

Backcountry Ankle Trauma: What to Do and When to do it

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QUESTION 1:

- A low energy Pilon fracture is characterized by:

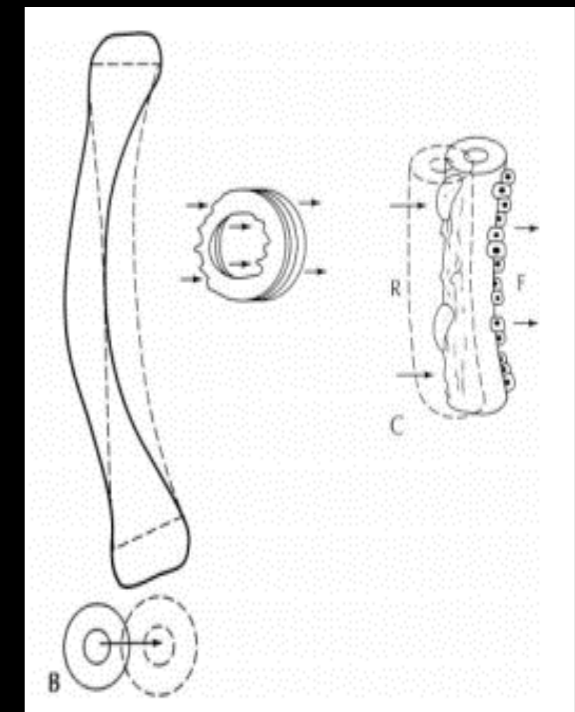


QUESTION 2: Who am I?

- I have no muscular attachments
- I have no tendinous attachments
- 70% of me is covered by cartilage

QUESTION 3:

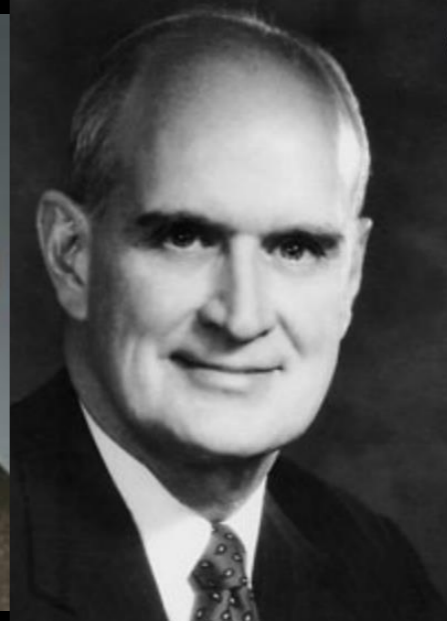
- What is an impediment to bony fusion?



Summary: 5 Topics

1. What to do in the field
2. Specific injuries around the ankle joint
 - Tibial Pilon fractures
 - Talus fractures
3. The Sequelae of these injuries
4. Cutting edge treatment and research

A special thanks to my
mentors....



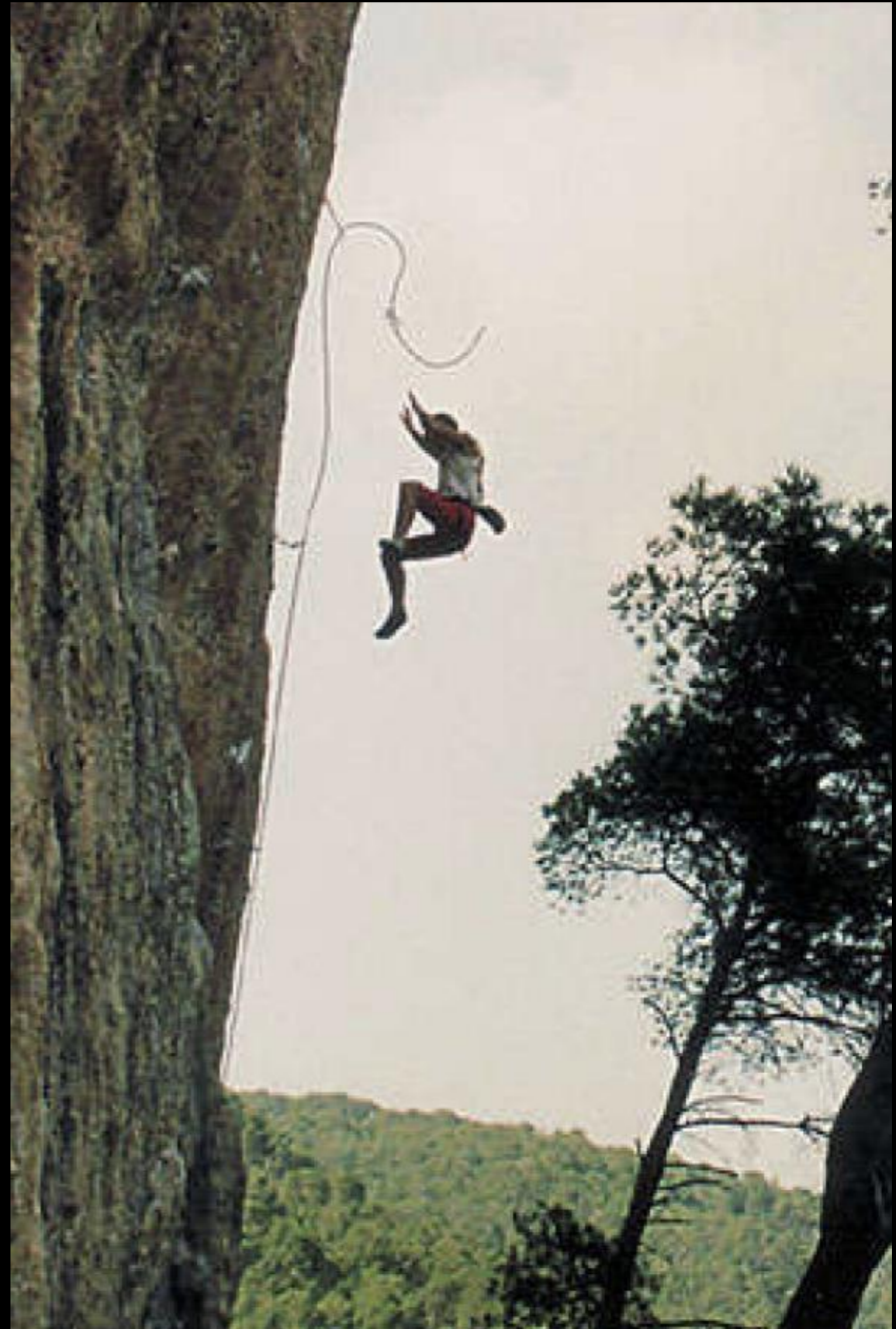
1. What to do in the Field

The Outdoors are Beautiful...





...but things happen...





- Non sterile environment
- Medical professionals far away
- Remote locations
- “Don’t go out alone”



If you or your friends are injured, then you need to learn how to survive!



FATAL ACCIDENT!

The HORRIBLE Cerro Torre Mountain Climbing TRAGEDY 2022

Watch >

Here are the most important things to do!

Do a rapid Assessment:

Assessment

- Inspection



Assessment

- Inspection
- Open Wound



Assessment

- Inspection
- Open Wound
- **Pulses**



Assessment

- Inspection
- Open Wound
- Pulses
- **Deformity**



Treatment

Open Wounds

- Remove foreign debris



Open Wounds

- Put a clean liquid on the wound to flush out bacteria



Wound Contamination 4 Classes

- No 1. "Clean"
 - No 2. "Clean-Contaminated"
 - No 3. "Contaminated"
 - No 4. "Dirty"
-
- Based on general surgical incisions

No 1: Clean Wound

- No 1. "Clean" when the skin has been cleaned and readied for suturing
- Uninfected
- No inflammation



No. 4: Dirty/Infected Wound

- Dirty, dead tissue
- Purulence
- Foreign objects, wood grass, dirt, urine, manure
- > 4 hours of initial wounding



Infection rates correlate with severity of wounds

- Clean: 1.5-3.9%
- Clean contaminated: 3.0-4.0%
- Contaminated: 8.5%
- Dirty wounds: 28-40%

Treat a dirty wound by irrigating it
with a cleaner solution

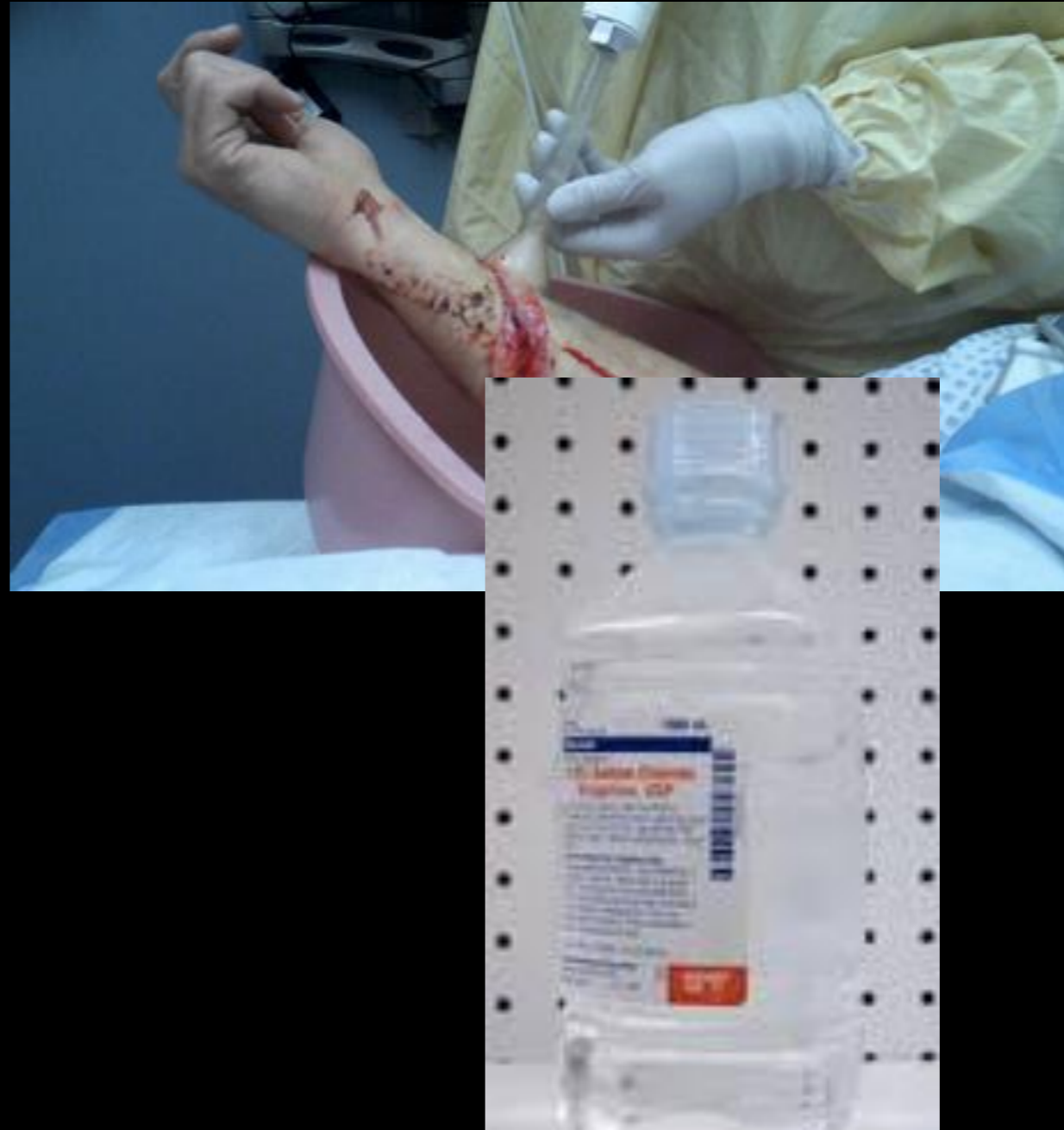
Does Irrigating help?

- Remove debris
- Hydrate wound
- Remove surface pathogens
- Remove necrotic tissue
- Shown to decrease infection rate



Ideal Solution

- Isotonic
- Non-hemolytic
- Non-toxic
- Transparent
- Easy to sterilize
- Cheap
- Readily Available



Normal Saline

- Isotonic
- Lowest Toxicity
- Used most
- Does NOT cleanse dirty wounds as well as other solutions
- Wound infection similar with potable water



Sterile Water

- Prepared by distilling water
- Hypotonic
- Causes cell swelling/lysis
- Used in developing countries



Potable water

- Water that is safe to drink
- 89% of the world has access
- As effective in reducing bacterial counts as normal saline



Iodine

- Broad spectrum antibiotic
- Kills bacteria
- Works against Staph Aureus
- Similar wound infection rates cf. Normal Saline
- Cytotoxic to normal skin and wounds
- Discolors wounds/desiccant



Hydrogen peroxide 3%

- Commonly used
- Effectiveness in doubt
- No negative effect on wounds
- Ineffective in reducing bacterial count



Use whatever you have on hand!

- Wound soaking
- Ineffective in reducing bacterial counts
- Pour it on!



Volume of Irrigant

- No evidence that any specific volume is correct
- Rule of thumb: irrigate until the wound is clear of debris



Cover the open wound with a clean sterile dressing



Hemorrhage



Major hemorrhage can cause death in minutes!



Hemorrhage

- Control it with compression

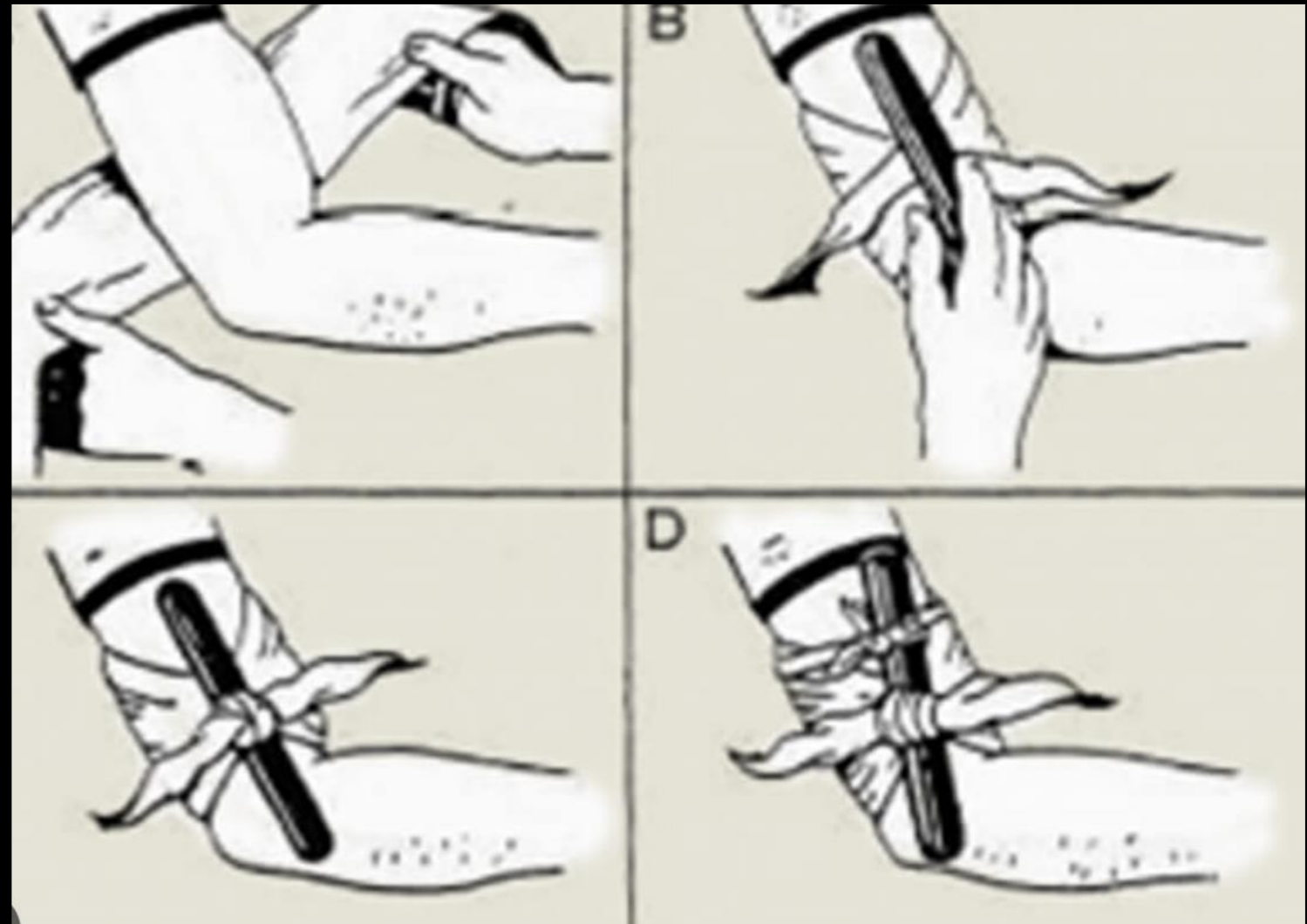


If bleeding doesn't stop: Use a
Tourniquet



If you don't have a tourniquet, make one!

- Improvised
- CANNOT use on trunk or neck



Tourniquet: How long can I keep it on?

1. Applied for over 6 hours:
2. Permanent nerve damage (numbness and muscle fibrosis)
3. Ischemia
4. Gangrene and loss of limb



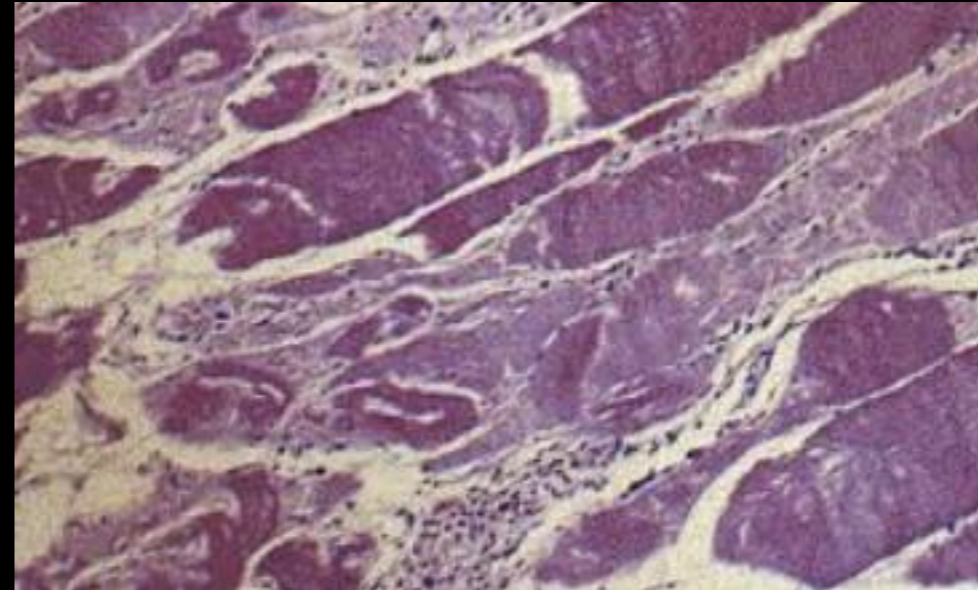
Tourniquet: How long can I keep it on?

1. Arm: 1.5 hours
2. Leg: 2 hours



Tourniquet: How long can I keep it on?

1. Longer than 2 hours:
2. Permanent nerve injury
3. Muscle injury
(contractures,
rhabdomyolysis,
compartment syndrome)
4. Vascular injury
5. Skin necrosis



Wakai A, Winter D C, Street J T. et al Pneumatic tourniquets in extremity surgery. J Am Acad Orthop Surg 2001;9:345–351.

Call 911 for help!

- Two Bear Air
- Kalispell, MT



(406) 758-5610

2. Specific Injuries About The Ankle Joint

The Ankle Joint

- Tibia
- Fibula
- Talus



Closed Fractures

Definition:

A broken bone in which the skin is intact

Chief Complaint:

17 yo male jumped off a gymnasium balcony...





)

Open Fractures

Definition:

A broken bone in which the skin is not intact

Chief Complaint:

34 yo male fell from a height...





Specific Injuries

Tibial Pilon Fractures

Pilon Fracture: What is it?

A fracture of the tibia near the ankle

Pilon means pestle in French



Characteristics

- Very challenging fractures to manage
- Outcomes unpredictable
- Soft tissue management is paramount in optimizing outcomes

Problems: Pilon Fractures

- Anatomy difficult to restore



Problems: Pilon Fractures

- Surgery associated with poor wound healing
- “There is not a lot of meat around the bones”



