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Distraction Osteogenesis: A Method of Surgical Reconstruction after Tumor Resection or Radiation Therapy

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Orthopedic Tumor Surgery

Radical resections for tumor control

- Osteogenic Sarcoma, Ewing's Sarcoma, etc.

Tumors often located in extremities

Large bone/soft tissue compartments

Emphasis on negative margins

Large resections lead to large bone defects

- Need for reconstructive options to put the limb back together

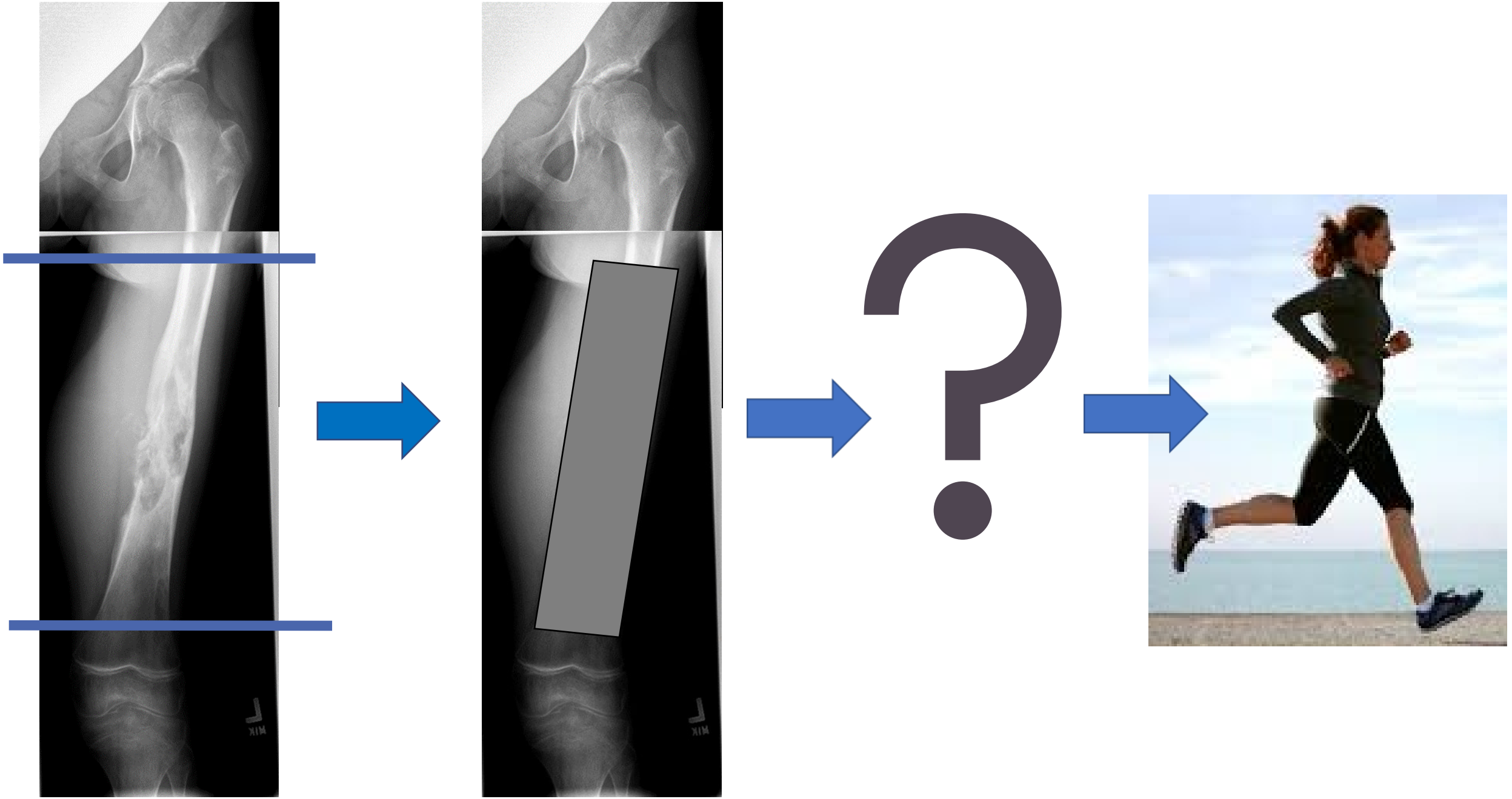
Functional loss due to nature of surgery

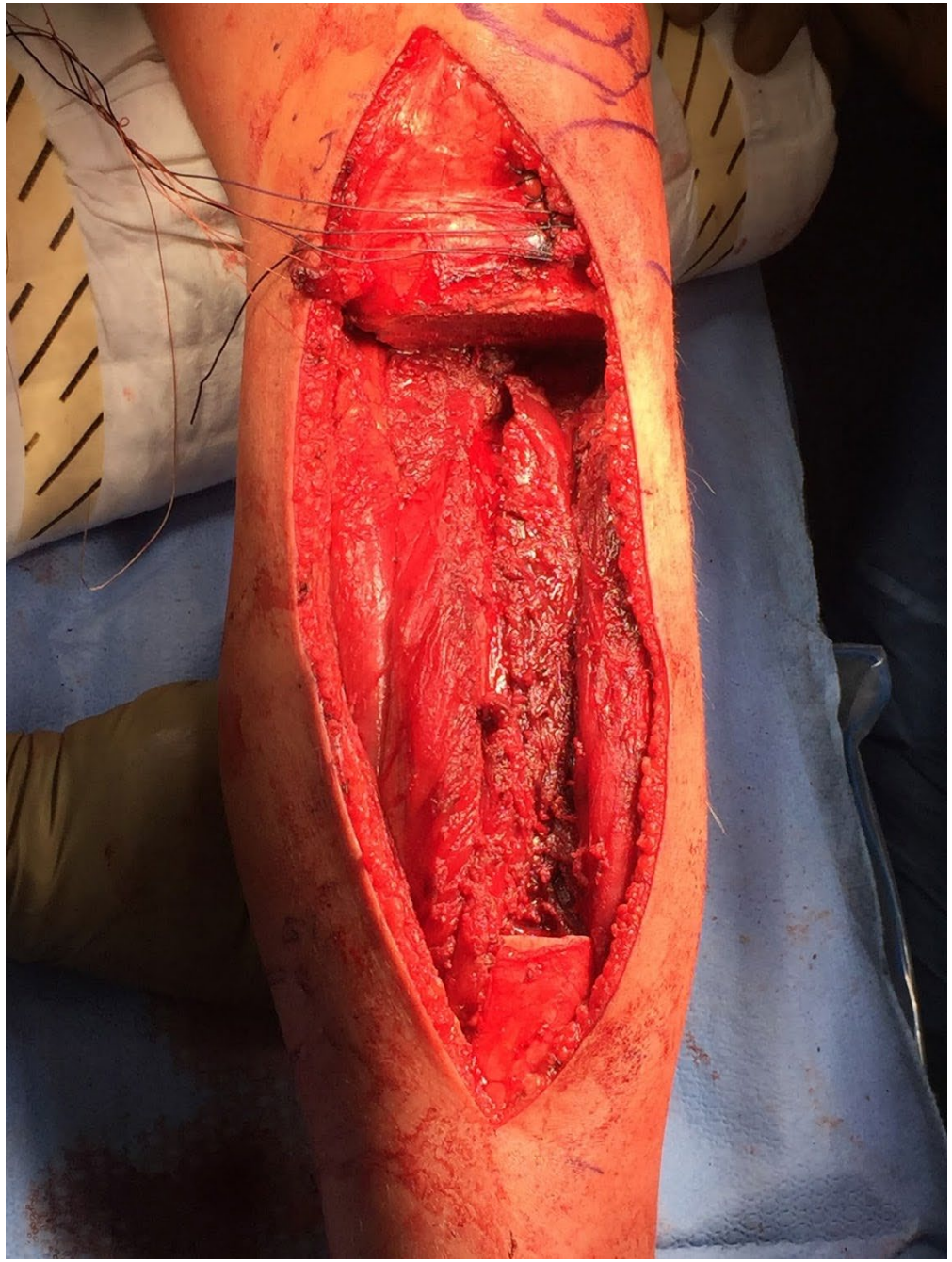
What would you do?

16 y/o with a new diagnosis of osteogenic sarcoma of the femur

- Tumor includes the diaphysis of the femur and extends 20 centimeters
- The hip and knee joint are preserved
- Complete resection is possible with negative margins
- No metastatic disease
- Pre-op chemotherapy 3 months
- Post-op chemotherapy 6 months

WHAT RECONSTRUCTION OPTION WOULD YOU CHOOSE FOR YOURSELF??





Traditional Reconstruction Options

Amputation→ above knee, below knee, rotationplasty

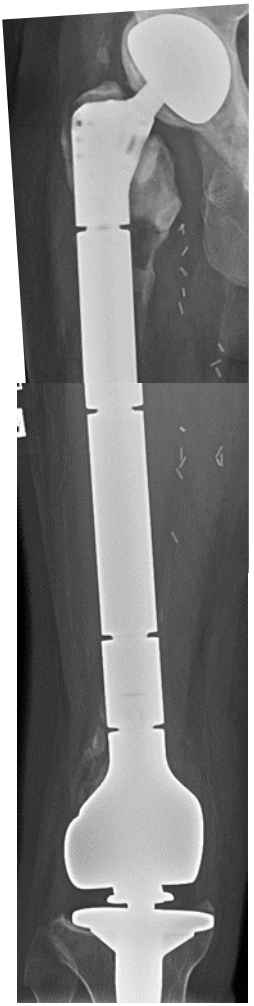
Pros

- Safe/quick surgery
- Excellent oncological surgery
- Minimal infection risk
- Minimal down time
- Good functional outcome with prosthesis

Cons

- Amputation…
- Phantom limb pain
- Activity modification
- Stump revisions

Traditional Reconstruction Options



Metal Replacement

Pros

- Minimal down time
- Return to basic function quickly
- Faster surgical time
- Good oncological surgery

Cons

- High lifetime infection risk
- Limb length discrepancy
- Hardware loosening
- Limited ability to do high impact activity
- Need for revision surgeries later in life
- Loss of bone stock
  - Which leads to loss of activity

Traditional Reconstruction Options

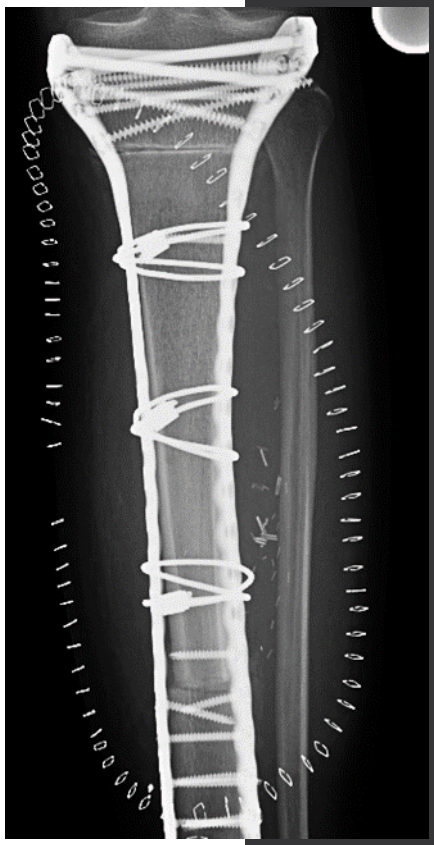
Allograft

Pros

- Good oncological surgery
- Ability to incorporate into host bone
- Preserve joint until maturity
- Faster recovery and return to basic activity

Cons

- High lifetime infection risk
- High incidence of failure/revision
- Will likely require joint replacement later in life
- Non-union
- Limited activity allowance
- Long time until full allograft incorporation

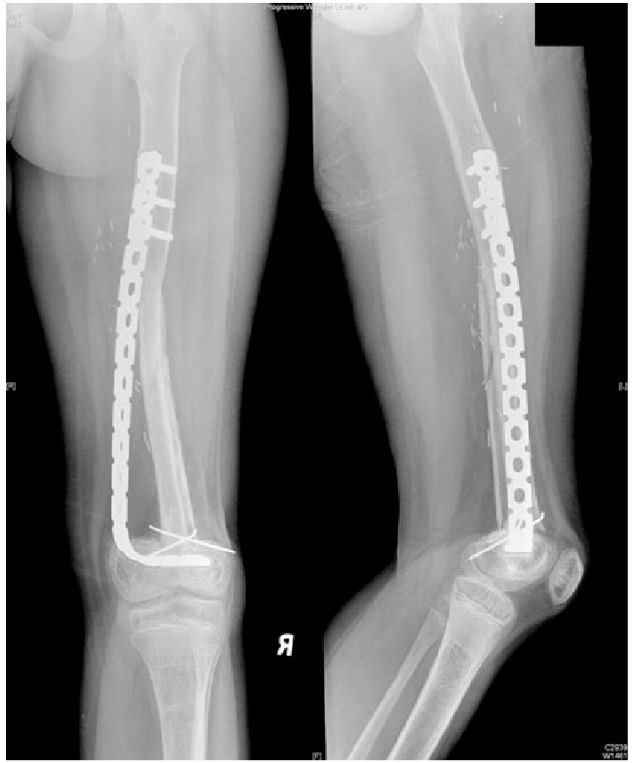


Traditional Reconstruction Options

Vascularized Fibula

Pros

- Good functional outcome at full healing
- Good oncological surgery
- Autograft
- Ability to heal and respond to stress



