MODES OF FAILURE

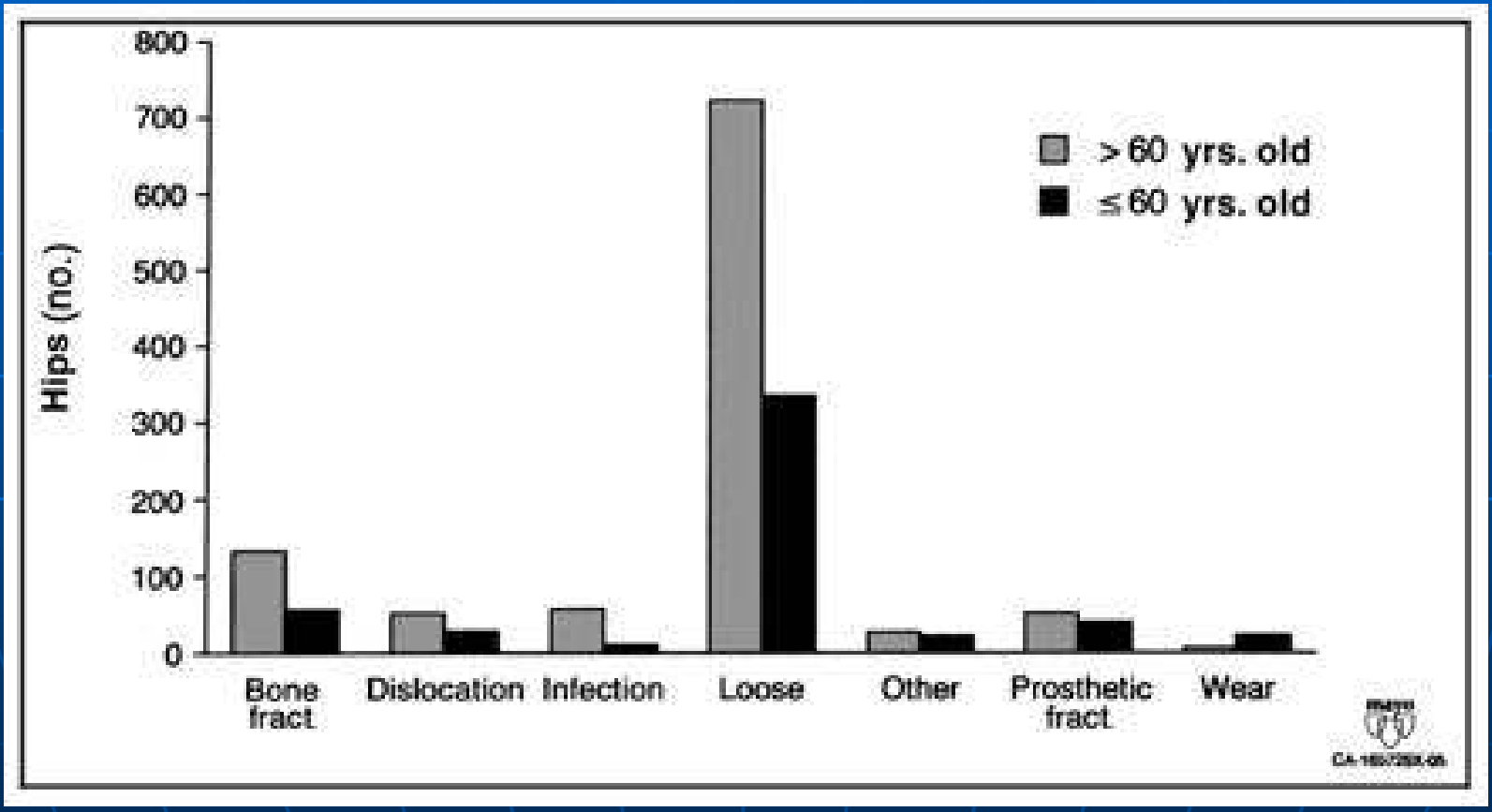
TOTAL HIP REPLACEMENT

Inder Gill

Causes of THA Failure

- Wear of articular bearing surface
- Aseptic/mechanical loosening
- Infection
- Instability
- Peri-prosthetic fracture
- Implant failure

REASON FOR REVISION



Lewallen DG, Berry, DJ. JBJS 79: 1881-90, 1997.

Timing of TJR Failure

- Early (<10%)
  - *Dislocation*
  - Infection

- Late (> 5 yrs post op)
  - *Wear of articular bearing surface*
  - Osteolysis
  - Mechanical loosening
  - Peri-prosthetic fracture

Causes of THA Failure

- **Wear of articular bearing surface**
- Aseptic/mechanical loosening
- Infection
- Instability
- Peri-prosthetic fracture
- Implant failure

WEAR

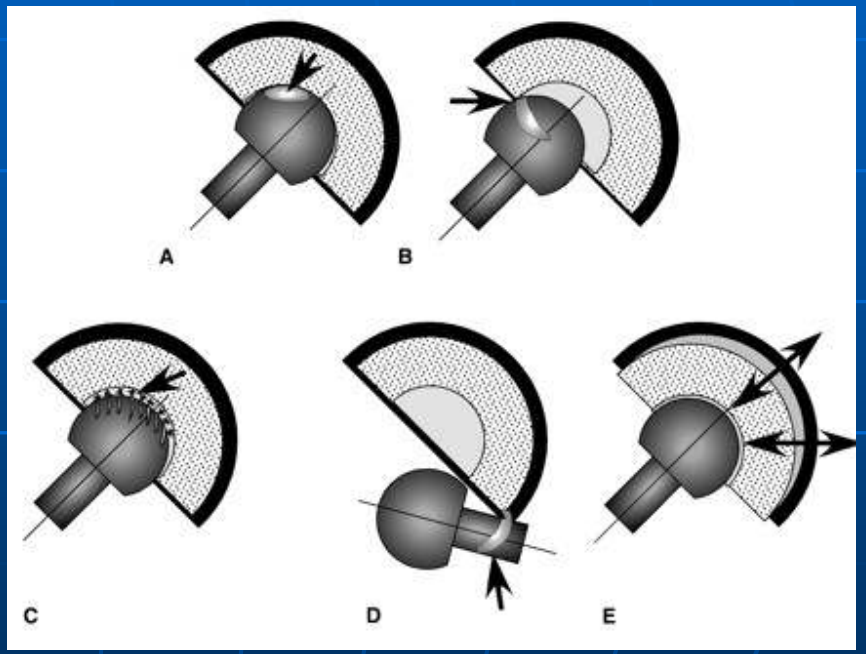
- Wear: loss of material (with the generation of wear particles) that occurs as a result of relative motion between opposing surfaces under load.

TYPES OF WEAR

- **Abrasive:** in which the harder of the surfaces produces grooves in the softer material
- **Adhesive:** in which the softer material is transferred as a thin film onto the harder surface
- **Fatigue:** in which repetitive loading produces subsurface cracks and particles, or sheets of material subsequently delaminate.
- **Third body and corrosive**

MODES OF WEAR

- **Mode 1**: motion b/w one primary bearing surface and another.
- **Mode 2** : primary bearing surface articulates with a nonbearing surface.
- **Mode 3** : entrapped abrasive particles between primary bearing surfaces - 3rd body wear
- **Mode 4** : motion at two secondary or nonbearing surfaces.



FACTORS DETERMINING WEAR

- the coefficient of friction
- surface finish
- hardness of the materials
- applied load
- sliding distance
- number of cycles

MEASURING WEAR

- Clinical roentgenographic studies usually report linear wear rates, whereas in vitro studies often report volumetric wear
- wear commonly is expressed as the linear distance of penetration of the head into the polyethylene
- Manual measurement
- digitized roentgenographs and computer-assisted wear measurements

PATHOGENESIS

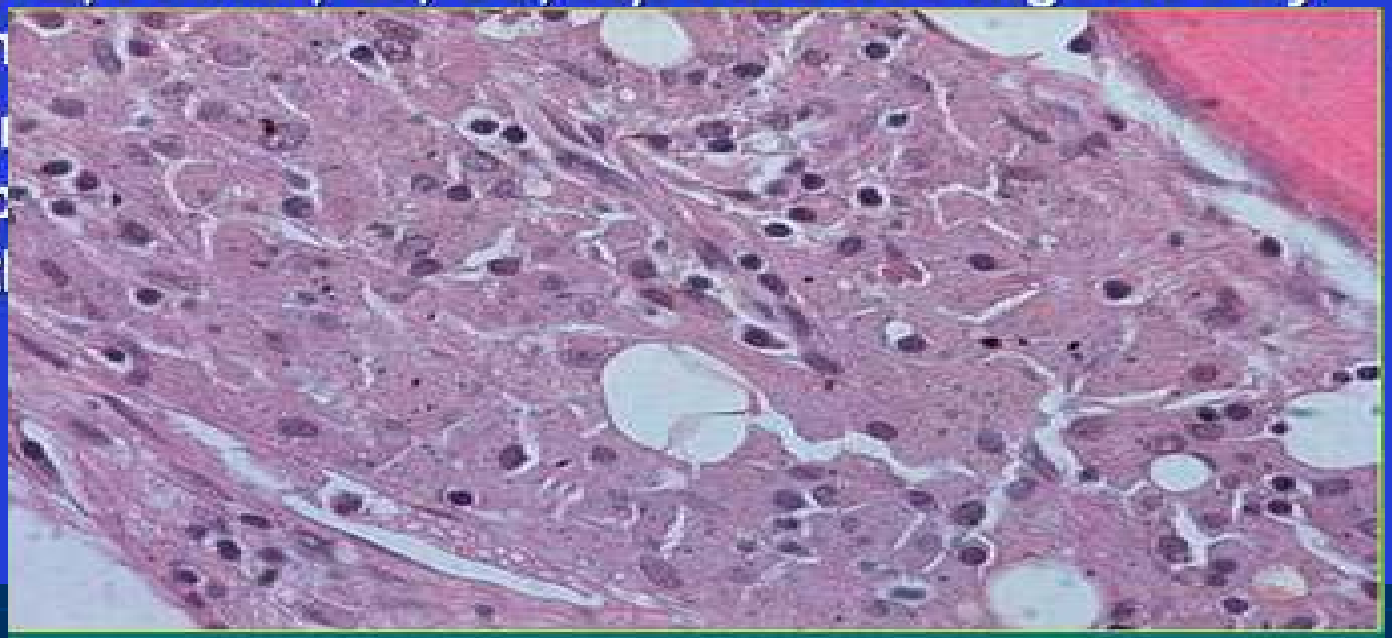
- Definite relationship b/w particle size and foreign body reaction
- Particles 0.5 - 10 microns stimulate a macrophage response and osteolysis
- greater than 10 microns tend to elicit a giant cell reaction with no osteolysis
- macrophages release IL-1, PGE2,TNF, IL-6 : these mediate bone resorption