Case Example

W.B. is an 53 yo male with Right ankle
disfigurement

History of Present Illness

Working at home

Fell through the ceiling 16 feet onto cement floor below him



Surgical History

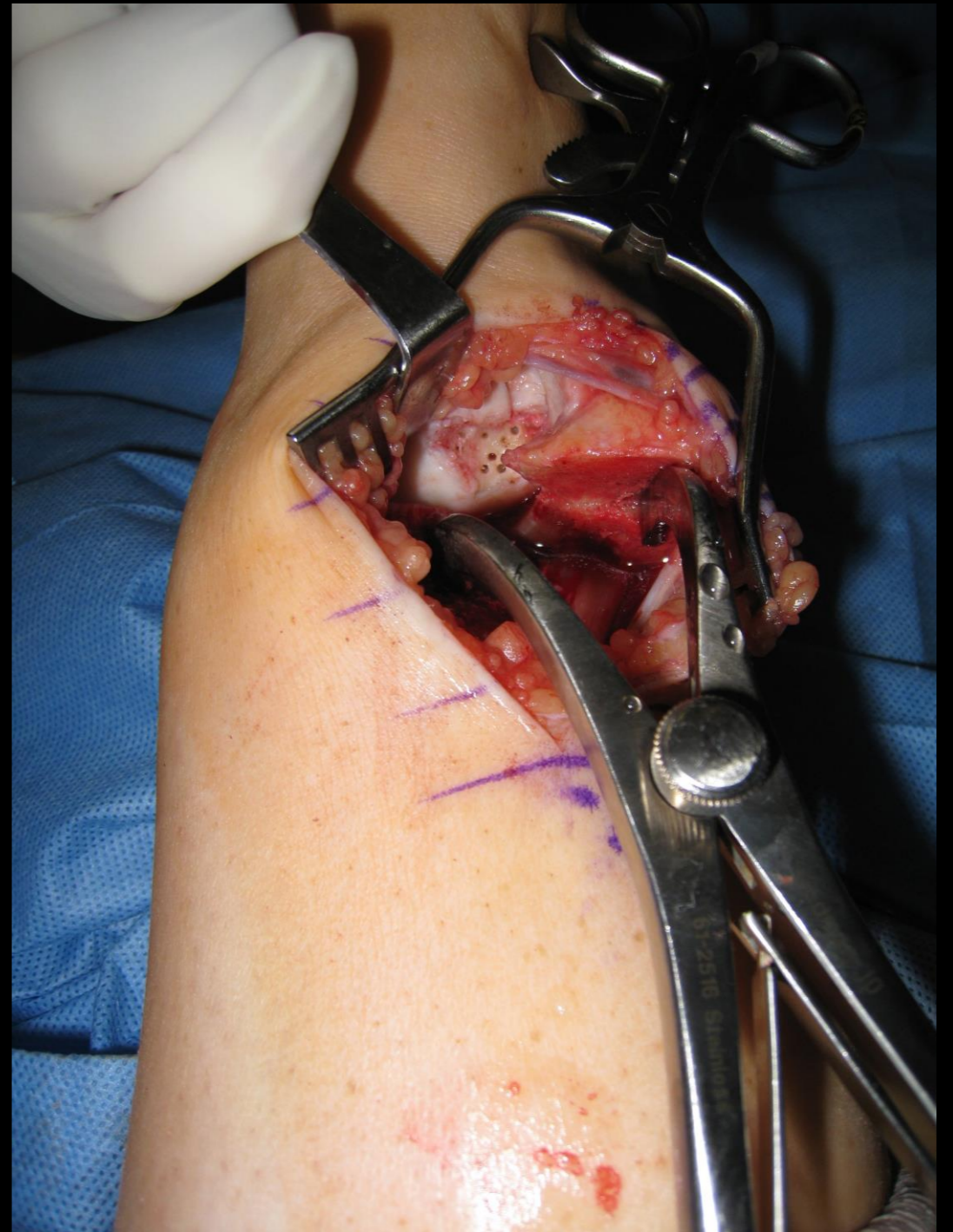


Surgical History

His Jeans were entrapped in
open fibula fracture

Irrigation and Debridement x

2



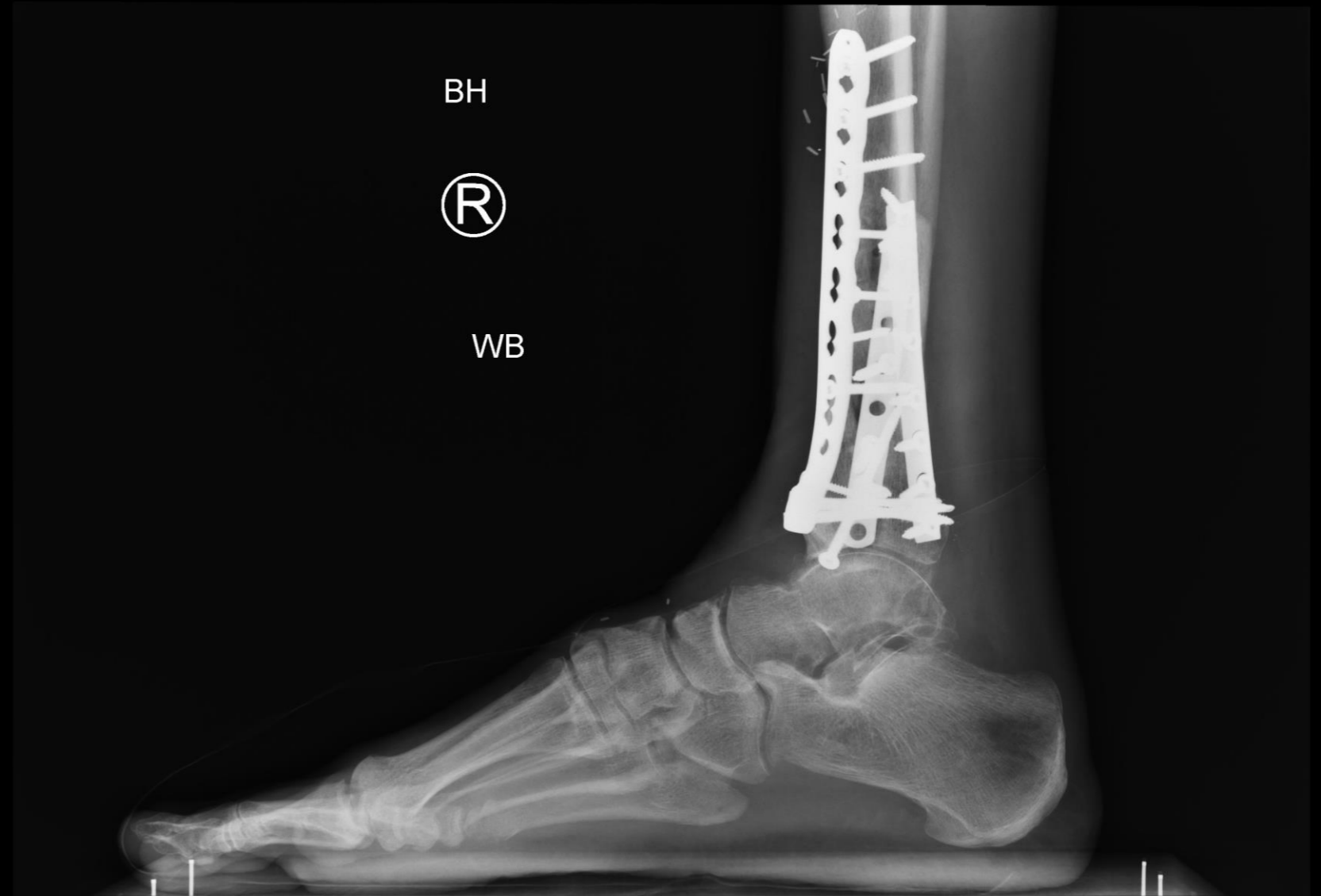
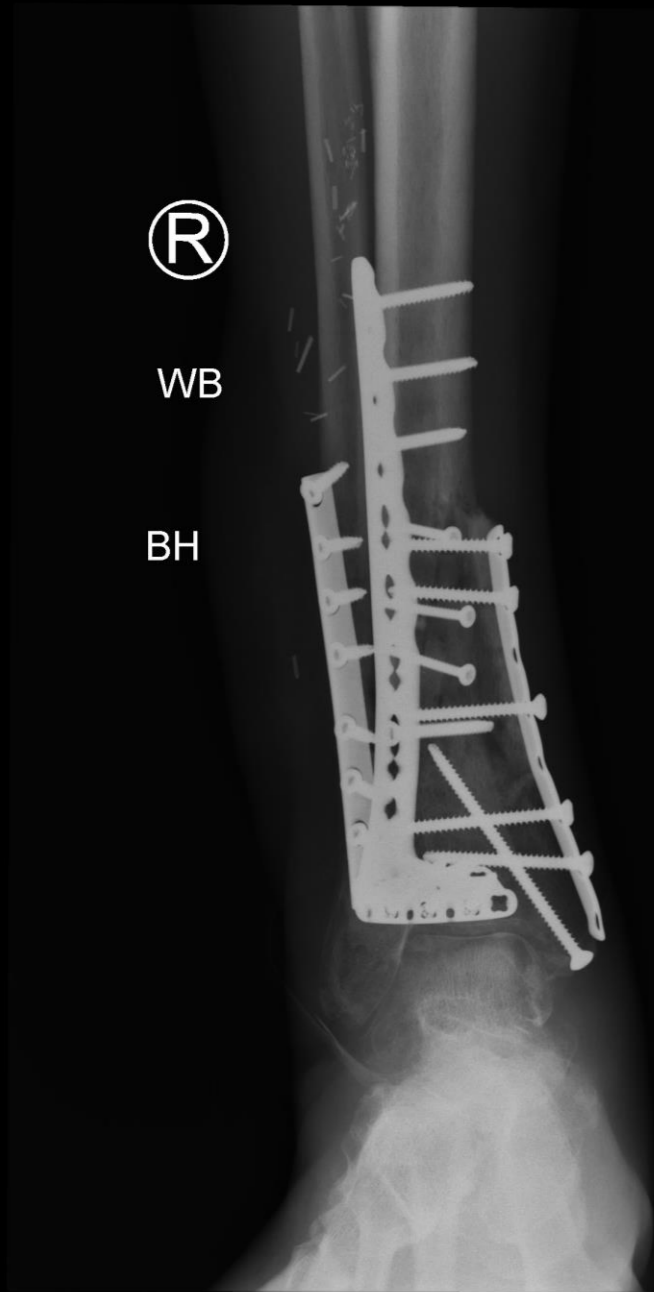
Surgical History

Ex fix

talar osteochondral
defect microfracture



ORIF pilon



Surgical History

Bone infection developed

Surgical History

I&D

Antibiotic bead placement

Wound VAC placement

Free flap placement



Surgical History

Repeat fibular I&D

Surgical History

Repeat Fibular I&D--again

Hardware removal

I&D tibial pilon

Antibiotic Bead placement

Surgical History

Pilon external fixture removal, cast placement

Post Ex Fix



Healed Pilon





New Fracture



What next?

He has had many many surgeries...

He had too much pain and disability...



Tibial Pilon

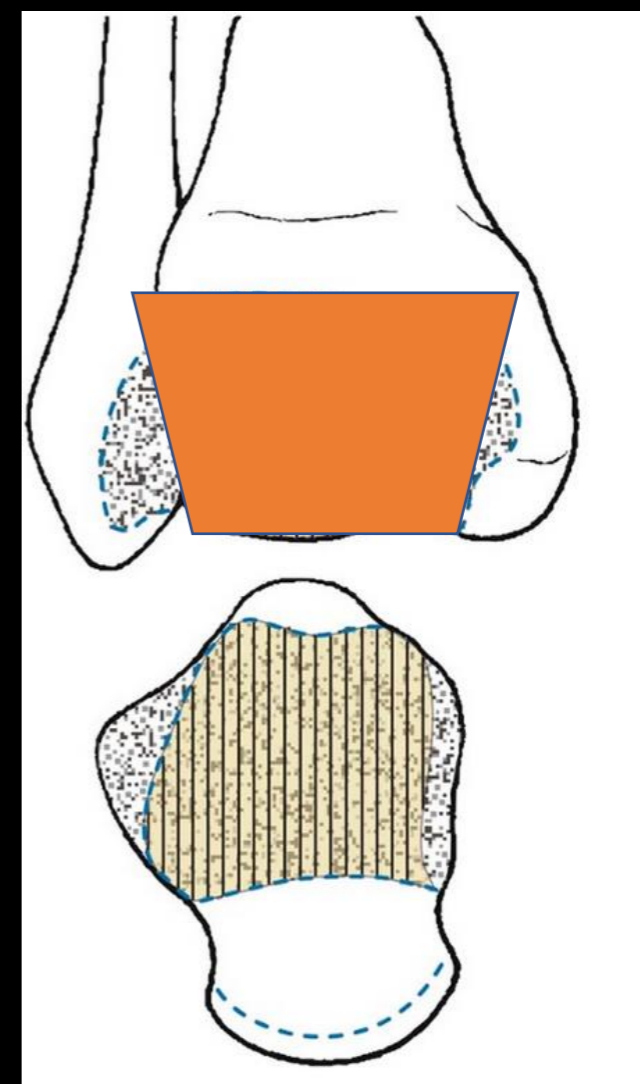
- First described 1911 by Destot
- Less than 1% of all LE fractures

Anatomy

1. Distal tibia articular surface shape: irregular rectangle

2. Wider anteriorly

3. Concave coronal and sagittal

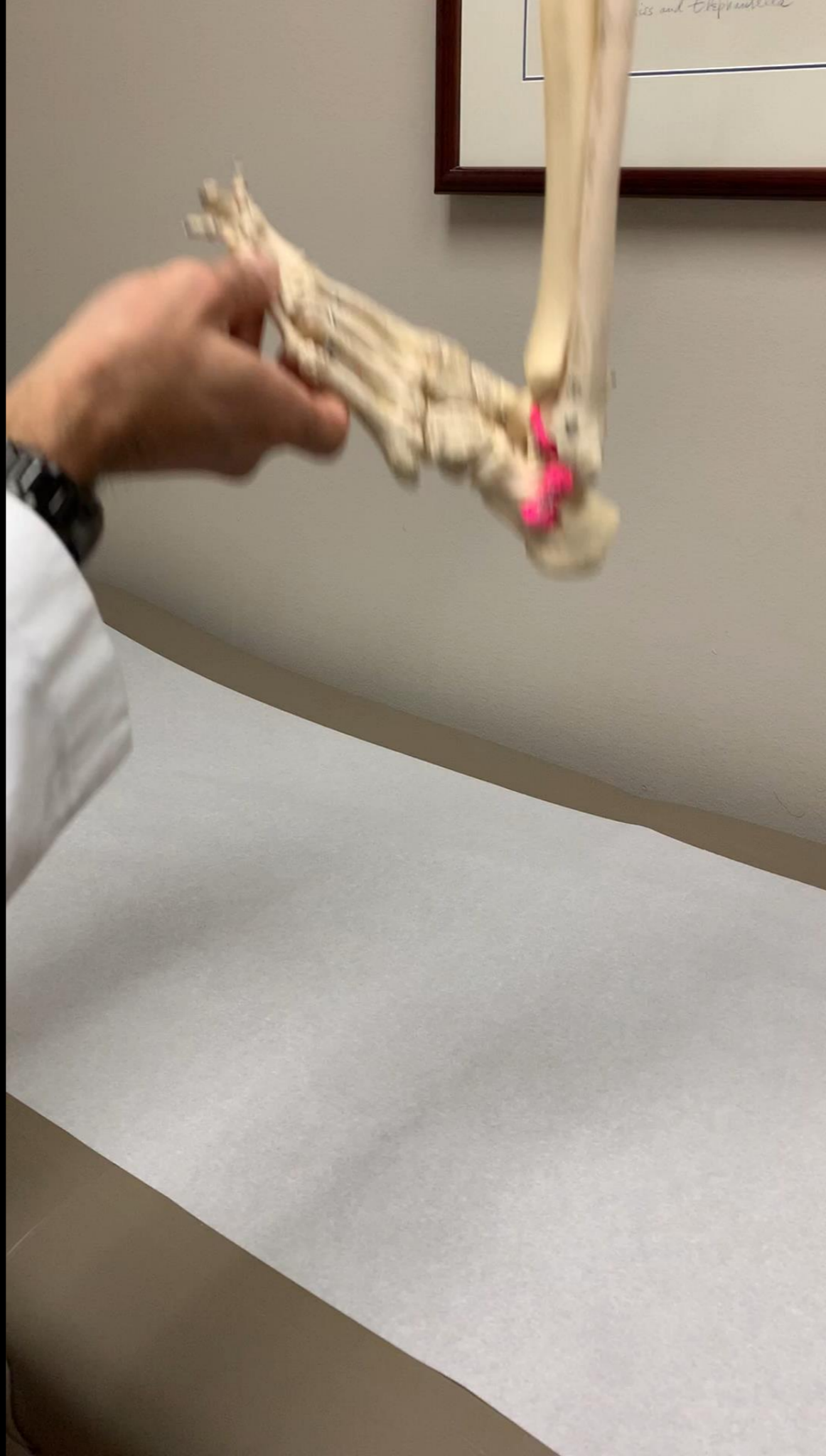


Anatomy

Metaphysis: thin cortex,
dense cancellous bone,
strongest bone near
subchondral plate

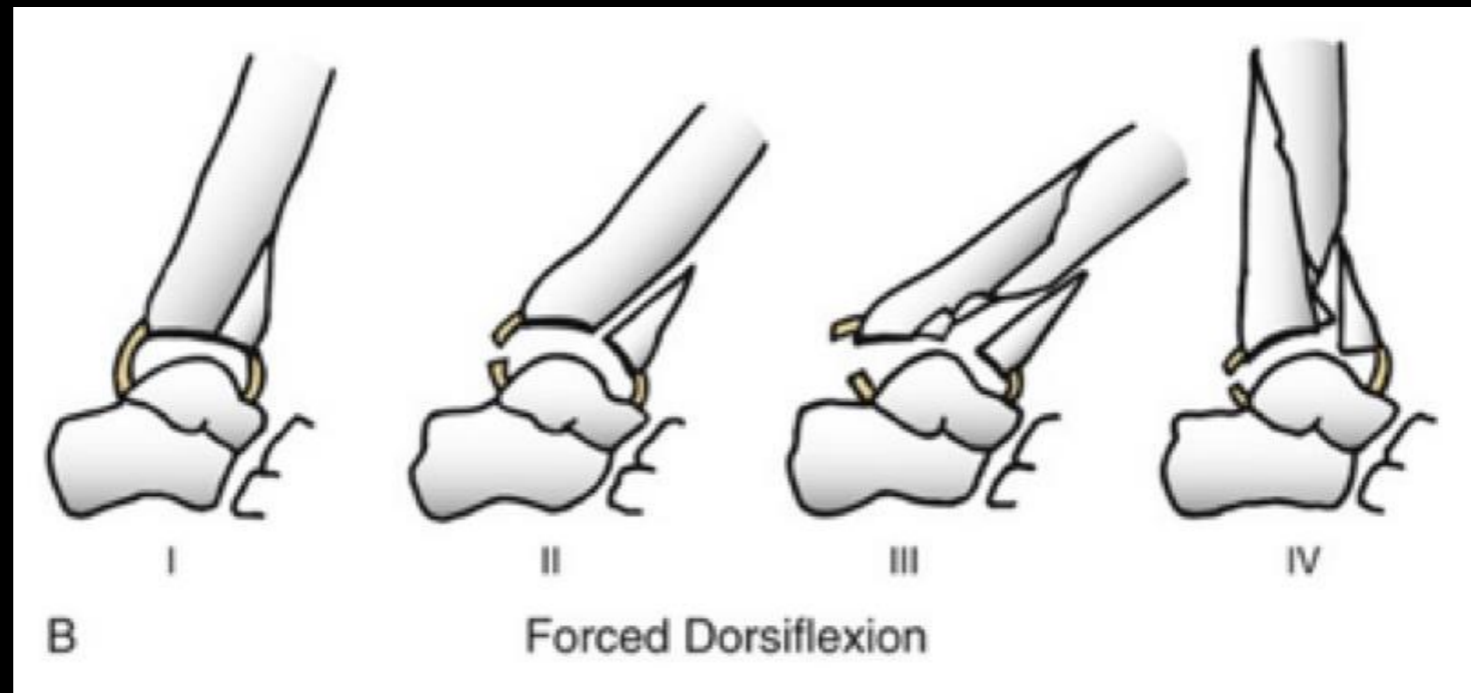


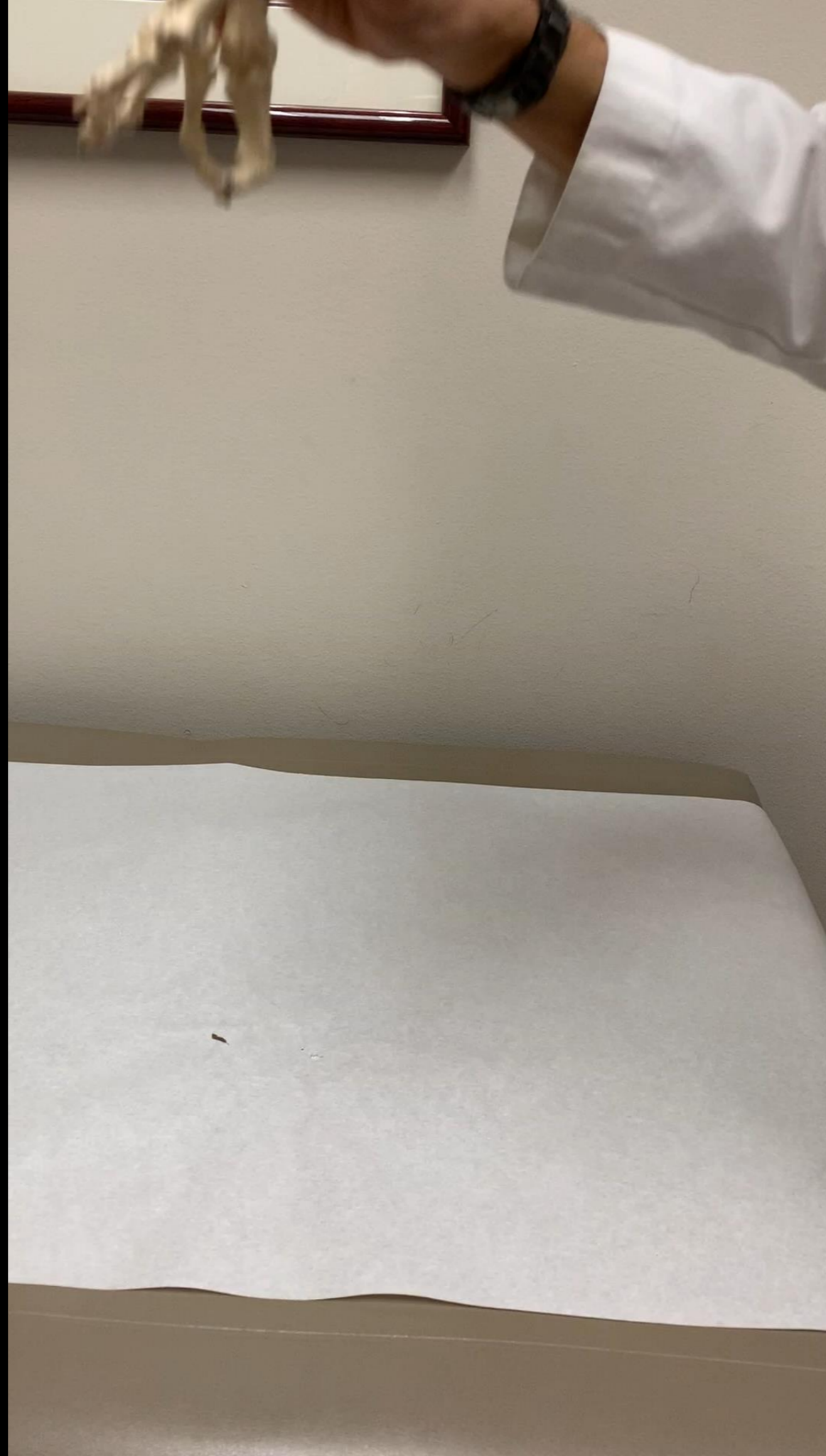
Mechanism of Injury



Mechanism of Injury

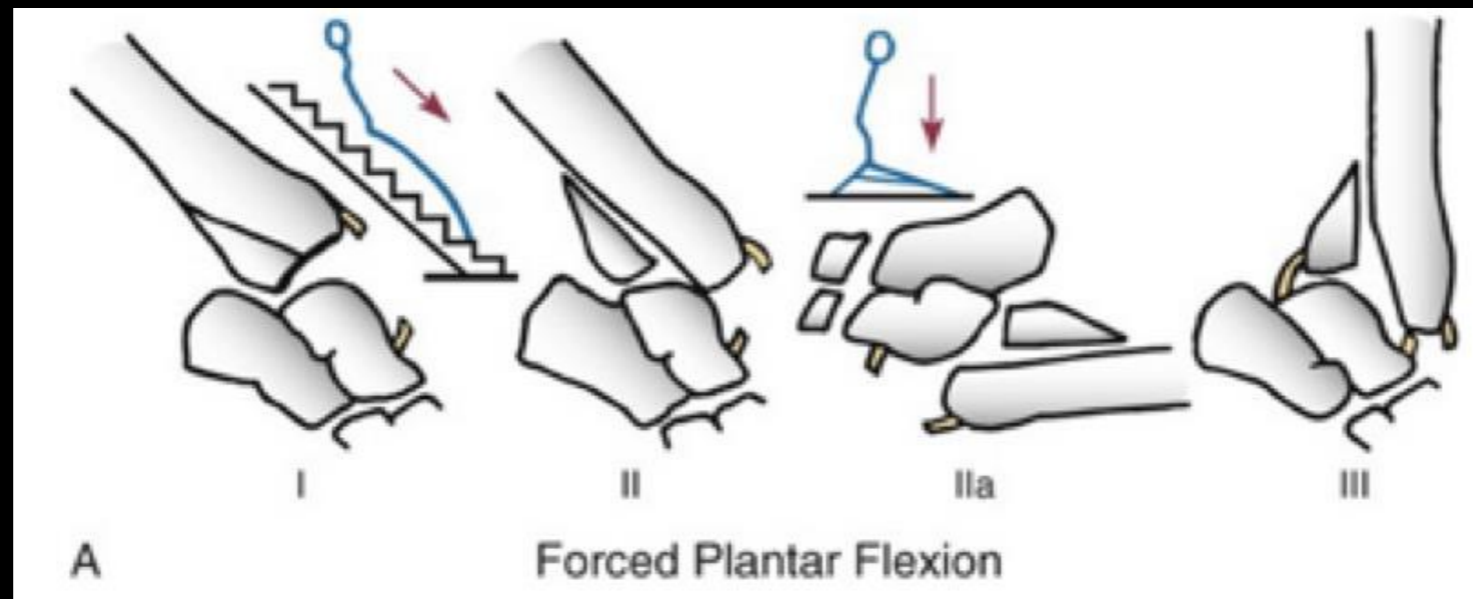
- Vertical compression and dorsiflexed foot:
anterior impaction





Mechanism of Injury

Vertical compression and plantarflexed foot:
posterior malleolar fracture



Mechanism of Injury: High Energy

- Metaphyseal comminution
- Displaced articular fragments
- Soft tissue injury



Mechanism of Injury: Low Energy

- Associated with torsion
- Spiral fractures
- Decreased comminution
- Less soft tissue injury



