Treatment of Peri-Implant Fractures of the Femur

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Fractures around Implants

Pose Unique
Fixation
Challenges

Number of Implants in the Femur are Increasing

- Population is Aging
- Joint Replacement - Indicated More Often
- Fracture Fixation - Indicated More Often

Increasing Number of Implants in the Femur

- Over 123,000 Total Hip Replacements
- Over 150,000 Total Knee Replacement

each year in the United States

Numbers Expected To Increase with Aging Population

Increasing Number of Implants in the Femur

- Over 300,000 Hip Fractures

each year in the United States

almost all are treated surgically with internal fixation or prosthetic replacement

As the Number of Implants Placed Increases

the Number of Associated Fractures will Increase

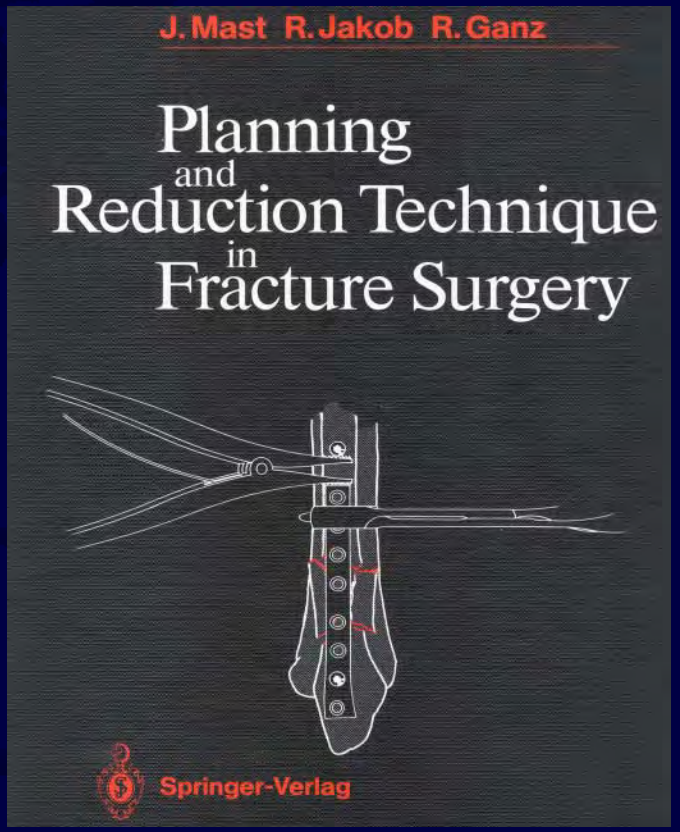
High Mortality after Periprosthetic Hip Fracture

- Mortality following a periprosthetic hip fracture (89% 1-year survival) is:
  - significantly greater than the mortality after primary total hip replacement (97% 1-year survival) in matched patients
  - And statistically similar to the mortality following hip fractures (83.5%)

Pre-Operative Planning

- As with all fracture fixation surgery, pre-operative planning is essential.

- Planning begins with classification
- Templating is extremely valuable
- Surgeon must be sure that he/she has an adequate selection of specialized implants available
  - Including cables, special plates & screws of appropriate size and length



Be Prepared!

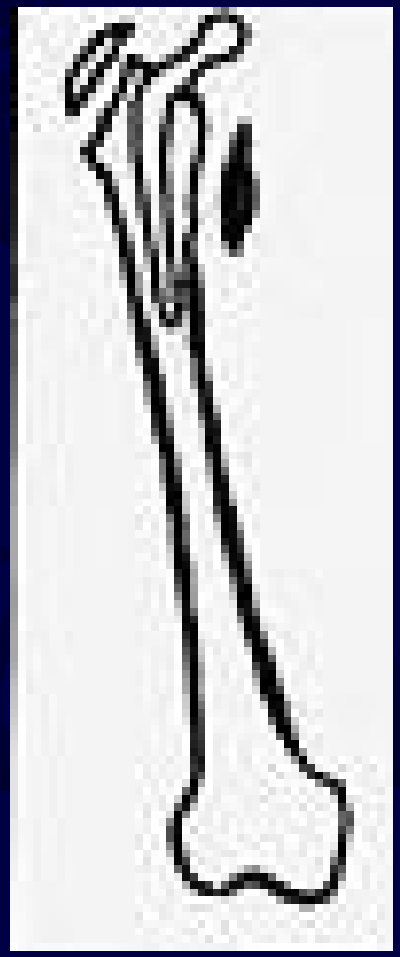
- The surgeon may need to use specialized implants not usually kept “on the shelf” at his/her hospital.
  - Examples include specialized peri-prosthetic screws, claw plates for the greater trochanter, cable systems, and broken screw/implant removal devices

Classification

- The most commonly used classifications for periprosthetic fractures around hip replacements are the Vancouver and AAOS classifications.
- The most commonly used classification for periprosthetic fractures around knee replacements is the Neer classification.

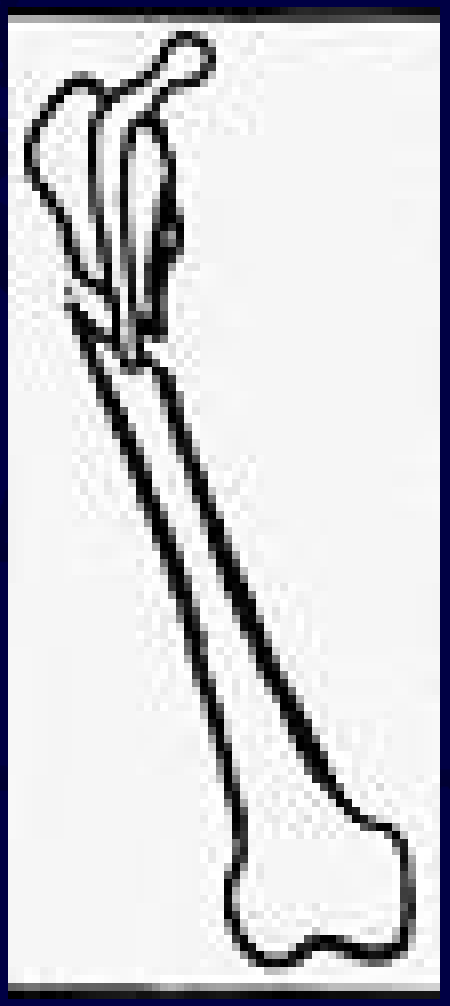
Vancouver Classification of Periprosthetic Hip Replacement Fractures

- Type A:
- Fracture at the trochanters
  - A_L at lesser trochanter
  - A_G at greater trochanter
    - Illustrations from Duncan CP and Masri BA: Fractures of the Femur after hip replacement. Instr Course Lect 44:293-304, 1995



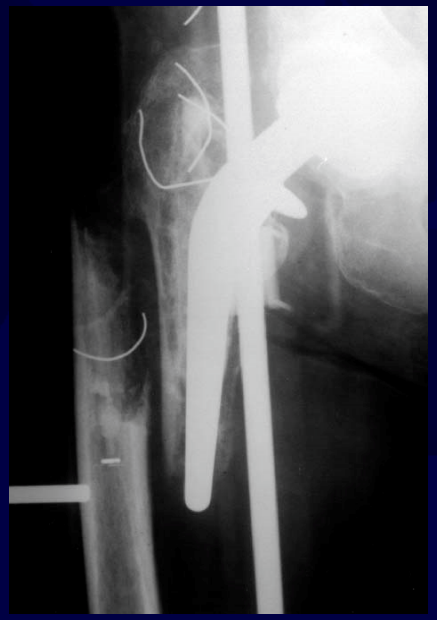
Vancouver Classification of Periprosthetic Hip Replacement Fractures

- Type B1: fracture is around or just below a well-fixed stem



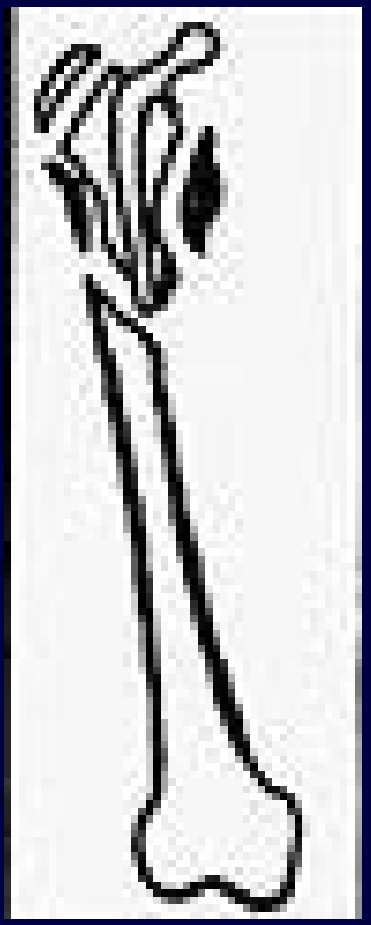
Vancouver Classification of Periprosthetic Hip Replacement Fractures

- B2
  - Fracture is around or just below a loose stem



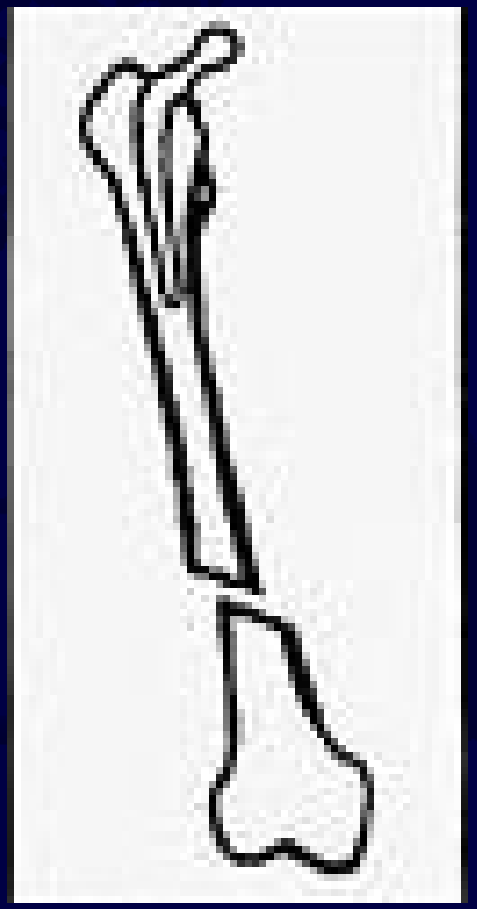
Vancouver Classification of Periprosthetic Hip Replacement Fractures

- B3
  - Fracture is around or just below a stem with poor proximal femoral bone stock