- ref: Amstutz etal CORR 276: 7-17, 1992Howie etal OCNA 24: 571- 582, 1993

OSTEOLYSIS AFTER THA

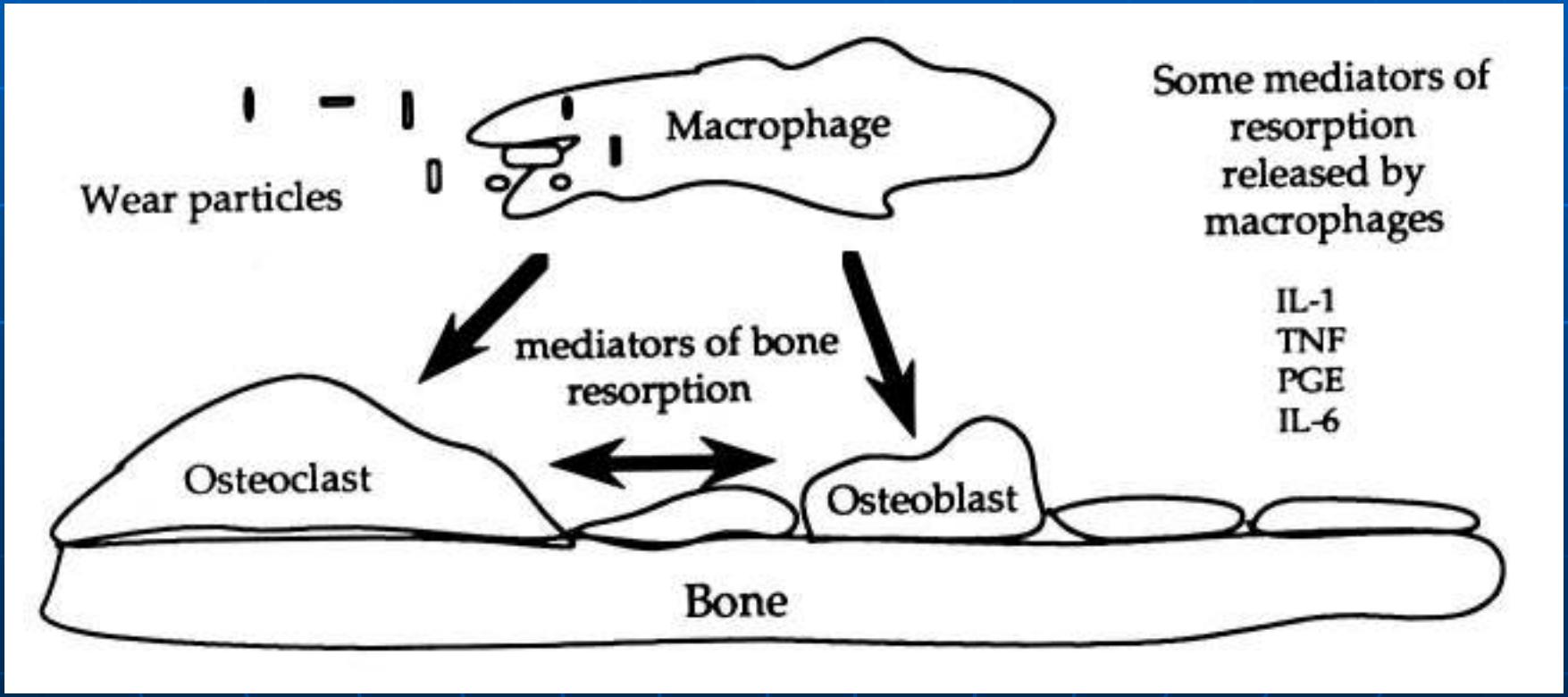
PATHOGENESIS

- Histiocytic response to wear debris (PE, PMMA, Cr, Co, Ti). Particles ingested by m
- In
  p
  t



