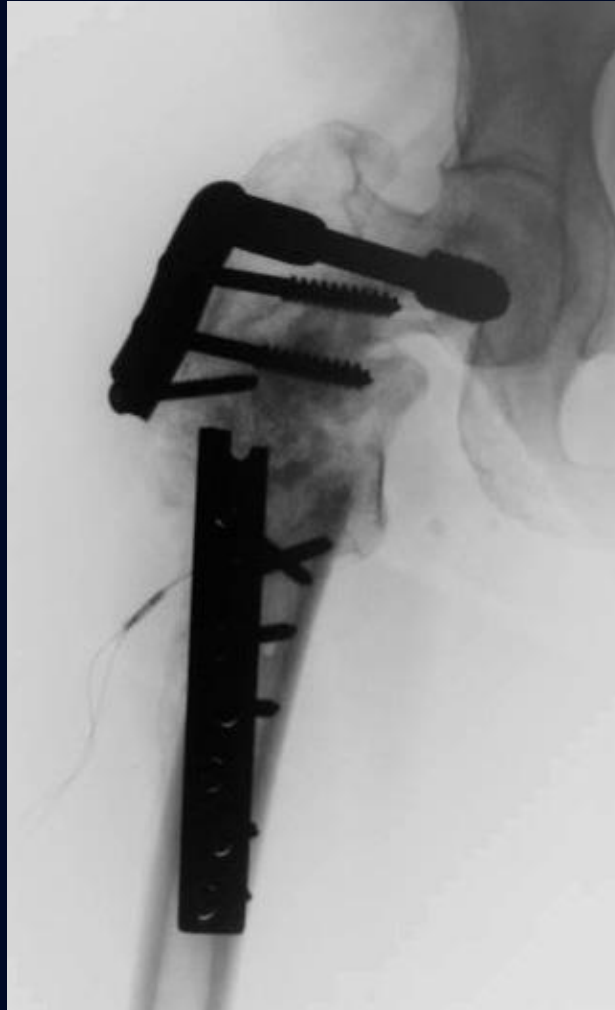


Reflections On Extremity Non-Unions

A Single Surgeon Experience With 627 Cases



Donald A Wiss MD Los Angeles, California

Retrospective Analysis of A Prospective Database



Three Study Objectives



1. To Compare and Stratify the Healing Rates After **Index** Non-Union Surgery Using Contemporary Methods of Fixation
2. To Report the Prevalence of Recalcitrant Non-Union
3. To Identify Specific Demographic, Injury, and Treatment **Risk Factors** For Development of a Recalcitrant Non-Union

Recalcitrant Non-Union

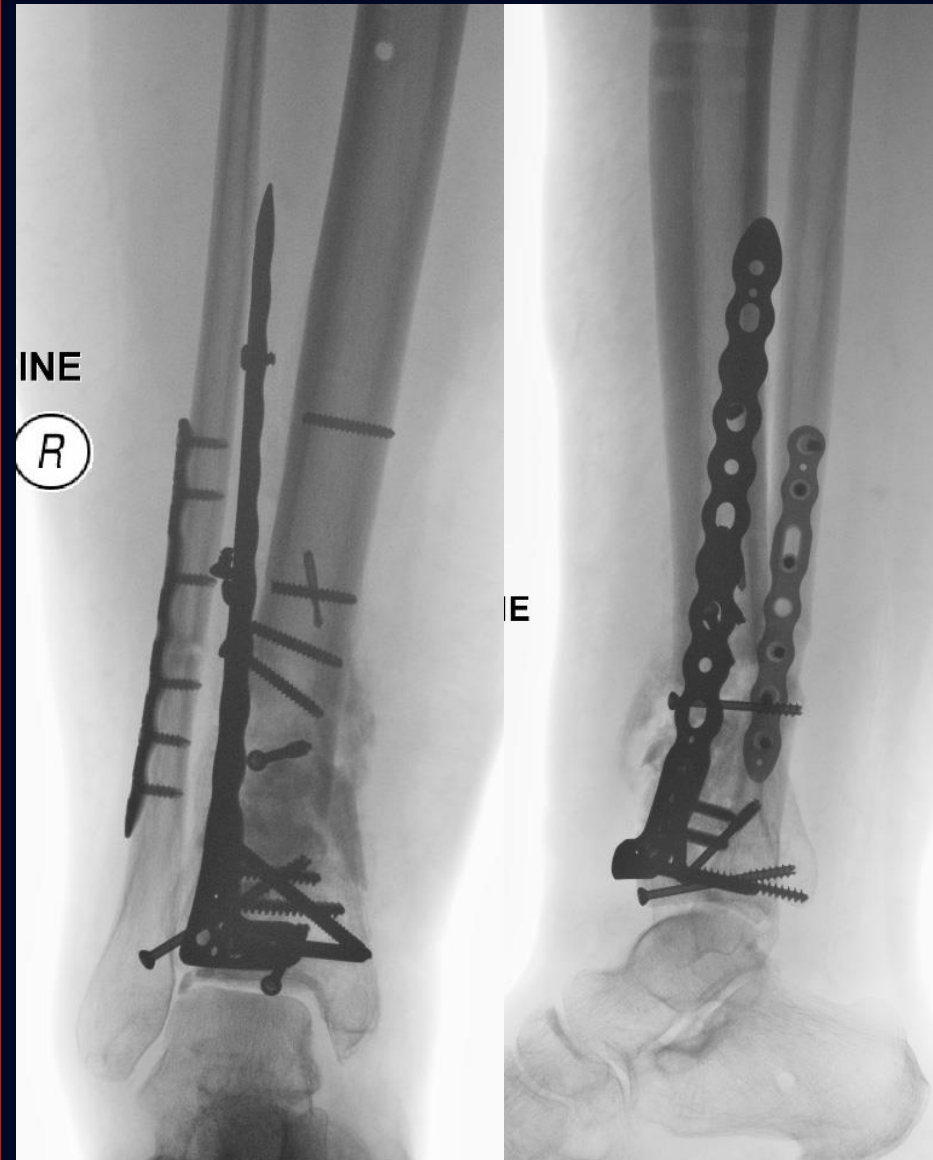


A **Recalcitrant Non-Union** Was Defined
As The Group Of Patients Who Required A
Secondary Intervention After Their Index
Non-Union Surgery And Those Patients
Who **Did Not Heal** (RNU)



Extremity Non-Unions Just To Be Clear

- **Not** Discussing Today
 - Anatomy
 - Biomechanics
 - Surgical Techniques
 - Segmental Defects
 - Chronic Osteomyelitis
 - Rehabilitation
 - Functional Outcomes



Non-Union Introduction

- Challenging Clinical Problem
- Broad Spectrum Of Injuries
- Thoughtful Intervention
- No Single Method Of Treatment
- Creative Approaches
- Treatment Failures Are Not Uncommon



Non-Union Knowledge Base

- 37 Yr Personal Experience
 - 10 Years - County Hospital
 - 1981 - 1991 (Learning Curve)
 - 27 Years Hybrid Private /
Academic Practice
 - 1991-2018 (Data Collection)



Fracture / Non-Union Database

July 1991 - July 2018

6392	Fractures	90%
------	-----------	-----

704	Non-Unions	10%
-----	------------	-----

7096	Total	100%
------	-------	------

Non-Union Database

	Study Period	Study Group
Tibia	253	222
Femur	141	122
Humerus	136	125
Clavicle	78	71
Miscellaneous	96	87
Total	704	☆ 627 (89%) ☆

Non-Union Research Follow-Up

- 89% FU Always Raises Eyebrows
- Acute Fracture Care From ER
 - Transient Population
 - Many in HMO's, Managed Care, etc
 - LA Tourist Destination
- **Non-Union Patients Find Me !**
- Told They Were In Research
- Minimum 1 Year FU Commitment

10 Year Follow-Up



Non-Union Study Design

Retrospective Analysis Of

Prospectively Collected

Cohort of Patients With A

Non-Union Treated With

Internal Fixation With Or

Without Bone Graft

Classic Excel Spreadsheet

Age	Sex	Side	Fx Location	Fx Grade	Smoker	Diabetic	Mech. Injury	Infection	Initial Treat	Prior Proc.	Wiss Index	Healing
34	F	L	D/3	Closed	Non	No	MVA	No	Plate	1	Conv Plate & ICBG	Primary
54	F	R	P/3	Closed	Non	No	Fall/Height	No	Plate	1	Conv Plate & ICBG	Primary
45	M	L	D/3	Open High IIIA	Smoker	No	Motorcycle	No	Plate	2	Conv Plate	2nd Intervention
85	F	R	M/3	Closed	Smoker	No	Fall	No	Plate	2	Exchange Nail	2nd Intervention
43	M	L	M/3	Closed	Smoker	No	Fall/Sports	No	Non-op	0	IM Nail	Primary
32	M	L	D/3	Open High IIIA	Former	No	Motorcycle	No	Plate	1	Conv Plate	Primary
71	M	R	M/3	Closed	Non	No	Fall/Sports	No	Nail	4	Exchange Nail	Not Healed
65	M	R	D/3	Closed	Non	No	Fall/Sports	No	Plate	1	IM Nail	Primary
45	M	L	D/3	Closed	Non	No	Motorcycle	No	Plate	4	Conv Plate	2nd Intervention
45	M	R	M/3	Closed	Smoker	Unknown	MVA	Primary	Nail	2	Exchange Nail	Primary
29	M	R	P/3	Closed	Smoker	No	MVA	Primary	Plate	2	IM Nail	Primary
49	M	L	M/3	Closed	Non	No	MVA	No	Nail	1	Exchange Nail	Not Healed
71	F	L	P/3	Closed	Non	No	Fall	No	Plate	1	IM Nail	Primary
45	M	L	D/3	Open High IIIA	Smoker	Yes	Industrial	Primary	Nail	4	Conv Plate	Primary
49	M	L	M/3	Closed	Smoker	No	Fall	No	Nail	1	Exchange Nail	Primary

Pam Swan

Non-Union Data Base

Unique Opportunity To Compare
Similar Groups Of Non-Unions
Treated By A Single Surgeon Using
Different Methods Of Treatment



Non-Union Study Questions

Would Any Specific Method Of Fixation,
Bone Grafting Or Augmentation, Result
In A Statistically Significant Improved
Rate Of Non-Union Healing



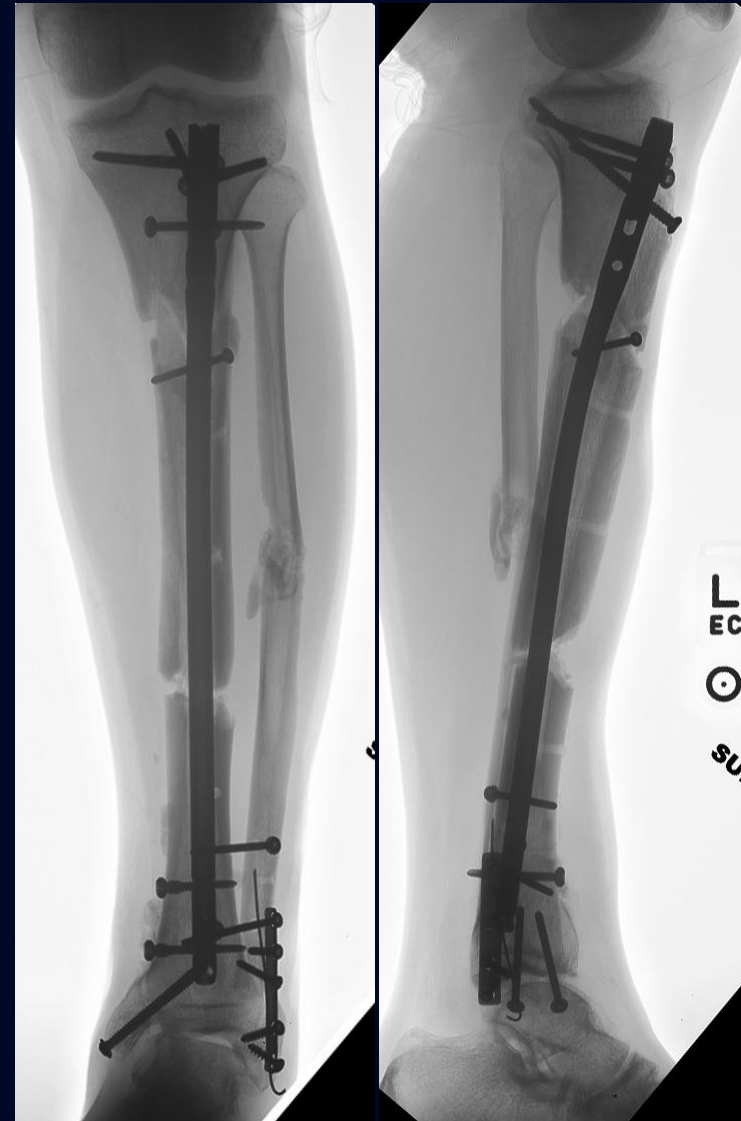
Non-Union Study Question

In Femoral And Tibial Non-
Unions Did Treatment With
An Intra-Medullary Nail
Compared To Plate
Osteosynthesis Affect
Rates Of Healing?



Non-Union Study Question

Did The Number of Surgical
Procedures **Prior** To Referral
For Non-Union Treatment
Have Prognostic Significance
In Determining Outcome ?



Non-Union Study Question

Were There **Specific Risk
Factor(s)** That Contributed To
The Development Of A
Recalcitrant Non-Union In
This Study Population



Non-Union Study Key Concept



Many Non-Union Studies Fail To Capture The
True Incidence Of Recalcitrant Non-Unions &
Simply Report Their Rate Of Successful Bony
Union Independent Of The Number Of Non-
Union Surgeries Require To Achieve Union



Non-Union

Strength Of Study

- Single Surgeon Study
- Experienced Fracture Surgeon
- Research Interest In Topic
- Prospective
- Good Follow-Up



Non-Union Weakness Of Study

- Non-Randomized
- Selection Bias
- Reviewer Bias
- Changing Methods Of Rx
- No Outcomes Measures



Non-Union

Historical Definition

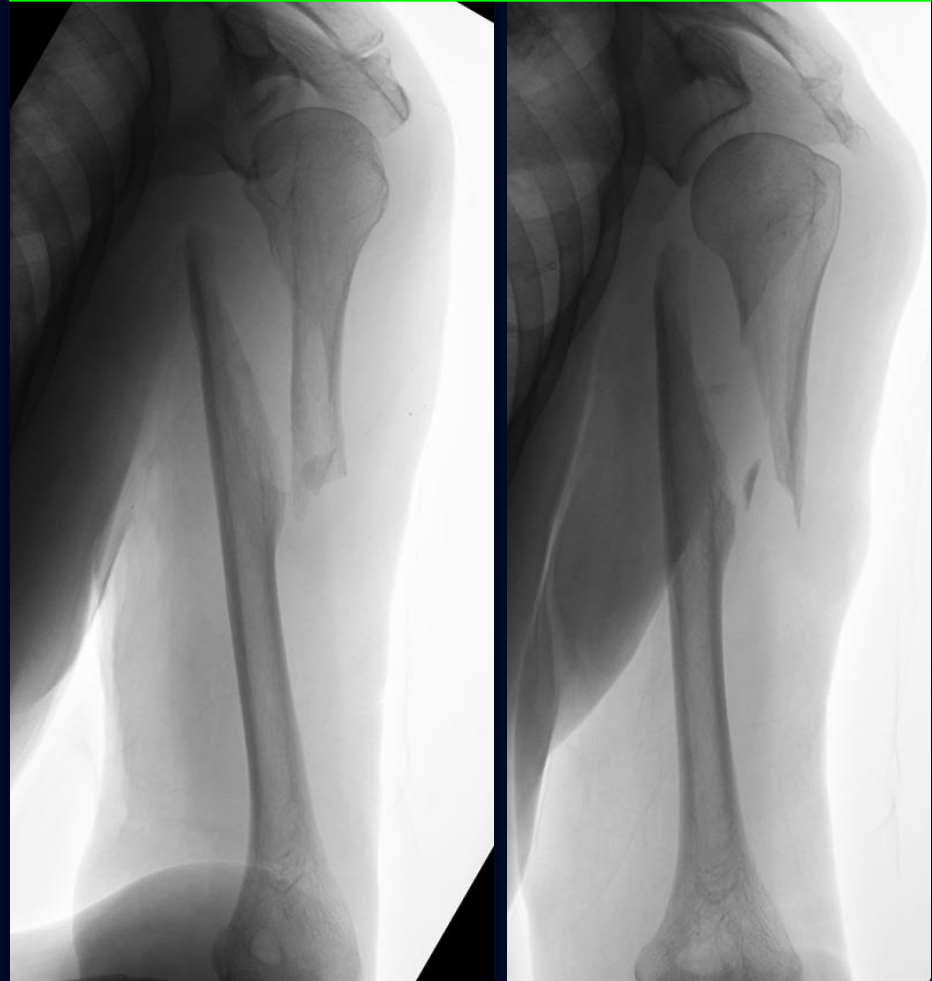
- Literature Confusing
- Little Consensus
- Defined Time Frames
- Not Statistically Validated



Non-Union Study Definition

Pain Or Motion At The
Fracture Site Without
Progressive Signs Of
Healing Between 3-5 Months
After Injury Or There Was
Fixation Failure Without Signs
Of Healing

77 Yr Female 12 Weeks Following A Fall



This Is A Non-Union !

Non-Union Patient Problems

- Prolonged Morbidity
- Unable To Work
- Multiple Surgeries
- Psycho-Social Impairment



Non-Union Patient Problems

- Disabled
- Depressed
- Destitute
- Divorced
- Draining
- Drug Dependent

6D's



Non-Union Surgeon Problems

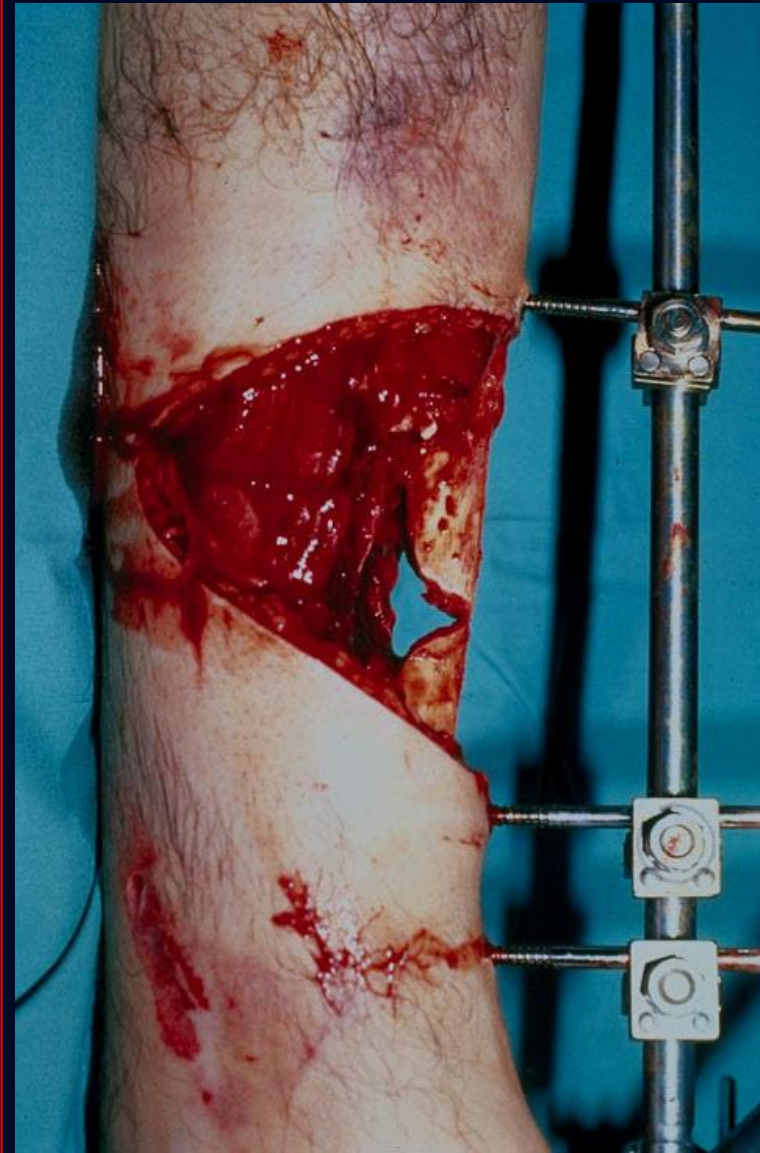
- Correct Alignment
- Correct Rotation
- Equalize Leg Lengths
- Prevent / Rx Infection
- Restore Function



Non-Union

Multi-Factorial Etiology

- Compromised Soft Tissues
- Inadequate Local Vascularity
- Fracture Instability
- Critical Bone Defects
- Concomitant Infection



Non-Union Etiology Patient Factors

- Tobacco / Alcohol & Drugs
- Nutritional & Immune Status
- Meds: Steroids, Biologics, etc.
- Medical Co-Morbidities
 - Diabetes
 - Kidney Disease
- Social Support / Homeless



Non-Union

Etiology Surgeon Factors

- Surgeon Errors
 - Wrong Implant
 - Wrong Location
 - Wrong Size
- Technical Errors
 - Poor Reductions
 - Inadequate Stability
 - Failure To Graft



Non-Union Patient Assessment

- History
- Physical Exam
- Risk Factors
- Imaging Studies
- Nuclear Medicine Scans
- Laboratory Studies
- Pre-Op Planning
- Intra-Operative



Non-Union History

- Detailed History
- Mechanism Of Injury
- Initial Method Of Treatment
 - Non-Operative
 - Internal Fixation
 - External Fixation
- Wound Vac, Beads, Flaps
- History Prolonged Antibiotics



Surgical Detective

Non-Union

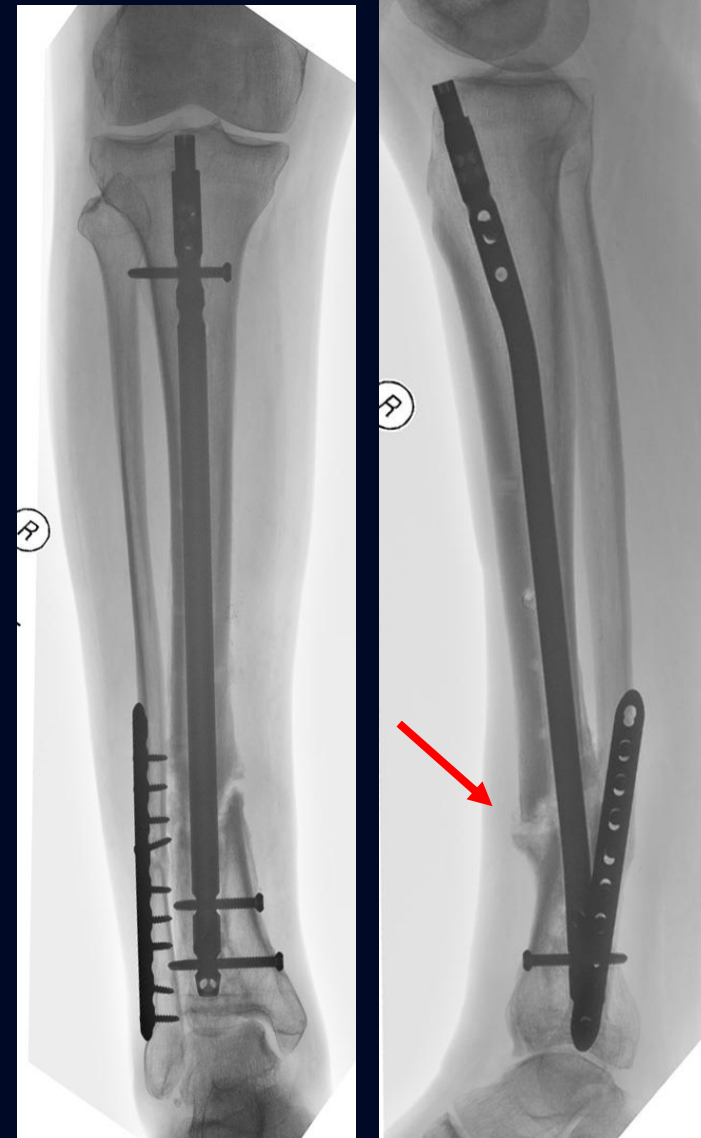
Physical Examination

- Status Of The Soft Tissues
- Clinical Deformity
- Pain Or Motion At Fracture Site
- Adjacent Joint Function
- Neuro-Vascular Examination



Non-Union Imaging Studies

- Plain Radiographs
 - Gold Standard
 - Adequate For Diagnosis
 - Oblique Views Helpful
- CT & MRI
 - Useful In Selected Cases
 - Limits With Existing Hardware



Non-Union Nuclear Medicine Scans

- Used 1^o To Evaluate For Infection
 - **Bone Scan:** High Sensitivity, Low Specificity
 - **Indium WBC :** Better Specificity
 - **Technetium 99 WBC Scan:** Replaced Indium, Better Imaging
- Not Routinely Employed



Non-Union Laboratory Studies

- Basic Minimum
 - CBC & Diff
 - ESR & CRP
 - CMP
- Metabolic Work-Up
 - Metabolic Panel, Vitamin D
 - Alkaline Phos, Mg, Cortisol
 - Thyroid, Albumin, A1C
- Selected Patients



Stucken CS, Olszewski DC, Creevy WR, Tornetta P

Preoperative Diagnosis Of Infection In Patients With Nonunions

JBJS 95: 1409-1412, 2013

Protocol: CBC, ESR, CRP, WBC / Sulfur Colloid Scan

Predicted Probabilities Of Infection Associated With

Zero, One, Two, Or Three Tests Were 18%, 24%, 50%, & 86%

Without The Nuclear Scan, The Predicted Probabilities For

Zero, One, Two, Three Risk Factors Was 20%, 19%, 56%, 100%

J van den Kieboom et al. **Diagnostic Accuracy Of Serum Inflammatory Markers
In Late Fracture Related Infection** Bone & Joint J 2018; 100B: 1542-50

8284 Articles Identified; Only 6 Were Suitable For Inclusion!

	Sensitivity	Specificity
CRP	77%	68%
WBC	52%	67%
ESR	45%	79%

Conclusion: CRP, WBC, ESR Are Insufficiently Accurate To
Diagnose Late Fracture Related Infection. However, They May
Be Suggestive

Non-Union Patient Evaluation

- **No** Non-Union Emergencies
- Uncommon Infection Urgencies
- Careful History & Exam
- Review Medical Records
- Obtain Previous Radiographs
- Pre-Op Planning



Non-Union Pre-Op Planning

- Plastic Surgery Consultation
- Infectious Disease Consultation
- Vascular Studies (ABI' s, Duplex, etc)
- Internal Medicine
- Obtain Previous Records & X-Rays
- Selected Subgroup Of Patients
 - Aspirate Fracture Site
 - Stage Surgery



Non-Union

Plastic Surgery Consult

- Soft Tissue Reconstruction
 - Prior To Non-Union Surgery
 - At The Time Of Non-Union Surgery
 - After Non-Union Surgery
- Type Of Soft Tissue Repair
 - Rotational Flap
 - Free Tissue Transfer



Non-Union Infection Consideration

- Hold Antibiotics Until
 - Multiple (7-8) Deep Cultures
 - Hold For 2 Weeks (p. Acnes)
- Antibiotic Strategies
 - Cephalosporin
 - Vancomycin
- Antibiotic Nails, Beads, Spacers



Olszewski D, Streubel PN, Stucken C, et al.