Cons

- Long recovery time
- Long period of non-weight bearing
- Watchful waiting
- Donor site morbidity
- Vascular failure
- Allograft infection
- Long term activity modification
- Revision surgery

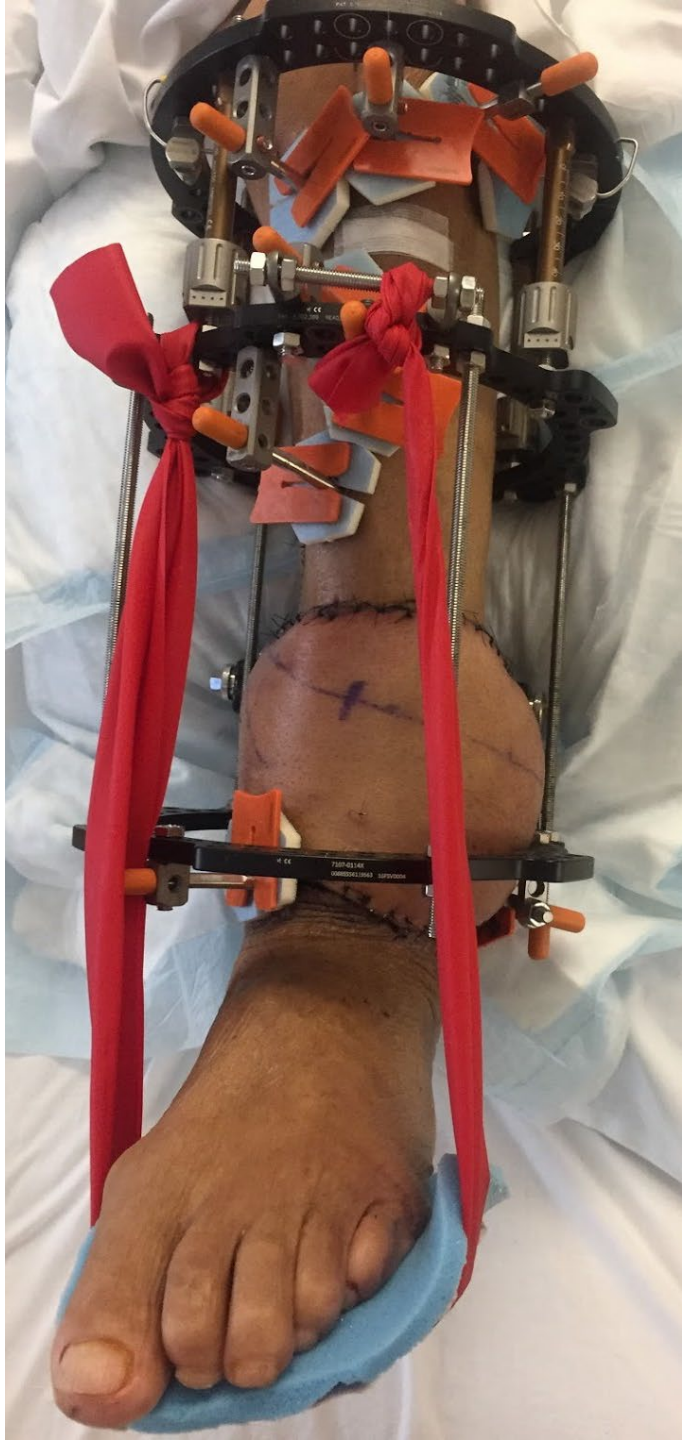
Distraction Osteogenesis

Pros

- Good oncological surgery
- Ability to preserve joints
- Excellent long term functional result
- No activity limitations/modifications
- Ability for bone to fight infection/heal fractures
- Own bone, no foreign material
- Ability to correct length discrepancy
- Does not burn any surgical bridges
- Minimal need for revision surgery later in life

Cons

- Long surgical time
- Technically complex procedures
- Up to 3 years until maximal recovery
- Long/complicated process
- Requires visits every 2 weeks
- Uncomfortable/painful
- Limited short term mobility
- Short term risk of infection of pin sites, etc.



DO versus Traditional

Distraction osteogenesis is difficult in the short term,
but yields a long term benefit.

Other reconstruction options are easier in the short term and have a faster recovery, but have significant long term complications.

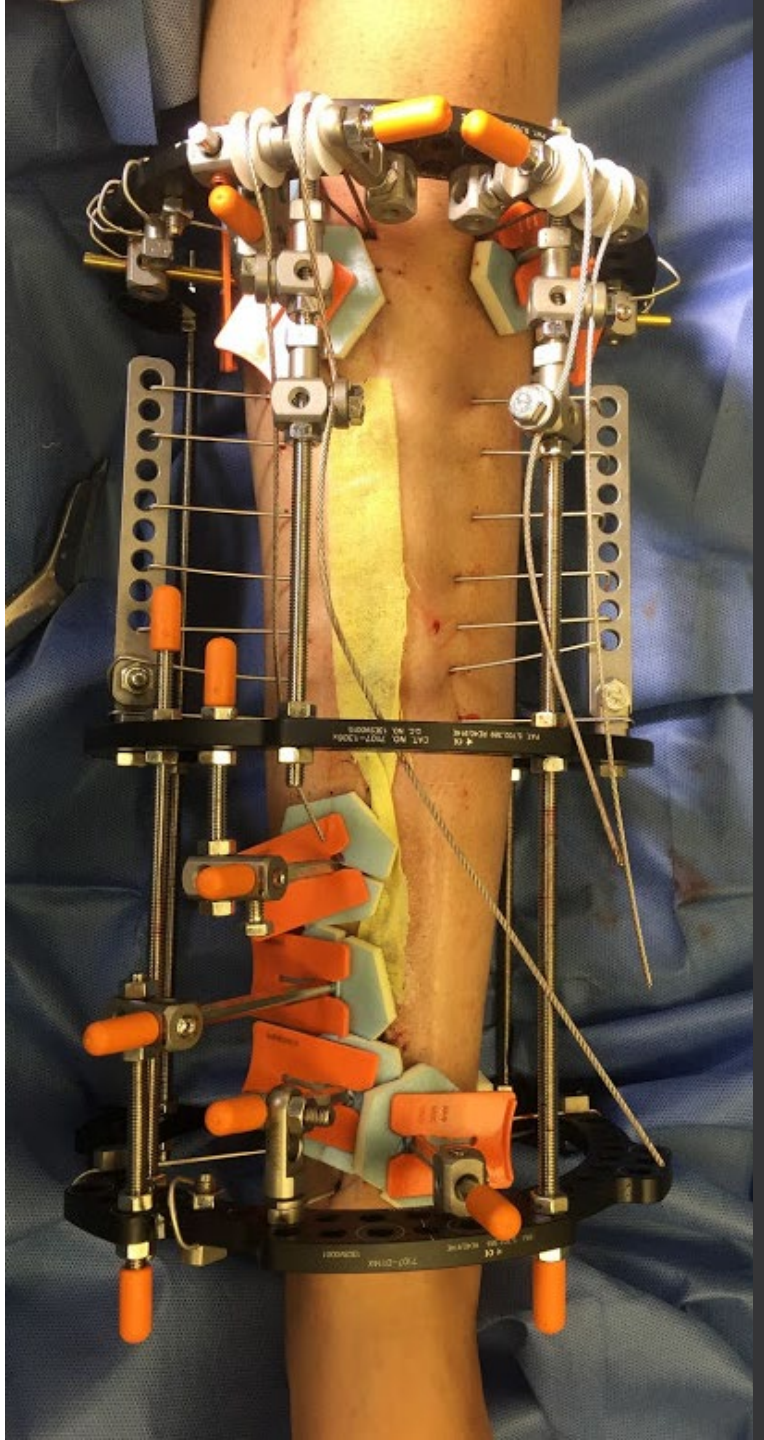
What would you do?

- 16 y/o with a new diagnosis of osteogenic sarcoma of the femur
  - Tumor includes the diaphysis of the femur and extends 20 centimeters
  - The hip and knee joint are preserved
  - Complete resection is possible with negative margins
  - No metastatic disease
  - Pre-op chemotherapy 3 months
  - Post-op chemotherapy 6 months

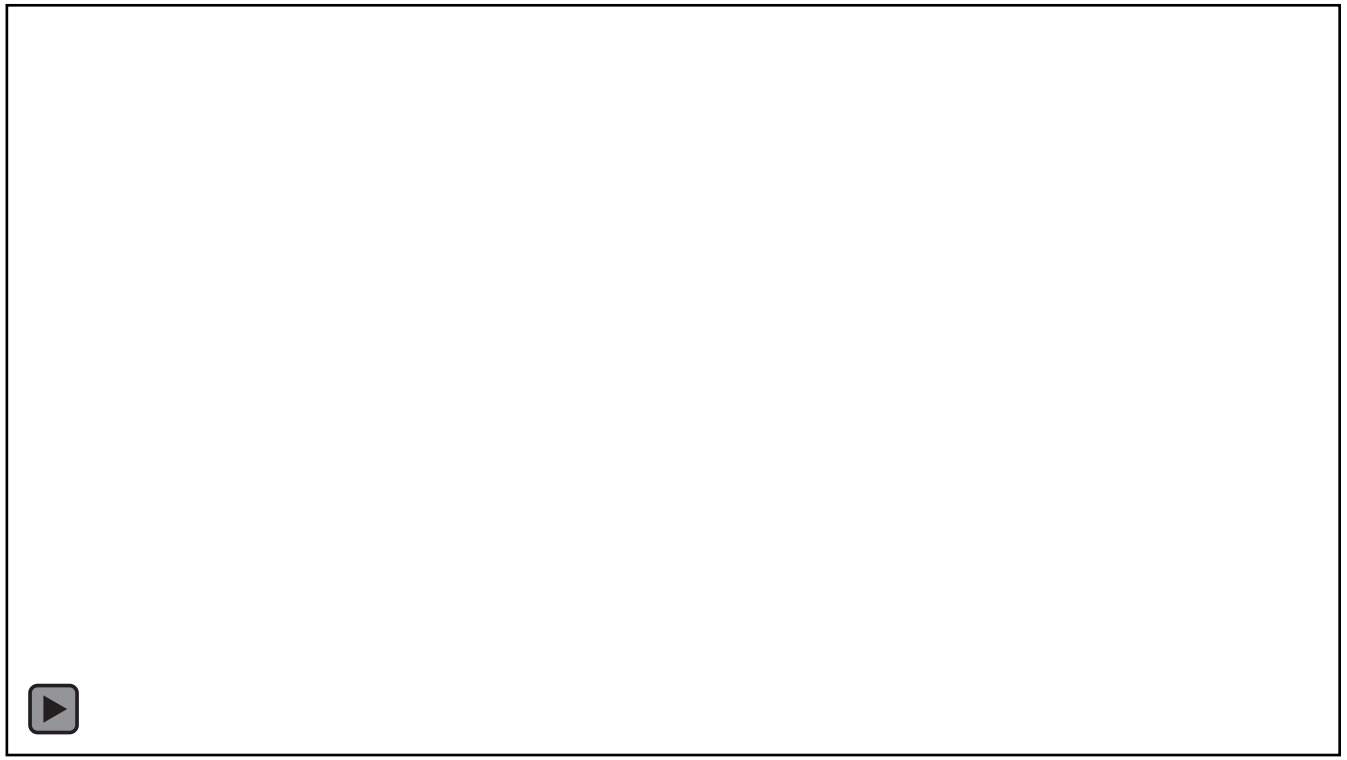
WHAT RECONSTRUCTION OPTION WOULD YOU CHOOSE FOR YOURSELF??