Foamy macrophages and giants cells producing cytokines and proteases

Osteolysis / Aseptic loosening

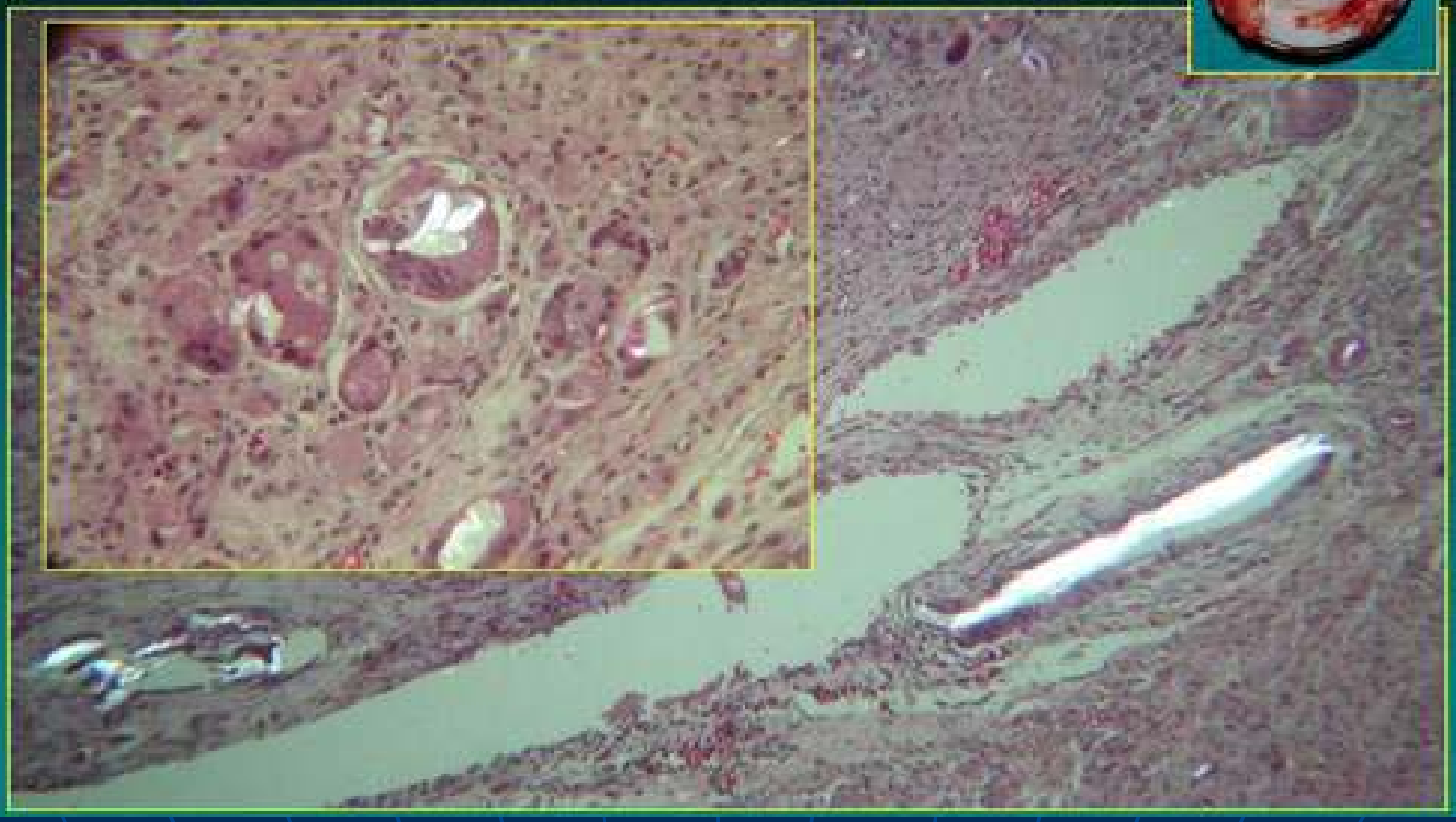


Osteolysis

Effective Joint Space

Wear

Polyethylene Wear and Biologic reaction



OSTEOLYSIS

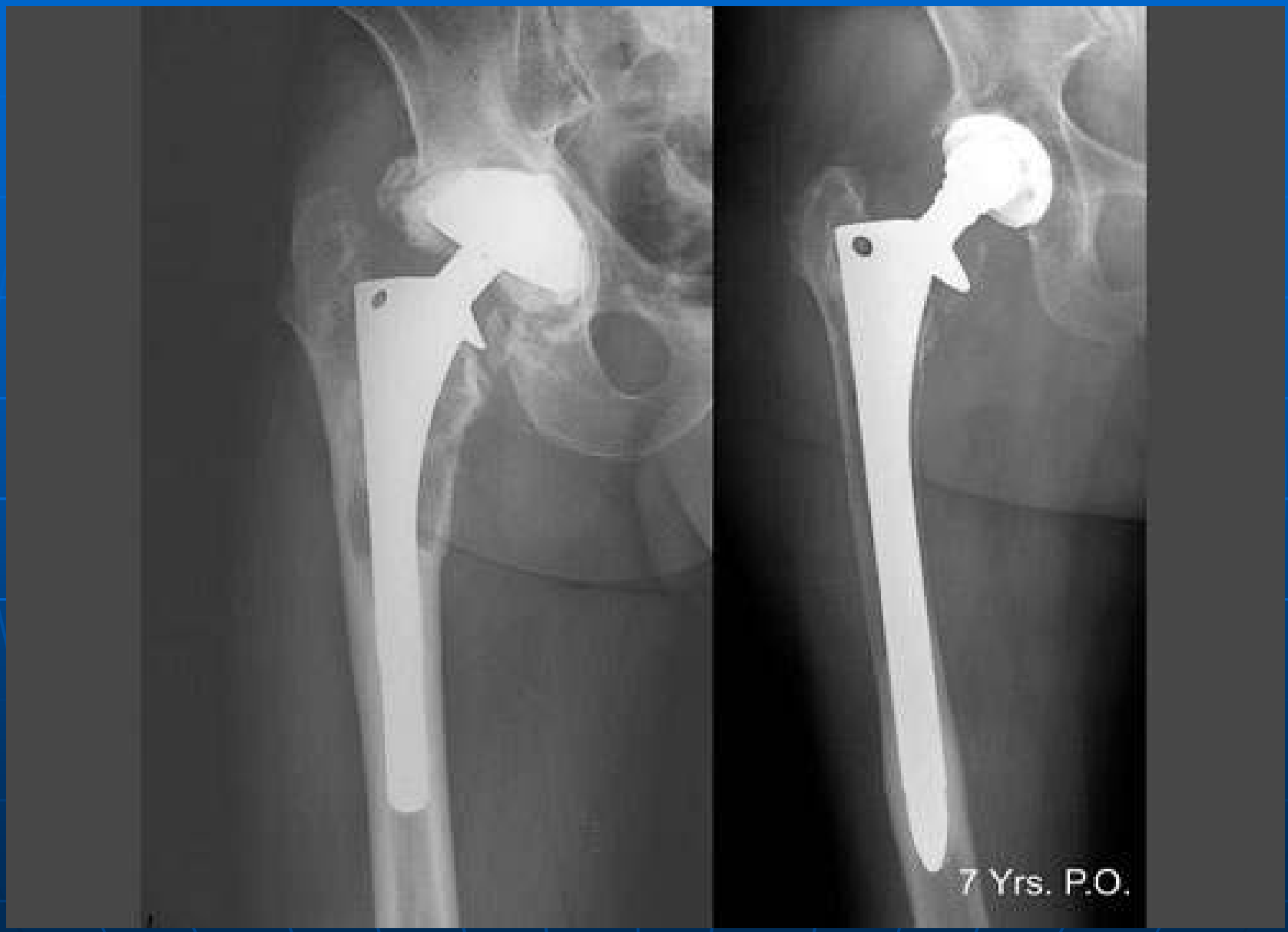
DEFINITIONS

- **Osteolysis:**

  Periprosthetic bone loss mediated by intracellular enzymes and generated by the production of wear debris

- **Stress shielding:**

  Proximal periprosthetic bone resorption generated by load bypass of the proximal femur


7 Yrs. P.O.

POLYETHYLENE

- Molecular weight has been correlated with the wear resistance
- Manufacturing – direct compression moulding
- Sterilization- gamma irradiation
- Shelf life

Attempts to Improve Wear

- Resin changes
  - crystallinity
  - molecular weight
- Sterilization techniques
  - gamma irradiation
  - ETO and gas plasma
  - annealing vs remelting

1st Gen. Highly Crosslinked (HXLPE)

- Introduced in 1998
- Simulator – Hip 90% ↓; Knee 20-40% ↓
- Clinical hip studies – 50 to 75% ↓ wear
- HXLPE – one of the most significant development in past 2 decades

2nd Generation HXLPE

- Developed to *reduce wear and free radicals* to *maintain mechanical properties* with *annealing*
  - vitamin E HXLPE
  - X3 – a sequential irradiation and annealed HXLPE

Wear

Articulation surface

- Metal / Polyethylene
- Ceramic / Polyethylene
- Metal / Metal
- Ceramic / Ceramic

Comparison

	Ceramic ceramic	Metal metal	Metal poly
Scratch resistance	++++	+++	+
wetability	+++	++	+
Ion release	0	+++	+
Coefficient of friction	+++	++	+
Wear resistance	++++	+++	++

DISADVANTAGES

Ceramic

- Fracture
- Noise

Poly

- Wear
- Fracture
- Data?

MM

- Cancer
- ALVAL

Metal-on-Metal Articulations

Larger Diameter Bearings

- Lower wear with larger diameter M-M bearing (all other factors equal)
- Higher sliding velocity improves lubrication
- Greater ROM prior to impingement (favorable head:neck ratio)
- Reduced risk of dislocation
- Enables resurfacing
- *The High Function Hip*

Cancer Risk Following TJR

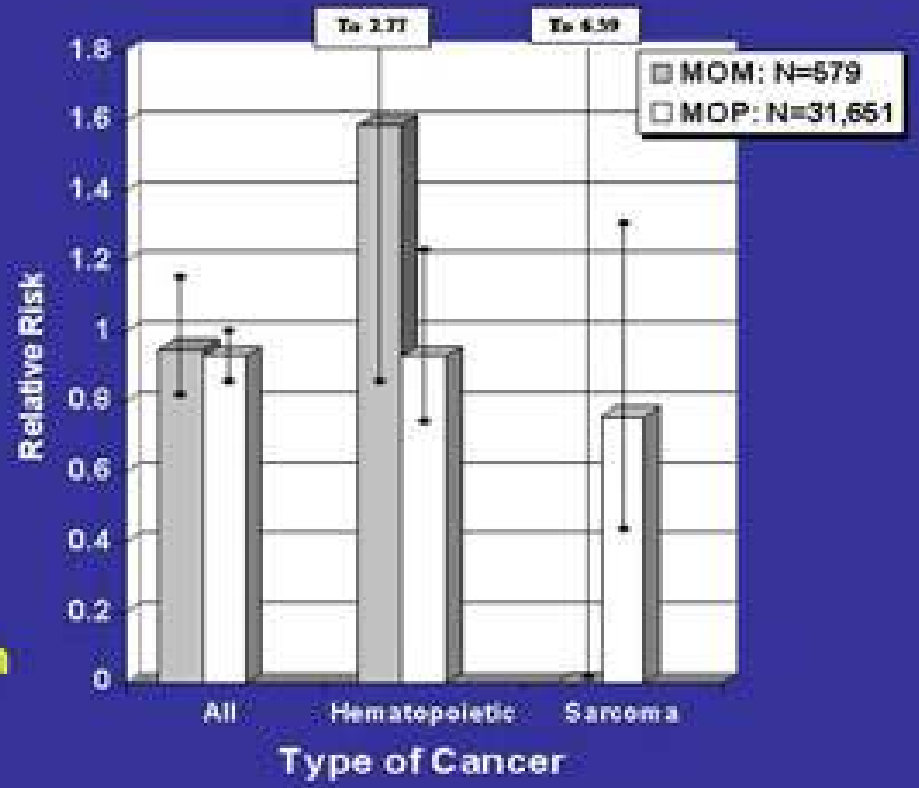
Tharani et al., JBJS (Am.) 2001

Relative Risk

- **All cancers:**
  - **After MOM: 0.95**
  - **After MOP: 0.93**
- **Hematopoietic:**
  - **After MOM: 1.59**
  - **After MOP: 0.93**
- **Sarcoma:**
  - **After MOM: 0.00**
  - **After MOP: 0.76**

★ **MOM data from Visuri**

★ **MOP data from Paavolainen**



ION PASSAGE VIA PLACENTA

- 3 FEMALE PATIENTS WITH M-M HIPS
- UMBILICAL CORD SERUM AND MATERNAL SERUM
- AVG OF 3.8 YEARS POST OP

MATERNAL SERUM LEVELS

- Cr 1.6, 0.5, & 0.9 PPB
- Co 1 PPB I1 PATIENT UNDETECTABLE IN 2

UMBILICAL CORD SERUM

- Cr & Co UNDETECTABLE IN ALL SPECIMENS

Brodner, JOA, 2004

CUP INCLINATION vs ION LEVELS

- 3 GROUPS OF 20 PATIENTS EACH

CUP INCLINATION

- HIGH (55-63^0) MEAN 58^0
- INTERMEDIATE (44-46^0) MEAN 45^0
- LOW (23-37^0) MEAN 33^0

NO STATISTICALLY SIGNIFICANT DIFFERENCE IN Co & Cr ION LEVELS IN THE 3 GROUPS

- 3 PATIENTS WITH 58^0, 63^0, 61^0 WITH Co 9.8-53.6 X NORMAL AND Cr 9.5-30.5 X NORMAL
- RECOMMENDATIONS PLACE CUPS ACCURATELY!

CERAMIC

Previous Experience

Ceramic fx (3-5%)
1970's - 80's

- Large grain size material
- Inclusions / grain boundaries
- No standards for testing
- Poor tolerances for taper designs