Fate Of Patients With A “Surprise” Positive Culture After Non-Union Surgery

J Orthop Trauma 30:e19, 2016

666 Consecutive Non-Unions

453 Considered At Risk (68%)

91 (20%) Had Surprise Positive Culture 9 Considered Contaminants

83 Rx With Antibiotics & 66 (80%) Healed 12 (14%) Remain Infected

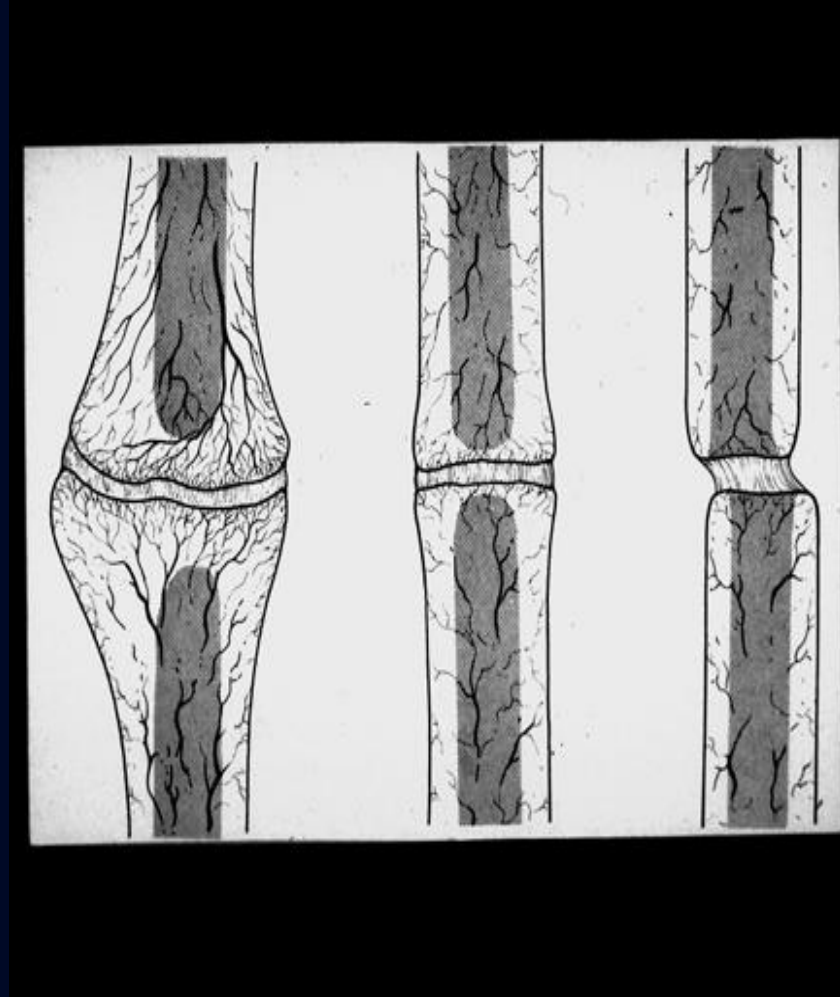
Conclusion: Multiple Intra-Op Cultures In Pts Having Non-Union Surgery

78% Healed After Index Procedure & 92% Healed After Additional Surgery

All Patients Who Have A Positive Culture Should Be Treated With Antibiotics

Non-Union Classification

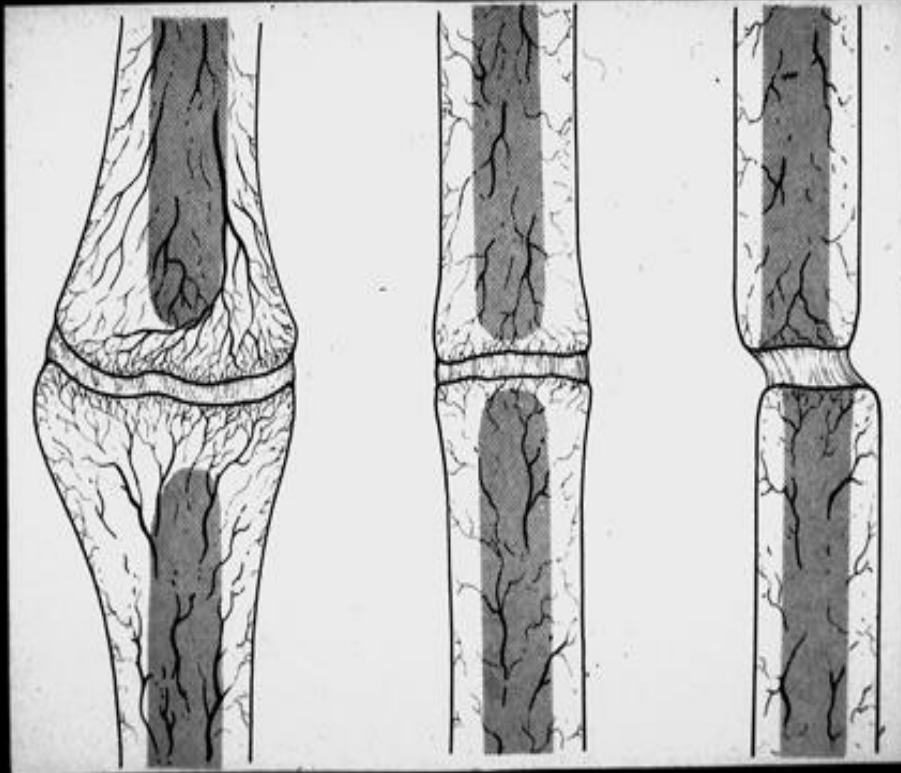
- Are They Useful ???
- Guide Treatment?
- Influence Outcome?
- Inter & Intra Observer Variability
- Academic / Practical



Weber AO / ASIF Classification

Hypertrophic

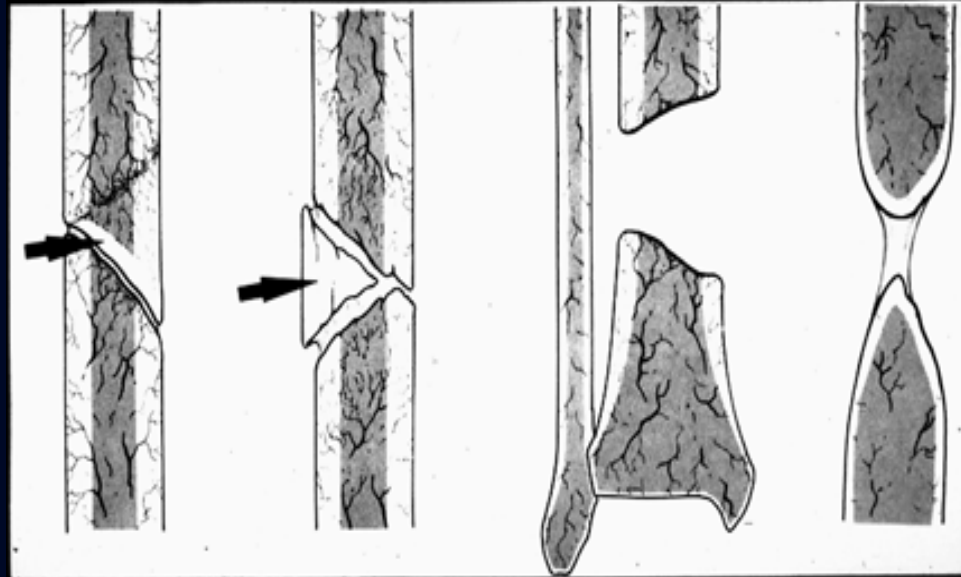
Atrophic



Oligiotrophic

Torsion Wedge

Congenital

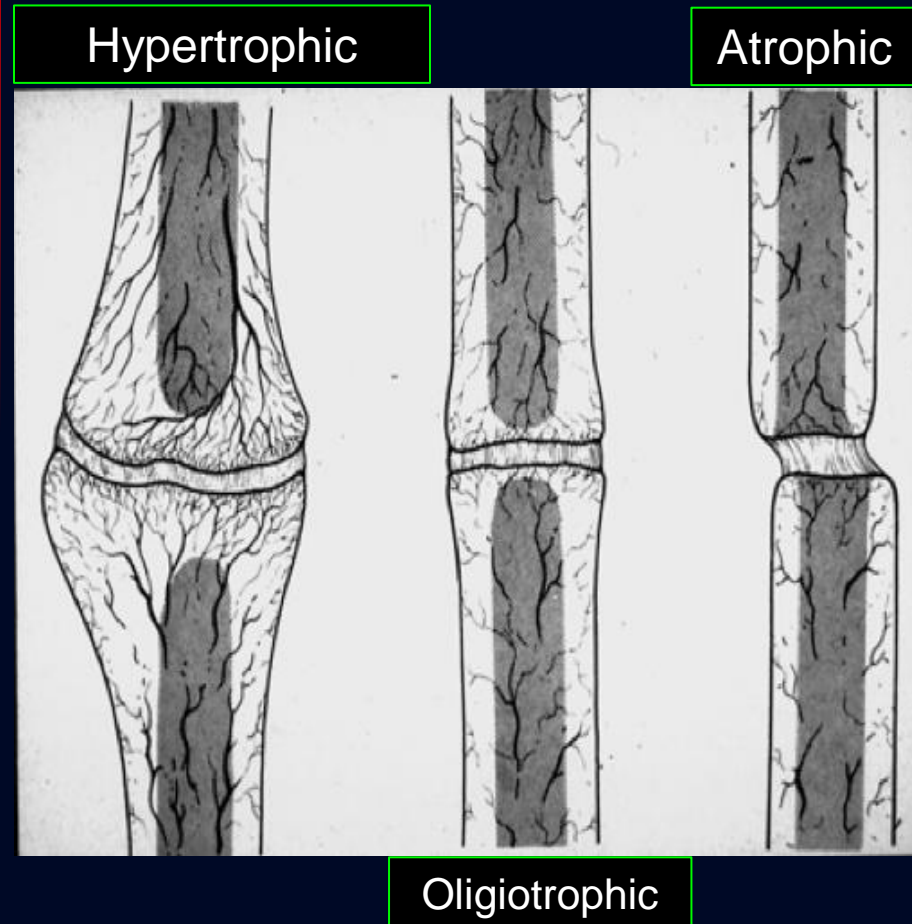


Bone Loss

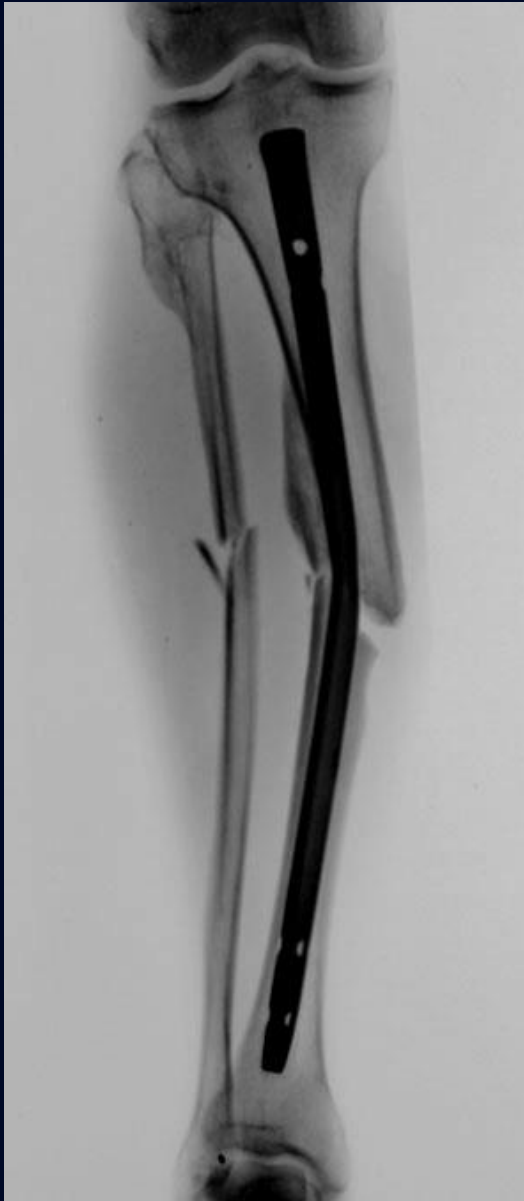
Non-Union

Weber AO Classification

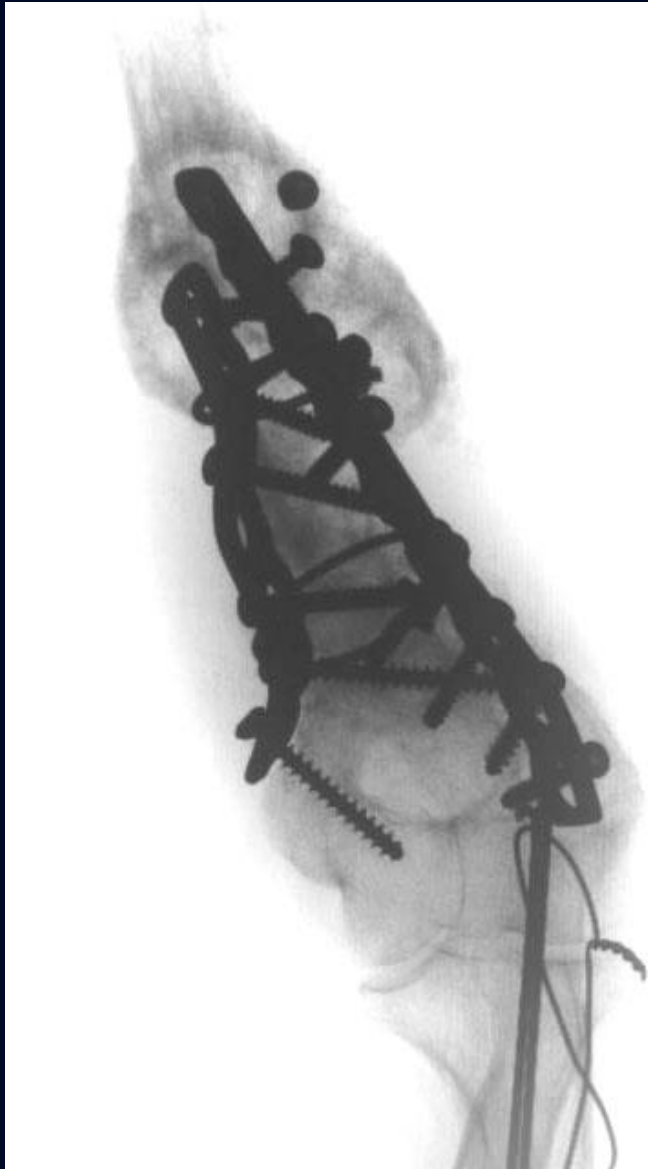
- Inadequate; Overly Simplistic
- Based On Plain Radiographs
- Infer The Vascular Status
- Prior Surgery With Implants
- Not Statistically Validated
- Does It Guide Treatment?



How Would **You** Classify These Non-Unions?



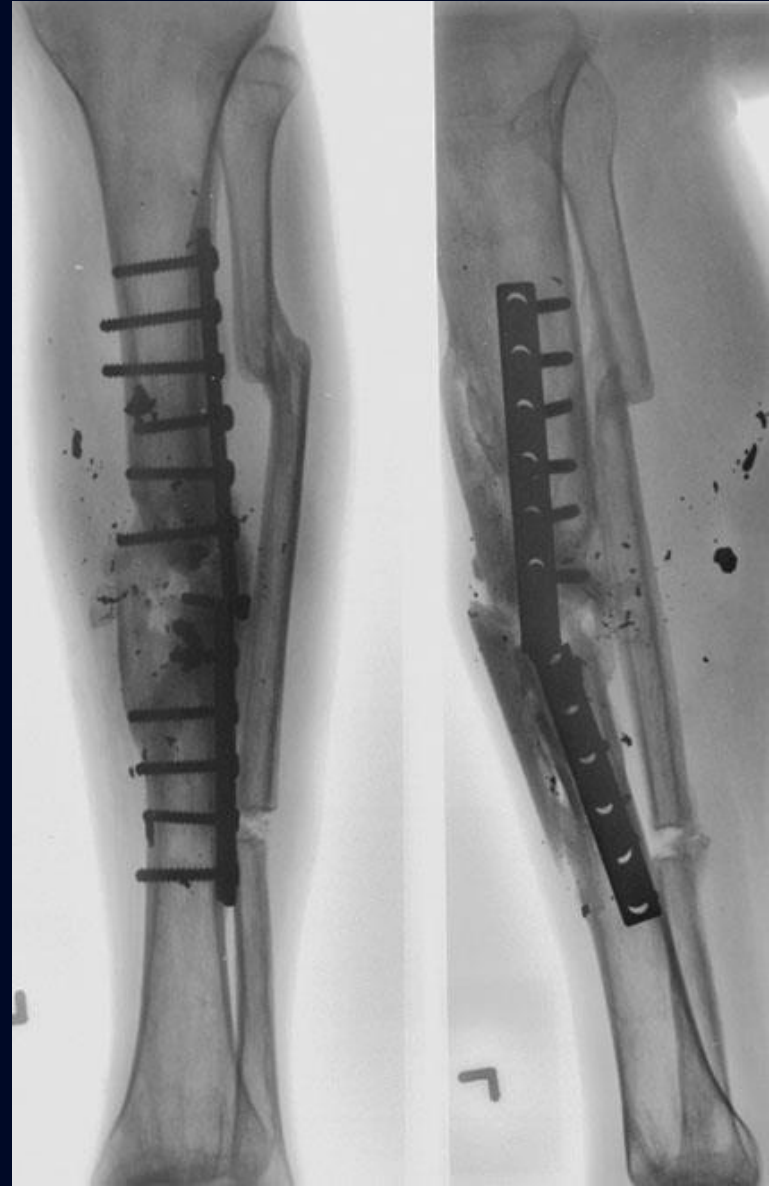
How Would **You** Classify These Non-Unions?



Non-Unions

Classification Factors Not Addressed

- Existing Hardware
- Allografts
- Soft Tissues
- Radiation
- Medications
- Nutrition
- Tobacco & ETOH
- Etc. Etc. Etc.



Non-Union Observations

- Weber AO Model Not Inclusive
- Did Not Guide My Treatment
- Historical Research Tool ??
- May Be Too Simplistic



Non-Union Pre-Operative Planning

- Type Of Implant (Nail, Plate?)
- Stabilization +/- Bone Graft
- Deformity Correction
- Take Down Of Nonunion
- Infection Considerations
- Staged Management





Non-Union Treatment Principals

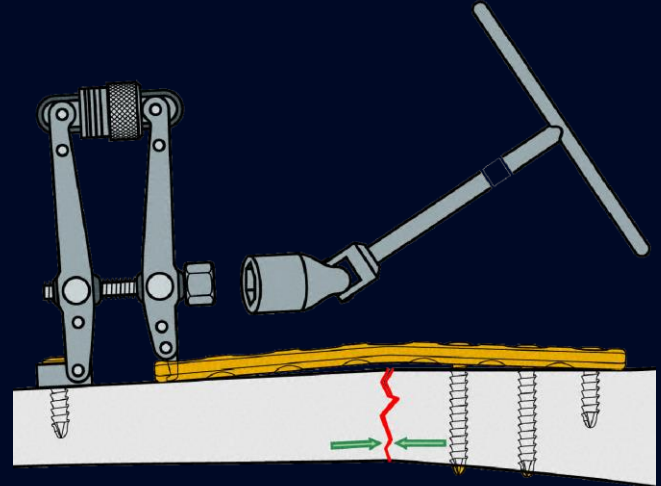


In Aseptic Hypertrophic & Some
Oligiotrophic Non-Unions The
Mesenchymal Tissue At The Non-
Union Site Retains The Capacity
To Form Osseous Tissue



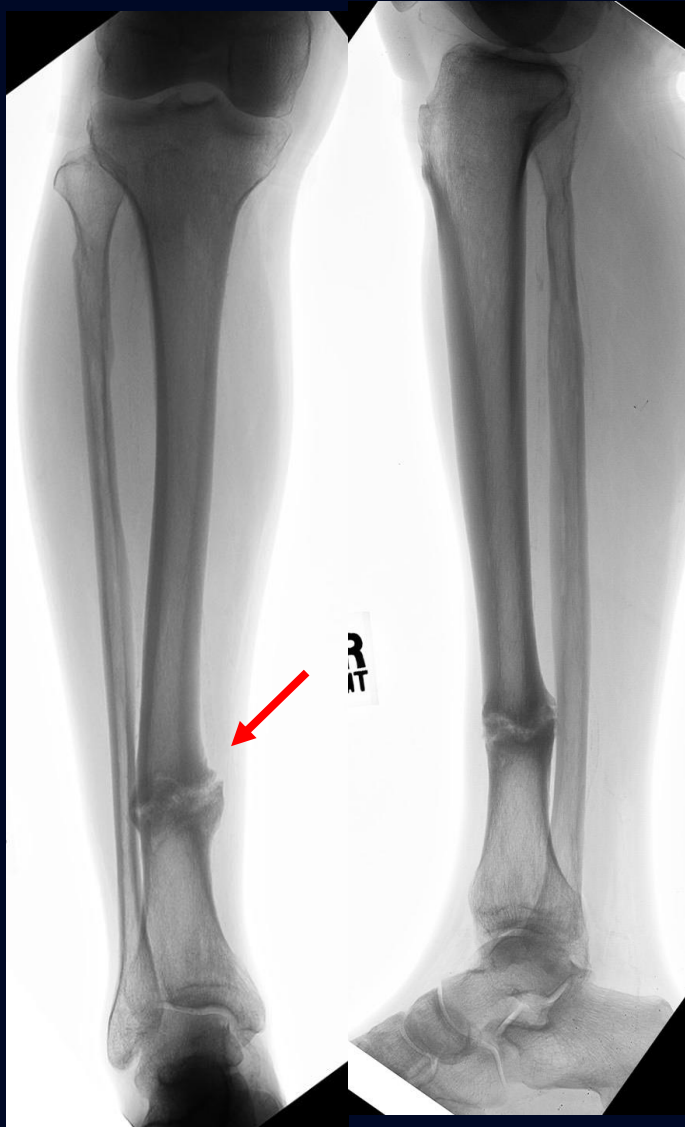
Non-Union Proper Stimulus

- Functional
 - Electrical / Ultrasound
 - Mechanical
 - Biological
- } ☆

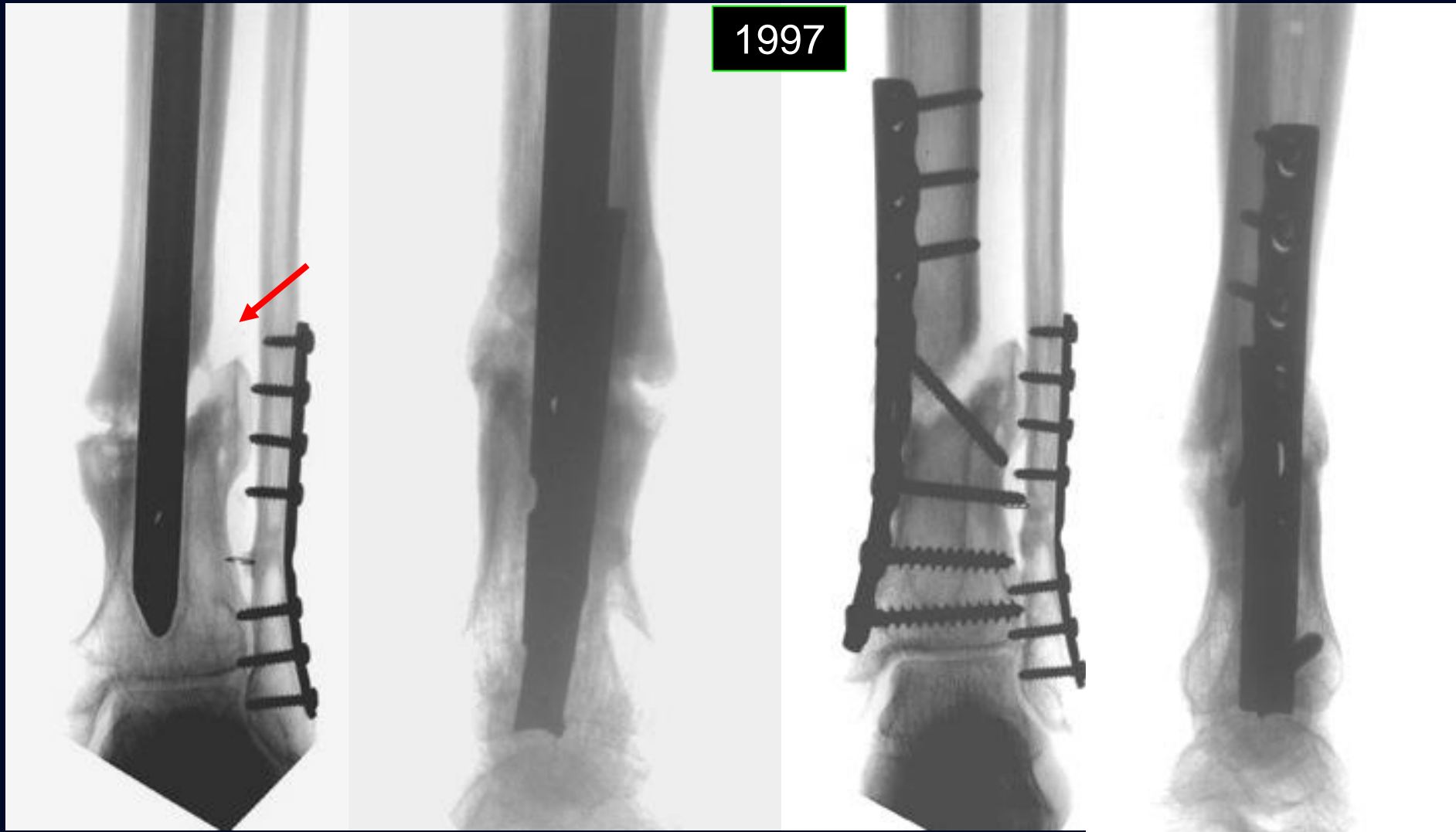


Singularly Or Combination

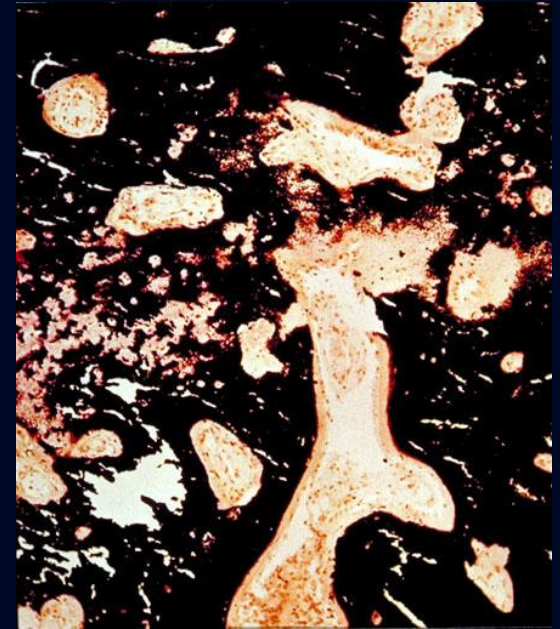
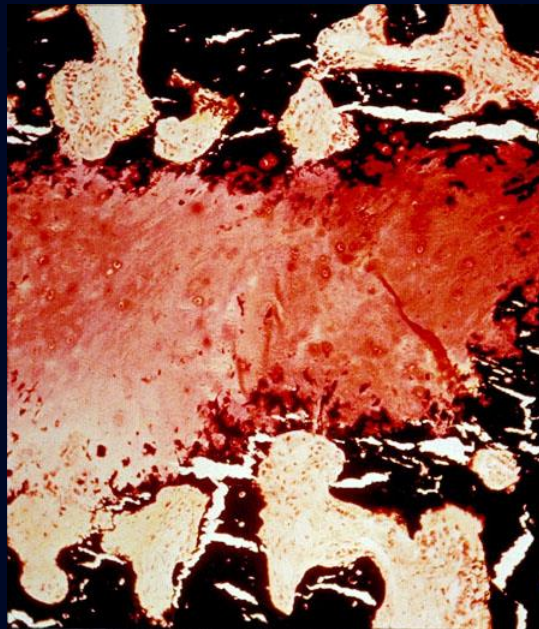
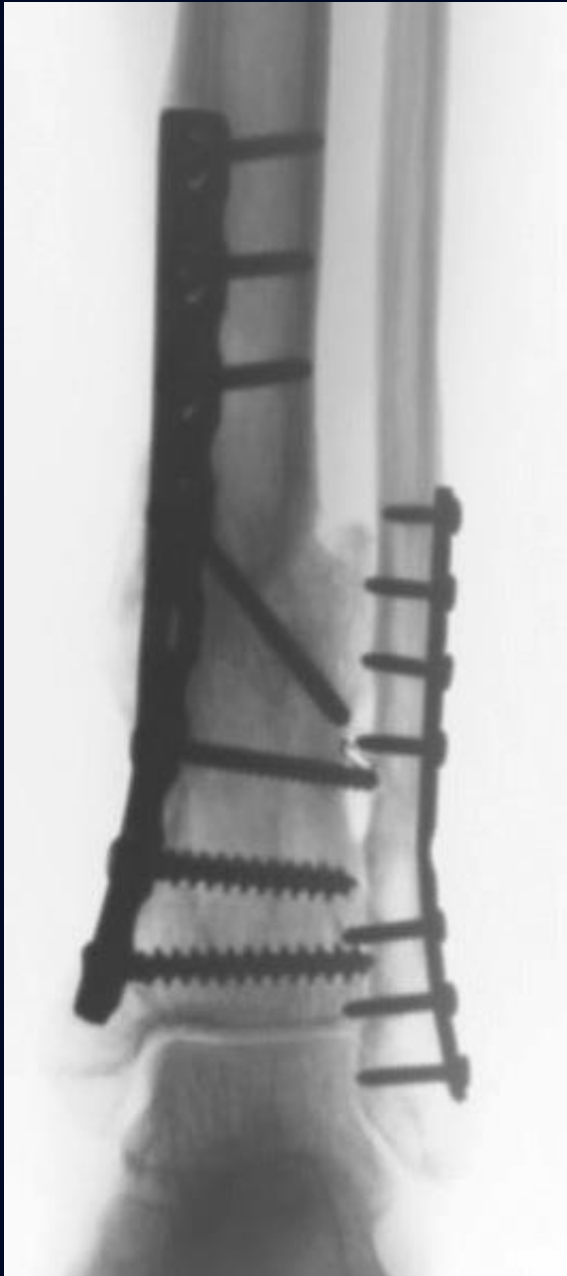
Stability Achieved With Closed Reamed IM Nailing Leads To Healing At 6 Months