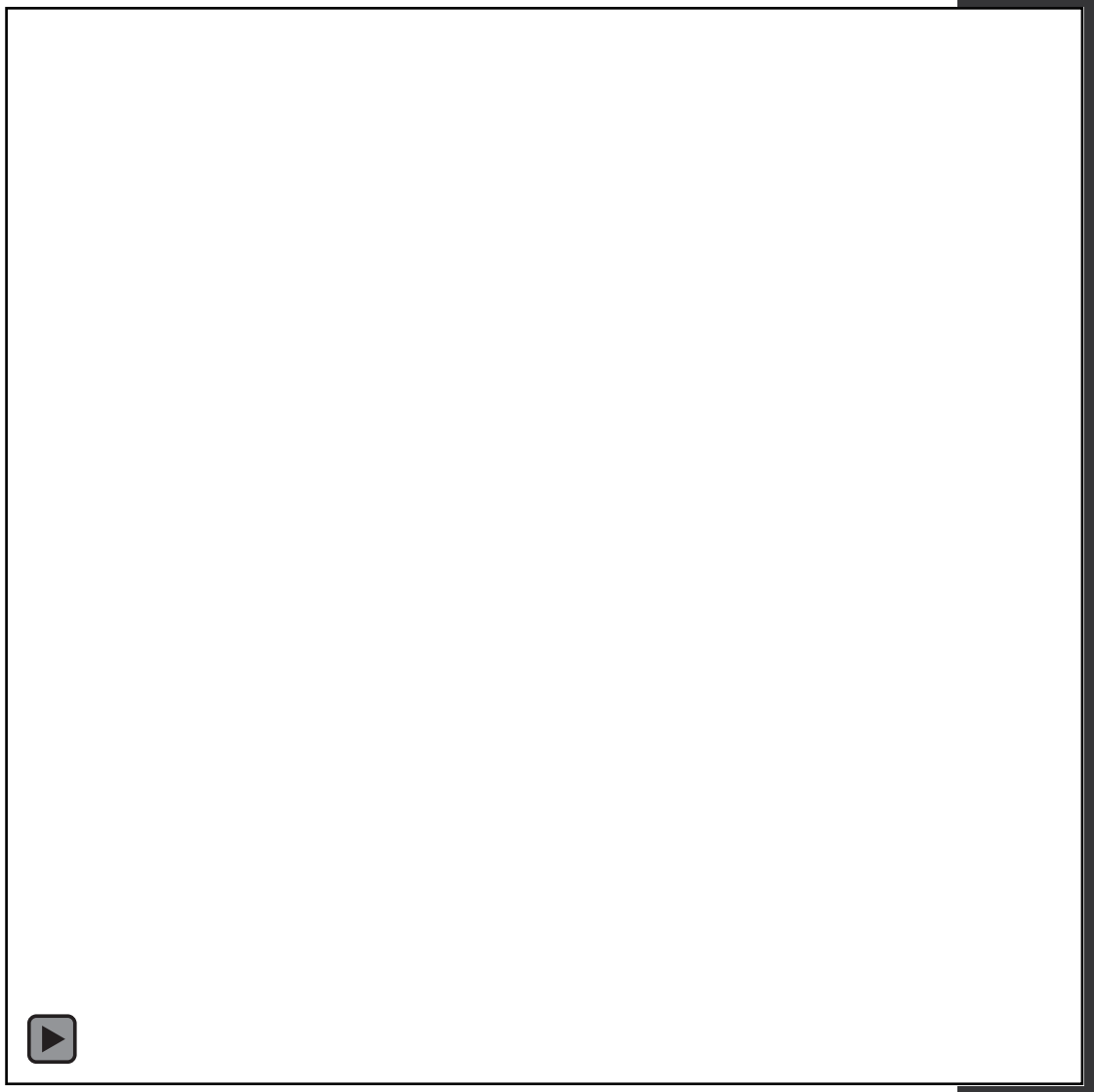
Post Radiation Therapy Rehabilitation and Growth Correction

- Many pediatric cancers metastasize to the bone
- Many can still be cured with high dose radiation therapy to sites of osseous metastasis
  - Rhabdomyosarcoma
  - Neuroblastoma
  - Retinoblastoma
- Radiation has detrimental effects on bone structure & physeal growth
  - Limb-Length Discrepancy
    - Variable: minimal - Complete Physeal Arrest
  - Growth Deformity/Angulation
    - Curvature of Long Bones
    - Limited Range of Motion of Joints



After radiation therapy to metastatic site of neuroblastoma in left proximal tibia



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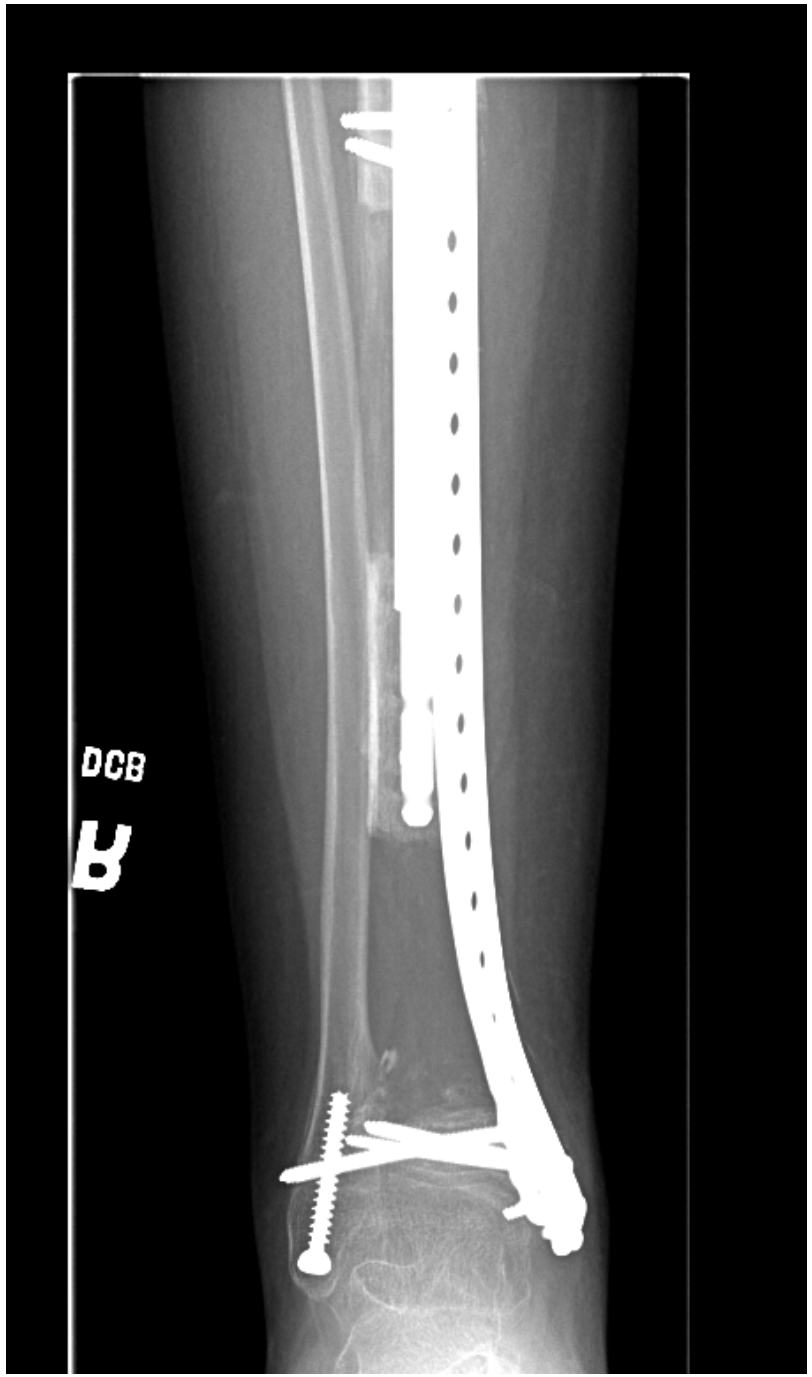
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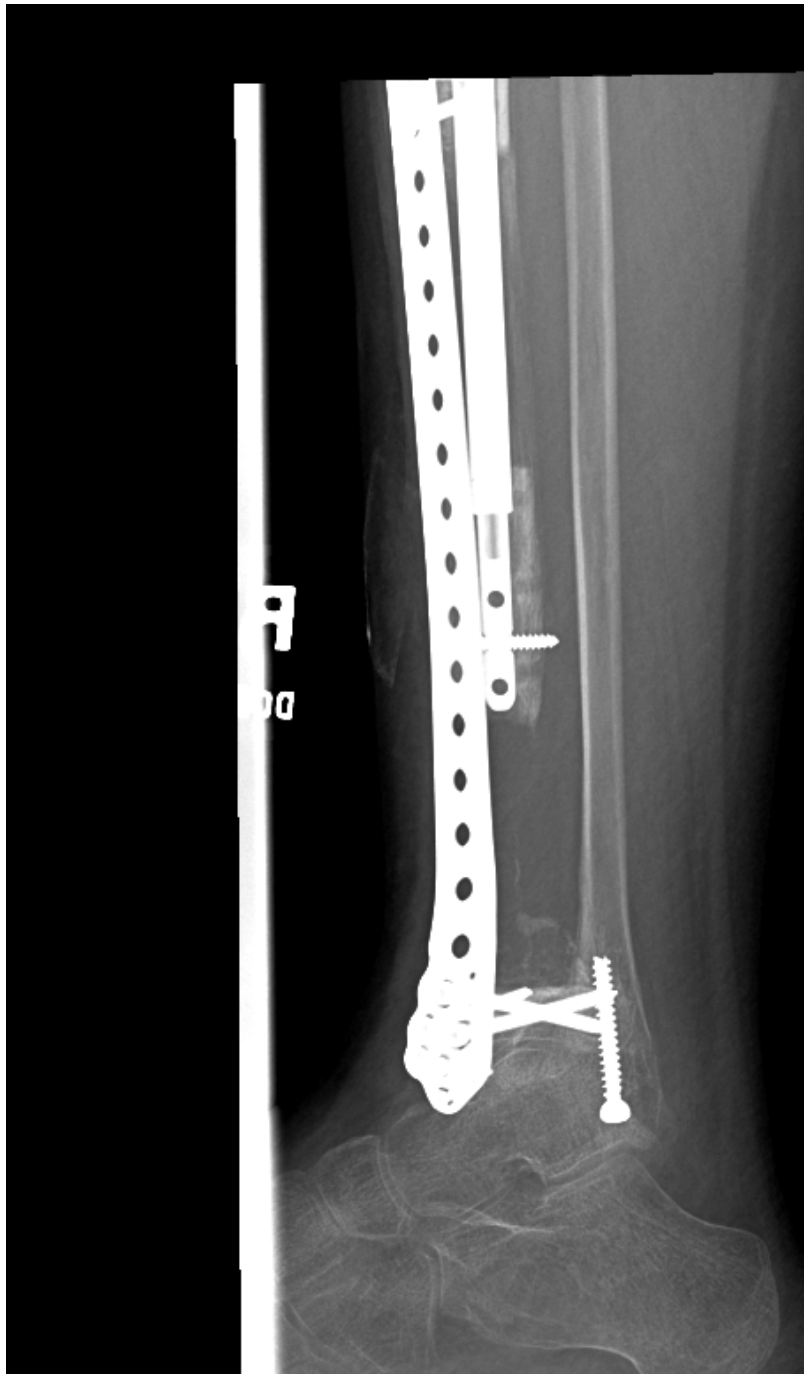