Vancouver Classification of Periprosthetic Hip Replacement Fractures

- Type C
  - Fracture Well Below the Stem



AAOS Classification of PeriProsthetic Hip Fractures

- Level I: (Proximal to Lesser Trochanter)
  - Type I: proximal to the intertrochanteric line
  - Type II: vertical split above lesser trochanter
- Level II: (<10 cm. distal to Lesser Trochanter)
  - Type III: Split below the lesser trochanter
- Level III:(>10 cm. distal to Lesser Trochanter)
  - Type IV: Fracture at the tip of the stem.
    - A: spiral
    - B: short oblique or transverse
  - Type V: Severely comminuted Type III or IV
  - Type VI: Fracture distal to the prosthesis

Neer Classification of Periprosthetic Knee Replacement Fractures

- Type I: Extra-articular or Non-displaced Femur Fx
  - <5mm of displacement or > 5 degrees angulation
- Type II: Extra-articular Femur Fx
  - >5mm of displacement or > 5 degrees angulation
- Type III: Comminuted Femur Fx.
- Type IV: Fractures at the Tip of Stemmed Femoral Prostheses
- Type V: Tibial fracture

Fractures around Implants: Unique Fixation Challenges

- Original Placement of the Implant may predispose to later fracture
- Long Term Presence of the Implant may change the structure of bone and increase susceptibility of fracture
- Implant Itself may interfere with healing or the placement of fixation devices

Peri-Implant Fractures May be Caused by Technical Problems During Implant Placement

Risk Factors for Intra-operative Periprosthetic Fractures

- For patients with hip replacements: increased risk of periprosthetic fracture if:
  - Press-fit implant
    - (larger prosthesis compared to medullary canal)
  - Long Stem implant
    - (mis-match between stem and femoral bow)
  - Revision Procedure
    - (compromised bone stock)
    - (cement removal – 44% risk of intra-operative fracture)
    - (impaction bone grafting techniques 4-32% risk)
  - Limited Incision technique 3% risk
    - (poorer visualization of the anatomy)

Technical Problems during Implant Placement include:

- Notching Anterior Femoral Cortex during Knee Replacement
- Cracking Calcar during Hip Replacement
- Penetrating Shaft during Hip Replacement
- Cracks between Screw Holes during Internal Fixation

Notching Anterior Femoral Cortex During Knee Replacement

May have 40% fracture rate at 8 years

Figgie et. al. J. Arthroplasty 1990

- Incidence of Supracondylar Femur Fracture after Total Knee Replacement:

  .6 to 2.5%

Fracture Associated with Implant Placement

- Fracture of the Femoral Neck may occur with Antegrade Intramedullary Rodding
- Stress Riser at Insertion Site

Calcar May Fracture During Hip Arthroplasty

If the prosthesis or trials are not properly sized

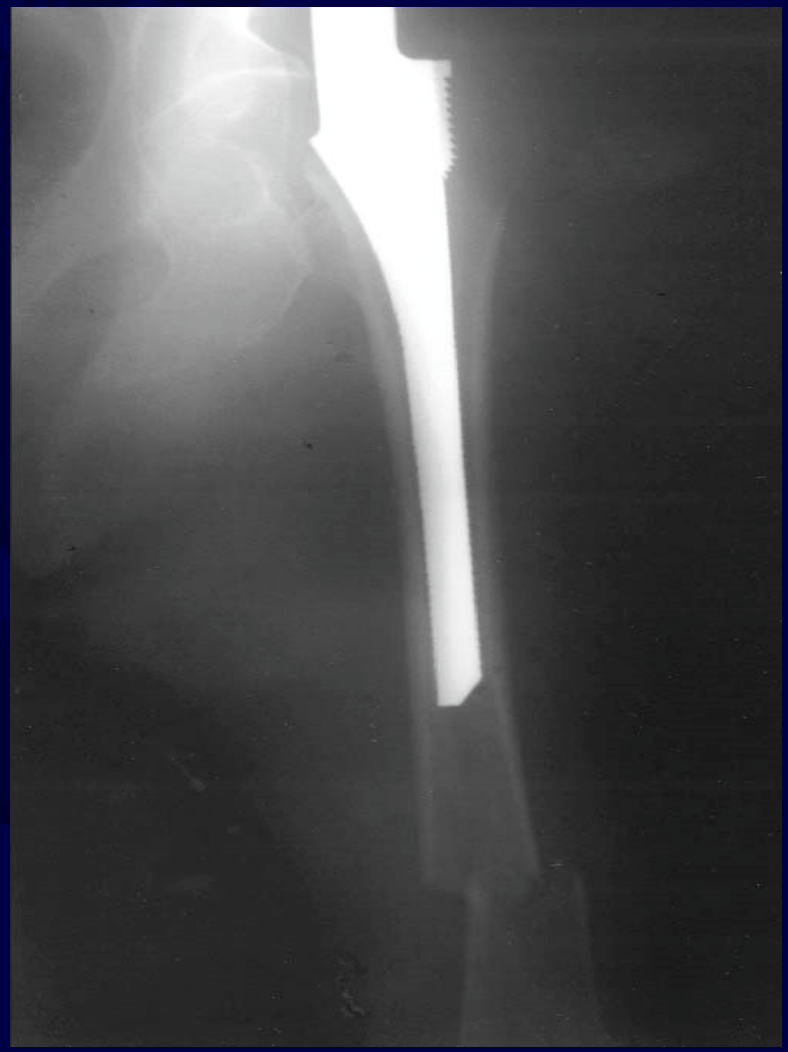
Femoral Stem may Perforate the Femoral Shaft

During

Hip Replacement especially if the femur is bowed

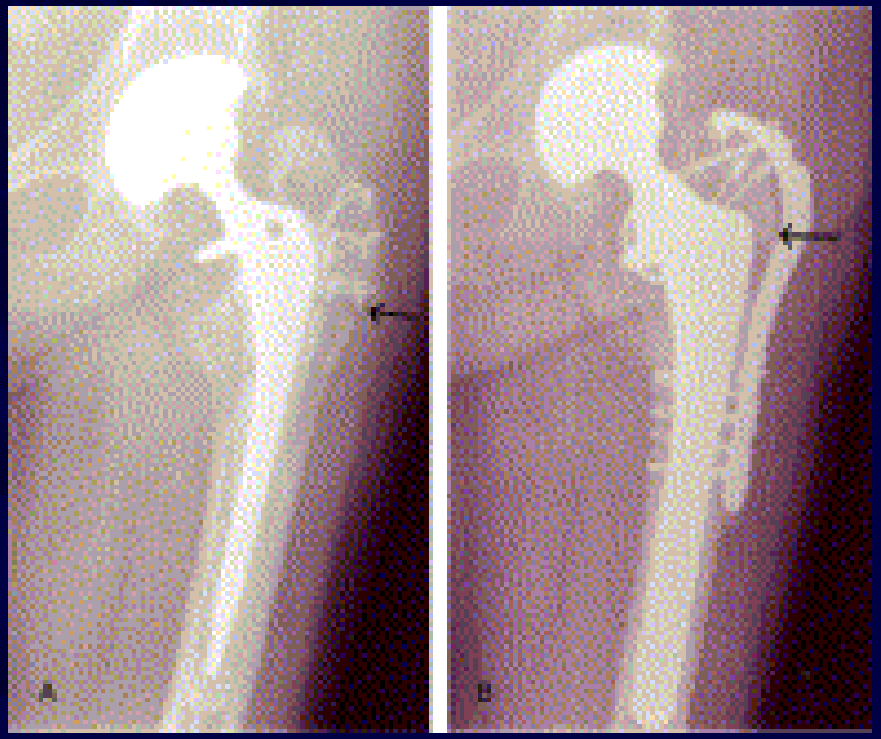
3.5% fracture rate during Primary Total Hip Replacement

Shaw & Greer, 1994



Greater Trochanteric Fracture

- Greater Trochanteric fractures can occur during placement of a total hip prosthesis, during removal, or due to a separate traumatic injury
- Options for fixation include cerclage wires or a claw plate



Zarin, JS, Zurakowski, D, and Burke, DW: J.Arthroplasty. 2009 Feb;24(2):272-80
Claw Plate Fixation of the Greater Trochanter in Revision Total Hip Arthroplasty

The Bone Can Crack Between Screw Holes During Internal Fixation

Especially in osteoporotic bone

Stress Risers During Internal Fixation

- Any Drill Hole up to 20% of the bone's diameter will weaken bone by 40%
  - 90% of fractures around fixation implants occur through a drill hole
  - Koval et. al. 1994

Stress Risers During Internal Fixation

- Fractures Tend to Occur at the End of Implants where weaker bone meets the rigid device

Fractures can occur Postoperatively

- Incidence of 0.6 – 2.5% of hip fractures

Fractures Associated with Implant Removal

- During Prosthetic Revisions
  - 17.6% fracture rate compared to 3.5% during primary hip replacements
  - (5 times the rate for primary hip replacement)
  - through osteoporotic bone or osteolytic defects

Fractures Associated with Implant Removal

- Zickel IM Nails – are associated with Subtrochanteric Fractures after Removal

- Plates Stress Shield
  - Cortical bone - increased rate of fractures after removal (especially forearm)

Problems with Treating Peri-Implant Fractures

- Implants may block new fixation devices
  - Stems, rods, and bone cement may fill the medullary canal preventing IM fixation of fractures
  - Stems and rods may also block screw fixation through the medullary canal to hold plates on bone
- Implants may impair healing due to endosteal ischemia
- Defects in bone from Osteolysis, Osteoporosis, and Implant Motion may compromise fixation

Peri-Implant Fracture Fixation Methods

- Follow Standard Principles of Fixation
- Must Achieve Stable Anatomic Fixation while Preserving Soft Tissue Attachments
- Indirect Reduction Techniques
- Careful Preoperative Planning
- Intra-Operative Flexibility/Creativity
- Choose the Device That Fits the Patient

Periprosthetic Femur Fractures

- Treatment Options are:
  - Long-stem revision arthroplasty
  - Cortical strut allografting
  - Plate fixation with screws
  - Plate fixation with cables
  - Intramedullary Devices

Treatment Options

Most Important Factor in Treating Peri-Implant Fractures is the Status of the Implant

- When the Implant is Loose, Mal-aligned or Deformed
  - Consider Revision/Replacement

- When the Implant is Stable, and Well Aligned with Good Quality Bone
  - Consider Fixation

Implant Revision/Replacement

- Avoids potential difficulties of fixation
  - does not have to avoid the implant
  - does not require stable fixation in poor bone
- Avoids potential complications of malunion or nonunion
- Indicated if Implant is Loose, Mal-Aligned, Deformed or there is Poor Bone Quality