Non-Union One Year After Nailing. ORIF With A Neutralization Plate & Lag
Screw; Local Bone Graft; Non-Union Site Not “Taken Down”



Uneventful Healing At 7 Months; Non-Union Tissue Differentiates Into Bone





Non-Union Treatment Principals



In **Atrophic & Septic Non-Unions** The

Mesenchymal Tissues Between The Ends Of

The Nonunion Site Do **Not** Predictably Retain

The Capacity To Form Osseous Tissue

10 Mos S/P Fracture

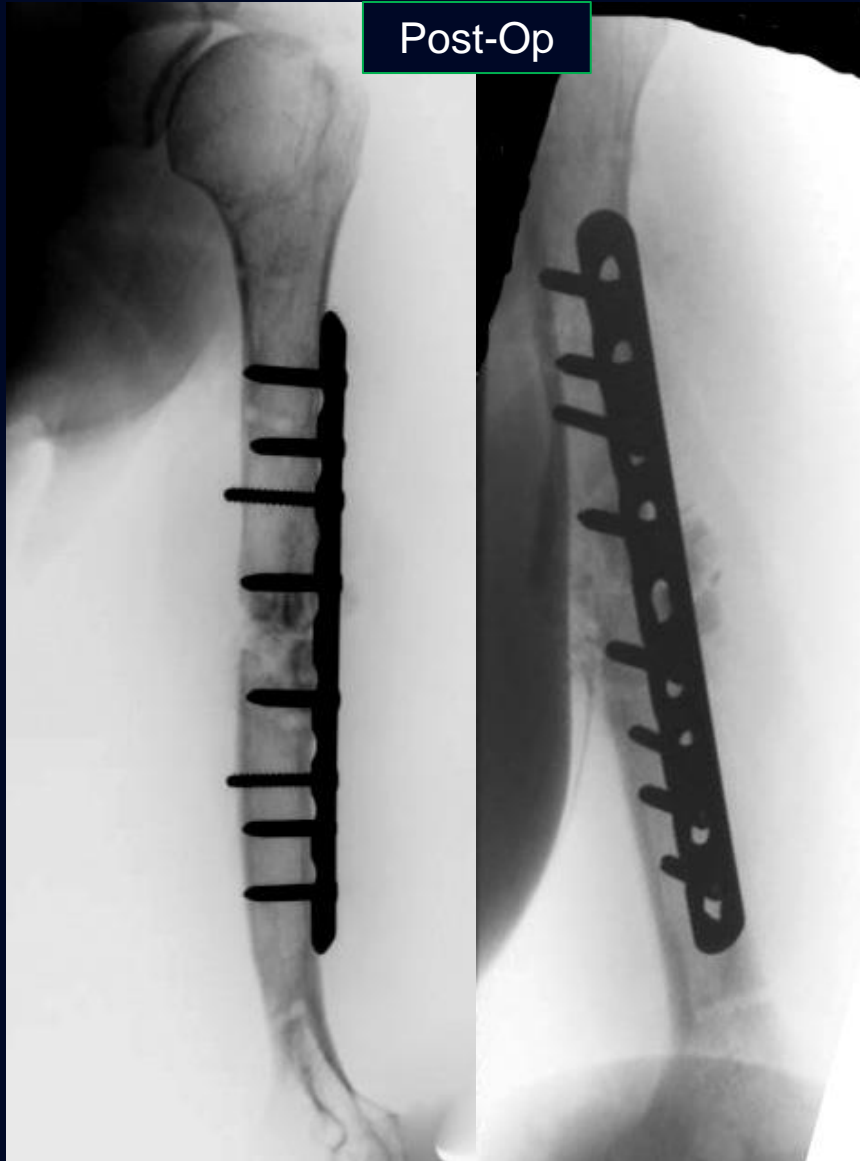


Atrophic Non-Union 10 Months After IM Nailing Of A Grade II Open Humeral Shaft Fracture



ORIF With A Locked Plate & ICBG

Post-Op

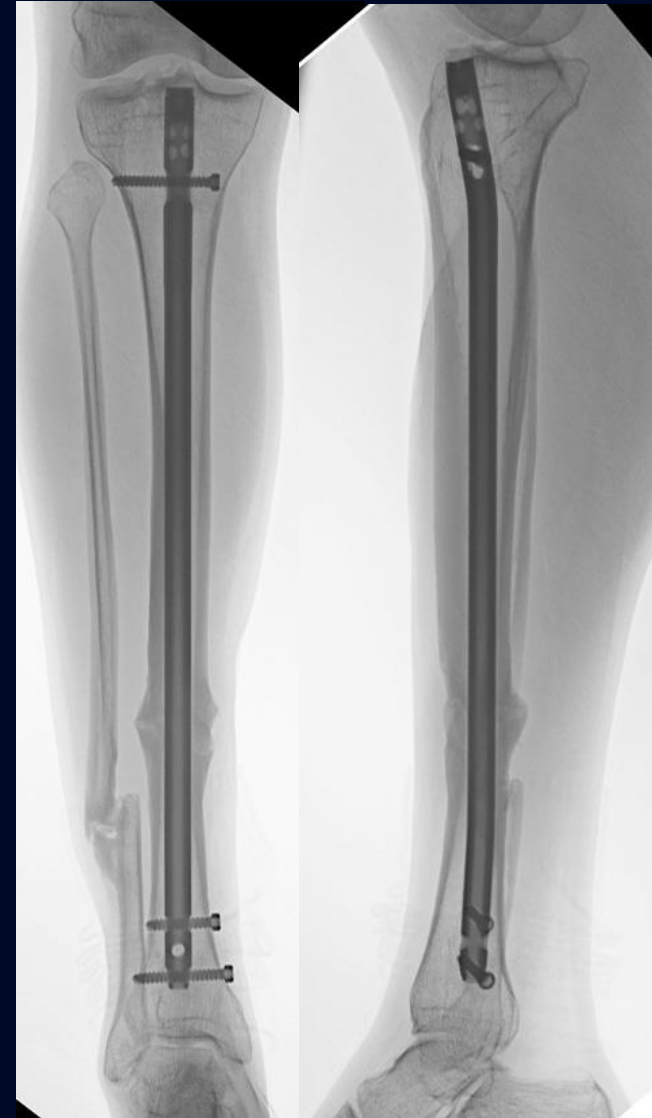


17 Month FU; Healed



Wiss Non-Union Study

- Not A Protocol Driven Treatment Study
- I Utilized The Best Available Evidence
To The Guide Treatment 1991-2018
- Both Implants & Biologics Changed
Over The Course Of This Study



Non-Union Treatment Principals

Femur & Tibia

- Diaphysis: Reamed IM Nail
 - Epi-Metaphyseal: Plate Fixation
 - Oligio & Atrophic: Graft Augmentation
-
- Deformity Correction
 - Stable Internal Fixation
 - Early Functional Rehab

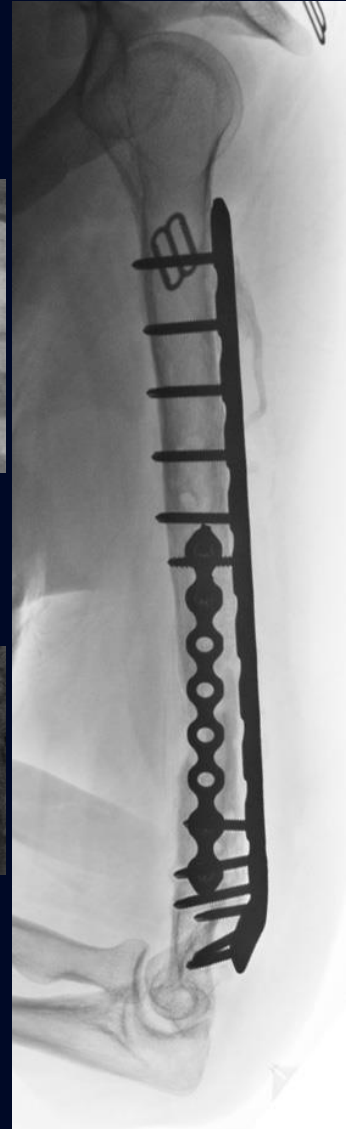


Non-Union

Treatment Principals

Upper Extremity

- Long Plates
 - Second Small Plate
 - Graft Augmentation
-
- Deformity Correction
 - Stable Internal Fixation
 - Early Functional Rehab





Non-Union Outcomes Study Definitions



- **Healing As Intended (HAI)** - **No** Further Interventions
Following The Index (Wiss) Procedure
- **Secondary Interventions (2°)** – Unplanned Return To The
Operating Room For **ANY** Reason Related To The Non-
Union Prior To Healing Such As I&D, Flaps, STSG,
Dynamization, Revision ORIF, Grafting, etc. **But Healed**
- **Not Healed** With No Further Surgical Treatment Planned

Non-Union Outcomes Study Definitions



Recalcitrant Non-Union Was The Combined Group
of Patients Who Required A **Secondary** Intervention
As Well As Those Patients Who **Did Not Heal** (RNU)

Non-Union Database

5 Anatomic Sub-Groups

- Tibia
- Femur
- Humerus
- Clavicle
- Miscellaneous
 - Forearm
 - Ankle
 - Other



Retrospective Review 1991-2018
Tibial Non-Union
N = 222

Healed (96%)
N = 213

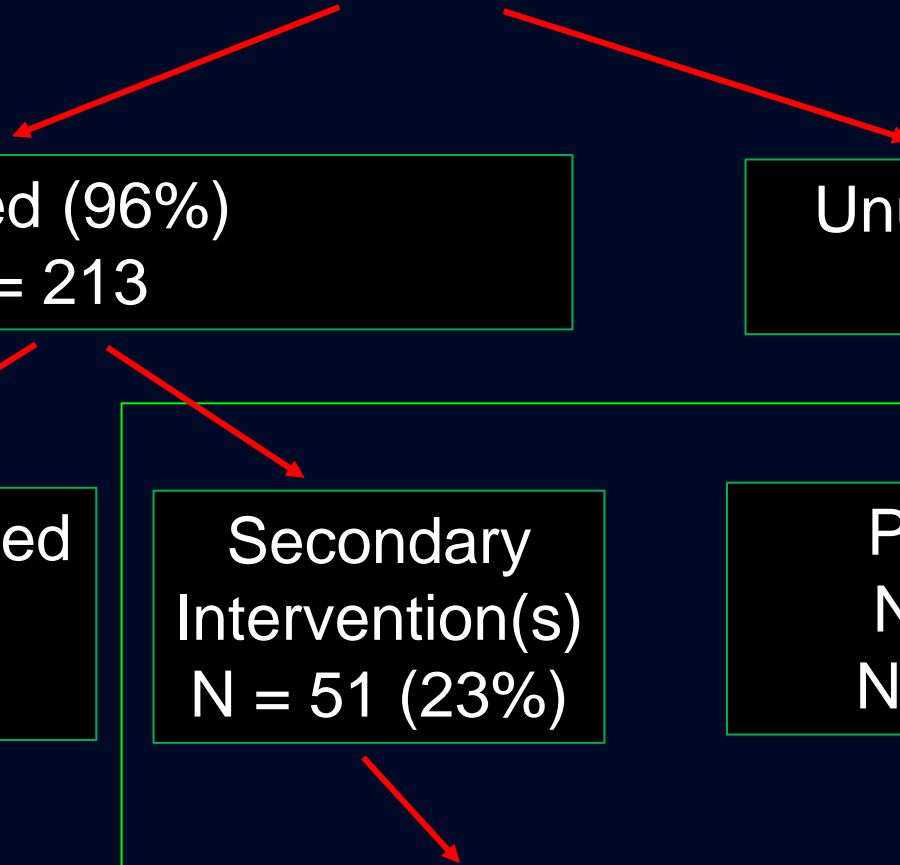
Ununited (4%)
N = 9

Healed As Intended
“Wiss Index”
N = 162 (73%)

Secondary
Intervention(s)
N = 51 (23%)

Persistent
Nonunion
N = 9 (4%)

Recalcitrant Non-Union N = 60 (27%)



Tibial Non-Union

Methods And Materials

- 112 Closed (50%), 110 Open (50%) Fractures
 - 129 Plates (58%), 64 Nails (29%), 29 (13%)
 - 126 Graft Augmentation (57%)
 - 44 Smokers (20%), 14 Diabetics (6%)
 - 16 Compartment Syndromes (7%)
 - 49 Flaps (22%)
 - 50 Infections (22%)
- } ☆



Risk Factor For A Recalcitrant Tibial Non-Union N=222

Not Statistically Significant

Bi-Variate Analysis	P-Value
Age	0.326
Sex	0.744
<input checked="" type="checkbox"/> Smoking	0.732
Diabetes	0.076
Laterality	0.705
Mechanism Injury	0.207
<input checked="" type="checkbox"/> Type of Non-Union	0.747
Duration Of Non-Union	0.408
<input checked="" type="checkbox"/> Graft Type	0.517

Risk Factor For Recalcitrant Tibial Non-Union N=222

Statistically Significant

Bi-Variate Analysis	P-Value
Initial Rx – External Fixation	0.036
High Grade Open Fracture	0.001
Deep Infection	0.001
Compartment Syndrome	0.001
Primary Or Reconstructive Flap	0.001
2+ Prior Procedures	0.001

Risk Factor For Recalcitrant Tibial Non-Union N=222

Multivariate Regression Analysis

Variable	P Value	Odds Ratio
Age + 10 Years	0.712	0.95 (0.73 – 1.24)
Smoker	0.778	1.13 (0.49 – 2.57)
Diabetes	0.216	0.25 (0.03 -2.28)
Low Grade Open Vs Closed Fracture	0.973	0.99 (0.42 – 2.29)
High Grade Open Vs Closed Fracture	0.010	0.20 (0.06 – 0.68)
Infection	0.001	6.59 (2.96 – 14.64)
Compartment Syndrome	0.032	3.83 (1.12 – 13.14)
Prior Procedures 0-1 Vs 2+	0.295	1.60 (0.66 – 3.85)

Risk Factor For a Recalcitrant Tibial Non-Union: N=222

Closed Versus Open Fractures

# Cases	Cohort	HAI	Secondary	Not Healed	P-Value
112	Closed	83 (74.1%)	25 (22.3%)	4 (3.5%)	<0.001
44	Low Grade Open	40 (91%)	3 (6.8%)	1 (2.2%)	
66	Open High Grade	39 (59.1%)	23 (34.8%)	4 (6.1%)	
222		162	51	9	

Risk Factor For a Recalcitrant Tibial Non-Union: N=222

Infection

Cases	Cohort	HAI	Secondary	Not Healed	P-Value
172	No Infection	142 (82.5%)	26 (15.1%)	4 (2.3%)	0.001
31	Pre-Referral Infection Hx	19 (61.2%)	9 (29.0%)	3 (9.8%)	
15	Post Non-Union Infection	1 (6.7%)	13 (86.6%)	1 (6.7%)	
4	Other	0 (0.0%)	(75.0%)	1 (25.0%)	
222		162	51	9	

Risk Factor For a Recalcitrant Tibial Non-Union: N=222

Compartment Syndrome

# Cases	Cohort	HAI	Secondary	Not Healed	P-Value
16	Compartment Syndrome	6 (37.5%)	9 (56.2%)	1 (6.2%)	<0.001

Risk Factor For a Recalcitrant Tibial Non-Union: N=222

Soft Tissue Reconstruction

Cases	Cohort	HAI	Secondary	Not Healed	P-Value
19 Flaps Done At The Time Of Injury					0.001
15	Free Flap At Injury	5 (33.0%)	9 (60.0%)	1 (7.0%)	
4	Rotation Flap At Injury	3 (75.0%)	1 (25.0%)	0 (0.0%)	
30 Flaps Done At The Time Of Non-Union Surgery					
25	Free Flap At NU	11 (44.0%)	12 (48.0%)	2 (8.0%)	
5	Rotation Flap At NU	2 (40.0%)	1 (20.0%)	2 (40.0%)	
49		21	23	5	

Risk Factor For a Recalcitrant Tibial Non-Union: N=222

Stratification By Number Of Prior Procedures

# Cases	# Procedures	HAI	Secondary	Not Healed	P-Value
23	Non-Operative	20 (86.9%)	2 (8.7%)	1 (4.3%)	0.001
70	One	60 (85.7%)	8 (11.4%)	2 (2.9%)	
63	Two	45 (71.4%)	18 (28.6%)	0 (0.0%)	
66	Three Or More	37 (56.1%)	23 (34.8%)	6 (9.1)	
222		162	51	9	

Healing the Index Tibial Nonunion: Risk Factors for Development of a Recalcitrant Nonunion in 222 Patients

Donald A. Wiss, MD,^a John Garlich, MD,^a and Randy Sherman, MD^b

Objectives: To compare and stratify the healing rates after our index nonunion surgery using contemporary methods of fixation, report the prevalence of recalcitrant non-union, and identify specific demographic, injury, and treatment-related risk factors for the development of a recalcitrant nonunion.

Design: Retrospective analysis of a prospectively collected database.

Setting: Academic Level 1 Trauma Center.

Patients/Participants: Two hundred twenty-two tibial nonunions treated with internal fixation by a single surgeon.

Intervention: Bivariate and multivariate regression analysis were performed to compare healing rates by the type of fixation and graft augmentation and to identify specific demographic, injury, and treatment-related risk factors for the development of a recalcitrant nonunion.

Results: Of the 222 patients, 162 (73%) healed as intended and 51 (23%) required 1 or more subsequent interventions to achieve union (96%). Nine fractures (4%) failed to unite. The 60 fractures (27%) that required a subsequent intervention(s) or failed to consolidate were defined as recalcitrant nonunions. There were no statistically significant differences in the recalcitrant rate when we compared plates versus nails or types of bone graft. Risk factors for developing a recalcitrant nonunion were multifactorial and included grade III open fractures, compartment syndrome, deep infection, and 2 or more prior surgical procedures.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

(*J Orthop Trauma* 2021;35:e316–e321)

INTRODUCTION

Nonunion following treatment of a tibial fracture is a disabling condition that results in pain, impaired ambulation, inability to return to work, and psychological impairment.^{1,2} Open tibia fractures are common because of the asymmetric soft tissue envelope surrounding the tibia, increasing the likelihood of soft tissue injury, impaired healing, and infection. Fracture stabilization with or without graft augmentation is usually indicated to promote union, alleviate pain, and restore function. However, treatment can be prolonged, and outcomes were unpredictable. Thus, a tibial nonunion places substantial burdens on the patient, surgeon, and health care systems with serious implications for limb function and quality of life.^{1,2}

There is a considerable body of literature that has identified risk factors for nonunion following acute tibial fractures.^{3–13} Most are related to fracture severity, such as the mechanism of injury, fracture grade, loss of cortical continuity, fracture displacement, or location. Additional risk factors that have been reported include compartment syndromes, infection, and smoking. Despite these challenges, multiple nonunion studies have documented satisfactory rates of healing using modern surgical techniques and contemporary implants.^{14–20} However, some nonunions can be very difficult to treat and require more than one surgery to obtain union. These cases have been referred to as recalcitrant.²¹ To date,

Clinical Cases

Healed As Intended

Elite College Football Player 7 Months S/P ORIF

Distal Third Tib-Fib

MIPPO Fixation

Non-Union

Posterior Tibial Nerve Injury

Infection Work-Up Negative

Would Would You Do

Nail?

Plate?

External Fixation?

Something Else?

1999



Deformity Correction Revision ORIF + Local BG



36 Month Follow-Up Healed At NFL Combine

Resumed Football
Career

8 Years In NFL

2 Seasons 1000

Yards Rushing



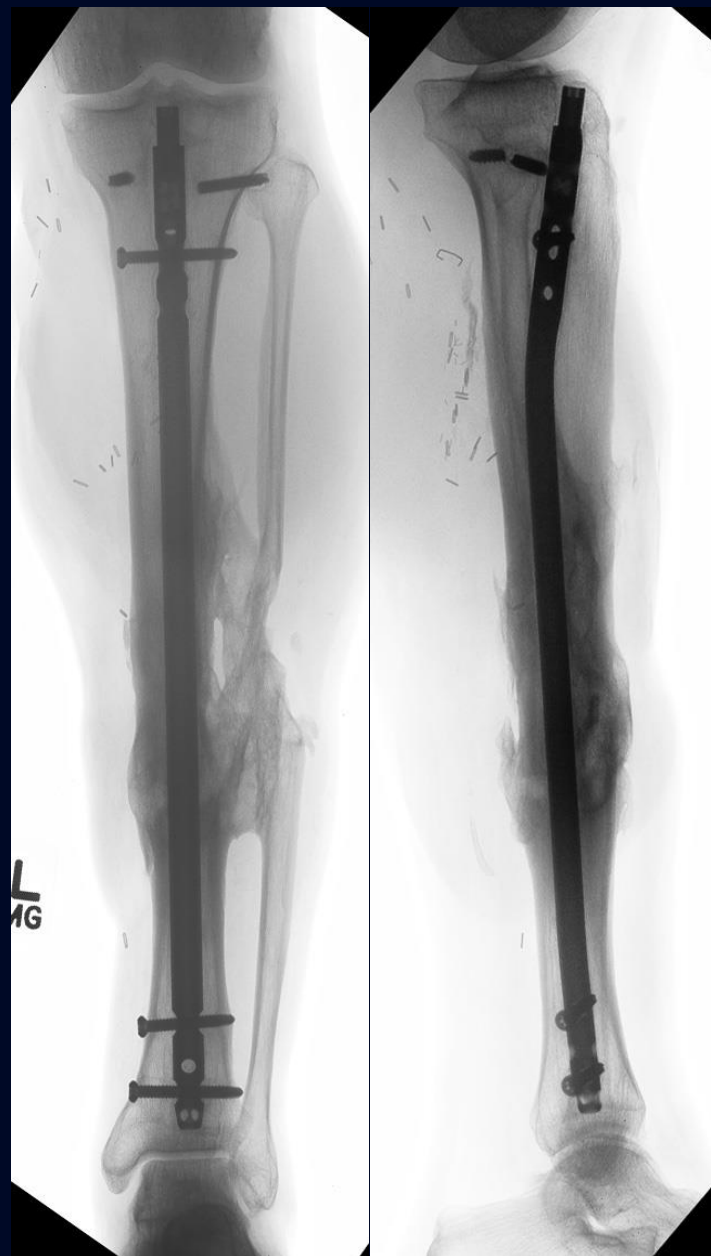
45 Male S/P MCA With
Grade IIIB Open Tibia.
External Fixation, I & D,
Free Tissue Transfer,
STSG. Previous ICBG &
IM Nailing. Infection Work-
Up Negative



