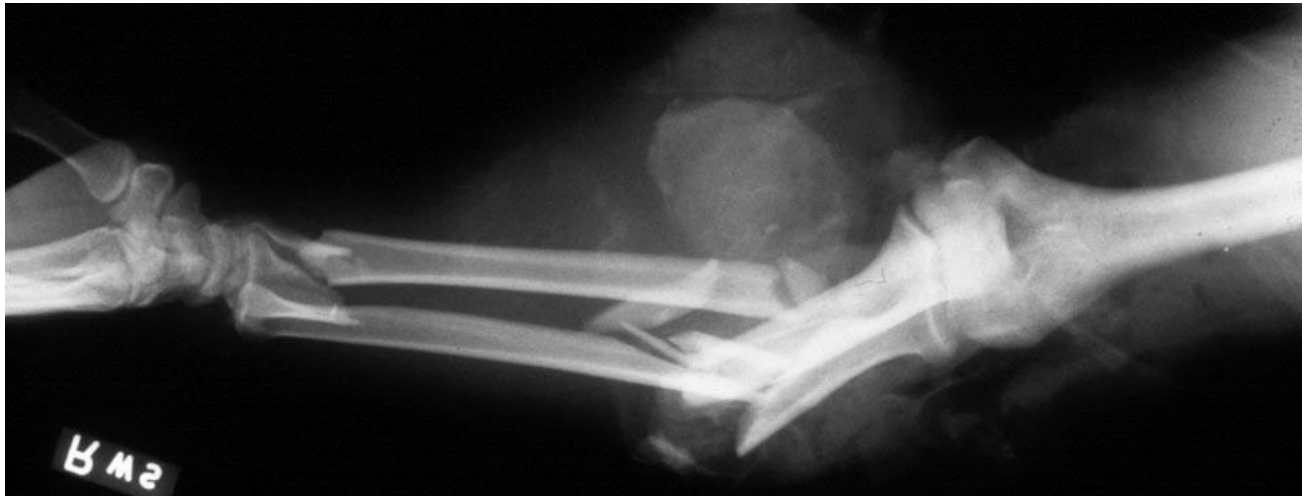
Forearm Fractures



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Forearm Fractures: Introduction

- Goals: To Understand:
  - Relevant Anatomy
  - Incidence, & Mechanism of Injury
  - Clinical Findings
  - Classification
  - Treatment Options/Techniques/Indications
  - Surgical Approaches
  - Outcomes/Expected Results

Relevant Anatomy of Forearm Fractures

- Bones & Ligaments:
- Muscles:
- Neurovascular Structures:

Bone & Ligamentous Anatomy of the Forearm

- Form Follows Function:
  - The shapes of the Ulna & Radius – especially the radial bow – are important for rotation
  - The Interosseous Membrane tethers the two bones obliquely from the distal ulna to the proximal radius

- Figure used with permission: Terry Light M.D.

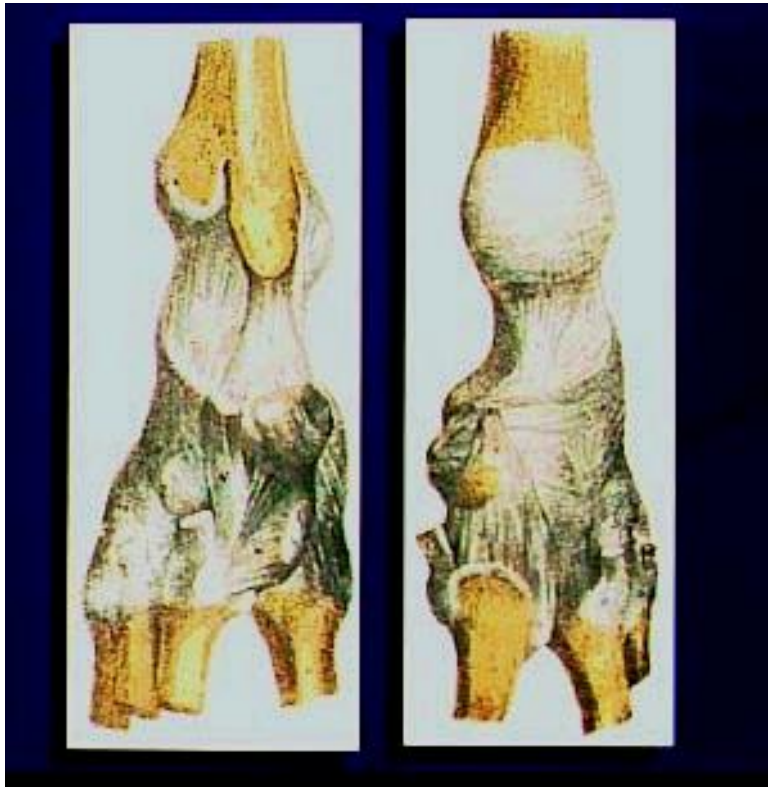
Bone & Ligamentous Anatomy of the Forearm

- Proximal Radioulnar Joint & Elbow
  - Injury to the Radiocapitellar Joint is associated with the Monteggia fracture
  - The Annular Ligament connects the Radius & Ulna proximally

- Figure used with permission: Terry Light M.D.

Bone & Ligamentous Anatomy of the Forearm

- Distal Radioulnar Joint:
  - Ligamentous wrist attachments include the Triangular Fibrocartilage
  - There is a complex relationship of the radius to the ulna and carpal bones
  - Damage to the DRUJ is associated with Galleazzi fractures



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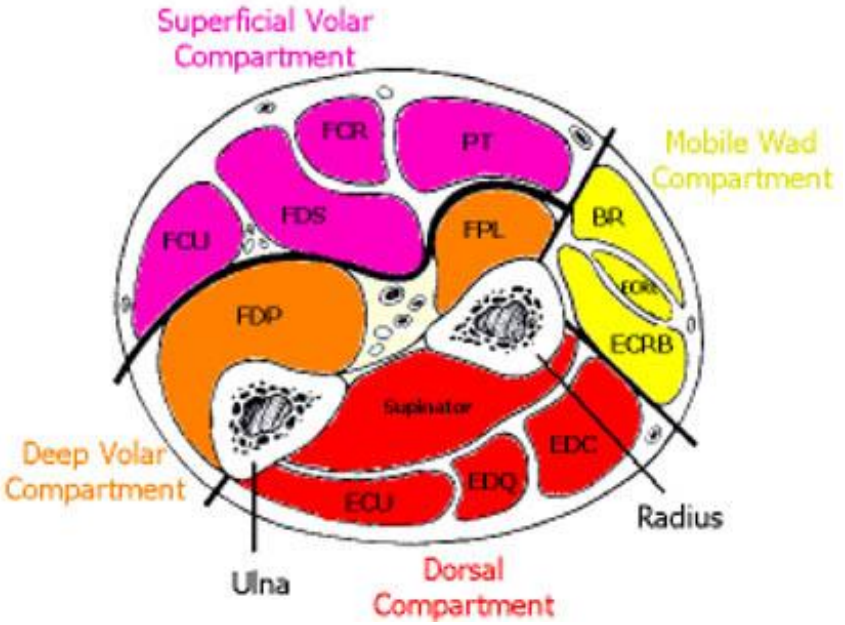
Muscle Anatomy of the Forearm

- Compartments:
  - Posterior (Dorsal): Extensors
  - Anterior (Volar): Flexors
  - Mobile Wad
    - (Brachioradialis, Extensor Carpi Radialis Brevis, Extensor Carpi Radialis Longus)



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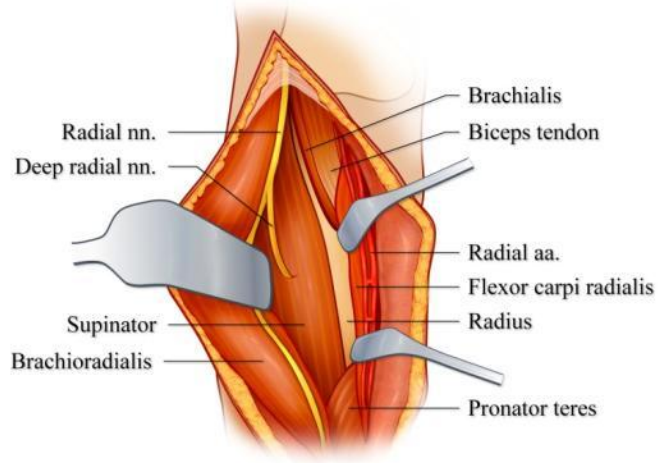
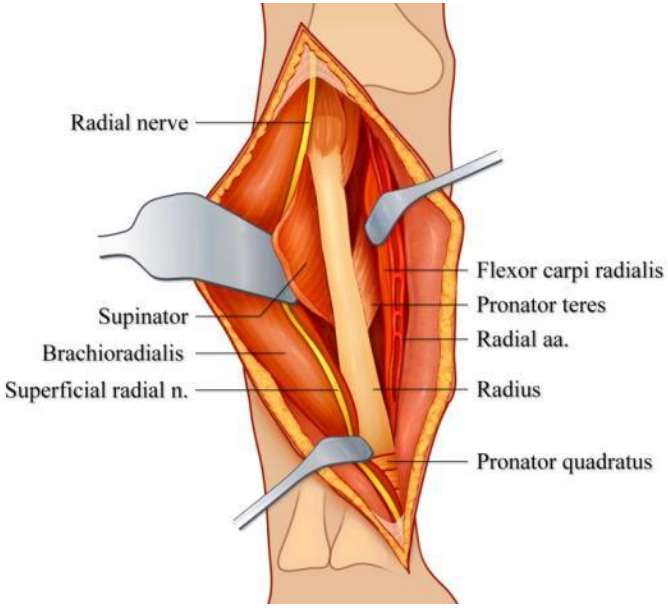
Neurovascular Forearm Anatomy

- Radial Nerve:
  - Be aware of its Posterior Interosseous (Deep) Branch which runs along the neck of the radius proximally
  - Be aware of its Sensory (Superficial) Branch distally

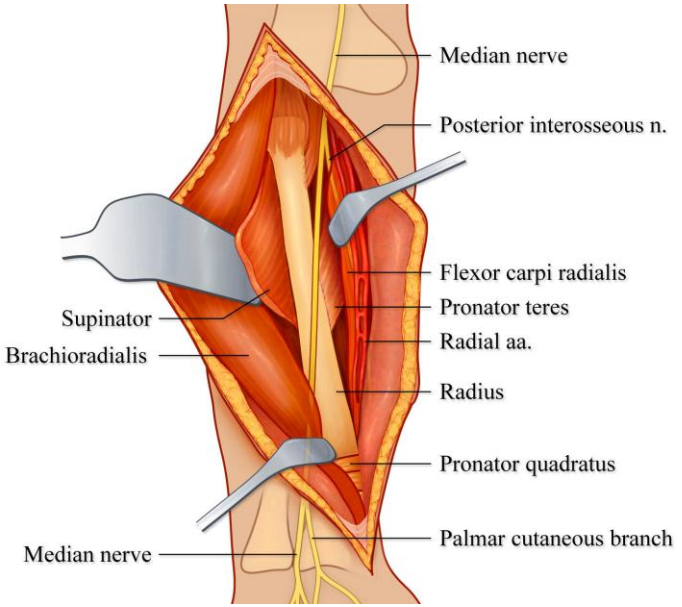




Neurovascular Forearm Anatomy:

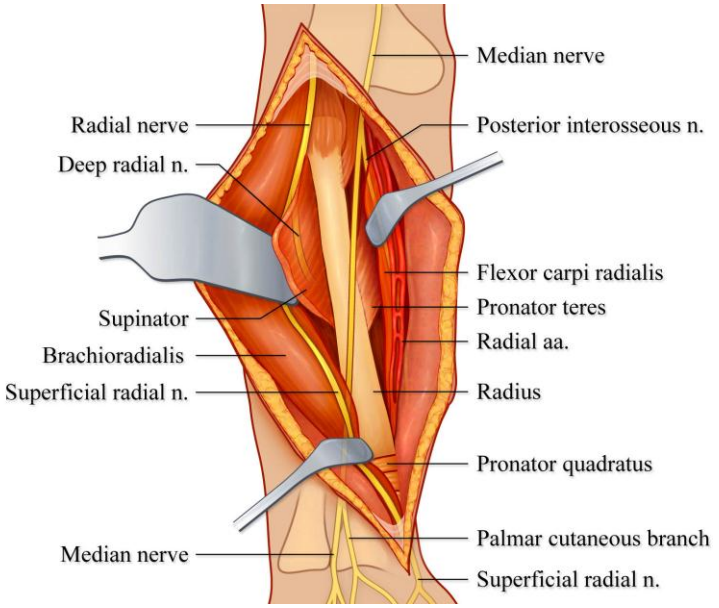
- Radial Artery
  - Located behind the brachioradialis muscle

Radial Artery



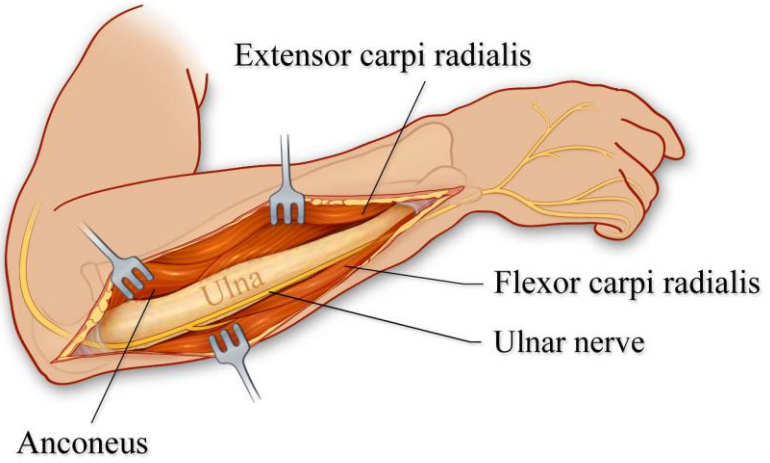
Neurovascular Forearm Anatomy

- Median Nerve:
  - Midline location
  - In danger distally as it heads for the carpal tunnel
  - Anterior Interosseous Nerve travels along the interosseous membrane



Neurovascular Forearm Anatomy

- Ulnar Nerve
  - Travels along ulna
  - Subcutaneous at the elbow
- Ulnar Artery
  - Travels along ulna



Incidence of forearm fractures

- Radius and/or ulna fractures are 44% of all emergency department fractures
- In 1998 there were 1.5 million fractures of the hand and forearm of which 650,000 were of the radius and ulna
  - 110,000 were between the ages of 18-64 years old
  - 195,000 were between 5-14 years old
- Accidental falls were the most common cause (47%)
    - J Hand Surgery 2001: 26A: 908-15

Mechanism of Injury of Forearm Fractures

- Forearm Fractures from low energy trauma can be due to a direct blow
  - e.g. Nightstick (isolated ulna) fracture where the arm is used to block a blunt object
- Or can be due to indirect transmission of forces
  - e.g. Monteggia fracture (ulna with radial head dislocation) where axial load is combined with rotation as with a fall on the outstretched arm
  - e.g. Galeazzi fracture (distal radius with distal radioulnar joint disruption) where axial load is combined with pronation

Mechanism of Injury of Forearm Fractures

- Forearm Fractures from high energy trauma may be due to direct or indirect forces
  - May have associated systemic injuries
  - May have associated fractures
    - Floating Elbow (Humerus & forearm fractures)
    - Multiple Segmental Fractures (Conveyer Belt injury/Crush)

Forearm Fracture Clinical Findings

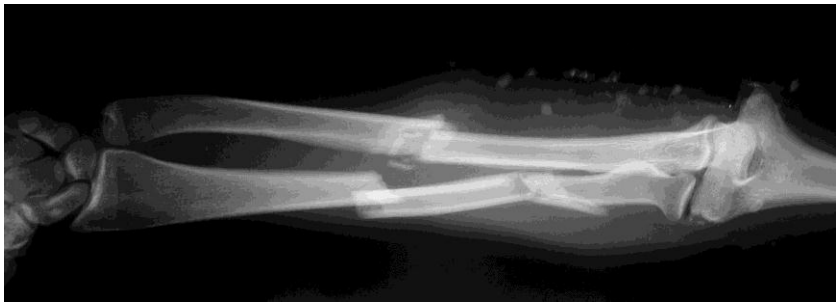
- Patients present with deformity, swelling & pain
- Don't Miss:
  - Injury to joint above (elbow) & below (wrist)
  - Compartment Syndrome
  - Open wounds
    - Remember the ulnar border is subcutaneous and even superficial wounds can expose the bone
  - Associated Nerve injuries
    - Especially with open fractures
- Obtain AP & Lateral X-rays of the Entire Forearm including the Wrist & Elbow

Forearm Fracture Clinical Exam

- Identify Localized Swelling, Tenderness, and decreased motion
- Carefully examine any wounds over the ulna
- Palpate the elbow especially the radial head
- Palpate the wrist especially stability of the distal radioulnar joint
- Carefully assess neurovascular function for all nerves of the forearm & hand
- Assess firmness of compartments, pain with passive stretch, and measure pressures if in doubt

Forearm Fracture Radiographic Exam

- Good Quality AP & Lateral X-rays of the entire forearm including the elbow & wrist are necessary



Forearm Radiographic Exam

- The Radial Head Must be aligned with the Capitellum on All views
- Example:
  - "Simple" Ulna Fracture on AP:

  - But the Radial Head is Dislocated on the Lateral!