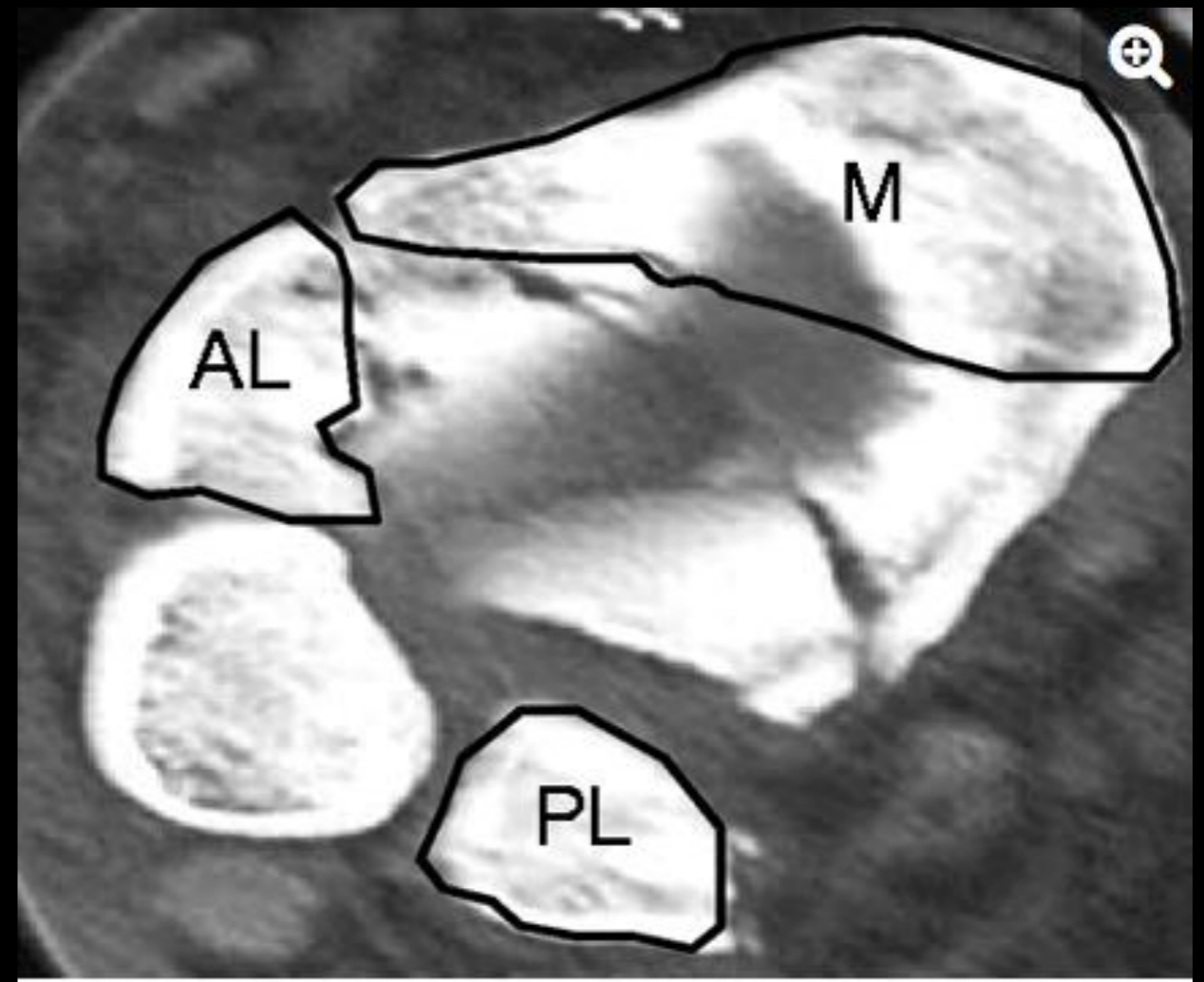
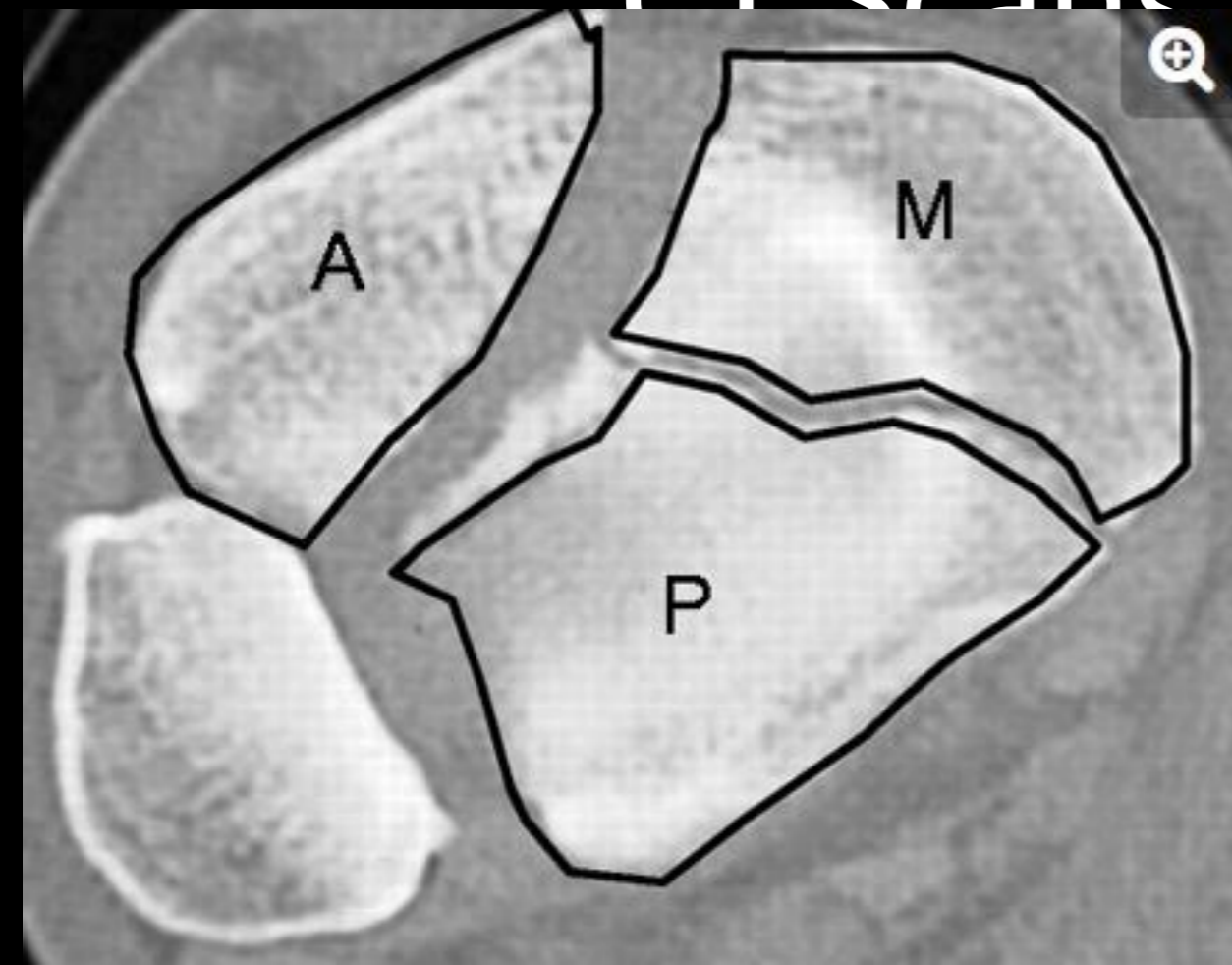


Topliss et al analyzed 126 pilon fractures patterns Plain XR and CT

Six major articular fragments identified: anterior, posterior, medial, anterolateral, posterolateral, and die-punch

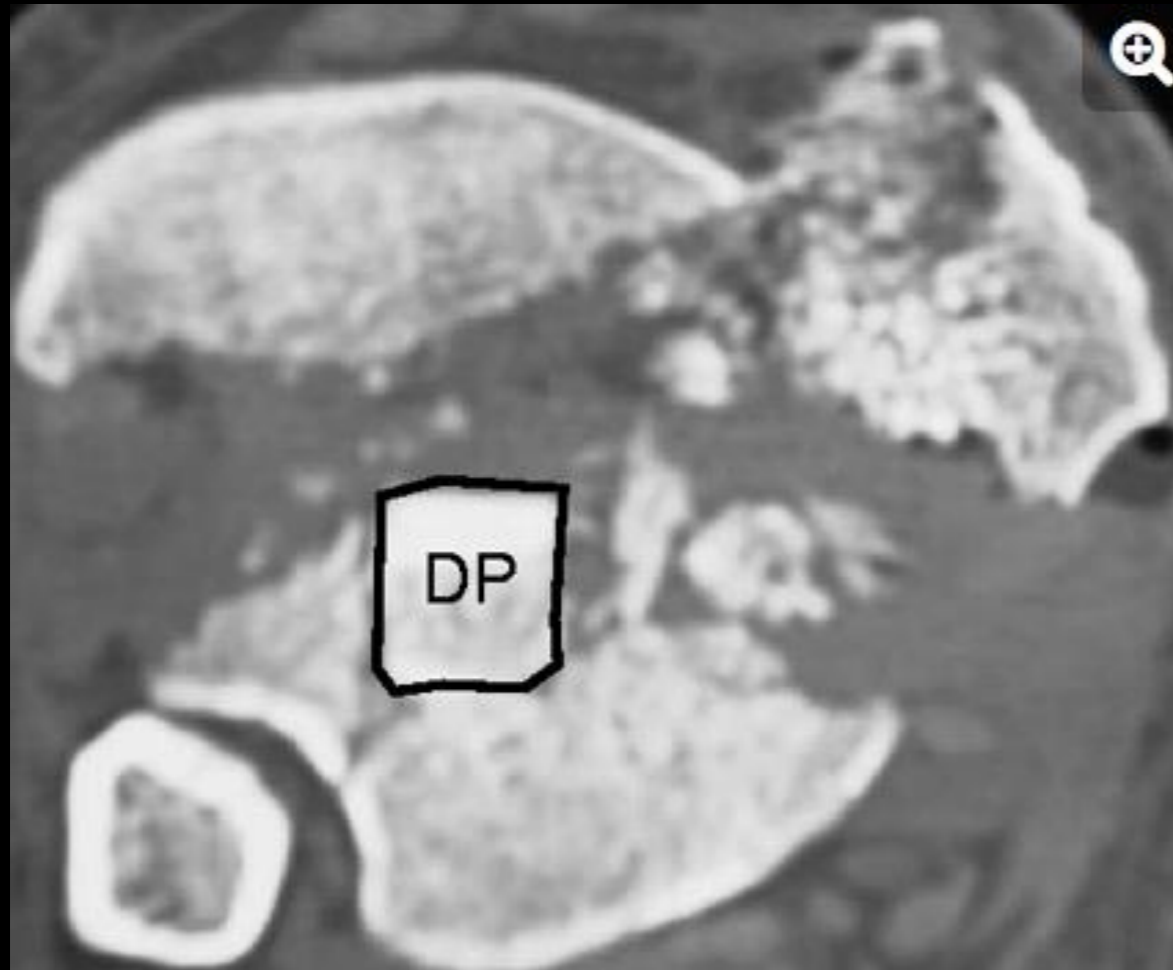
Topliss CJ, Jackson M, Atkins RM. Anatomy of Pilon Fractures of the Distal Tibia. J Bone Joint Surg Br. 2005 May;87(5):692-7

CT Scans



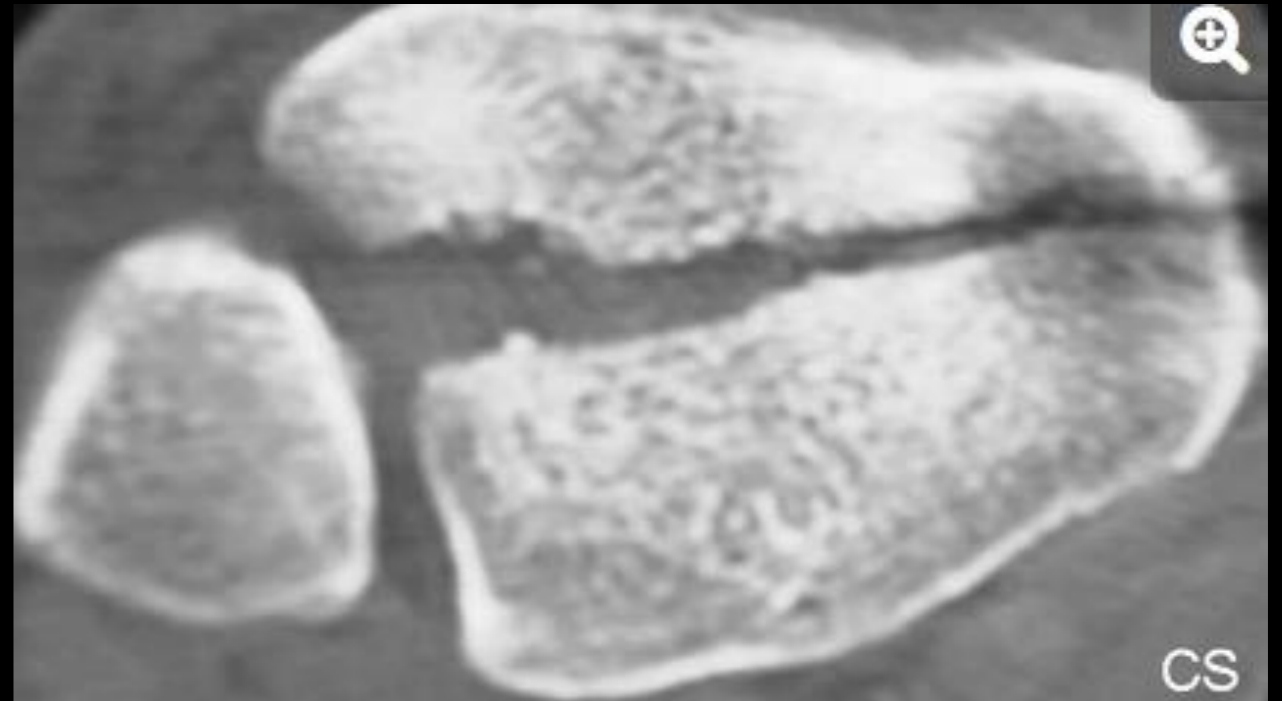
Topliss CJ, Jackson M, Atkins RM. Anatomy of Pilon Fractures of the Distal Tibia. J Bone Joint Surg Br. 2005 May;87(5):692-7

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Topliss CJ, Jackson M, Atkins RM. Anatomy of Pilon Fractures of the Distal Tibia. J Bone Joint Surg Br. 2005 May;87(5):692-7

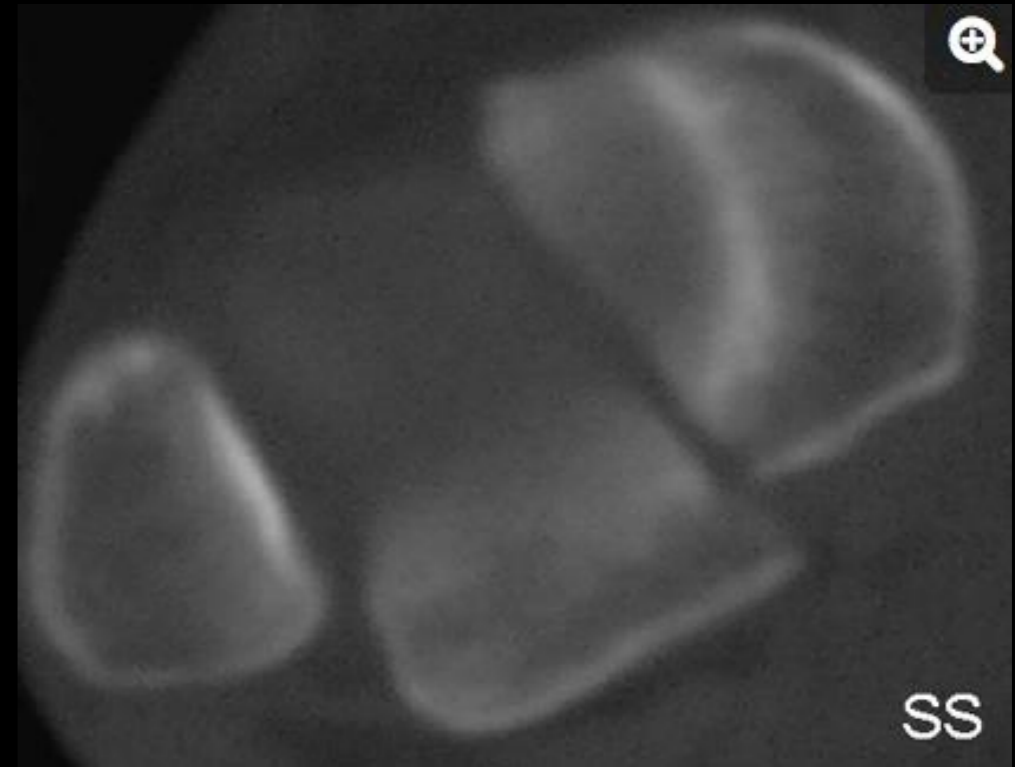
Coronal Split



Two main fracture groups identified:

Coronal fractures occurred in older patients with low-energy injuries valgus angulation

Sagittal Split



Sagittal fractures occurred in younger patients, high-energy injuries varus angulation

Goals of Treatment

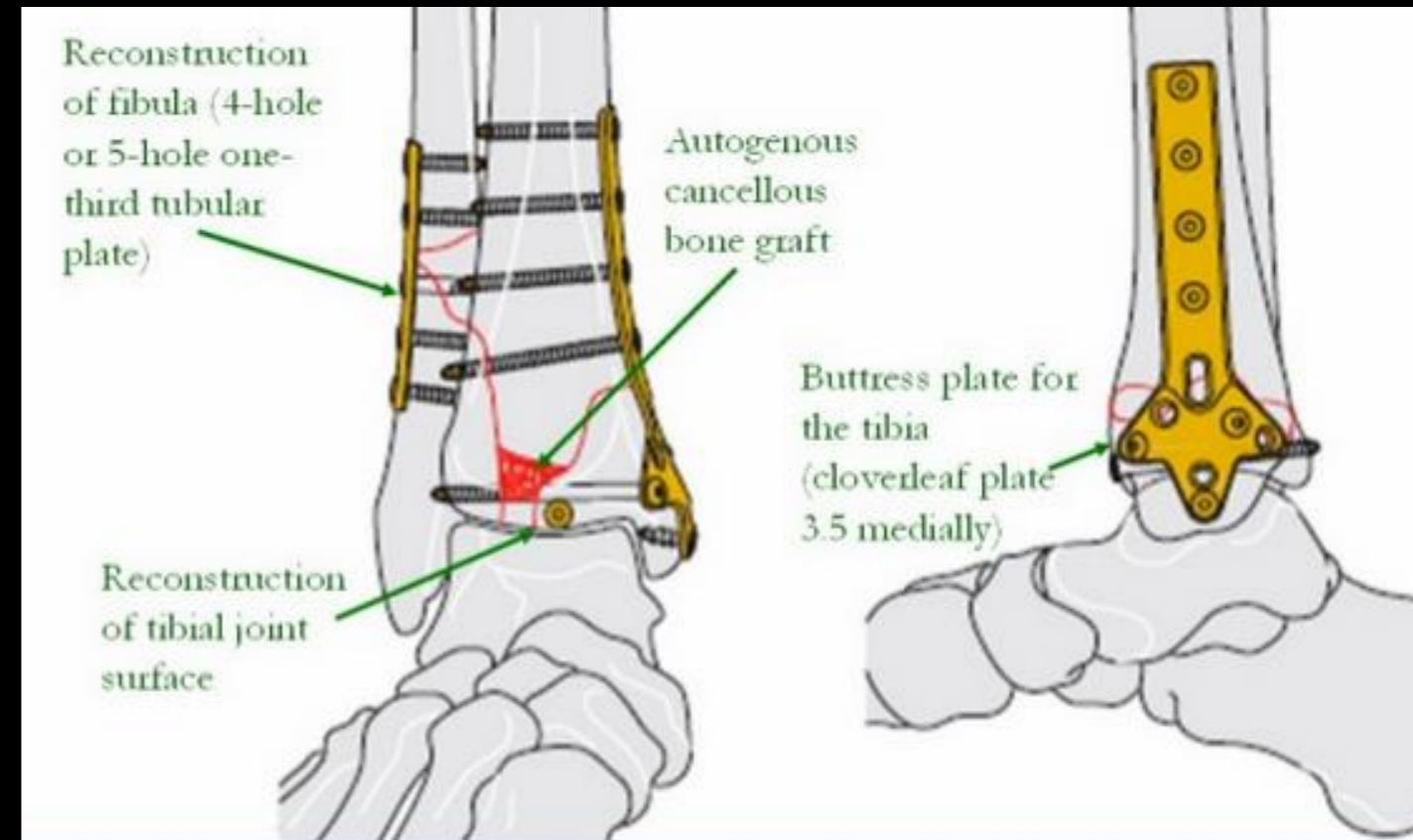
- Reconstruct articular surface
- Restore mechanical axes
- Allow for early joint range of motion



Historical Treatment

1969 Ruedi and Allgower classic technical principles:

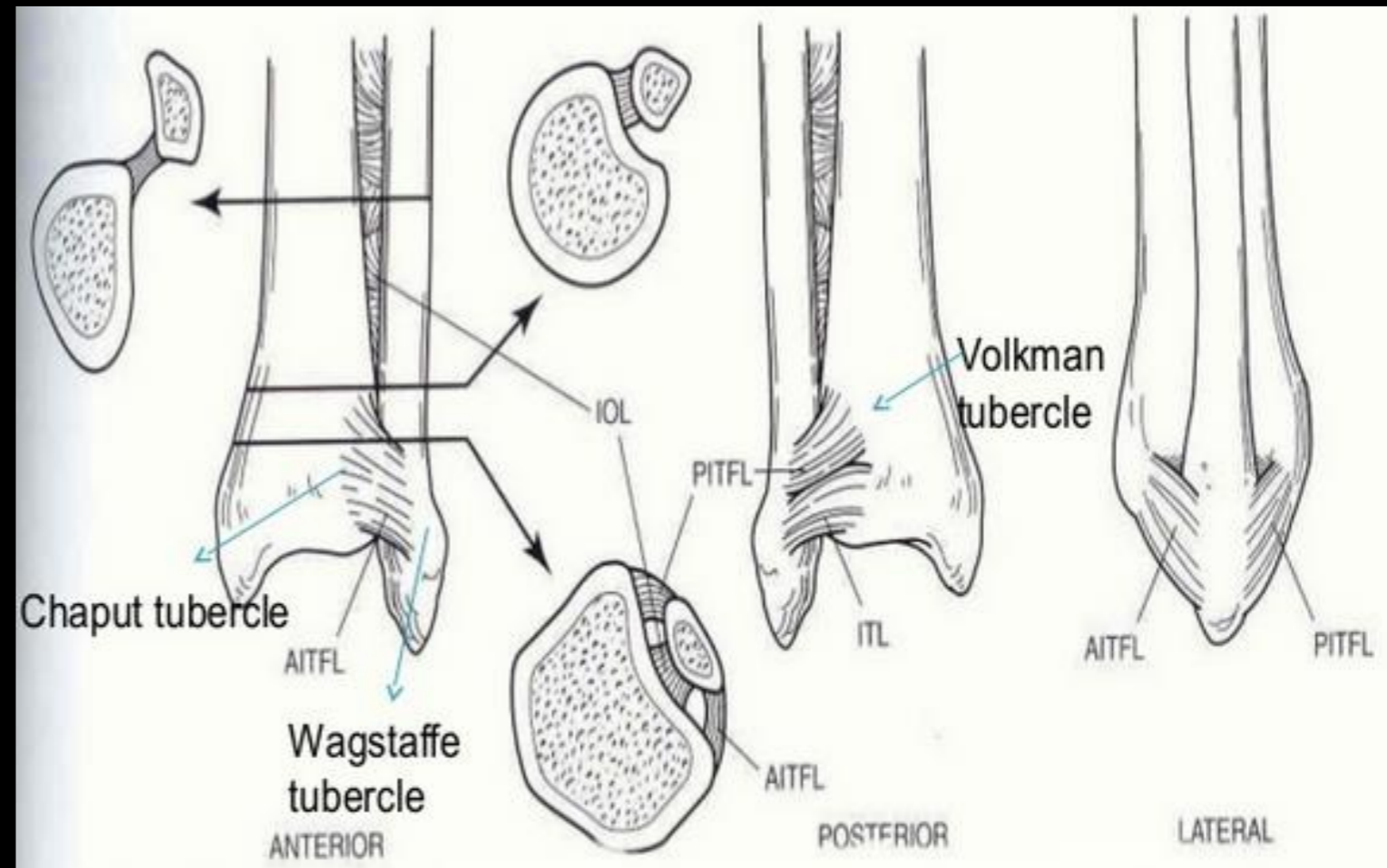
1. Reduce and restore length of the fibula
2. Correct distal tibial valgus
3. Reduce Chaput fragment
4. Reduce Volkmann fragments
5. Restore tibial articular surface
6. Use autologous bone grafting in metaphyseal defects
7. Buttress plating of tibia to prevent varus angulation



Anatomy

Anterior tibiofibular ligaments arises from the tibial Chaput tubercle anterior to the fibular notch

Inserts on the Wagstaffe tubercle of the distal fibula



Evolution of Treatment Options

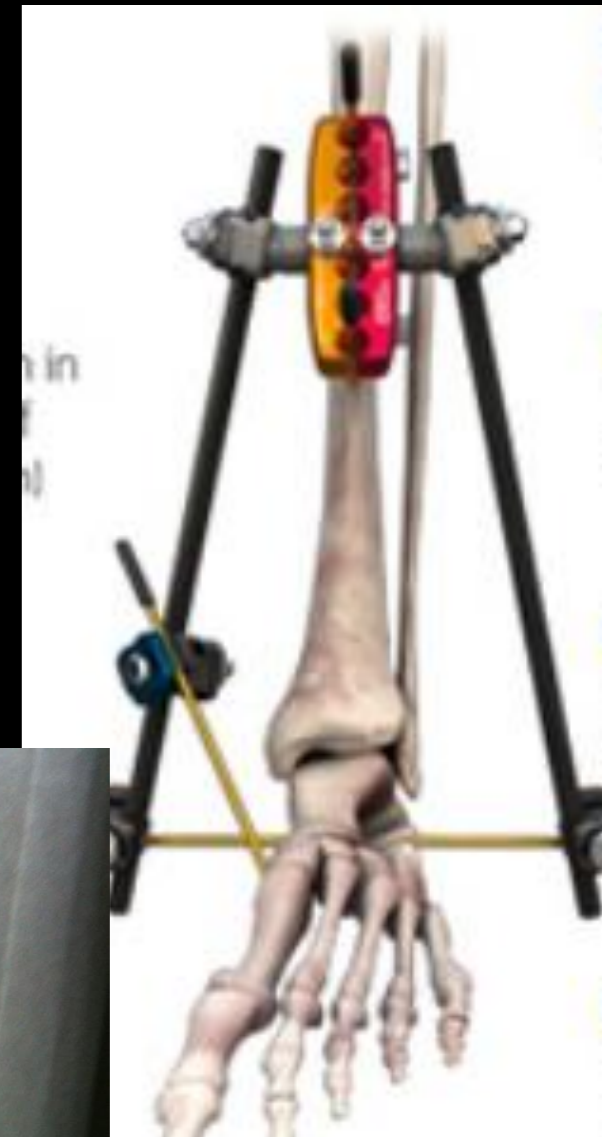
Ruedi and Allgower did not discuss soft tissue injuries

With increasing highway speeds, higher energy pilon fracture incidence is increasing



2023 Current Treatment Options: Initial Ex Fix

- Simple A frame, delta with calcaneal transfixion pin
- Multiplanar unilateral frame requires medial half pin with one in the talar neck and one in the calcaneus



Swelling...

