PLEASE CLICK ON THE FOLLOWING LINK TO WATCH THE LECTURE ONLINE:-

https://www.youtube.com/live/iVxBe74U_NU

Principles in nonunion management

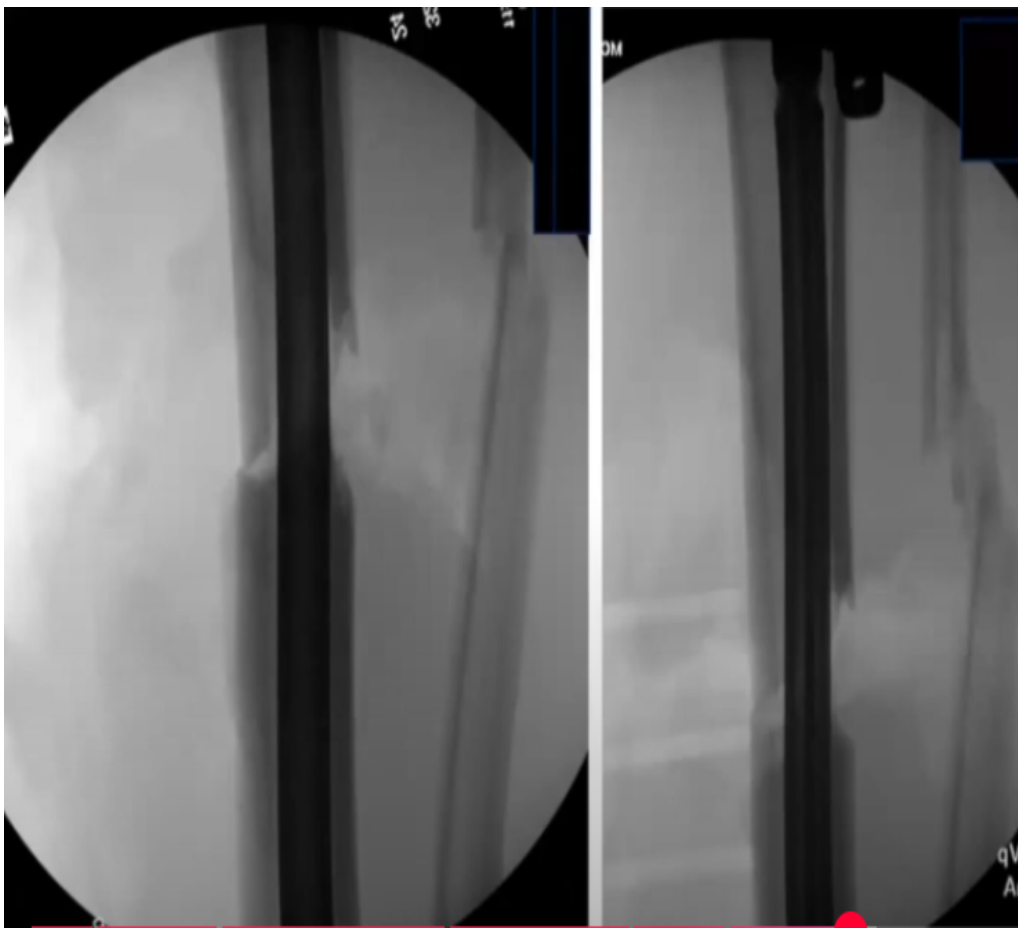
Mohammad Bani Mustafa

Case

- 34 years old male
- On Motorcycle, hit by a care
- Open tibia fracture

- Describe this fracture ?
- Debridement strategy ?
- Fixation construct ?

Post op x-rays



1 year later

- Pain
- Flap sealed
- Ambulate with cane

Main factors to consider ?

How do you approach this ?

Learning objectives

- Classify the nonunion type
- Employ an appropriate pre-operative workup for nonunion patients
- Plan your treatment strategy according to the patient needs
- Understand the methods to obtain stability, biological augmentation, and infection control

Definition

- ***Nonunion*** occurs when a fracture has failed to heal in the expected time and is not likely to heal without further intervention.

- ***FDA*** definition of nonunion :
  - A minimum of **9 months** post occurrence and is not healed
  - has **not** shown radiographic progression for **3 months**

- ***Delayed union*** occurs when a fracture requires more time than usual to heal and Shows healing progress over time

Definition

Radiographic and **clinical** diagnosis

- Non-progression toward radiological healing
- Non-improving clinical progression

- Hardware failure is a common finding

Research article | Open access | Published: 26 January 2013

Tibia shaft fractures: costly burden of nonunions

Evgeniya Antonova, T Kim Le, Russel Burge & John Mershon

BMC Musculoskeletal Disorders **14**, Article number: 42 (2013) | Cite this article

- Among the 853 patients, 99 **(12%)** had nonunion
- All categories of care were more expensive in nonunion patients than in those without nonunion
  - Median total care cost ($25,556 vs. $11,686)
  - Outpatient physical therapy (60% vs. 42%)
  - Opioids pain medication (90% vs 76 %)
  - Duration of opioids (5.4 vs 2.8 months)

> J Bone Joint Surg Am. 2013 Dec 18;95(24):2170-6. doi: 10.2106/JBJS.L.00803.

The devastating effects of tibial nonunion on health-related quality of life

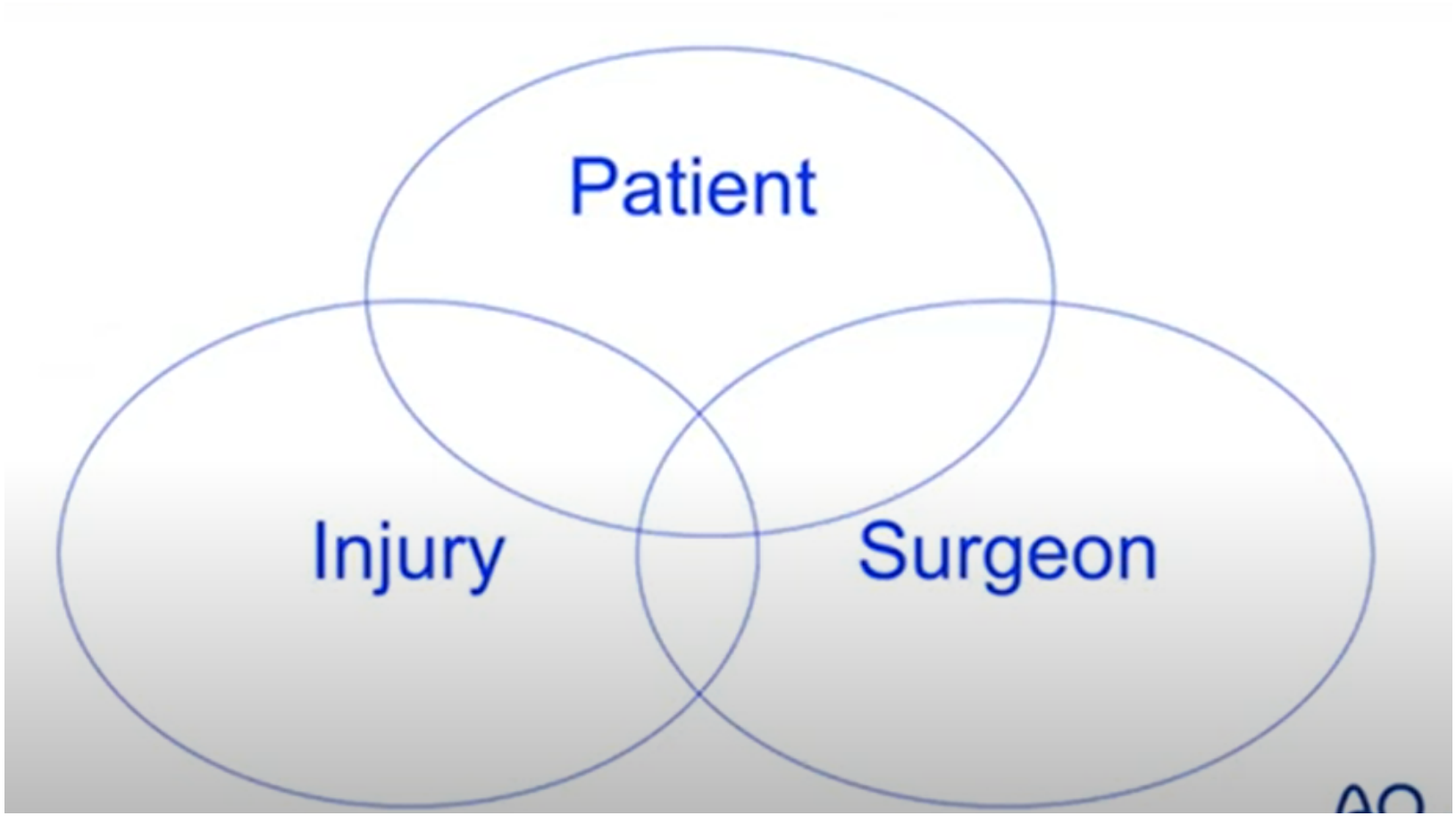
Mark R Brinker [1], Bryan D Hanus [2], Milan Sen [3], Daniel P O'Connor [4]