Closed Reamed IM Nailing



20 Month Follow-Up



Pre-Op



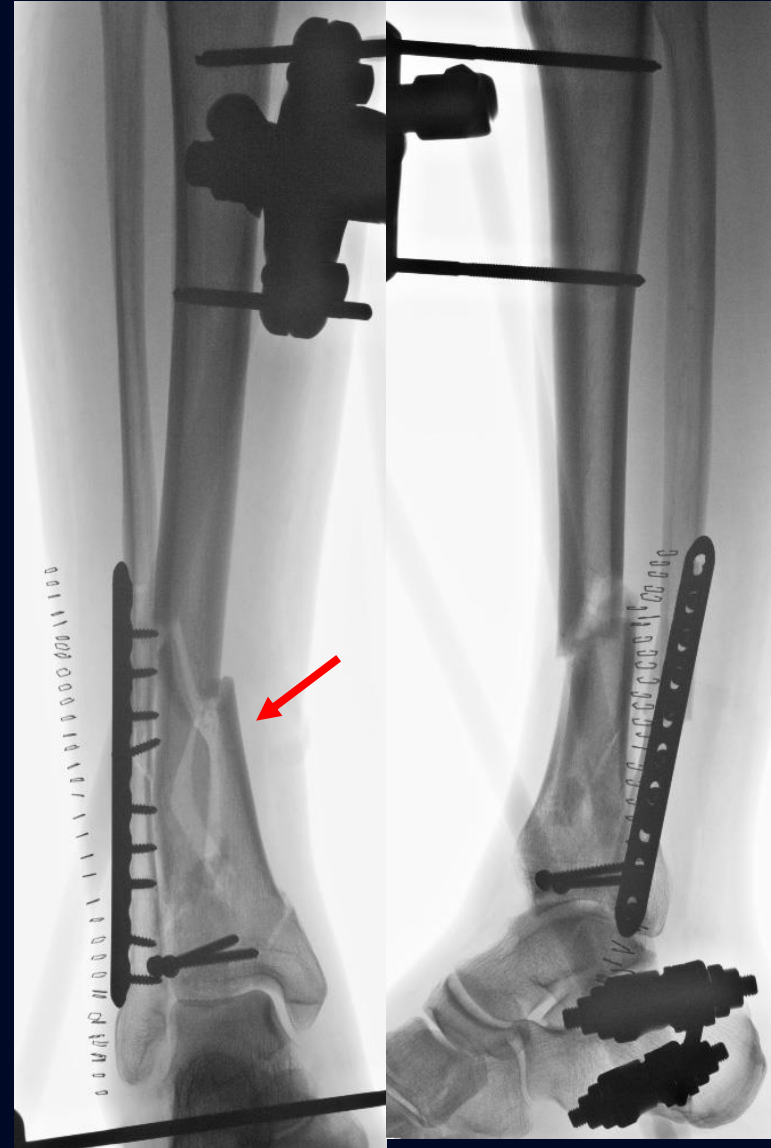
Post-Op



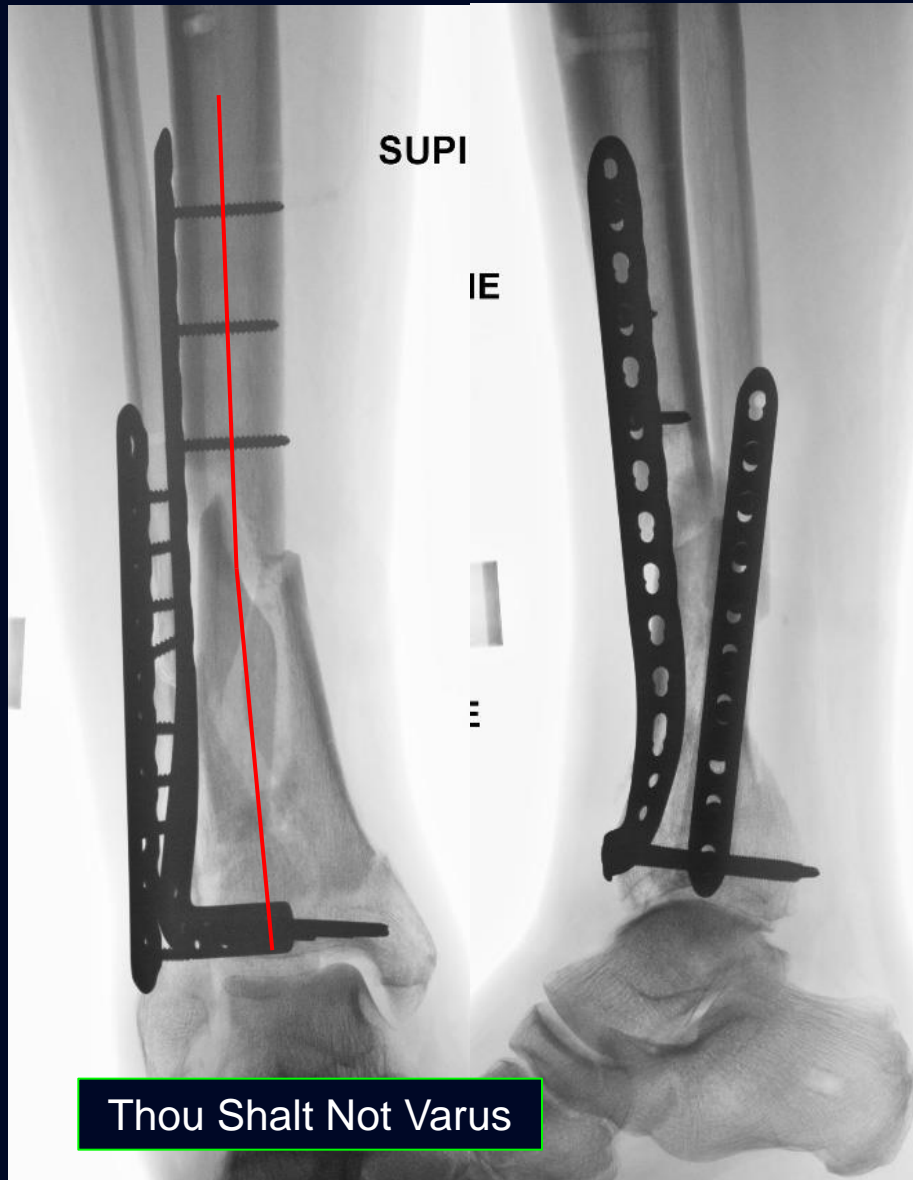
Clinical Cases

Secondary Intervention

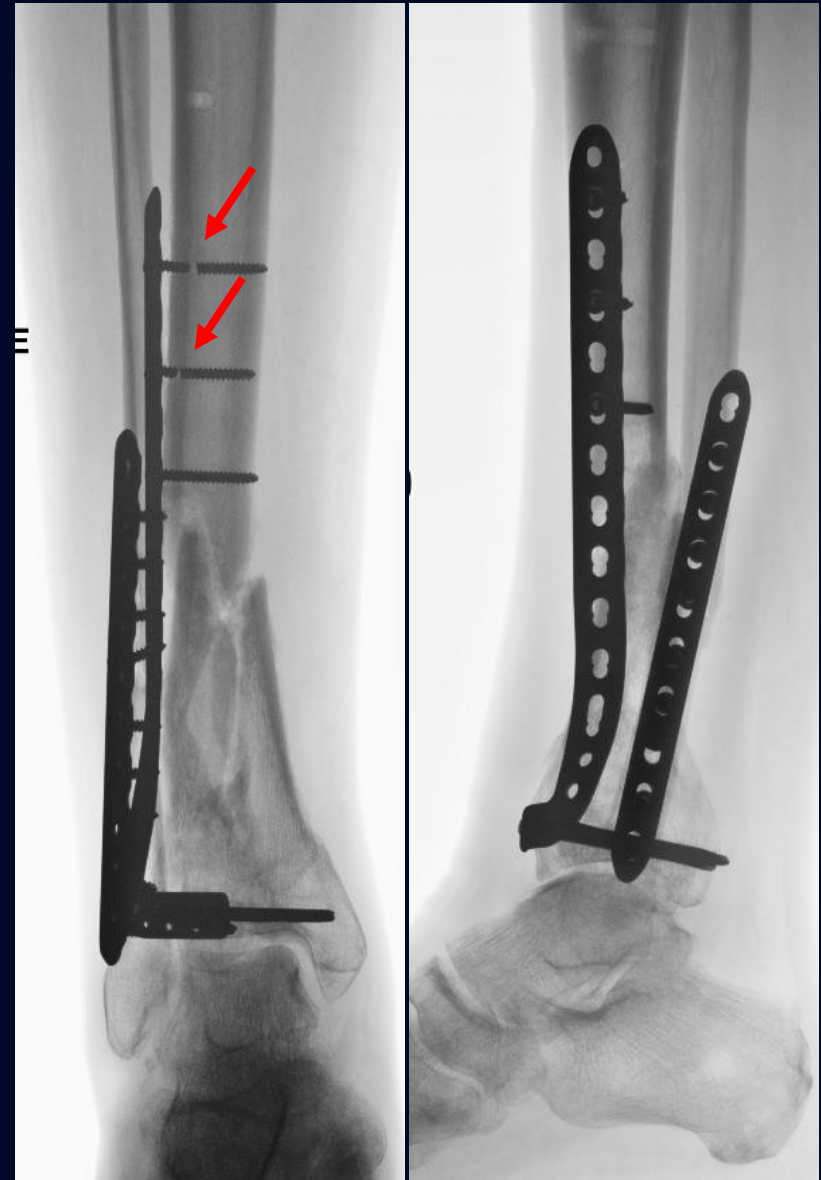
53 Year Veterinarian Fell 8 Feet
From A Ladder Sustaining A Grade II
Open Medial Distal Tibia & Fibula
Fracture. Treated At Outside By I & D
With Limited Internal And External
Fixation



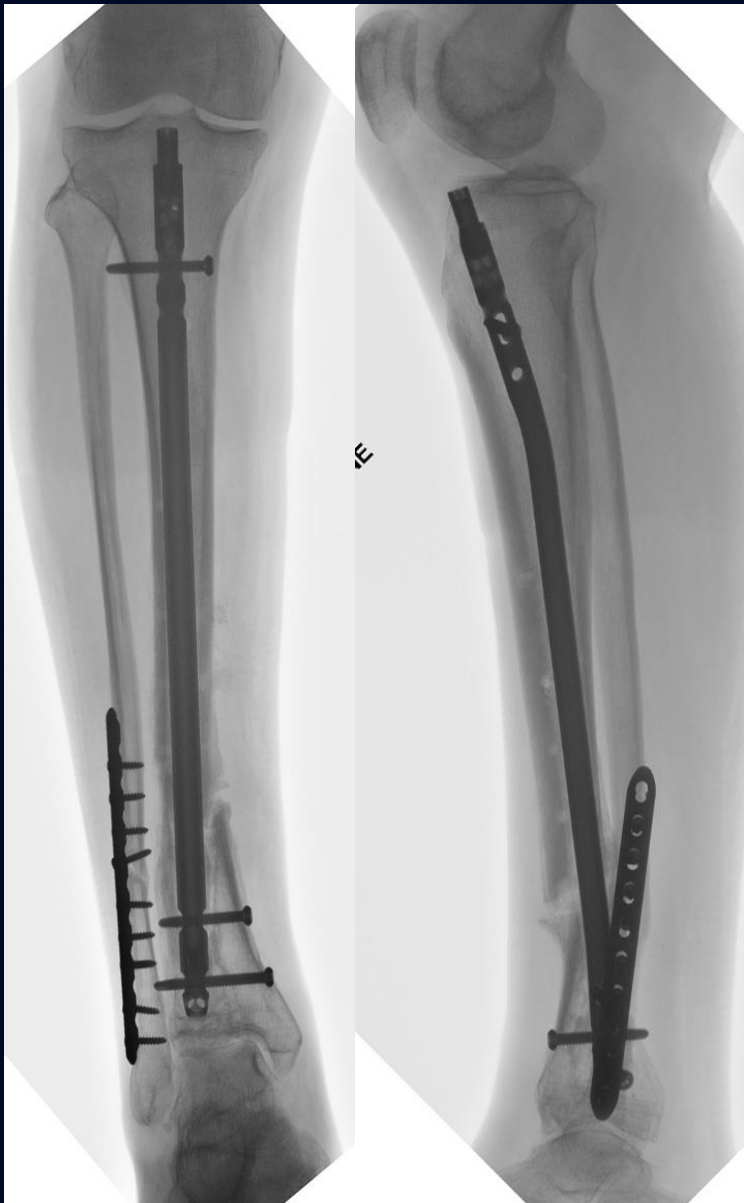
MIPPO By Me At 4 Weeks; Residual
4° Varus, Distracted, Unstable Fixation



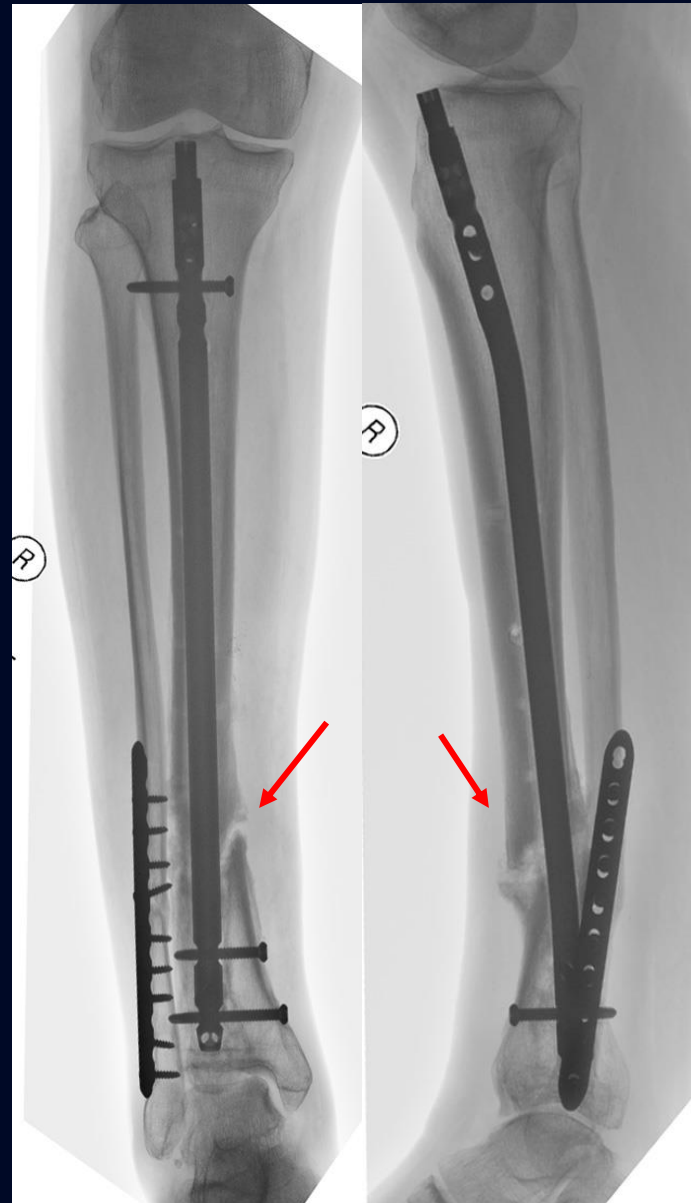
Fixation Failure & Non-Union At 5
Months; Virtually No Healing



Revised With An IM Nail



Persistent Non-Union



Augmentation Plate & BMP



Final Follow-Up Healed



Good Example Of Secondary Intervention

Clinical Cases

Not Healed

80 Yr Female With Monostotic

Pagets Disease Of The Tibia;

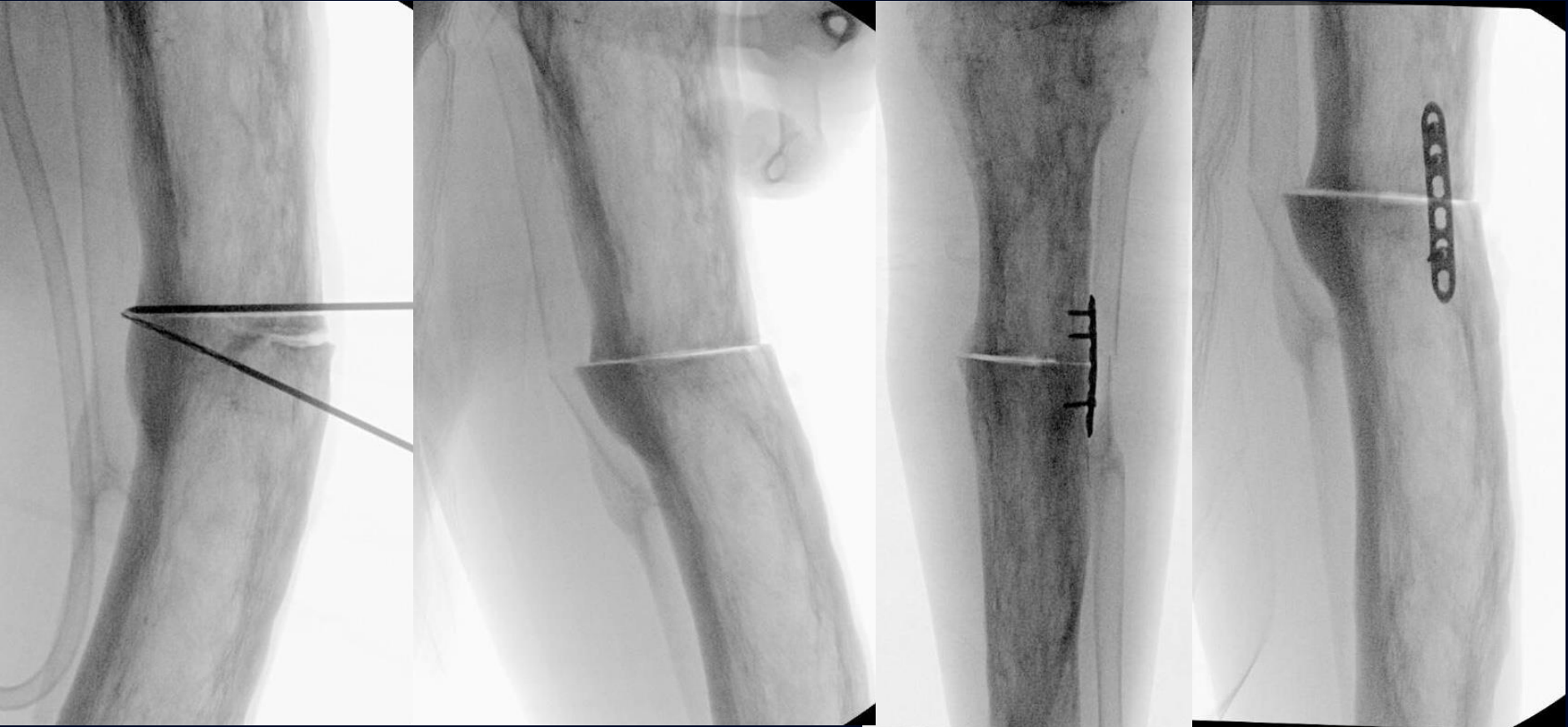
Long Standing Highly

Symptomatic Stress Fracture

Non-Union



Osteotomy & Deformity Correction; Temporary Mini-Plate



Reamed Intra-Medullary Nail



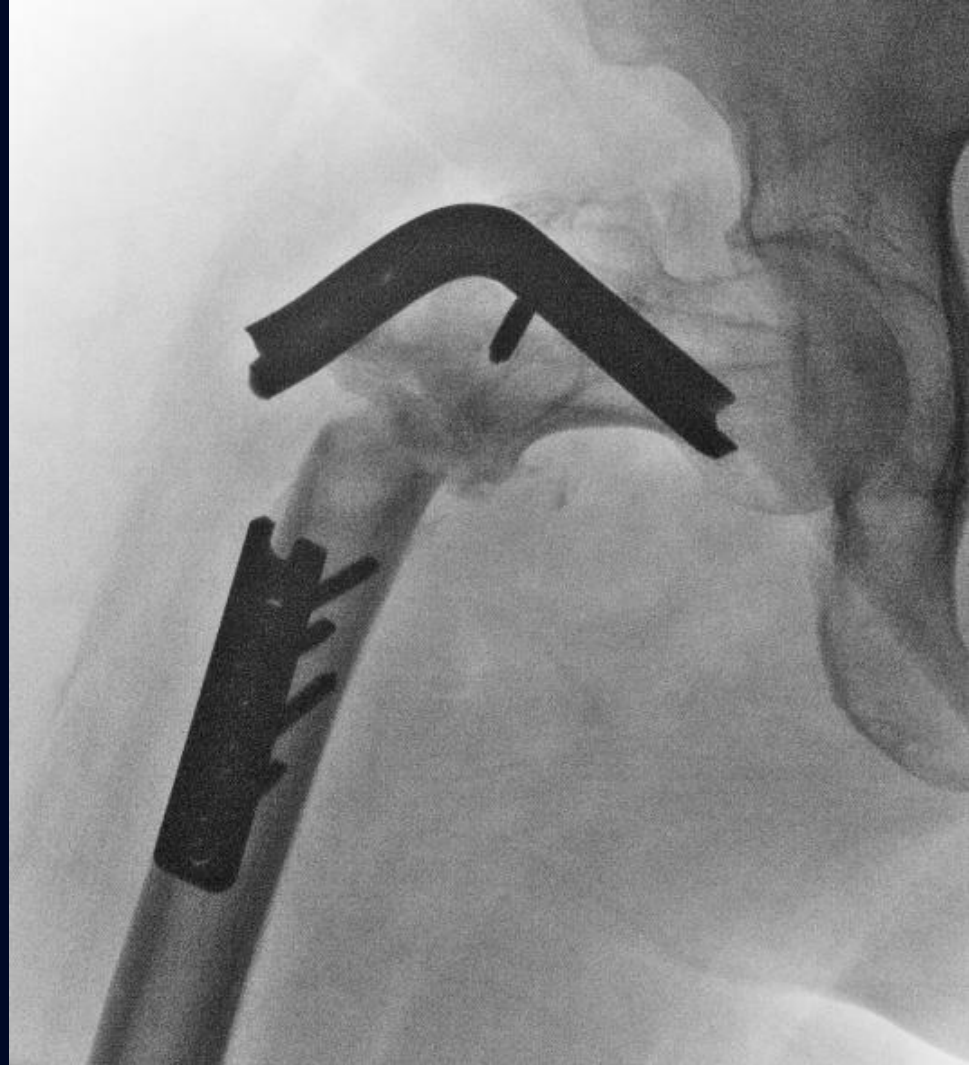
Not Healed At 10 Months



Nonunion

5 Anatomic Sub-Groups

- Tibia
- Femur
- Humerus
- Clavicle
- Miscellaneous
 - Forearm
 - Ankle
 - Other



Retrospective Review 1991-2018
Femur Non-Union
N = 122

Ultimately Healed (83%)
N = 102

Ununited (16%)
N = 20

Healed As Intended
"Wiss Index"
N = 81 (66%)

Secondary
Intervention
N = 21 (17%)

Persistent
Nonunion
N = 20 (17%)

Recalcitrant Non-Union N = 41 (34%)

Femoral Non-Union Methods & Materials

- 101 Closed (82%), 21 Open (18%) Fractures
- 66 Males (55%), 56 Females (45%)
- 47 Plates (38%), 75 IM Nails (62%)
- 31 Smokers (26%), 14 Diabetics (12%)
- 17 Metabolic Bone Non-Unions (14%)
- 9 Peri-Prosthetic Non-Unions (7%)
- 7 Hip-Shaft Non-Unions (6%)



Risk Factors For A Recalcitrant Femoral Non-Union N=122

Not Statistically Significant

Bi-Variate Analysis	P-Value
Age	0.700
Sex	0.891
<input checked="" type="checkbox"/> Smoking	0.488
Diabetes	0.399
Fracture Grade	0.488
Mechanism Injury	0.288
Initial Treatment	0.681
<input checked="" type="checkbox"/> Implant Type	0.719
Graft Type	0.095

Risk Factors For A Recalcitrant Femoral Non-Union N=122

Statistically Significant Variables

Bi-Variate Analysis	P-Value
Infection	0.003
Metabolic Bone	0.009
Multi-Variate Regression	
Current Smoker	0.049
3+ Prior Procedures	0.002

Multivariate Regression Analysis Femur

Variable	p Value	Odds Ratio
Age + 10 Years	0.676	1.06 (0.81 – 1.39)
Current Smoker	0.049	2.57 (1.0 – 6.59)
Diabetic	0.476	1.57 (0.45 – 5.41)
# Prior Procedures 2 vs 0-1	0.124	2.09 (0.82 – 5.37)
# Prior Procedures 3+ vs 0-1	0.002	6.97 (2.03 – 23.91)
Metabolic Bone	0.106	2.63 (0.81 – 8.5)
Open vs Closed Fracture	0.245	0.47 (0.12 – 1.68)

Risk Factor For a Recalcitrant Femoral Non-Union: N=122

Implant Type

# Cases	Cohort	HAI	Secondary	Not Healed	P-Value
26	Conventional Plate	19 (73%)	4 (15%)	3 (12%)	0.719
21	Locking Plate	16 (76%)	3 (14%)	2 (10%)	
29	Primary Nail	17 (59%)	7 (24%)	5 (17%)	
46	Exchange Nail	29 (63%)	7 (15%)	10 (22%)	
122		81	21	20	

Risk Factor For a Recalcitrant Femoral Non-Union: N=122

Infection

# Cases	Cohort	HAI	Secondary	Not Healed	P-Value
111	No Infection	76 (68.4%)	19 (17.1%)	16 (14.4%)	0.003
8	Primary	5 (62.5%)	2 (25%)	1 (12.5%)	
3	Secondary	0 (0%)	0 (0%)	3 (100%)	
122		81	21	20	

Risk Factor For a Recalcitrant Femoral Non-Union: N=122

Metabolic Bone

11 Bisphosphonate, 3 Radiation, 1 Paget, 1 Osteogenesis Imperfecta; 1 Other

# Cases	Cohort	HAI	Secondary	Not Healed	P-Value
17	Yes	9 (53%)	1 (6%)	7 (41%)	0.009
105	No	72 (69%)	20 (19%)	13 (12%)	
122		81	21	20	

Risk Factor For a Recalcitrant Femoral Non-Union: N=122

Stratification By Risk Factors

Factors Include: Current Smokers, Deep Infection, 2+Prior Procedures, Metabolic

# Cases	Cohort	0 Risk Factors	1 Risk Factor	2+ Risk Factor	P-Value
81	Healed As Intended	50 (81%)	26 (55%)	5 (38%)	<0.001
21	Secondary Intervention	9 (14%)	10 (21%)	2 (15%)	
20	Not Healed	3 (5%)	11 (23.%)	6 (46%)	
122		62	47	13	

Risk Factor For a Recalcitrant Femoral Non-Union: N=122

Stratification By Number Of Prior Procedures

Number of Prior Surgical Procedures

# Cases	Cohort	0 / 1	2	3+	P-Value
81	Healed As Intended	53 (74%)	21 (64%)	7 (41%)	0.065
21	Secondary	9 (13%)	8 (24%)	4 (23%)	
20	Not Healed	10 (14%)	4 (12%)	6 (35%)	
122		72	33	17	

Risk Factor For a Recalcitrant Femoral Non-Union:

Graft Augmentation

# Cases	Cohort	HAI	Secondary	Not Healed	P-Value
14	ICBG	11 (79%)	3 (21%)	0 (0%)	0.095
22	BMP	15 (68%)	3 (14%)	4 (18%)	
6	Both	2 (33%)	3 (50%)	1 (17%)	
81	No Graft	53 (65%)	13 (16%)	15 (19%)	
122		81	21	20	

Risk Factors for Development of a Recalcitrant Femoral Nonunion: A Single Surgeon Experience in 122 Patients

Donald A. Wiss, MD,^{a,b} John Garlich, MD, MHDS,^a Sohaib Hashmi, MD,^a and Adam Neustein, MD^a

Objectives: The goals of the study were (1) to document the healing rates of femoral nonunions stratified by those that healed as intended, healed after a subsequent intervention, and those that did not heal; (2) to report the prevalence of recalcitrant femoral nonunions and (3) to identify specific demographic, injury, and treatment-related risk factors for the development of a recalcitrant nonunion.

Design: Longitudinal observational cohort study.

Setting: Academic Level 1 trauma center.

Patients/Participants: One hundred twenty-two femoral nonunions treated with either a plate or intramedullary nail by a single surgeon between 1991 and 2018.

Intervention: Bivariate and multivariate regression analysis were performed to identify specific demographic, injury, and treatment factors in patients who developed a recalcitrant nonunion.

Results: Although 83.6% of the femoral nonunions eventually healed, only 66% “healed as intended” with 17.2% requiring 1 or more additional procedures to consolidate and 16.4% of nonunions failing to unite. There were no statistically significant differences in the recalcitrance rate when we compared treatment with conventional versus locked plates or primary versus exchange nailing. Risk factors for developing a recalcitrant nonunion were deep infection, current smokers, metabolic bone disease, and patients who had undergone 3 or more prior surgical procedures.

Conclusions: The use of both intramedullary nails and modern plates were associated with a high rate of recalcitrance. Infection, current smokers, metabolic bone disease, and 3 or more prior surgical procedures were predictors for the development of a recalcitrant nonunion.