NEWER GENERATION

Hot
Isostatic
Pressing

Dense fine grain
Uniform boundaries
Fewer inclusions

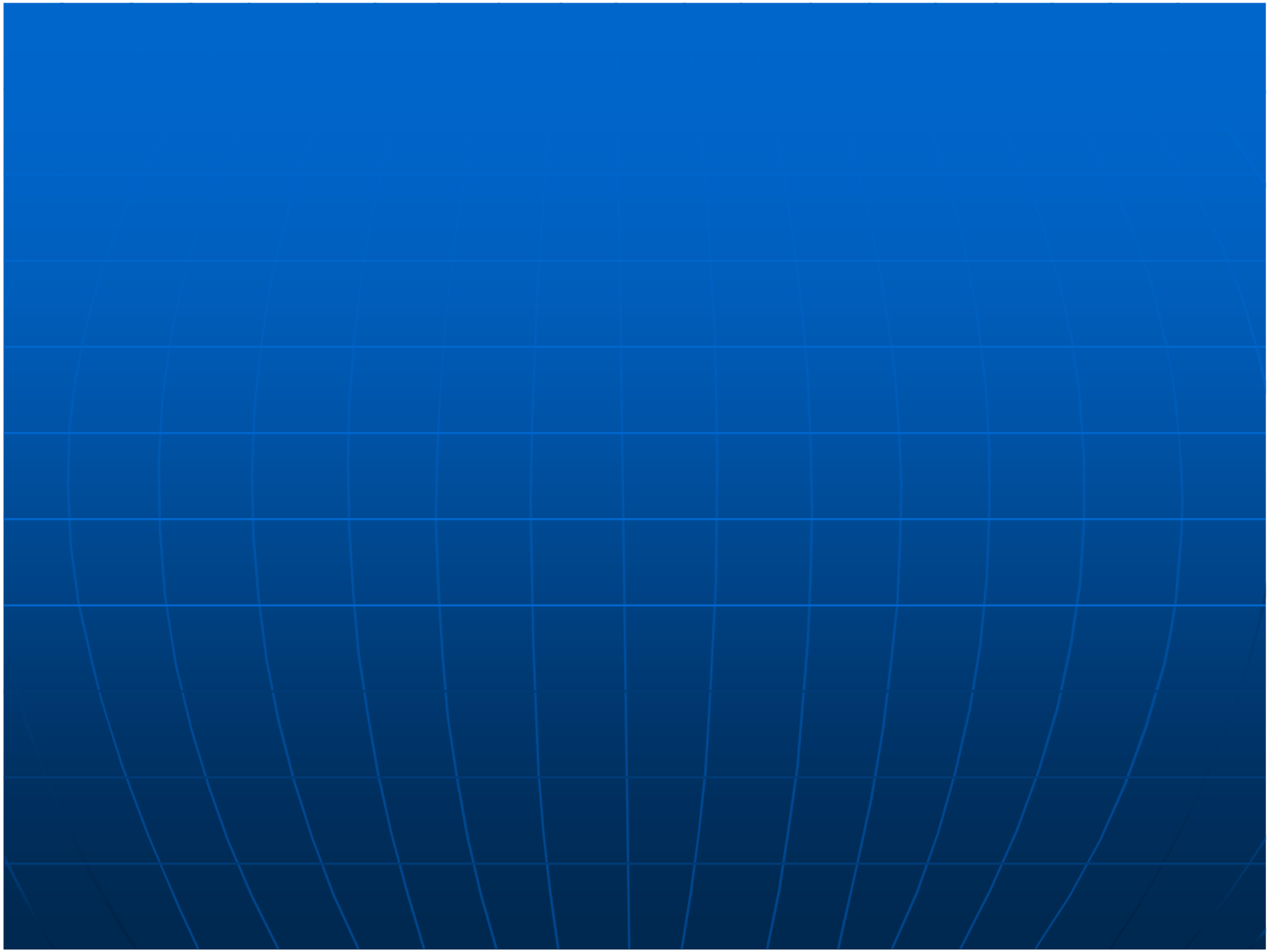
Grain Size (µm)	4.2	3.2	1.8
Burst Strength (kN)	46	58	65

- High tolerances (taper design)
- Laser etching instead of mechanical engraving
- Proof testing all implants

Causes of THA Failure

- Wear of articular bearing surface
- **Aseptic/mechanical loosening**
- Infection
- Instability
- Peri-prosthetic fracture
- Implant failure

Fixation



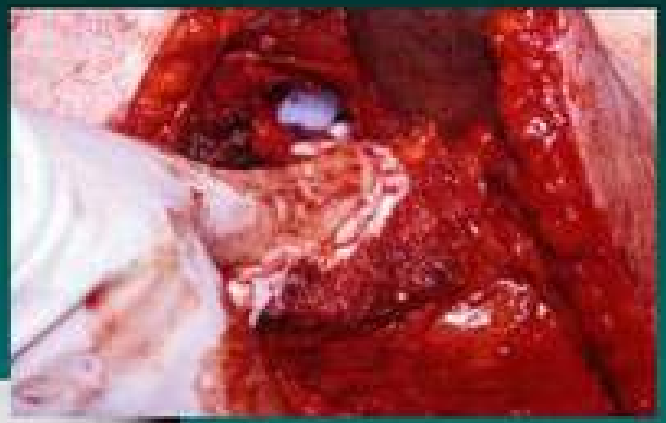
Manifestation of Osteolysis

- Surgical technique
  - cement mantles
  - cement penetration
- Implant design
  - 'no hole' cementless cups
  - tapered cemented stems
- Common theme - cemented and cementless
  - provide barrier to particles, minimise effective joint space

Cemented stem

First-generation of cementing technique

- ✓ Finger-packing doughy cement into the unplugged femoral canal
- ✓ Stainless steel
- ✓ Sharp corners with a narrow medial border



Charnley, '79

Cemented stem

First-generation of cementing technique

	Cases	F.U.	Loosening
Stauffer *CORR '82*	301	10 yr	30 %
Wrobleski *CORR '86*	116	16.6 yr	29 %
Kavanagh *JBJS '89*	166	15 yr	28 %
Stringa *Arch Putti '89*	148	7 yr	13.5 %
Ling *CORR '92*	433	16.4 yr	3 %
Schulte *JBJS '93*	322	20 yr	6 %
Stringa *GIOT '96*	104	18 yr	10.4 %

CEMENTATION

- SECOND GENERATION:

Medullary Plug

Cement Gun

- THIRD GENERATION:

Pulsatile Lavage

Reduction of porosity (Vacum mixing)

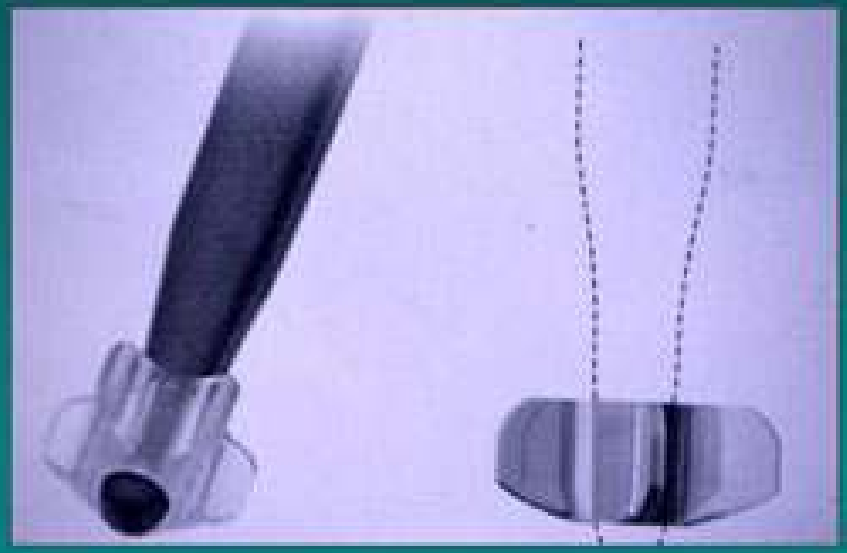
Pressurization

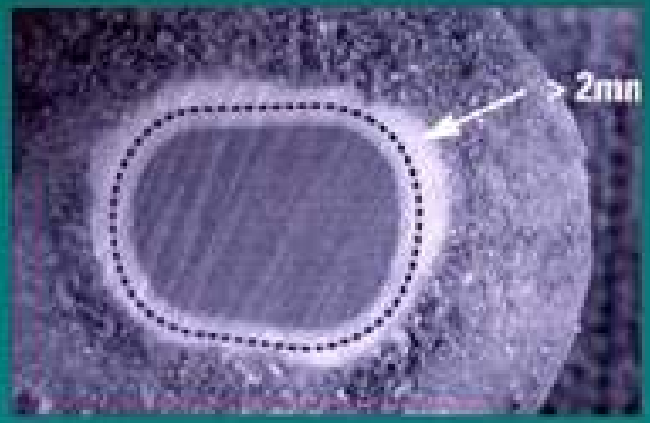
Precoating

Cemented stem

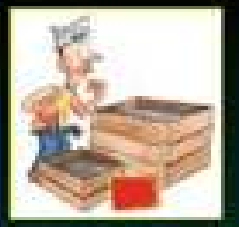
Fourth-generation of cementing technique