Affiliations + expand

PMID: 24352770 DOI: 10.2106/JBJS.L.00803

- 237 tibia nonunions over a ten-year period
- Short Form (SF)-12 Physical Component Summary score (27.4)
  - Extremely disabling effect on physical health
- The AAOS Lower Limb Core Scale score (52.0)
  - High levels of physical disability
- The SF-12 Mental Component Summary score (42.3)
  - Detrimental effect on mental health

Etiology and Predisposing Factors



Predisposing Factors

Patient Factors

- Smoking
- Vascular disease
- Endocrinopathy
  - DM, Thyroid/ parathyroid disorders, Vit D deficiency, Ca and/or Phos abnormality
- Malnutrition
- Osteoporosis
- Balance, compliance with weight bearing restrictions
  - Psychiatric conditions, dementia
- Medications:
  - Steroids, chemotherapy, Immunosuppressive
  - (NSAIDs) ???

NSAIDs ??

Controversial topic at present

- Multiple studies suggest that NSAIDs used for HO prophylaxis will increase the rate of nonunion in patients with long bones fractures

- Use of NSAIDs in the early post operative period may double the chance of fracture healing problems
- NSAIDs now are being used more often in early fracture care to reduce the need for opioids

Avoid NSAIDs when treating nonunion

SYSTEMATIC REVIEW ARTICLE

The effect of NSAIDs on postfracture bone healing: a meta-analysis of randomized controlled trials

Al Farii, Humaid MD, MRCS (Ir)*; Farahdel, Leila MD; Frazer, Abbey MD; Salimi, Ali MD; Bernstein, Mitchell MD, FRCSC

Author Information

OTA International 4(2):p e092, June 2021. | *DOI:* 10.1097/OI9.0000000000000092

- Six RCTs (609 patients) were included
- NSAIDs that do not include **indomethacin** can be used for pain management without having a significant effect on bone healing

- The use of NSAIDs for short duration, **less than 2 weeks**, does not show a statistical increase in nonunions

A commentary by Willem-Jan Metsemakers, MD, PhD, is linked to the online version of this article at jbjs.org.

Risk of Nonunion with Nonselective NSAIDs, COX-2 Inhibitors, and Opioids

Michael D. George, MD, MSCE, Joshua F. Baker, MD, MSCE, Charles E. Leonard, PharmD, MSCE, Samir Mehta, MD, Todd A. Miano, PharmD, MSCE, and Sean Hennessy, PharmD, PhD

Investigation performed at the University of Pennsylvania, Philadelphia, Pennsylvania

- Selective COX-2 inhibitors were associated with a greater risk of nonunion than nonselective NSAIDs

Predisposing Factors

Injury Factors

- Mechanism of injury
  - High energy
- Location
  - distal tibia , scaphoid, base of the 5th metatarsal
- Pattern
  - Comminution
  - Segmental fractures and those with butterfly fragments
  - Bone loss
- Open fracture

Risk Factors for nonunion

Surgeon Factors

- Poor soft tissue handling and excessive stripping

- Mechanical stability
  - Absolute stability with gap or poor reduction
  - Relative stability with excessive motion

- Improper technique
  - too short implant
  - Poorly fitting nails

Classification of Nonunion

based on the presence or absence of infection

- Septic nonunion
- aseptic nonunion

Based on the biological condition at the fracture site

- Atrophic
- Oligotrophic
- Hypertrophic

Atrophic nonunion

- **Not enough biology**
- Poor blood supply

- Causes could be related to
  - Primary injury : open, IIIB
  - Management : soft tissue stripping
  - Host factors : DM, smoking

- **No callus** on radiograph
- **Cold** or no uptake on bone scan

Hypertrophic Nonunion

- Biology is more than sufficient
- Hypervascular
- Cause : **mechanical factors** (inadequate stability)

- Abundant callus “Elephant’s foot”
- Increased uptake on bone scan

Oligotrophic Nonunion

- Viable but shows minimal healing potential
- Cause : **inadequate reduction, bone gap**
- Minimal callus on x ray
- **increased uptake** on bone scan