Forearm Fracture Radiographic Exam

- The Relationship of the Distal Ulna & Radius must be symmetric with the opposite wrist
  - Definite evidence of DRUJ disruption include widening of space between the radius & ulna, radial shortening more than 5mm., an ulnar styloid fracture, and volar dislocation of the carpus compared to the ulnar shaft

Forearm Fracture Classification

- Descriptive:
  - Isolated Fractures of Radius or Ulna
    - Ulna = Nightstick
  - Fracture of Both Bones (no ligament injury)
  - Fracture of One Bone w. Ligament Rupture
    - Ulna w. Radial Head Dislocation = Monteggia
    - Radius w. DRUJ Dislocation = Galleazzi
  - Fracture of Both Bones w. ligament injury

Forearm Fracture Classification

AO/ASIF Classification

- A: Simple Fracture (no comminution)
- B: Wedge Fracture (single butterfly fx)
- C: Complex Fracture
  - Segmental
  - Comminuted
- Refers to diaphyseal fracture
  - no intra-articular component of the classification

AO Classification of Forearm Fx Type A

- Simple Fracture
  - Ulna Alone, Radius Intact
  - Radius Alone, Ulna Intact
  - Both Bones broken

- Example: transverse radius fracture

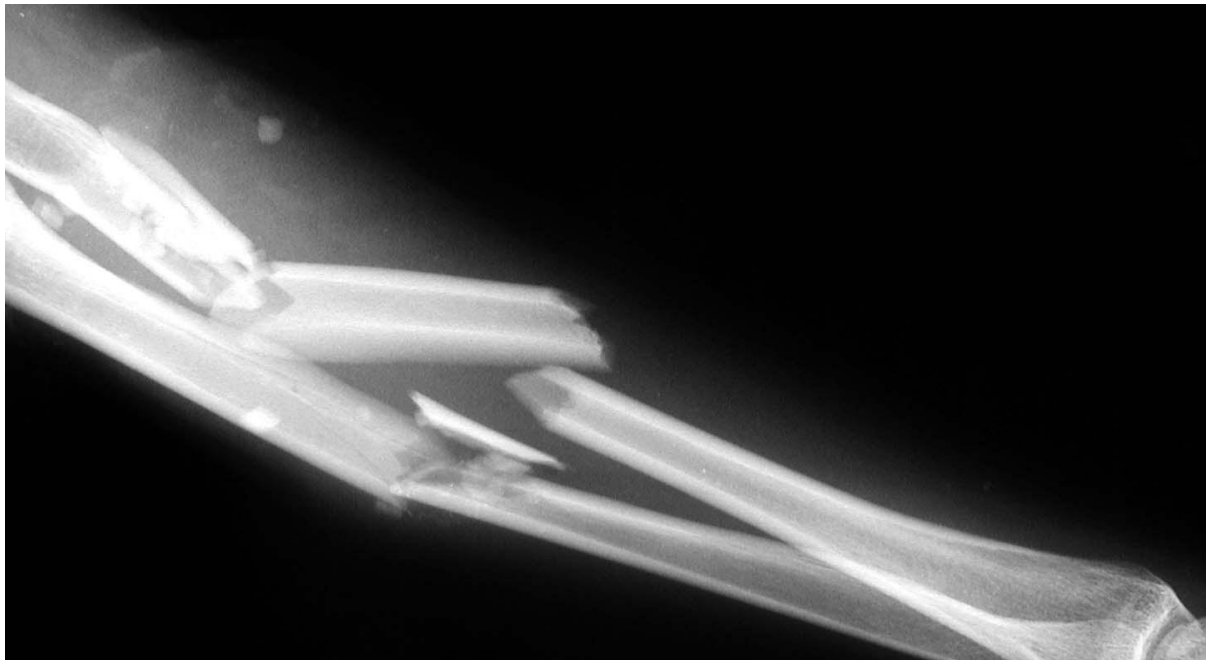
AO Forearm Fracture Classification Type B

- Wedge Fractures
  - Ulna Alone
  - Radius Alone
  - Both Bones

- Example: Both Bones

AO Forearm Fracture Classification Type C

- Complex Fractures
  - Ulna Alone
  - Radius Alone
  - Both Bones



- Example: both bones

Forearm Fracture Treatment Goal

- Obtain & Maintain Anatomic Reduction
  - Restoration of the Normal Relationships between the Radius & Ulna and the Radial Bow is Essential for a Functional Forearm

Treatment of Forearm Fractures Options:

- Closed Reduction & Casting:
  - High rates of nonunion & malunion and poor functional results
- Open Reduction & Internal Fixation:
  - High rates of union and excellent function

Nonsurgical Treatment of Forearm Fractures

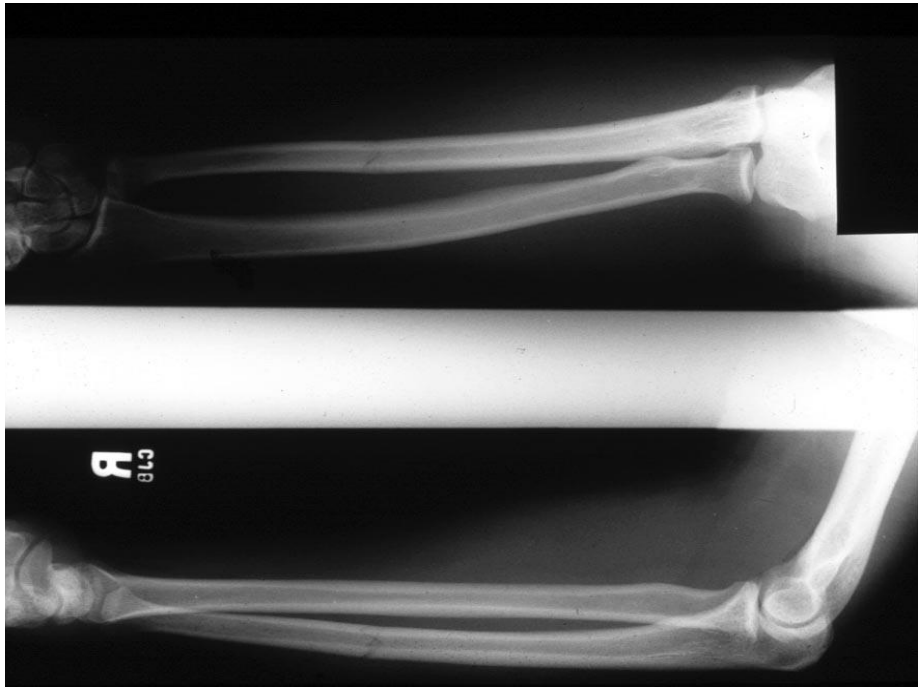
- Functional Brace or Cast
  - Ulna: ONLY for STABLE Closed Fractures of the Distal 1/3 with <10 degrees Angulation
  - Radius: ONLY if completely nondisplaced and radial bow maintained. (ie, gunshot injury)

Isolated Ulna Fracture ("Nightstick")

Case Example:

- 30 y/o male hit with a golf club
- Closed fracture.
- No angulation on x-rays
- Treatment Options?

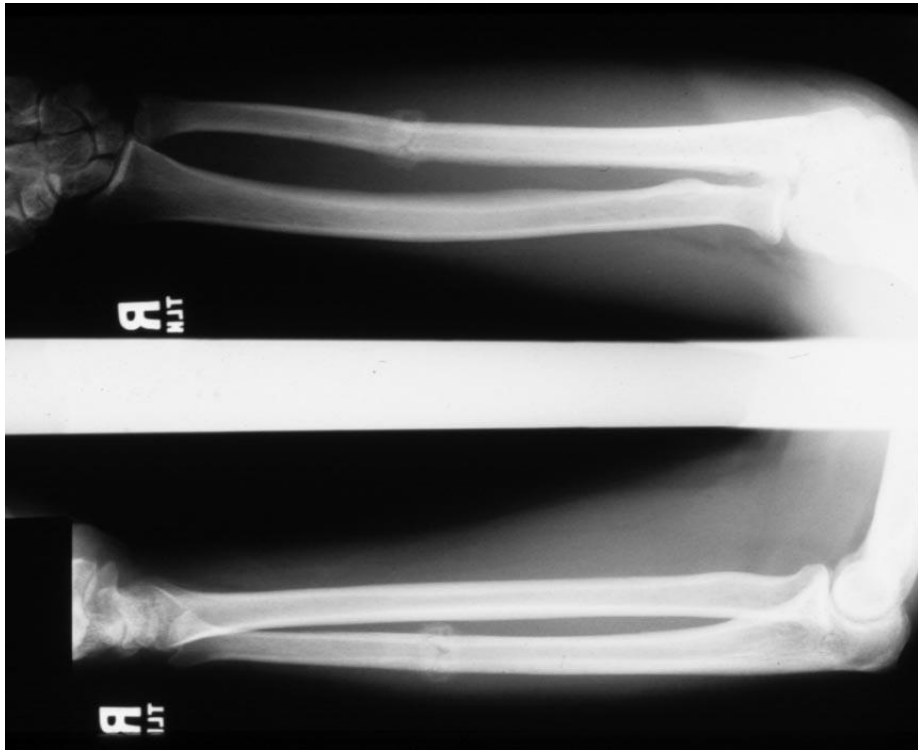
- Injury AP & Lateral X-rays



Nightstick Fracture

- Treatment Choice:
  - Closed splinting with early motion
- Teaching Points:
  - Can treat nondisplaced closed isolated fractures without ORIF

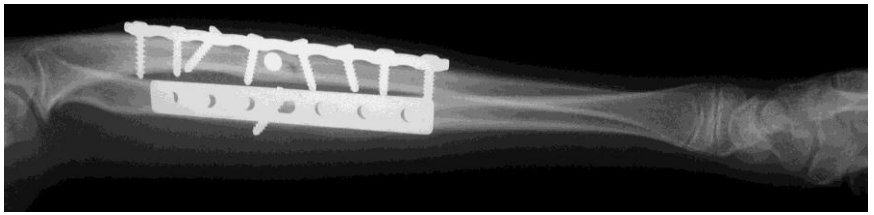
- AP & Lat X-rays at 3 month follow-up

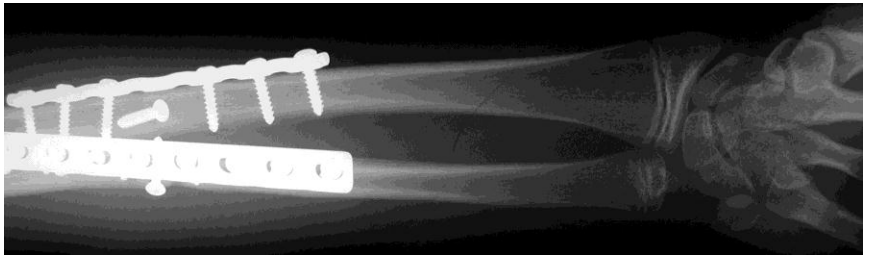


Surgical Treatment of Forearm Fractures

- Indicated - All Unstable Forearm Fractures and All Open Forearm Fractures
  - Very Few stable enough to treat nonsurgically in adults
  - Most girls >10y/o and boys >12y/o require surgery

- Options:
  - External Fixation
  - Intramedullary Rods
  - ORIF with Plates





External Fixation of Forearm Fractures

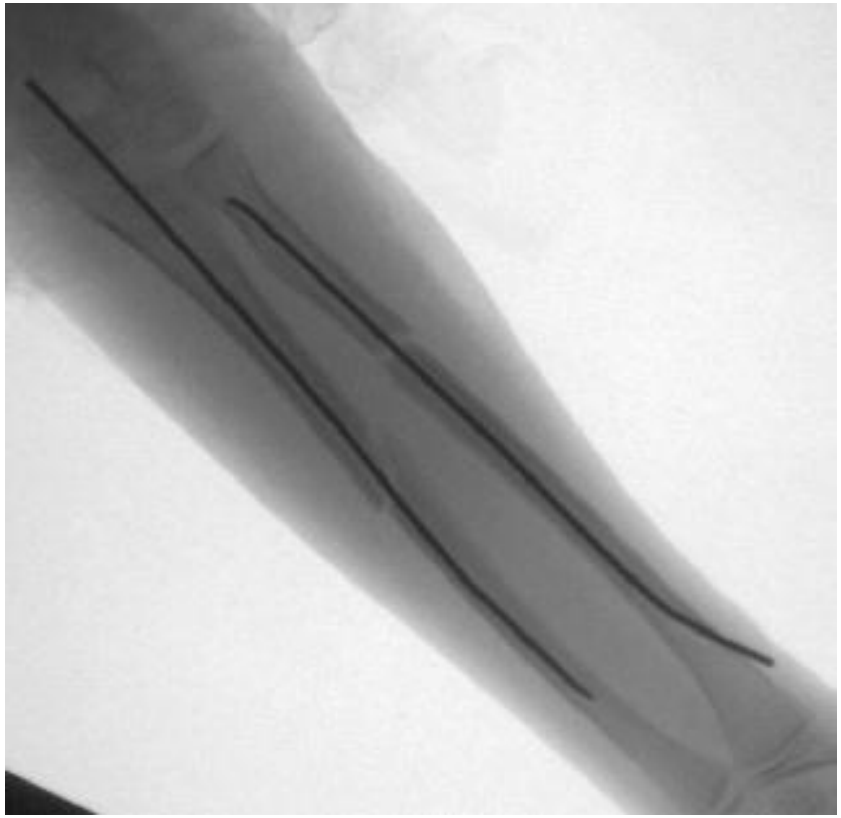
- ONLY: Gustilo Types IIIB&C Open Fx's
  - (Other open fractures treated with Irrigation/Debridement & ORIF & bone grafting at time of definitive closure)
- Usually must be revised to internal fixation when soft tissues allow

Intramedullary Fixation of Forearm Fractures

- Indications: Controversial
  - Not routinely Used
    - Acts as an internal splint only
    - Problems of **rotational instability**, loss of radial bow, shortening, and nonunion
    - May have improved results with contoured rods
  - May be useful when soft tissues compromised
  - Or in Pathologic fractures or impending fractures
    - where the device protects the whole bone

Pediatric fractures

- Intramedullary fixation for pediatric transverse fractures works well
  - Supplemented by cast immobilization (because rigid fixation is not achieved)

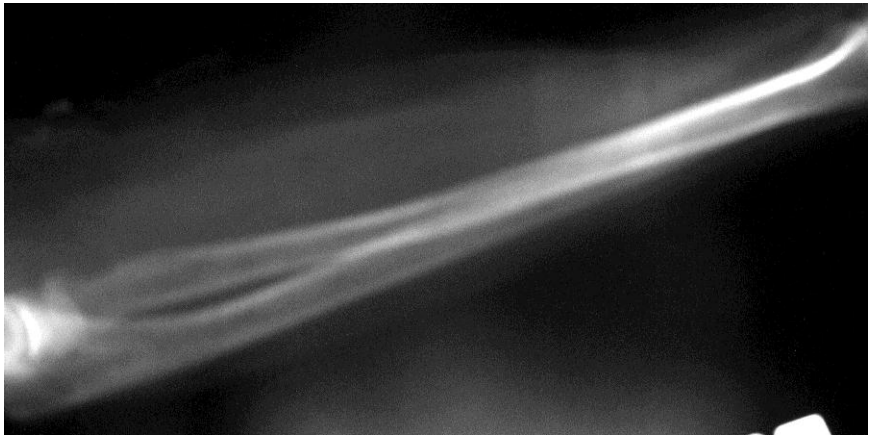


Intramedullary Fixation

Case Example: Pathologic Lesion/Fracture

- Elderly Female with Metastatic Breast CA
- Problem: Multiple Radius Lesions
- Goals: Minimize surgical trauma, and improve quality of life with limited lifespan
- Options?