Key Words: non-union, femur, trauma, risk factors

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

(*J Orthop Trauma* 2021;35:619–625)

INTRODUCTION

A small but not insignificant number (1%–10%) of acute femur fractures fail to unite despite the use of contemporary implants and improved surgical techniques^{1–6} When a femoral nonunion develops, it produces profound physical disability and usually requires surgery.⁷ Numerous risk factors for the development of a femoral nonunion have been reported and include fracture severity (open fractures, bone loss, and mechanism of injury), metabolic factors (diabetes mellitus and osteoporosis), as well as errors in surgical technique (undersized nails and overly rigid plate constructs).^{8–15}

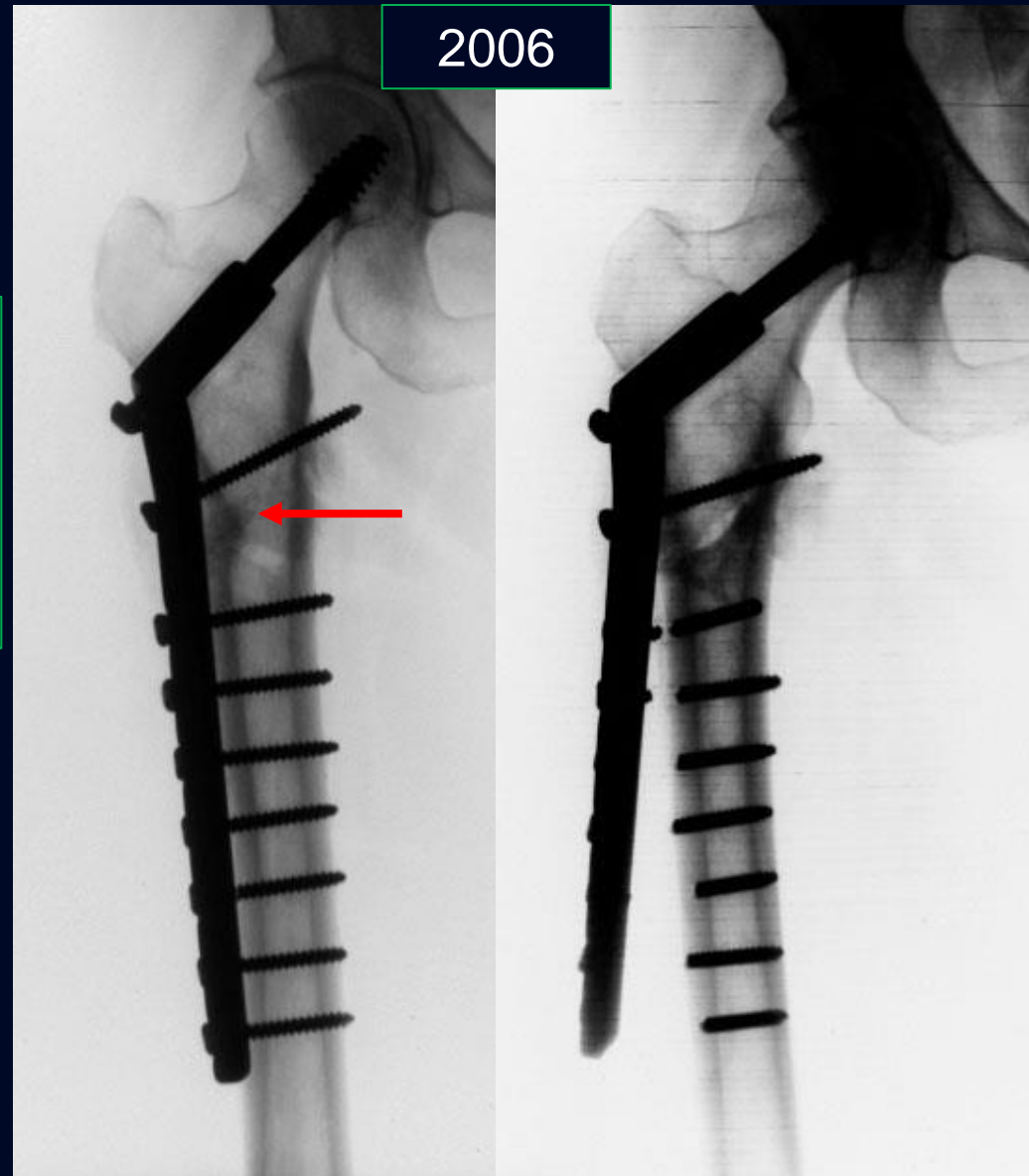
Although most femoral nonunions heal after the index nonunion surgery, others require one or more surgical procedures to heal and have been referred to as recalcitrant.^{16–18} Surprisingly, few studies have examined specific patient, demographic, injury, or treatment factors that contribute to failures in healing the index nonunion surgery.^{10–13,15} Furthermore, many nonunion studies fail to stratify their rates of healing based on the number of surgeries that were required to obtain union.⁶

In this study, we defined a recalcitrant femoral nonunion as one that did not unite after the initial nonunion procedure. The goals of the study were (1) to document the healing rates stratified by those that healed as intended, healed after a secondary intervention, or did not heal; (2) to report the prevalence of recalcitrant femoral nonunions; and (3) to identify demographic, injury, and treatment-related risk factors for the development of a recalcitrant nonunion.

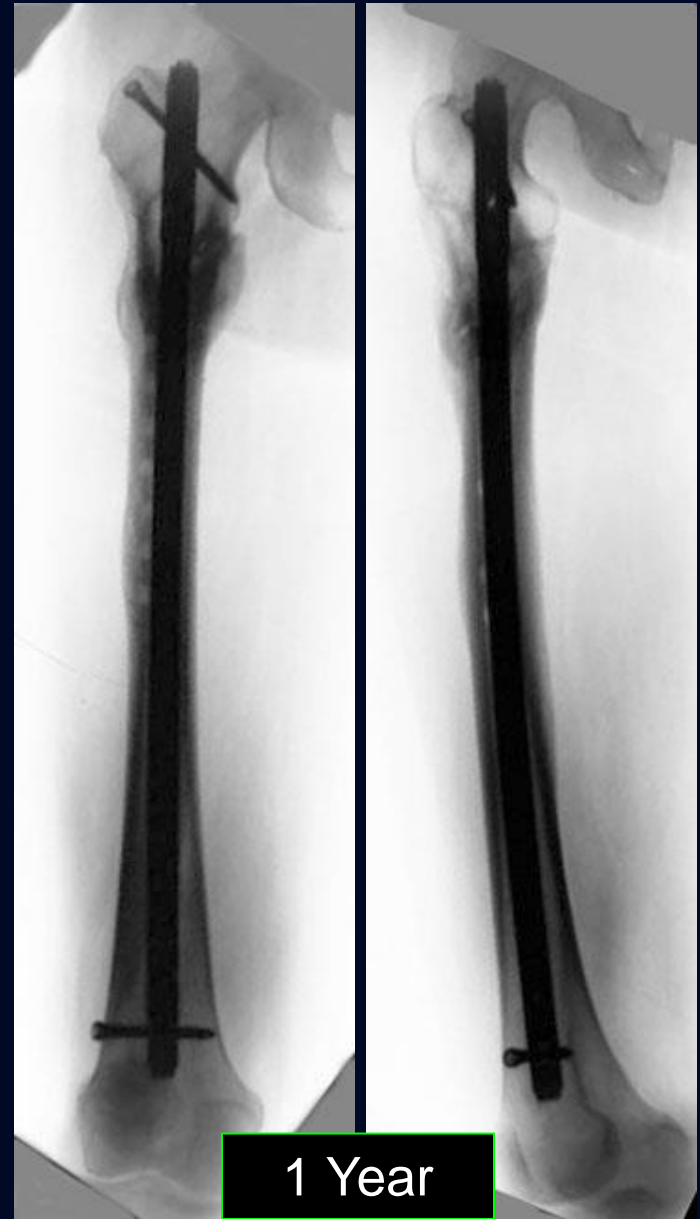
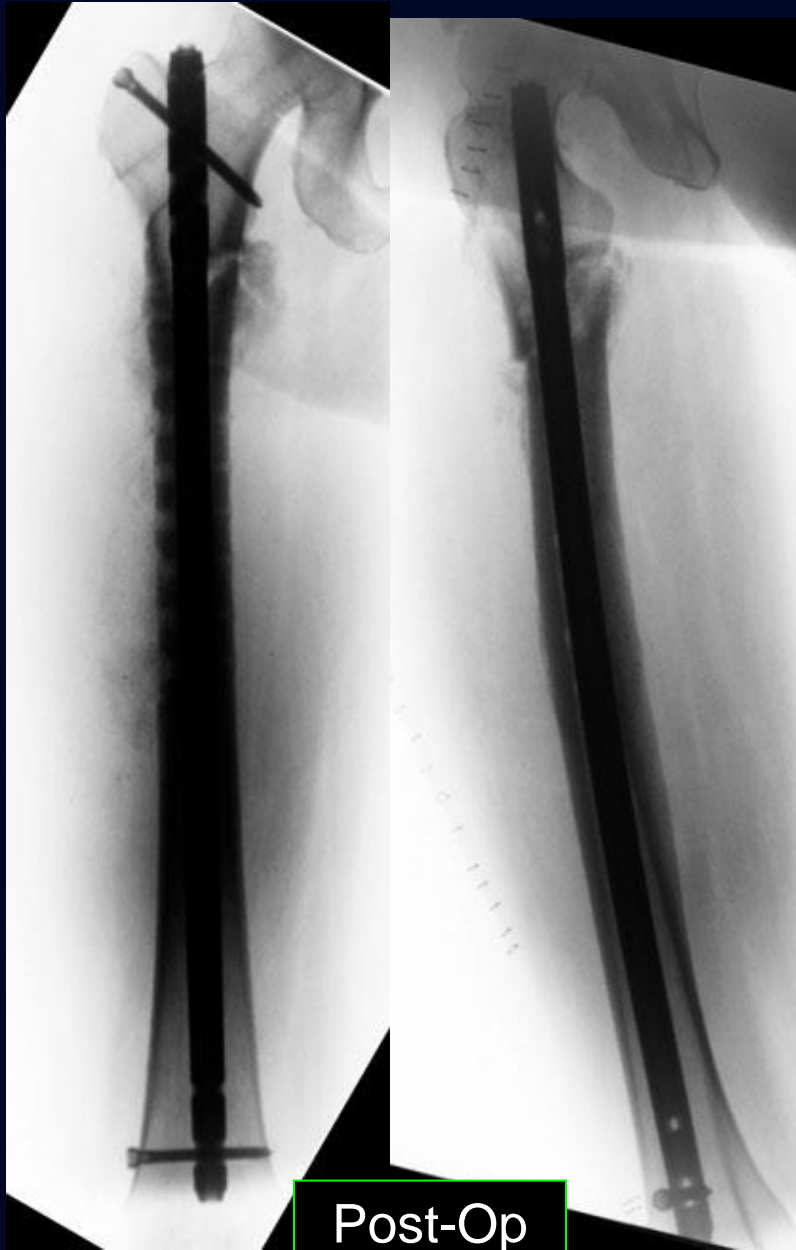
Clinical Cases Femur Healed As Intended (HAI)

77 Yr Female Subtrochanteric Fracture Treated With Plate

Missed
Bisphosphonate
Fracture



Complex Hardware Removal & Locked Antegrade Nailing

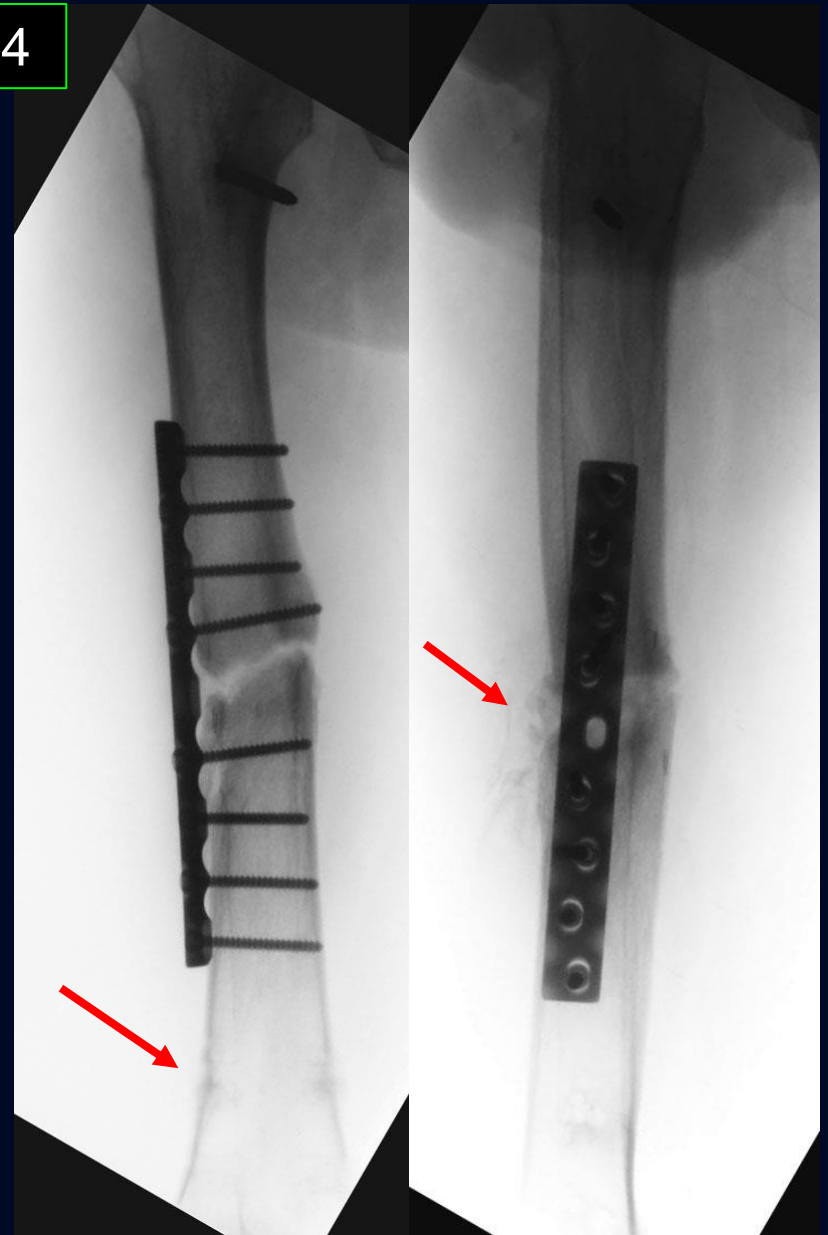


Open Femur Fx IM Nail X 2

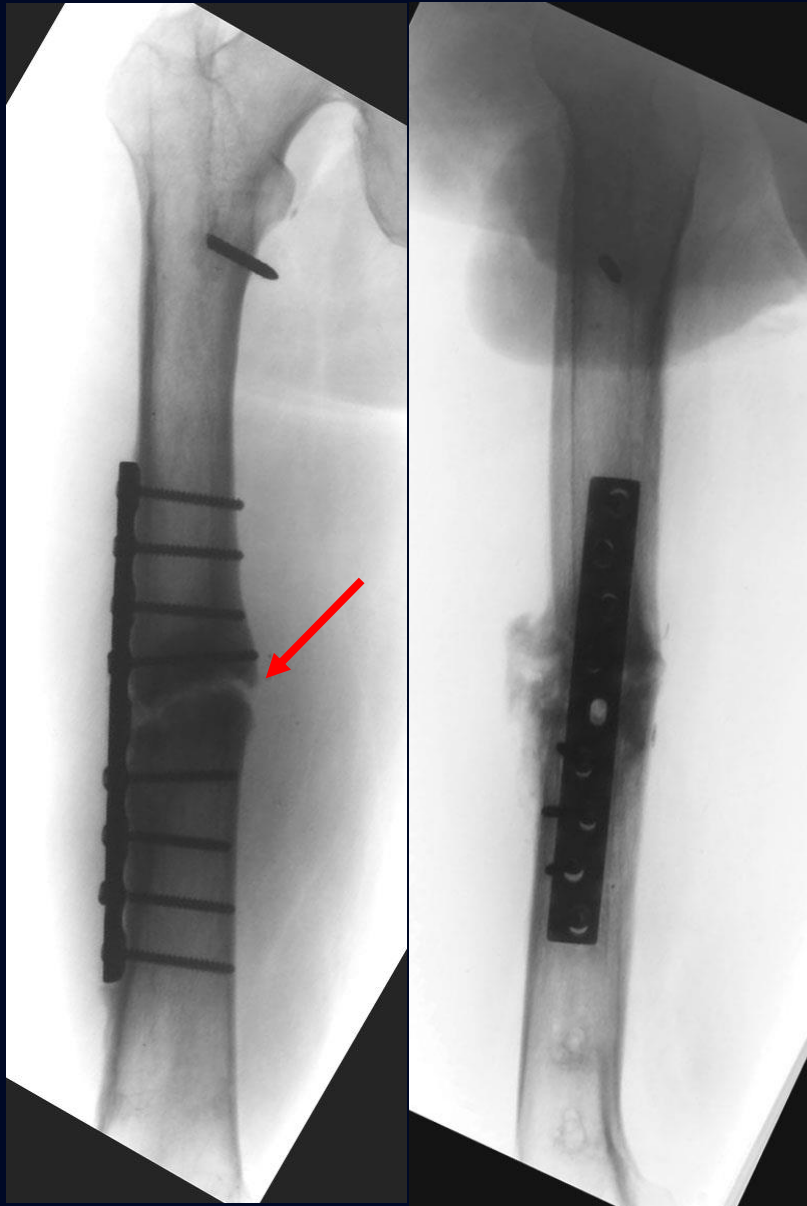


Tensioned LCDC Plate + ICBG

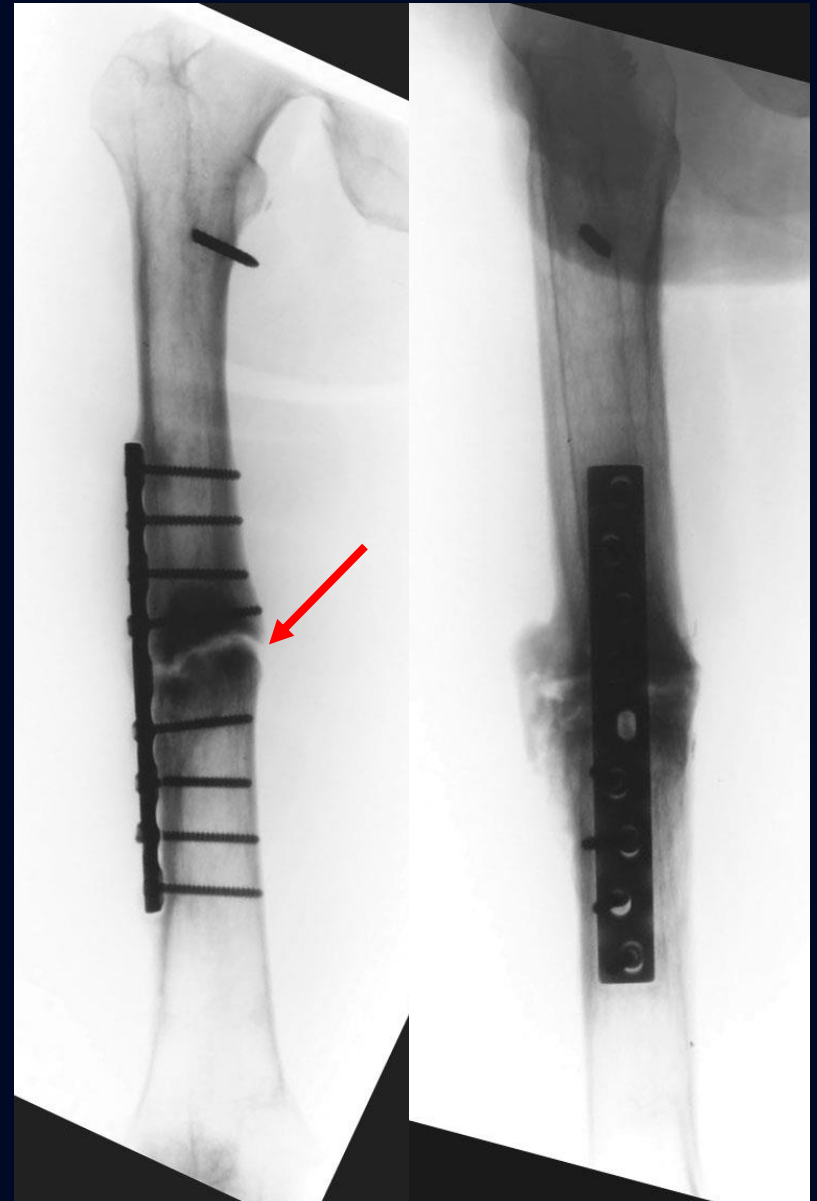
2004



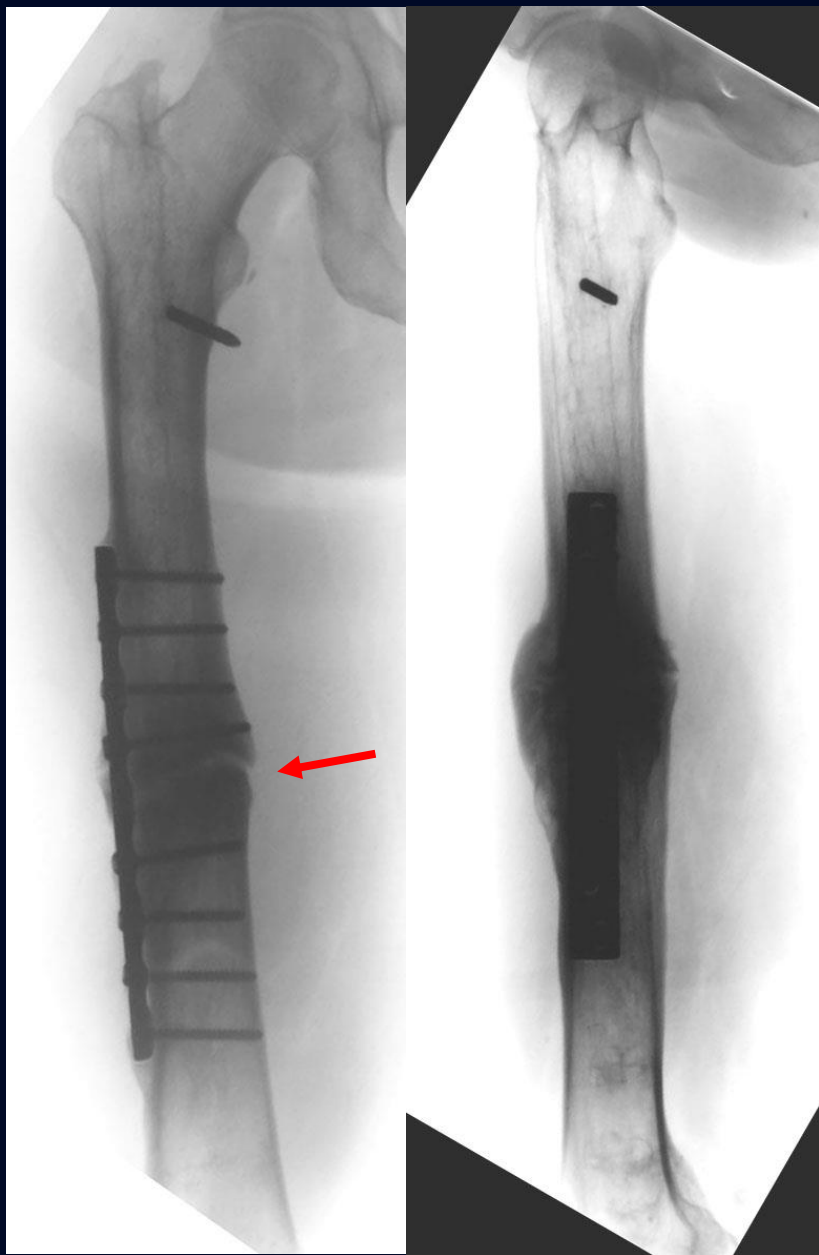
6 Months; Persistent Fracture Line



15 Months; Post-Op; I'm Concerned



2 Years Post-Op



14 Yr Research Follow-Up; Healed



19 Months Post-Op ORIF; Failed Fixation & Non-Union



Reamed 13 mm Retrograde Nail & BMP



1 Month Post-Op

Persistent Non-Union & Pain



6 Months Post-Op

Treatment With An Augmentation Plate @ Nail With ICBG & BMP

Immediate Post-Operative



Follow-Up At 12 Months Healed



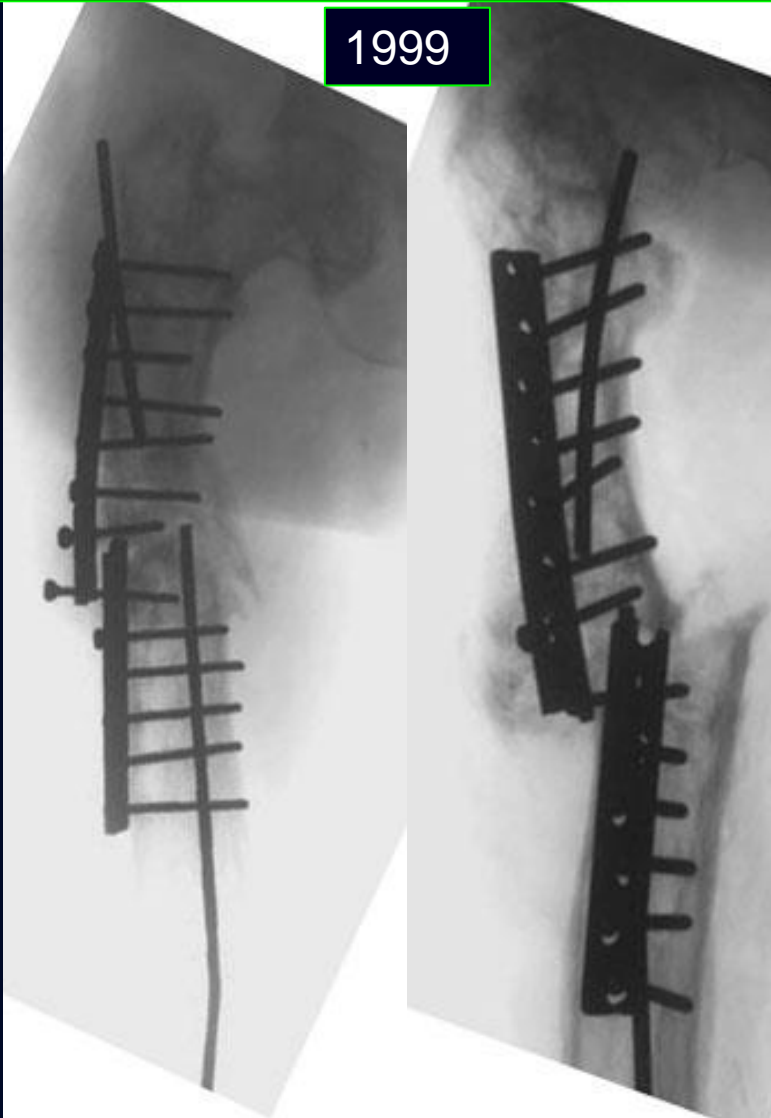
Another Example of A Secondary Intervention With Healing