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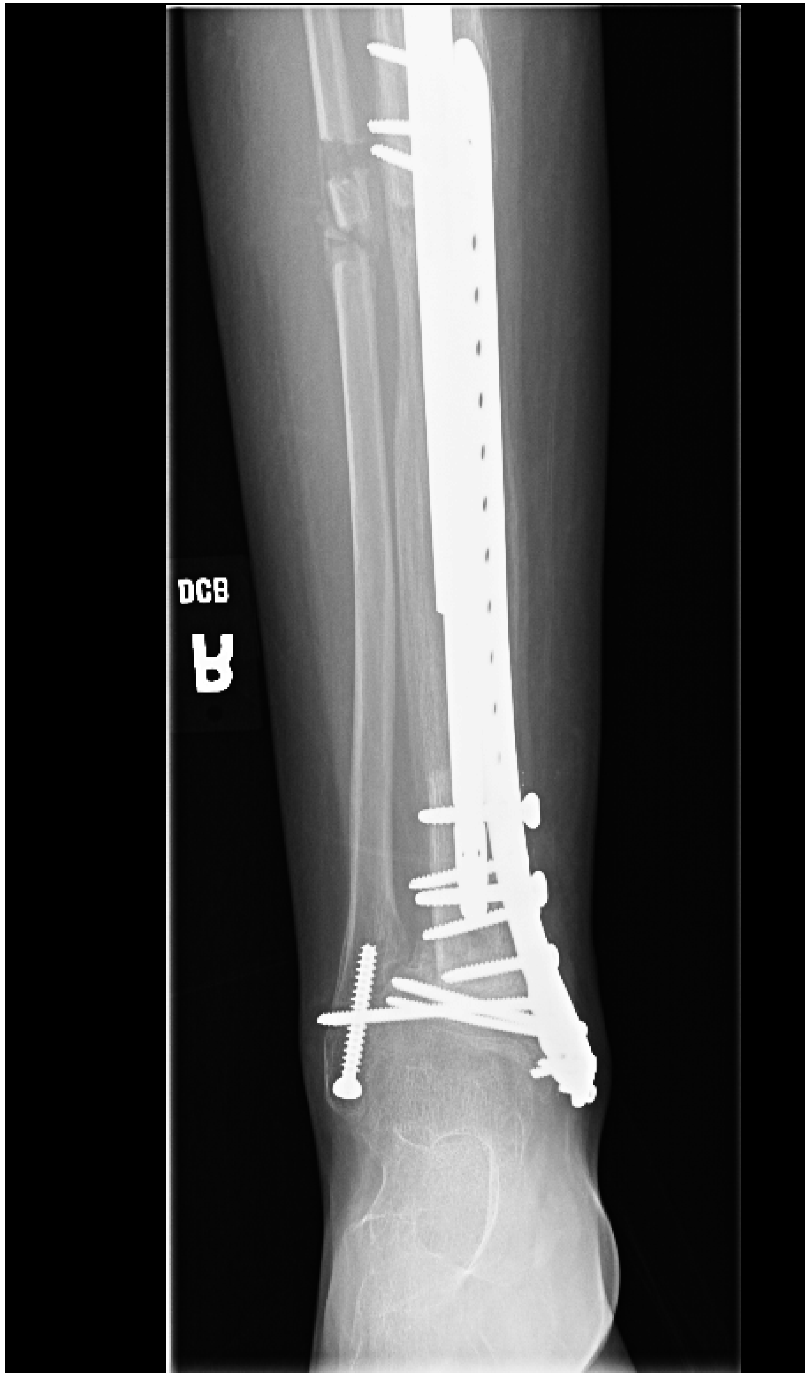
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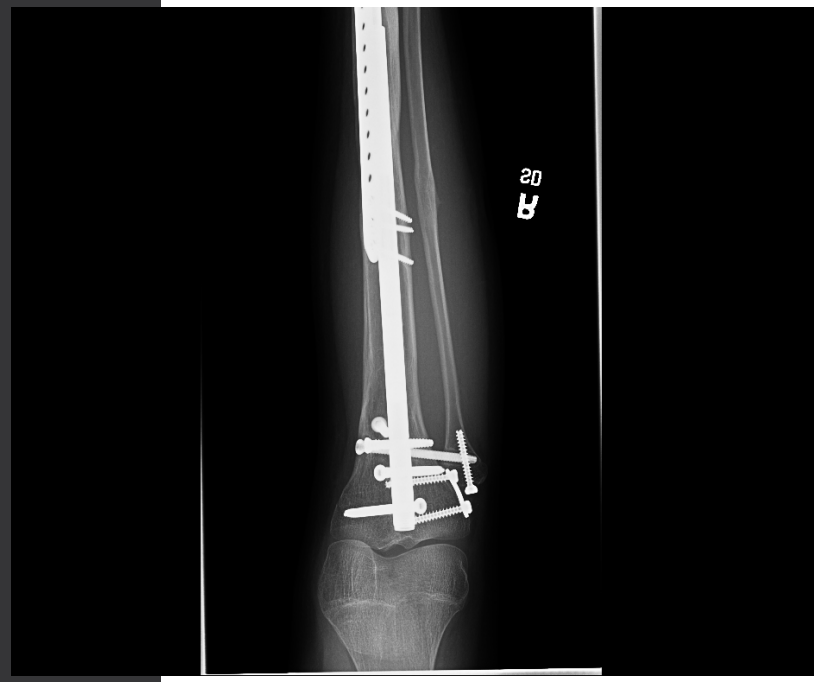
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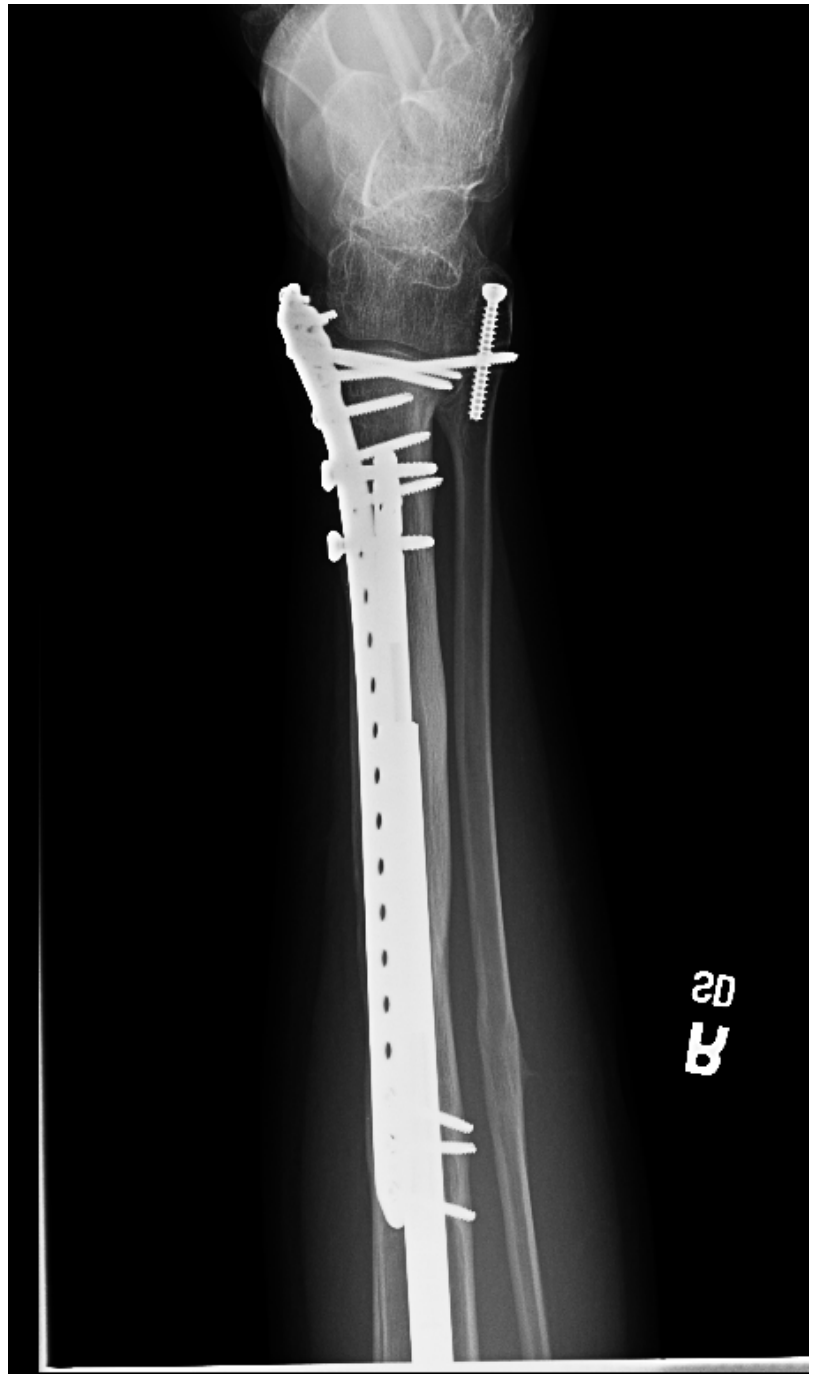
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UPREP
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Distraction Osteogenesis

- Formation of new bone by re-creation of fracture callus microenvironment by doing a controlled cut (osteotomy) of the bone.
- Slow distraction of the two bone pieces where cut was made.
  - New bone forms in line with axial traction applied.

Collagen

↓

Osteoid lined osteoblasts

↓

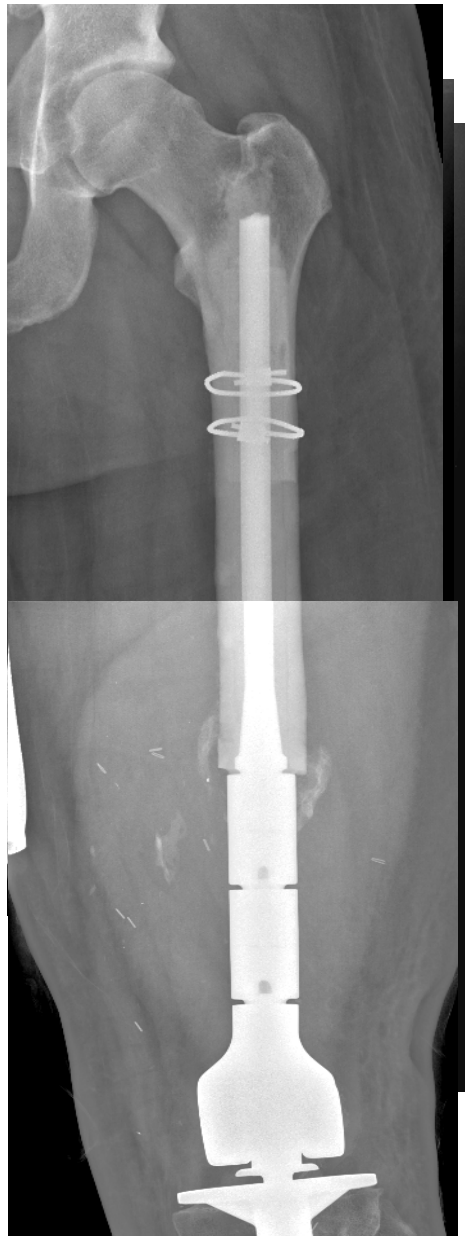
Mature bone formation

Why is there a need for bone regeneration in oncology?

Some good current reconstructive options

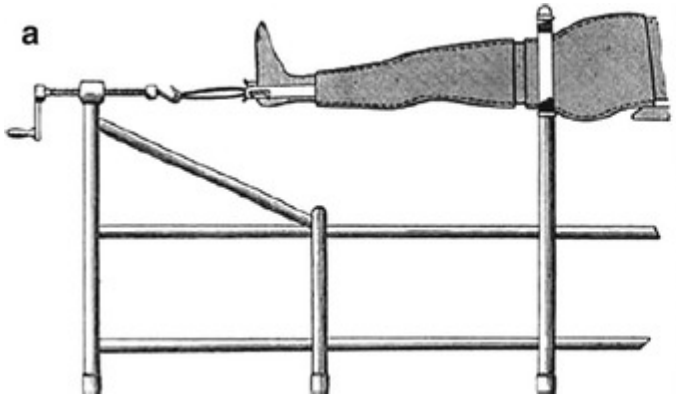
- Endoprosthesis
- Allograft
- Alloprosthetic composite
- Vascularized Fibula
- Amputation

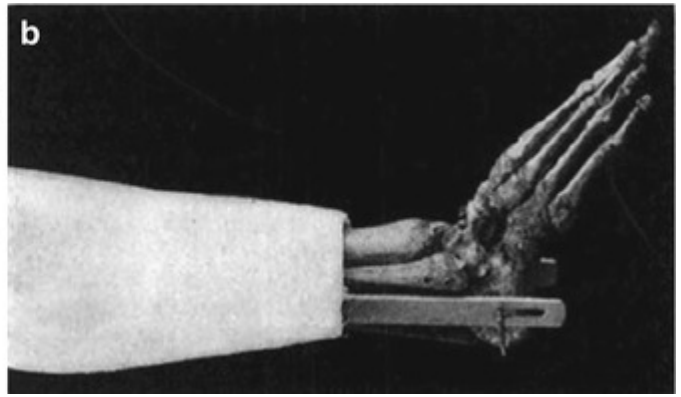
BUT… Failure Rates are 20-70%



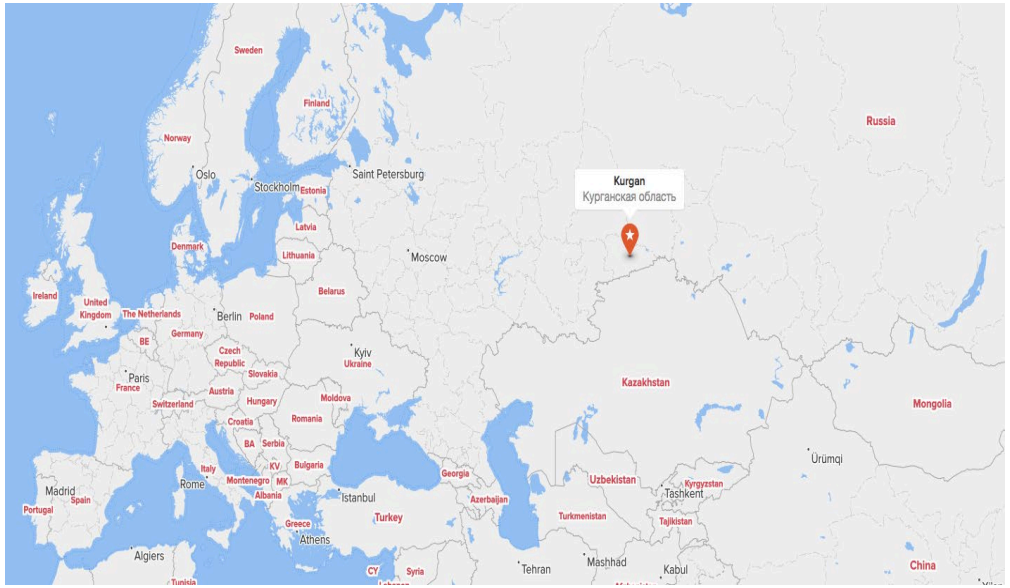
History of DO: Dark Ages

- 1905, Alessandro Codivilla, MD
  - Stretched the entire gap/distance in 1 setting under anesthesia
  - External fixation
- 1934, Wagner Technique
  - Osteotomy with external fixation
  - Separate bone with an external device as fast as patient could tolerate
  - Fill defect with bone graft and plate the bone
  - High rates of failure (infection, nonunion, fracture, stiffness)