- ✓ Stem centralization
- ✓ Optimization of cement distribution





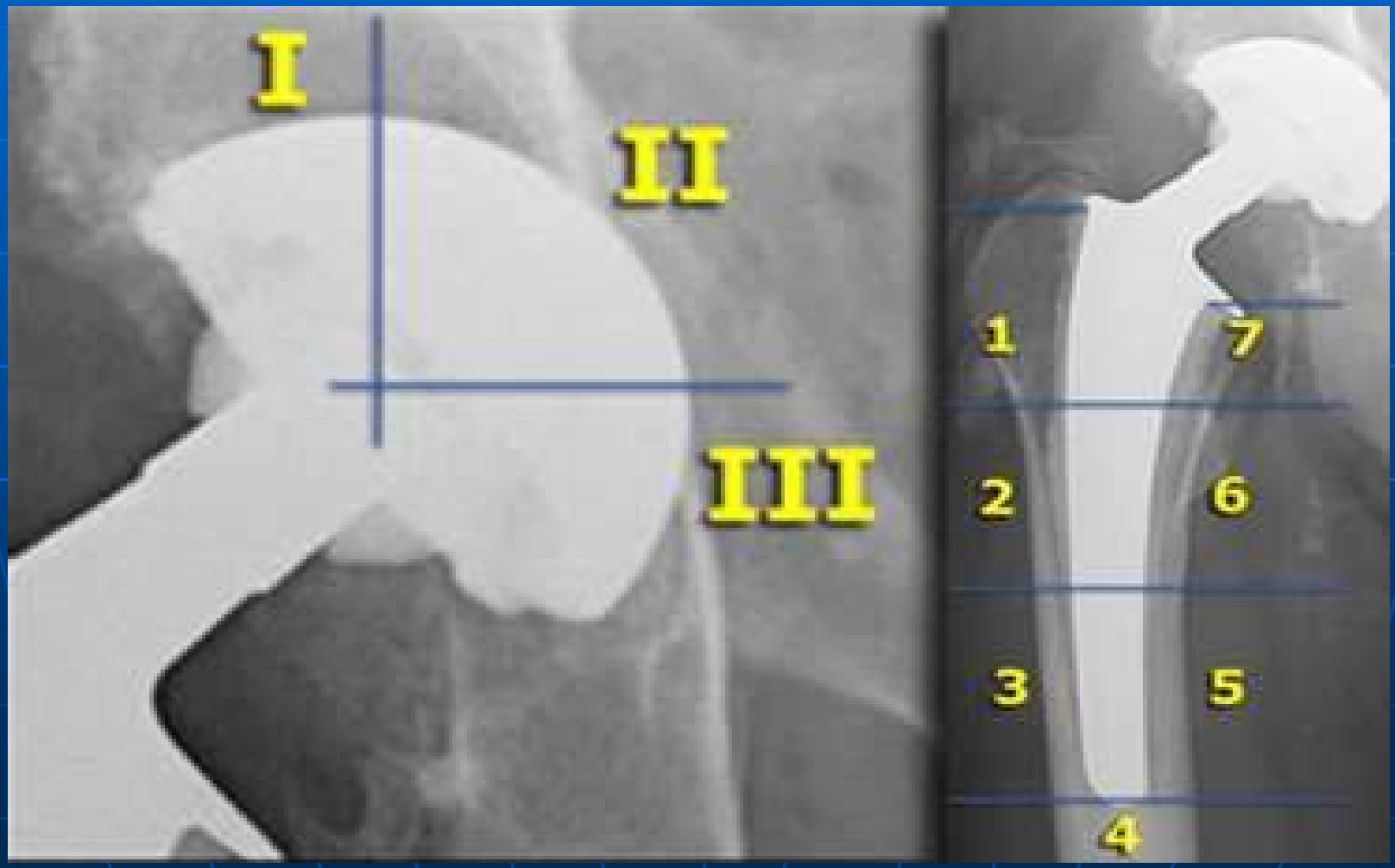
Cemented stem



Fourth-generation of cementing technique

	Cases	F.U.	Loosening
Levy *AAOS '96*	139	8 yr	1.4 %
Meneghini J. Arthroplasty '03	102	9 yr.	2%

CEMENTATION ZONES



BARRACK GRADING

- **Grade A**: medullary canal completely filled with cement (white out).
- **Grade B**: a slight radiolucency exists at the bone cement interface.
- **Grade C**: a radiolucency of more than 50% at the bone cement interface.
- **Grade D**: a radiolucency involving more than 100% of the interface between bone and cement in any projection, including absence of cement distal to the stem tip

Barrack et. al. JBJS 1992

Cemented Stem

Pre-requisites for Durable Fixation

- Adequate cement mantle
- Cementing technique (pressurization & porosity reduction)
- Co-Cr alloy
- Tapered geometry

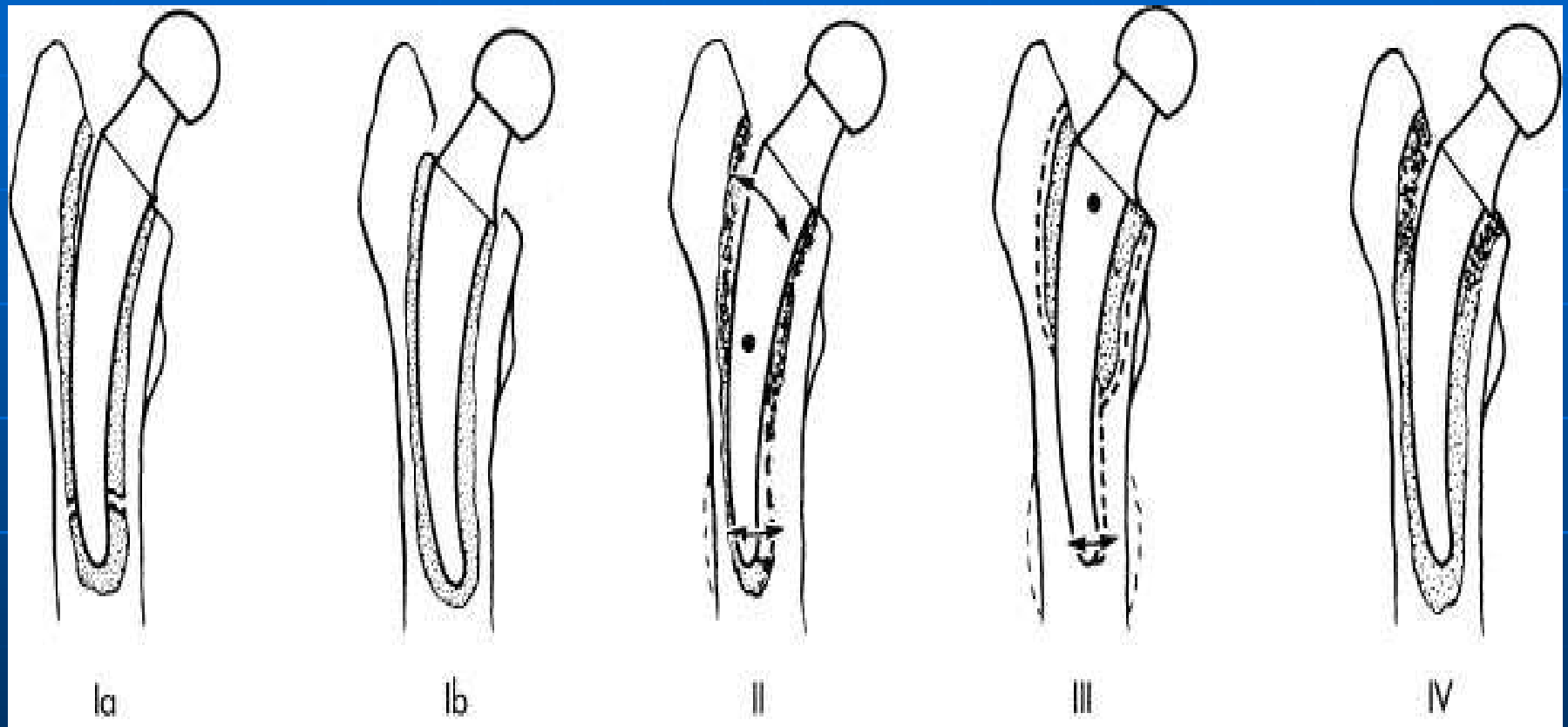
Cemented Stem

- Cracks within cement n
- De-bonding between st
- Osteolysis from particul

MODES OF FAILURE

- **1a** - subsidence of stem in cement mantle
- **1b** - subsidence of cement mantle and stem
- **2** - medial stem pivot - centre of rotation at middle of stem
- **3** - calcar pivot - centre of rotation at calcar
- **4** - bending cantilever fatigue

- ref: Gruen, McNiece and Amstutz □" Modes of failure of cemented stem- type femoral components : a radiographic analysis of loosening " CORR 141: 17, 1979



Femoral Roentgenographic Grading

Grade	Harris	Radiolucent Lines
0	None	no radiolucency
1		<50 % lucency
2	Possible	>50 % but <100 % lucency
3	Probable	continuous (100 %) lucency
4	Definite	migration, cement/stem fracture; cement-prosthesis lucency

Harris WH et al; *JBJS* 64-A:1063, 1982

THR with Cement

Surface Roughness

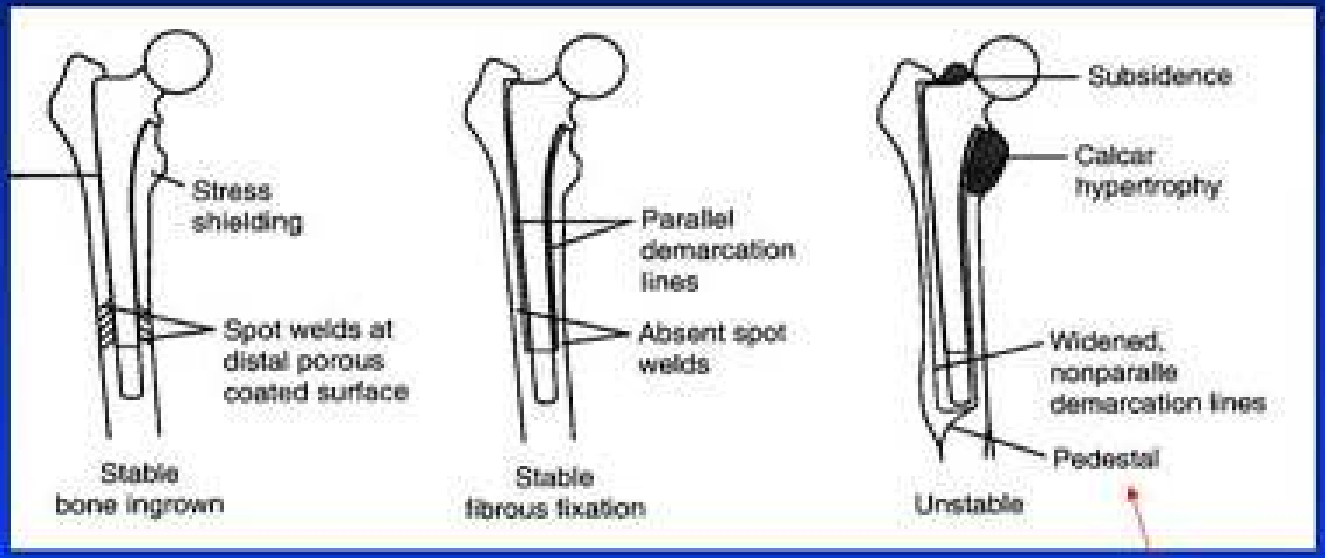
- More roughness: tighter bond between stem & cement
- Tighter bond: more stress transfer
- Tighter bond: less relaxation
- Tighter bond: greater tensile stresses
- Tighter bond: higher fatigue fracture of cement

Cemented Stem: Results

Polished (Gie et al. Hip Society 2003)

- Exeter experience
- 1970-75: polished, 2.8% revision
- 1976-85: matte-finish, 10% revision
- 1986-2003: polished, modular, 0% revision

Uncemented Femoral Components



Beware of rotation of serial radiographs!