Clinical Cases Femur

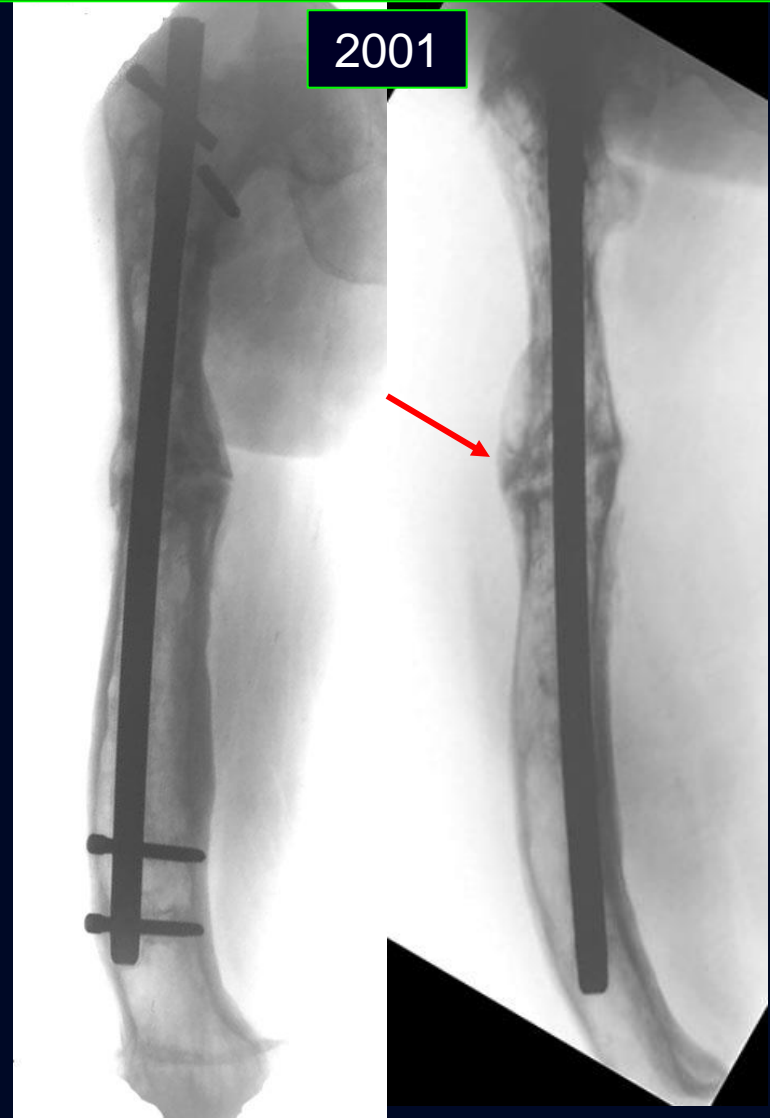
Not Healed

69 Yr Female Pathologic Fracture 2nd To Pagets Disease S/P Three Failed Surgeries; Complex Hardware Removal & Locked Nailing Which Is Not Healed But The Patient Is Minimally Symptomatic

1999



2001



Closed Intra-Medullary Nailing Of A Bisphosphonate Fracture

Nailed In Varus & Distracted

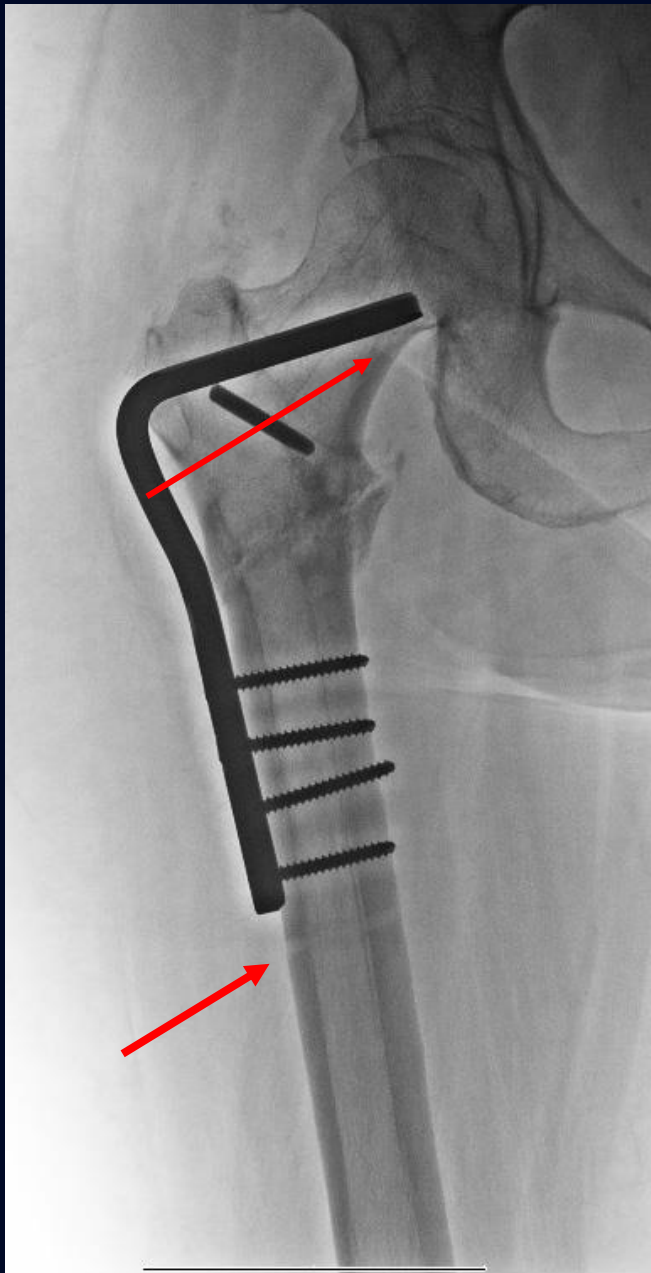


W:25
C:519

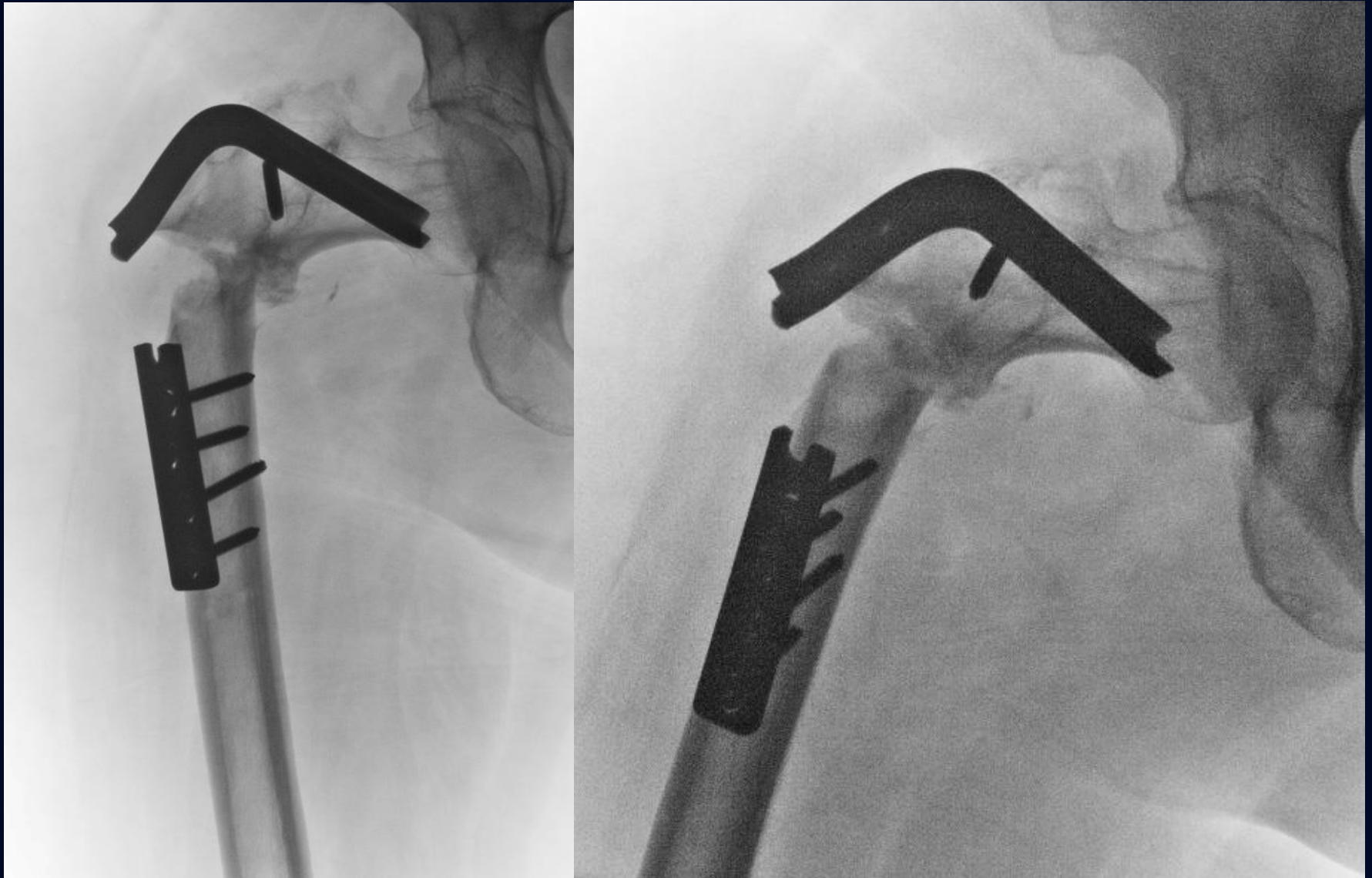
Revised With A TFN; Persistent Painful Non-Union at 18 Mos



Tensioned 95 Degree AO Blade Plate (By Me)

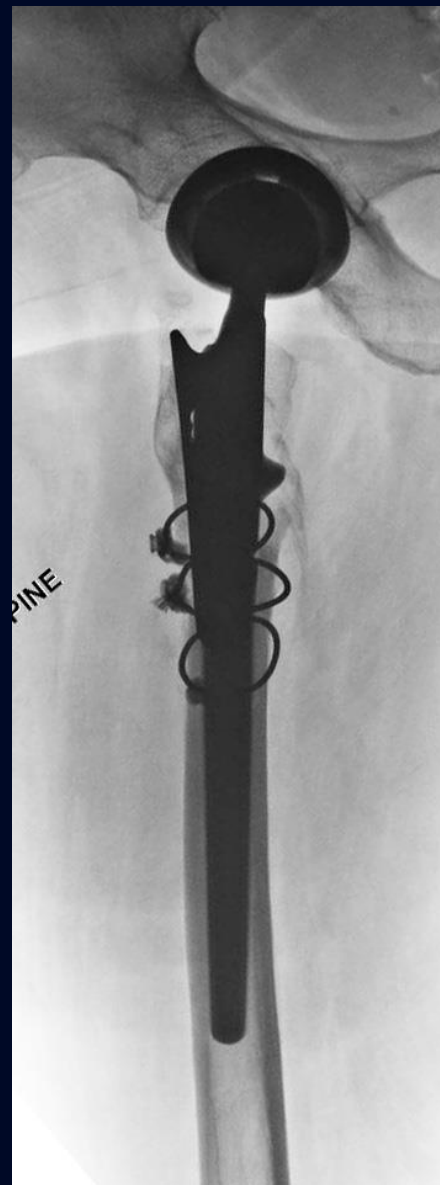


Failed At 8 Months While Walking Her Dog



Now What?

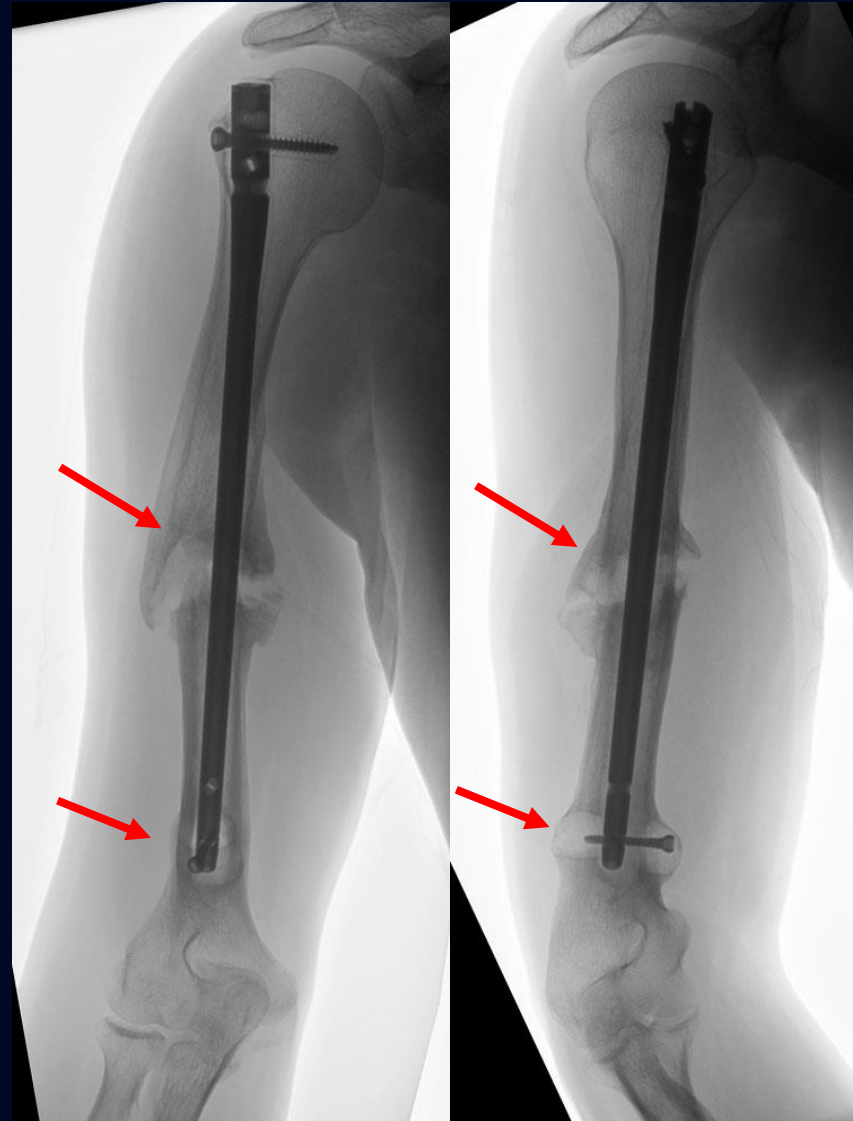
6 Salvaged With A Calcar Replacement Total Hip



Non-Union

5 Anatomical Subgroups

- Tibia
- Femur
- **Humerus**
- Clavicle
- Miscellaneous
 - Forearm
 - Ankle
 - Other



Humeral Non-Union

Current Concepts

- Uncommon Condition
- Difficult To Treat
- Radial Nerve Issues
- Osteoporosis
- Functional Impairment



Retrospective Review 1991-2018
Humeral Non-Union
N=125

```
graph TD; A[Retrospective Review 1991-2018  
Humeral Non-Union  
N=125] --> B[Healed (90.4%)  
N=113]; A --> C[Ununited (9.6%)  
N=12]; B --> D[Healed As Intended  
N=105 (84%)]; B --> E[Secondary Intervention  
N=8 (6%)]; C --> F[Persistent Nonunion  
N=12 (10%)]; E --> G[Recalcitrant Non-Union N=20 (16%)];
```

Healed (90.4%)
N=113

Ununited (9.6%)
N=12

Healed As
Intended
N=105 (84%)

Secondary
Intervention
N=8 (6%)

Persistent
Nonunion
N=12 (10%)

Recalcitrant Non-Union N=20 (16%)

Humeral Non-Union

Methods & Materials

- 39 Males (31%), 86 Females (69%)
- 65 Right (52%), 60 Left (48%)
- Age 22-89 Yrs Average Age 57 Yrs
- 109 Closed (87%), 16 Open (13%) Fractures
- 33 P/3 (26%), 58 M/3 (46%), 31 D/3 (25%), 3 Seg
- 59 Non-Op (46%), 36 Plates (29%), 21 Nails (17%)
- All 125 Non-Unions Were Plated (100%)



Risk Factors For A Recalcitrant Humeral Non-Union N=125

Statistically Significant Variables

Bi-Variate Analysis	P-Value
Initial Operative Treatment	0.041
History Deep Infection	0.001
2+ Prior Procedures	0.008
Multi-Variate Regression	
Non-Op Versus Plate	0.039

Multiple Logistic Regression Analysis Humerus

Observation	Odds Ratio	Confidence Interval	p- Value
Age + 10 Years	1.06	0.78 – 1.45	0.695
Current Smoker	2.69	0.80 – 9.03	0.118
Non-Op Vs Nail	1.68	0.35 – 8.10	0.551
Non-Op Vs Plate	3.73	1.09 – 12.76	0.039
Non-Op Vs Other	4.18	0.60 – 29.37	0.165
Atrophic / Oligi vs Hyper	1.48	0.38 – 5.85	0.573

Risk Factor For a Recalcitrant Humeral Non-Union: N=125

Implant Type

# Cases	Cohort	HAI	Secondary	Not Healed	P-Value
29	Conventional Plate	23 (79%)	2 (7%)	4 (14%)	0.52
96	Locking Plate	82 (85%)	7 (7%)	7 (7%)	
125	All Plates	105 (84%)	9 (6%)	11 (10%)	
125		105	9	11	

Risk Factor For a Recalcitrant Humeral Non-Union: N=125

Stratification By Number Of Prior Procedures

Number of Procedures

# Cases	Cohort	0 / 1	2	3+	P-Value
95	Healed As Intended	84 (80.0%)	7 (87.5%)	4 (33.3%)	0.008
16	Secondary	12 (11.4%)	1 (12.5%)	3 (25.0%)	
14	Not Healed	9 (8.6%)	0 (0%)	5 (41.7%)	
125		105	8	12	

Healing the Index Humeral Shaft Nonunion

Risk Factors for Development of a Recalcitrant Nonunion in 125 Patients

Donald A. Wiss, MD, and John M. Garlich, MD, MHDS

Investigation performed at Cedars Sinai Medical Center, Los Angeles; and Southern California Orthopedic Institute, Van Nuys, California

Background: Humeral shaft nonunions are challenging to treat, and those that require >1 surgical procedure in order for a nonunion to heal are termed recalcitrant. Most studies on nonunion have evaluated the union rate independent of the number of procedures required to achieve union. The aims of the present study were (1) to compare the healing rates after the index operation for the treatment of a nonunion with conventional versus locked plating with or without graft augmentation, (2) to report the prevalence of recalcitrant nonunion, and (3) to identify risk factors that predict a recalcitrant nonunion.

Methods: We performed a retrospective analysis of a prospectively collected database of 125 humeral shaft nonunions treated with open reduction and plate fixation by a single surgeon over 25 years. Univariate and multivariate regression analyses were performed to compare healing rates by type of plate fixation and biological augmentation and to identify demographic, injury, and treatment-related risk factors for the development of a recalcitrant nonunion.

Results: One hundred and five patients (84%) had healing after the index procedure for the treatment of nonunion. Twenty patients (16.0%) required secondary procedures and were defined as having a recalcitrant nonunion. Eight of these patients (6.4% of the overall group) healed after the secondary interventions, and 12 (9.6% of the overall group) had a failure to unite. There were no significant differences in healing rates between conventional and locked plates or between the types of bone graft (autogenous or recombinant human bone morphogenetic protein). Risk factors for the development of a recalcitrant nonunion were plate fixation of the acute humeral fracture, a history of deep infection, and ≥ 2 prior procedures.

Conclusions: Plate fixation with bone graft augmentation remains a successful method for the treatment of humeral shaft nonunions. Neither plate type nor graft type reduced the risk of a recalcitrant nonunion. Factors that predicted a recalcitrant nonunion were operative fixation of the acute fracture with a plate, a history of deep infection, and ≥ 2 surgical procedures.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Clinical Cases Humerus

Healed As Intended

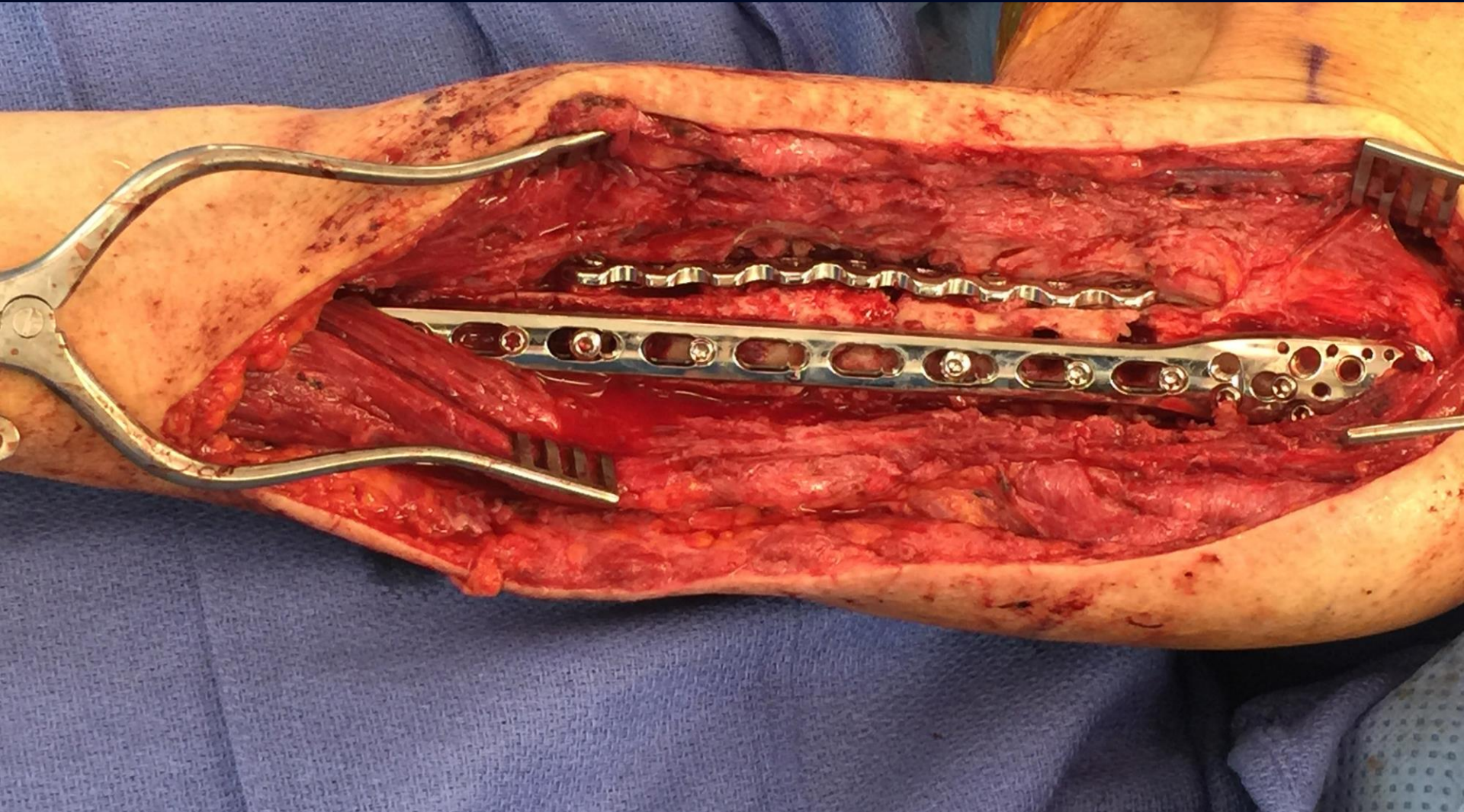
54 Year Old Female; Two
Previous Platings & One
ICBG. Presents With A
Persistent Painful Non-Union



Revision ORIF With A Full Length
Peri-Articular Locking Plate &
Supplemental Anterior Plate. Two
Inter-Fragmentary Screws. Combined
ICBG and BMP



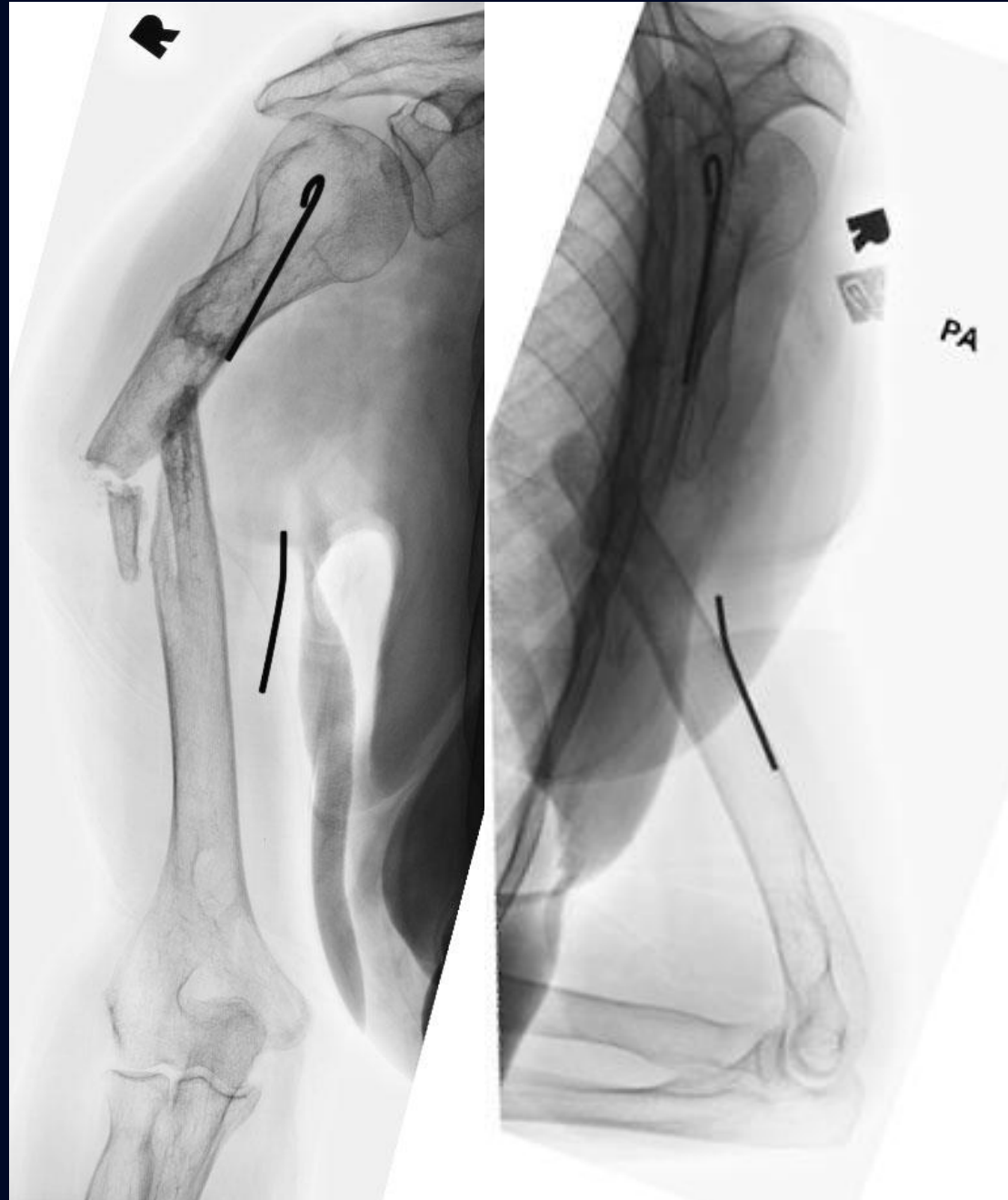
Intra-Operative Clinical Photo



18 Month Follow-Up; Healed



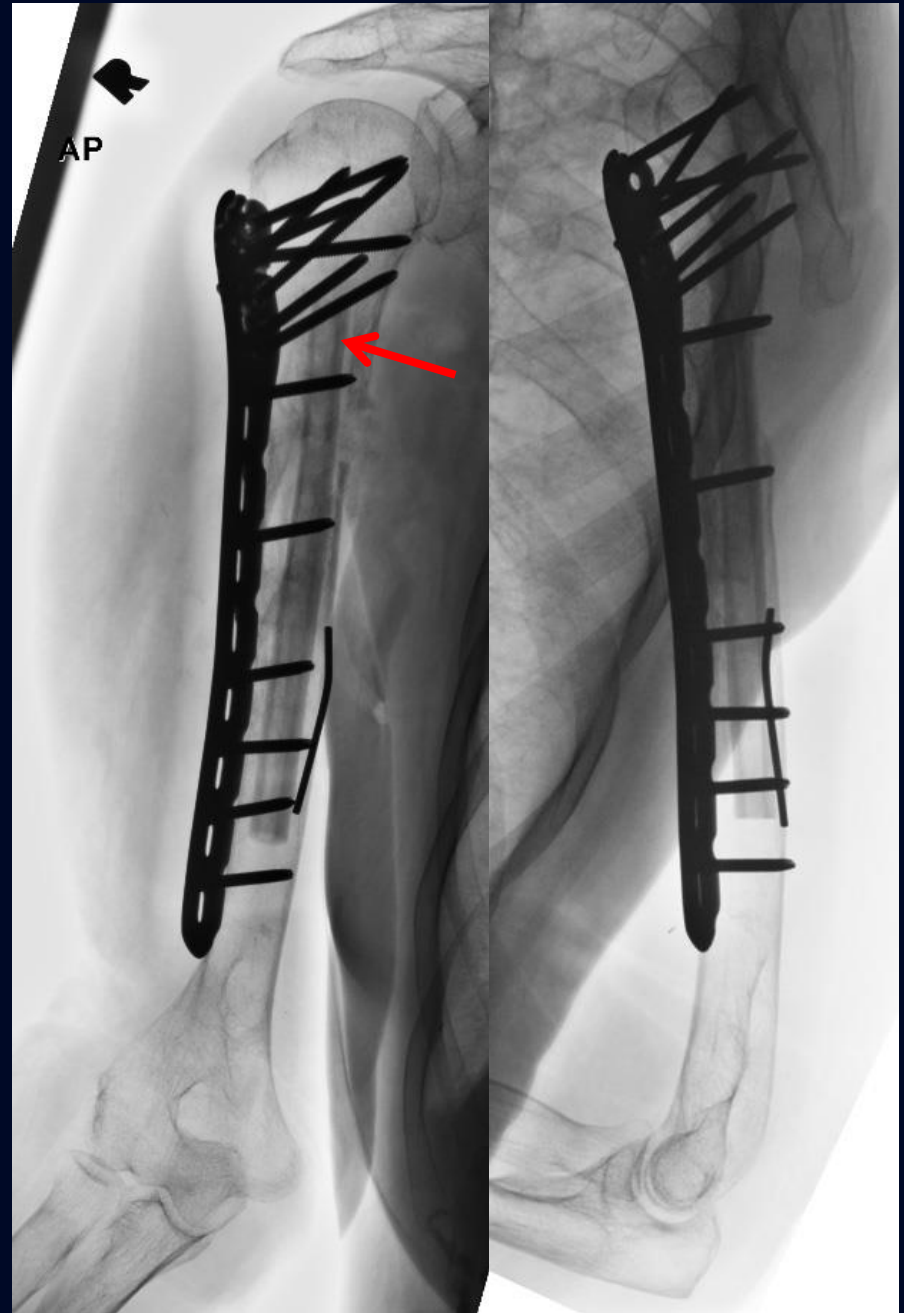
78 Yr Female From LA Lived
In Tunisia Past 40 Years
Working In A Private School;
Fell Sustaining An
Osteoporotic Humeral Shaft
Fracture; 2 Failed Surgeries