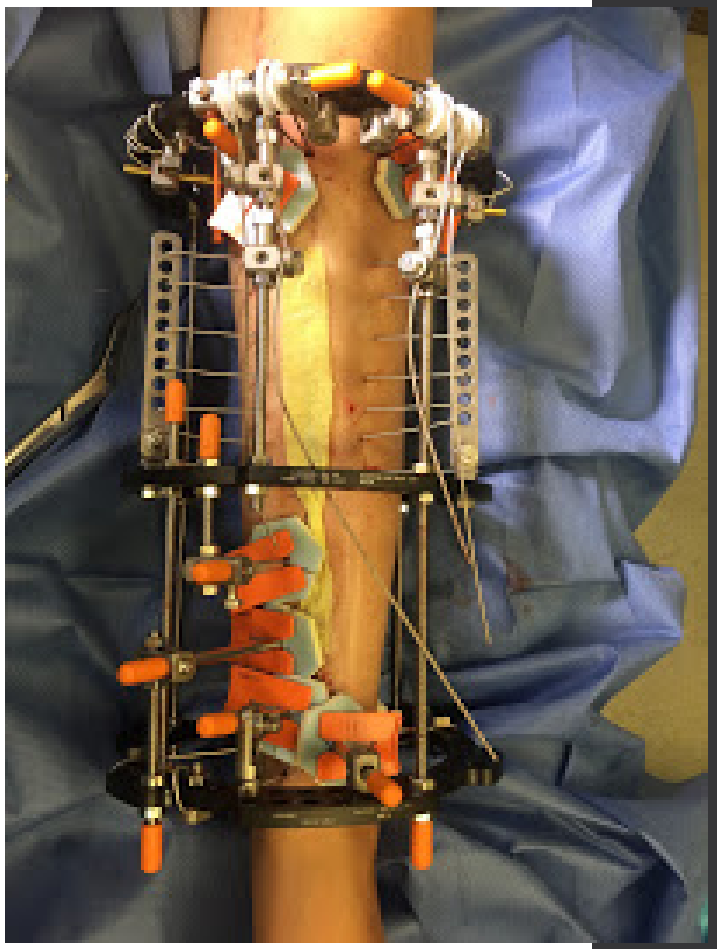
History of DO: Modern Era *during the Cold War (1950s)*

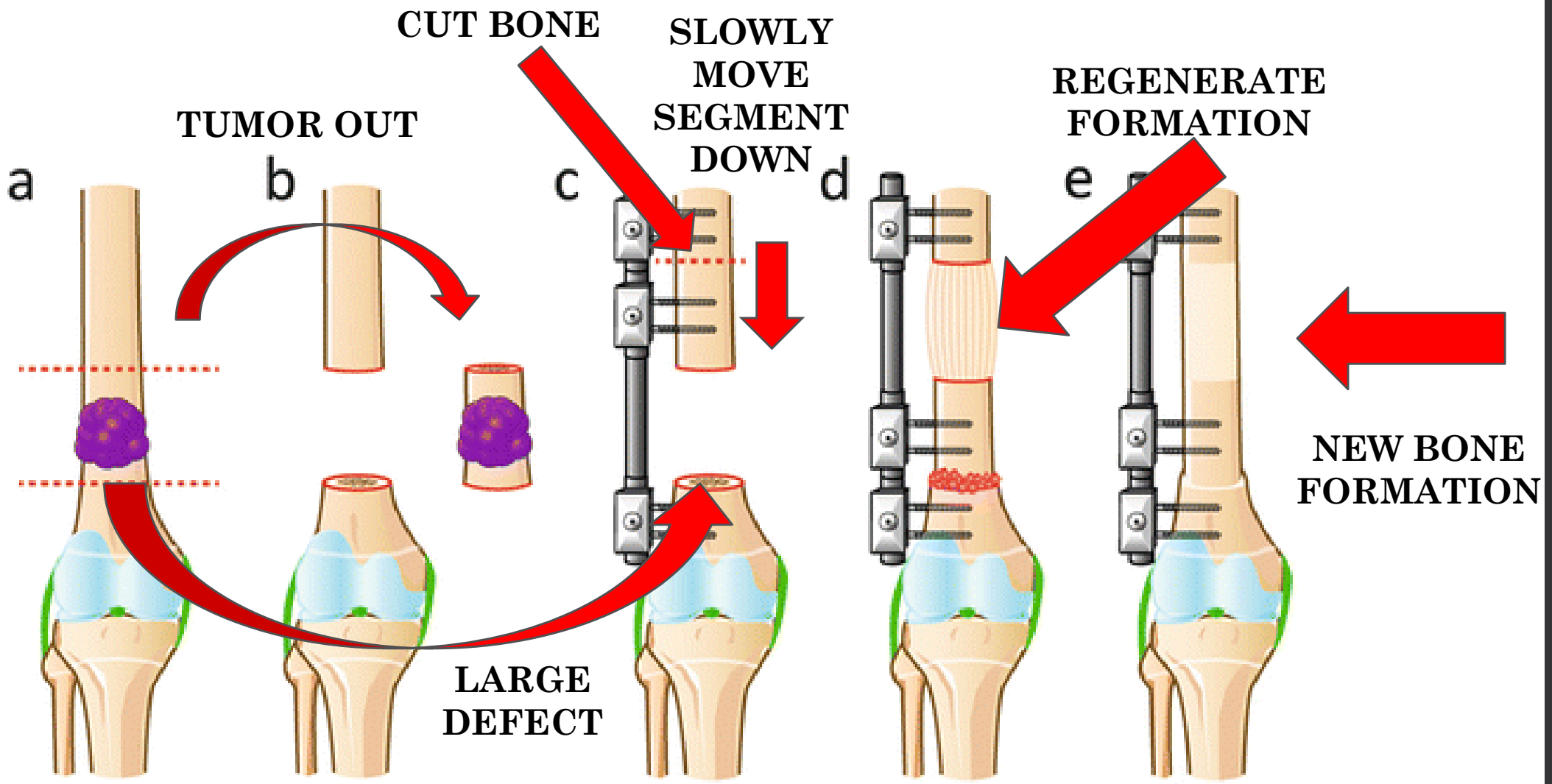


- Gavriil Ilizarov, MD, PhD
- Russian surgeon during the cold war covering a large, frozen tundra of Siberia
- Applied external fixator for compression of tibial fracture
- Patient turned the screws the wrong way…

History of DO

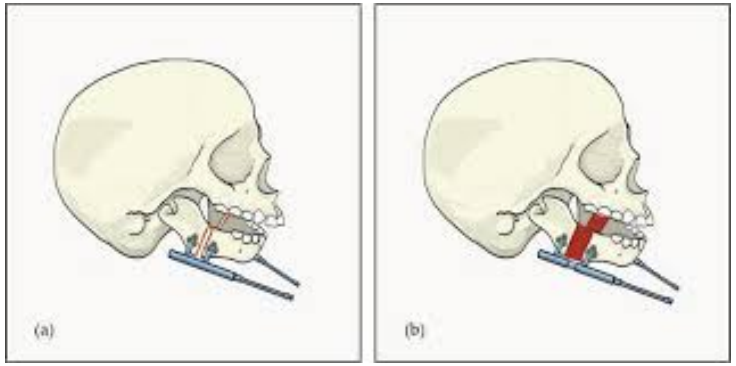
- Ilizarov began focusing his career on orthopedics
  - External fixation and the device
  - Conducted exhaustive studies on the tibias of Mongrel dogs to elucidate the best technique, rate and rhythm of distraction
- Brought it to Italy, then Spain
- Eventually came to US via NYU/HJD in late 1987

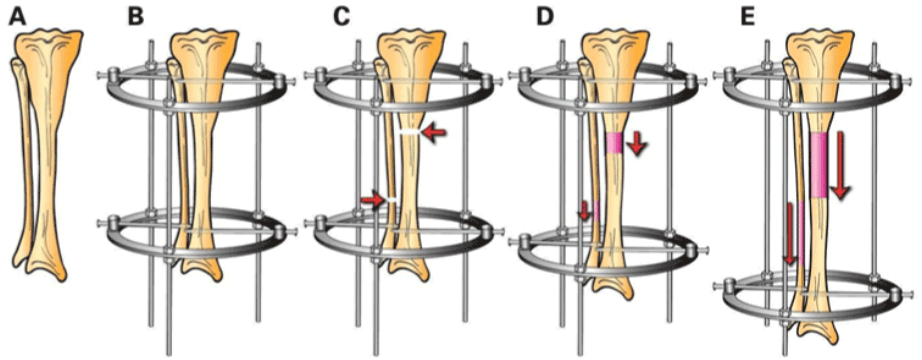


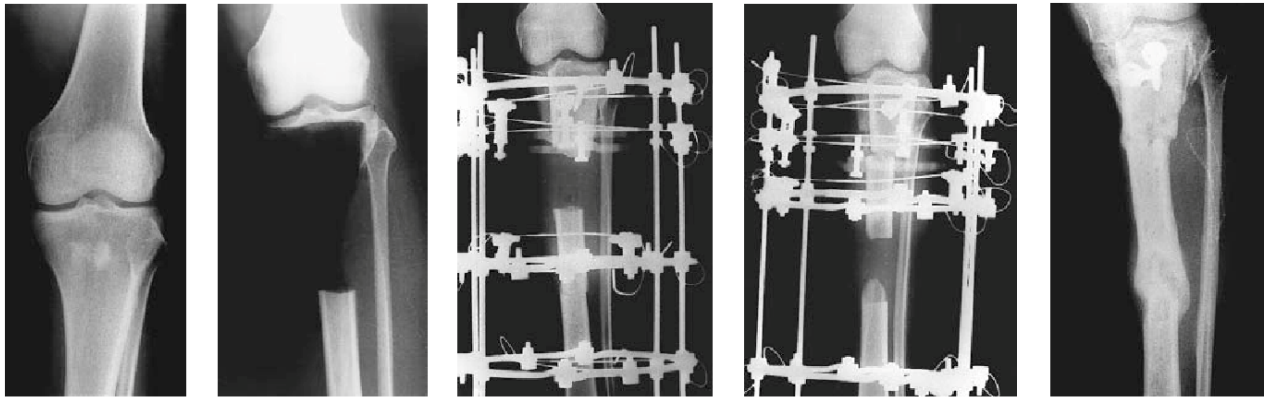

CUT BONE
SLOWLY MOVE SEGMENT DOWN
REGENERATE FORMATION
TUMOR OUT
a
b
c
d
e
NEW BONE FORMATION
LARGE DEFECT

Uses of Distraction Osteogenesis

- Congenital Deformities
  - Congenital femoral deficiency, tibial hemimelia, fibular hemimelia
  - Ollier's Disease, MHE, Hemihypertrophy
- Neurofibromatosis, Congenital Pseudoarthrosis Tibia
- Rickets
- Post-traumatic Injuries
  - Physeal Injuries, Trauma, Non-union, Malunions
- Infections
- Osteomyelitis, Septic Arthritis, poliomyelitis
- Short Stature, Achondroplasia
- Maxillofacial Surgery
- Cosmetic Lengthening
- Bone Defects after Tumor Surgery