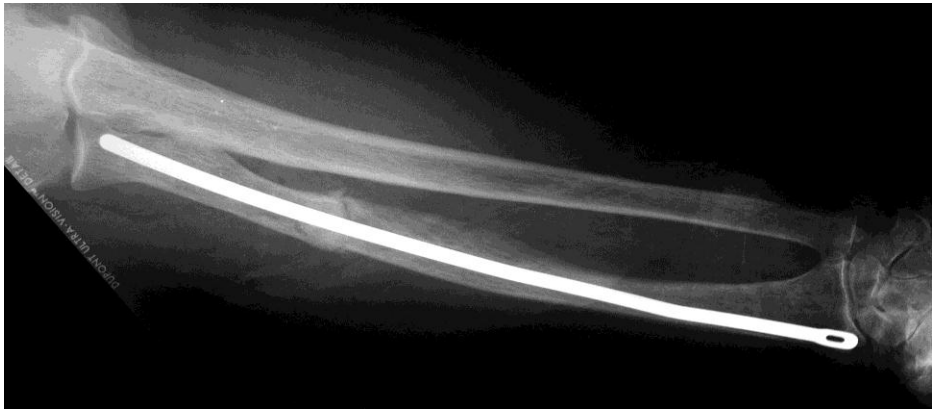
- AP&Lateral X-rays:



Intramedullary Fixation

Case Example: Pathologic Lesion/Fracture

- Intramedullary Fixation Provides Protection for the whole bone in the patient with multiple pathologic lesions
- Intramedullary Rod Fixation. AP&Lat



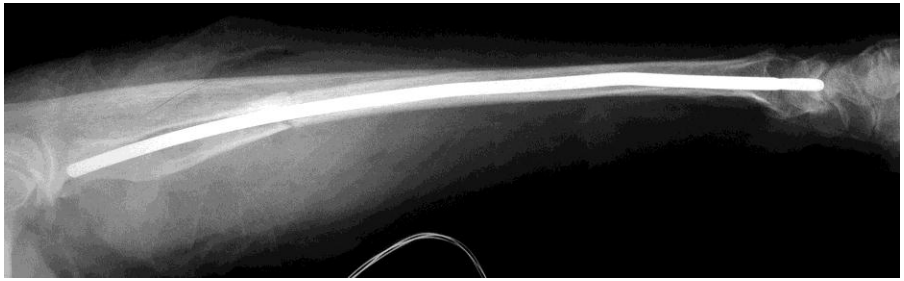


Plate Fixation of Forearm Fractures

- Indications: Treatment of Choice for most forearm diaphyseal fractures including types I, II, and IIIA open fractures and those associated with compartment syndrome
- Plate Fixation consistently provides stable strong anatomic fixation that eliminates the need for external casting, & allows early functional motion with union rates over 95%.

Principles of Plate Fixation

- Restore Anatomic Reduction
- Restore Ulna & Radial Length
  - Prevents subluxation of either proximal or distal radioulnar joints
- Restore Rotational alignment
- Restore Radial Bow
  - Essential for rotational function of forearm

The Role of Bone Grafting

- Bone Graft if there is Severe Bone Loss or the patient has an Open Fracture Severely Compromising Local Biology
  - If >1/3 cortical circumference is lost, consider bone grafting because interfragmentary compression becomes impossible
    - But the standard teaching that >30% comminution “requires” grafting has been challenged where newer biologic techniques are used.
      - Wright, RR, Schmeling, GJ, and Schwab, J.P. The necessity of acute bone grafting in diaphyseal forearm fractures: a retrospective review. J. Orthop Trauma 11:288-94, 1997.

Technical Tips for Plate Fixation of Forearm Fractures

- Use 3.5 LC-DC or DCP
  - 7 cortices in each fragment including a Lag screw
- Reduce and provisionally fix the “easier” bone first, and then the other
  - Sometimes it is necessary to loosen fixation on the first bone to obtain reduction of the second

Technical Tips for Plate Fixation of Forearm Fractures

- Use Indirect Reduction Techniques Preserving Soft Tissue Attachments
  - Periosteal stripping must be minimized
  - Narrow retractors placed to avoid penetration of interosseous membrane
- Close or Skin Graft Open Wounds within 3-5 days

Goal of Forearm Surgery: Anatomic Reduction

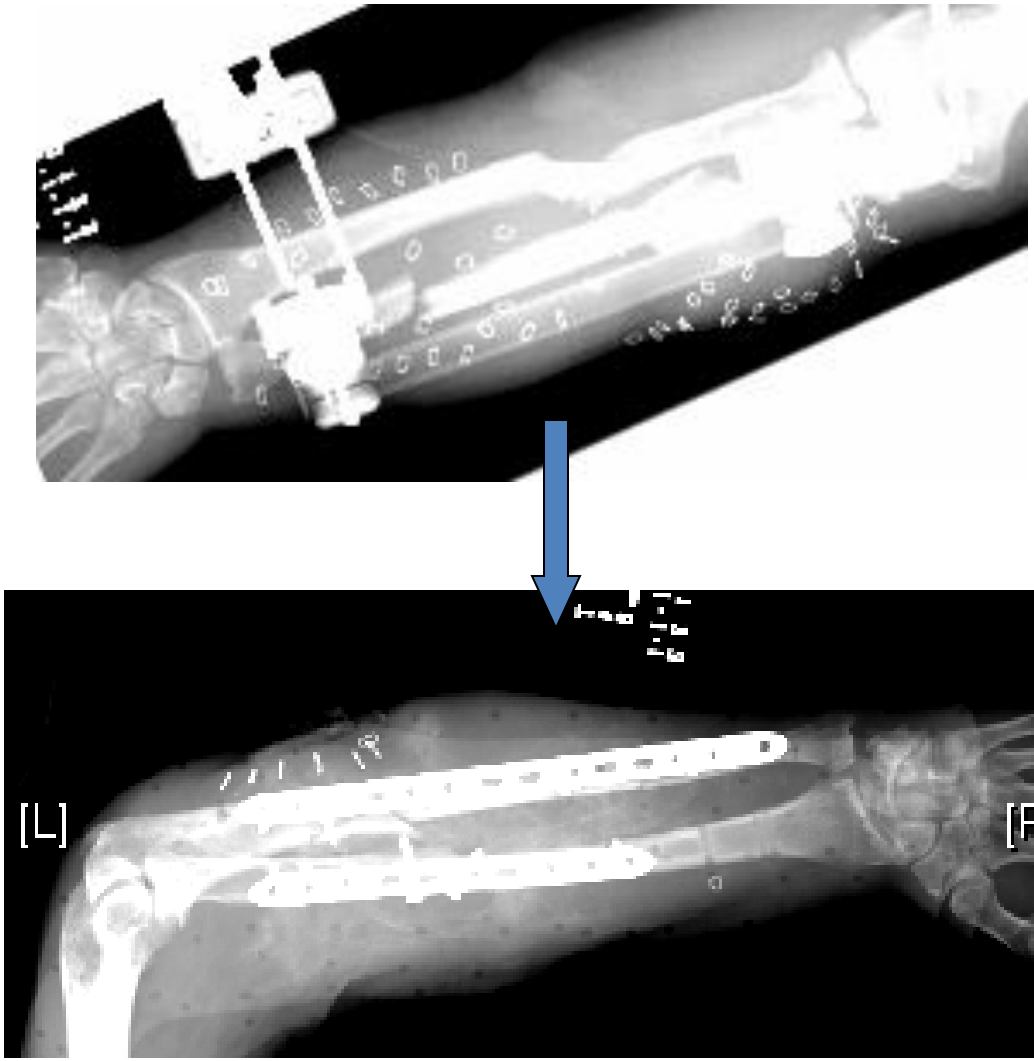
- The Length of the Ulna is vital to forearm stability and must be maintained to prevent wrist pain and impingement
- The Bow of the Radius is vital to forearm rotation and Length must also match the ulna to avoid wrist symptoms
- Successful functional outcome correlates directly with accuracy of anatomic reduction

Restoration of Radial Bow

- Restoration of the Radial Bow can be difficult in comminuted fractures.
  - If anatomic reduction techniques are used, this is accomplished with meticulous “jigsaw puzzle” reduction one fragment at a time using the standard AO technique of making 5 fragments into 4, then 4 into 3 etc. and lag screws for inter-fragmentary compression

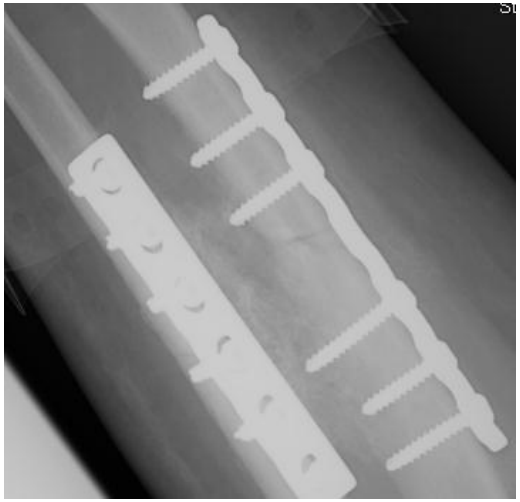
Restoration of Radial Bow

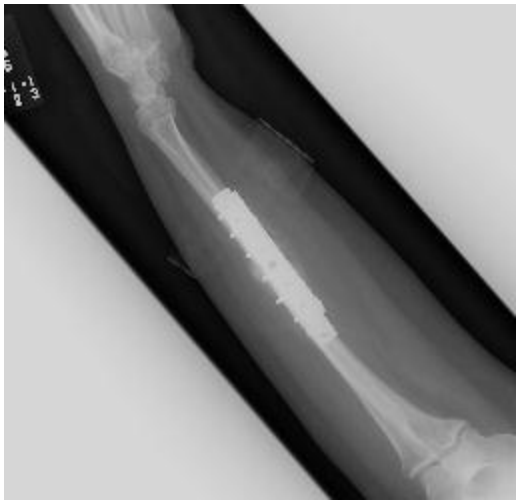
If bridging techniques are used, this can be accomplished with a careful bending of the plate. Or placing the plate anteriorly (or posteriorly) and indirectly curving the bone beneath it.



Type of Plate?

- Standard is LC-DC or DCP.
- Proven results: Reliable Healing
- Less expensive than Locking Plates
- Especially indicated when Rigid Fixation can be achieved in relatively Uncomminuted Fractures.





Type of Plate?

- Locking Plates: More Controversial
- Act as internal “external fixator” and results not as proven as standard non-locking techniques.
- Especially indicated when Rigid fixation cannot be achieved because of comminution or soft tissue injury makes bypassing the zone of injury important

Locking Plate v Compression Plate

- No statistically high level reliable prospective randomized studies comparing standard compression plating to locking plating
  - Some examples of (statistically low level) articles:
    - Leung, F. and S.P. Chow: J of Orthopaedic Surgery 2007: Locking compression Plate in the treatment of forearm fractures: a prospective study
      - 32 patients were treated with locking plates for forearm shaft fracture. There were 2 delayed unions and 2 re-fractures after plate removal.
    - Sharma, S. et al: Internet J of Orthopaedic Surgery 2009: Treatment of Diaphyseal forearm fractures by locking compression plate
      - 30 patients. All healed.
- Based on current literature, there is "little or no clinical data to support the routine use of locked plating for diaphyseal fractures of the forearm"
    - Haidukewych, G. and Ricci, W.: Locked Plating in Orthopaedic Trauma: A Clinical Update. J. of the AAOS 16: 347-55, June 2008

Hybrid Plating

- Locking Plating (using fixed angled screws locked into the plate):
  - Advantages: preserves biology with enough mechanical stability to allow early motion & function. Heals with callus formation.
  - Disadvantages: bridging techniques more difficult to achieve anatomic reduction. Without lag screw or dynamic plate compression, possibly more likely to have a residual gap and nonunion.
- Compression Plating (using standard screws that do not lock into the plate):
  - Advantages: improved mechanical stability that allows early motion and function. Heals by primary bone healing. (When compression is achieved)
  - Disadvantages: reduction techniques that strip the periosteum may damage the biology increasing the risk of nonunion or infection.
- Hybrid Combination of compression techniques (lag screw fixation) and locking screw plating (for neutralization) may be useful combining the advantages of both techniques.
  - (Strauss, E.J. et al, The Current Status of Locked Plating: the Good, the Bad, and the Ugly. J Orthop Trauma, 22: 479-86, August 2008

Forearm Fracture Plate Fixation

Case Example

- 50y/o male with comminuted both bone forearm fracture after motor vehicle accident

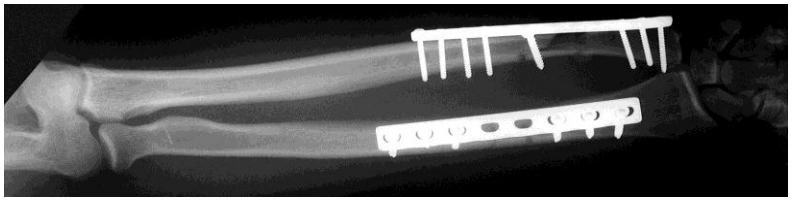
- Injury AP&Lat:

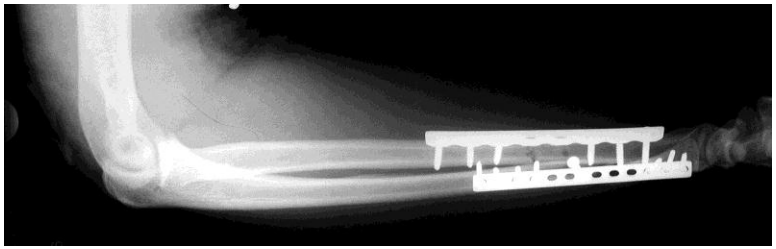
Forearm Fracture Plate Fixation

Case Example

- Treatment: Both Bones fixed with plates. Anatomy restored including distal radioulnar joint and radial bow.
- Usually 3.5 LC-DC plates are preferred
  - Here: narrow distal ulna required 2.7 DCP
  - Teaching Point: Match the hardware to the size of the bone

- Postop:





Forearm Fracture Plate Fixation

Case Example

- 33 y/o male with segmental open both bone forearm fracture after conveyer belt injury

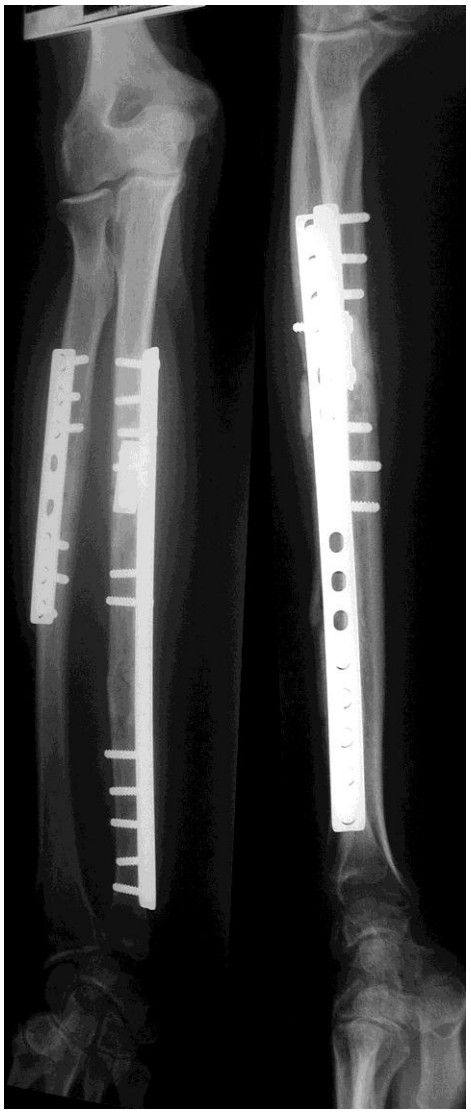
- Options?