Schatzker and Tile: surgery in the setting of massive swelling is hazardous—must be avoided

Wait up to 3 weeks



Surgical Timing

ORIF performed too soon usually leads to skin necrosis and wound healing problems:

1980s to 2000s literature: Immediate ORIF leads to wound complication rates of up to **100%**



Sirkin M, Sanders R, DiPasquale T, Herscovici D Jr: A staged protocol for soft tissue management in the treatment of complex pilon fractures.

Patterson MJ, Cole JD: Two-staged delayed open reduction and internal fixation of severe pilon fractures. J Orthop Trauma 1999;13(2):85-91.

Wyrsh B, McFerran MA, McAndrew M, et al: Operative treatment of fractures of the tibial plafond: A randomized, prospective study.

Conroy J, Agarwal M, Giannoudis PV, Matthews SJ: Early internal fixation and soft tissue cover of severe open tibial pilon fractures. Int

Pay attention to:

1. Timing of your intervention
2. Patient Risk Factors
3. Soft tissue management
4. Plating Techniques
5. Post operative soft tissue management



RESULTS: Is articular reduction or injury pattern more important?

NEITHER INJURY SEVERITY OR FRACTURE REDUCTION CORRELATES WITH CLINICAL OUTCOMES

Articular reduction does significantly correlate with future ankle arthritis

Outcomes are not predictable

Best predictors of clinical outcomes:

Patient socioeconomic status

Level of education

Marsh JL, Weigel DP, Dirschl DR: Tibial plafond fractures: How do these ankles function over time? J Bone Joint Surg Am 2003;85(2):287-295.

Williams TM, Nepola JV, DeCoster TA, Hurwitz SR, Dirschl DR, Marsh JL: Factors affecting outcome in tibial plafond fractures. Clin Orthop Relat Res 2004;(423):93-98.

Outcomes **High** Energy Pilon

35% persistent stiffness

33% ongoing pain

Many get arthritis

Conclusions

- Very challenging fractures to manage
- Outcomes unpredictable, often poor
- Outcomes related to socioeconomic status and level of education



QUESTION 1:

- A low energy Pilon fracture is characterized by:



1. An axial compression mechanism of injury
2. Significant comminution
3. A torsion mechanism
4. Lower socioeconomic status

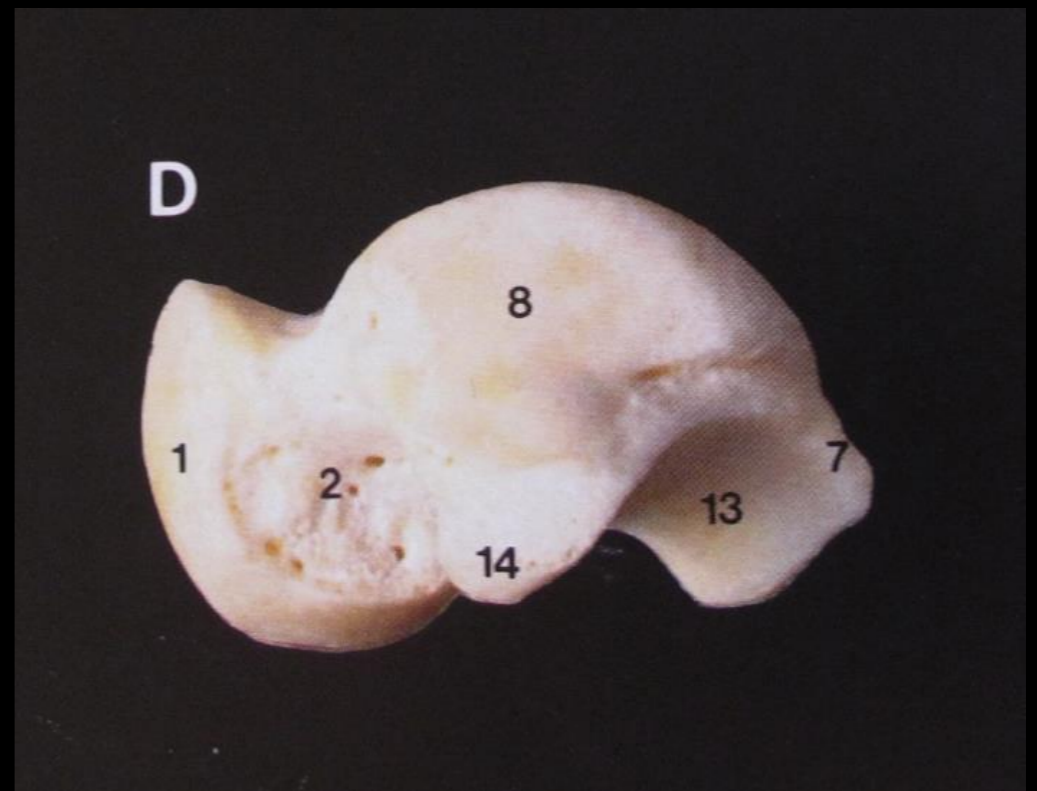
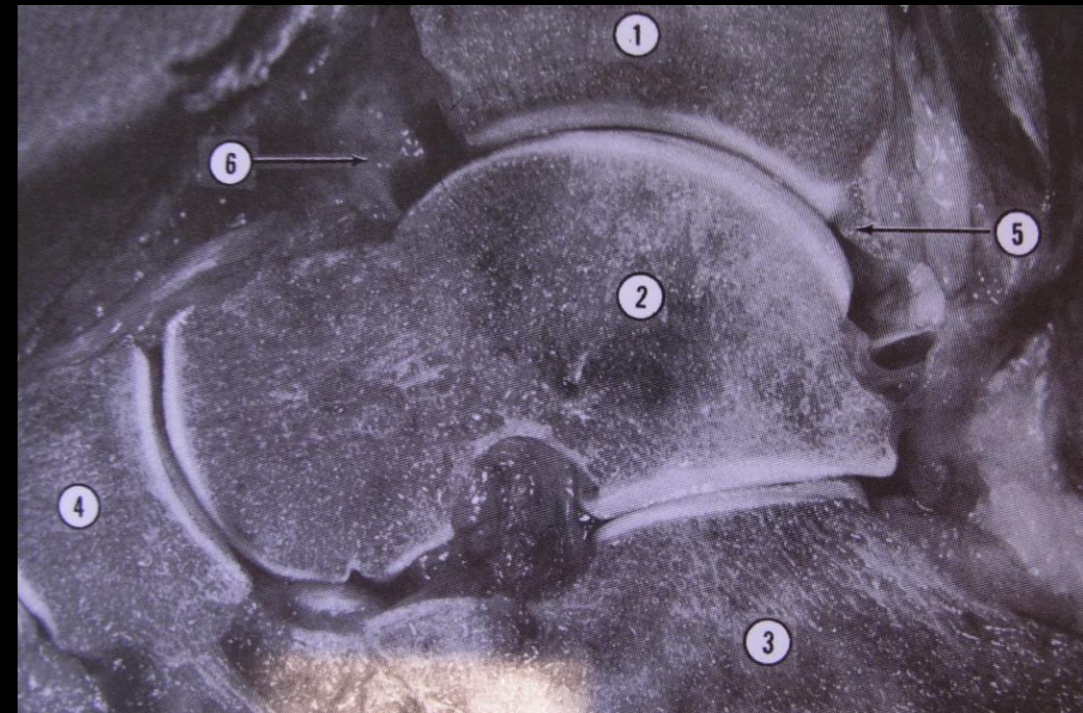


Talus Fractures

The Talus: What is it?



- The talus is the key in the transition of forces between the foot and the leg and body
- Has no origins or insertions of any musculotendinous units
- 70% of the talus is covered with articular cartilage



Talar Fractures

- “Aviator’s astragalus”
- Anderson described 18 talar neck fractures WWI pilots
- The impact of the rudder bar on the foot during a crash is the mechanism of fracture







CROSS TABLE



S = 400/ESE = 1781
1/2 Ankle AP

Compressed 8:1

Hansel Ashby MD

3 images

Series: MJO

W

S

11:40:2



S = 400/ESE = 1923
2/2 Ankle AP

Compressed 10:1

Ready

Start

Novel-delivered Applicati...

Universal Manager

Talus Fractures

- Results are highly variable but are dependent upon initial fracture displacement
- As such, operative intervention should be considered for displaced fractures

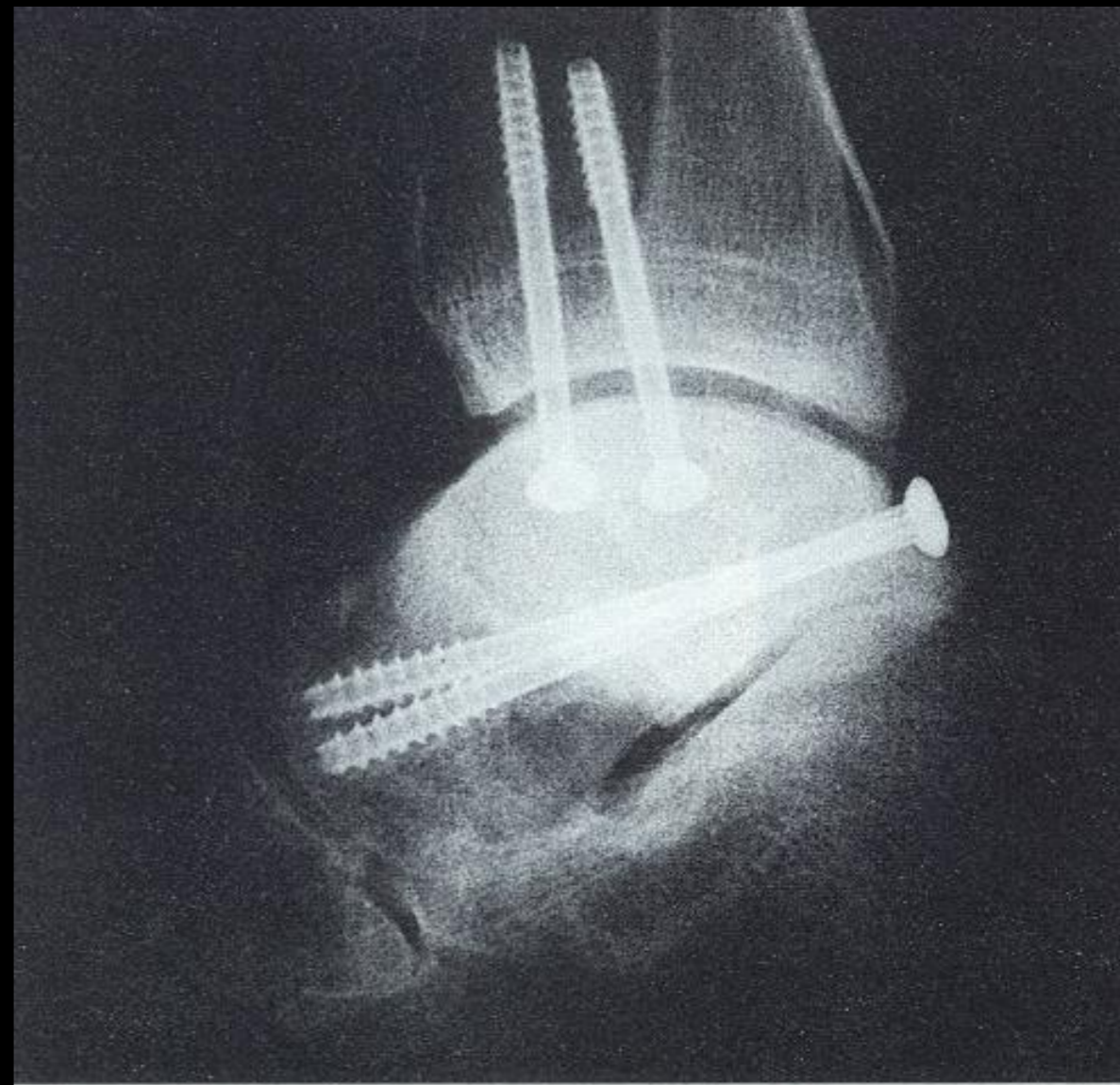


Talus Fractures Complications

- **Avascular necrosis**

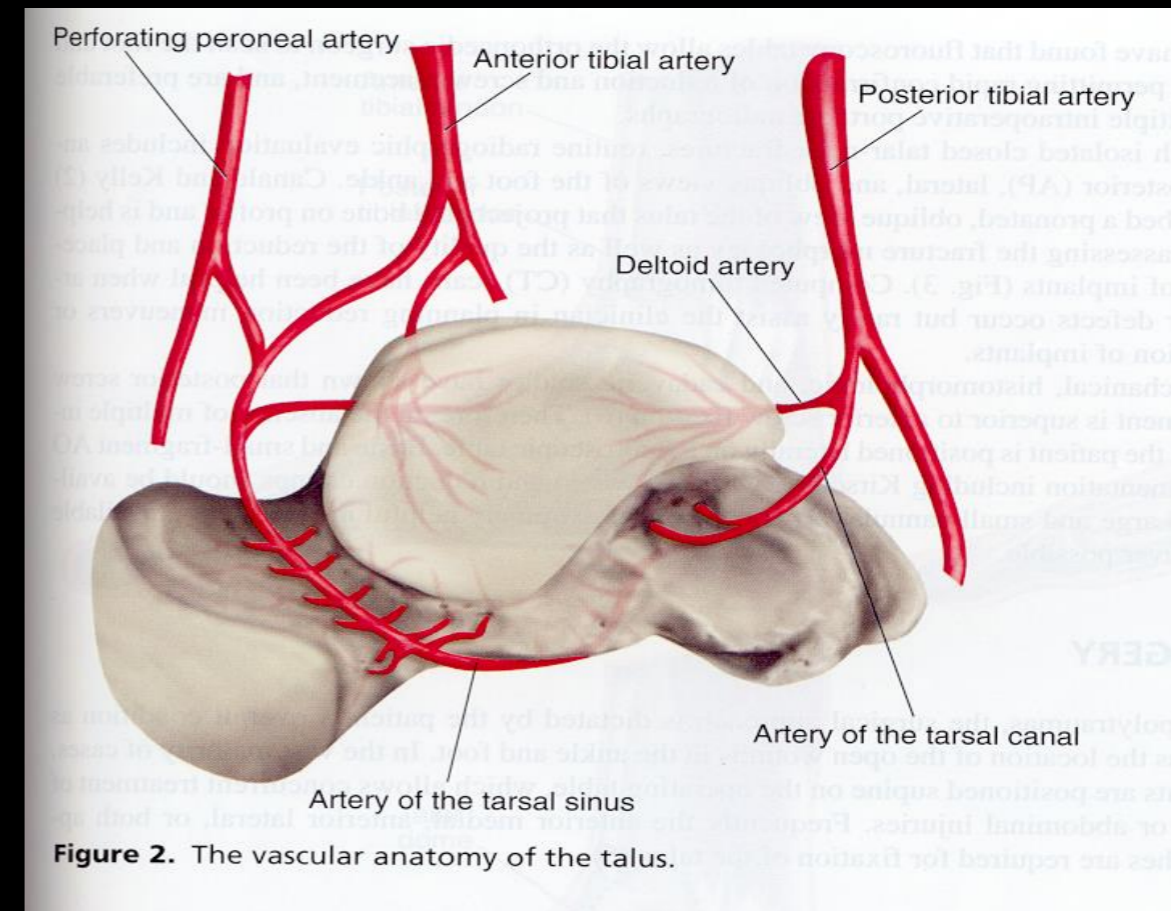
- Nonunion

- malunion



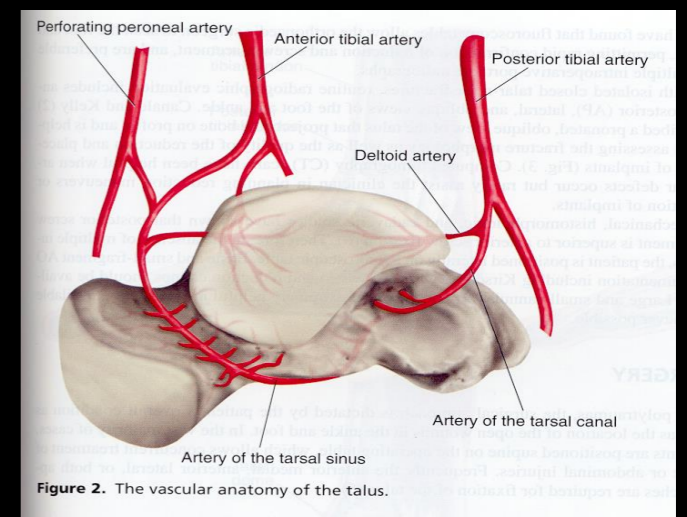
Anatomy - Blood Supply

- **Talar neck and head:** Artery to the sinus tarsi (peroneal and dorsalis pedis arteries)
- **Talar Body:** Artery of the tarsal canal (posterior tibial artery)
- **Posterior Talus:** Posterior tibial artery through calcaneal branches



Anatomy - Blood Supply

- Preservation of at least of three major extraosseous sources can allow adequate circulation via anastomotic channels



Classification

- Fracture type associated with prognosis

Classification

- Type I: NONDISPLACED vertical neck fracture



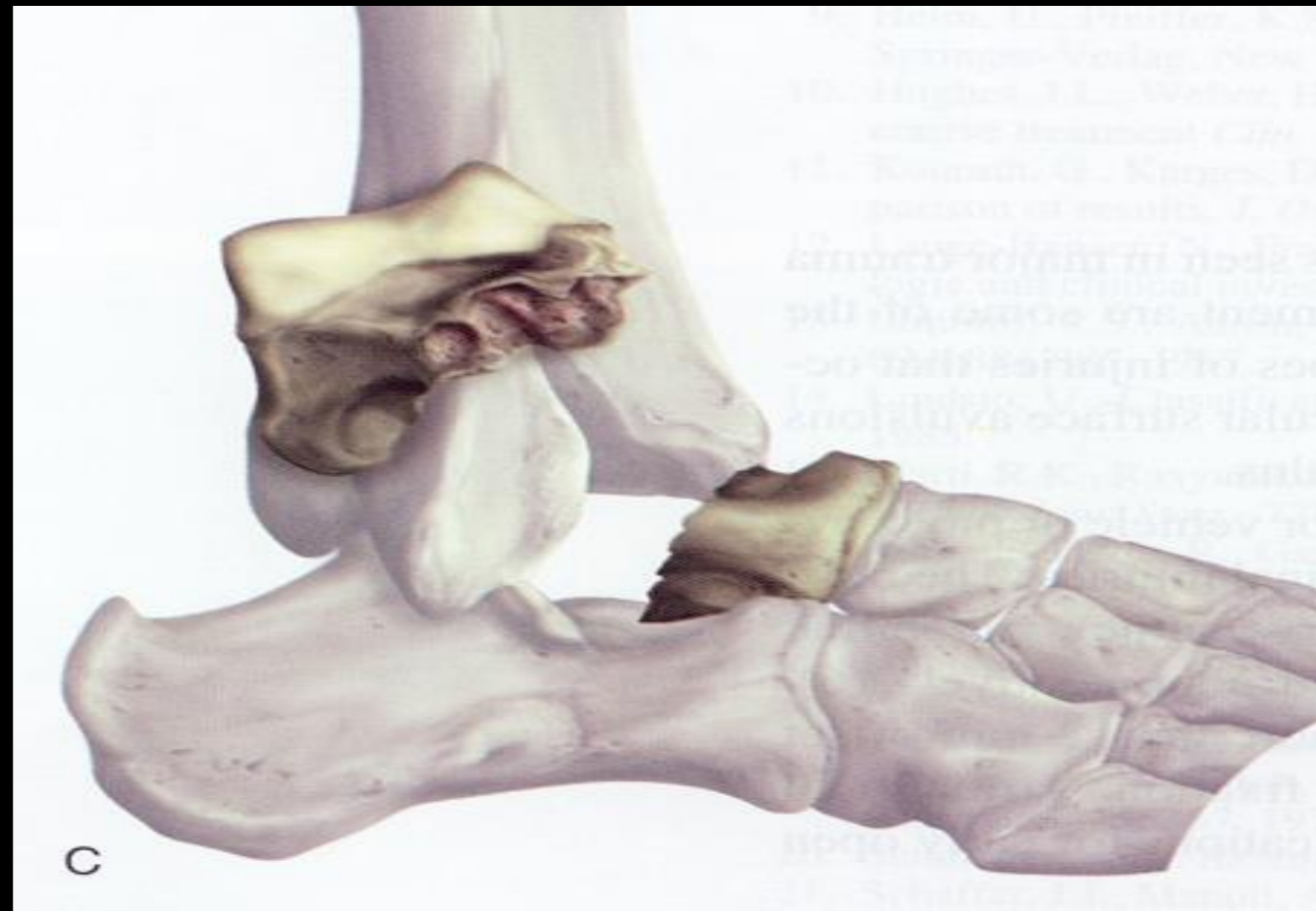
Classification

- Type II: Displaced fracture with subluxation/dislocation of the subtalar joint



Classification

- Type III: Displaced fractures with dislocation of the talar body from both the subtalar and ankle joints



Classification

- Type IV: (Canale and Kelly) Rare variant of type III in which the head of the talus is also dislocated from the talonavicular joint



Hawkins' Classification

- Type I fracture: fracture through the middle and posterior subtalar facets
 - **1 of 3** talar blood supplies injured—**anterior lateral neck**