Case Example 1: Revision of Loose Prosthesis Complicated by Fracture

- 82 y/o F
  - Pre-existing LOOSE Hip Replacement
  - Fell sustaining Peri-Prosthetic Femoral Shaft Fracture
  - X-ray Findings: Osteolysis, Subsidence

Case Example 1: Revision of Loose Prosthesis Complicated by Fracture

- 82 y/o F
  - Treatment: Prosthesis Removal, Strut Medial Allograft, and Long Stem Femoral Revision
  - Follow-up - allograft incorporated and prosthesis stable with healed fracture at 6 months

Case Example 2: Hip Replacement after Fracture at Tip of DHS Implant

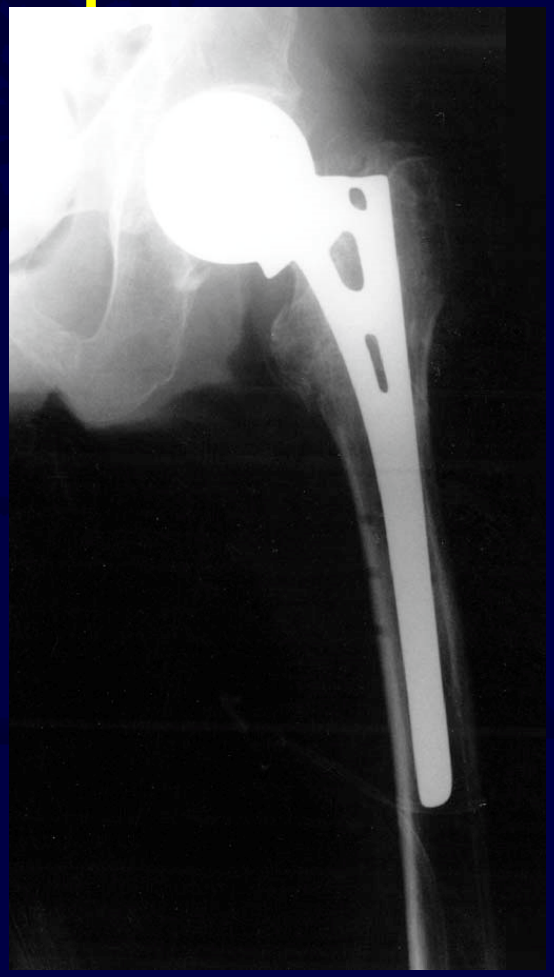
- Elderly M
  - DHS for Intertrochanteric Hip Fracture Fixation

Case Example 2: Hip Replacement after Fracture at Tip of DHS Implant

- Elderly M
  - Intertrochanteric Fracture Healed
  - Fell 1 year later sustaining Femoral Neck Fracture at tip of lag screw
  - X-rays showed poor bone stock

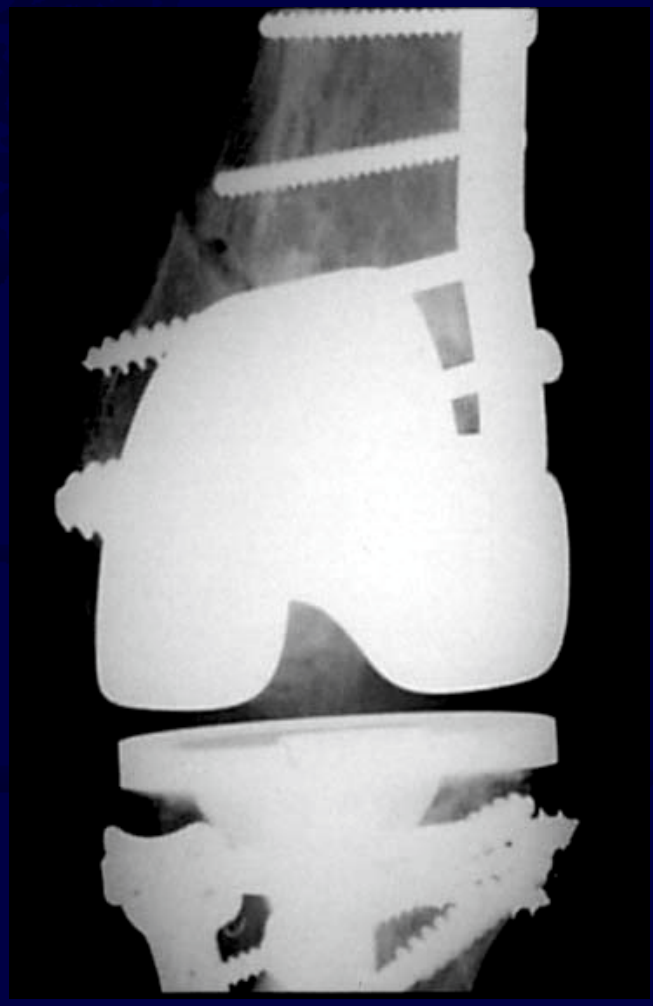
Case Example 2: Hip Replacement after Fracture at Tip of DHS Implant

- Elderly M
  - Treatment: Hardware Removal, Hemiarthroplasty
  - Follow-up : Functioning well at 6 months



Fixation Around An Implant

- Avoids Difficulties of Implant Removal
  - may be technically difficult
  - may be time-consuming
  - may cause further fracturing of bone
- Indicated if Implant is Stable, Well Aligned, and Bone Quality is Good



Peri-Implant Fracture Fixation

- A Wide Selection of Devices Must be Available:
  - Special Plates with Cerclage Wires
    - Curved Plates to Match the anterior Bow of the Femur are Now Available.
  - Flexible Intramedullary Rods
  - Rigid Intramedullary Rods

Plating Techniques for Peri-Implant Fractures

- Advantages of Plates:
  - Allow Direct Fracture Reduction and Exact Anatomic Alignment
    - Less Chance of Later Prosthetic Loosening due to Mechanical Mal-alignment
  - Allow Interfragmentary Compression and A Rigid Construct for Early Motion

Plating Techniques for Peri-Implant Fractures

- Disadvantages of Plates:
  - Biologic and Mechanical Disadvantages Compared to IM devices even with Indirect Techniques
  - Require Special Plates which accept Cerclage Wires, and/or allow Unicortical Screws and/or match the shape of the bone

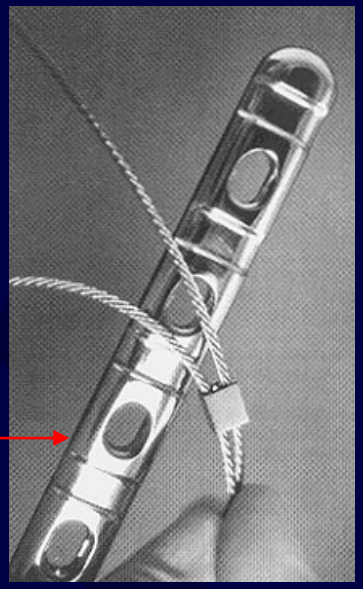
Case Example 3: Fracture at the Proximal End of a Supracondylar Nail Treated with a Plate

- Elderly F
  - Pre-existing healed supracondylar femur fracture
  - New fracture at end of rod after MVA
  - Treatment: ORIF with Plate/wires
  - Follow-up: Healed after 3 months and still asymptomatic at 2 years

PeriProsthetic Fracture

For Hip Peri-
Prosthetic Fixation

-Standard is with
Plate or Allograft



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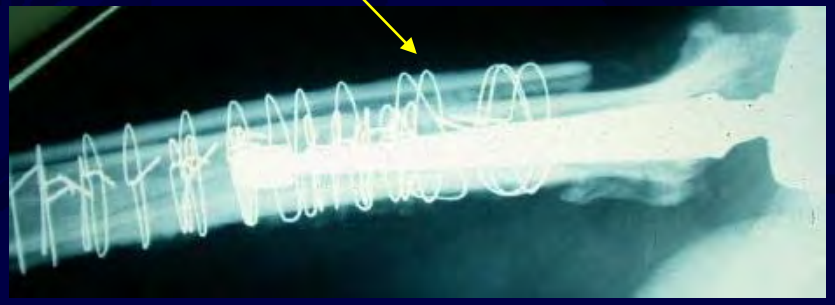
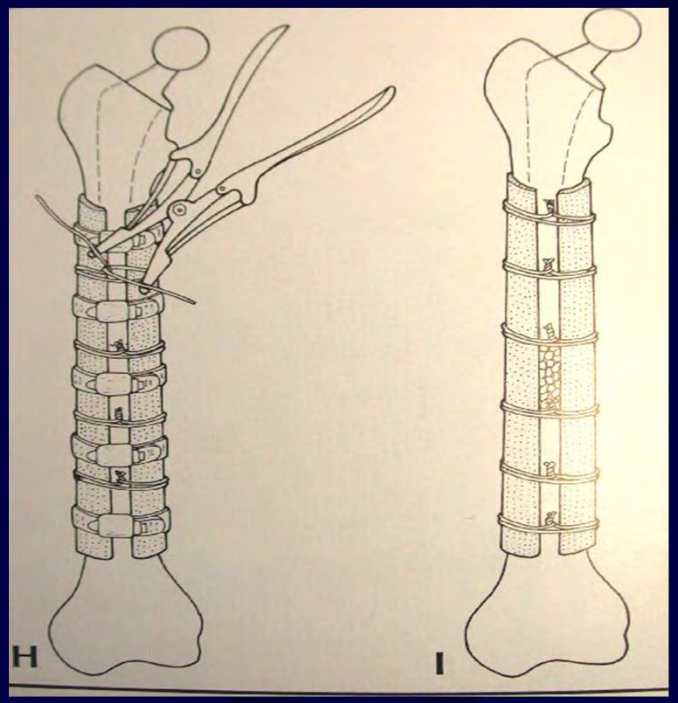


Allograft Technique



- Picture/x-ray courtesy of Dr. John Cardea

Plate Technique

- Advantages of
  Plate over Allograft
  - Less Invasive
    - Leaves Medial Soft Tissues Intact
  - Avoids Potential Allograft Risks
    - Including Donor Infection
  - Stronger
    - Allograft bone can be Brittle

Combined Allograft Struts & Plates

- Mechanically the use of allograft struts and plates has been found to be stronger than plates alone (with or without locking screws)
  - Rad Zdero, Richard Walker, James P. Waddell, and Emil H. Schemitsch
    Biomechanical Evaluation of **Periprosthetic** Femoral Fracture Fixation

    J. Bone Joint Surg. Am., May 2008; 90: 1068 - 1077.
- Although this study was *in vitro* and so did not take into account the additional biologic trauma inherent in placing the allograft struts

Recent Clinical Studies Controversial

- M.A. Buttaro, G. Farfalli, M. Paredes Núñez, F. Comba, and F. Piccaluga
  Locking Compression Plate Fixation of Vancouver Type-B1 **Periprosthetic** Femoral **Fractures**
  J. Bone Joint Surg. Am., Sep 2007; 89: 1964 - 1969.
  - Conclusion: Plate Fixation Should be Supplemented by Allograft Struts

- Catherine F. Kellett, Petros J. Boscainos, Anthony C. Maury, Ari Pressman, Barry Cayen, Paul Zalzal, David Backstein, and Allan Gross
  Proximal Femoral Allograft Treatment of Vancouver Type-B3 **Periprosthetic** Femoral **Fractures** After Total Hip Arthroplasty. Surgical Technique
  J. Bone Joint Surg. Am., Mar 2007; 89: 68 - 79.
  - Conclusion: Allograft Struts alone are enough. Plates not necessary.