CEMENTED ACETABULUM

Acetabular Roentgenographic Grading

Grade	Radiolucency	Surgical Loosening
0	none	none
1	Zone 1	7 %
2	Zones 1 & 2	71 %
3	Zones 1, 2 & 3	94 %
4	Cup migration, cement fracture	100 %

Hodgkinson JP et al; *Clin Orthop*, 228:105, 1988

UNCEMENTED ACETABULUM

- Radiographic Loosening Criteria (APR)
  - Radiolucent lines >1mm that initially appeared after two years
  - Progression of radiolucent lines after two years
  - Radiolucent lines in all three zones
  - Radiolucent lines 2 mm or wider in any zone
  - Migration

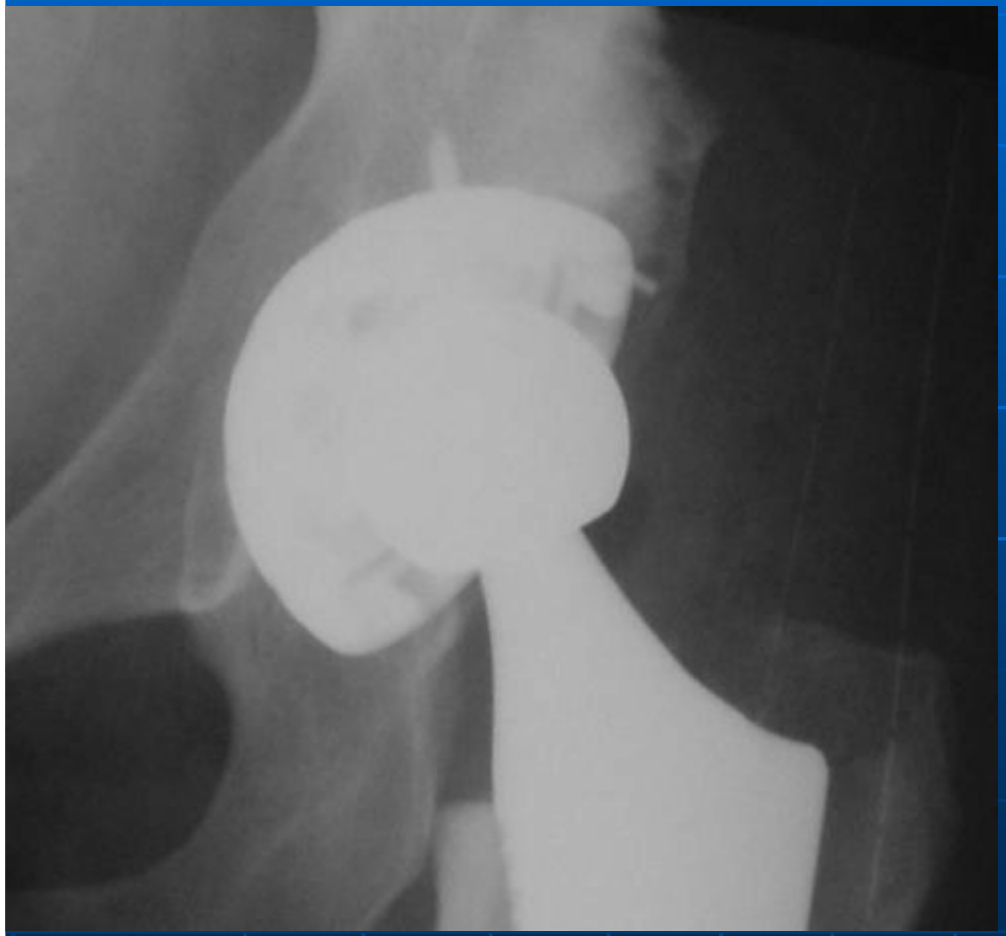
  94% Sensitivity, 100% Specificity

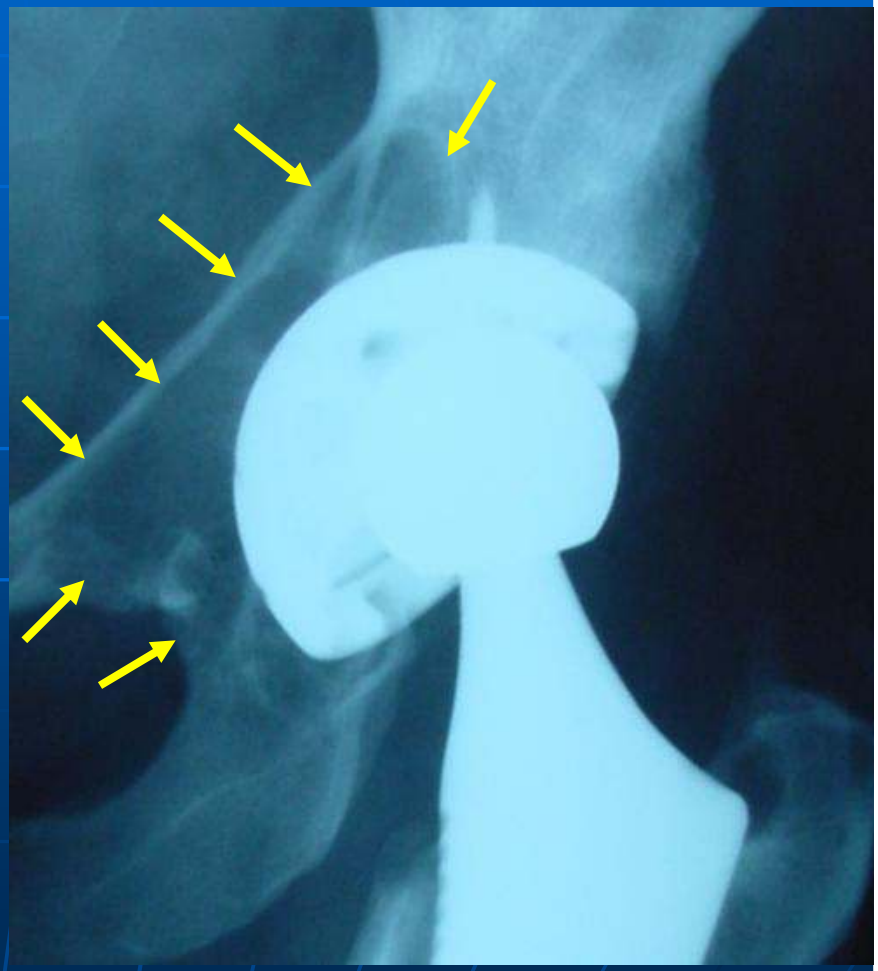
Udomkiat P, Wan Z, Dorr LD . J Bone Joint Surg Am Dec 2001

Different Presentation

- Cementless
  - osteolysis
  - may be asymptomatic
  - catastrophic failure (‘loosening’)
  - periprosthetic fracture
- Cemented
  - loosening
  - usually symptomatic
  - may be asymptomatic
  - periprosthetic fracture