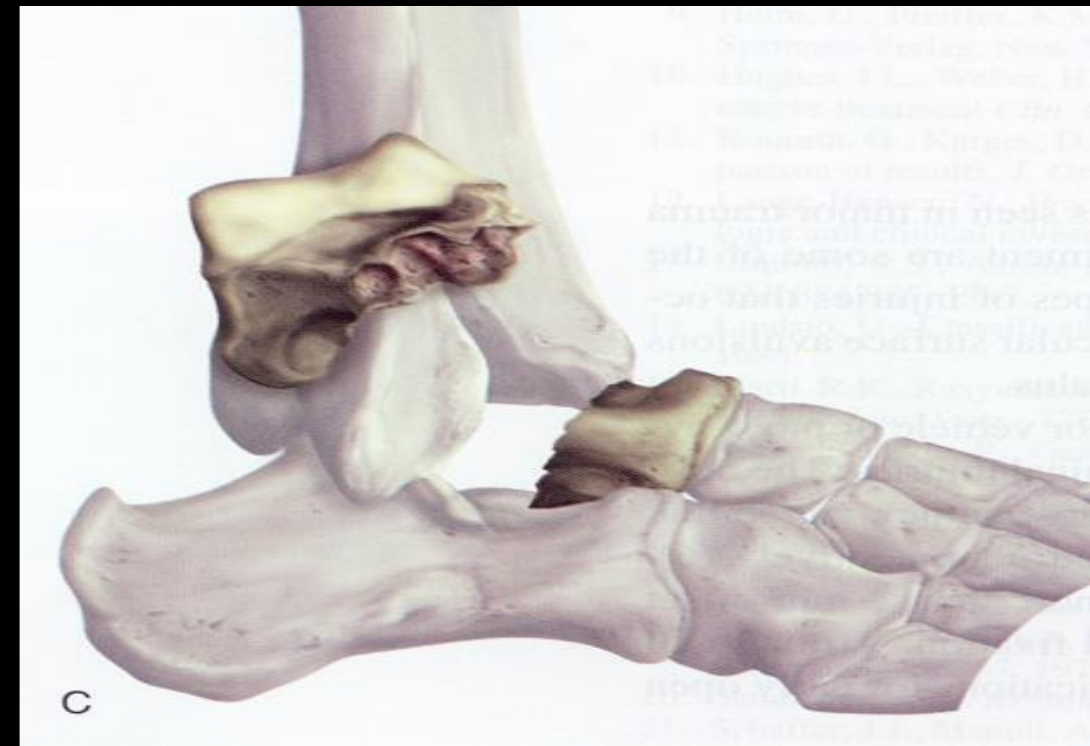
Hawkins' Classification

- Type II fracture
 - Two blood supply sources injured
 - Medial blood supply usually left intact



Hawkins' Classification

- Type III fracture:
 - Talar body dislocated posterior medially, between posterior tibia cortex and Achilles
 - **All three sources of blood supply interrupted**
 - 50% open injuries



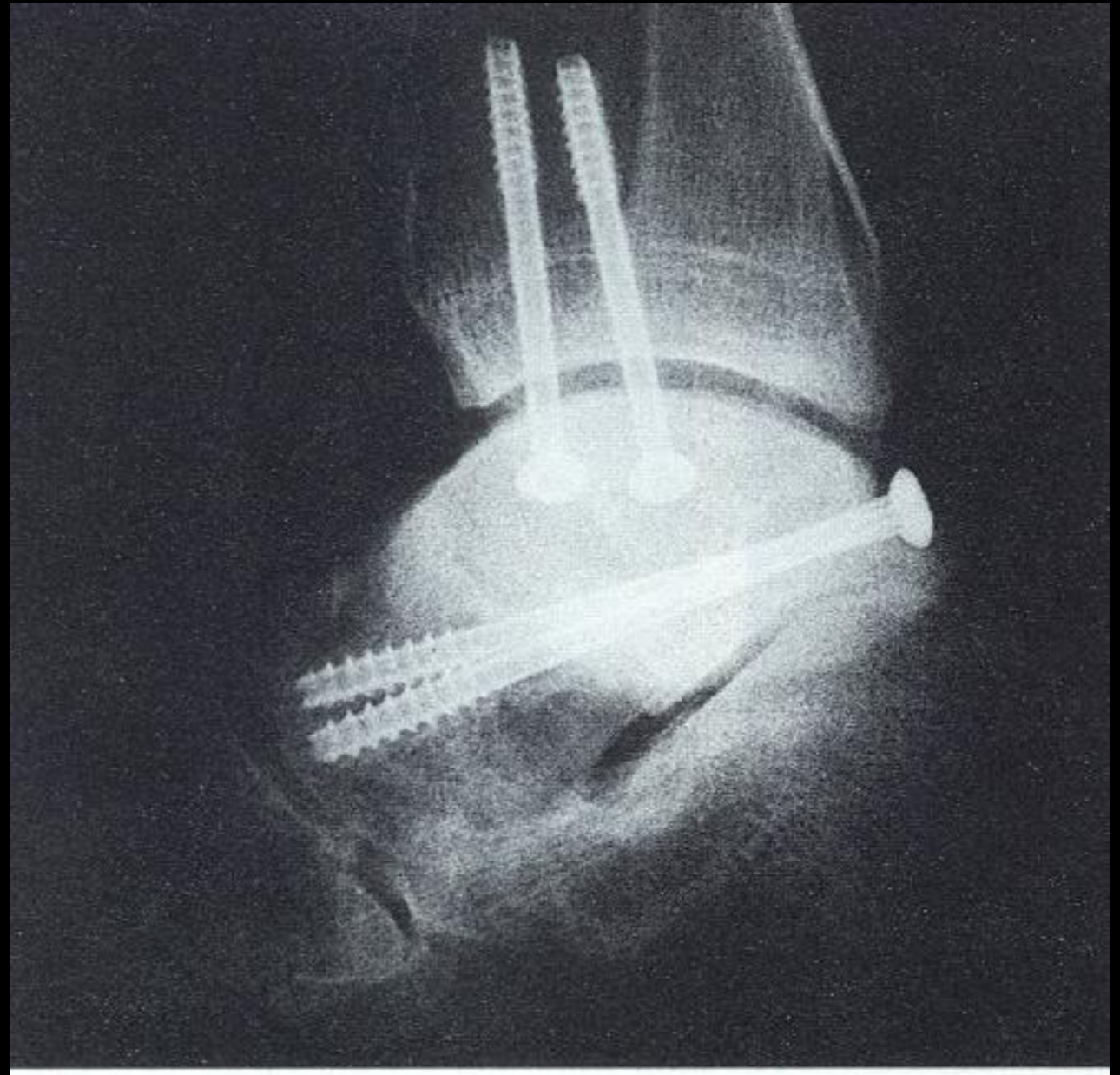
Hawkins' Classification

- Type IV fractures
 - Rare 4% of all fractures
 - All with unsatisfactory results



Most Worrisome Complication:

- Osteonecrosis



Complications

- Osteonecrosis is the result of disruption of the blood supply to the talus
- The Hawkins' class of fracture is related to the probability of osteonecrosis
 - Type I - 0 to 13%
 - Type II - 42 to 50%
 - Type III - 84 to 91%

Treatment

- Prompt reduction of dislocations
- Prevent skin necrosis
- Evaluate vascular status



Treatment - Neck and Body

- **ANATOMIC REDUCTION** of the fracture is the preferred method of treatment

CROSS TABLE

R
B.F.



Pat



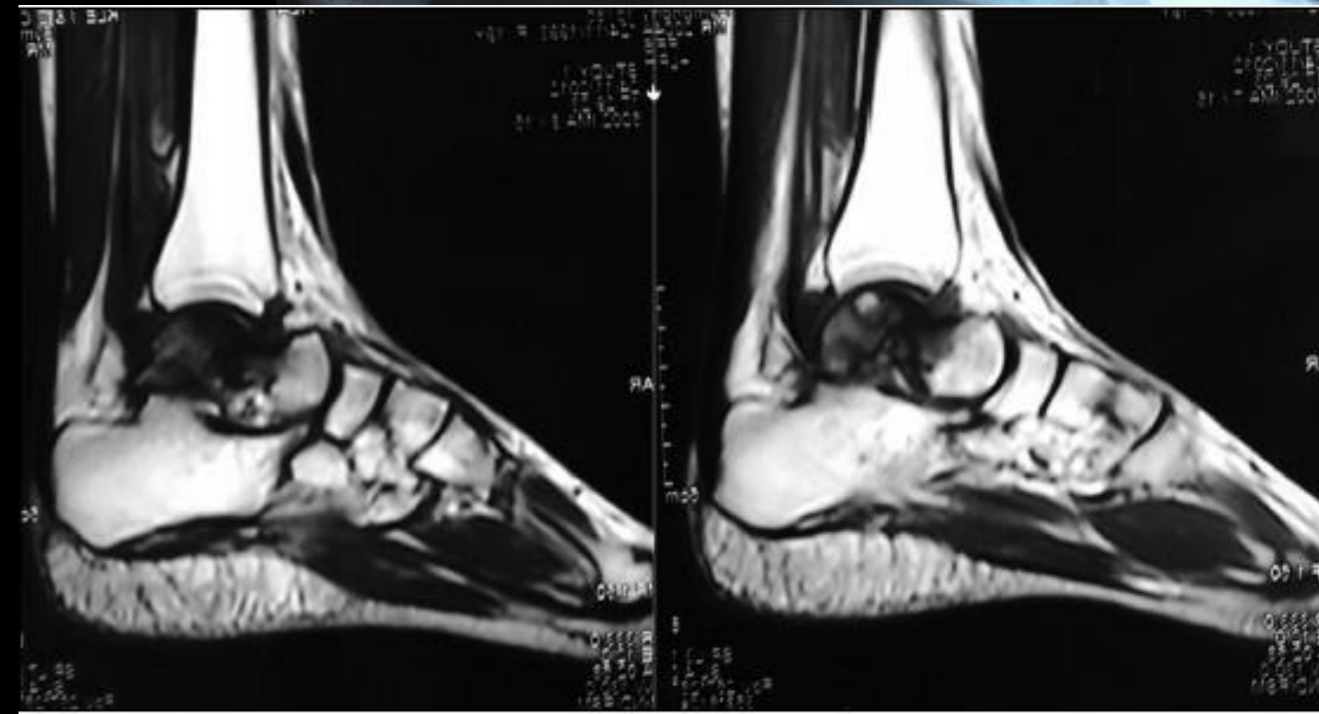
R
G
M

STANDING
04.30.10

fx

General: Talus Fractures

- Consider Titanium screws to evaluate for post operative avascular necrosis with MRI scanning



Save or discard extruded talar body?

- Marsh et al.:
 - With saved talus: deep infection **38%**
 - **71%** poor outcomes
 - ??? Explant the talus if no soft tissue remains attached in a contaminated wound



Talectomy: Salvage

- Talectomy - shortens the extremity and makes shoe wear difficult—very poor results



SOLUTIONS:

**Why not maintain the
joint and replace the
Talus?**

Talar Replacement

- Takakura 2015
 - Total talus replacement
 - N = 55
 - All had pain improvement
 - All had functional improvement





Ceramic Total Talus Kyocera



- Known in the U.S. as a copier company
- Hit it big making ceramic semiconductor parts
- Kyocera = **Kyoto Ceramics**

Ceramic Total Talus Kyocera



- Preoperative CT scans from contralateral limb
- 2 mm cuts

Topography Kyocera Total Talus



Ceramic Total Talus

Kyocera



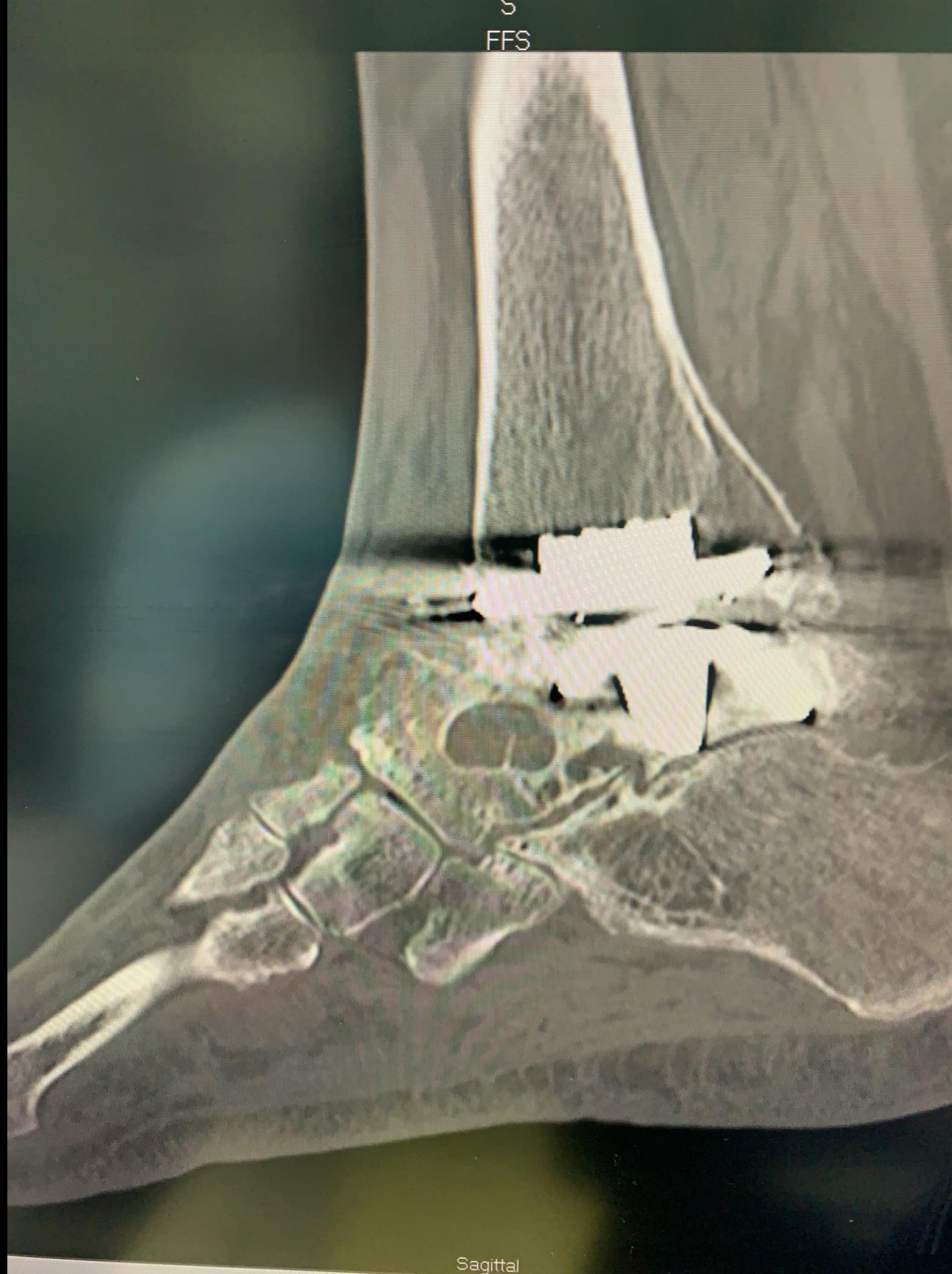
- There is no way it will be exported from Japan
- Serious concerns of getting sued

U.S. Case example

- 65 yo F failed STAR.
- Can no longer fully bear weight.
- She is miserable.



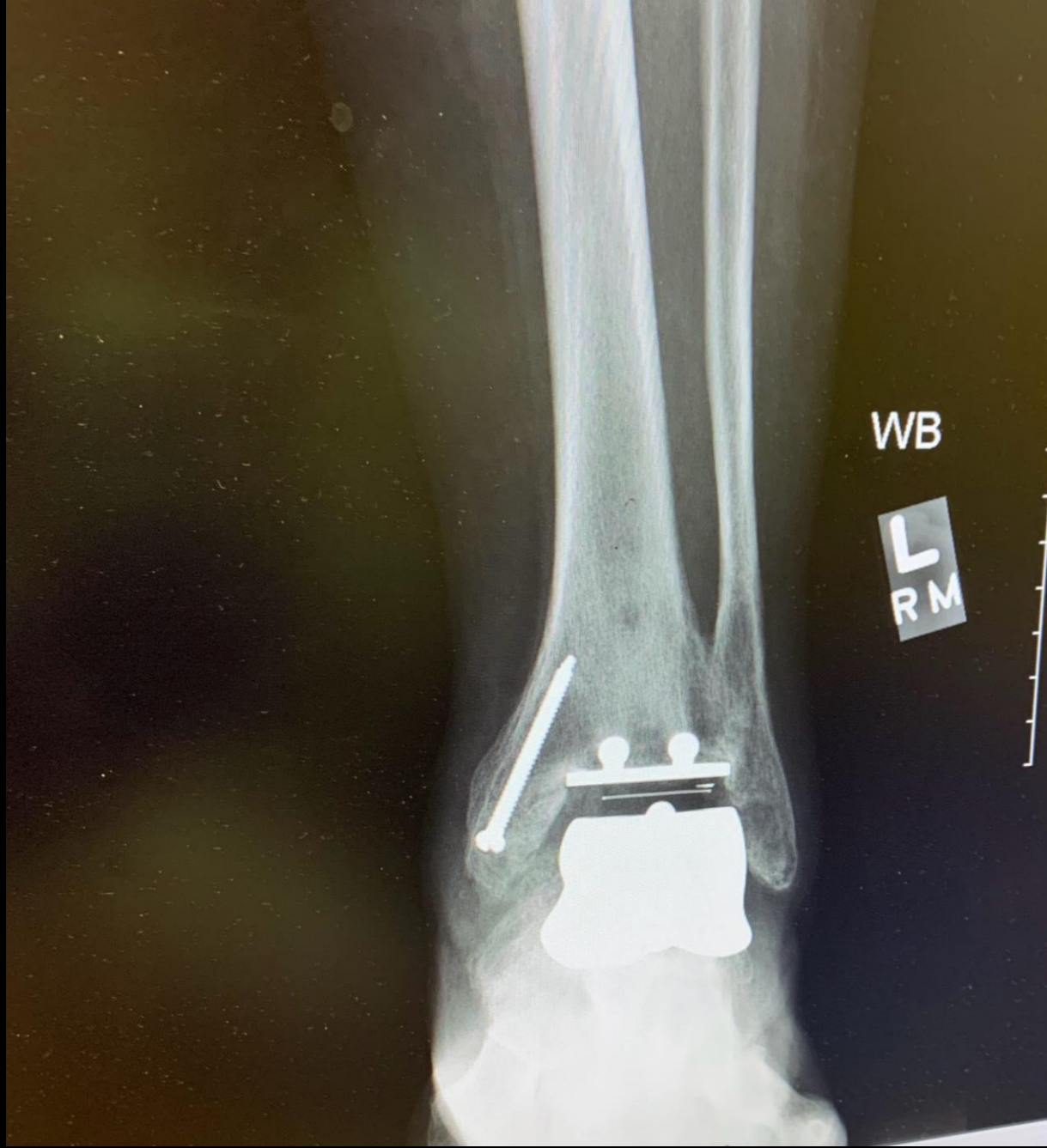
Case 3



I will continue to support the organization and remain committed to achieving its goals. I will continue to support the organization and remain committed to achieving its goals. I will continue to support the organization and remain committed to achieving its goals.

Have a great day!





Case 3



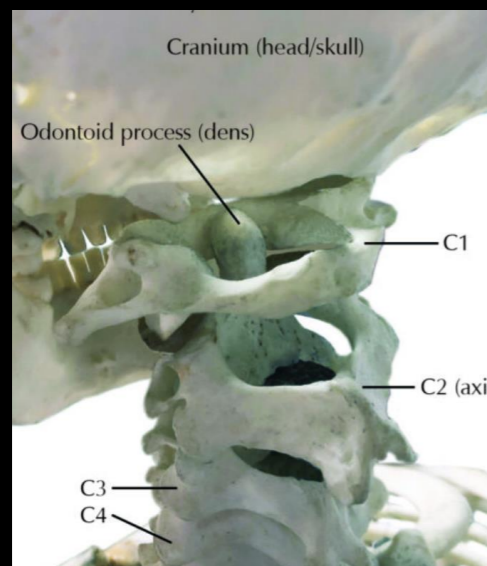
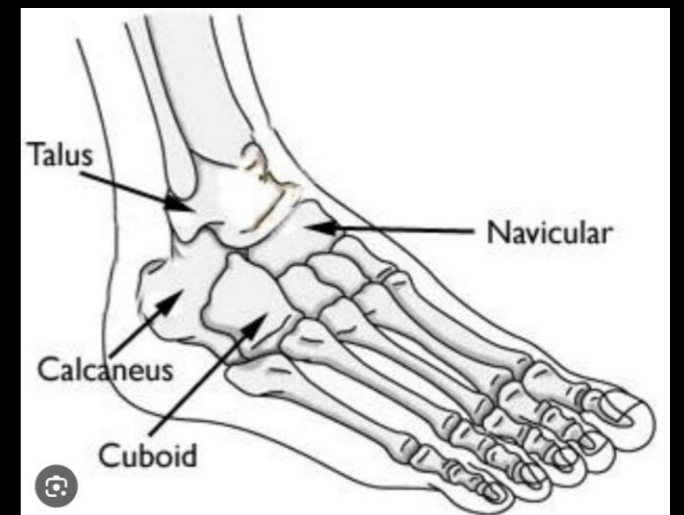
Case 3



QUESTION 2: Who am I?

- I have no muscular attachments
- I have no tendinous attachments
- 70% of me is covered by cartilage

1. A human tooth
2. Calcaneus
3. Carpal Navicular
4. Talus
5. Odontoid
6. Tibial Sesamoid



5. Cutting Edge Treatment and Research

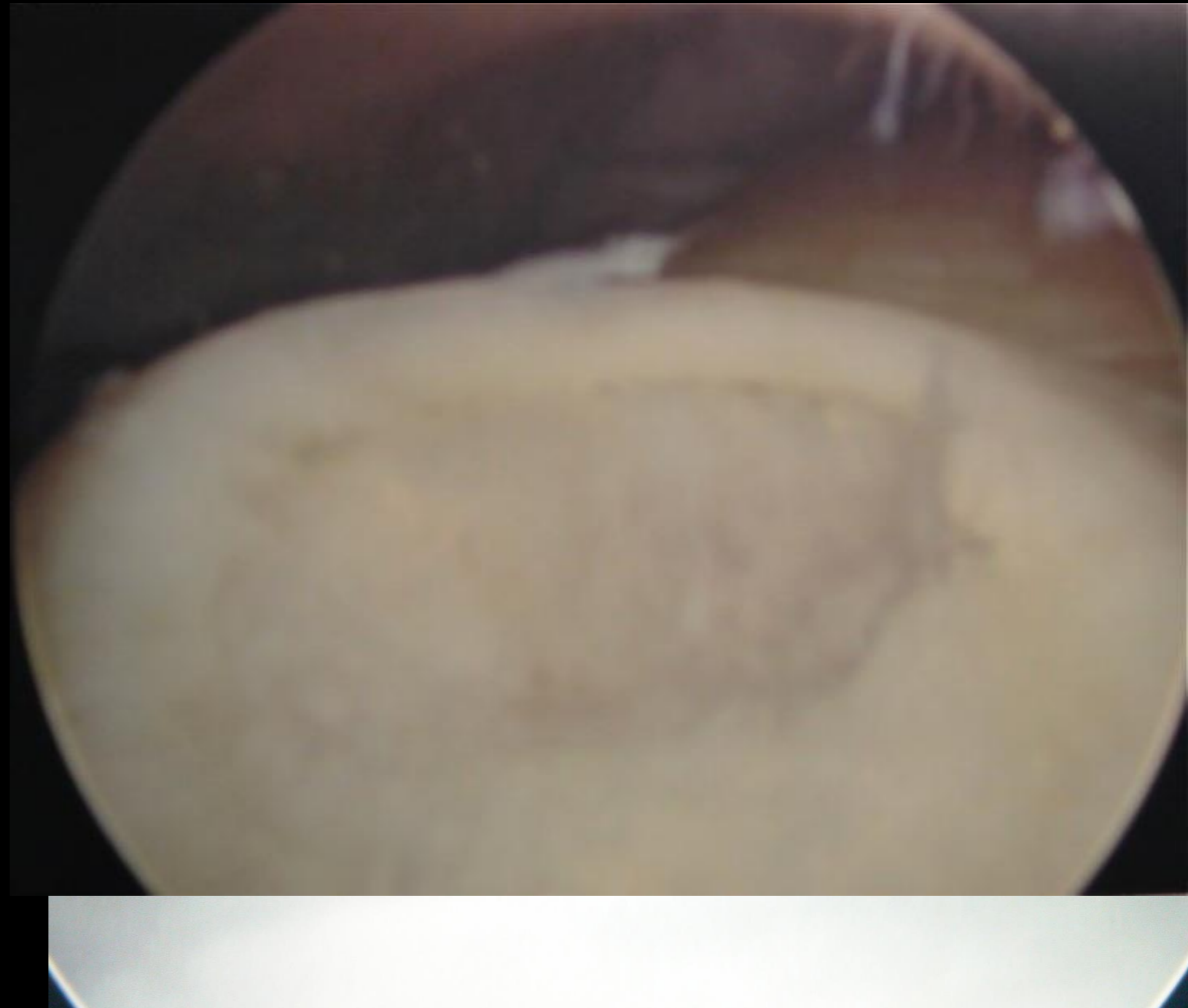


The sequelae and final
common pathway of
many pilon and talus
injuries

Ankle Arthritis

Arthritis Basic Science

- Begins with cartilage damage
- Cartilage apoptosis



Arthritis Basic Science

- Osteophytes grow



Arthritis Basic Science

- Progresses until raw bony edges touch each other



How do Patients walk with Ankle Arthritis?