- William M. Ricci, Brett R. Bolhofner, Timothy Loftus, Christopher Cox, Scott Mitchell, and Joseph Borrelli, Jr.
  Indirect Reduction and Plate Fixation, without Grafting, for **Periprosthetic** Femoral Shaft **Fractures** About a Stable Intramedullary Implant. Surgical Technique
  J. Bone Joint Surg. Am., Sep 2006; 88: 275 - 282.
  - Conclusion: Plate fixation alone is enough. Struts not necessary.

PeriProsthetic Fracture

Plate or allograft attachment is by Cerclage Wires or unicortical screws

or

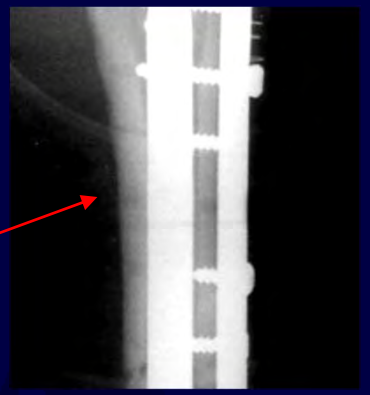
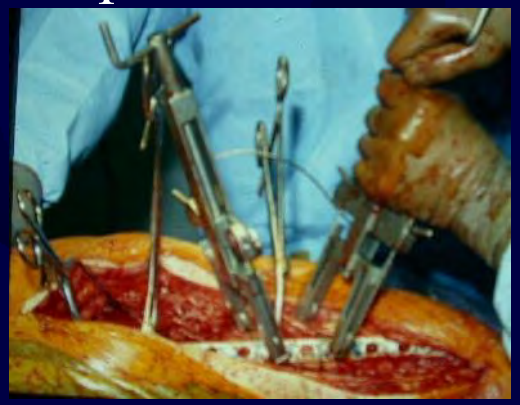


Plate Techniques May Use Cables to attach the plate to the bone

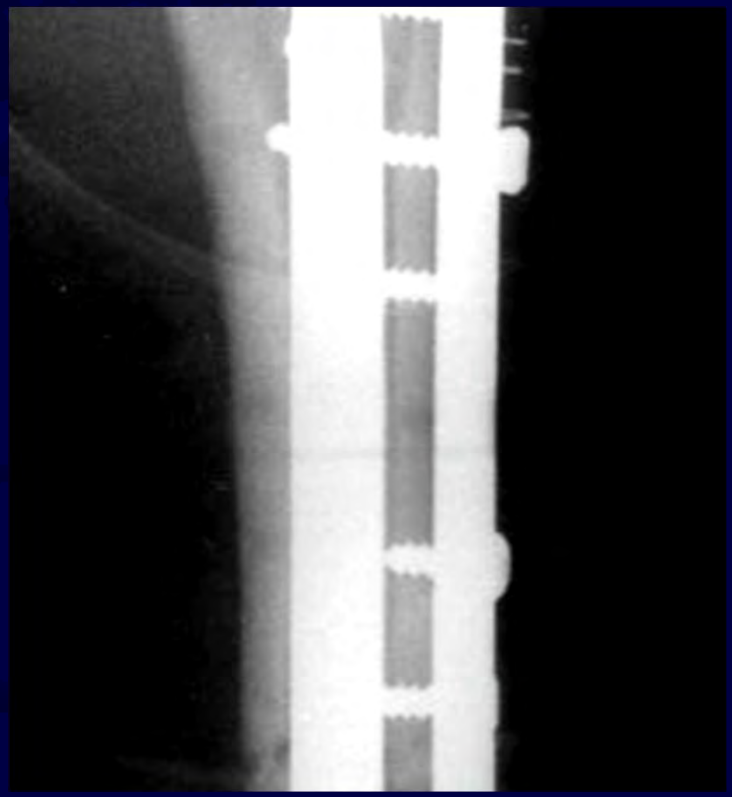
- Cables
  - Require Extensive Exposure
  - And are Technically Demanding
  - So the fewer Used, the Better: To decrease operative trauma and operating time



•Pictures courtesy of Dr. John Cardea

Plate Techniques Can Also Use Screws to Attach the Plate to Bone

- Screws
  - Can be Placed Easier than Cables
  - And Can be Placed Percutaneously with less soft tissue trauma than Cables
- So using Screws instead of Cables should decrease operative trauma and operating time



Use of plates with cables: There are many reports

- Examples:
  - -Ogden and Rendall, *Orthop Trans*, 1978
  - -Zenni, et al, *Clin Orthop*, 1988
  - -Berman and Zamarin, *Orthopaedics*, 1993
  - -Haddad, et al, *Injury*, 1997

But none of these address the question: how many cables are necessary?

Cables:

- Cables resist bending loads:

  -Mihalko, et al, *J Biomechanics*, 1992

- BUT Cables resist torsional loads poorly compared to screws

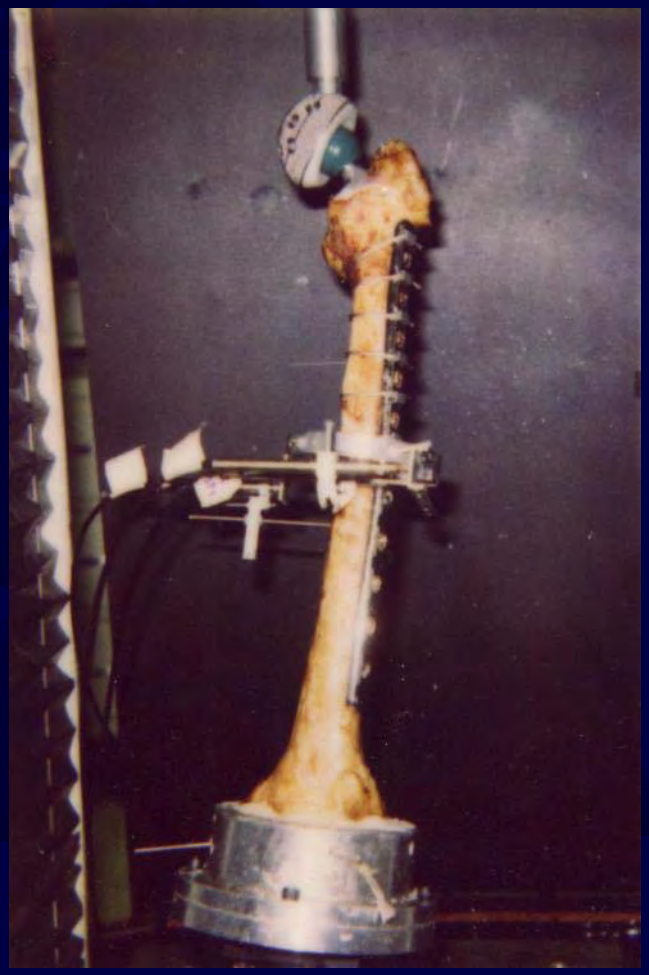
  -Schmotzer, et al, *J Arthroplasty*, 1996

The Use of Screws should improve Rotational Stability

PeriProsthetic Fracture

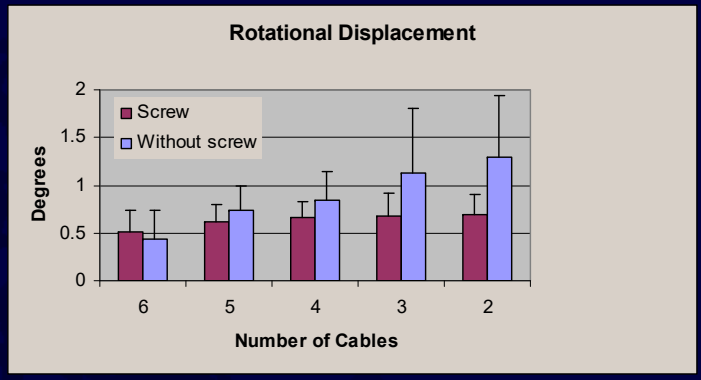
- Cerclage Wires are Less Mechanically Sound than Unicortical Screws

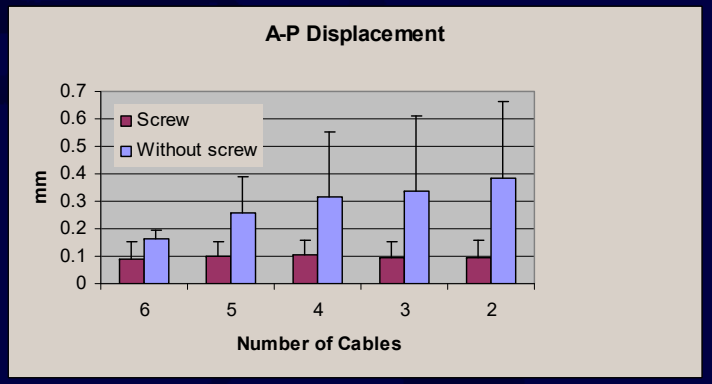
- Lohrbach & Rabin MidAmerica Orthopedic Assoc. Annual Meeting 2002

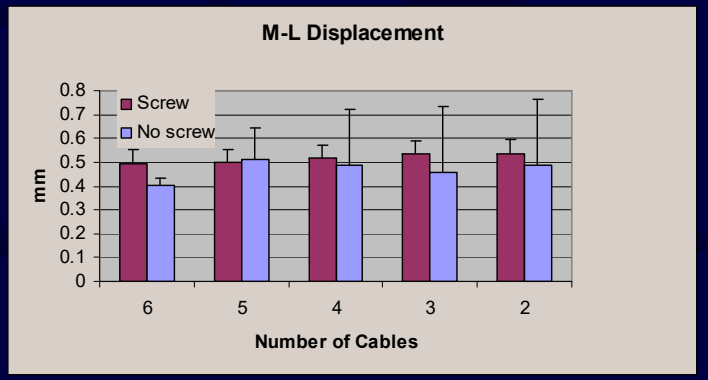


Conclusions:

- A unicortical screw significantly increases torsional and A-P stability and should be added to cable-plate constructs
- At least six cables are needed in the absence of a unicortical screw to improve A-P and rotational stability







Lohrbach & Rabin MidAmerica Orthopedic Assoc. Annual Meeting 2002

Case Example 4: Fracture at Distal End of Hip Replacement Stem Treated with a Standard Plate

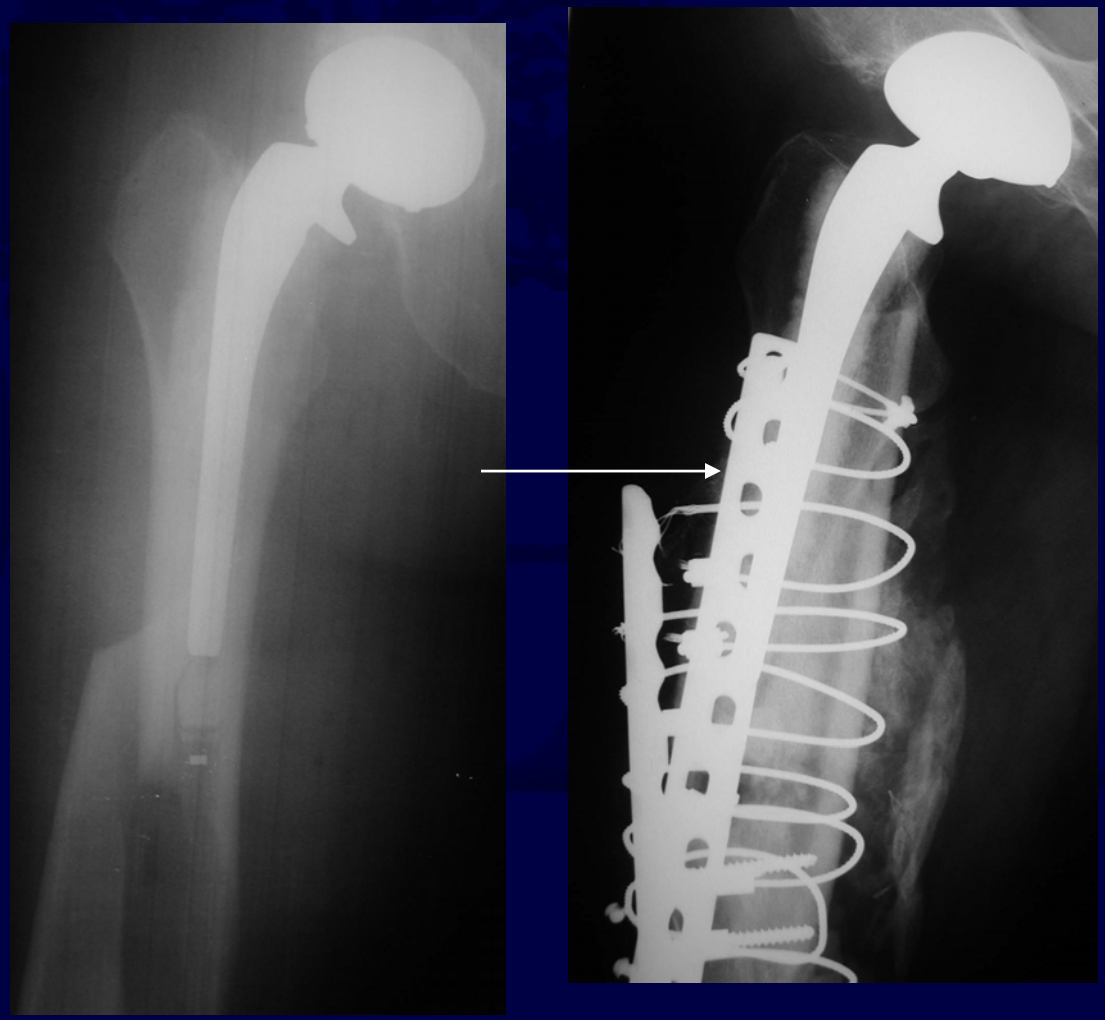
- Elderly F
  - Pre-existing Asymptomatic Hip Arthroplasty
  - Fell out of a car sustaining fracture at tip of stem
  - X-rays showed a solid prosthesis

Case Example 4: Fracture at Distal End of Hip Replacement Stem Treated with a Standard Plate

- Elderly F
  - Treatment: DCP plate w. screws/cerclage wires
  - Follow-up: Healed/Asymptomatic at 3 years

Case Example 5: Peri-Prosthetic Fracture Treated with Locking Compression Plate

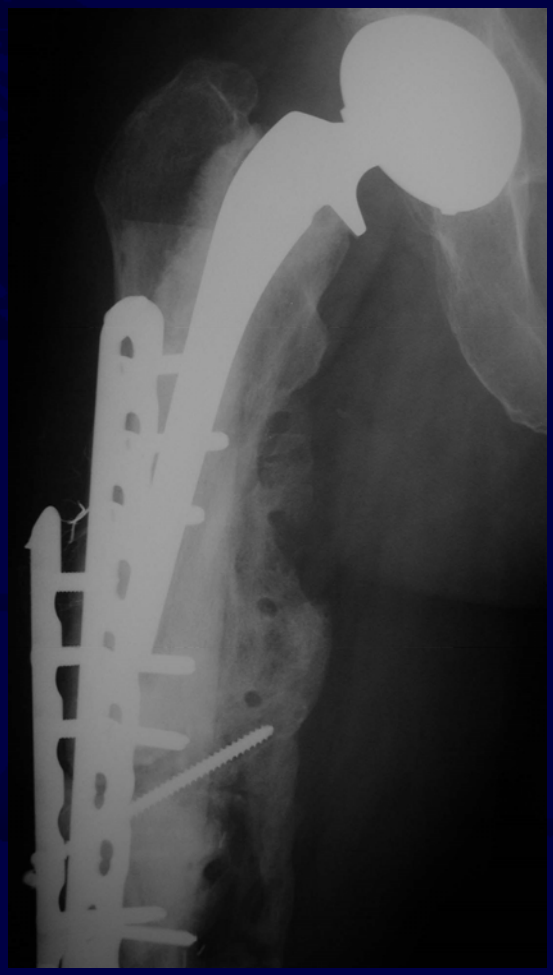
- 73y/o M
  - Healthy
  - 3 previous platings



Case Example 5: Peri-Prosthetic Repair with Locking Plates

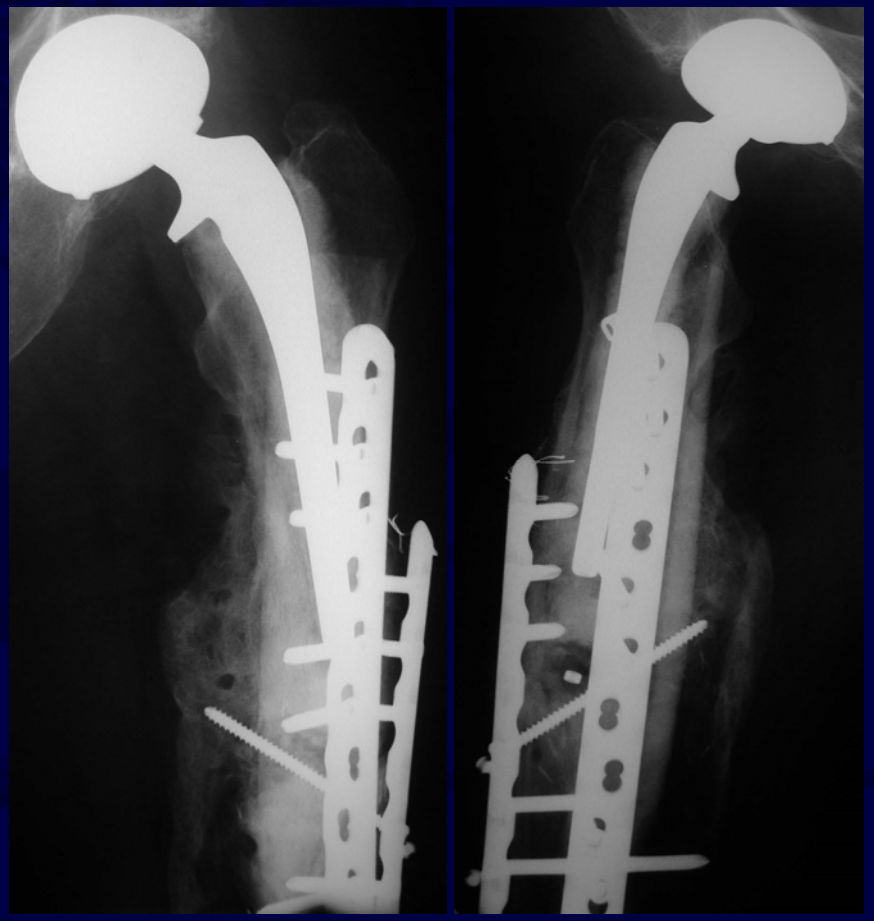
- Treatment = Double Locked Compression Plate, electrical stimulator, Hardware removal

- Locking Screw Plates are Ideal because they provide stable fixed angled unicortical fixation



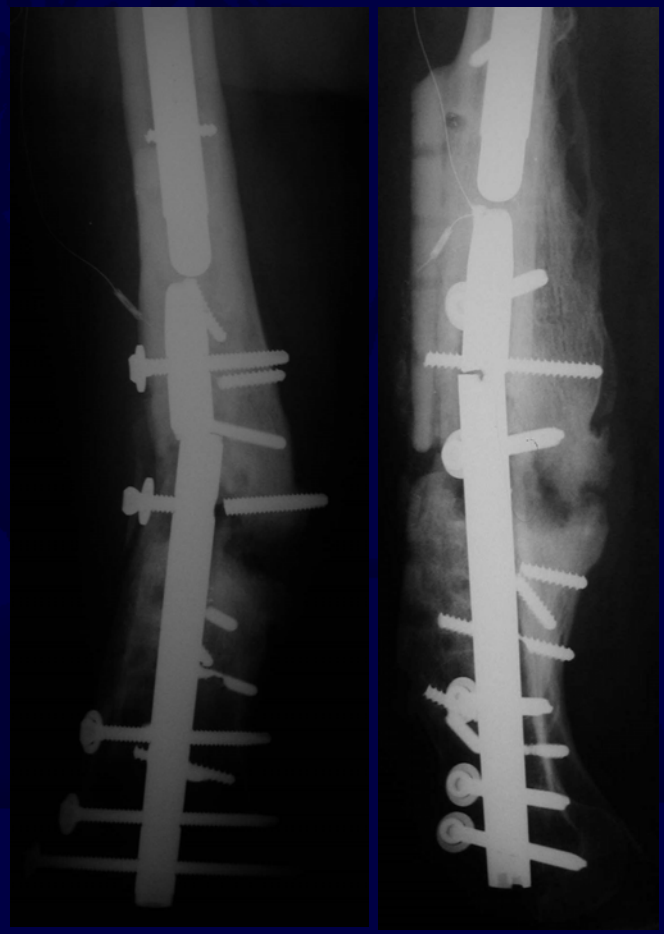
Case Example 5: Peri-Prosthetic Repair with Locking Plates