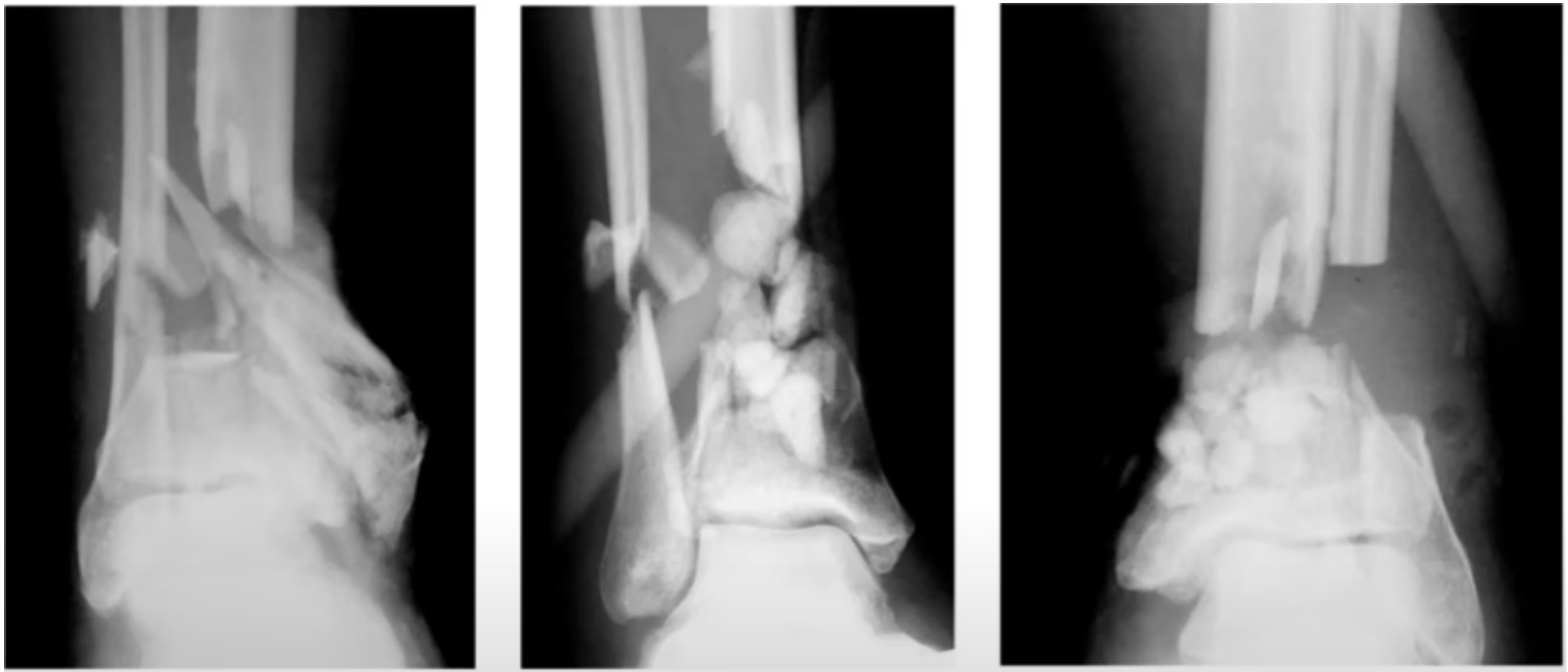
Infected nonunion

Infection inhibit fracture healing by causing excessive remodeling and osteolysis

How does it happens ?

- Inadequate debridement of an open fracture
- Bacterial contamination at time of surgery
- Failure of primary wound healing (poor surgical time)

poor surgical time !



That intramedullary cortical fragment will become a sequestrum!

Evaluation and Diagnosis

- History ?
- Physical examination ?
- investigations ?

Worksheet for patients with nonunions.

GENERAL INFORMATION

Patient Name: _____ Age: _____ Gender: _____

Referring Physician: _____ Height: _____ Weight: _____

Injury (description): _____

Date of Injury: _____

Mechanism of Injury: _____ Pain (0 to 10 VAS): _____

Occupation: _____ Was Injury Work Related?: Y N

PAST HISTORY

Initial Fracture Treatment (Date): _____

Total # of Surgeries for Nonunion: _____

Surgery #1 (Date): _____

Surgery #2 (Date): _____

Surgery #3 (Date): _____

Surgery #4 (Date): _____

Surgery #5 (Date): _____

Surgery #6 (Date): _____

(Use backside of this sheet for other prior surgeries)

Use of Electromagnetic or Ultrasound Stimulation? _____

Cigarette Smoking # of packs per day _____ # of years smoking _____

History of Infection? (include culture results) _____

History of Soft Tissue Problems? _____

Medical Conditions: _____

Medications: _____

NSAID Use: _____

Narcotic Use: _____

Allergies: _____

Mark R. Brinker & Daniel P. O'Connor (2015) Nonunions: Evaluation and Treatment. In: Bruce D. Browner (ed.). *Skeletal trauma: basic science, management, and reconstruction ; [get full access and more at ExpertConsult.com]*. 5. ed. Philadelphia, Pa, Elsevier, Saunders.

PHYSICAL EXAMINATION

General: _____

Extremity:

Nonunion: _____ Stiff _____ Lax

Adjacent Joints (ROM, compensatory deformities): _____

Soft Tissues (defects, drainage): _____

Neurovascular Exam: _____

RADIOLOGIC EXAMINATION

Comments _____

OTHER PERTINENT INFORMATION _____

_____

_____

NONUNION TYPE

_____ Hypertrophic

_____ Oligotrophic

_____ Atrophic

_____ Infected

_____ Synovial Pseudarthrosis

Mark R. Brinker & Daniel P. O'Connor (2015) Nonunions: Evaluation and Treatment. In: Bruce D. Browner (ed.). *Skeletal trauma: basic science, management, and reconstruction ; [get full access and more at ExpertConsult.com]*. 5. ed. Philadelphia, Pa, Elsevier, Saunders.

Metabolic and endocrine abnormalities in patients with nonunions

Mark R Brinker [1], Daniel P O'Connor, Yomna T Monla, Thomas P Earthman

Affiliations + expand

PMID: 17805023 DOI: 10.1097/BOT.0b013e31814d4dc6

- Among series of 683 patients with nonunion, 37 had unexplained nonunions
- 83 % (31 pts)had one or more new diagnoses of metabolic or endocrine abnormalities
  - 68 % vitamin D deficiency
  - 21 % thyroid abnormality
  - 11 % central hypogonadism
- **8 patients (25 %) achieved bony union with medical treatment only**

Radiographic Union Scale of Tibia

TABLE I RUST and mRUST Scoring Criteria

	Radiographic Criteria		
	Callus	Fracture Line	Score*
RUST	Absent	Visible	1
	Present	Visible	2
	Present	Invisible	3
mRUST	Absent	Visible	1
	Present	Visible	2
	Bridging	Visible	3
	Remodeled	Invisible	4

*A score is given to each of the visible cortices in 2 orthogonal radiographs (anteroposterior and lateral). The final score is the sum of the 4 cortex scores.