- Ankle arthritis patients have as poor a quality of life as those with hip arthritis...
- ...worse disability than heart disease



- The Long Accepted surgical intervention has been a fusion

- What is fusion?

- **Arthrodesis:** The **procedure** in which two bones are brought together to eliminate the joint itself.
- **Fusion:** The physical process in which two bones form one solid bone.





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Elapsed
Time
1:06 Min.

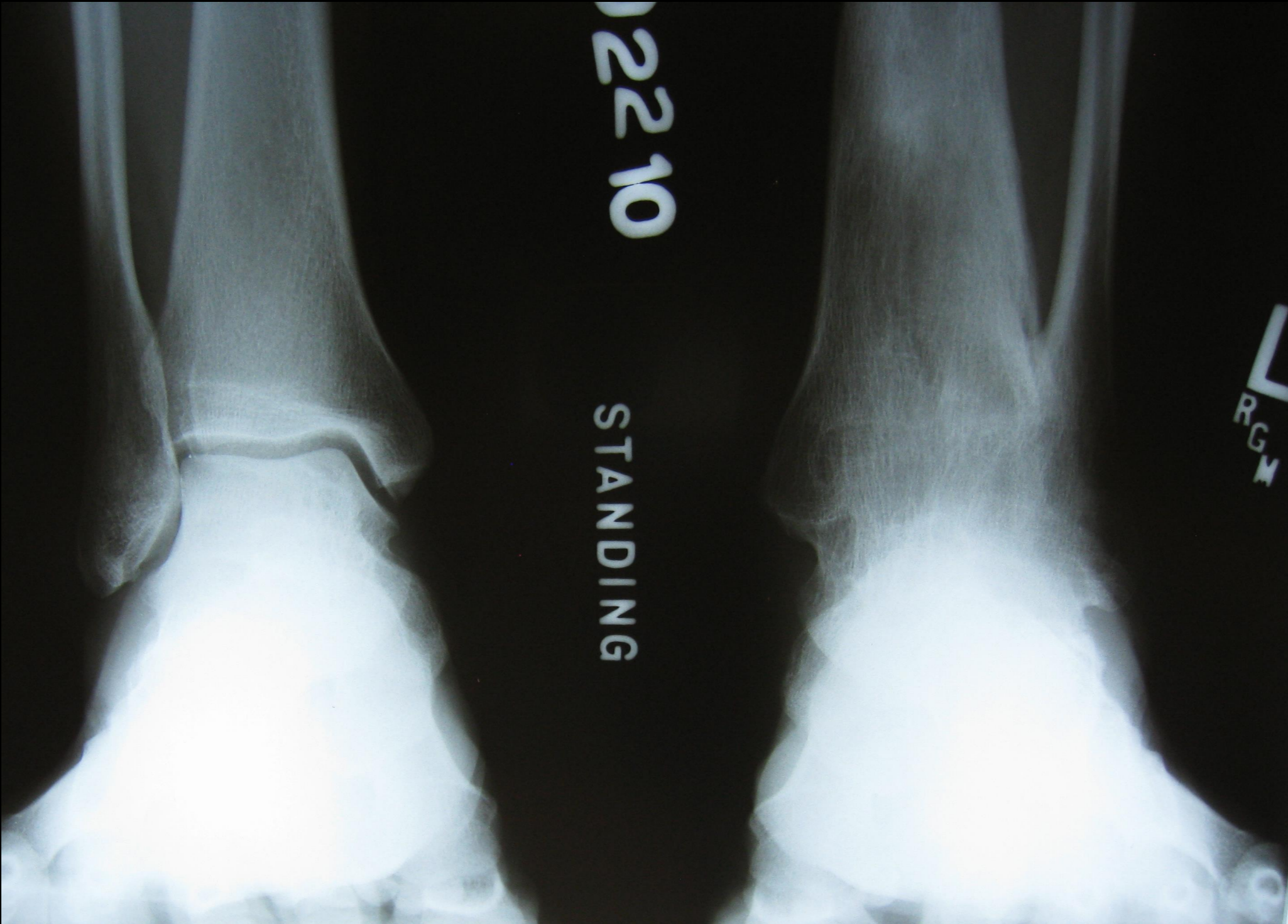
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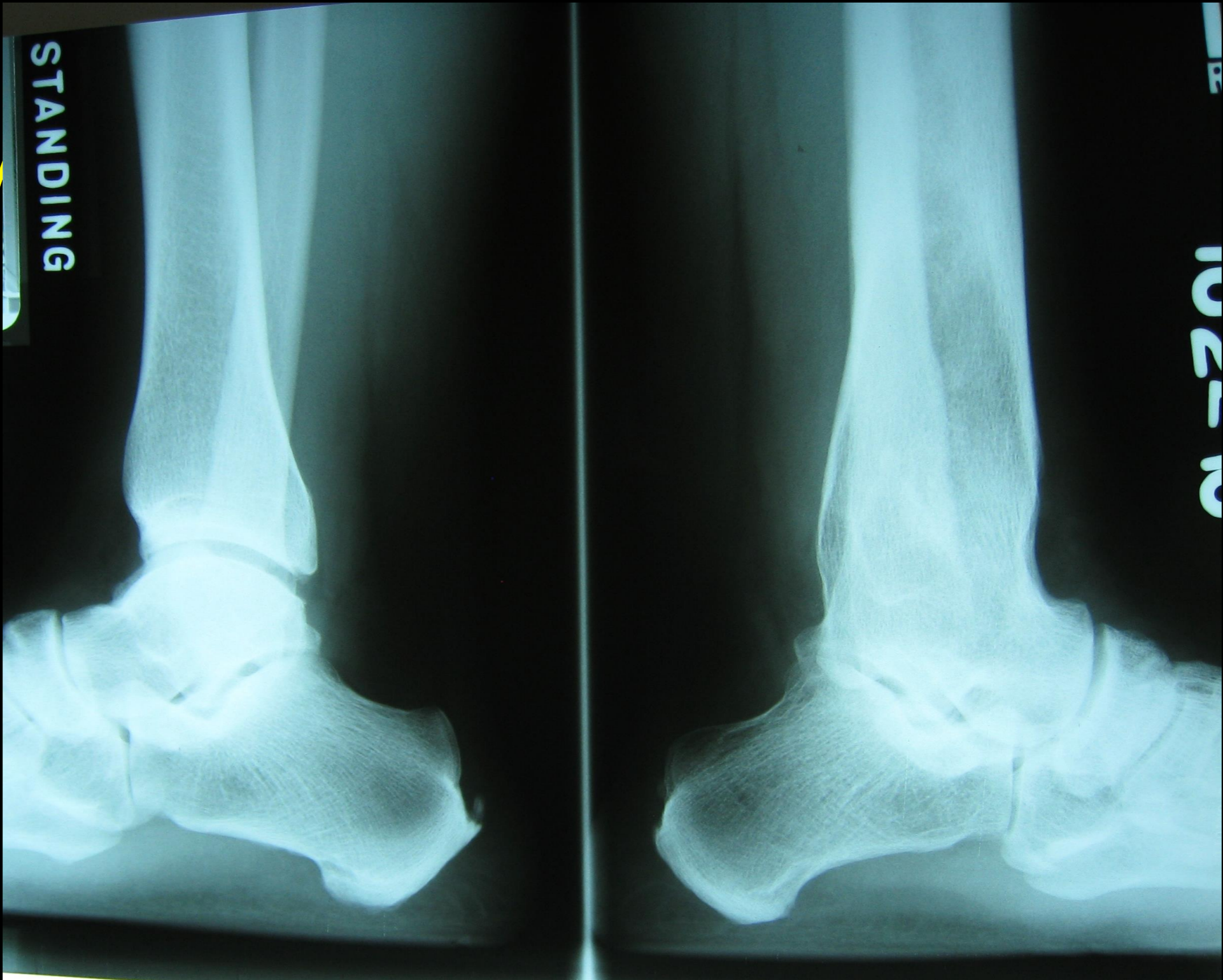
Ankle Arthrodesis



How do people walk with a fusion?







Here is another one...

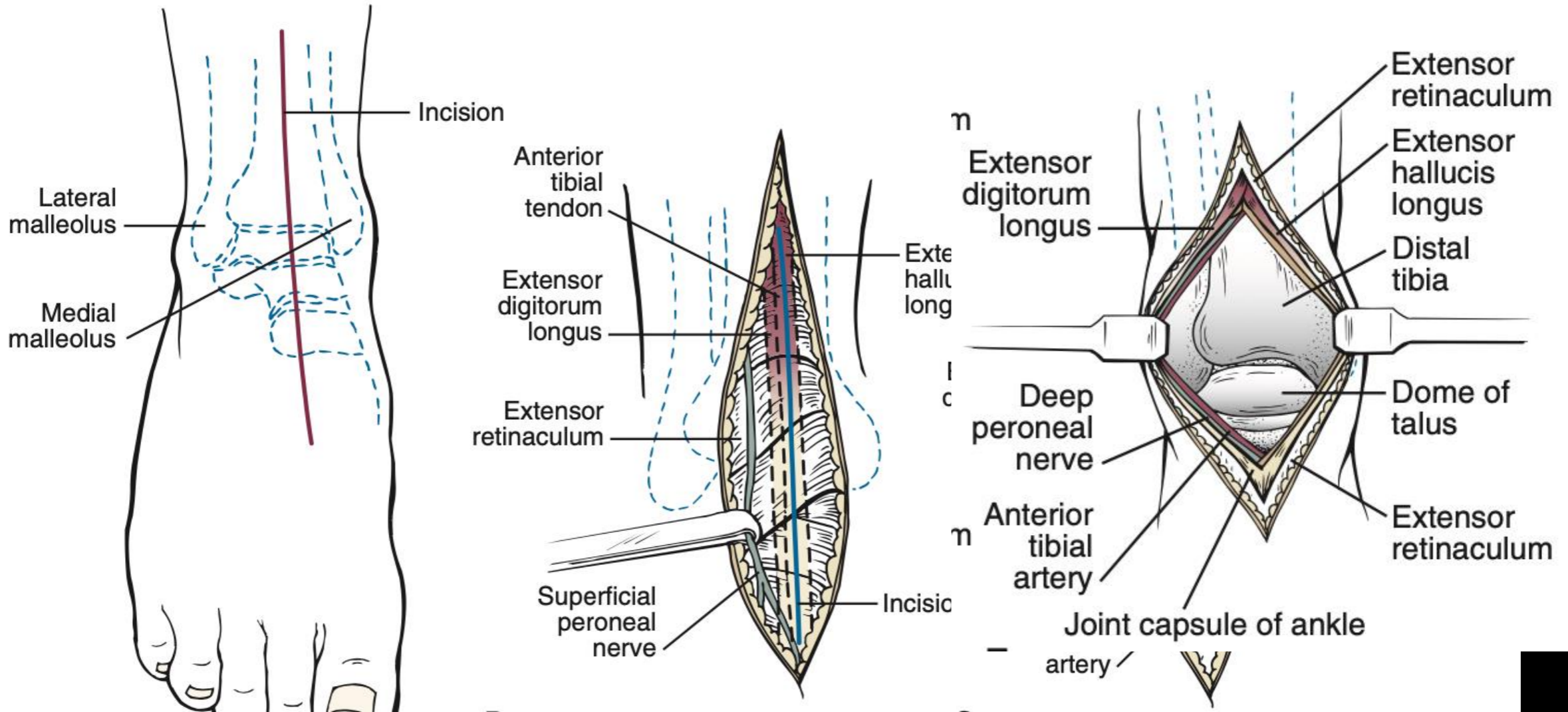


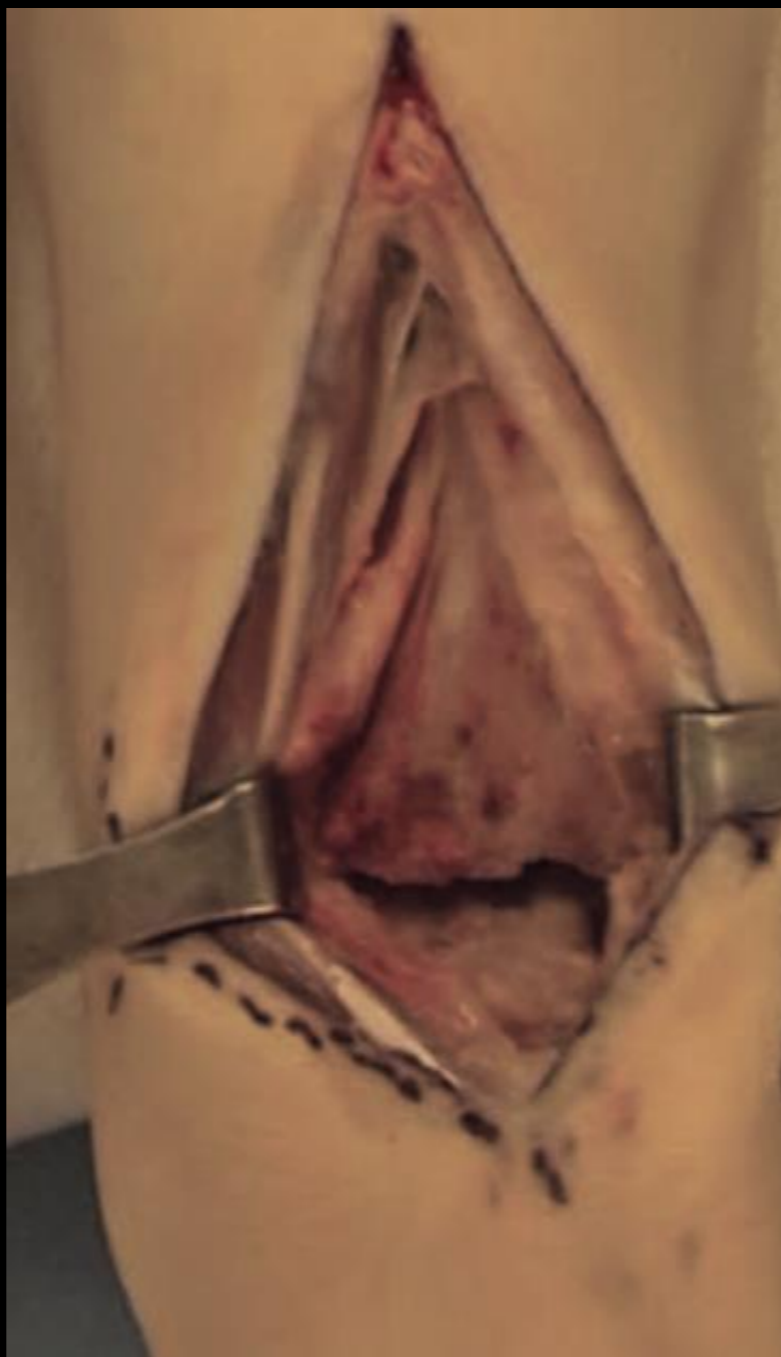


Results of Ankle Fusion

Generally good!

Pain typically is eliminated when the ankle joint is solidly fused





lating



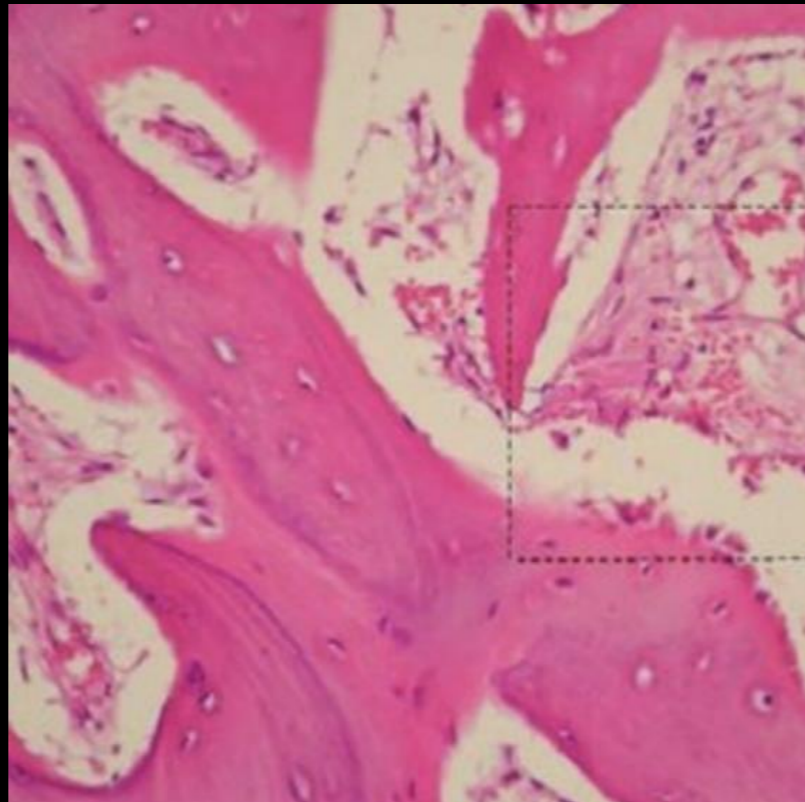
Anterior Plating

3 recent papers:

90–100% fusion rate

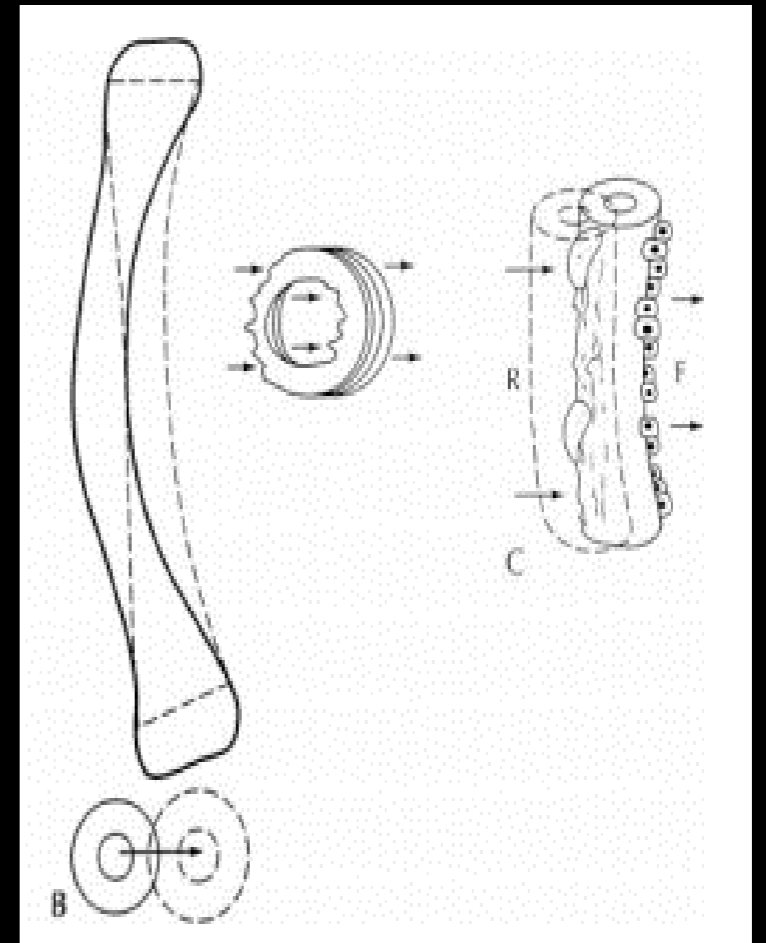
Fusion occurred 12.2 to 15 weeks

How To Achieve a Fusion?



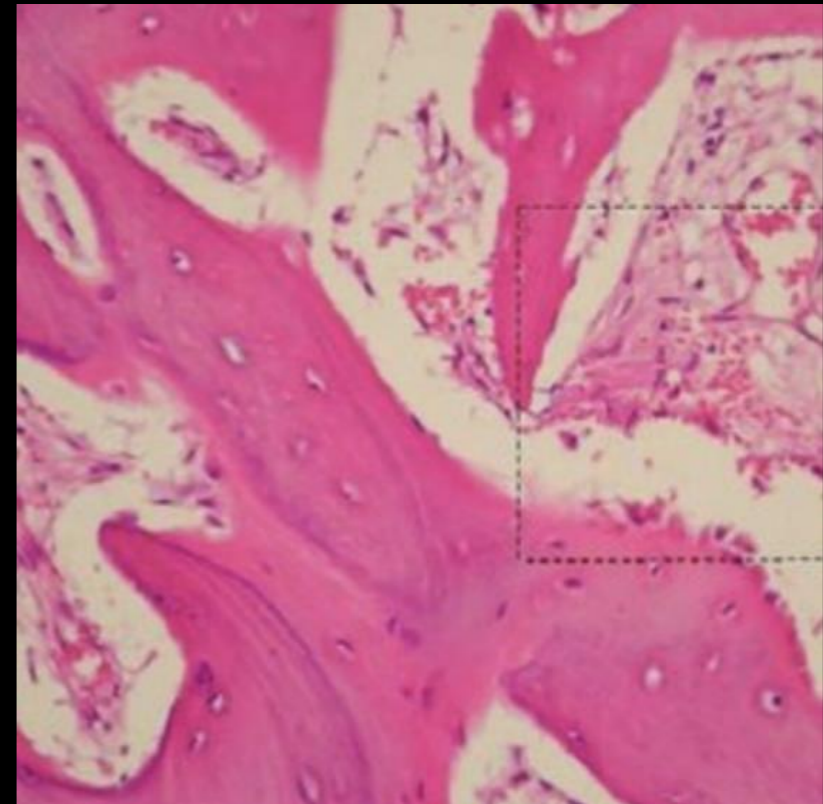
Recipe for Fusion

- Rigid, stable fixation enhances early bone formation
- **CONSTANT COMPRESSION** leads to stronger bone



Recipe for Fusion

- Need **small gaps <0.01 mm**
- Need the right amount of strain **1000 μ strain**
- Need loads **of 300-700 N**
- Need loading at the appropriate time—NOT TOO EARLY



How to Achieve a Good Clinical Result?