- Clinically painless by 6 weeks
- Radiographically appeared healed at 2 months
- Follow-up 13 months
- Complication: S. epi post-op infection required I&D & e-stim removal at 3 months



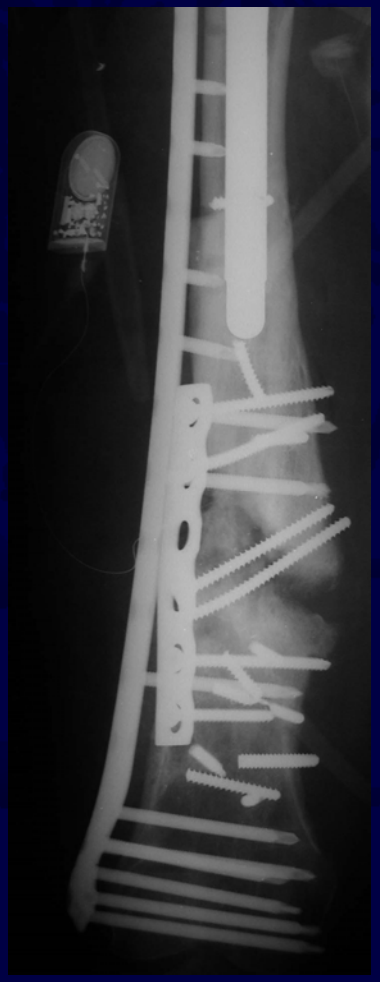
Case Example 6: Peri-Prosthetic Repair with LISS Plate

- 49 y/o F
  - Healthy: Fracture at end of Hip Stem
  - 3 previous platings,
  - 1 previous retrograde rod



Case Example 6: Peri-Prosthetic Repair with LISS

- Treatment = LISS + locking plate, electrical stimulator, bone graft
- (LISS – less invasive stabilization system)



Case Example 6: Peri-Prosthetic Repair with LISS

- Follow-up 19 mo.
- No Pain by 2 mo.
- Bridging 5 mo.

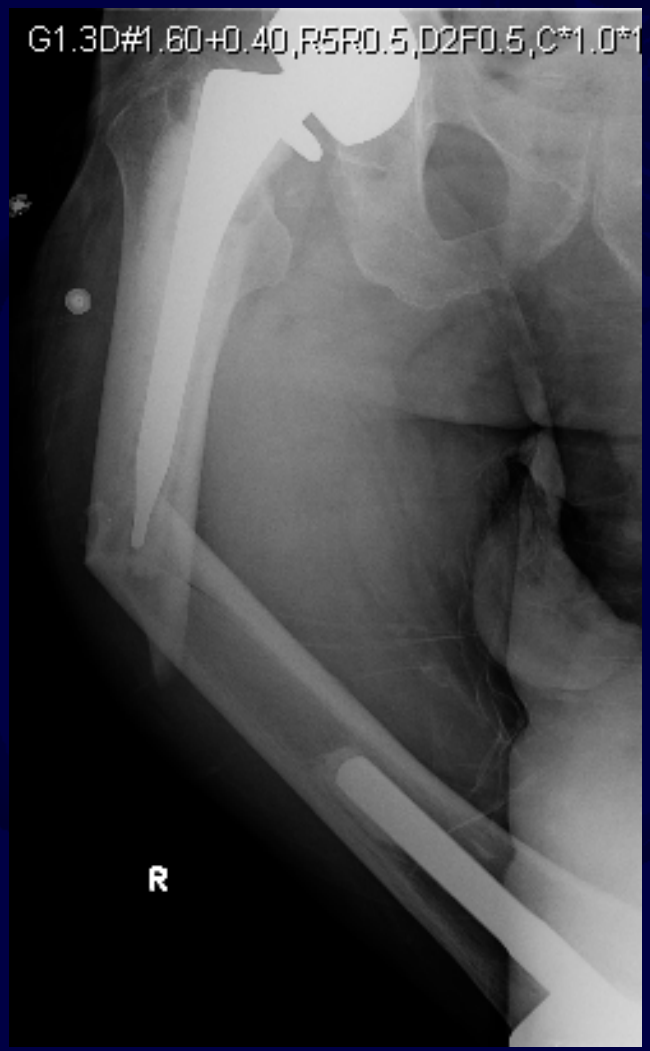
Case Example 7: Fracture Distal to Hip Stem Treated with Curved Locking Plate

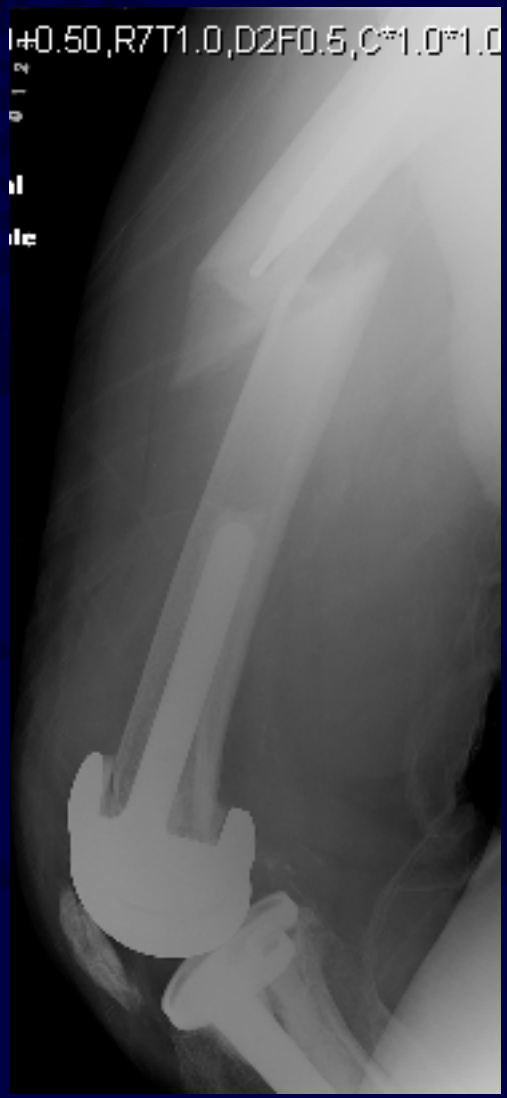
72 y/o Male with Hip Replacement for Arthritis

X-ray from Routine Annual Follow-up (6 months prior to fracture)