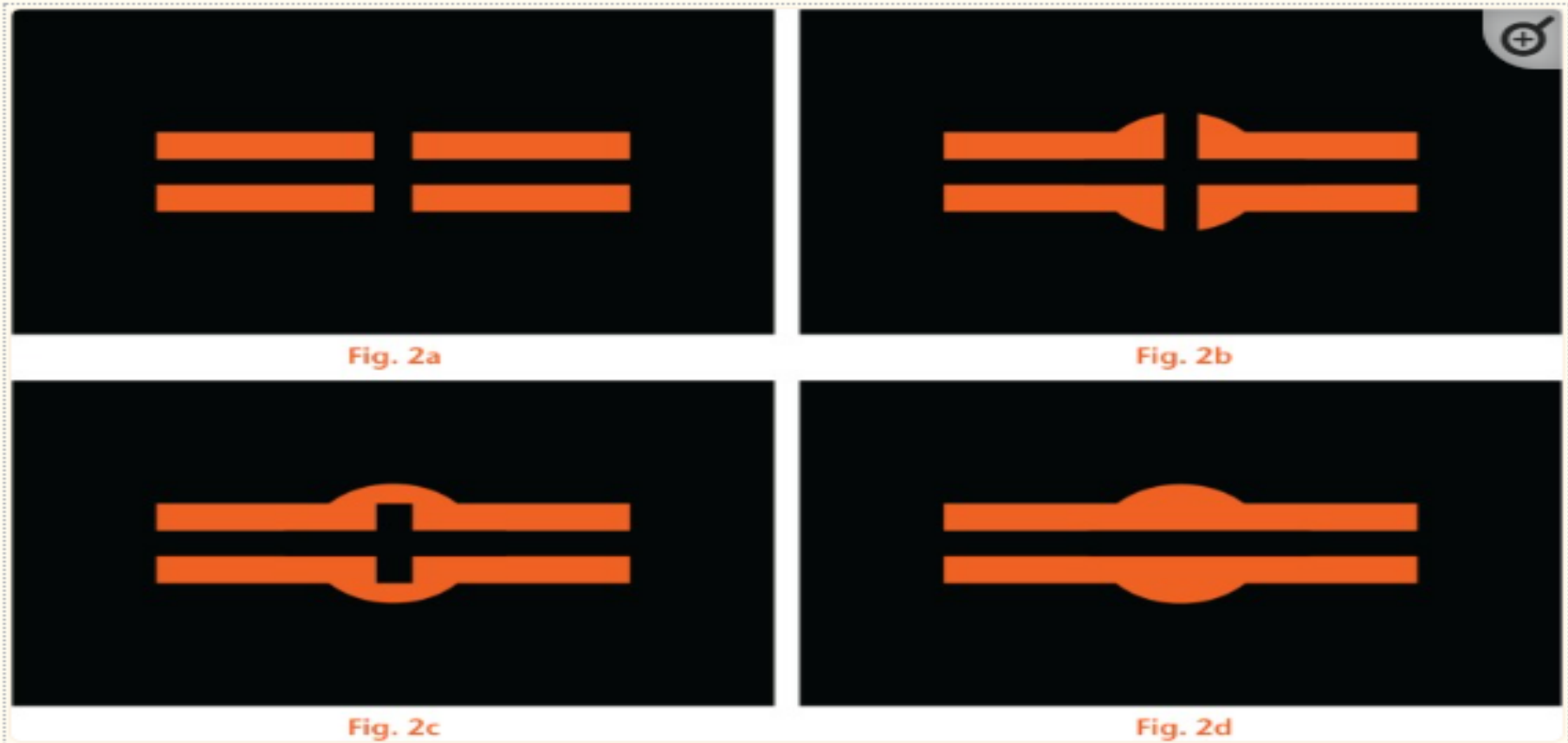


Fig. 2a

Fig. 2b

Fig. 2c

Fig. 2d

Diagrams showing a) a fracture with a fracture line and no callus formation; this would be assigned a radiographic union scale in tibial (RUST) fracture score of 1; b) a fracture with callus formation and a fracture line; this is scored as 2; c) a fracture with bridging callus, but the fracture line is still visible across both cortices; this is scored as 3 and d) complete bridging of the callus with no evidence of fracture line and is scored as 3.

ACTA ORTHOPAEDICA et TRAUMATOLOGICA TURCICA
www.aott.org.tr

Research Article

Reliability of RUST and modified RUST scores for evaluation of union in pediatric and adult femoral shaft fractures

Abdulhamit Mısır[1], Kadir İlker Yıldız[2], Turan Bilge Kızkapan[3], Erdal Uzun[4], Mustafa Özçamdallı[5], Sinan Oğuzkaya[6]

- 24 pediatric and 24 adult patients
- A RUST score of ≥10 and mRUST score of ≥12 were excellent predictors of fracture union
- The diagnostic value of the mRUST score is more evident in adult fractures

- A cohort of 146 distal femur fractures were retrospectively

- The mRUST score of ten points at 24 weeks can be used as a viable screening method with the highest sensitivity, specificity, and accuracy for healing of med-diaphyseal femur fractures

The callus fracture sign: a radiological predictor of progression to hypertrophic non-union in diaphyseal tibial fractures

S Salih [1,✉], C Blakey [1], D Chan [1], J C McGregor-Riley [1], S L Royston [1], S Gowlett [2], D Moore [2], M G Dennison [1]

▸ Author information ▸ Article notes ▸ Copyright and License information

PMCID: PMC4666228 PMID: 26602552

- It represent a prognostic sign where the fracture would eventually form a hypertrophic non-union

- Those patients should undergo a period of increased fracture stabilization prior to removal of their implant

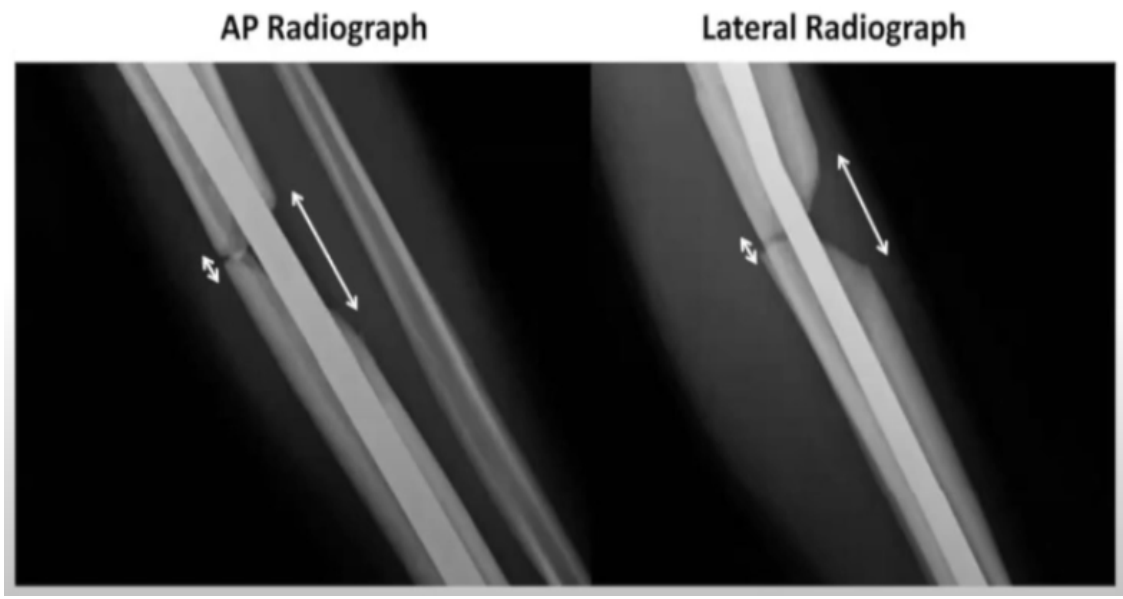
J Orthop Trauma. 2016 May;30(5):e158-63. doi: 10.1097/BOT.0000000000000531.

Defining the Lower Limit of a "Critical Bone Defect" in Open Diaphyseal Tibial Fractures

Nikkole M Haines [1], William D Lack, Rachel B Seymour, Michael J Bosse

- 40 patients, open #, IMNs
- To determine healing outcomes with bone gap of 10-50 mm (≥50% of cortical circumference)

- Patients with (**RABG**) < 25MM have a reasonable probability of achieving union without additional intervention



Radiographic apparent bone gap (**RABG**)