ORIF With Fibular Strut Graft

And Long Peri-Articular

Locked Plate & BMP



2 Year Follow-Up In
Los Angeles; Healed
Working And Living In
Tunisia



Clinical Cases Humerus

Secondary Intervention

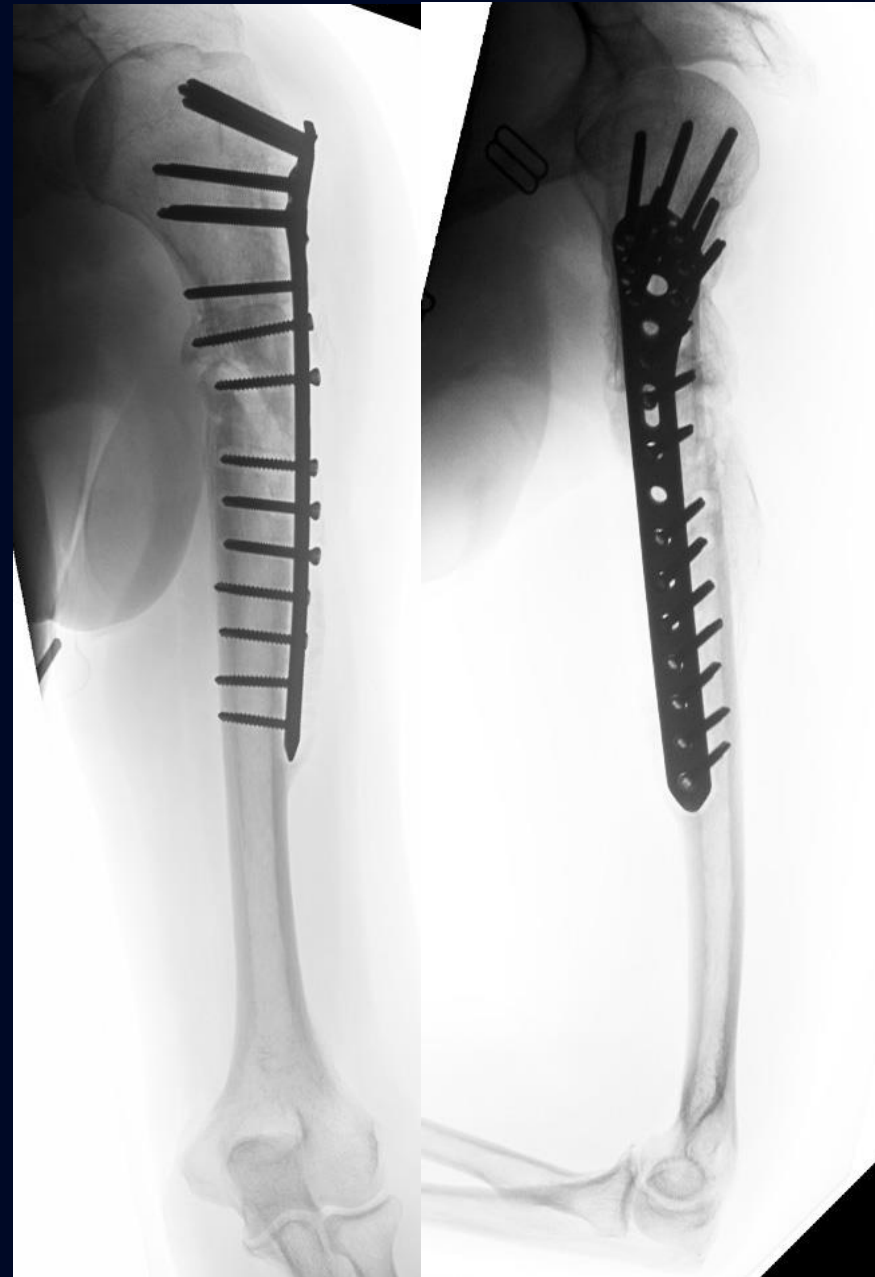
63 Yr Female Attorney

Ground Level Fall; Two (2)

Previous ORIF; Long Standing

Psoriasis On Biologics; Now

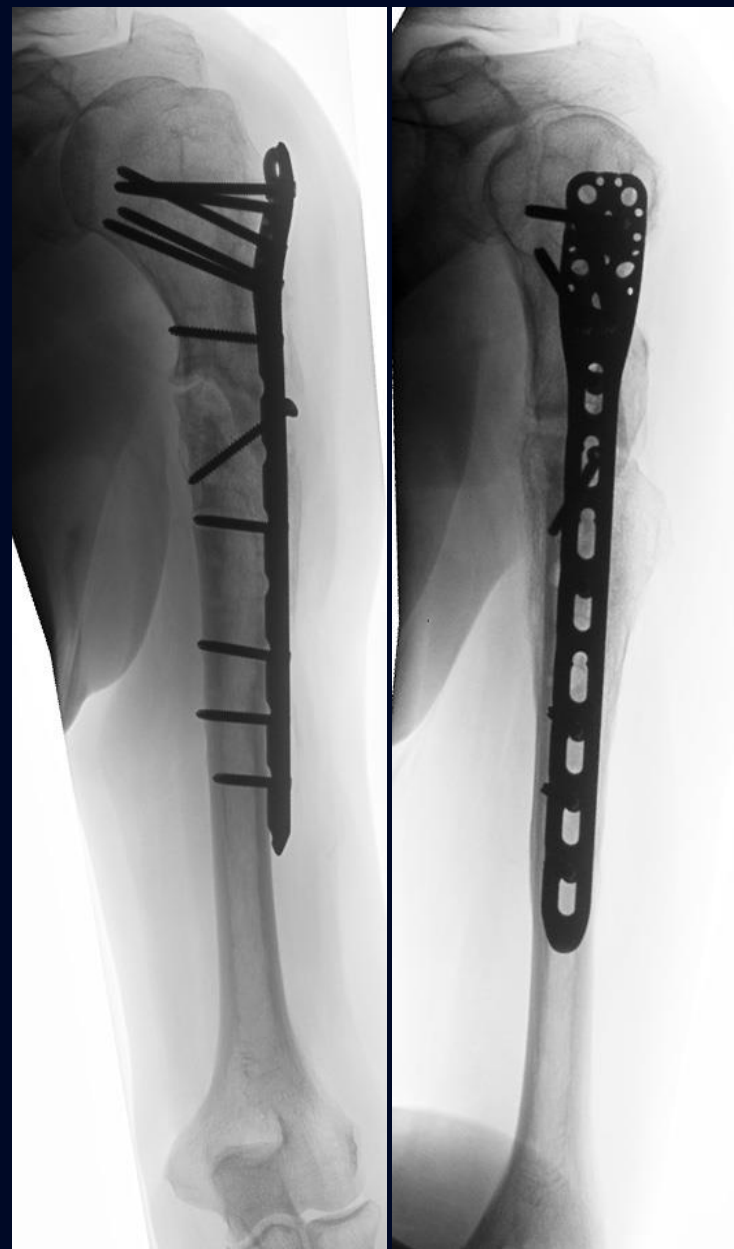
With Painful Non-Union



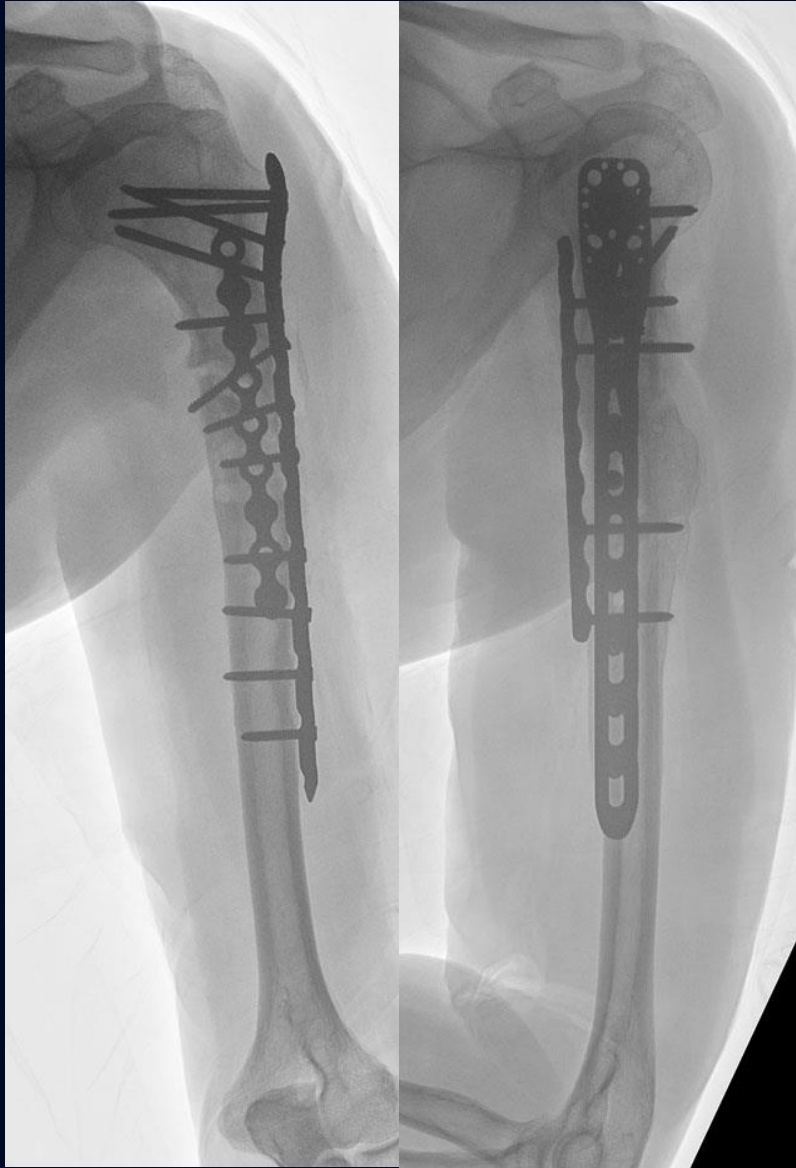
Revision ORIF With BMP



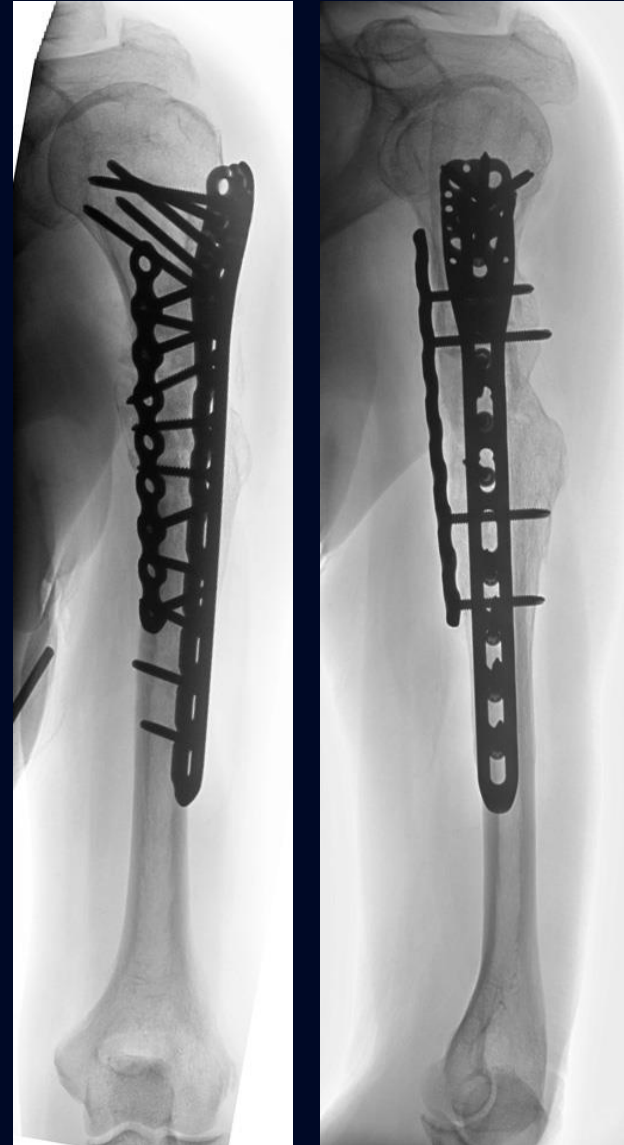
Not Healed 6 Months Later



Revision With 2 Plates & ICBG



Final Follow-Up At 18 Months Healed

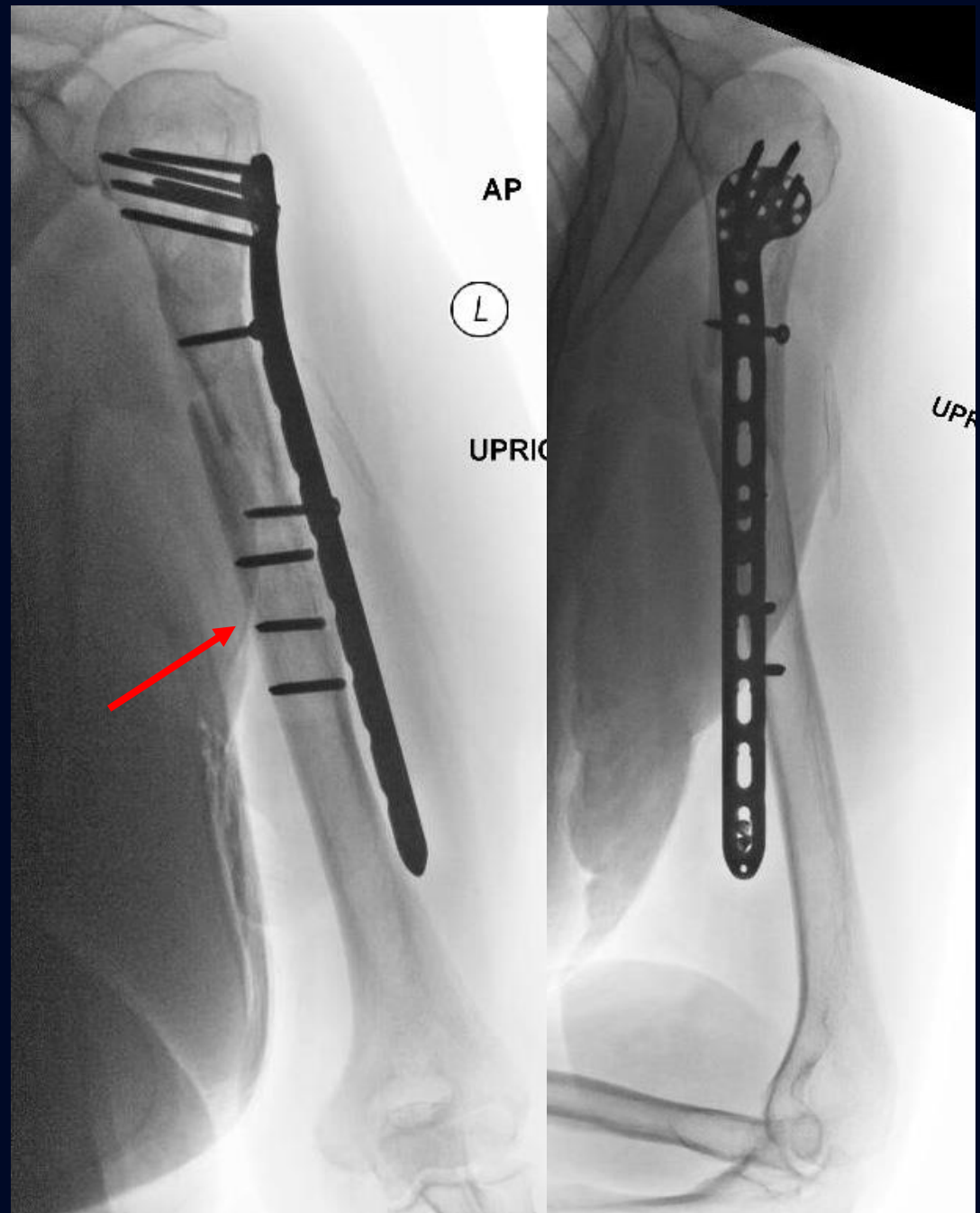


Another Good Example Of Secondary Intervention

Clinical Cases Humerus

Not Healed

59 Yr Female S/P Fall From
Step Ladder Sustaining P/3
Humerus Fracture. ORIF At
Outside Hospital. 2 Pack A
Day Smoker. Probable
Alcoholic. Referred At 10
Months With A Non-Union
and Failed Hardware



Revision ORIF With Long
Peri-Articular Plate And
Spanning Anterior Plate;
BMP Augmentation

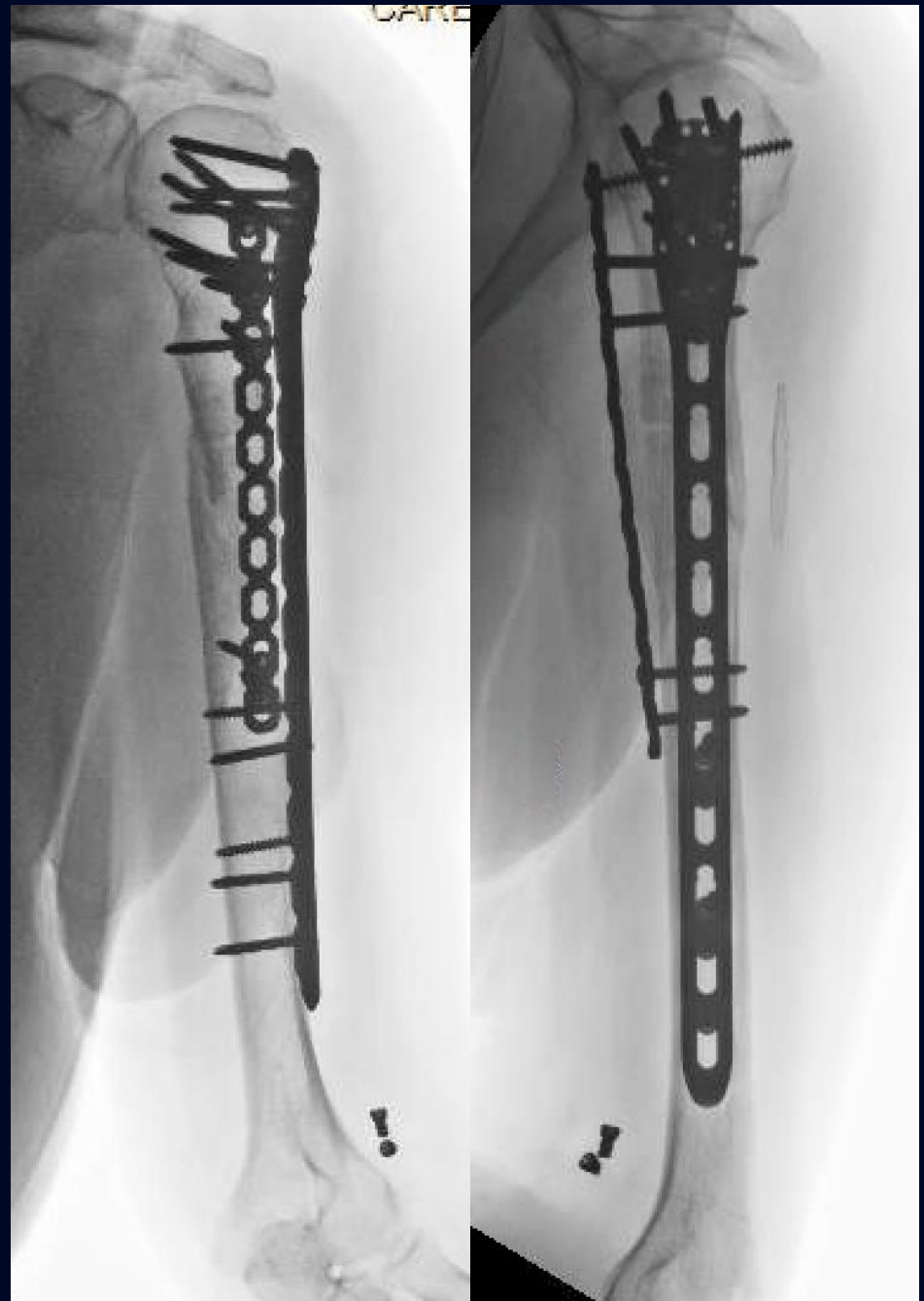


6 Month Follow-Up

Moderate Pain

Smoking & Drinking

X-Rays A Hint Of Healing



15 Month Follow-Up

Still Moderate Pain

Poor Shoulder ROM

Smoking & Drinking

Not Healed

Last Follow-Up

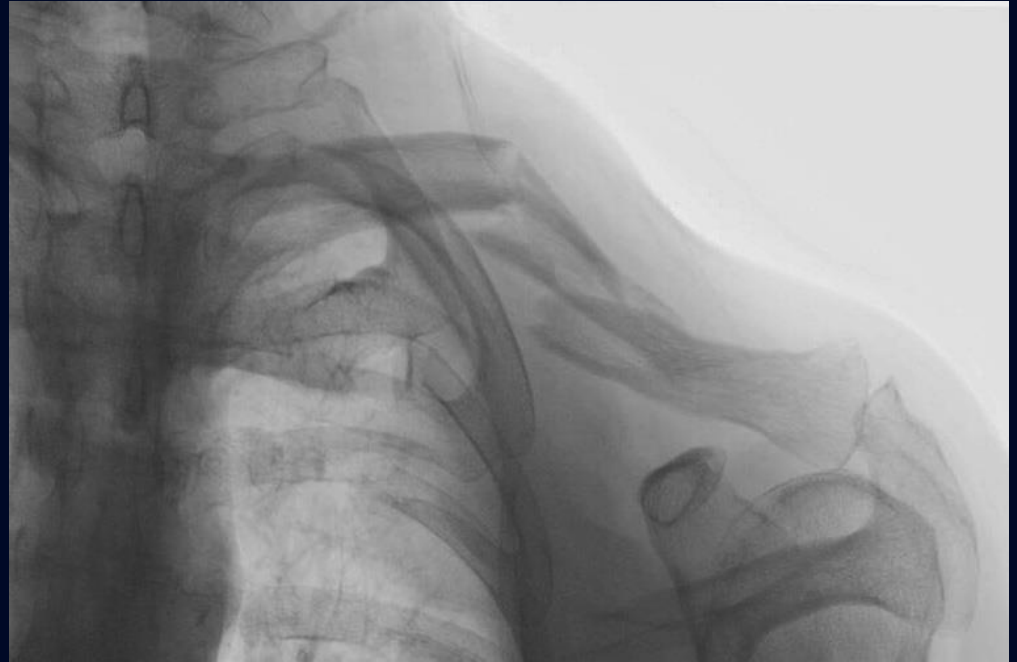
Moved To Texas



Clavicle Non-Union

5 Anatomical Sub-Groups

- Tibia
- Femur
- Humerus
- **Clavicle**
- Miscellaneous
 - Forearm
 - Ankle
 - Other



Clavicle Non-Union

July 1991 - December 2018

Non-Union	78
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Lost To Follow-Up	7
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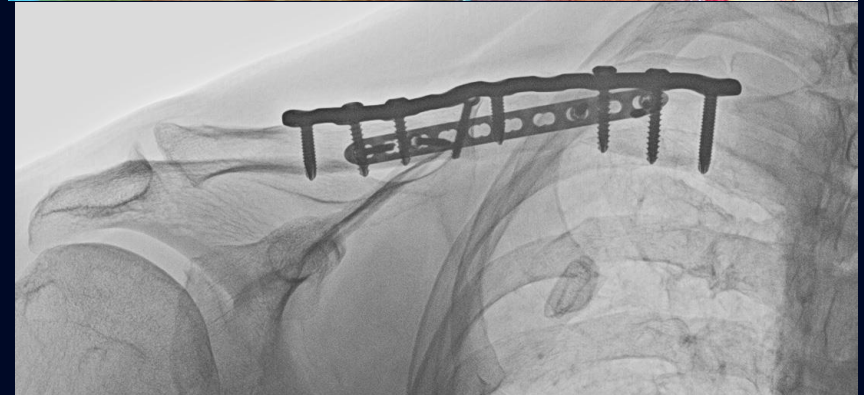
Study Group	71
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All Treated With A Plate

Clavicle Fractures

Rationale For Plate Fixation

- Stable Fixation
- All Locations & Fx Patterns
- Length & Rotational Control
- Early Rehab & ROM



Retrospective Review 1991-2018

Clavicle Non-Union

N=71

Healed (91.5%)

N=65

Ununited (8.5%)

N=6

Healed As
Intended

N=62 (87.3%)

Secondary
Intervention

N=3 (4.2%)

Persistent
Nonunion

N=6 (8.4%)

Recalcitrant Non-Union N=9 (12.6%)

Risk Factor For a Recalcitrant Clavicle Non-Union: N=71 Bi-Variate Or Multi-Variate Regression Analysis

Variable	Odds Ratio	95% Confidence Interval	p -Value
Age	1.03	0.93 – 1.08	0.91
Male	4.33	0.47 – 39.96	0.20
Former Smoker	2.00	0.31 – 13.06	0.47
High Energy Mechanism	0.45	0.03 – 6.15	0.55
Initial Operative Treatment	1.12	0.16 – 7.97	0.91
# Mos Injury To Wiss Index	1.10	1.01 – 1.21	0.42

Risk Factor For a Recalcitrant Clavicle Non-Union: N=71

Implant Type

# Cases	Cohort	HAI	Secondary	Not Healed	P-Value
19	Conventional Plate	16 (84.2%)	2 (10.5%)	1 (5.2%)	0.52
52	Locking Plate	46 (88.4%)	1 (1.9%)	5 (9.6%)	
71		62	3	6	

Risk Factor For a Recalcitrant Clavicle Non-Union: N=71

Stratification By Number Of Prior Procedures

Number of Procedures

# Cases	Cohort	0	1	2	P-Value
62	Healed As Intended	41 (89.1%)	16 (84.2%)	5 (83.3%)	0.485
3	Secondary	2 (4.3%)	1 (5.2%)	0 (0.0%)	
6	Not Healed	3 (6.5%)	2 (10.5%)	1 (16.7%)	
71		46	19	6	

Stratification By Number Of Prior Procedures N=71

Number of Procedures

# Cases	Cohort	0	1	2	P-Value
62	Healed As Intended	41 (89.1%)	16 (84.2%)	5 (83.3%)	0.485
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71		46	19	6	



Clavicle nonunion: plate and graft type do not affect healing rates—a single surgeon experience with 71 cases

Donald A. Wiss, MD, John M. Garlich, MD, MHDS*

Department of Orthopedic Surgery, Cedars-Sinai Medical Center, Los Angeles, CA, USA

Background: Clavicle nonunions often result after nonoperative treatment for the acute fracture. Those that require >1 surgical procedure in order for a nonunion to heal are termed recalcitrant. The aims of the present study were to (1) determine healing rates of clavicle nonunions after plate osteosynthesis using either a conventional or locked plate, (2) compare iliac crest bone graft vs. bone morphogenetic protein on nonunion healing, and (3) identify risk factors for the development of a recalcitrant nonunion.