- Injury:

Forearm Fracture Plate Fixation

Case Example

- ORIF with plate fixation including bridge plates and minimally invasive technique to preserve soft tissues
- See later section on infected nonunion for a similar patient treated with open reduction & intramedullary rod technique

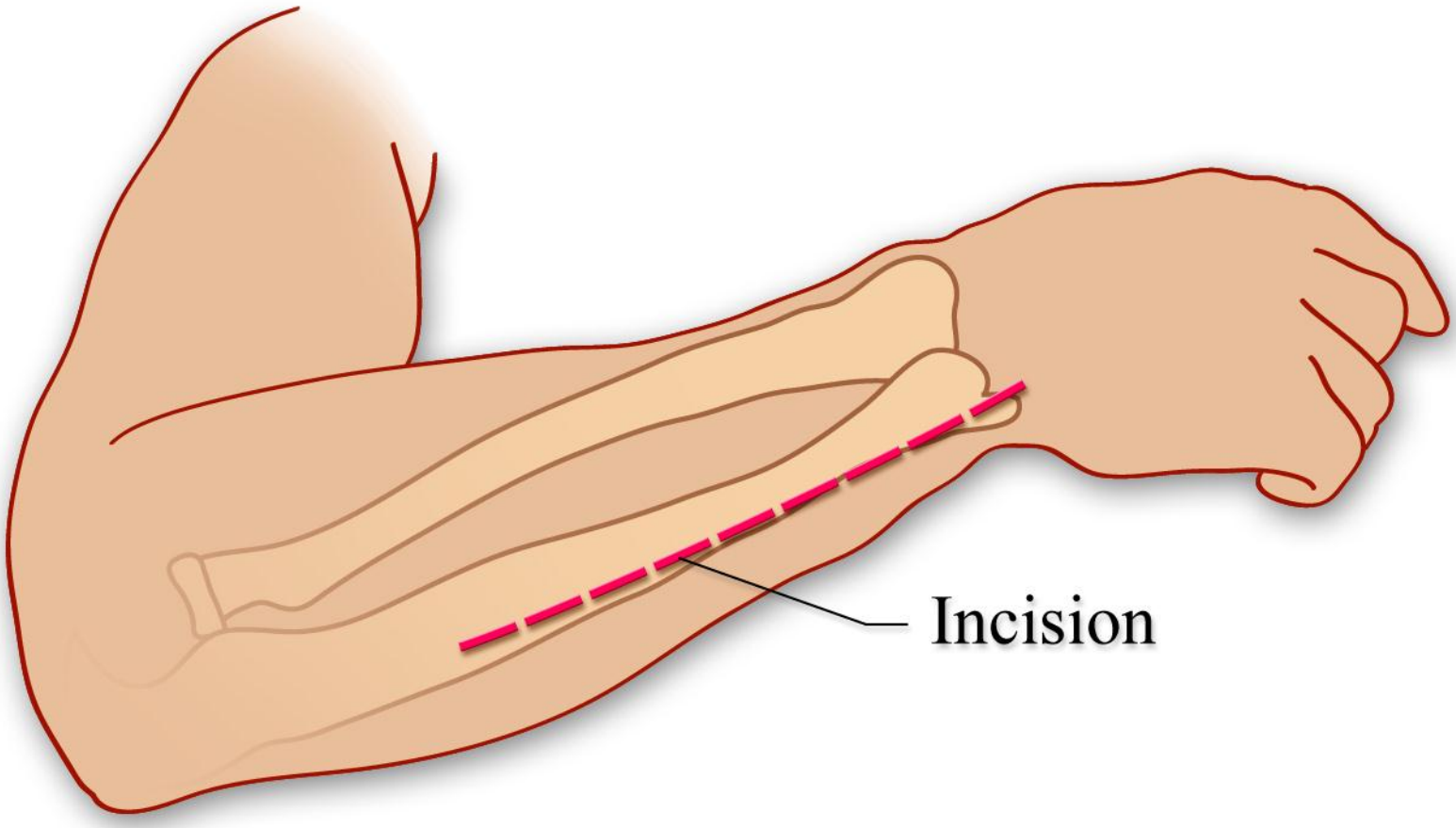


- 6 month follow-up:

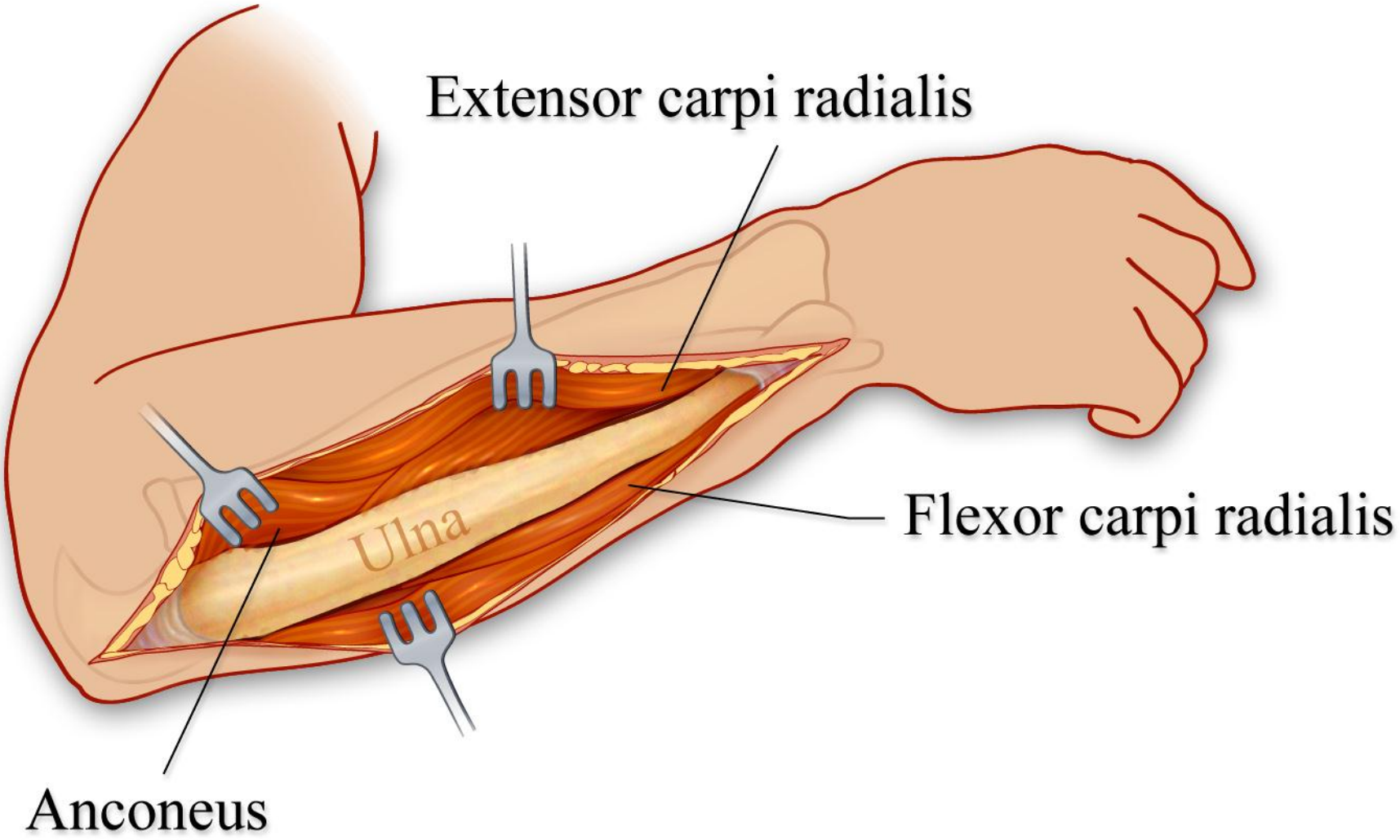
Surgical Approaches

- Ulna is approached along its subcutaneous border
  - the skin incision is made over muscle instead of bone either slightly anterior or posterior
  - a wide skin bridge should be maintained from the radial wound
  - deep dissection is between flexor carpi ulnaris and extensor carpi ulnaris

Ulna Approach



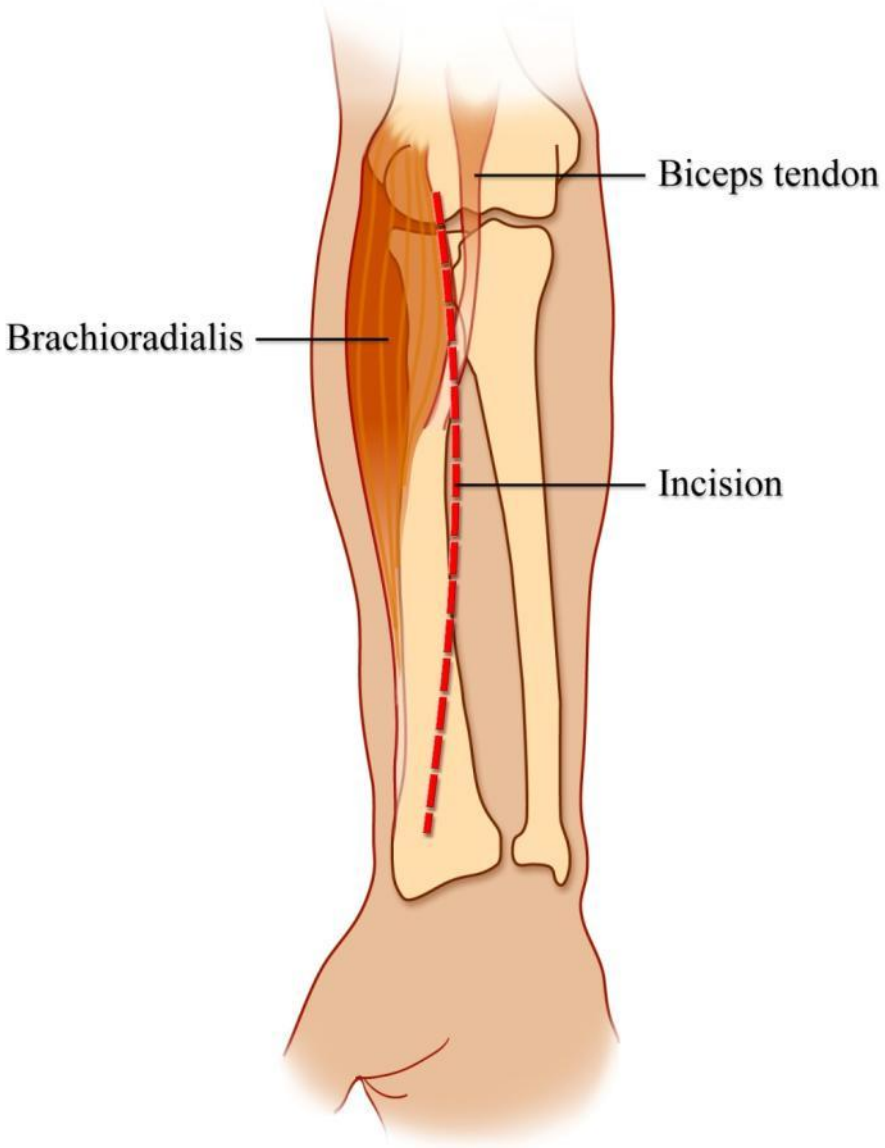
Ulna Approach



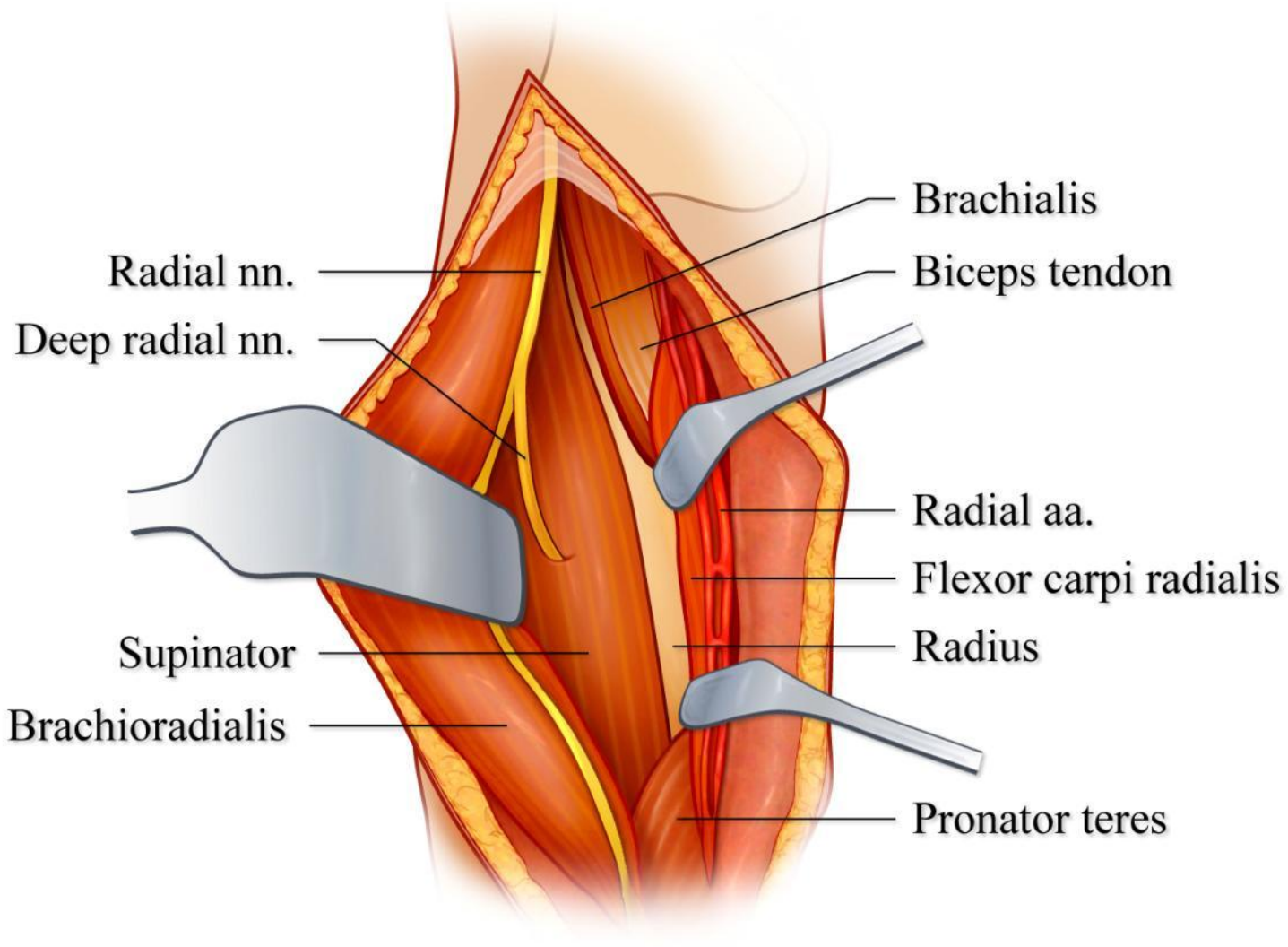
Surgical Approaches

- Radius is approached anteriorly for most distal fractures:
  - Anterior Approach:
    - Beware of Sensory Branch of Radial Nerve
    - Tendons of flexor carpi radialis & flexor pollicis longus are retracted ulnarly, while the radial artery is retracted radially