Imaging : CT scan

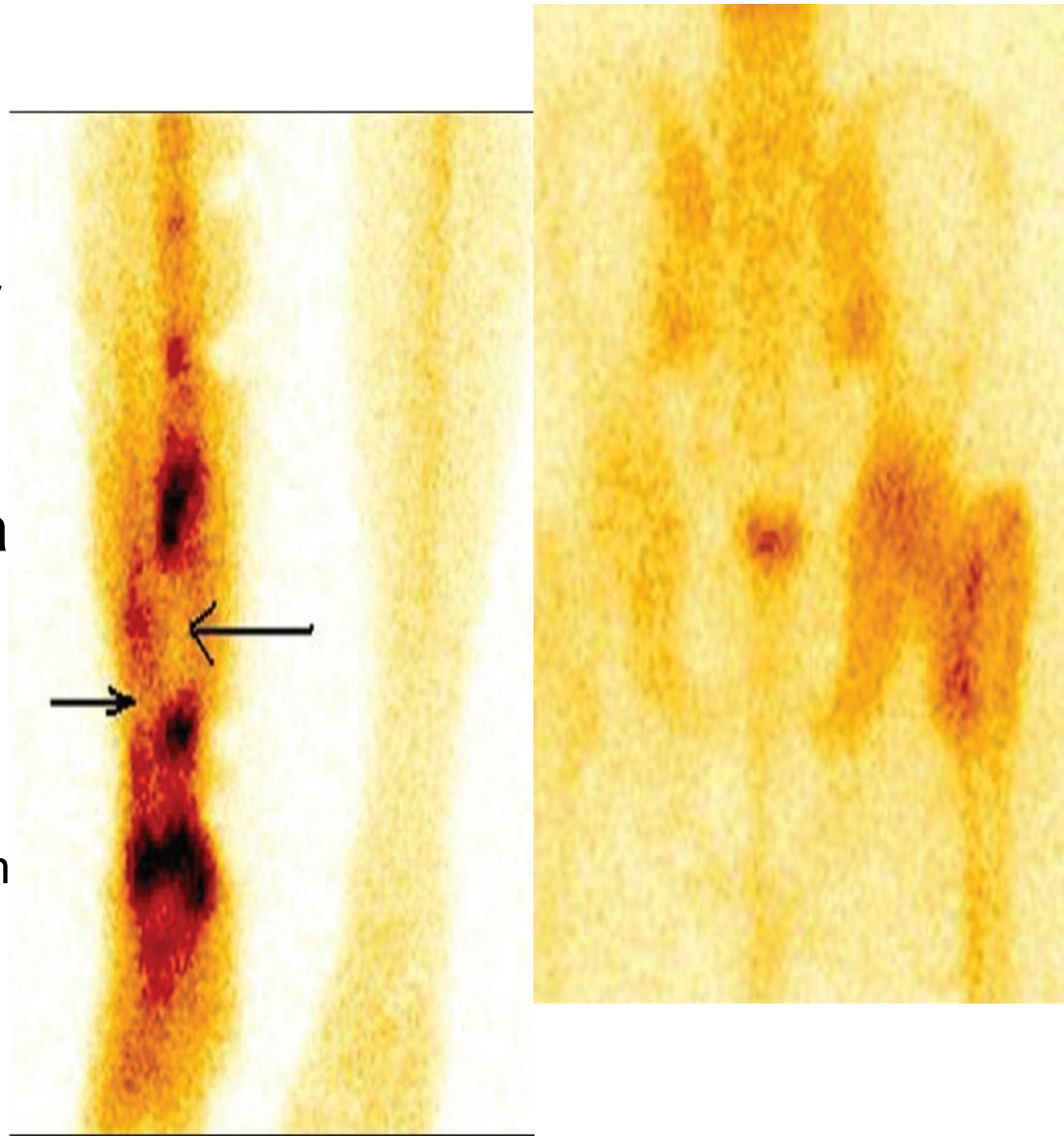
CT with MPR aided surgical planning by providing a more detailed assessment of:

- Malalignment (especially rotational)
- Angular deformities
- Bone gap
- Bridging bone percentage
- Intraarticular nonunion

Nuclear imaging

- Used to assess biological activity at nonunion site
- Poor or absent callus on radiographs does not always mea a lack of biological activity

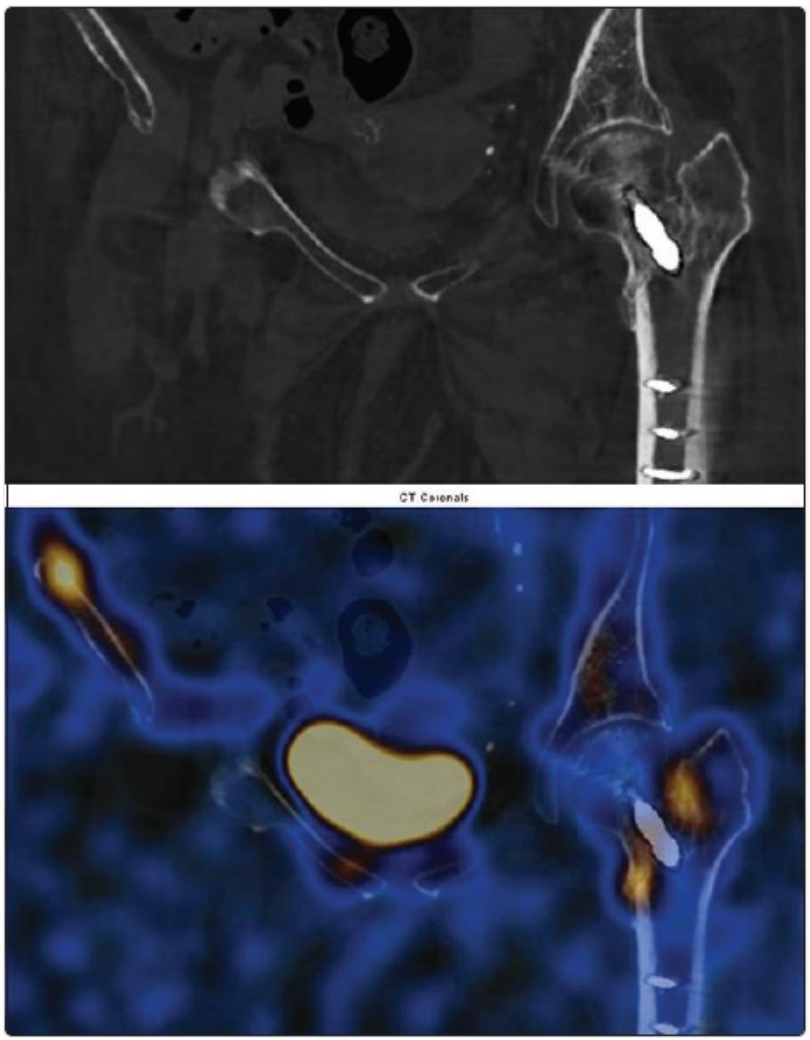
- Infection
- Increased blood flow, but are not pathognomon for infection.



Single-photon emission computed tomography (SPECT)

- differentiating infected from noninfected and vital from nonvital nonunions.

- high specificity but low sensitivity to confirm nonviability at a nonunion site



Patient’s – Goals & Expectations

- What are the patient’s goals and needs?
  - Household ambulation vs marathon runner
- Pain relief expectations
- Range of motion expectations
  - Long standing nonunions may have stiff adjacent joints
- Risks to neurovascular structures injury
  - radial nerve in humerus nonunion

Management

- We can treat nonunion in a lots of different ways

- So almost always strict to the **principles** in treating patients and move forward with systematic approach so you can be successful

Three steps approach to all nonunion patients

1. Try to determine why did this fracture not heal ?

- Extrinsic factors ?
  - smoking, metabolic disease
- Mechanical factors
  - poor fixation, alignment issue, improper implant
- Biology problem ?
  - bone loss, too much comminution, poor soft tissue coverage , infection,

Three steps approach to all nonunion patients

2. Determine how to treat base on possible causes for nonunion

- How to optimize biological environment ?
  - Treat infection, improve soft tissue coverage, add auto-graft
- How can I optimize implant factors ?
  - Increase stability , add compression
- Is there limb alignment issue ?
  - Correct the deformity

Three steps approach to all nonunion patients

3. How should I individualize treatment and manage expectations ?

- Not every patient is the same !