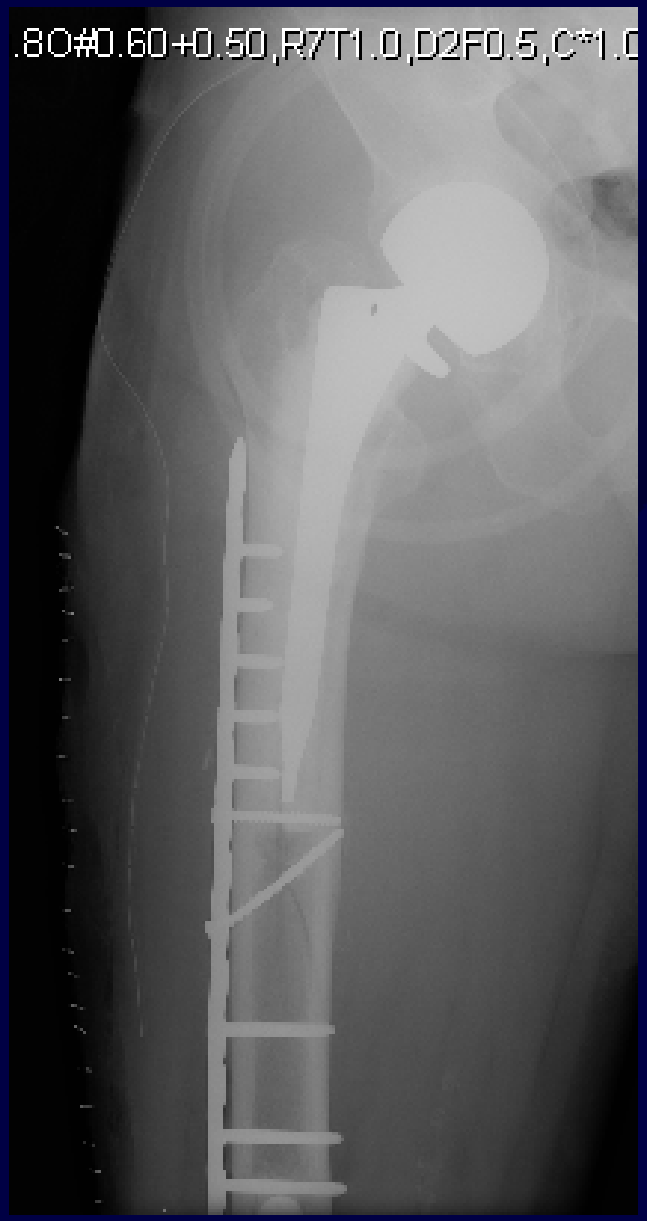
Case 7: Treatment with Curved Plate

- Fracture



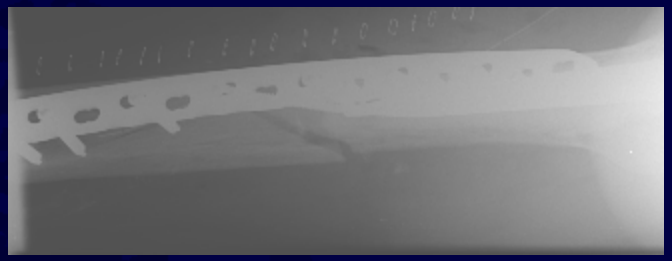


Case 7: Curved Plate



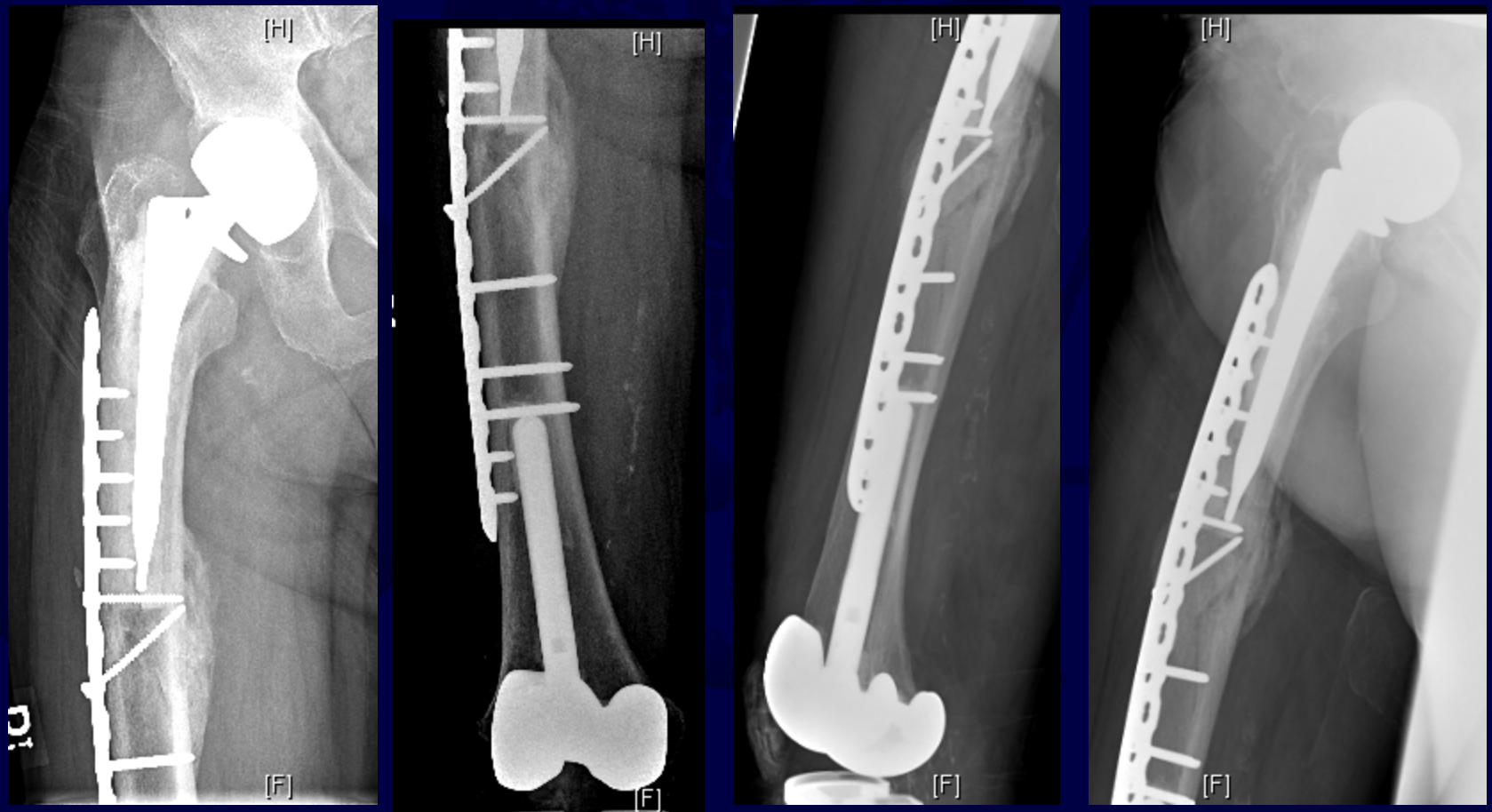
Intra-op

- Curved Plate Matches Bow of Femur



Case 7: Curved Plate Example

Healed at 6 months



Flexible Intramedullary Rods (Zickel, Enders etc.)

- Flexible Rods Advantages:
  - can be placed via minimal incisions
  - act as internal splints until fracture healing

Flexible Intramedullary Rods

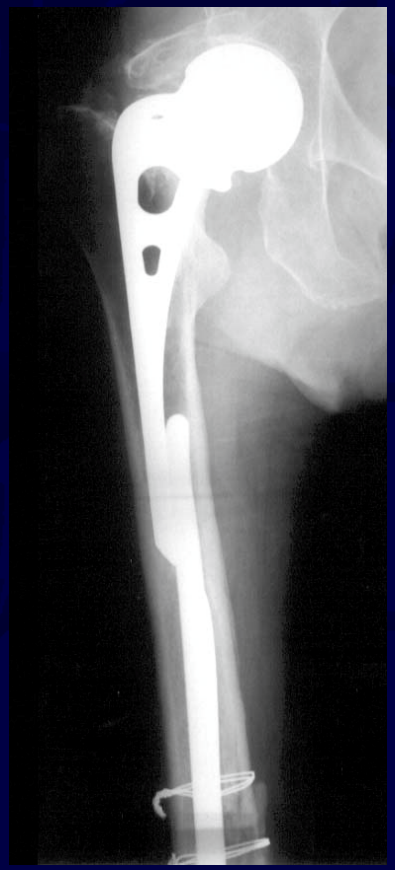
- Flexible Rods Disadvantages:
  - require external protection (cast or brace)
  - rarely allow early motion or weight-bearing
  - must be enough space in the medullary canal for implant and rod

Case Example 8: Distal Femur Fracture w. Proximal Hip Replacement Treated with Flexible IM Rod

- Elderly F s/p MI
  - Pre-existing Asymptomatic Hip Hemiarthroplasty
  - Fall sustaining distal femur shaft fracture
  - X-rays showed wide medullary canal and osteoporosis

Case Example 8: Distal Femur Fracture w. Proximal Hip Replacement Treated with Flexible IM rod

- Elderly F s/p MI
  - Treatment: Zickel Supracondylar Device
  - Follow-up: Healed Asymptomatic at 3yrs



Rigid Intramedullary Rods (Antegrade, Supracondylar, Retrograde)

- Rigid Rod Advantages:
  - Do Not Require External Support
  - Provide Rigid Fixation
  - Biologic & Mechanical Advantages of Intramedullary Position

Rigid Intramedullary Rods

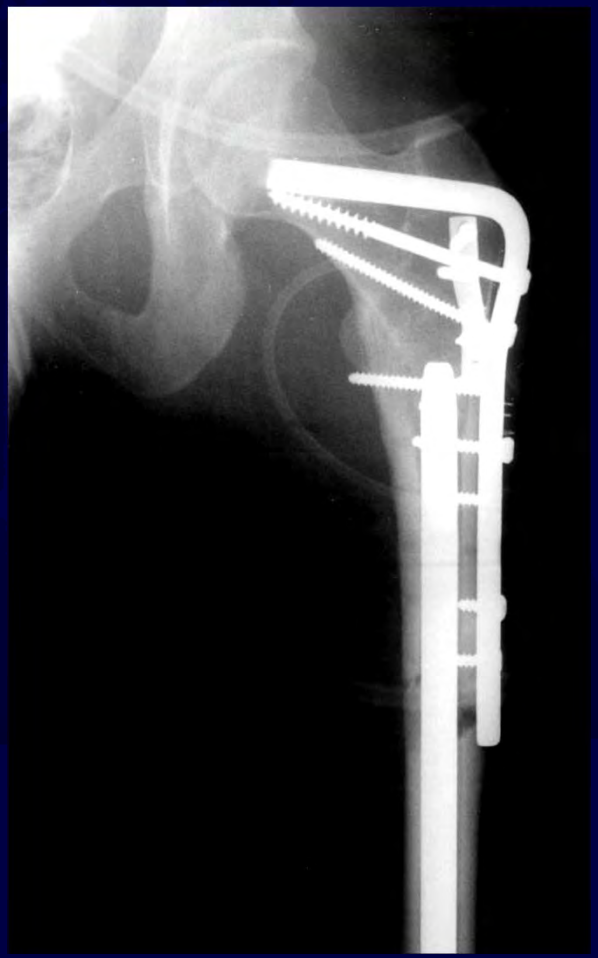
- Rigid Rod Disadvantages:
  - Cannot be used with a pre-existing stemmed implant

Case Example 9: Fracture at the End of a Blade Plate Treated with a Retrograde Nail

- Young M
  - 2 yrs after healed subtrochanteric hip fracture with retained blade plate
  - In a High Speed Motor Vehicle Accident, sustained a fracture at the distal end of the plate

Case Example 9: Fracture at the End of a Blade Plate Treated with a Retrograde Nail

- Young M
  - 2 yrs after healed subtrochanteric hip fracture with retained blade plate
  - Treatment: Retrograde Rodding
  - Follow-up: at 2 years healed and asymptomatic



Case Example 10: Fracture Above a Total Knee Replacement Treated w. an Antegrade Nail

- Elderly F
  - Bilateral Knee Replacements
  - Sustained Bilateral Distal Femur Fractures Proximal to Knee Replacements after MVA

Case Example 10: Fracture Above a Total Knee Replacement Treated w. an Antegrade Nail

- Elderly F
  - Bilateral Knee Replacements
  - Treatment: Bilateral Antegrade Rodding
  - Follow-up: at 3 years: Fractures healed and both knees asymptomatic

Summary

- If the prosthesis or implant is Loose, or Bone Quality is Poor - then the implant should be revised while fixing the fracture
- If the prosthesis or implant is Stable and Bone Quality is Adequate for Fixation - then the implant should be retained while the fracture is fixed following standard principles

Remember:

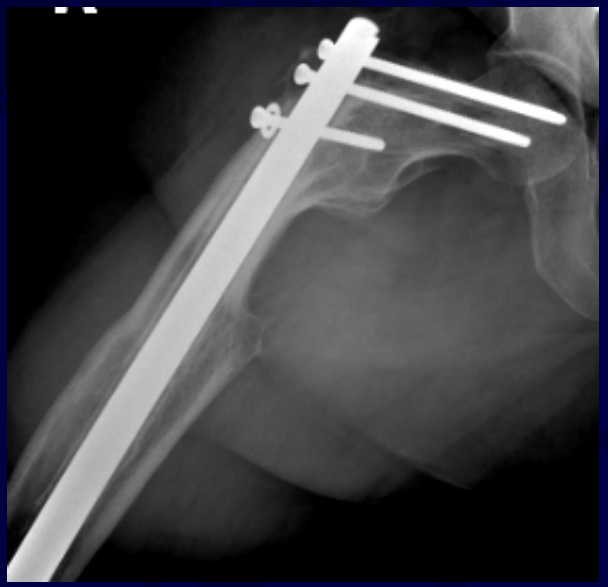
If Fixation is chosen: Follow Principles of Good Fracture Care