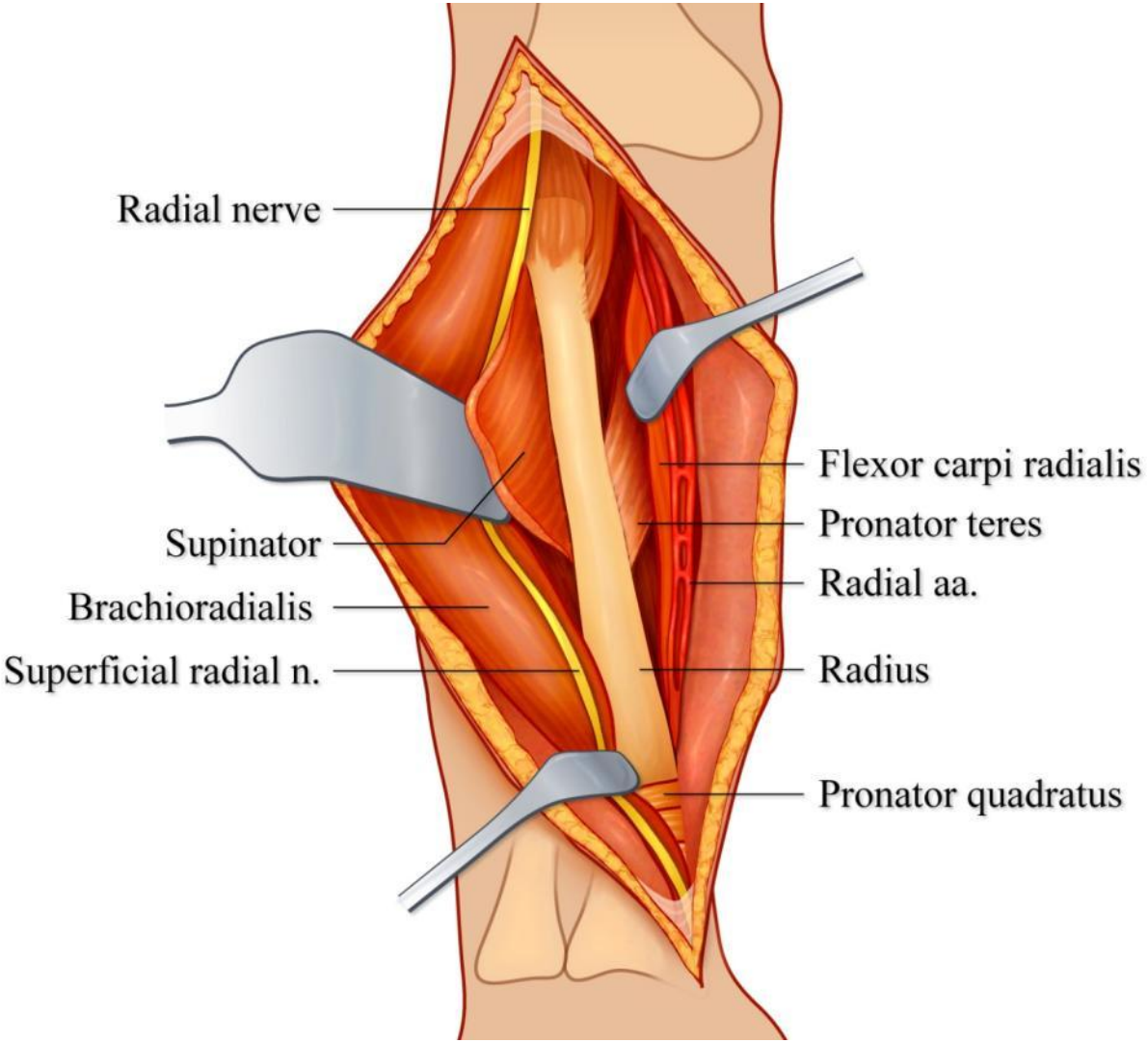
Anterior Approach to the Radius



Anterior Approach to the Radius



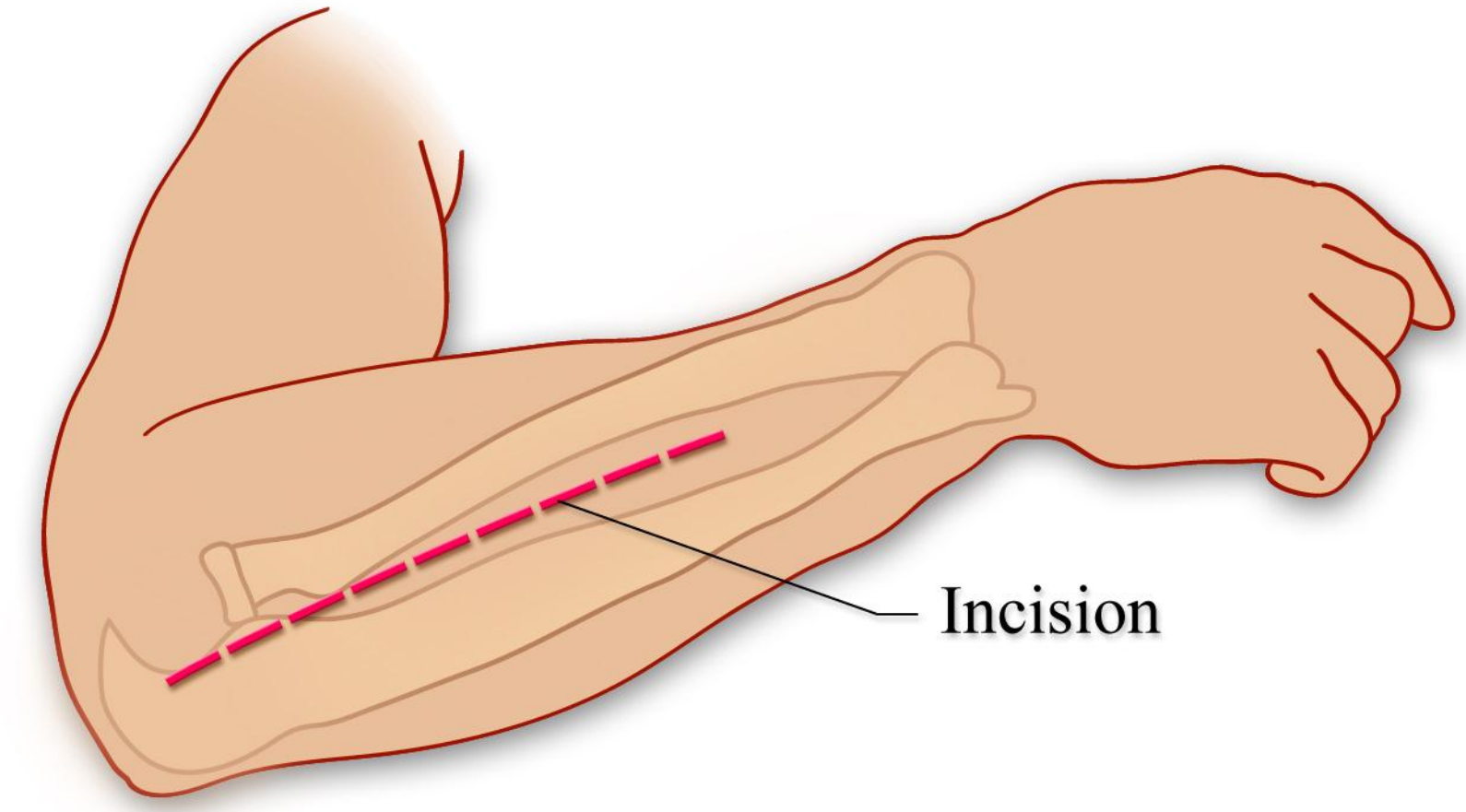
Anterior Approach to the Radius



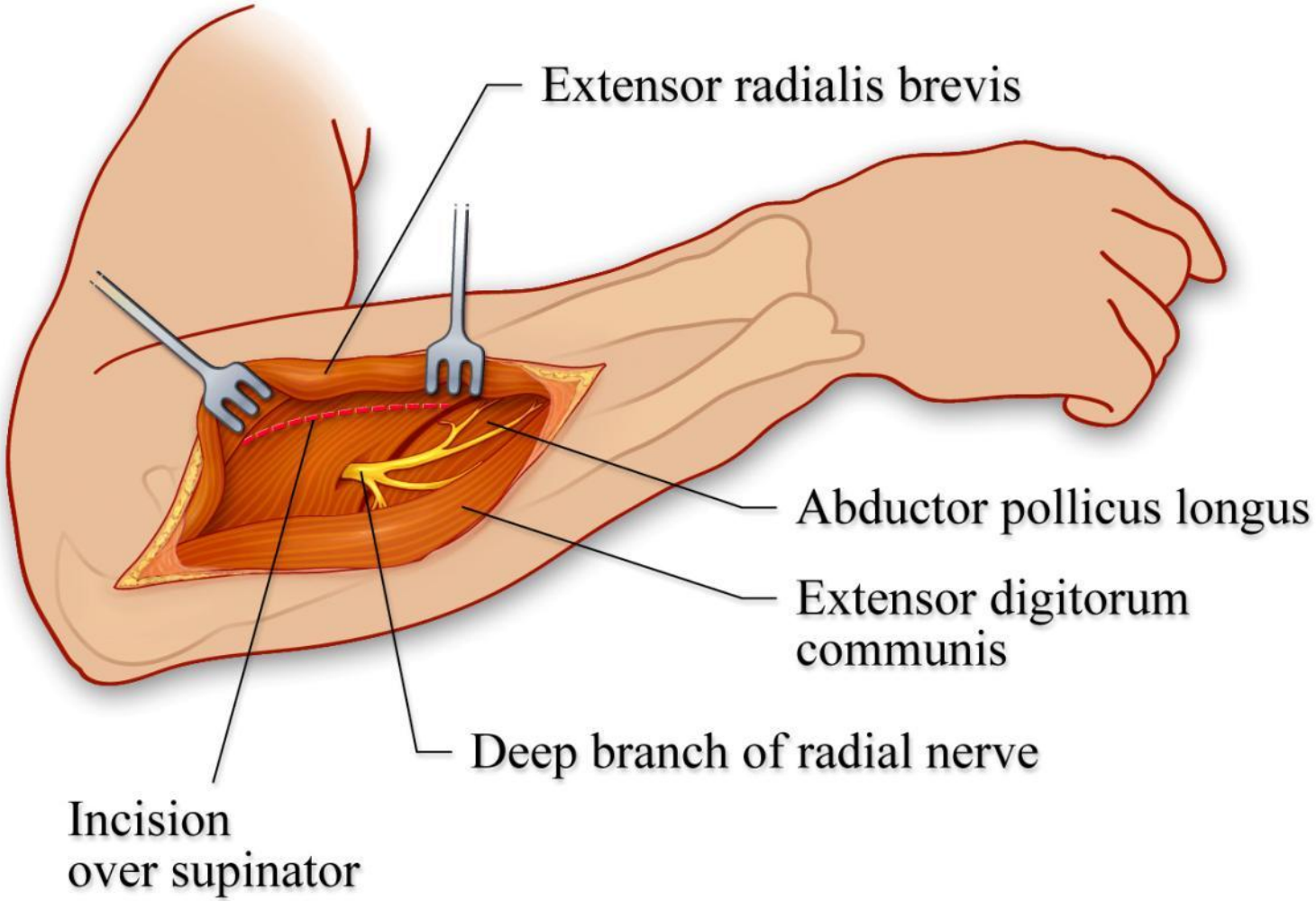
Surgical Approaches

- Radius is approached posteriorly for most proximal fractures
  - Posterior Approach:
    - Distally plates may irritate long thumb abductors
    - Proximally beware of deep branch of radial nerve

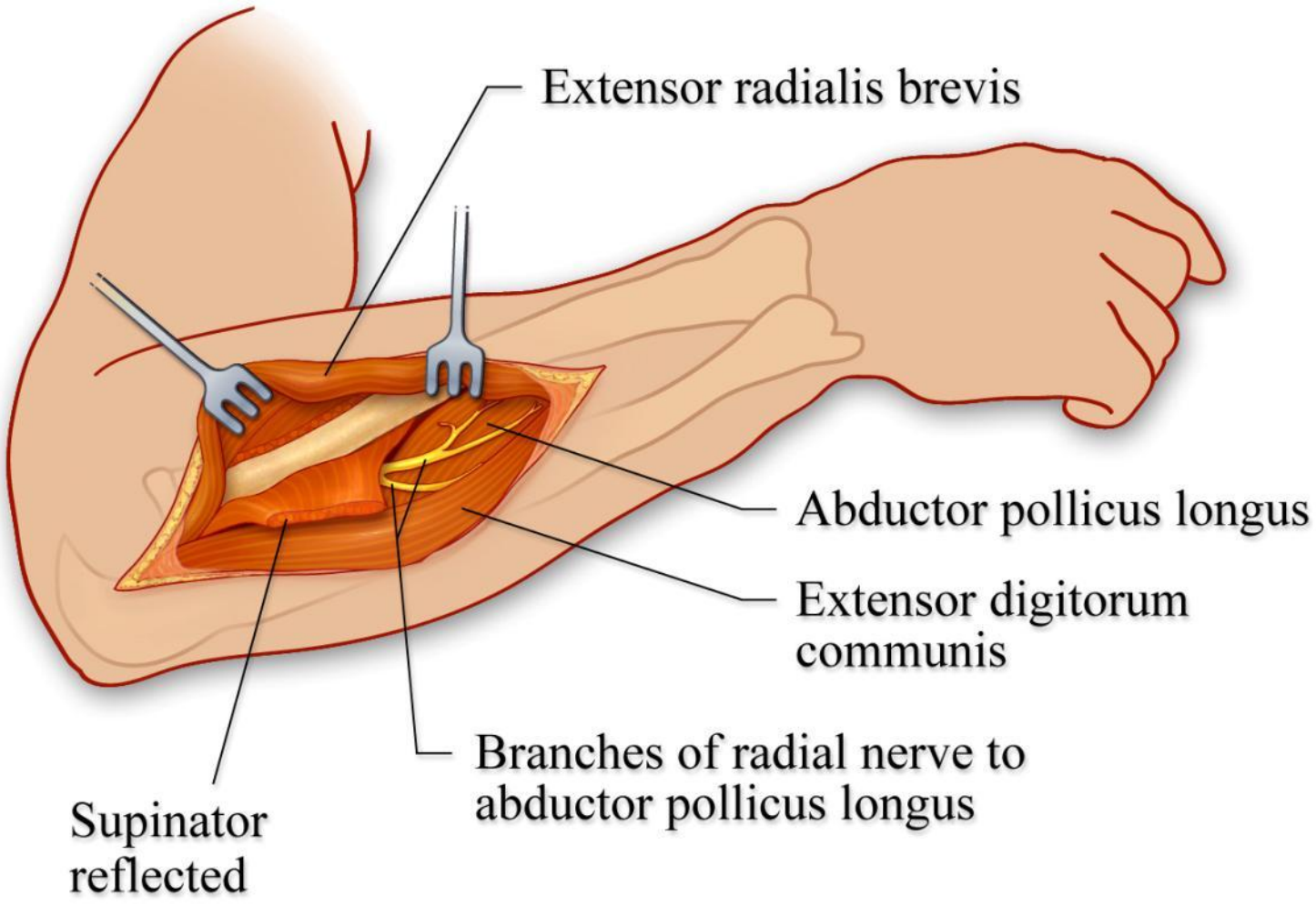
Posterior Approach to the Radius



Posterior Approach to the Radius



Posterior Approach to the Radius



Timing of Surgery

- Early Surgery is Desirable but not Essential
  - Easier reduction especially if shortening
  - Avoids pre-op immobilization
- Delayed Surgery
  - If poor soft tissues
  - If other injuries or medical problems prevent

Special Cases

- Fractures Associated with Joint Disruption
  - Galleazzi Fracture
  - Monteggia Fracture
  - Combined Patterns
- Fractures Associated with other Injury
  - Floating Elbow (Ipsilateral Humerus Fracture)
  - Open Fractures

Fractures Associated with Joint Disruption

Galeazzi & Monteggia

- Best Treatment
  - ORIF w. Plate Fixation of Diaphyseal Fracture
  - Joint Usually Reduces Indirectly and is stable
  - If Unstable: require open reduction of joint
  - If irreducible – it is usually because the diaphyseal fracture has been mal-reduced

Galeazzi Fractures

- Classic: Fracture of distal 1/3 radial shaft with Dislocation Distal Radioulnar Joint

- Variants: Fracture can occur anywhere along the radius or associated with fractures of both bones with DRUJ disruption

Galleazzi Fractures

Radiographic Signs of DRUJ Injury

- Fracture at Base of Ulnar Styloi
- Widened DRUJ on AP x-ray
- Subluxed Ulna on Lateral x-ray
- >5 mm Radial Shortening
- Radius Fracture < 7.5cm from the wrist joint
  - (unstable DRUJ in 55%)

Galleazi Fracture

Case Example

- Galleazi Fracture:
  - Distal Radius Fracture with Disruption DRUJ
- Goals: Restore Length & alignment
- Treatment options?

- AP & Lateral Injury:

Galleazi Fracture

Case Example

- Galleazi fracture is best treated with ORIF
- Volar approach is preferred
- DRUJ was stable after reduction so did not require separate fixation

- 3 month follow-up:

Galleazzi Fractures

- Always require Plate fixation of the Radius
  - Distal Medullary canal too wide/funnel shaped for intramedullary fixation
  - Sometimes require temporary pin fixation of DRUJ or repair of the ulnar styloid when fractured
- Postop:
  - If DRUJ stable – early motion
  - If DRUJ unstable – immobilize forearm in supination for 4-6 weeks in a long arm splint or cast
  - DRUJ pins are removed at 6-8 weeks

Galeazzi fractures

- May be associated damage to triangular fibrocartilage, which may require early or late repair with open or arthroscopic techniques

  - Can Occur with Low Velocity Gunshots
    - Lenihan, MR et al J.O.T. 1992:6:32-35.