Osteolysis *NOT* loosening - Asymptomatic

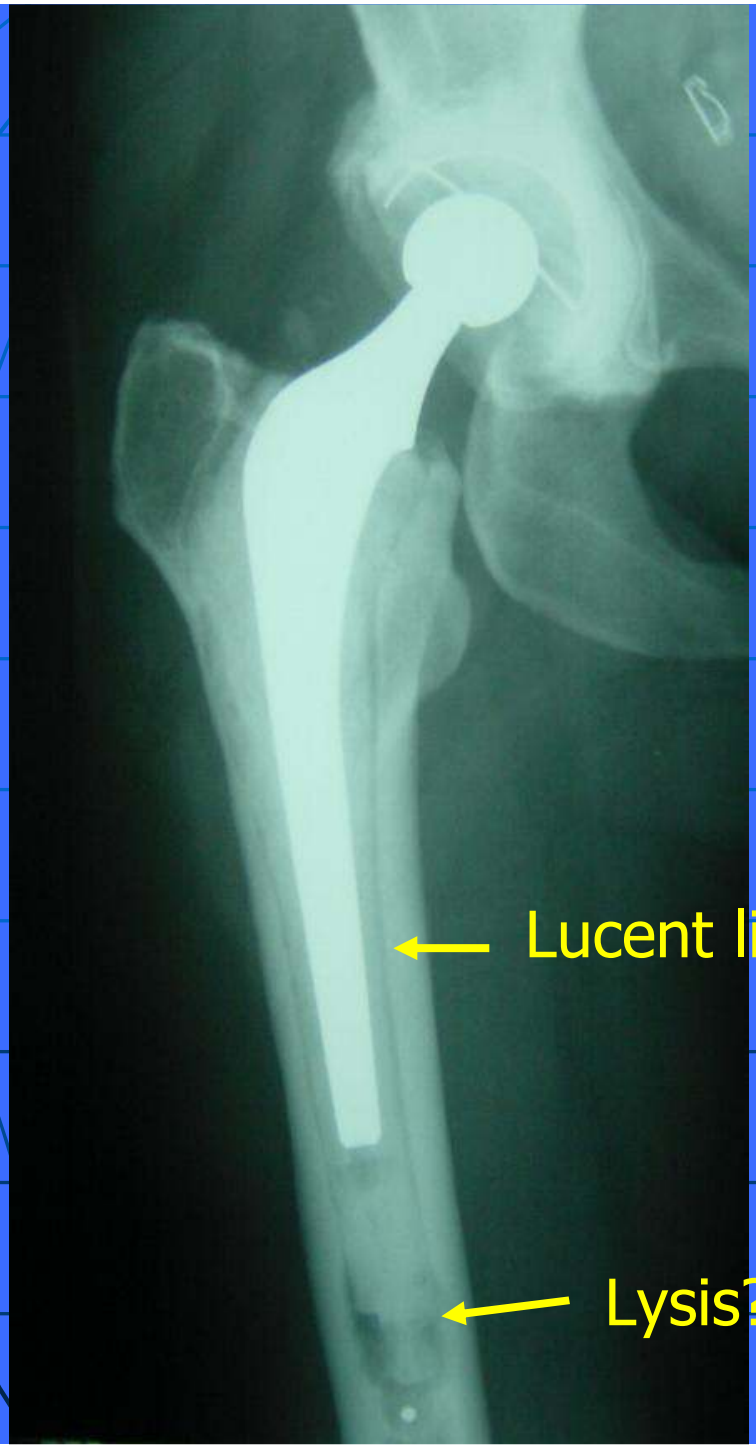


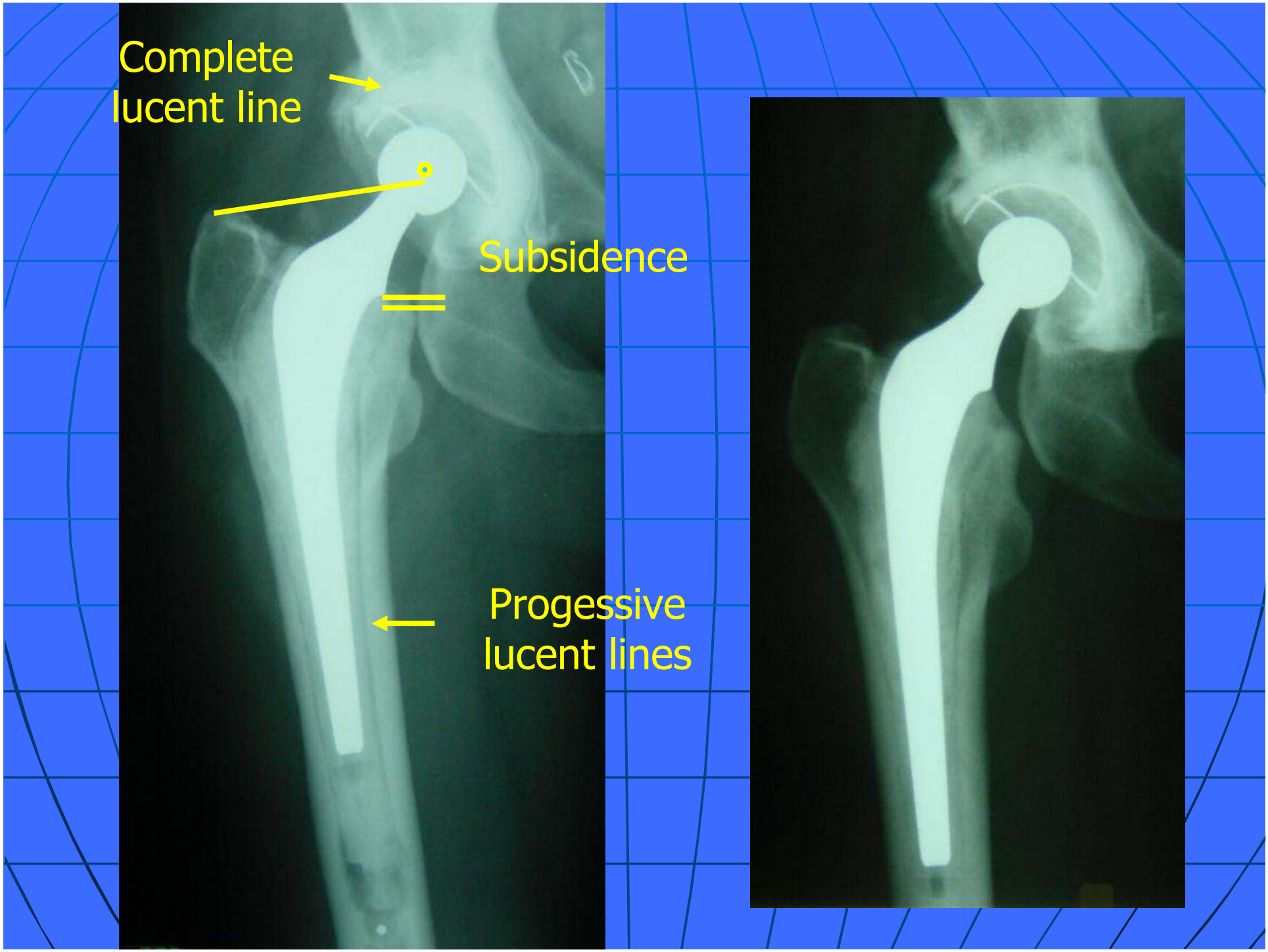


Diagnosis

- Serial comparable X-rays
- (symptoms)
  - pain
- Obtain oldest film possible
  - deep storage
  - other (original hospital)

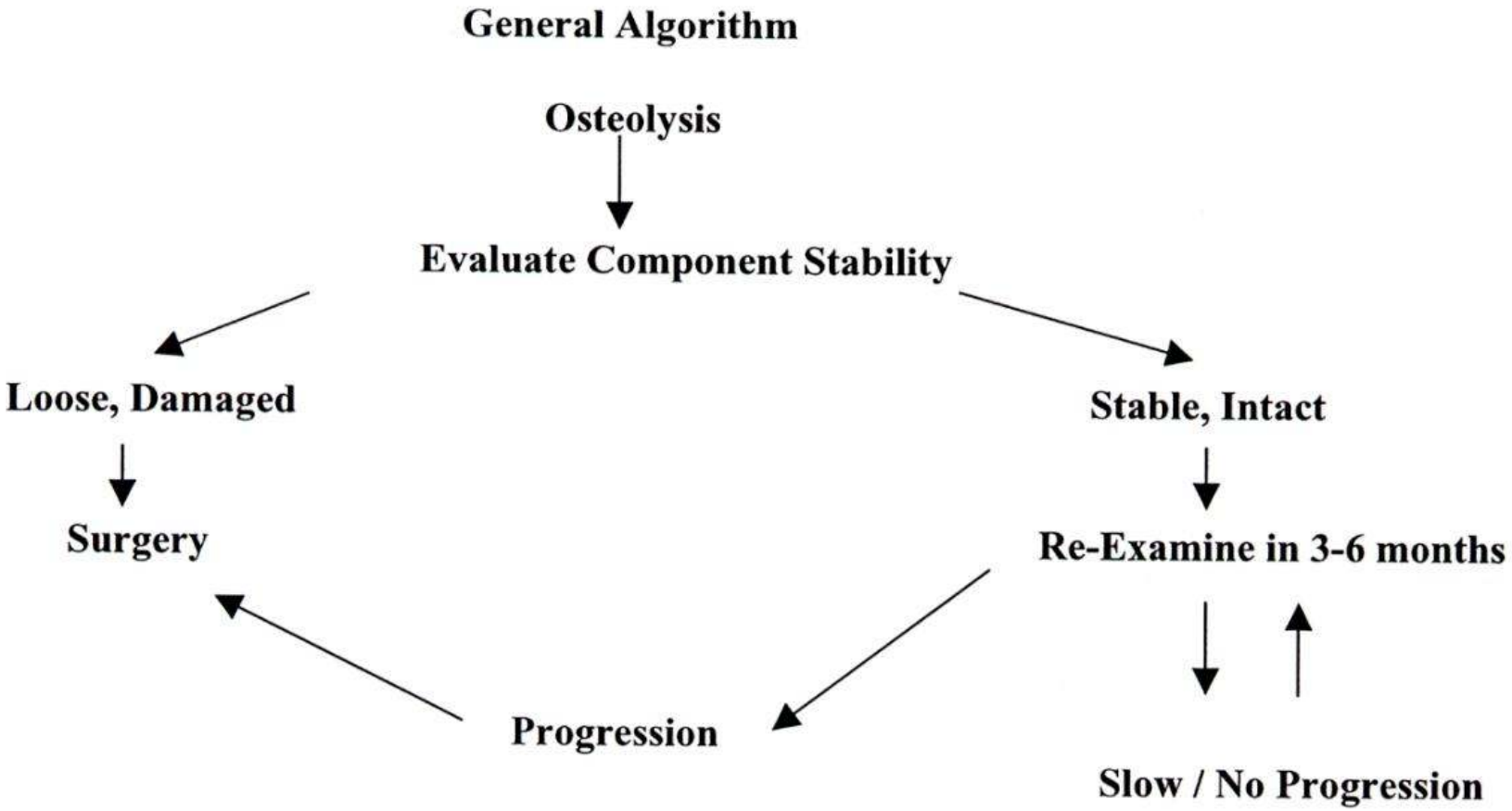
Cemented Hip




Complete
lucent line
Subsidence
Progessive
lucent lines

Rubash et al 1999

* Nonoperative Management [10]



Causes of THA Failure

- Wear of articular bearing surface
- Aseptic/mechanical loosening
- **Infection**
- Instability
- Peri-prosthetic fracture
- Implant failure

INFECTION

INCIDENCE

<1% of primary TJA's (TKA > THA)

2+ % of revision TJA's

*An additional 2.3 per 1000 prosthesis-years become infected between 2 and 8 years after implantation due to hematogenous seeding.

Steckelberg JM, et al, ASMicrobiol, 2000

Risk Factors

- Rheumatoid arthritis
- Psoriatic arthritis
- Immunosuppression, steroid therapy
- Diabetes
- Malnutrition, stasis dermatitis, hx of prior infection, prior surgeries, malignancy, obesity

Diagnosis

- History and Physical Exam
- X-rays
- Lab Studies
  - CBC
  - ESR
  - C-reactive protein
- Nuclear Medicine Scans
- Aspiration/Arthrogram with gram stain, cell count and culture
- Intra-operative frozen sections

Lab Studies
ESR

- Normal ESR
  - Men 0-9 / Women 0-20
- 30 mm/hr as a threshold for infection
  - sensitivity 60-96% and specificity 65-100%
- Elevated ESR requires further workup
  - Can be increased in RA, other inflammatory arthritis, cancer, lymphoma, multiple myeloma, and pregnancy

OKU - Hip and Knee Reconstruction
Chapter 17, 2000

Lab Studies
C - Reactive Protein

- Acute phase protein that can be used to follow the course of infection
- Peaks at 2 days post-op and normalizes within 2-3 weeks
- Rising CRP levels after the 3rd post-op day may indicate a complication such as infection
- 10 mg per liter is used as a threshold for total hip infection
  - sensitivity and specificity approx 90%

K Aalto et al. Corr. Vol 185. 1984. Pg.118-120

INFECTION

- ESR & CRP
  - Either alone, limited usefulness
  - Used together – excellent screening test

Worrisome history, risk factors, elevated ESR or CRP } Aspiration

OFF ABx!

Nuclear Medicine Scans

- Bone Scans
  - May indicate loosening after 12 months, but can not distinguish between septic and aseptic loosening
- Indium Scans
  - May increase specificity to 78%
  - When combined with Tc-99m sulfur colloid imaging specificity high as 95%

Palestro et al. Radiology Jun 1991 Pg. 645-648.