Case Example 11: Revision of Fixation Requiring Osteotomy

- 78 y/o Female:

X-rays from 7 years ago after treatment of infected intertrochanteric nonunion

Asymptomatic in interim

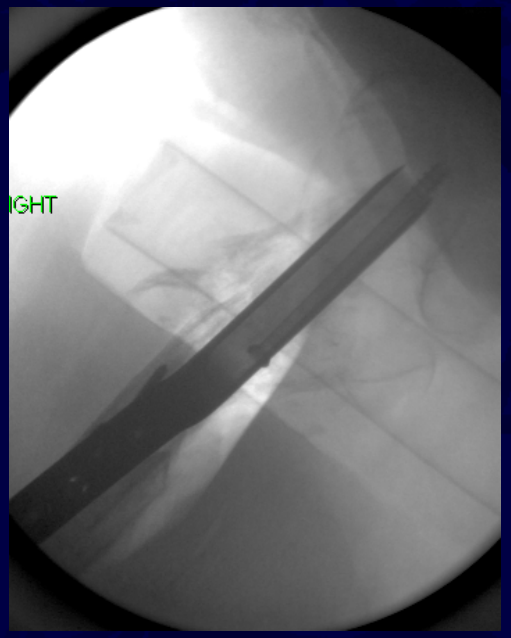


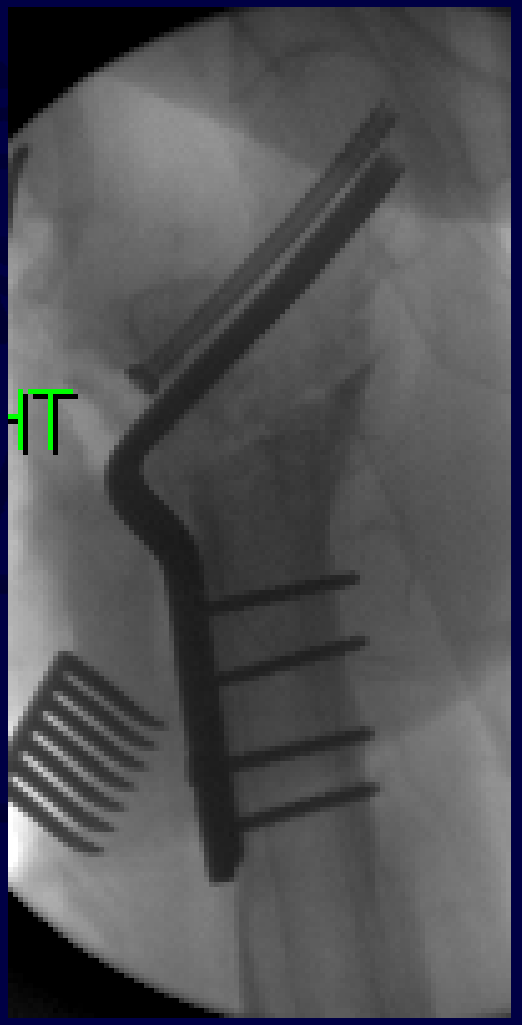
Example 11: Revision of Fixation

- Femoral Neck Fracture
- (Vertical Shear Pattern)

Example 11: Revision of Fixation

- Fixation of fracture with Valgus Intertrochanteric Osteotomy restores leg length and converts shear forces across the femoral neck fracture into compressive forces





Example 11: Revision of Fixation

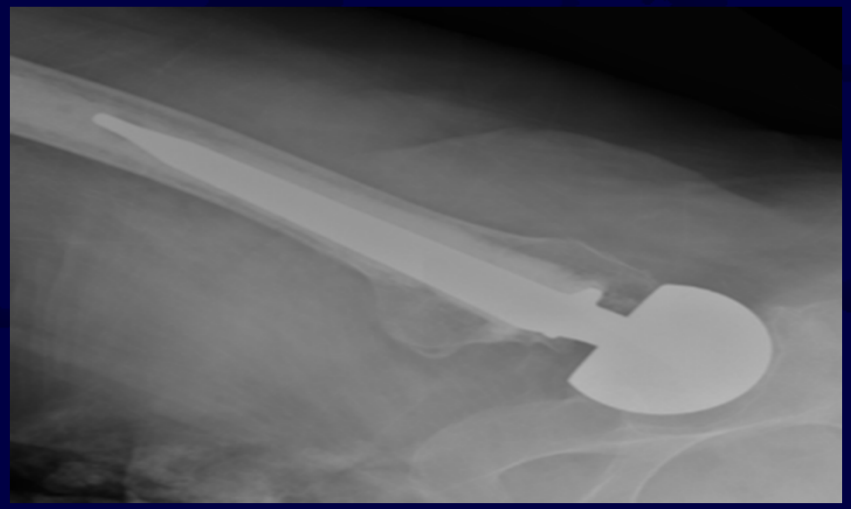
- Healing at 3 months:
- (Plans to shorten blade)

Warning!

- The Bone Quality Must be Adequate to Hold Fixation in addition to Stability of the Implant if Fixation is chosen instead of revision/replacement.

Example 12: Stable Prosthesis But Poor Bone Quality

- 90 year old Female with asymptomatic Hemi-arthroplasty at annual follow-up



Example 12: Stable Prosthesis But Poor Bone Quality

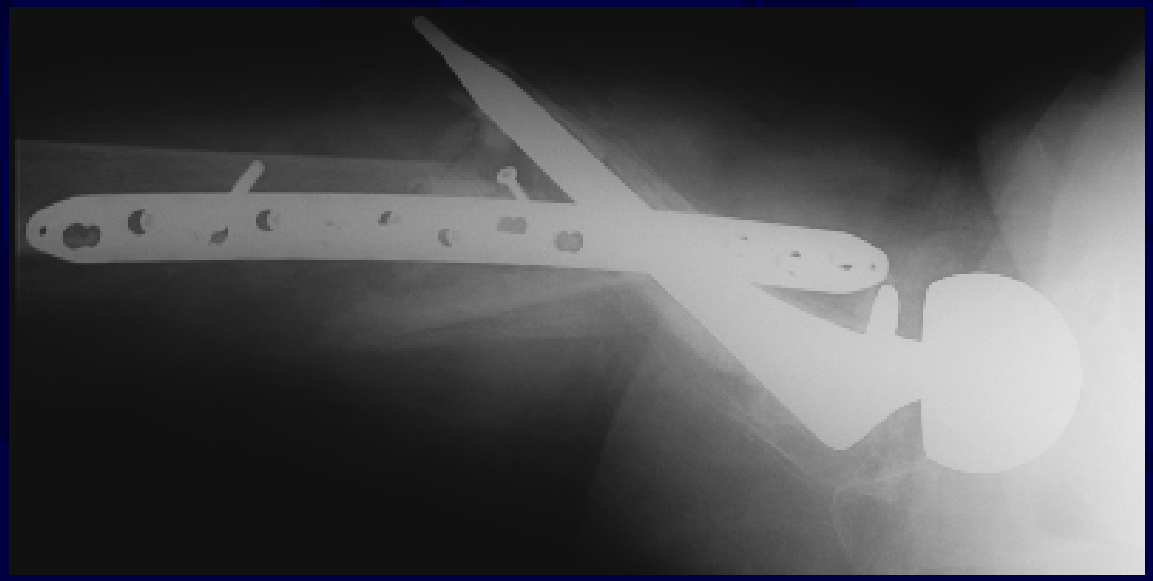
- Fracture
- 2 months later

Example 12: Stable Prosthesis But Poor Bone Quality

- Stable Prosthesis so Fixation with curved locked plate with Uni-cortical screws Chosen for Treatment

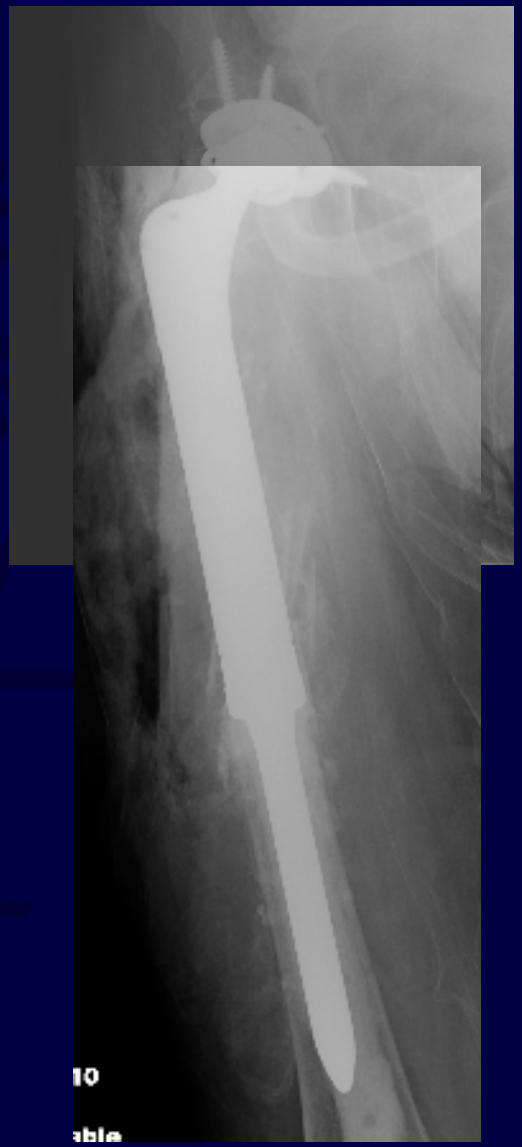
Example 12: Stable Prosthesis But Poor Bone Quality

- Plate Failure At 3 months



Example 12: Stable Prosthesis But Poor Bone Quality

- Salvage with Proximal Femoral Replacement



Conclusions

- Surgeon must carefully Evaluate Stability of the Implant
- Loose Fixation Implants will allow motion at the fracture site that interferes with healing and gets in the way of more stable fixation devices
- Loose Prosthetic Implants will be painful and also interfere with adequate fixation

Conclusions

If the prosthesis or implant is Loose,
or Bone Quality is Poor -

the implant should be revised while
fixing the fracture

Conclusions

If the prosthesis or implant is Stable and Bone Quality is Adequate for Fixation

the implant should be retained while the fracture is fixed following standard principles

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