Pay attention to proper alignment...

the alignment of the entire limb

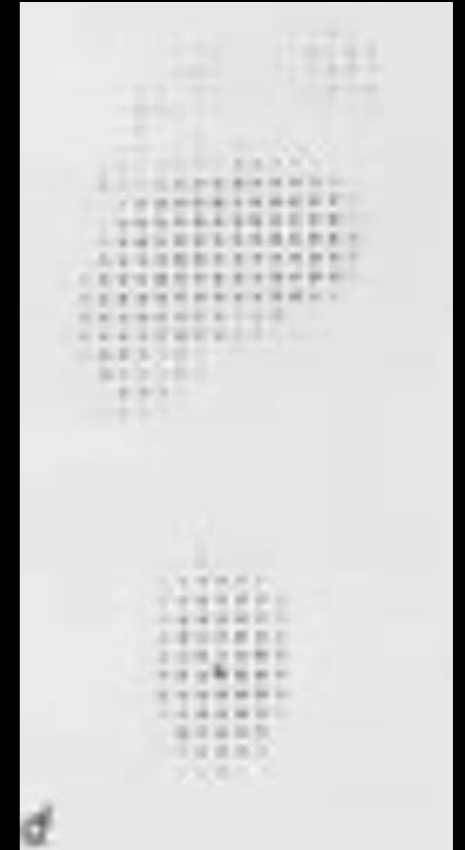


Make a Plantigrade foot

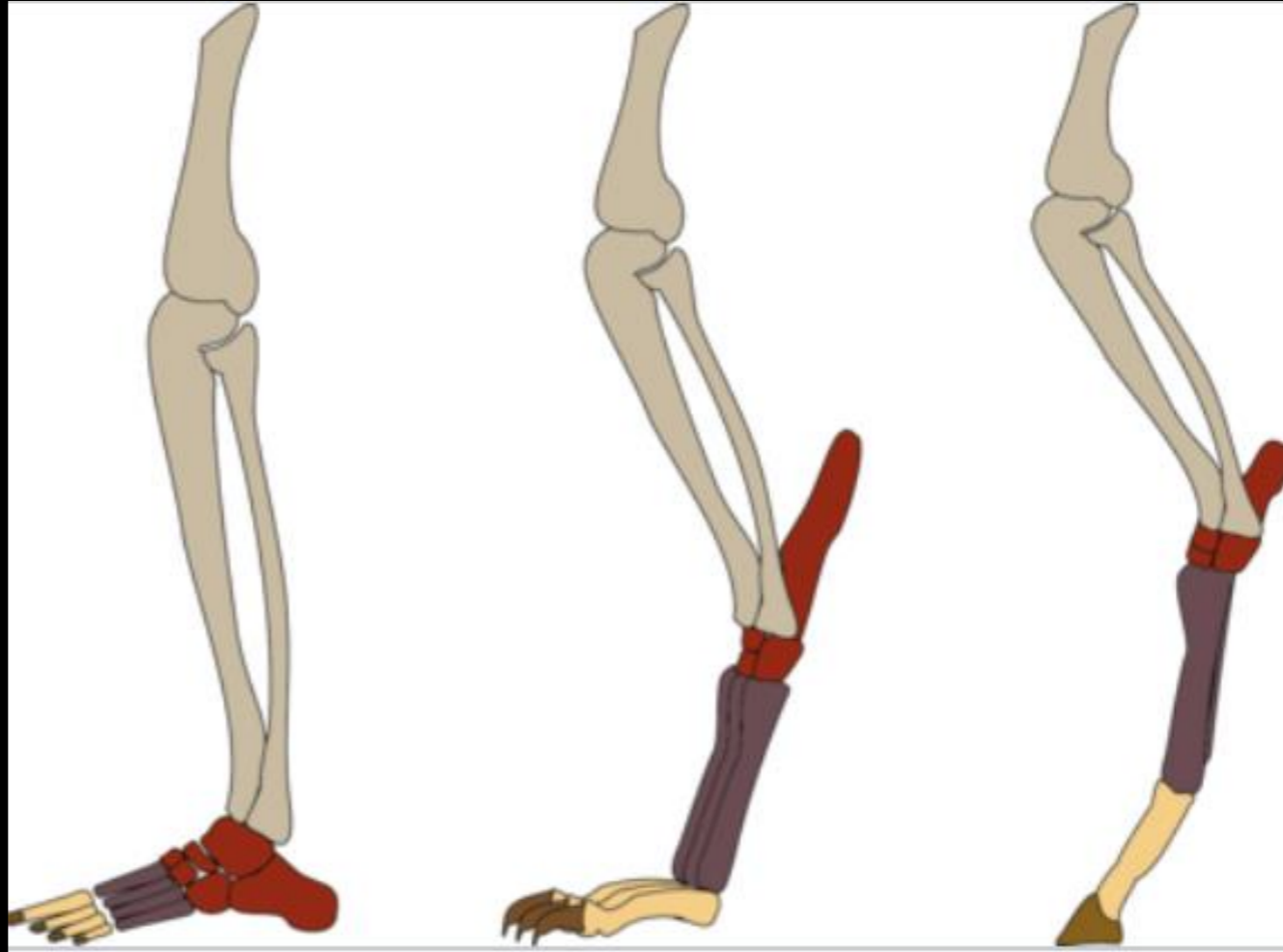
What is a Plantigrade foot?



Barograph



Harris Beath Mat



- **Plantigrade** refers to those animals who walk with the metatarsal bones flat on the ground
- Digitigrade: walking on the toes with the heel off the ground
- Unguligrade: walking on a hoof

Example: Plantigrade foot



Make a Plantigrade foot



Make a Plantigrade foot

Dorsiflexion/Plantarflexion: neutral

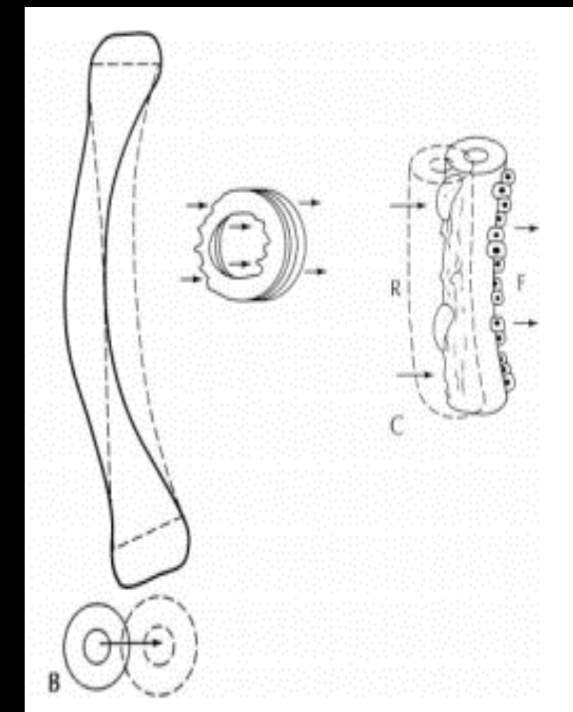
Varus/Valgus: 5 degrees valgus

Rotation: equal or slightly more externally rotated



QUESTION 3:

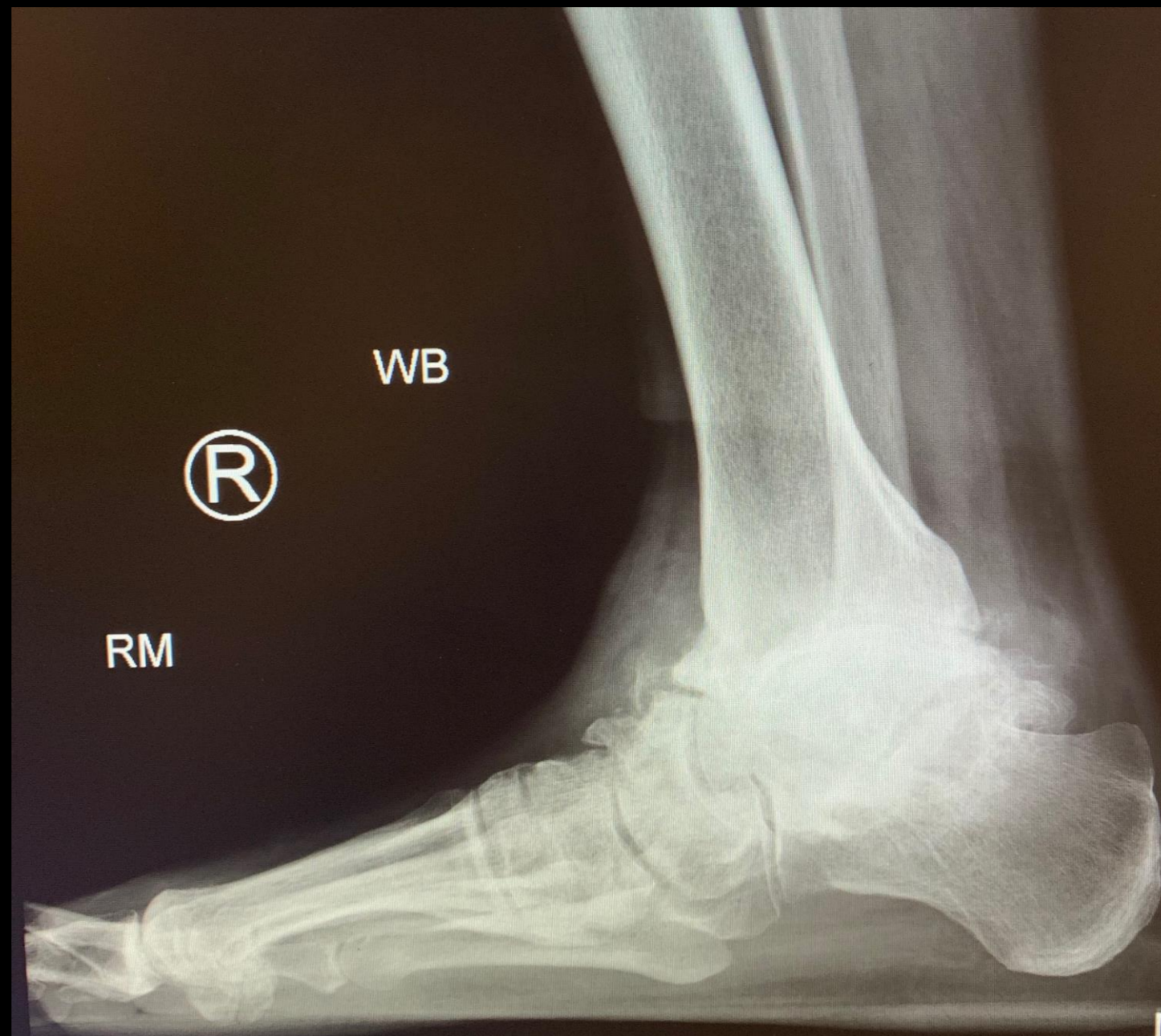
- What is an impediment to bony fusion?



1. Rigid stable internal fixation
2. Constant Compression
3. Early loading
4. Small gaps **<0.01 mm**
5. Loads **of 300-700 N**



Sometimes both joints around
the talus become arthritic...

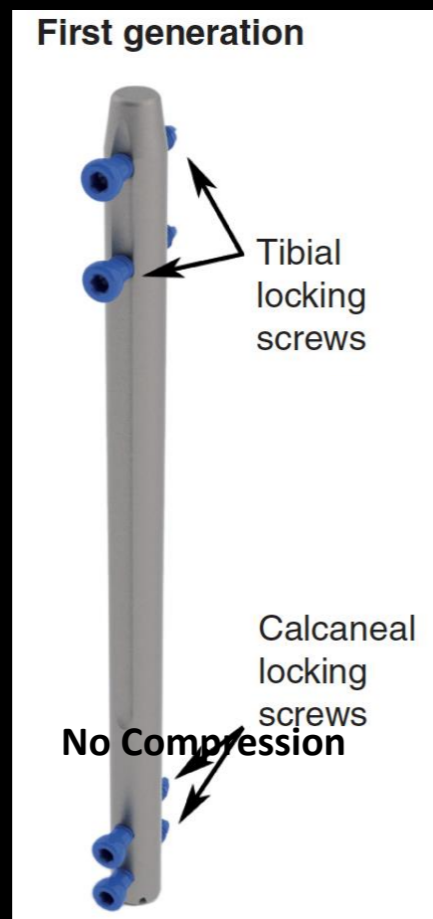


Treatment: Nail it!!!



Evolution of IM Nails

Generation 1



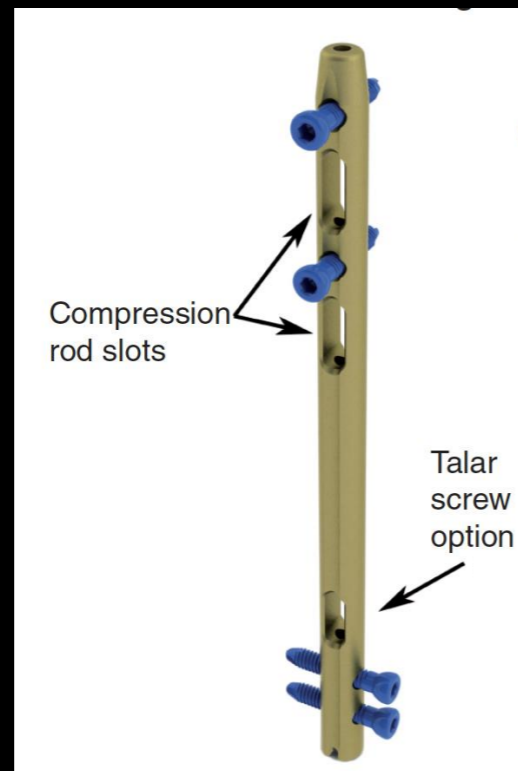
Surgeon provides external compression
By malleting the nail

Static fixation

Calcaneal and tibial locking screws

Evolution of IM Nails

Generation 2



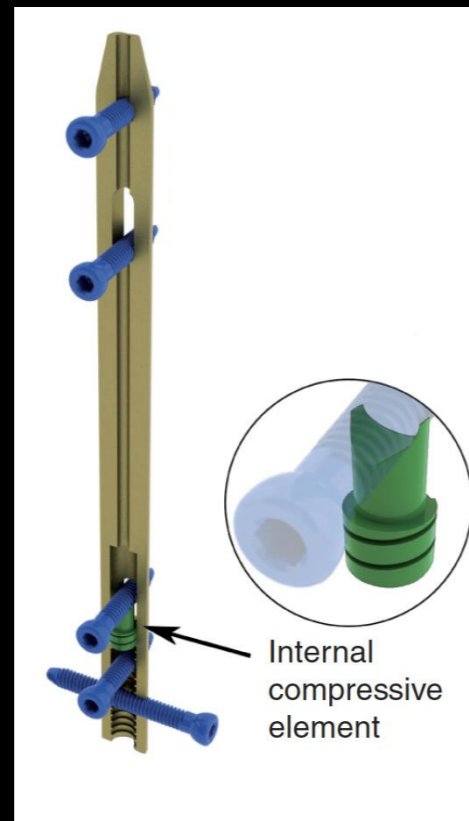
Compression via external fixation

Steinman pins placed through slots

Static fixation

Evolution of IM Nails

Generation 3



1. **Internal** compressive mechanism placed within the heel of the nail

2. **External** compression built into jig

Compresses the soft tissue of the heel

Modern Nails

All have in common:

UNSUSTAINED compression

90% of the compression is lost with 1 mm of bone resorption

Yacki CM, Khalil HF, Dixon SA, GallK, Pacaccio DJ. Compression forces of internal and external ankle fixation devices with simulated bone resorption. *Foot Ankle Int.* 31(1), 76–85 (2010)



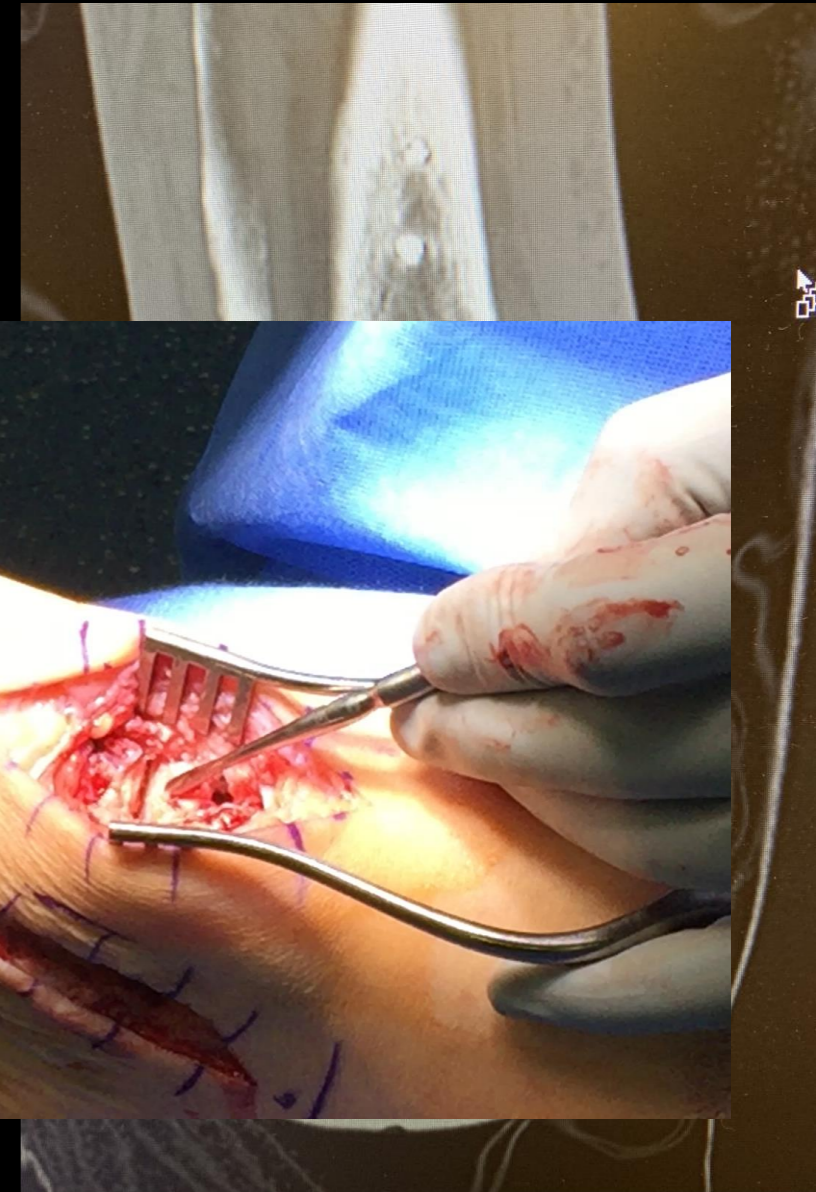
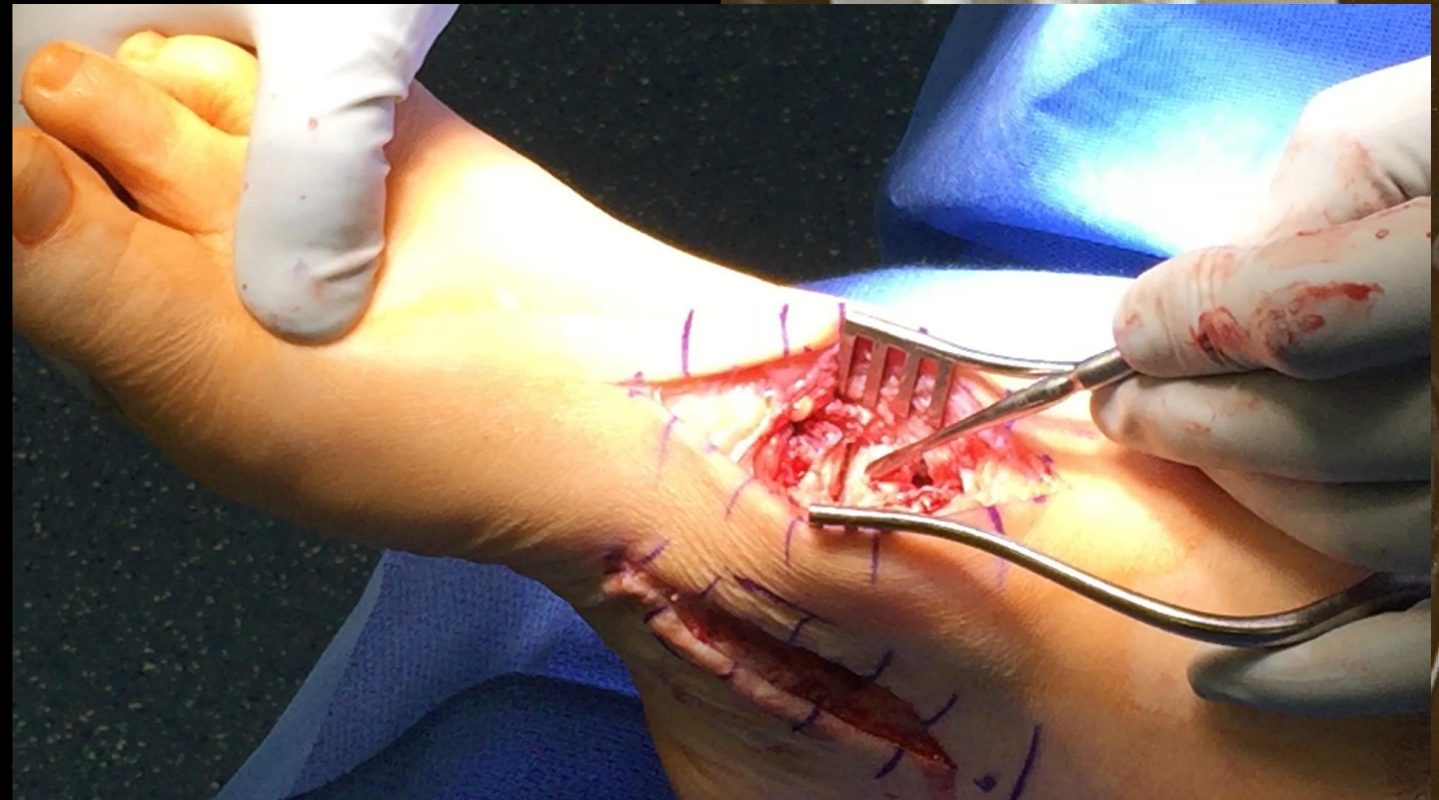
problem with Tibiotalar calcaneal Arthrodesis

Either the ankle joint or the subtalar joint
goes on to **nonunion**

Nonunion =

“It really sucks”

“A lot of work to fix it”



TTC Nonunion rates reported:

Up to 24%

Kim C, Catanzariti AR, Mendicino RW. Tibiotalocalcaneal arthrodesis for salvage of severe ankle degeneration. Clin. Podiatr. Med. Surg. 26(2), 283–302 (2009)

NiTiNOL

- 1959
- Nickel-titanium
- Nickel Titanium-Naval
Ordinance Laboratory
= NITINOL

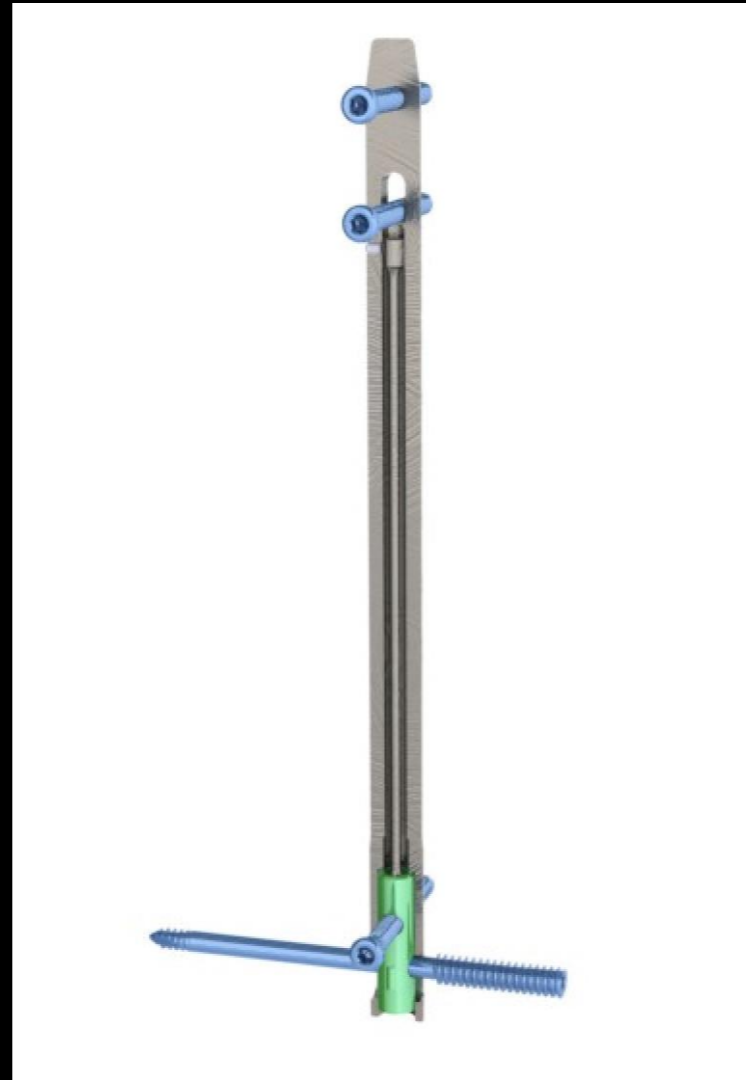


Nitinol

- Paperclip placed in hot water



Nitinol Nail



Key Features:

Maintains active post-operative compression across the joints

Stiff in bending and torsion, axially compliant

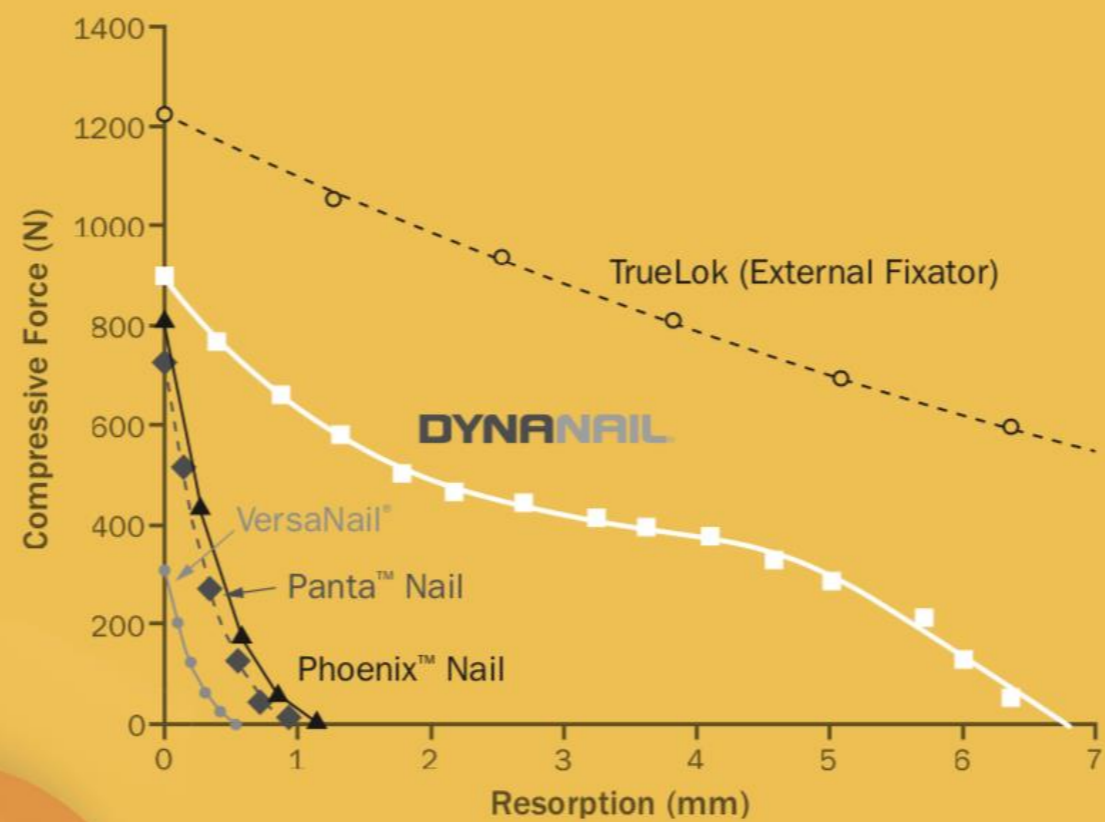
Offers immediate and continued dynamization





ACTIVE COMPRESSION

Same pseudoelastic NiTiNOL Technology that allows for post-operative compression to be maintained for up to 6 mm of bone resorption.¹



Competitive Performance Summary

What is the TTC fusion rate with non nitinol?