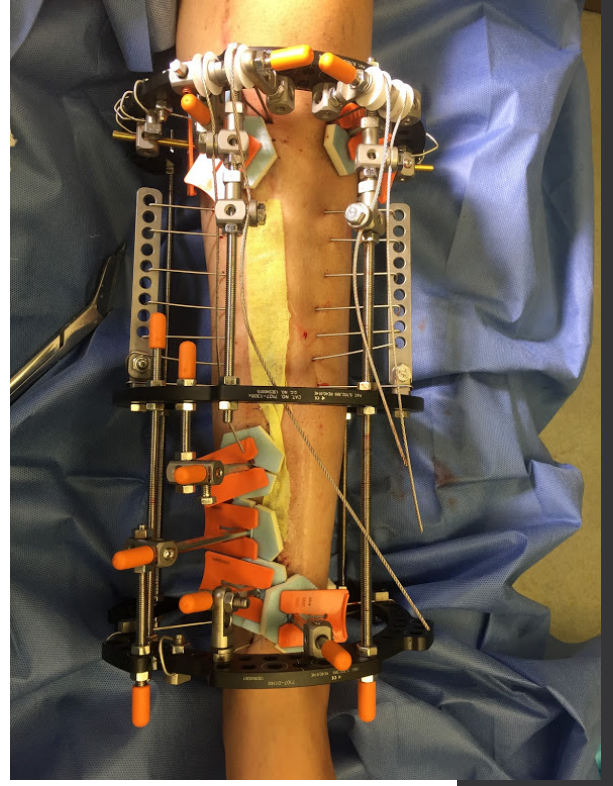


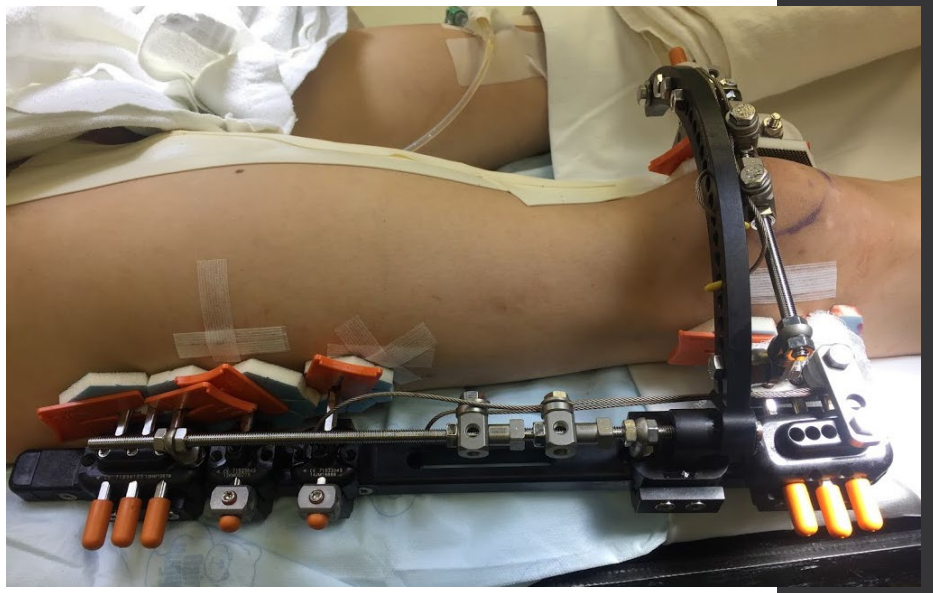


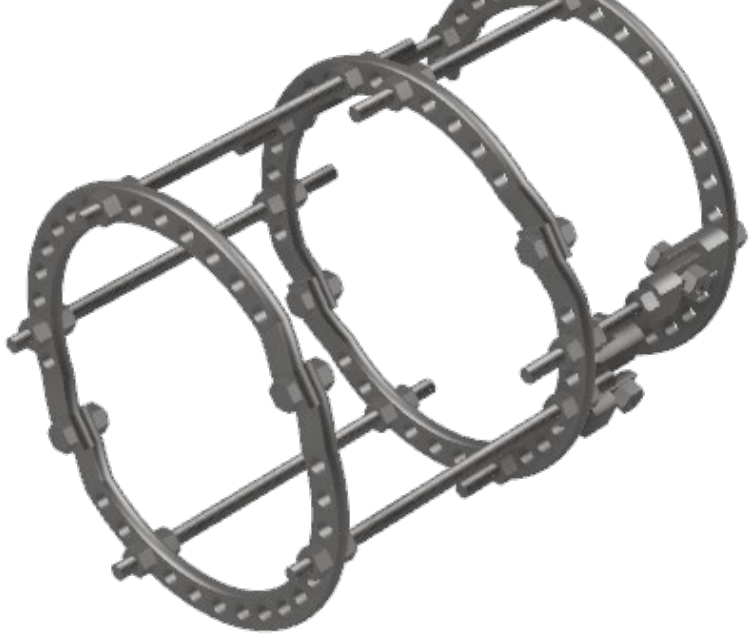


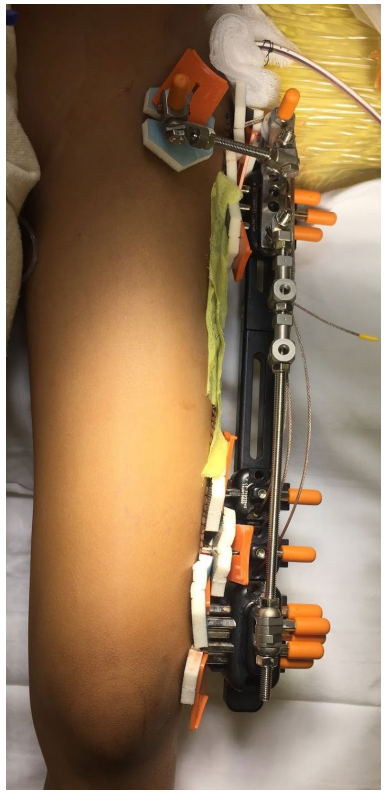
Principles of Distraction Osteogenesis

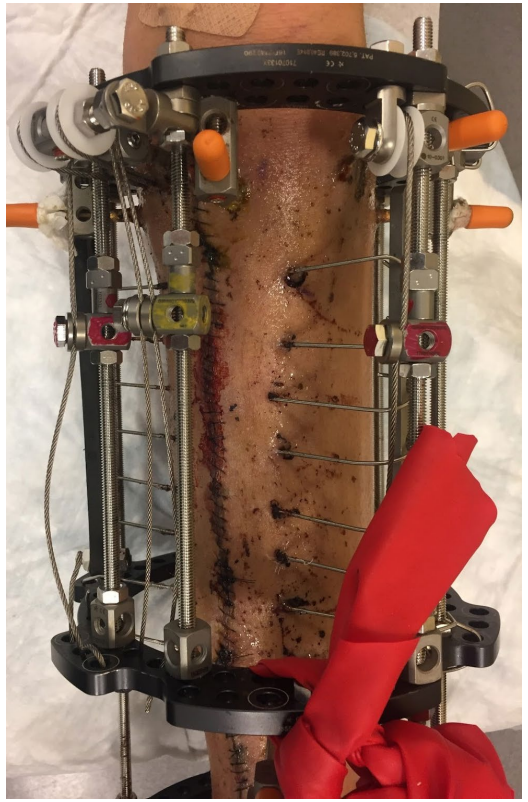
- Latency period
  - 7 days average
  - Premature consolidation vs nonunion
- Rate: 1mm per day
  - Too Slow vs Too Fast
- Rhythm: 4x per day
  - In as small an increment as possible throughout the day
- Location: metaphysis > diaphysis
  - Metaphysis heals faster
- Minimal periosteal stripping: percutaneous > open
  - Minimal endosteal damage: corticotomy > osteotomy
- Blood Flow
  - Peaks at 8x normal and 2x greater than fracture healing
  - Persists for at least 3 months afterwards











DO w/ External Fixation

- Ilizarov apparatus
- Monolateral external fixators
  - Monolateral Rail System (Smith and Nephew)
  - Limb Reconstruction System (Orthofix)
- Multiplanar external fixators
  - Taylor Spatial Frame (Smith and Nephew)
  - ADAM frame (Imed Surgical)

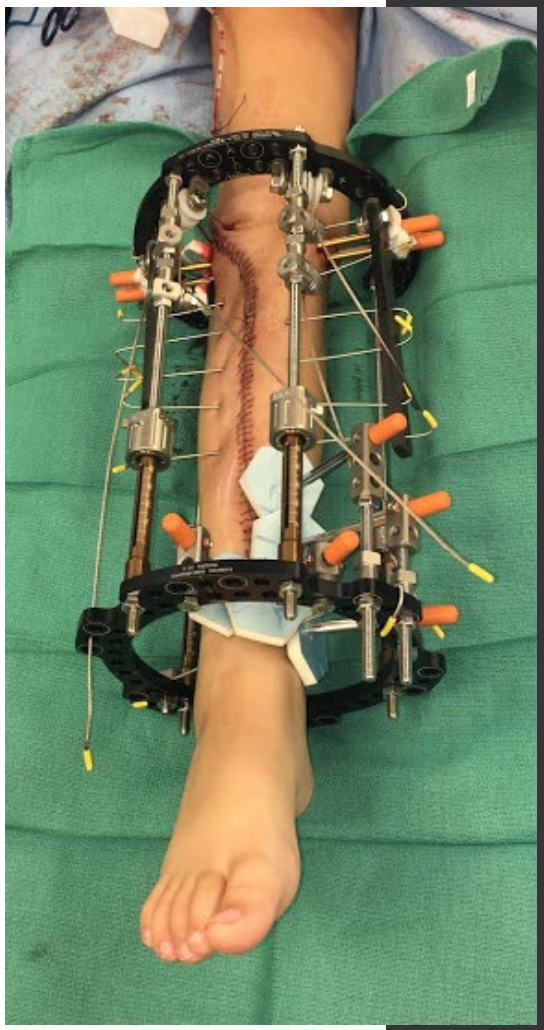
Distraction Osteogenesis w/ External Fixation

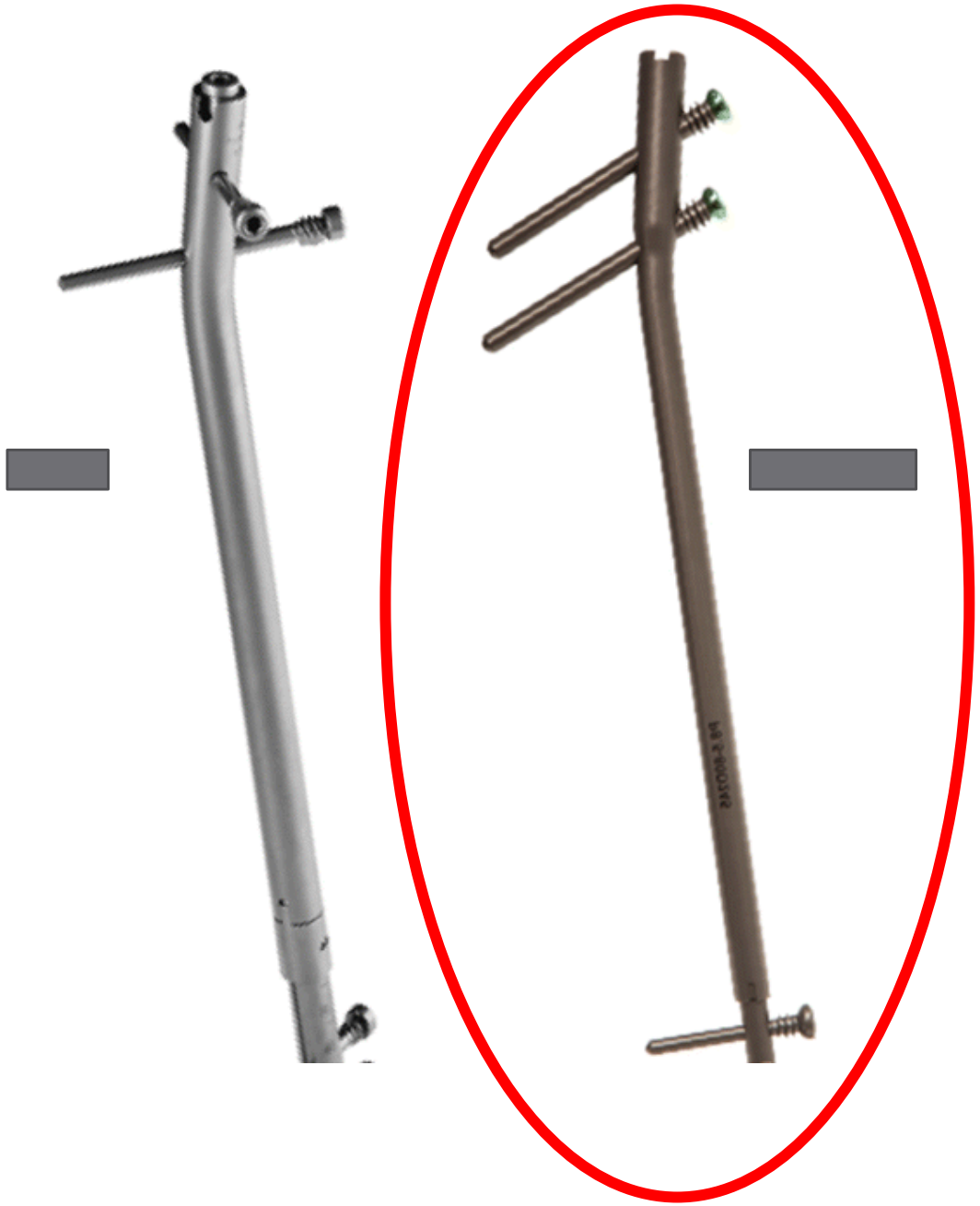
Advantages

- Good when resection is very close to joint
  - can stabilize segments as small as 6mm
- Can increase stability/strength by anchoring the device into neighboring bone
- Fine adjustments can be made in outpatient clinic
- Additional lengthening after transport
- Can move two segments at once cutting the time of bone growth in half
- Full activity, no restrictions

Disadvantages

- Risk of pin tract infections
- Causes muscle, ligament, and skin scarring which negatively affects rehabilitation
- Poor cosmetic result
- Long process
- Patient compliance
- Annoying!!