Methods: We performed a retrospective analysis of a prospectively collected database of 78 clavicle nonunions treated with open reduction and plate fixation with or without graft augmentation by a single surgeon over 25 years. Seventy-one patients over the age of 18 with at least 12 months of follow-up comprised the study group. We analyzed healing rates after the index clavicle nonunion surgery comparing plate type and graft technique as well as identifying risk factors for developing a recalcitrant nonunion.

Results: A total of 62 patients (87.3%) healed after their index nonunion surgery at our institution. Three patients (4.2%) required additional surgery but healed, and 6 patients (8.5%) remain un-united; these 9 patients (12.7%) were defined as recalcitrant. There was no statistically significant difference in healing rates between plate type ($P = .633$) or type of bone graft ($P = .157$). There were no identifiable risk factors for the development of a recalcitrant nonunion.

Conclusions: Plate fixation of clavicle nonunions remains a successful method of treatment. The type of plate or the method of bone graft did not produce different results. There were no demographic, patient, or injury characteristics associated with the development of a recalcitrant nonunion.

Level of evidence: Level IV; Case Series; Treatment Study

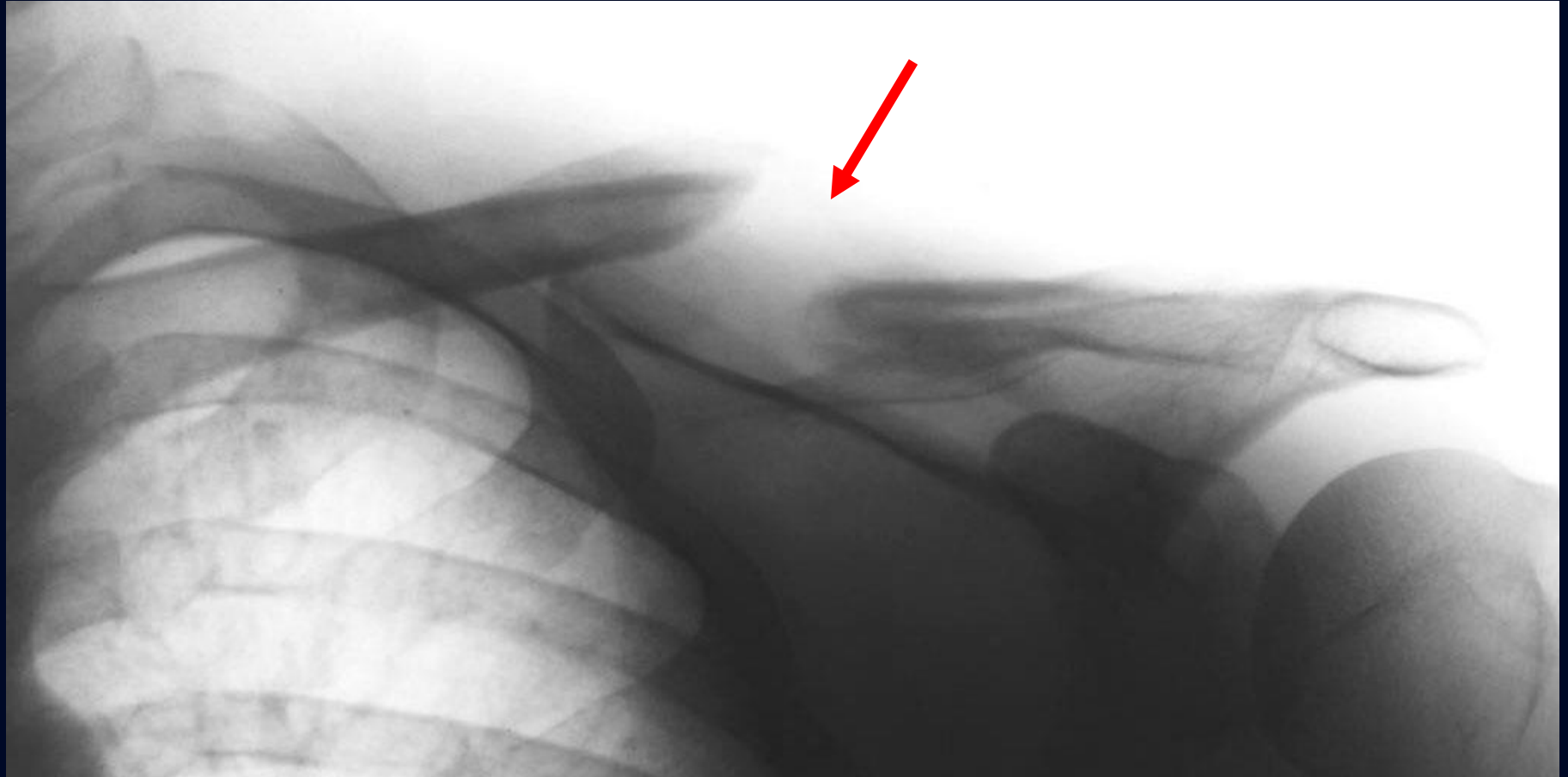
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Keywords: Clavicle; nonunion; recalcitrant; trauma; fracture; plate osteosynthesis

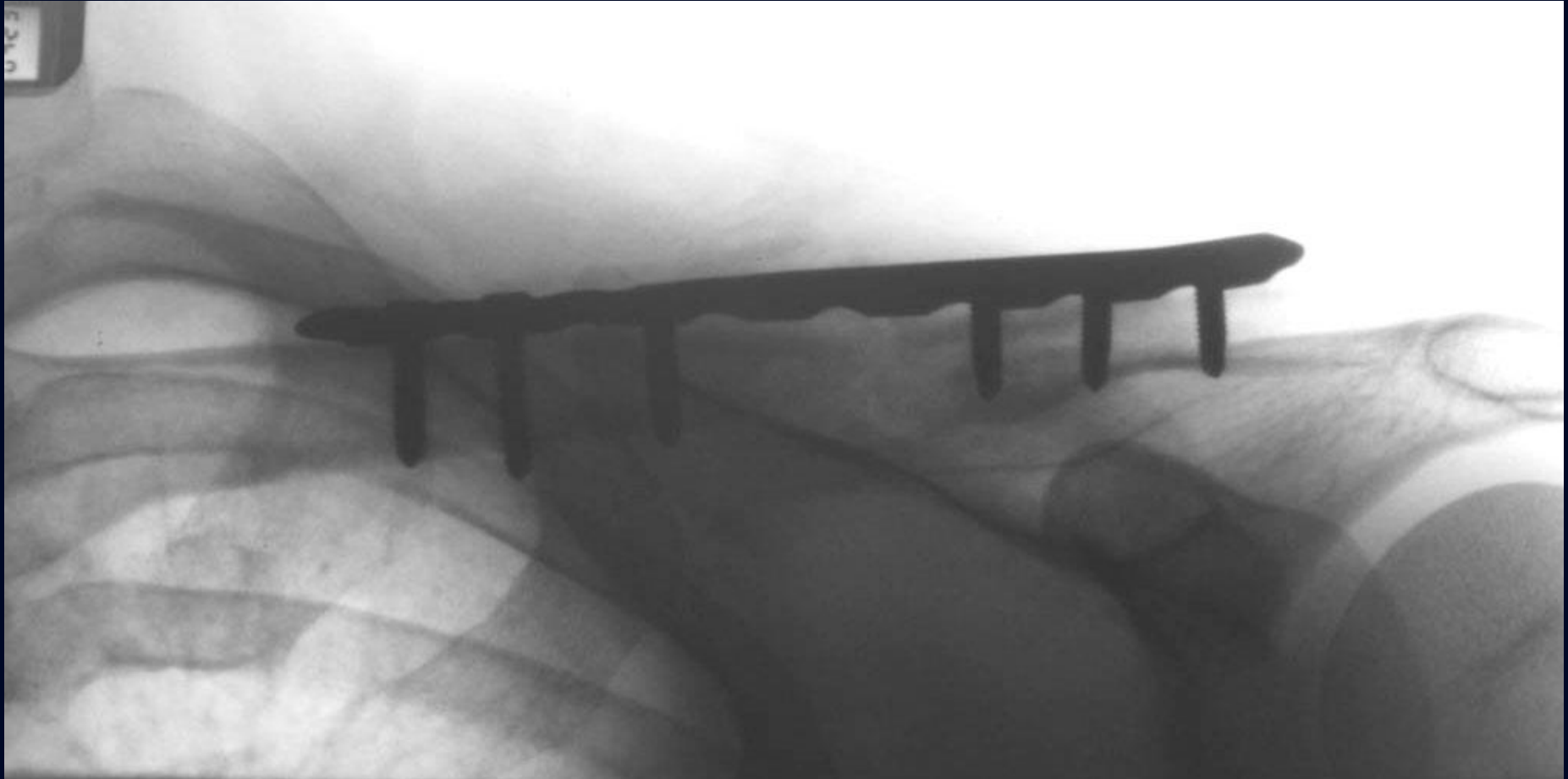
Clinical Cases Clavicle

Healed As Intended

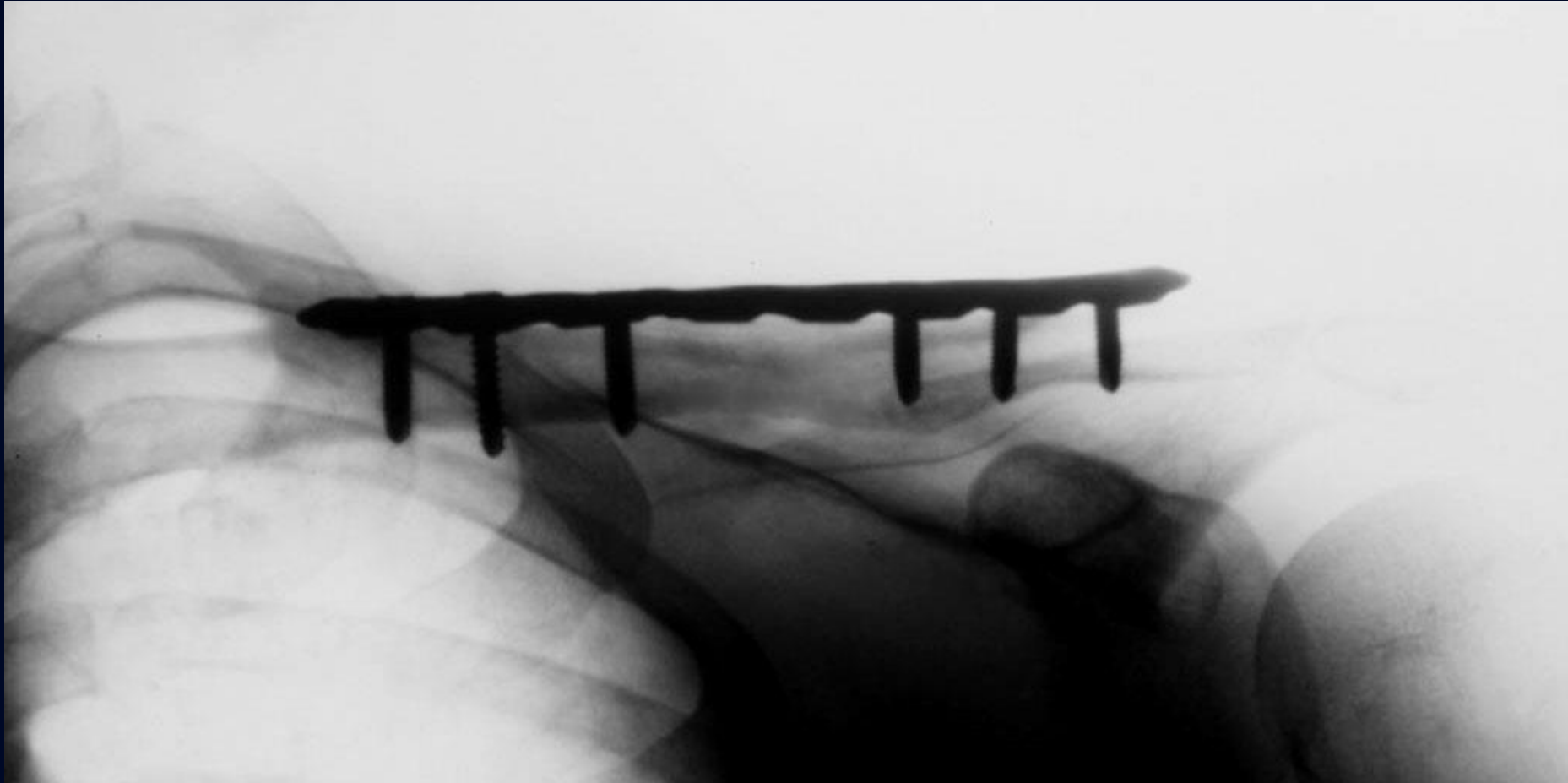
58 Yr Dentist 6 Mos S/P MVA With Painful Atrophic Nonunion



ORIF With Locked Compression Plate & BMP



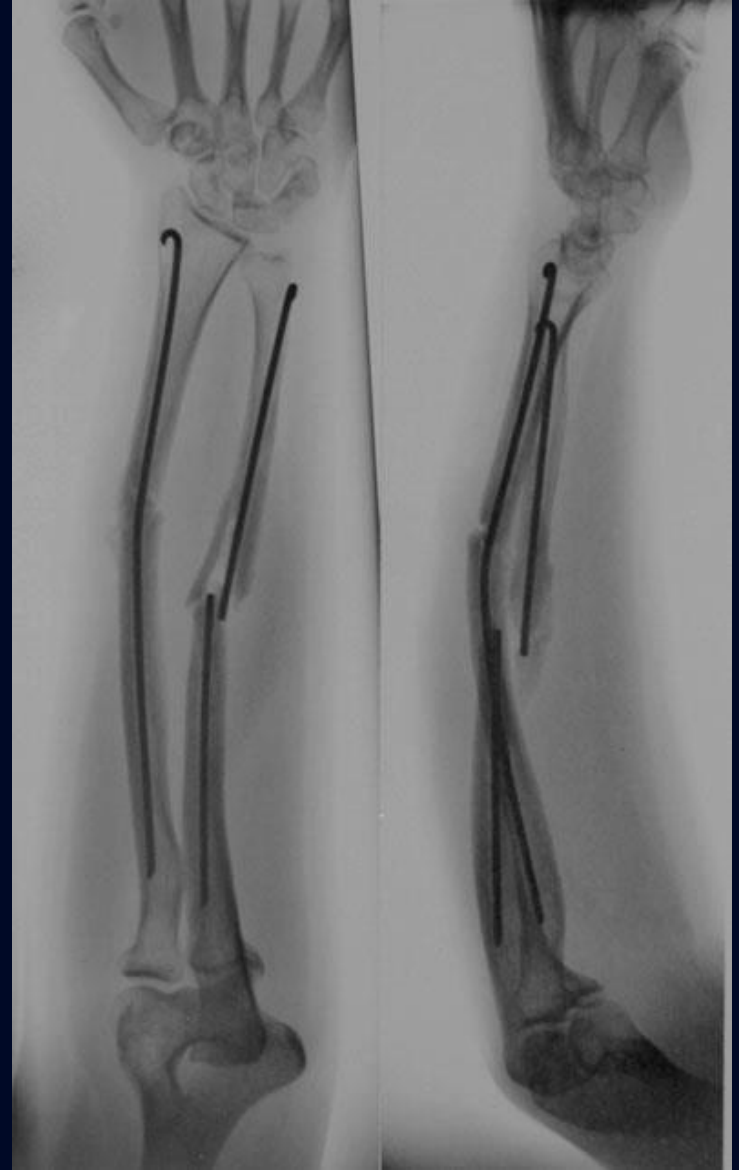
16 Month Follow-Up Healed



Non-Union

5 Anatomical Sub-Groups

- Tibia
- Femur
- Humerus
- Clavicle
- **Miscellaneous**
 - Forearm
 - Ankle
 - Arthrodesis



Miscellaneous Non-Union July 1991 – December 2018

Non-Union	96
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Lost To Follow-Up	11
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Study Group	87
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Miscellaneous Non-Unions





FINAL
THOUGHTS!

Non-Union Conclusions

- Documented The Rates Of Healing By Number of Procedures To Obtain Union
- While Overall Healing Rates Were High,
Many Patients Required Additional
Interventions To Achieve Union
- A Sub-Group Of Patients Did Not Heal



Non-Union Conclusions

The Term **Recalcitrant Non-Union**
Was Used To Capture Patients That
Required Secondary Interventions Or
Failed To Unite To Emphasize The
Difficulty In Treating Many Non-Unions



Non-Union Conclusions

Most Non-Union Studies Fail To Report
The True Incidence Of Recalcitrant Non-
Unions & Simply Record The Rate Of
Successful Bony Union Independent Of
The Number Of Non-Union Surgeries
Require To Achieve Union



Healing Rates By Anatomical Location

		Clavicle	Humerus	Femur	Tibia	p-Value
	n = 540	n = 71	n = 125	n= 122	n = 222	
Primary (HAI)	410 (76%)	62 (87%)	105 (84%)	81 (66%)	162 (73%)	<0.001
2° / Not Healed	130 (24%)	9 (13%)	20 (16%)	41 (34%)	60 (27%)	RNU
Primary (HAI)	410 (76%)	62 (87%)	105 (84%)	81 (66%)	162 (73%)	<0.001
Secondary	83 (15%)	3 (4%)	8 (6%)	21 (17%)	51 (23%)	} RNU
Not Healed	47 (9%)	6 (9%)	12 (10%)	20 (16%)	9 (4%)	

Non-Union Conclusions

After All The Blood, Sweat & Tears
Overall Healing Rate In The Study Was

Clavicle	91%
Humerus	90%
Femur	83%
Tibia	96%
Miscellaneous	89%

Non-Union Conclusions

There Were **No** Statistically
Significant Difference In Healing
Rates Between **Conventional
Plates & Locked Plates** In Any
Bone Or Location In This Study



Non-Union Conclusions

There Was **No** Statistically
Significant Difference In
Non-Union Healing
Between **Plates Or Nails**
In This Study



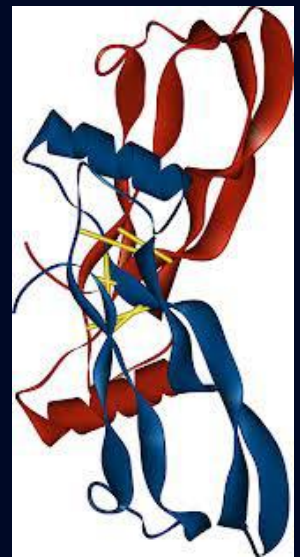
Non-Union Conclusions

There Was **No** Statistically Significant

Difference In Healing Rates Between

Autogenous Bone Grafts Or BMP

In Any Bone Or Location In This Study



BMP Molecule

Non-Union Conclusions

A History Of **Deep Infection** Was A
Statistically Significant Risk Factor
For Development Of A Recalcitrant
Non-Union In The **Tibia, Femur,**
And Humerus, But Not **Clavicle**



Non-Union Conclusions

Patients Who Had **Three or More**
Surgical Procedures Prior To Their
Index (Wiss) Procedure Were
Statistically More Likely To Develop
A Recalcitrant Non-Union



Non-Union Conclusions

Smoking Was A Statistically
Significant Risk Factor For
Development Of A Recalcitrant Non-
Union In The **Humerus & Femur**
But Not In The Tibia Or Clavicle



Recalcitrant Tibial Non-Union

Take Home Message

Risk Factors: Tibia

- High Grade Open Fracture
- Compartment Syndrome
- History Deep Infection
- Rotational Or Free Flap
- 3+ Prior Prior Procedures



Recalcitrant Femoral Non-Union Take Home Message

Risk Factors: Femur

- Current Smoker
- History Deep Infection
- Metabolic Fracture
- 3+ Prior Procedures



Recalcitrant Humeral Non-Union

Take Home Message

Risk Factors: Humerus

- Smoker
- Initial Operative Rx
- History Of Deep Infection
- 2+ Prior Procedures



Non-Union Conclusions



- The Principals Of Non-Union Treatment Are More Important Than The Type Of Implant Or Graft
 - Deformity Correction
 - Stable Internal Fixation
 - Biologic Augmentation
 - Early Functional Rehab



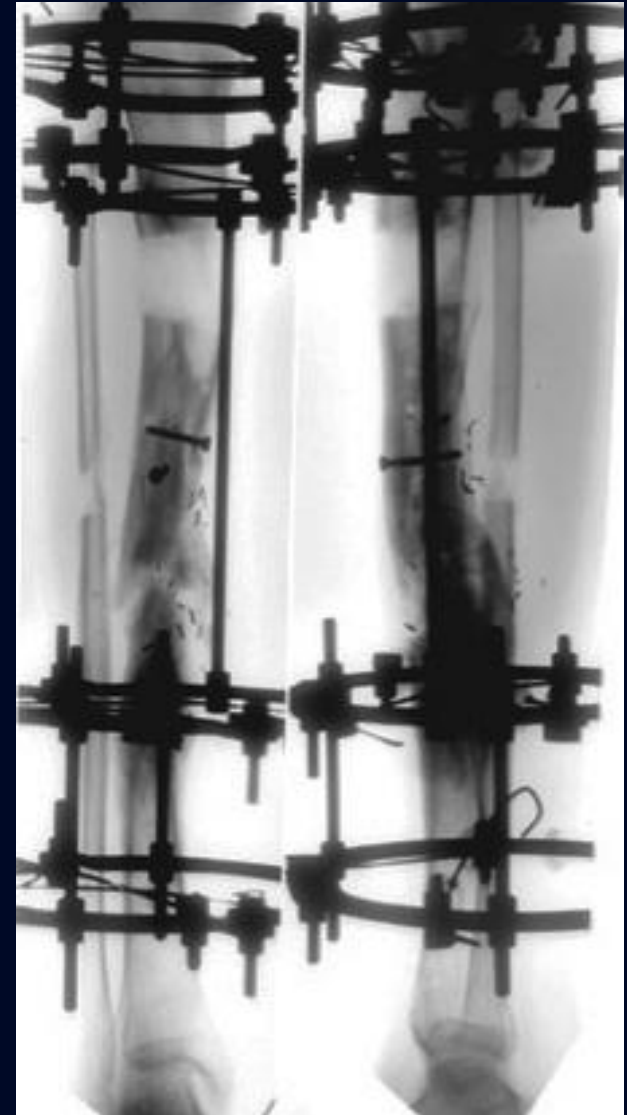
Non-Union Conclusions

- Discussing Risk Factors May Have Clinical Significance In Patient Care
 - Counsel Patients
 - 2° Interventions Common
 - Realistic Outcomes



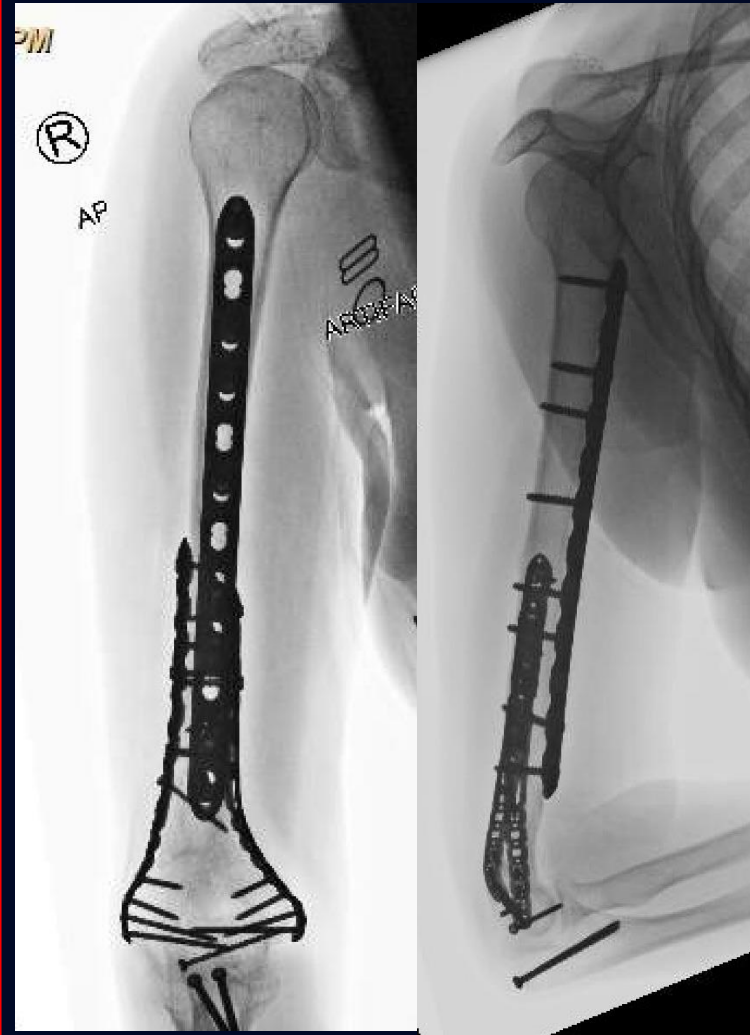
Wiss Non-Union Study Conclusions

- Multiple Weakness In This Study
 - No Outcome Measures Reported
 - No Cost Analysis
 - No Return-To-Work Information
 - No Fine Wire Frames
 - Selection Or Reviewer Bias



Wiss Non-Union Final Thought

- Many Surgeons Have Viewed Non-Union Surgery As A One & Done Procedure
- Only 75% - 80% Of Non-Unions Heal Their Index Procedure
- There Are Multiple Risk Factors That Require A More Aggressive Multi-Modal Approach In Selected Non-Unions To Reduce Morbidity & Improve Outcomes



It Is Not Enough To Stare Up The Steps; We Must Step Up The Stairs



Donald A. Wiss MD