Evaluation of Midterm Results of the Panta Nail: An Active Compression Tibiototalcalcaneal Arthrodesis Device.

Griffin MJ¹, Coughlin MJ².

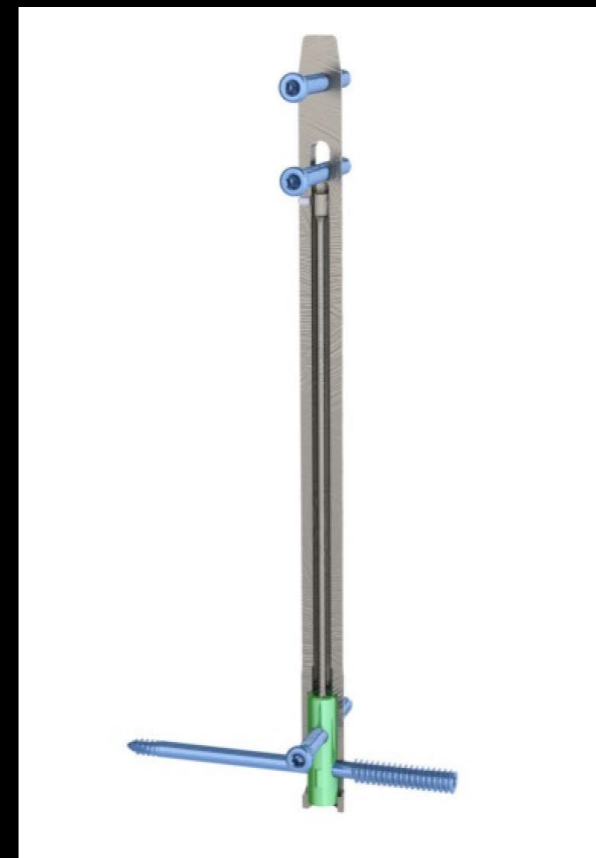
Lack of sustained compression
with continued bone
resorption and loading

N = 16

Fusion of both ankle and
subtalar joints: **65%**



Nitinol Nail Study



Study Design

Prospective

N= 29

Age 18 years and older

Diabetics and smokers included

Follow up: 2,4,6 weeks

3,6,12,24 months

CT scans obtained at 3 months

Nitinol TTC Nail

N=29

N=29 who have completed 3 month CT scans

93% joints fused (54/58)

Includes both subtalar and tibiotalar joints

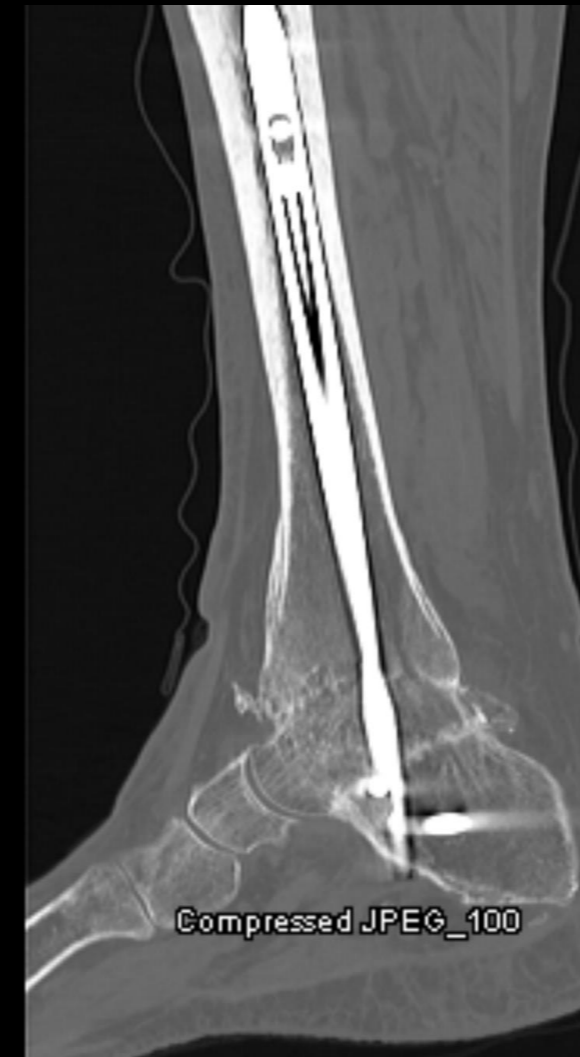
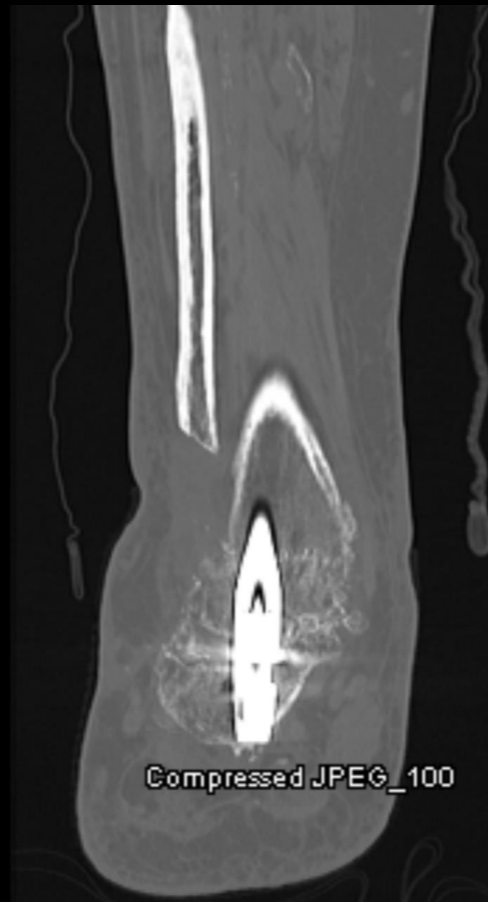
1 tibial stress fracture

2 wound infections

NiTiNOL TTC Nail

Tibiotalar fusion:
28/29 = 97%

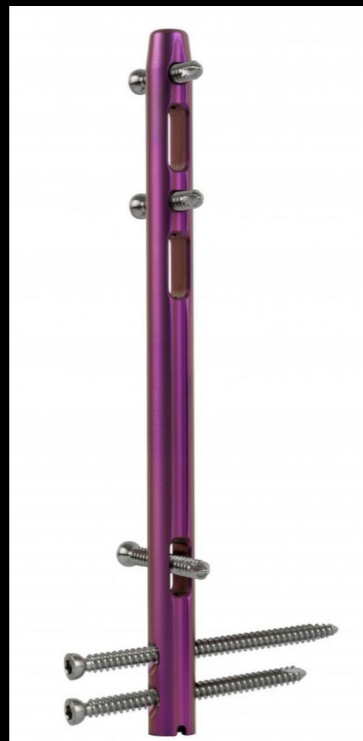
Subtalar fusion:
26/29 = 90%



Summary (Similar Idaho patient population)

Gen 2 nail:

Fusion of both ankle and subtalar joints:
65%



Dynanail

Fusion of both ankle and subtalar joints: 93%



Case #2

69 yo male. 2 year history progressive hindfoot
8/10 pain

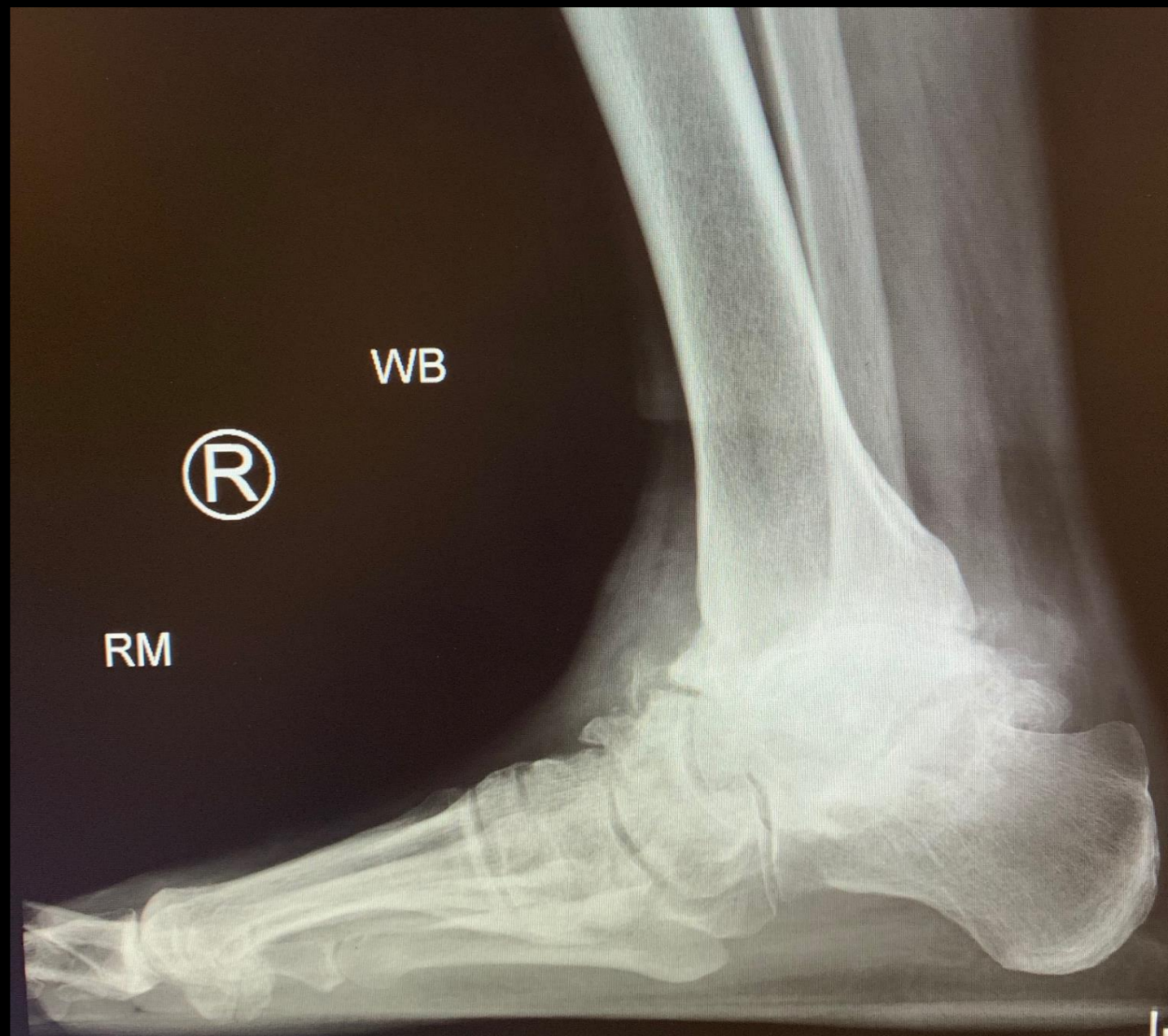
Exam

2+ DP and PT pulses

10 degrees hindfoot valgus

Pain medial, anterior, lateral tibiotalar joint

Pain medial and lateral subtalar joint





What would you do?

R
BZ
○

WB



R
BZ
○

WB





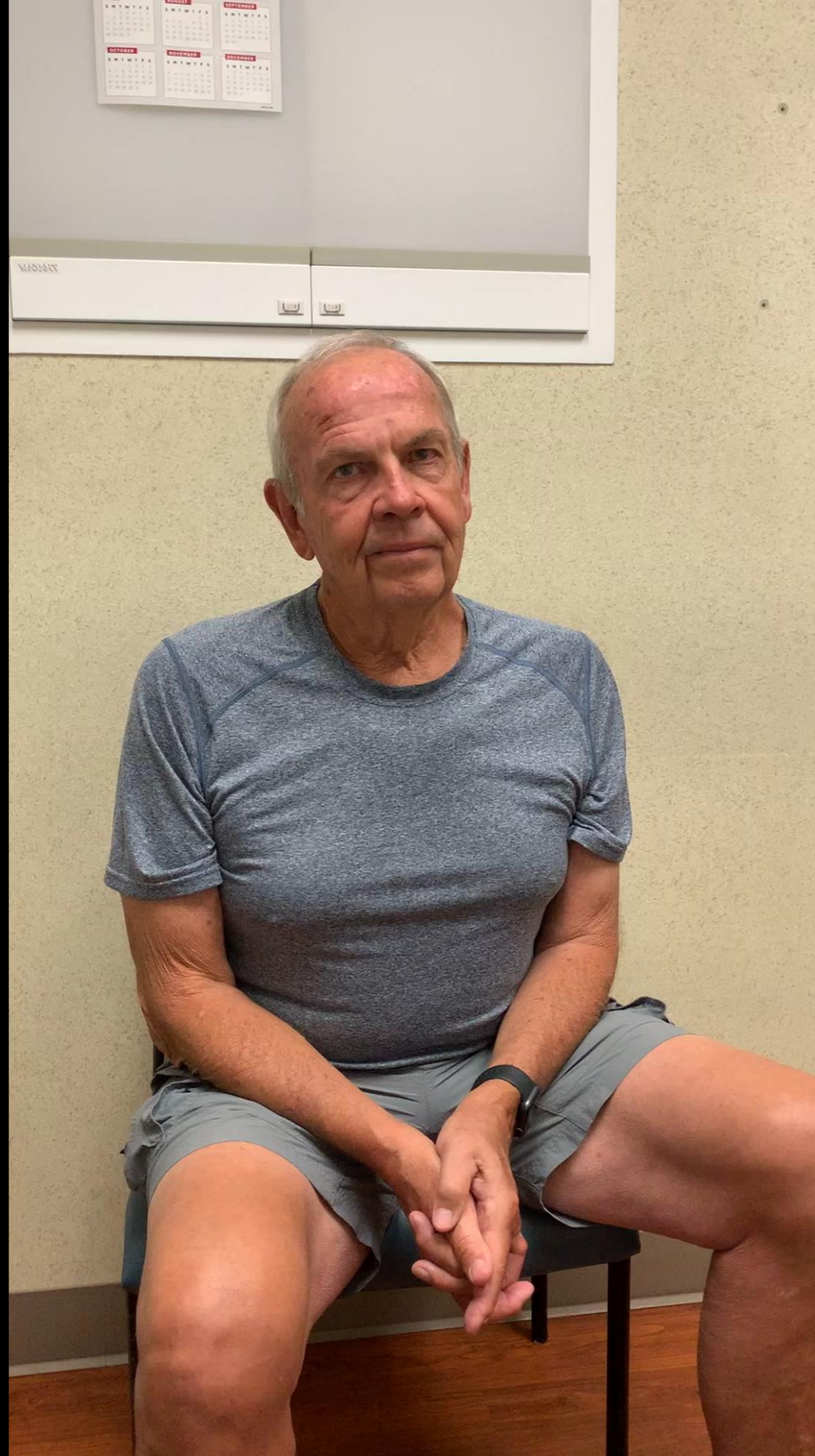
R
BZ
○

WB









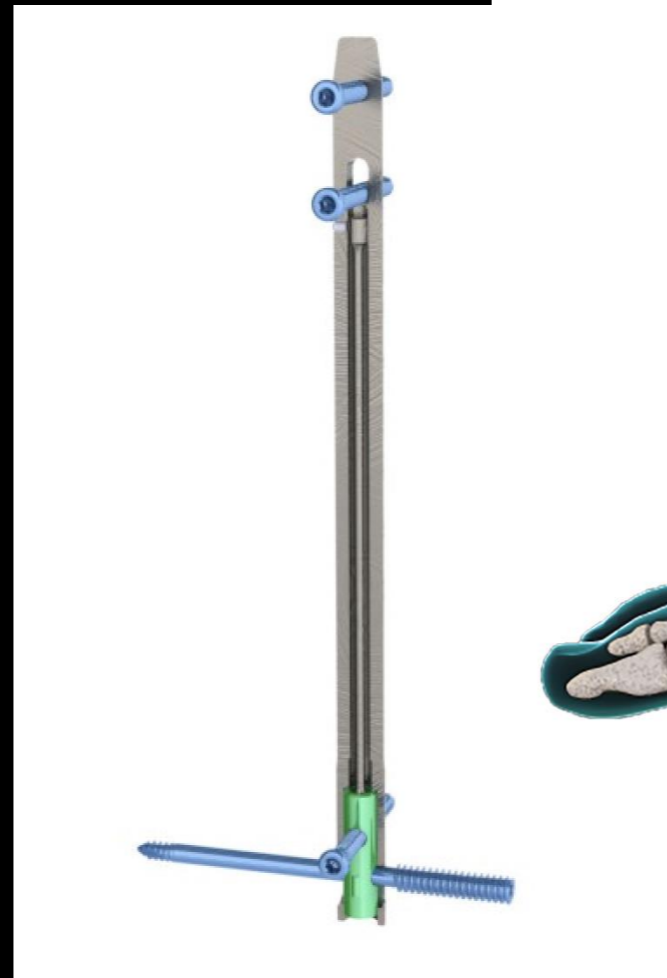
Conclusions

Nitinol TTC has a higher fusion rate

Gen 2 Nail: 65%

Dynanail: **93%**

Benefits of external fixation
(without ex fix complications)



Summary: Five topics

1. What to do in the field if you are injured
2. Specific injuries around the ankle joint
 - Tibial Pilon fractures
 - Talus fractures
3. The Sequelae of your injuries
4. Cutting edge treatment and research

QUESTION 1:

- A low energy Pilon fracture is characterized by:



1. An axial compression mechanism of injury
2. Significant comminution
3. A torsion mechanism
4. Lower socioeconomic status



Answer:

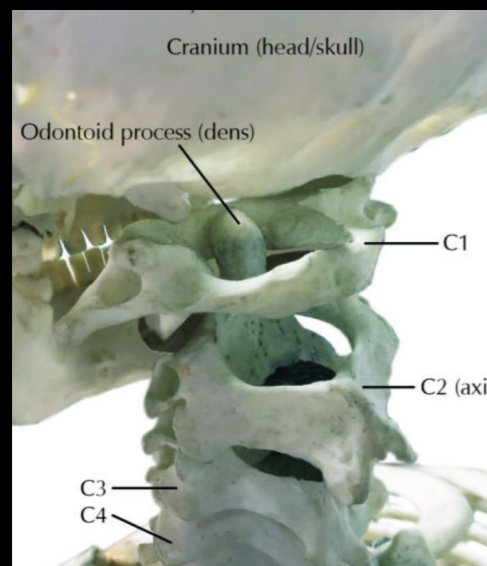
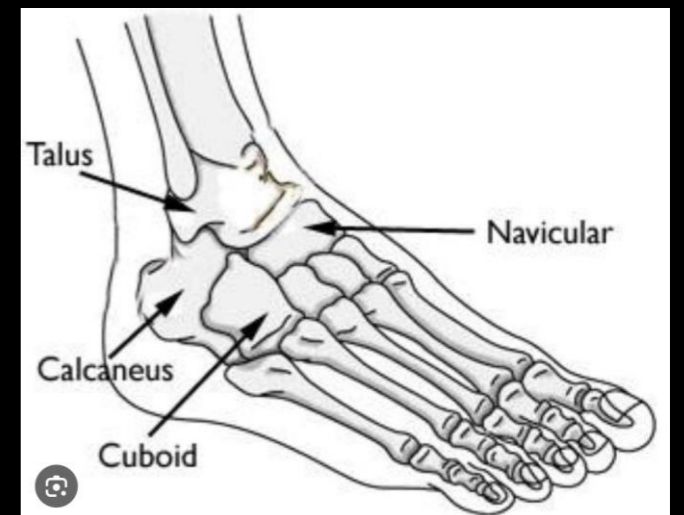
1. Axial compression mechanism of injury-**NO**, this is a **high energy pilon injury**
2. Significant comminution-**NO**, **high energy pilon injury**
3. A torsion mechanism-**YES**, **low energy injuries yield spiral fractures**
4. Lower socioeconomic status-**NO**



QUESTION 2: Who am I?

- I have no muscular attachments
- I have no tendinous attachments
- 70% of me is covered by cartilage

1. A human tooth
2. Calcaneus
3. Carpal Navicular
4. Talus
5. Odontoid
6. Tibial Sesamoid



Answer

1. Calcaneus-**NO**-The Achilles inserts **on this bone**
2. Carpal Navicular-**NO**-80% is **covered by cartilage**
3. Talus-**YES**
4. Odontoid-**NO**-the alar ligaments **attach**
5. Tibial Sesamoid-**NO**-80-90% is **covered by cartilage**



Thank You

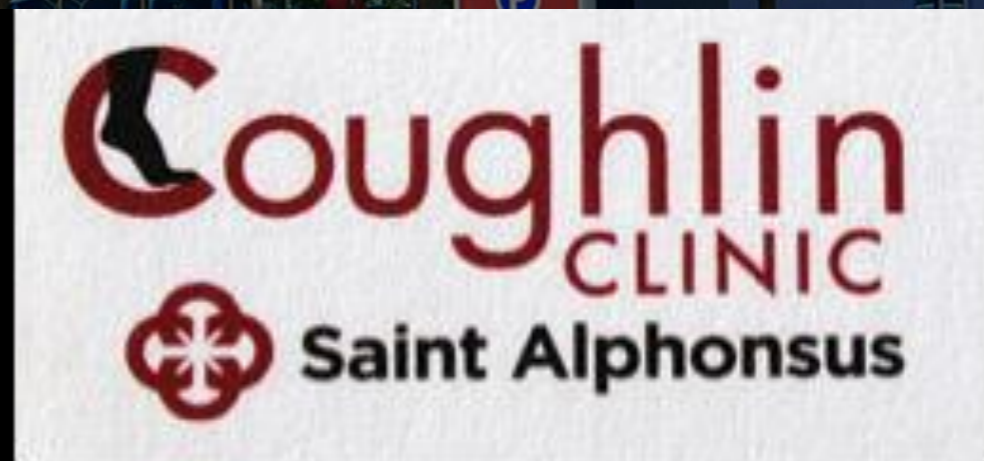
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Idaho

208-302-3100



Thank You

Christopher B. Hirose M.D.