DO w/ Intramedullary Lengthening Nail

DO w/ Intramedullary Lengthening Nail

Advantages

- Maintains bone alignment during transport
- No scarring from pins and wires
- No risk of pin tract infection
- Better cosmetic result
- No need for conversion surgery in the consolidation phase

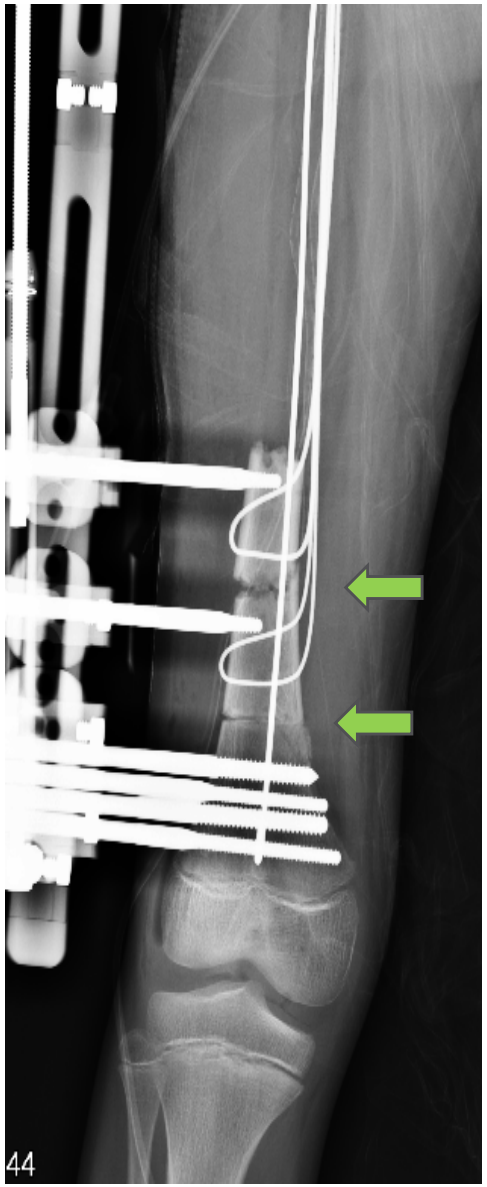
Disadvantages

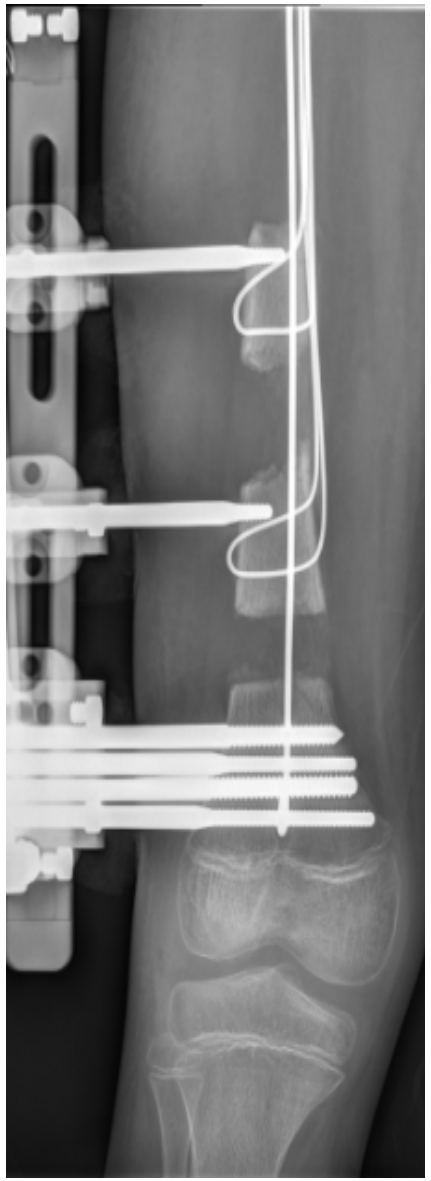
- Only allows transport of 1 bone segment
- Maximum lengthening capacity of 8cm
  - Need for multiple exchange surgeries
- No additional lengthening after bone transport completion

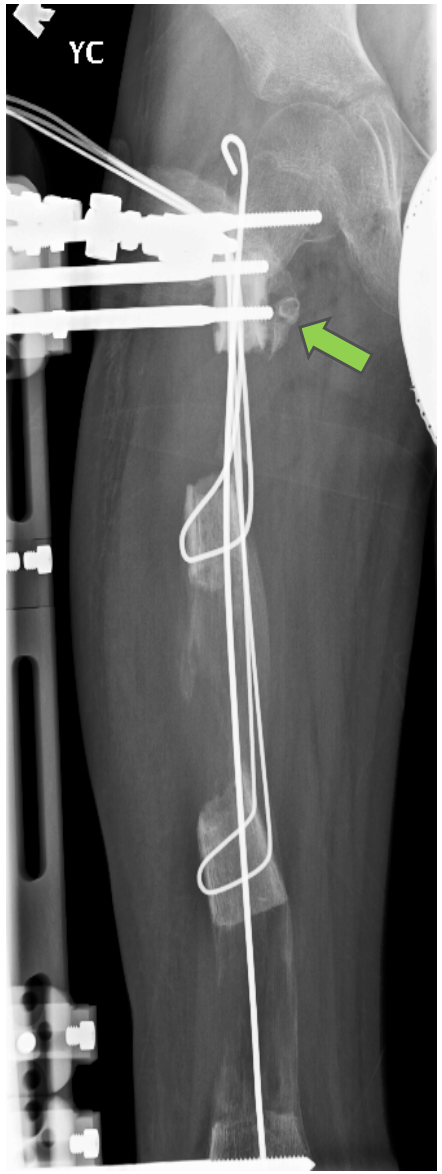
DO Complications

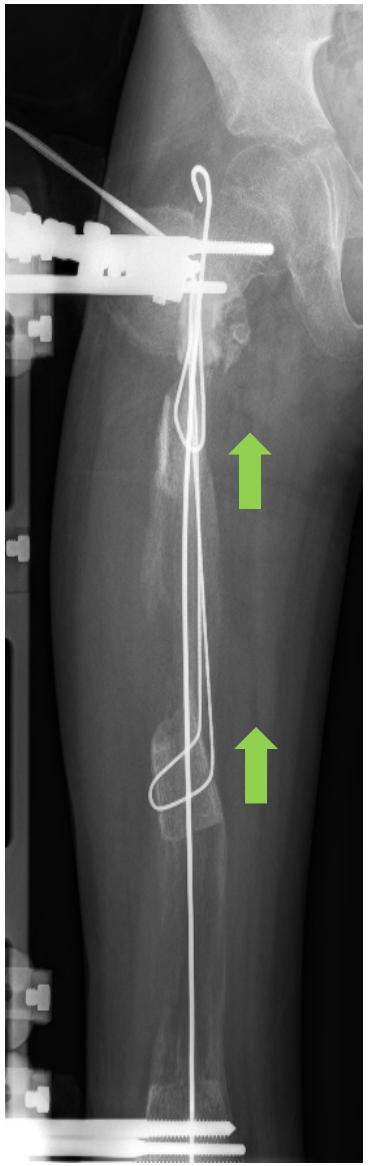
- Muscle contracture
- Joint subluxation/dislocation
- Deviation of transported bone segment
- Neuropathy
- Premature consolidation/delayed consolidation
- Non-union
- Hardware malfunction
- Deformity
- Fracture of regenerated bone
- Pin site infections (unique to external fixation)

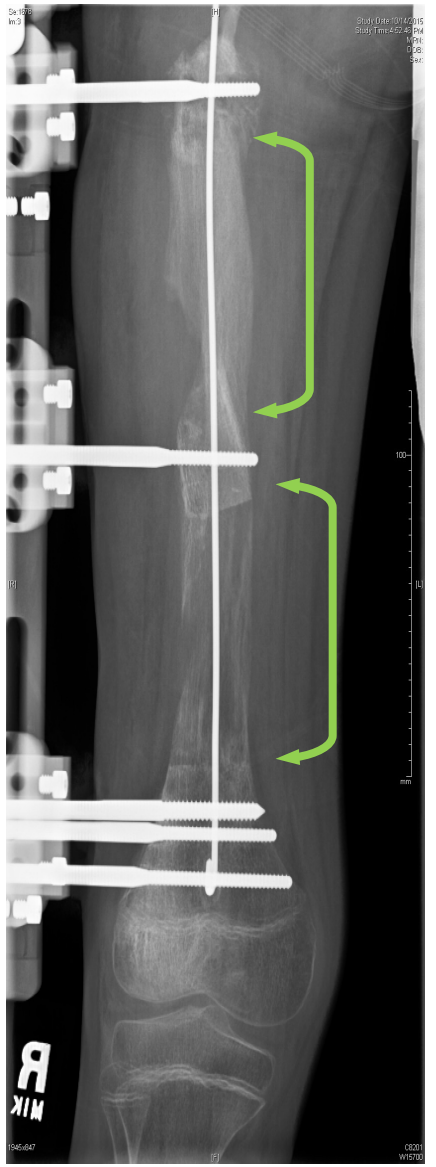
Femur acute + double level transport with wires