- What's the success of this treatment ?
- What can the patient tolerate ?
- Are there alternatives ?
- What's the backup plan ?

Management

Correct as many factors as possible prior to surgery

- Smoking cessation
- Correct blood sugar level
- Correct vit D level
- Optimize medication (NSAIDs cessation)
- Plastic surgery evaluation for soft tissue coverage issues

Non operative management

- Electrical stimulation
- Ultrasound
- Extracorporeal shock wave therapy

Best suited for **hypertrophic nonunions**

- Prerequisites :
  - No infection
  - No motion
  - No deformity
  - Gap less than 10mm

Role of non operative management

- All have clinical evidence to support effectiveness
- Few comparative studies between modalities
- Few comparative studies between non operative and operative methods

► Cureus. 2022 May 18;14(5):e25100. doi: 10.7759/cureus.25100

Outcomes of the Treatment of Fracture Non-union Using Combined Magnetic Field Bone Growth Stimulation: Experiences From a UK Trauma Unit

Vusumuzi Sibanda [1,✉], Fitzgerald Anazor [1], Jai Relwani [1], Baljinder S Dhinsa [1]

Editors: Alexander Muacevic, John R Adler

► Author information ► Article notes ► Copyright and License information

PMCID: PMC9205291 PMID: 35733483

- Bone growth stimulators using combined magnetic fields are a **viable** treatment option for established fracture non-union.

- They can result in improved outcomes and can avoid **risks** and **costs** associated with surgical options to treat non-union.

- Patients receiving OSD treatment require less opioids
- A significant benefit to cost savings per patient

ELSEVIER

Injury

Volume 48, Issue 7, July 2017, Pages 1339-1347

Healing of fracture nonunions treated with low-intensity pulsed ultrasound (LIPUS): A systematic review and meta-analysis

Ross Leighton [a], J. Tracy Watson [b], Peter Giannoudis [c d], Costas Papakostidis [e], Andrew Harrison [f], R. Grant Steen [g h]

- success rate for LIPUS >80%
- LIPUS treatment can be an alternative to surgery in high risk nonunion patients

Operative management

Classification guides treatment

- Hypertrophic : **stability**
- Atrophic + oligotrophic : **stability + biological** stimulation
- Infected: **infection control** + stability +- biological stimulation

Biological stimulation

- Autogenous bone graft: **gold standard**
  - ICBG, RIA
- Bone marrow aspirate
- Allograft bone
- Demineralized bone matrix
- BMP’ s (rhBMP-2 and rhBMP-7)
- Platelet concentrates

Surgical options

- Nail dynamization
- Nail exchange with larger nail
- Augmentation plates
- Compression plates
- External fixators

Nail dynamization

- 50 years male pt
- 8 months later after initial surgery

- Achieved osseous healing 6 months after dynamization

Nail dynamization

- 27 years old male pt
- 1 year after initial surgery

- **Unsuccessful** dynamization after 6 months !!

Original article | Open access | Published: 08 January 2022

Addition of shock wave therapy to nail dynamization increases the chance of long-bone non-union healing

Josef Stolberg-Stolberg, Thomas Fuchs, Moritz F. Lodde, Steffen Roßlenbroich, Patric Garcia, Michael Raschke ✉ & Jens Everding

Journal of Orthopaedics and Traumatology **23**, Article number: 4 (2022) | Cite this article

- 49 patients with long-bone non-unions (femur and tibia)
- 15 group D, 17 group S, 17 group DS
- Union rates
  - 60% for group D, 64.7% for group S and **88.2% for group DS**

- Combination therapy leads to a higher union rate

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(2), 3404-3408 | ISSN:2251-6727

Role of Fibular Osteotomy in Achieving Tibial Union

Dr. S.Senthil Velan [1*], Dr. P.Sankaralingam [2], Dr. Jeeva [3], Dr. Anu varshni [4]

- <u>20 cases</u>:
  - 7 cases fibular osteotomy + with dynamic interlocking nailing
  - 12 cases fibular osteotomy + PTB cast
  - 1 case fibular osteotomy + TENS + PTB cast

- <u>All of these cases</u> achieved union within six months
- No bone grafting was required in any of these cases


R
R
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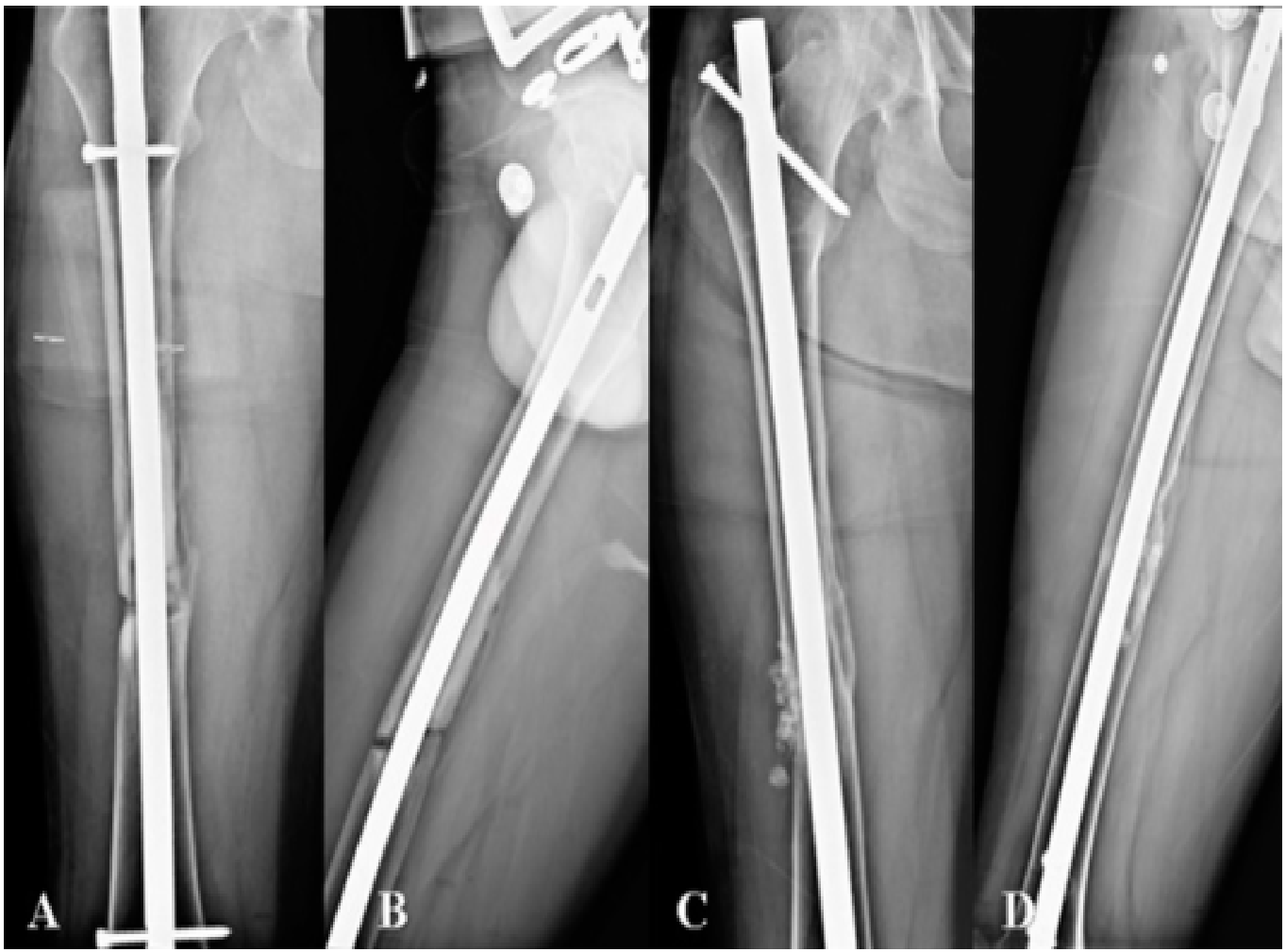
Nail exchange