Monteggia Fractures

Classic: Fracture of Proximal 1/3 Ulna with Dislocation of Radial Head

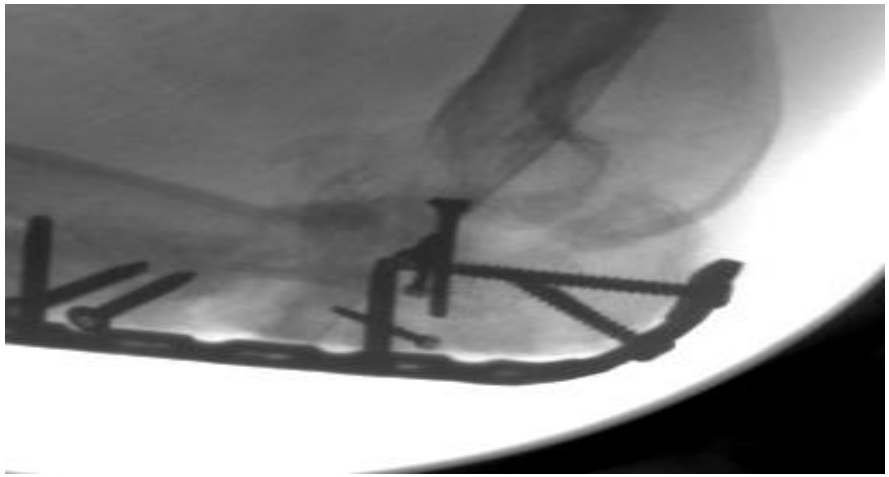
Type	%	Description	Example
I	60%	Both Anterior: Dislocation Radial Head & Angulation Ulna Fracture: Equivalent: Radial Head or Neck fractured	
II	20%	Both Posterior: Dislocation Radial Head + Angulation Ulna Equivalent: Posterior Elbow Dx.	
III	15%	Lateral Dislocation Radial Head + Any Fracture of Proximal Ulna	
IV	5%	Anterior Dislocation Radial Head + Fractures Proximal Shafts of Both Bones are at the same level	

Monteggia Type I

Type	%	Description
I	60%	Both Anterior: Dislocation Radial Head & Angulation Ulna Fracture: Equivalent: Radial Head or Neck fractured

Monteggia Type II

Type	%	Description
II	20 %	Both Posterior: Dislocation Radial Head + Angulation Ulna Equivalent: Posterior Elbow Dx.



Monteggia Type III

Type	%	Description
III	15%	Lateral Dislocation Radial Head + Any Fracture of Proximal Ulna

Monteggia Type IV

Type	%	Description
IV	5%	Anterior Dislocation Radial Head + Fractures Proximal Shafts of Both Bones are at the same level

Monteggia Fractures

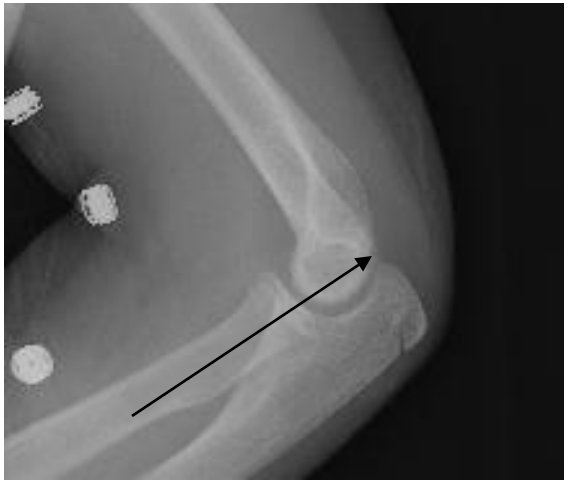
Radiographic Findings:

Normal:

- Line Drawn through Radial Head & Shaft should always line up with Capitellum
- Supinated Lateral: lines drawn tangential to head anteriorly and posteriorly should enclose the Capitellum

Monteggia Fracture:

These radiographic findings are disrupted



Monteggia Fractures

- After fixation of the ulna, the radial head is usually stable (>90%)
- If open reduction is required for the radial head, the annular ligament is repaired
  - Failure of the radial head to reduce with ulnar reduction is usually due to interposed annular ligament or rarely the radial nerve
- Associated Radial Head Fractures may require fixation

Monteggia Fractures

- Postoperative treatment depends on rigidity of ulnar fixation and stability of the radial head
  - Casting with more than 90 degrees of elbow flexion is rarely needed to maintain the radial head reduction (6 weeks)

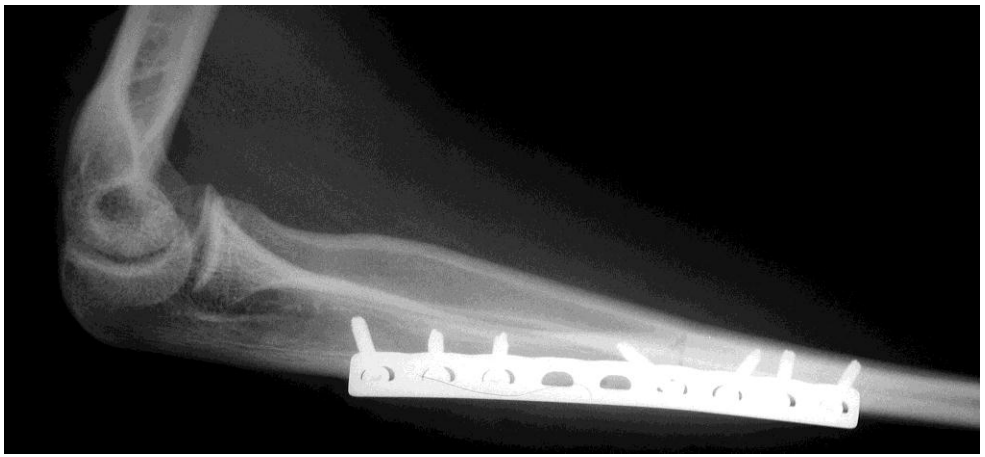
Monteggia Fractures

Case Example

- 25 y/o male with ulnar fracture & radial head dislocation after fall

- Treatment requires stable fixation of the ulna & reduction of the radius

- 



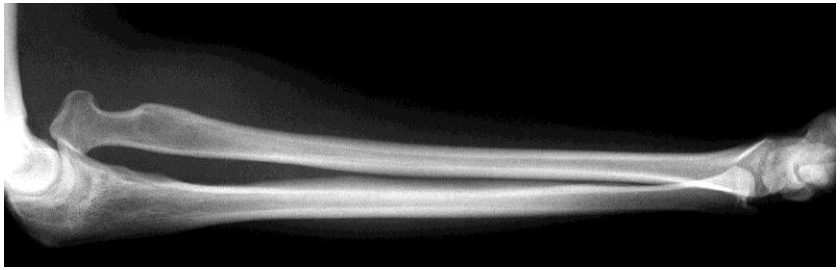
Monteggia Fractures

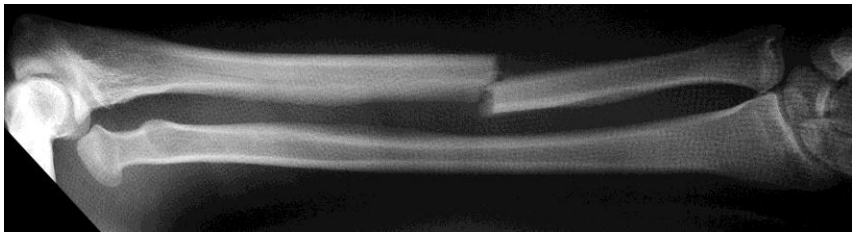
Case Example

- 20y/o with previous stiff elbow, presents with forearm pain after a fall.

- Is this a Monteggia fracture?

- Injury:





Monteggia Fractures

Case Example

- Patient had previous radial head dislocation.
- Treatment Options?
- X-rays from 2 years previously:

Monteggia Fractures

Case Example

- With congenital or old radial head dislocation, treatment is directed toward the shaft fracture. Attempted open reduction of the radial head will not succeed.

- 4 months postop.

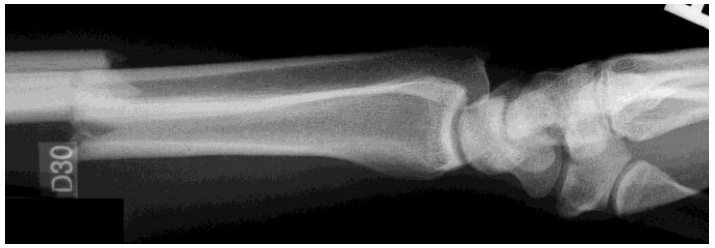
Combined Patterns

Case Example

- Remember that fracture patterns can be combined.

- Example:
  24 y/o male presented with both bone forearm fracture & distal radioulnar joint disruption after a fall on ice

- Injury:

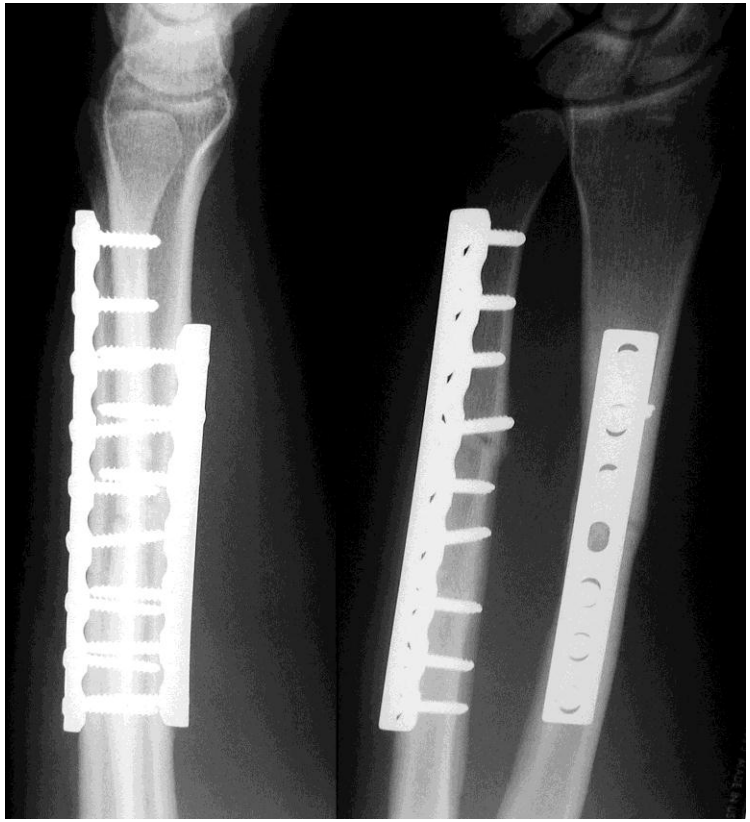


Combined Patterns

Case Example

- Despite anatomic internal fixation, this patient required later arthroscopy and repair of a triangular fibrocartilage tear

- 3 months postop:



Floating Elbow Injuries

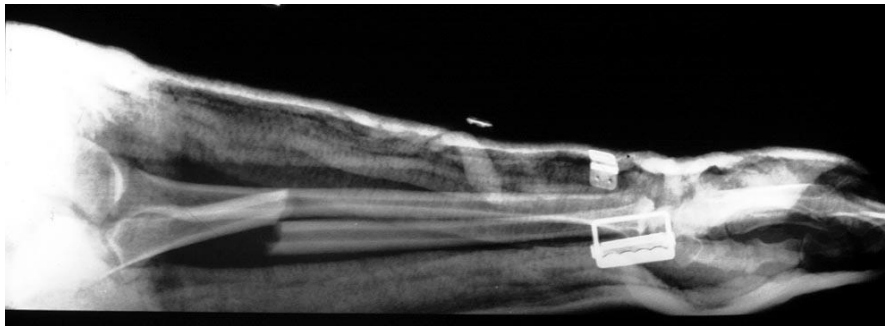
- Associated Ipsilateral Forearm & Humerus Fractures
  - Severe High Energy Injuries
  - Best Outcome with Fixation of Both Levels
  - High Incidence of Malunion & Nonunion or other complications

Floating Elbow

Case Example

- 25 year old male transferred from another hospital after a motor vehicle accident with a diagnosis of "ulna fracture"
- What's Wrong with this picture?

- Presenting x-ray



Floating Elbow

Case Example

- Initial x-rays were inadequate:
  - Always obtain the joint above & below
  - Must see the relation of the capitellum & radial head on all views
  - Don’t let Plaster obscure details
- Treatment?

- Repeat x-rays showing a floating elbow & Monteggia fracture

Floating Elbow

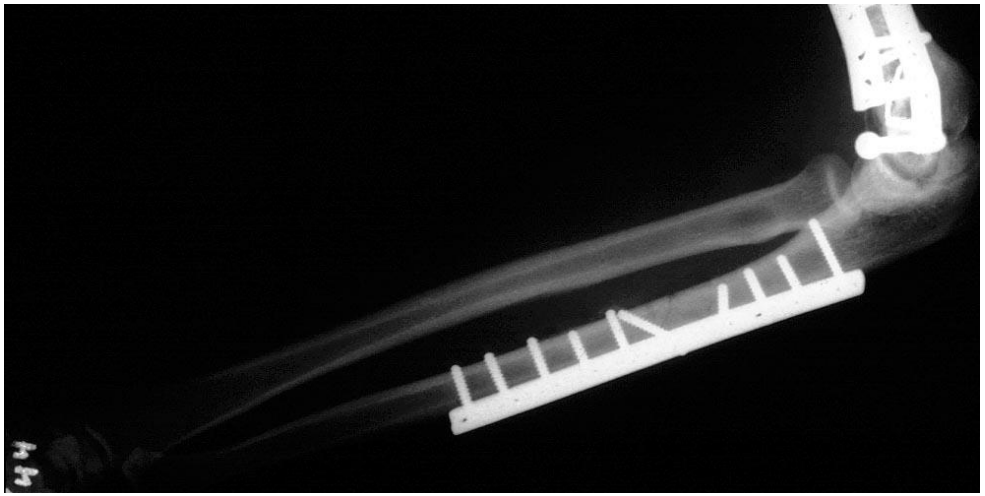
Case Example

- Treatment of a Floating Elbow Requires Fixation of Both Fractures

- AP & Lat

  At 2 yr f/u

- Teaching Points:
  - Get adequate x-rays
  - Obtain stable fixation of both fractures



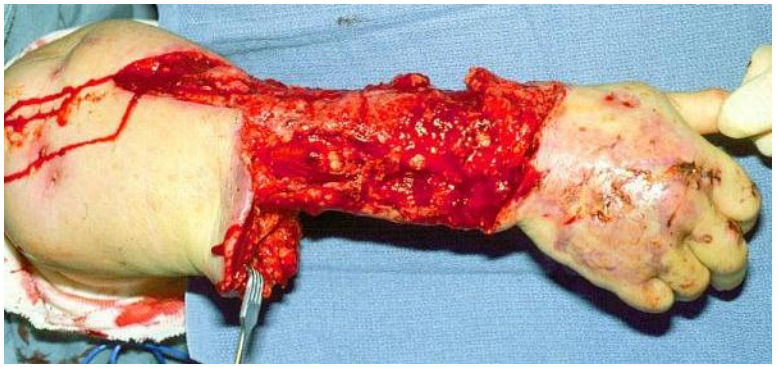
Open Fractures

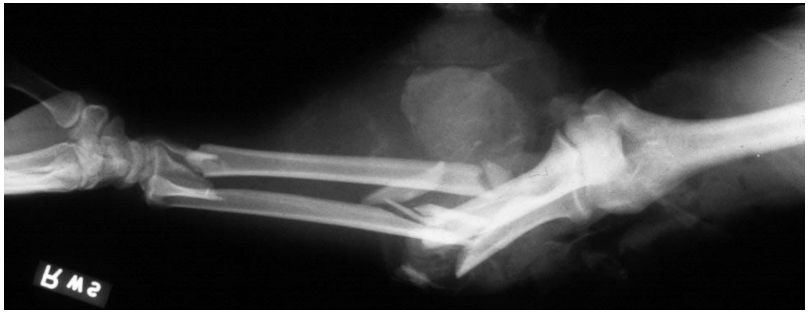
- Emergencies
- Require Irrigation/Debridement, Antibiotics
- Immediate Stabilization of Both Bones
  - Grades I, II, IIIA – immediate ORIF with plates
  - Grades IIIB, IIIC – consider external fixation

Open Forearm Fractures

Case Example

- 50y/o female s/p conveyor belt injury
- Segmental both bone forearm fracture with severe crush & skin loss, & contaminated
- Treatment Options?
- Priorities?