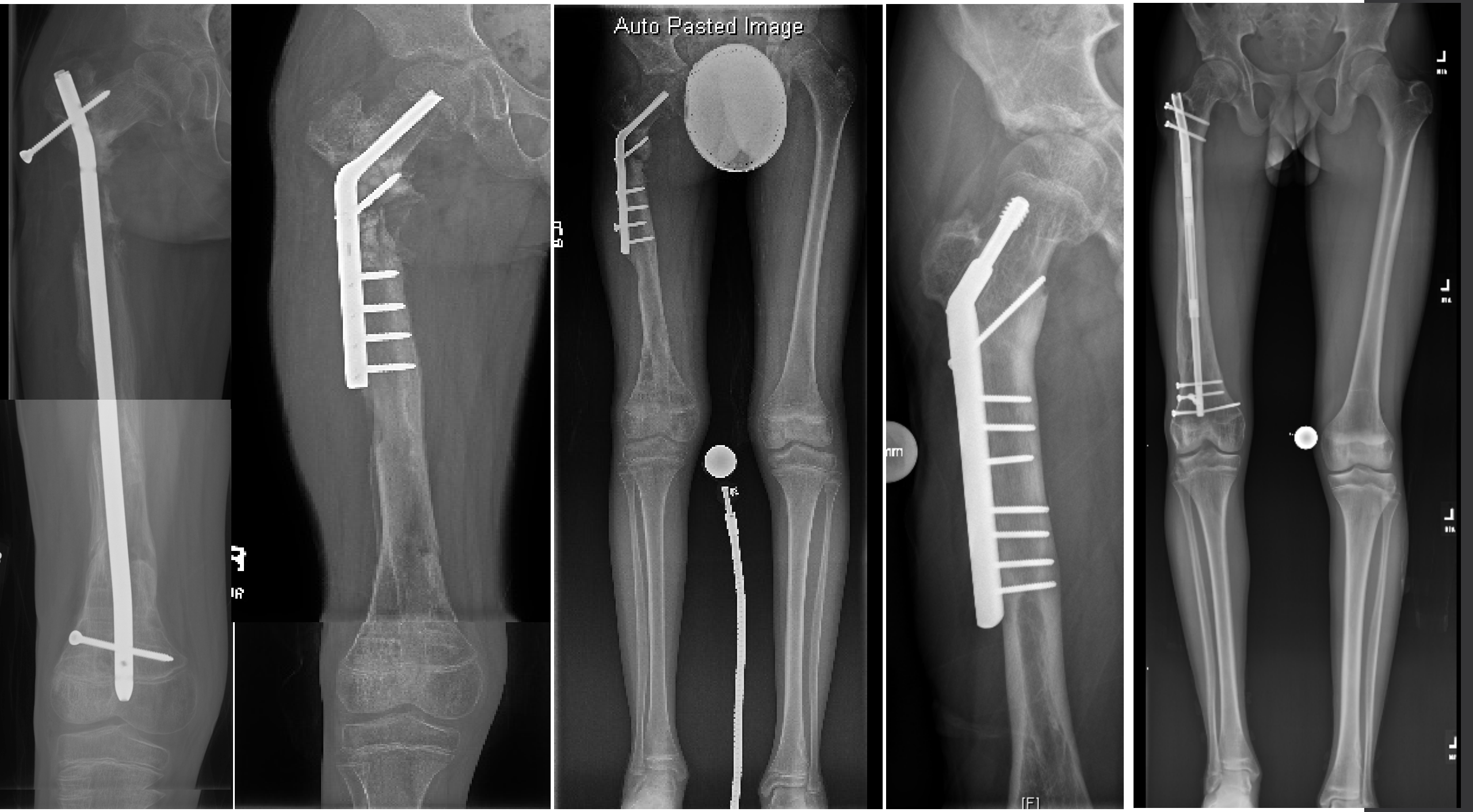








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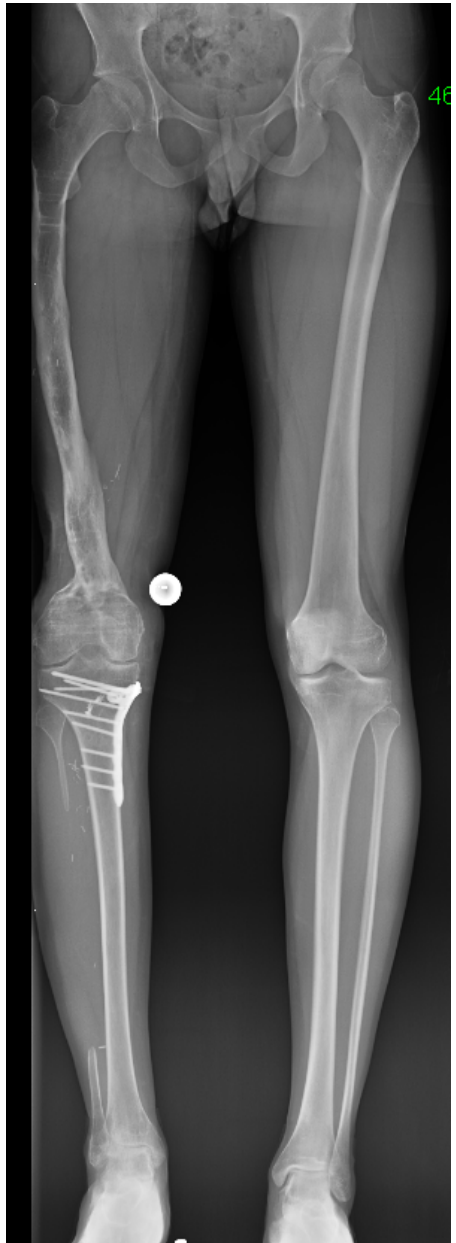
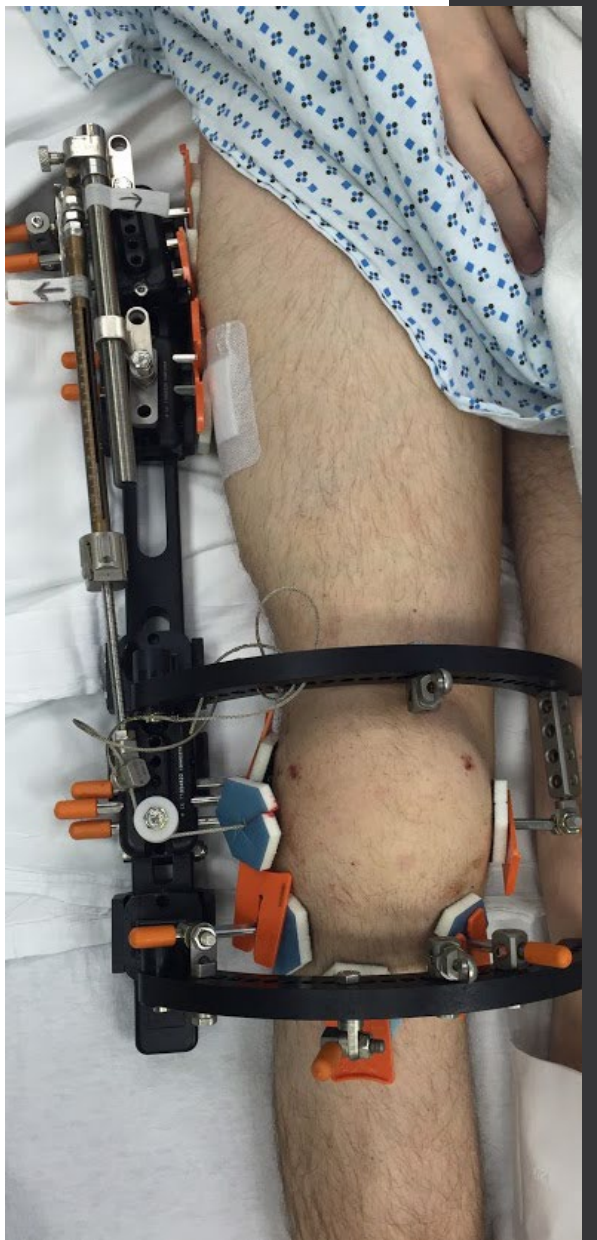
16 y/o M, osteosarcoma





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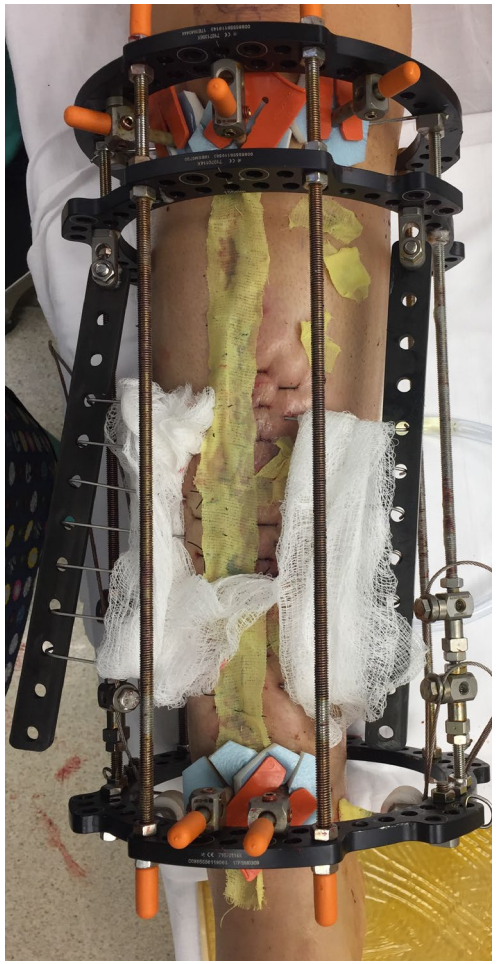

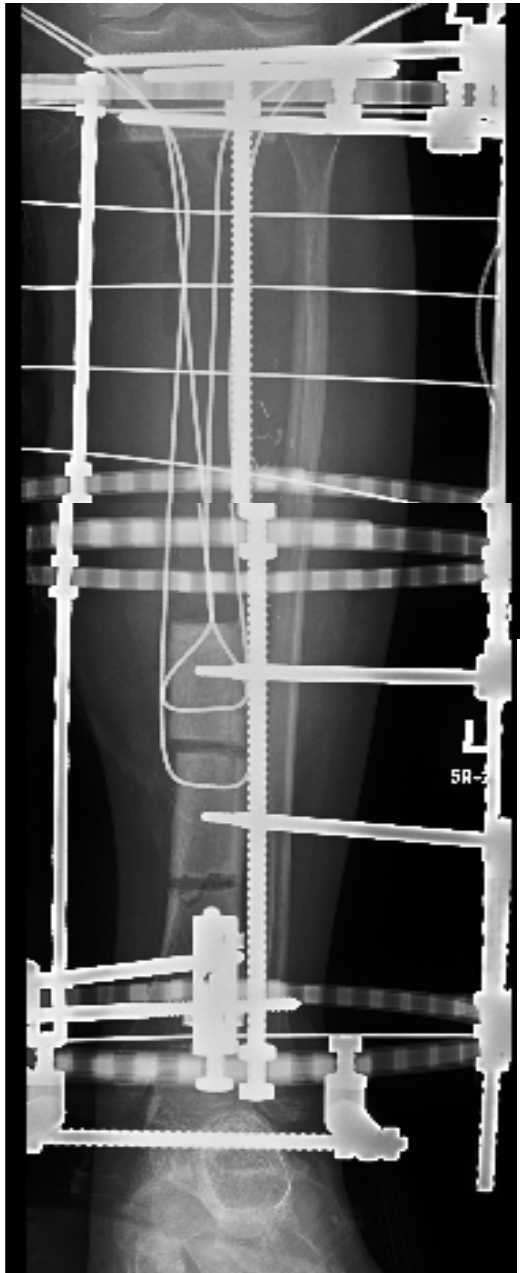

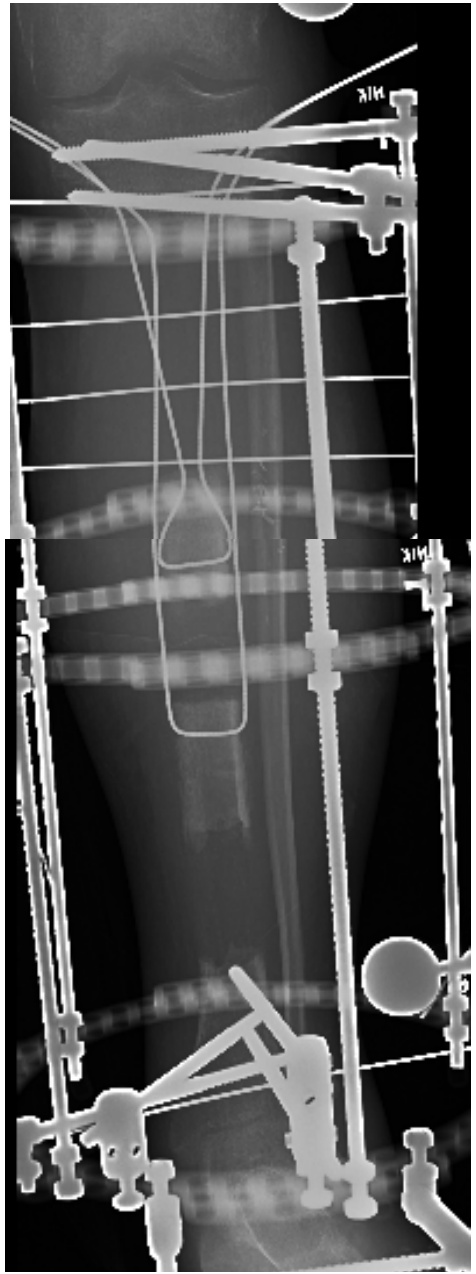

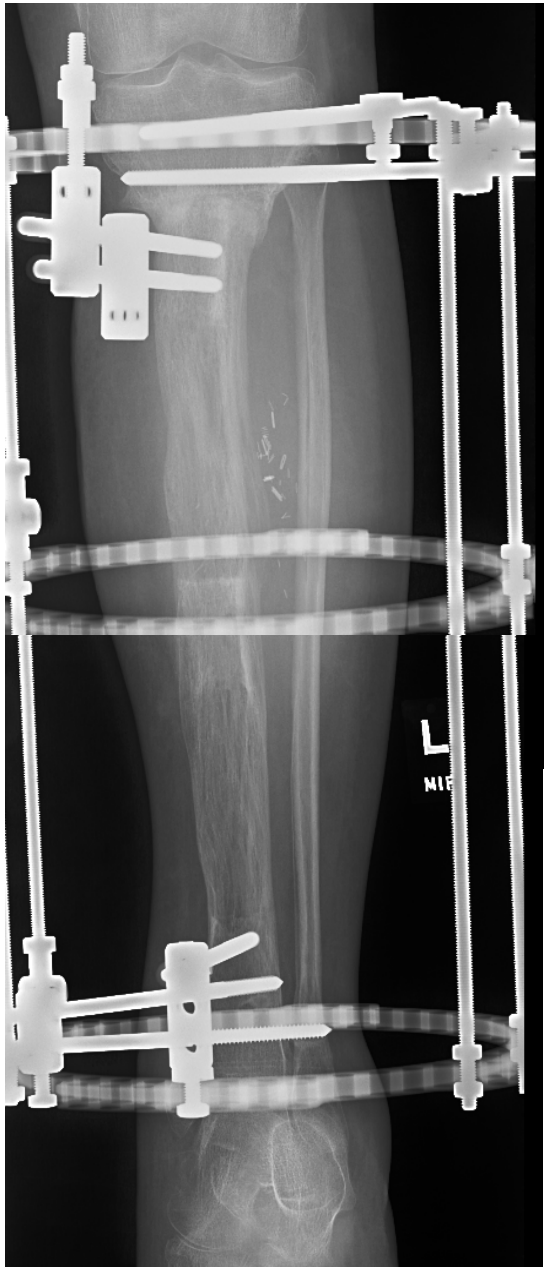

What would you do?

- 16 y/o with a new diagnosis of osteogenic sarcoma of the femur
  - Tumor includes the diaphysis of the femur and extends 20 centimeters
  - The hip and knee joint are preserved
  - Complete resection is possible with negative margins
  - No metastatic disease
  - Pre op chemotherapy 3 months
  - Post op chemotherapy 6 months

WHAT RECONSTRUCTION OPTION WOULD YOU CHOOSE FOR YOURSELF??

References

Content:

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