- 34 years,
- atrophic nonunion 8 months after initial surgery

- A new IMN, 2 mm larger
- Union 6 months later



Original Article

Exchange Nailing for Aseptic Nonunion of the Femoral Shaft after Intramedullary Nailing

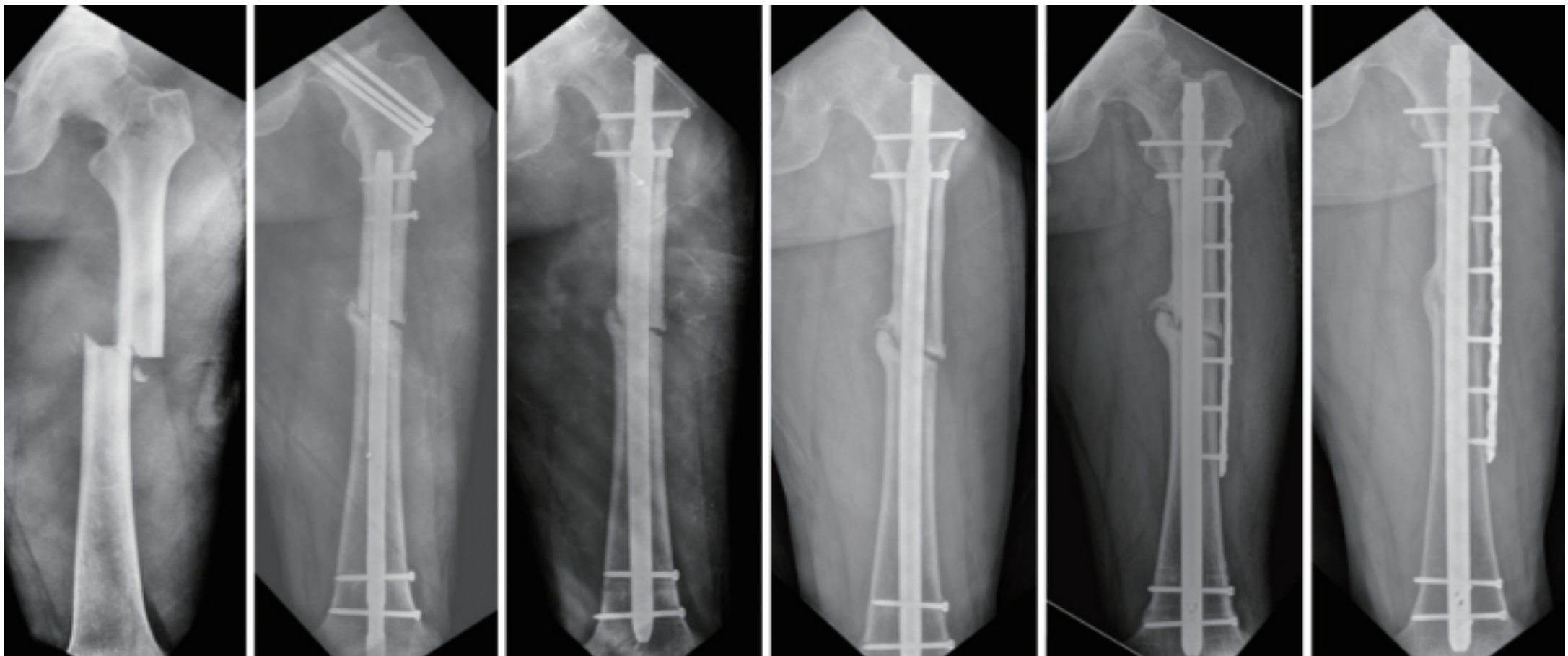
Sung-Soo Ha, M.D.[1,2], Chang-Wug Oh, M.D., Ph.D.[1,2], Jae-Wook Jung, M.D.[1,2], Joon-Woo Kim, M.D., Ph.D.[1,2], Kyeong-Hyeon Park, M.D., Ph.D.[1,2], Seong-Min Kim, M.D.[1,2]

Journal of Trauma and Injury 2020;33(2):104-111. DOI: https://doi.org/10.20408/jti.2020.010
Published online: June 19, 2020

- 30 cases of aseptic femoral shaft nonunion
- 27 achieved primary healing with exchange nailing by average time of 23.1 weeks

- Exchange nailing in femoral shaft nonunion is an efficient technique to achieve union with high healing (rates 70-90 %)

Augmentation plate



Comparative Study of Exchange Nailing and Augmentative Plating for Treating Aseptic Nonunion of Femoral Shafts Post Intramedullary Nailing: A Single-Blind, Multicentric Randomized Clinical Trial

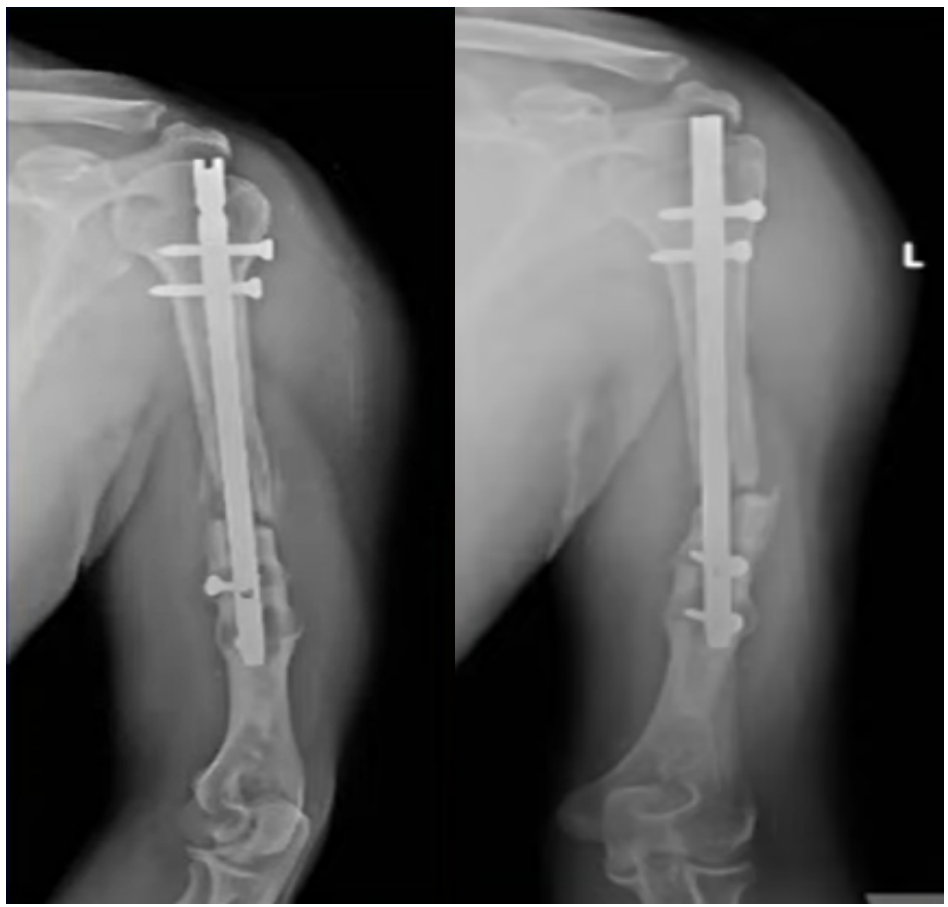
by Mehdi Motififard [1], Hamid Mousavi [1], Nasrollah Iranpanah [2], Hossein Akbari Aghdam [1], Mehdi Teimouri [1], Mohsen Aliakbari [1], Mohammad Parhamfar [1], Somaye Shirazi Nejad [3], Mahdi Shahsavan [3], Amin Daemi [4], Ashkan Salehi [1,*] and Mohammad Shahsavan [1,*]