Open Forearm Fractures

Case Example

- Priority was soft tissue management in this Grade IIIB open injury
- Initial Treatment was External Fixation to maintain length & alignment

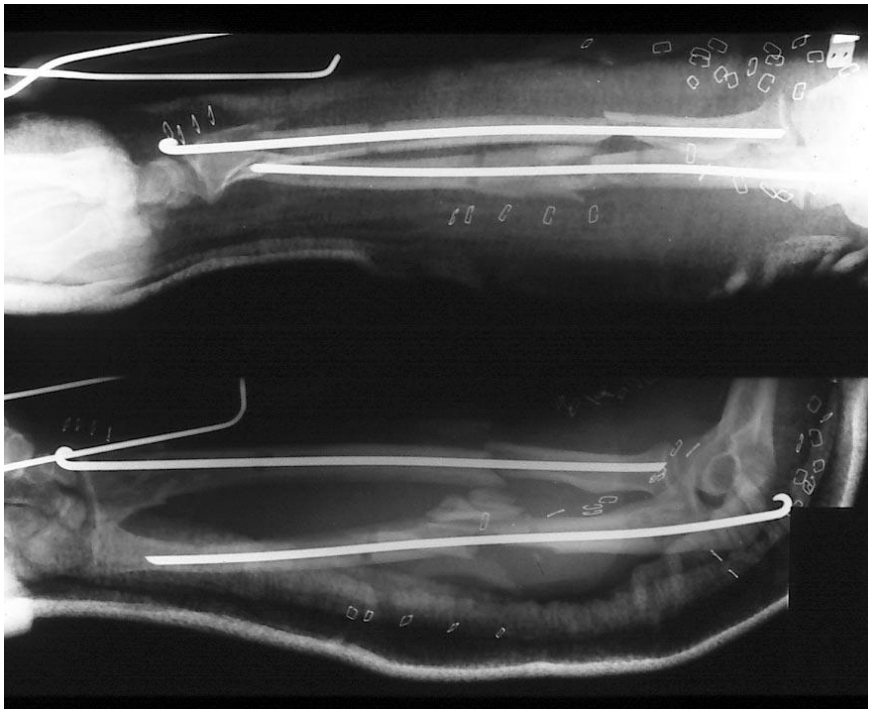
Initial External Fixation

- After multiple debridements, wounds were “clean” & soft tissue coverage was obtained with cross-abdominal flap
- Next Treatment Step?

Open Forearm Fractures

Case Example

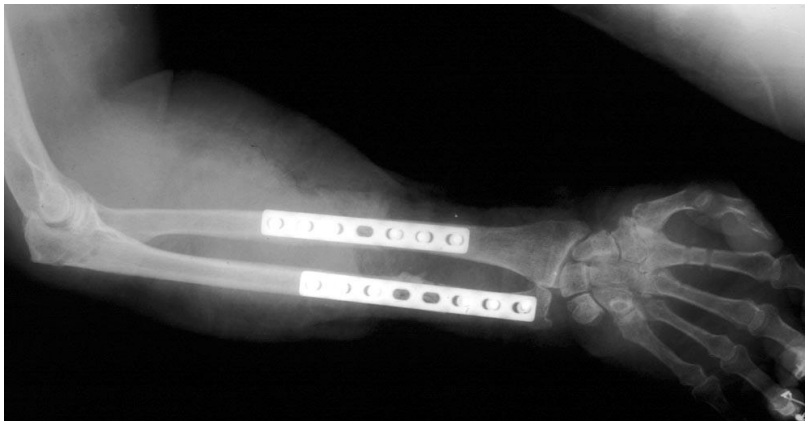
- Intramedullary Fixation at time of Plastics Closure to avoid further disruption of periosteal blood supply
- However, both fractures went on to nonunion. Why?
- Further treatment options?

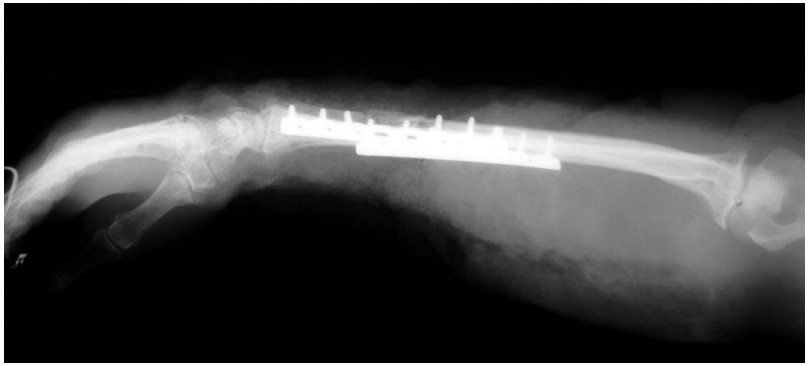


Open Forearm Fractures

Case Example

- Nonunion due to traumatic soft tissue damage & lack of stable fixation from the IM rods
- Both Bones healed with Plate Fixation
- But deep infection developed on radial side
- Treatment?



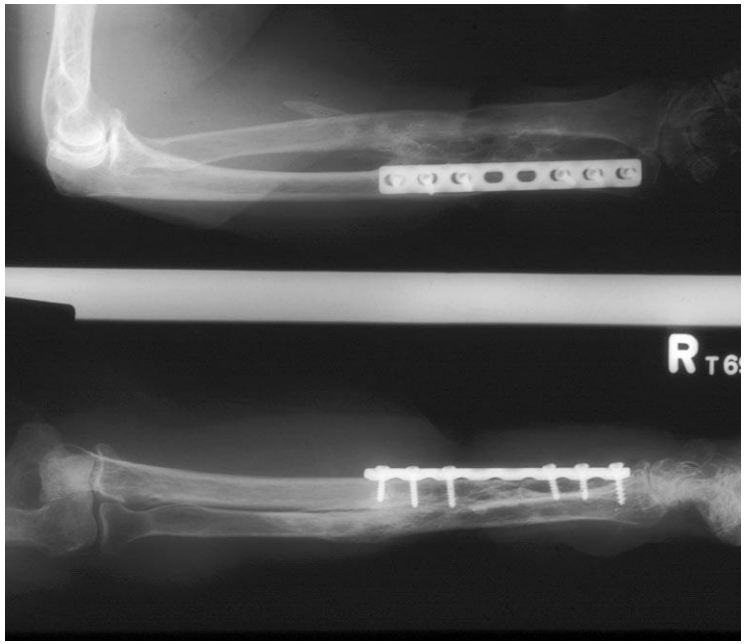


Open Forearm Fractures

Case Example

- Removal of Radial Plate & Debridement was successful
- Teaching Points:
  - Open Fractures require aggressive wound care
  - Temporary External Fixation should be replaced by Stable Internal Fixation

- 3 year follow-up:
  - Useful hand/elbow
  - Stiff forearm
  - No sign of infection



GunShot Wounds

- Low Velocity Gunshot wounds
  - do not require formal debridement (except entry/exit wounds)
  - Higher incidence of neurovascular injury, compartment syndrome, & technical difficulties due to increased comminution
  - Treatment is Open Reduction Internal Fixation (Plates)
- High Velocity Gunshot Wounds
  - Managed as Grade IIIB injuries
  - Require formal debridement
  - Higher incidence of complications

GunShot Injuries

Case Example

- 20y/o male –elbow entry wound
- Injury X-rays:

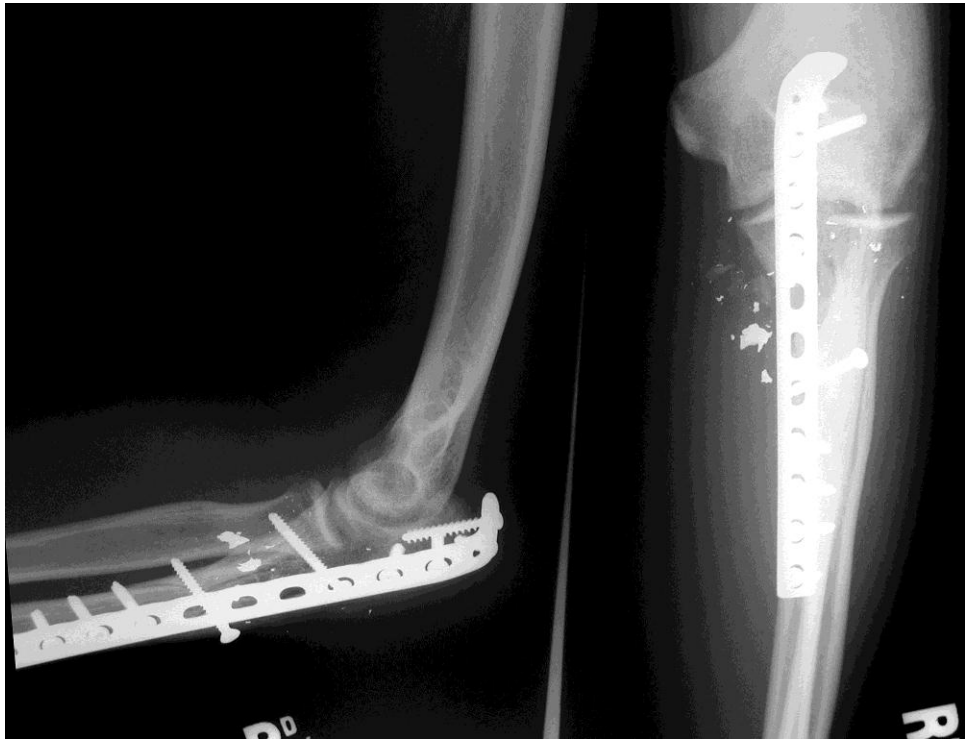
- Treatment Op[illegible]

GunShot Injuries

Case Example

- Although most gunshot wounds do not require formal debridement, operative I&D with ORIF allowed early motion & decreased the risk of infection of the exposed subcutaneous bone

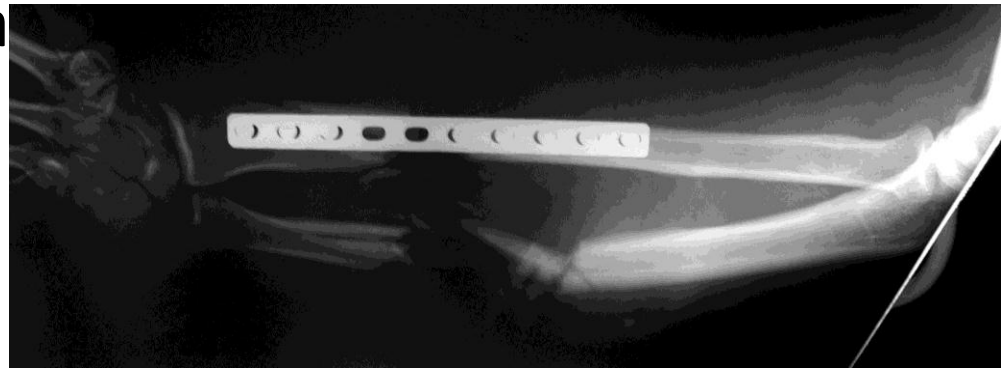
- 6 month follow-up:



Bone Loss after Forearm Fracture

Case Example

- 30 year old worker who caught his forearm in a machine

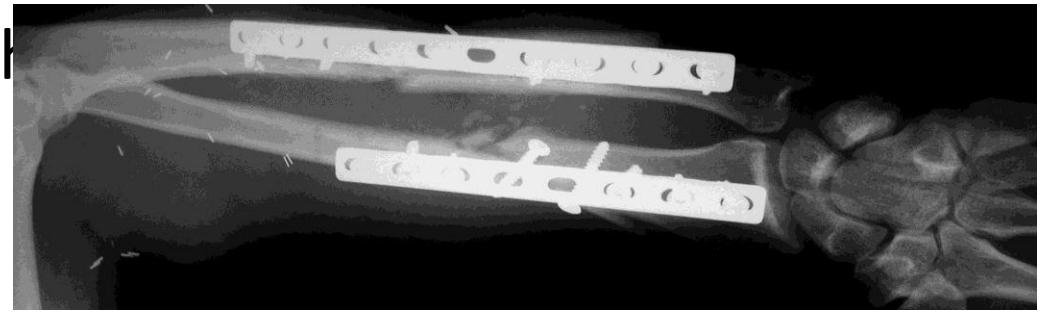


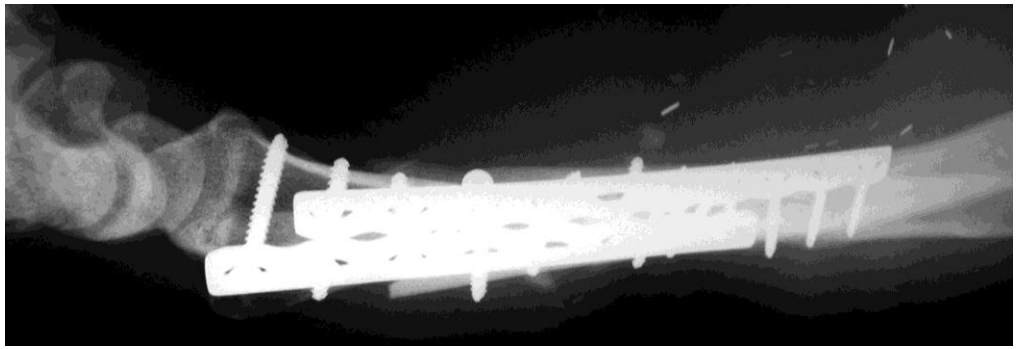
- Treatment options?

Bone Loss after Forearm Fracture

Case Example

- After multiple irrigation & debridements, ORIF was accomplished with a vascularized free fibula to fill the gap





Postoperative Treatment of Forearm Fractures

- Rehab when wound is healed with early active motion depending on type of fracture and rigidity of fixation
- Average time to union is 8-12 weeks

Outcomes after Forearm Fractures

Best Results with Anatomic Reduction that is Stable Enough for Early Motion

- Closed Fractures: Expect
  - 98% Union, 3% infection, 92% good function
    - Chapman, M et al: JBJS 1989:71A:159-69
  - 96% Union, >85% good function
    - Anderson, LD et al: JBJS 1975:57A:287-97
- Open Fractures: Expect
  - 93% Union, 4% infection, 85% good function
    - Moed, BR et al: JBJS 1986:68A:1008-17

Outcomes after Forearm Fractures

- “Stabilization with internal plate fixation following fracture of both bones of the **forearm** restores nearly normal anatomy and motion. However, a moderate reduction in the strength of the **forearm**, the wrist, and grip should be expected following this injury. Perceived disability as measured with the DASH and SF-36 questionnaires is determined by pain more than by objective physical impairment.”
- Kurt P. Droll, Philip Perna, Jeff Potter, Elaine Harniman, Emil H. Schemitsch, and Michael D. McKee
  Outcomes Following Plate Fixation of **Fractures** of Both Bones of the **Forearm** in Adults
  J. Bone Joint Surg. Am., Dec 2007; 89: 2619 - 2624**.**

Complications of Forearm Fractures

- Early
  - Compartment Syndrome
  - Neurovascular Injury
  - Infection
- Late
  - Nonunion/Hardware Failure
  - Infection
  - Malunion
  - Synostosis
  - Persistent Pain

Compartment Syndrome after Forearm Fractures

- Usually Due to High Energy Trauma/Crush
  - Can Occur with Low Energy (time related)
  - Can Occur with Gun shot injuries
- Predisposing Factors:
  - Vascular Injury, Coagulopathy, Limb Compression

Compartment Syndrome

- Early Diagnosis Necessary
  - High Index of Suspicion
    - Pain on Passive Stretch
    - Palpable Firmness or Tightness of the Compartment
    - Altered Sensation or Paresthesias
    - <30mmHg difference between compartment pressure and diastolic pressure
  - Early Treatment – Best Chance of Recovery

Compartment Syndrome

- Release all 3 forearm compartments and carpal tunnel
- Prevent iatrogenic Compartment Syndrome
  - By not closing fascia during surgery
  - By obtaining good hemostasis at surgery

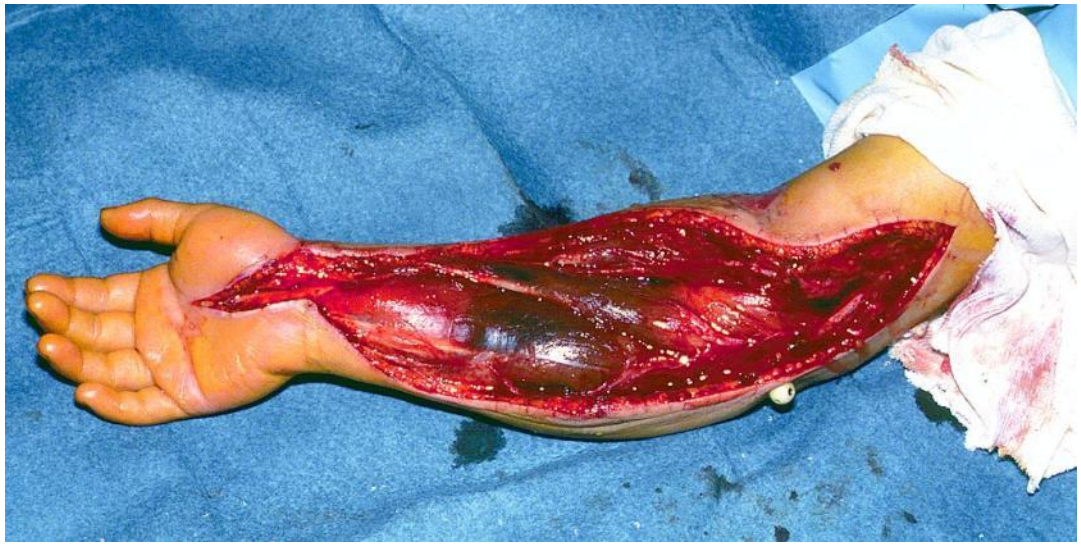
Compartment Syndrome

Case Example

- Benign Fracture

- Don’t Miss Compartment Syndromes!

