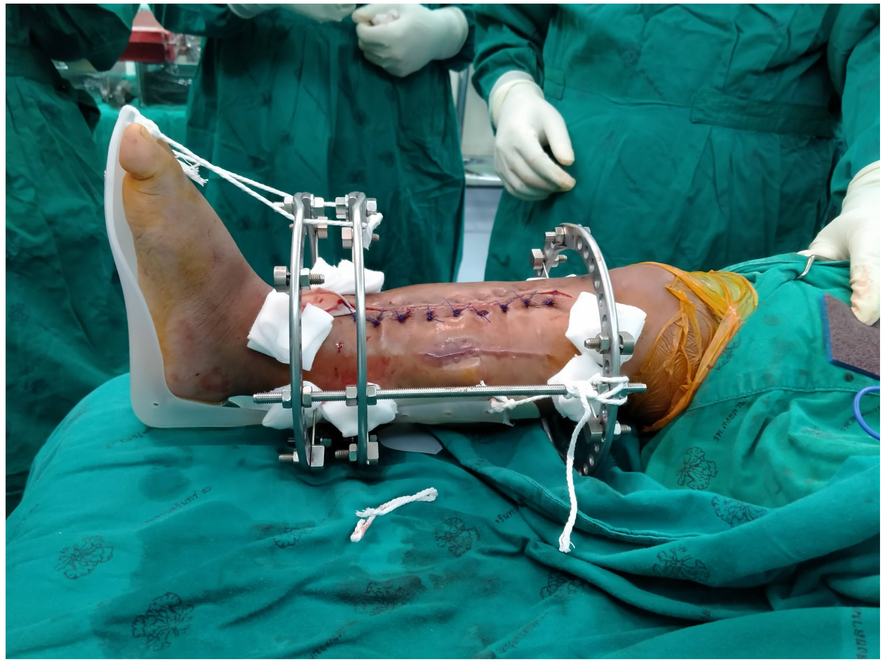


Management: change ALL pins and wires

BEWARE of MRI !!!!!!!!!

Complication: How to prevent / reduce





- **Infection**: **early detection !!!**
  - Antibiotic prophylaxis
  - Dressing protocol
- **Aseptic loosening**
  - HA coated wire/pin
- **Joint problems**
  - Stiffness: rehabilitation, hinge frame, AFO
  - Subluxation/dislocation: carefully pre-op / follow up assessment
- Others

Future ....

Hope ...

- (More) cheaper internal devices (IM nail, plate)
- If we still use the external devices, would they be possible to;
  - Good material surface in terms of prevention of bacterial adhesion
  - Easier to control by patient/family
  - Easier to assembly by surgeon

THANK YOU