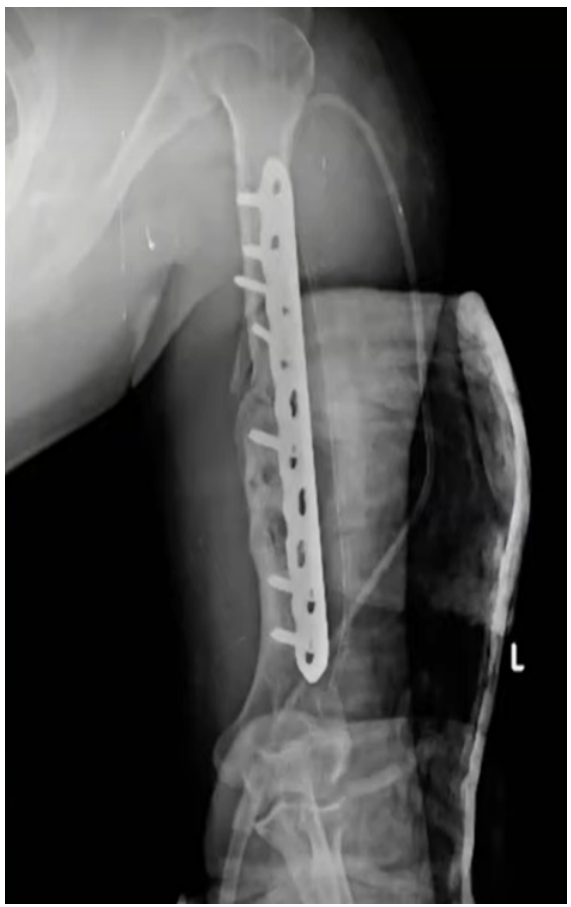
J. Clin. Med. **2024**, *13*(22), 6928; https://doi.org/10.3390/jcm13226928

The augmentative plating group vs. with the exchange nailing group

- shorter mean time to union (5.39 vs. 7.38 months)
- union rates at 12 months (100% vs. 89.65%)
- shorter operation time (99.46 vs. 106.45 min)
- reduced blood loss (514.79 vs. 547.72 mL)

40 yrs male, 16 months after initial surgery





Infected nonunion

- Most difficult type to treat

- Requires **staged** management
  - Eradicate infection first
  - Obtain union

- **Counselling** to the patient and family is crucial
  - Unpredictable outcome
  - Possibility of persistant infection, nonunion and amputation

Infected nonunion

- Debride aggressively
- 2 debridement's (even more)
- Remove all necrotic tissues (skin, muscle, bone)
- Send everything to culture (+ fungus , AFB)
- Excise sinus tract completely (send to histopathology SCC)
- Don’t elevate flaps
- Use a burr with constant cooling
- Shorten if you need to and you can lengthen later
- Treat dead space (antibiotic beads , vacc sponges)
- Optimize host factors

Infected nonunion

Systemic antibiotics

- Usually 4-6 weeks

- Oral rifampin for gram+ if hardware retained (penetrates the biofilm)

- ID consult is helpful
  - Manage AB level
  - Monitor toxicity
  - Good medico legal sense

Infected nonunion

Create stability and axial alignment

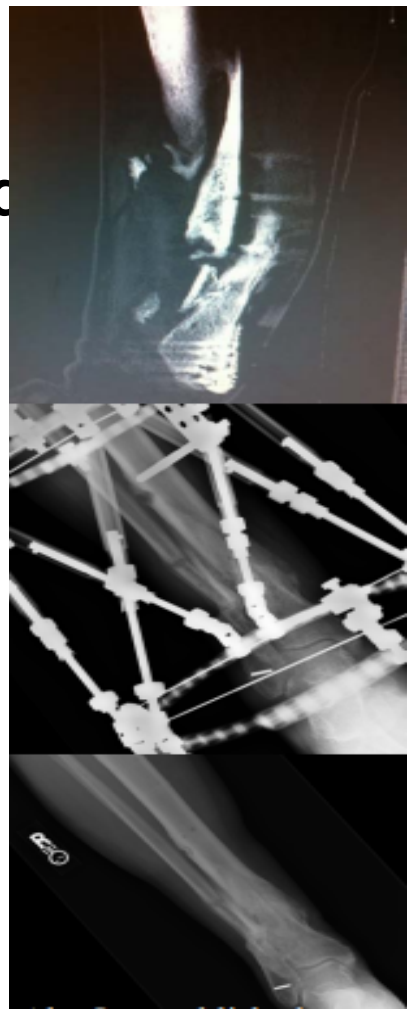
- **Initial stage** : All methods are viable if debridement was done well
  - Plates (good soft tissue coverage)
  - Antibiotic coated nails
  - External fixator

Infected nonunion

<u>Delayed</u> definitive reconstruction when infection eradicated

- Illizarov , TSF, Rail ex fix
- Gradual malalignment correction
- Bone transport with distraction osteogenesis
- Can generate large compressive forces at nonunion
- Allows mobilization of joints

- In complex cases, may be good for limb salvage but may require a <u>long period of time</u>



37 years female, open tibia #, septic nonunion

Home messages

- Nonunion can be a devastating consequence of a fracture and the cause of a massive amount of patient morbidity.
- Effective screening of nonunion risk may decrease this morbidity and subsequent healthcare resource use and costs
- Unexplained Nonunion can be the presenting feature of endocrinopathy

Home messages

- Nonunion should be considered infected until proven otherwise
- Infected nonunion has the worst prognosis with unpredictable results
- Deep bacterial colonization can only be assessed by taking deep cultures from everywhere
  - Don’t rely on superficial swab culture
- Stability is a pre-requisite for bone formation

Home messages

- Discuss with your nonunion patient and address his goals and expectations
  - Treating nonunion is not straight forward process and it not 100% successful
- A successful outcome requires the correct identification of all of the underlying cause(s) and addressing them appropriately
- Refer nonunion patients that exceed your skills

Thank you