- Horrible Result



Neurovascular Injury after Forearm Fracture

- Not Common unless open fracture
- Can be iatrogenic!
  - Posterior Interosseous Nerve injury with proximal radius approaches
  - Superficial Radial Nerve injury with anterior radius approaches
  - Anterior Interosseous Nerve injury during reduction of the radius
- If no recovery, explore nerve at 3 months

Infection after Forearm Fractures

- **Acute Infection:**
  - Irrigation & Debridement/ IV antibiotics
  - Maintain hardware if not loose

- **Late Infection:**
  - Irrigation & Debridement/ IV antibiotics
  - Replace failed hardware with cast or external fixator
  - Repeat Internal Fixation when infection cleared

Malunion after Forearm Fractures

There is Loss of Motion with >10 degrees of angulation

Decreased Grip Strength occurs with loss of the radial bow

- Schemitsch, EH & Richards RR JBJS 1992:74A:1068-78

- Treatment of Malunion is Osteotomy and Repair

Synostosis after Forearm Fracture

- Incidence: 1-8%
- Risks:
  - fracture of both bones at the same level,
  - closed head injury,
  - surgical delay > 2 weeks,
  - single incision,
  - and penetration of the interosseous membrane by bone graft or screws, bone fragments, or surgical instruments

Synostosis after Forearm Fracture

Treatment:

- Resection with interposition spacer
  - Restores motion in 50%
- Timing of resection unclear
  - ?Wait 1 year or until metabolically inactive on bone scan. No longer than 3 years

Synostosis after Forearm Fx

Case Example

20y/o in Motor Vehicle Accident

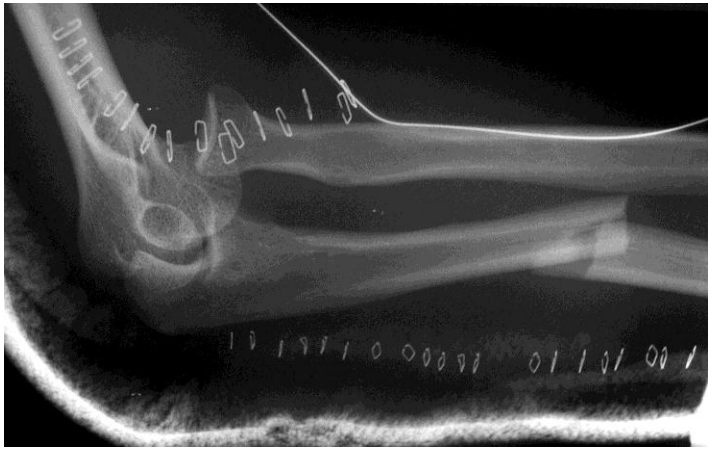
- Head injury
- Failed Attempt at ORIF elsewhere

Treatment included ORIF

Synostosis developed.

Options now?

- Presenting x-ray



- 5 months later

Synostosis after Forearm Fx

Case Example

- Treatment of Synostosis included resection of the bone with interposition fat “spacer” and early motion
- Motion @ 3 months

Persistent Pain after Forearm Fractures

Consider Plate Removal but Complications may Outweigh Benefits

- Should likely Wait 2 years in adults
  - Bone Density Does Not Normalize for 21 months
    - Rossen, JW et al, JBJS 1991:73B:65-7.
  - 4-20% Risk of Refracture
    - Usually through original fracture or screw hole
    - Especially if used too large a plate (4.5 DCP)
    - May be that fracture never healed
  - Infection & Nerve Injury other complications
  - Pain may persist after plate removal

Plate Removal after Forearm Fractures

Benefits may Not Outweigh Risks

- 67% have Residual Symptoms
- 9% patients are worse
  - Including Weather & Exercise Pain
  - Skin or Tendon Irritation

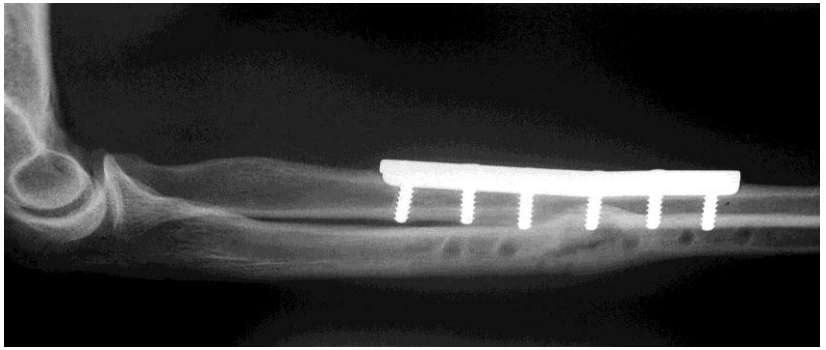
  - Mih, AD et al, CORR 1994:299:256-8

Refracture after Plate Removal

Case Example

- 33y/o female – s/p plate removal one month previously with persistent ulnar pain
- Refracture or Nonunion?
- Was Original Plate Technique Adequate?
- Treatment?

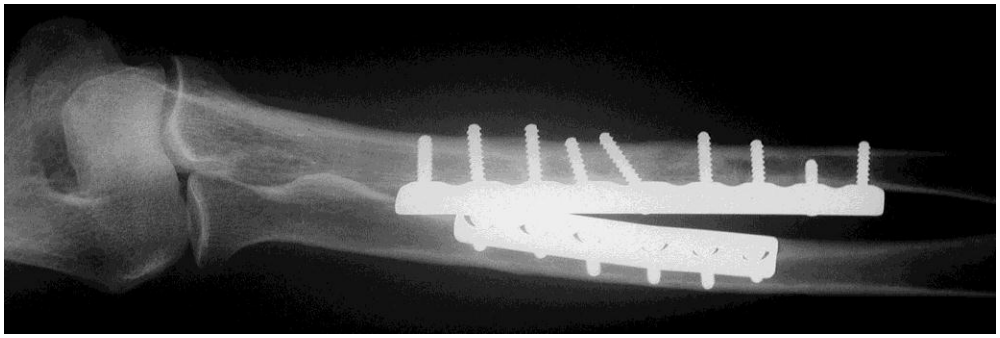
- AP & Lat X-rays

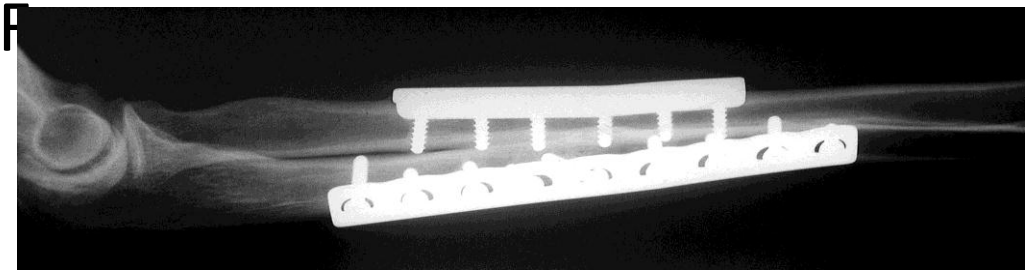


Refracture after Plate Removal

Case Example

- Original Technique was suboptimal
  - as judged by residual screw holes
  - Inadequate number of screws & no lag screw
- Treatment: Repeat ORIF with stable fixation
- 1 year follow-up





Nonunion/Hardware Failure after Forearm Fractures

- Nonunion is usually due to poor BIOMECHANICS
  - Poor Technique
    - Failure to create a stable construct (too few screws, improper compression)
    - Overaggressive iatrogenic damage to soft tissues
  - Poor Initial Fracture Characteristics
    - Open Injury with periosteal stripping
    - Comminuted fracture where interfragmentary compression cannot be achieved

Nonunion

- Aseptic Nonunion
  - Requires revision fracture fixation/bone graft
  - Segmental bone loss is replaced with intercalary bone graft
    - Iliac crest if <3.5cm
    - Consider vascularized fibular graft if >3.5cm

Aseptic Nonunion

Case Example

- 40y/o – “nightstick” fracture treated non-operatively
- Options?
- X-rays 6 months after initial injury

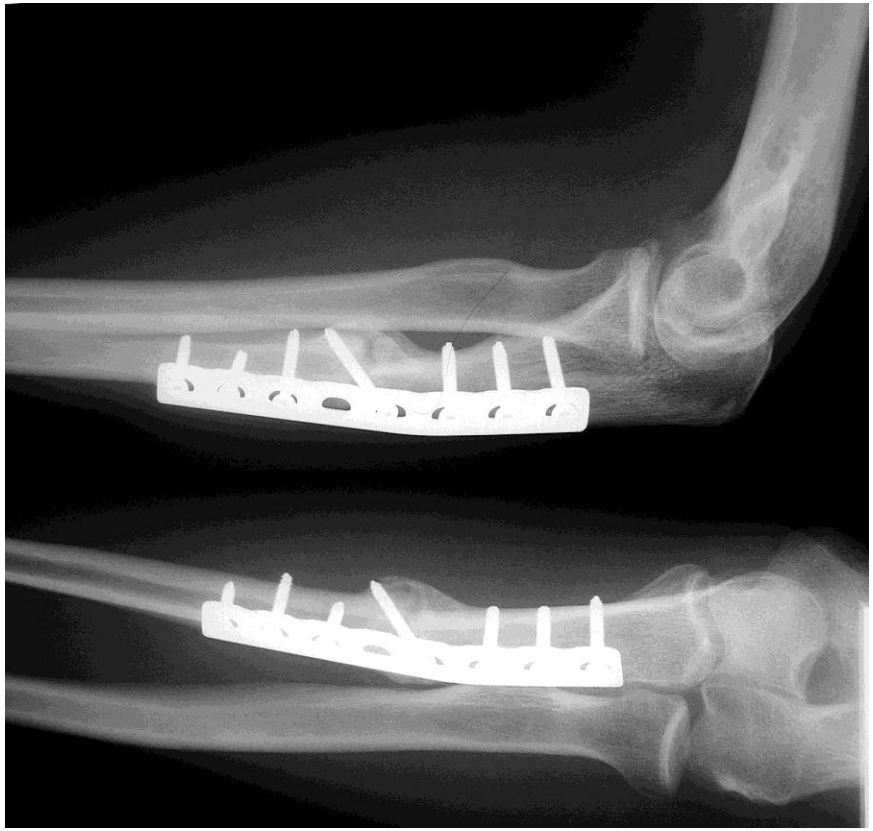
Aseptic Nonunion

Case Example

- Treatment of hypertrophic nonunion requires restoration of mechanical stability

- Treatment with ORIF

- 3 month follow-up



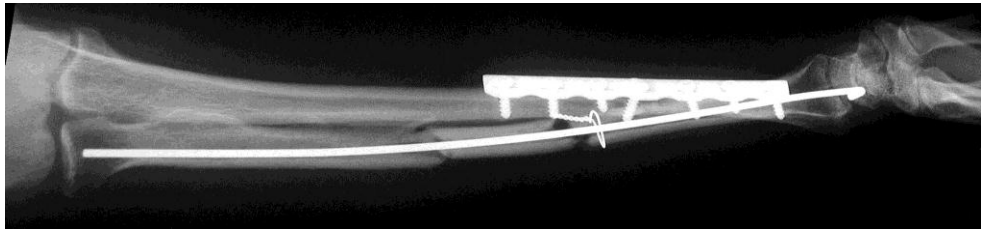
Nonunion

- Infected Nonunion
- Follow the same principles as aseptic nonunion
  - Achieve Mechanical Stability
  - Restore a Viable Biologic Environment
- Also: follow principles of infection control
  - Remove all infected and nonviable material

Infected Nonunion

Case Example

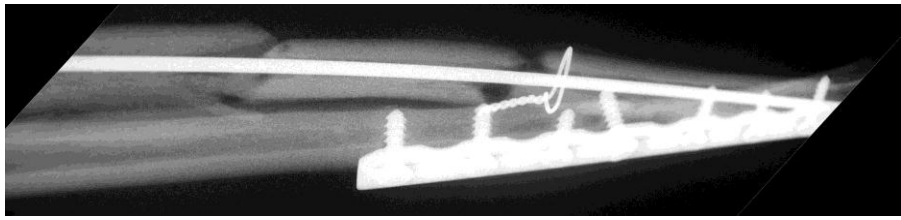
- 56y/o female s/p closed segmental both bone forearm fracture treated with open reduction & intramedullary fixation for the radius, plate fixation for the ulna – now painful & draining
- 5 months post-op



- What are the problems?

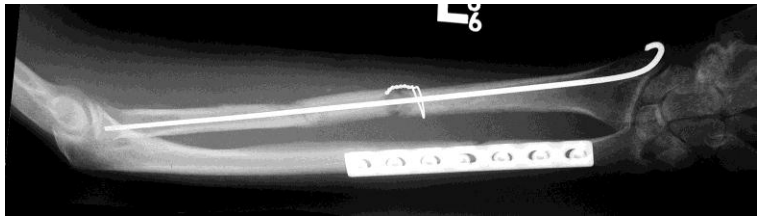
Infected Nonunion

Case Example



- Problem List:
  - Radius: Infected nonunion
  - Distal Radioulnar Incongruity
    - Radius shortened
  - Ulna nonunion
  - Malrotation
    - Lateral elbow & AP forearm

- Treatment?



Infected Nonunion

Case Example

Initial Treatment Was BioMechanically Poor

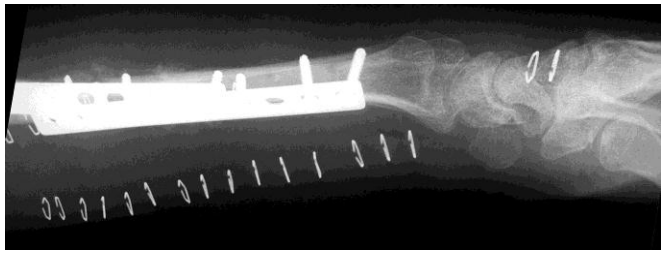
- Biology was not respected – the fracture site was opened, and bone cerclaged implying disruption of periosteal attachments
- Mechanics were not restored – the intramedullary rod did not provide stable fixation

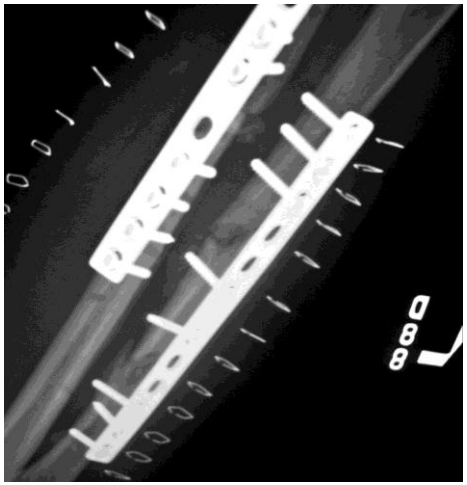
- Treatment of the Nonunion must restore Biomechanics

Infected Nonunion

Case Example

- Treatment:
  - Irrigation/debridement, IV antibiotics for infection
  - Stable Plate internal fixation with realignment to restore rotation.
  - Ulnar shortening to restore DRUJ
  - Bone Grafting at 6 weeks when no sign of active infection





Conclusions for Treating Forearm Fractures

- Achieve Mechanical Stability with Anatomic Reduction & Stable Internal Fixation
- Optimize the Biology of Healing with Anatomic Reduction, Indirect Techniques, & Maintenance of soft tissue attachments

And the Patient will have a Good Result