Most Commonly Cultured Organisms

- Coagulase-negative staphylococci (30-43%)
- *Staphylococcus aureus* (12-23%)
- Mixed flora (10-11%)
- Streptococci (9-10%)
- Gram-negative bacilli (3-6%)
- Enterococci (3-7%)
- Anaerobes (2-4%)
- No growth infection (11%)

TREATMENT

- Antibiotic therapy
- Incision and drainage of the hip
- Debridement and modified Girdlestone resection arthroplasty
- One- or two-stage revision to a total hip arthroplasty

Treatment Considerations

- Chronicity
- Virulence
- Glycocalyx formation
- Antibiotic sensitivity (resistance)
- Host factors

TREATMENT CHOICE DEPENDS ON CHRONICITY

Selection of the best modality of treatment is largely dependent on the chronicity of the disease

Gearen P, Borden LS: J of Arthr. 1987

Acute – within 3 weeks of seeding

Chronic – known to be present > 3 weeks

DEBRIDEMENT WITH RETENTION OF COMPONENTS

- Acute infection with cemented components (exchange tibial insert)
- Meticulous synovectomy and copious irrigation
- 6 weeks IV antibiotics
- Arthroscopic cleanout, multiple irrigations are far less successful

Debridement with Retention

- Borden & Gearen 1987 5/6 83%
- Teeny, et al 1990 3/5 60%
- Wasielewski, et al 1996 6/8 75%
- Mont, et al 1997 20/24 83%

TWO STAGE EXCHANGE

- Chronic infection (> 3 weeks)
- ? Acute infection with resistant organsims

CHRONIC INFECTION
ONE vs TWO STAGE

One Stage	50 - 75% Success
Two Stage	80 - 95% Success

PREREQUISITES FOR REIMPLANTATION

- CRP normal
- ESR returning to normal
- Dry, supple, non-tender wound
- Negative aspiration - cultures and synovial fluid analysis

Causes of THA Failure

- Wear of articular bearing surface
- Aseptic/mechanical loosening
- Infection
- **Instability/Dislocation**
- Peri-prosthetic fracture
- Implant failure

Incidence

- Primary THA: 0.5% - 8%
  3.9%
- Revision THA: 5% - 25%
  14.4%

Phillips et al, 2003

Causes of Dislocation in THA

1) Component malposition
2) Component impingement

3) Bone/soft tissue impingement
4) Inadequate soft tissue balance
5) Patient non-compliance

Surgical Approach

- Direct Lateral (Hardinge): **0.43%**
- Posterior Approach (no repair): **4.5%**
- Posterior Approach with repair: **0.49%**

Avoiding Dislocation in Total Hip Arthroplasty

1)Pre-op planning
2)Accurate component implantation
3)Trial ROM
4)Soft tissue repair
5)Patient Education
6)Recognize High Risk Patients

Causes of THA Failure

- Wear of articular bearing surface
- Aseptic/mechanical loosening
- Infection
- Instability
- **Peri-prosthetic fracture**
- Implant failure

Vancouver Classification

- A – Troch
- B1 – At Tip, well fixed
- B2 – at tip, loose stem, good bone stock
- B3 – loose stem, Poor Bone stock
- C – Well Below Stem

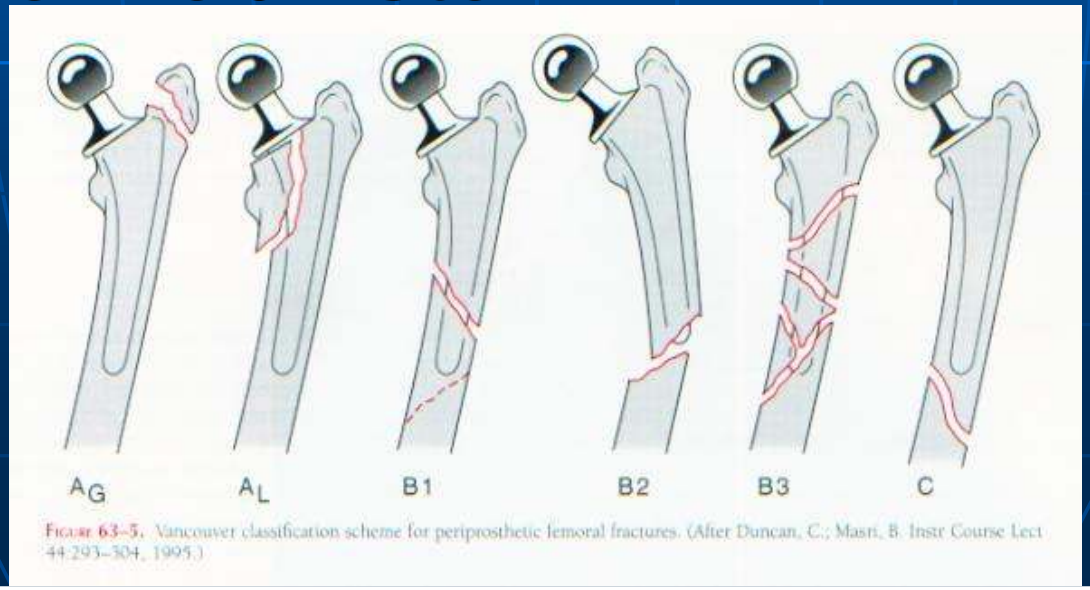


FIGURE 63–5. Vancouver classification scheme for periprosthetic femoral fractures. (After Duncan, C.; Masri, B. Instr Course Lect 44:293–304, 1995.)

TREATMENT

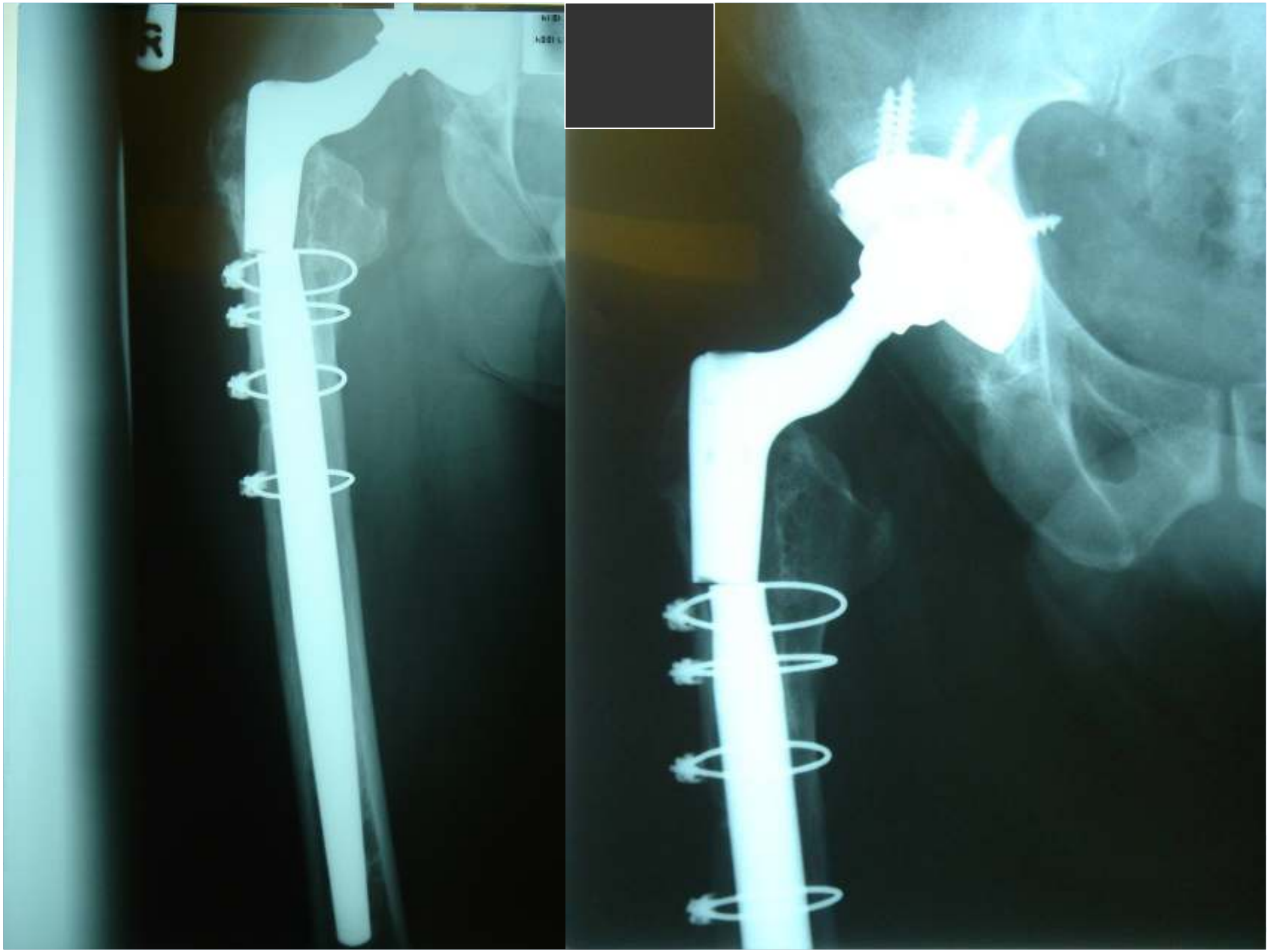
- Troch Fx's:
  - Lesser – only Tx if substantial medial cortex involved
  - Greater – Crutches, Limit Abduction
- Diaphyseal:
  - Fixed – ORIF w/ cerclage + struts/plate
  - Loose, Good Bone Stock – Long Stem
  - Loose, Poor Bone Stock – Bulk allograft in young, Tumor prosthesis in old (>70)
- Distal: ORIF, Address implant later

Causes of THA Failure

- Wear of articular bearing surface
- Aseptic/mechanical loosening
- Infection
- Instability
- Peri-prosthetic fracture
- **Implant failure**

RESPONSE TO STEM FRACTURE

- Broader Prostheses
- Less Cement
- More Rigid Construct
- Less Decoupling
- Failure of Cement-Bone Interface



THANK YOU!

QUESTIONS?