Total Hip Arthroplasty:
-component concepts and an overview of normal and abnormal findings

Clark Brixey, M.D.

Inspiration

- “Stable alignment. No complications.”

Overview

- Components
  - Materials used
  - Fixation to bone
  - Bearing surfaces
- Post operative radiographic evaluation
  - Normal findings
    - Early
    - Late
  - Pathologic considerations
    - Early
    - Late

Materials

- Metals
  - Titanium and titanium alloys (titanium-aluminum-vanadium)—more commonly used today
  - Cobalt-chromium alloys
  - Stainless steel and titanium supporting hardware
- Cement: space-filler and adhesive
  - Polymethyl methacrylate (acrylic plastic) mixed with barium
- Polyethylene: bearing surface lining acetabular component
  - Ultrahigh molecular weight material also used in bullet-proof vests and lining (“boards”) around hockey rinks.
- Ceramics: prosthetic femoral heads and acetabular bearing surfaces
  - Zirconia—more widely known in faux jewelry
  - Alumina—more widely known as ingredient in antacids

Roberts, C., *et al*, Radiographic Imaging of Hip Replacement Hardware, *Seminars in Roentgenology*, 2005.

Fixation to Bone

- Direct mechanical fixation
  - Internal fixation screws or spikes
- Passive interference fit
  - Tightly fitted components pressed into place (press fit)
- Bone cement
  - Adhesive—gluing component to bone
  - Space-filler contributing to closer interference fit
- Porous ingrowth/ongrowth
  - Remodeling bone attaches directly to component

Roberts, C., *et al*, Radiographic Imaging of Hip Replacement Hardware, *Seminars in Roentgenology*, 2005.

Types of Replacements

- Bone fixation technique:
  - Cemented
  - Non Cemented
  - Hybrid—combination of cemented and noncemented components

- Bearing surface
  - Polyethylene
  - Ceramic
  - Metal on metal
  - Combination

Cemented

Non cemented

Hybrid

Cemented Fixation

- Benefits
  - Immediate attachment to bone
    - Early weight bearing
    - Early pain relief
  - Less long term thigh pain
- Limitations
  - No integration of bone
  - Some studies report gradual diminution of quality over time

Ni, G.X., *et al*, Review article: Cemented or uncemented femoral component in primary total hip replacement?, *J Ortho Surg*, 2005; 13(1):96-105.

Cementless Fixation

- Benefits
  - "Osseointegration": attachment of lamellar bone to implant
- Limitations
  - Integration takes 4-12 wks and may continue up to 3 years
  - Increased reports of thigh pain
  - Stress shielding

Khanuja, H.S., *et al*, Cementless Femoral Fixation in Total Hip Arthroplasty, *JBJS Am* 2011;93:500-9.

Osseointegration: Surface characteristics of an implant

- Ingrowth: bone grows inside a porous surface
  - Porous metals
  - Sintered beads—microspheres
  - Fiber mesh coatings

- Ongrowth: bone grows onto a roughened surface
  - Grit (abrasive) blasting—may be used as adjunct below mesh or sintered beads
  - Plasma spraying—molten metal powder sprayed on surface

Khanuja, H.S., *et al*, Cementless Femoral Fixation in Total Hip Arthroplasty, *JBJS Am* 2011;93:500-9.

Bearing surfaces

Polyethylene

Metal on metal

Ceramic

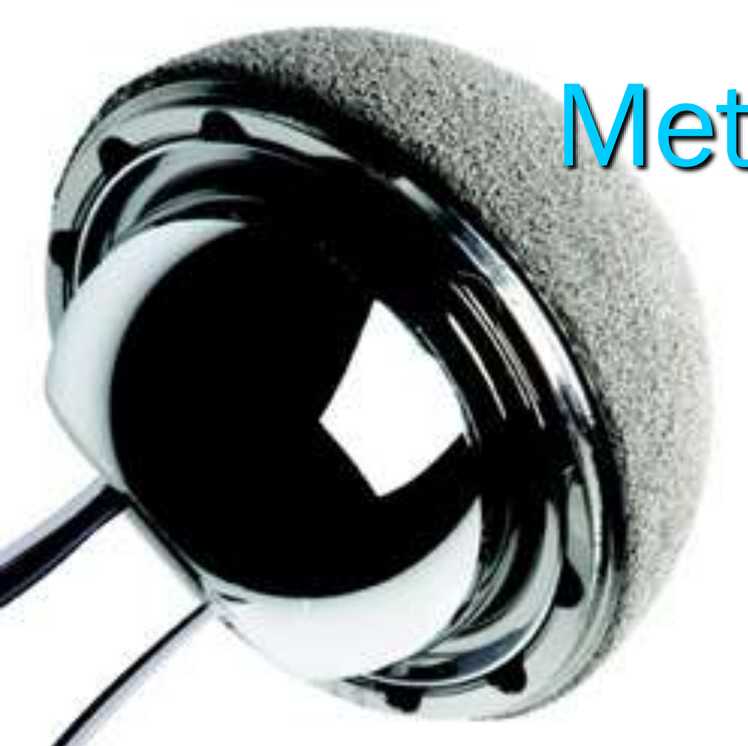
http://www.hipreplacement.com/DePuy/technology/implants/bearings/index.html

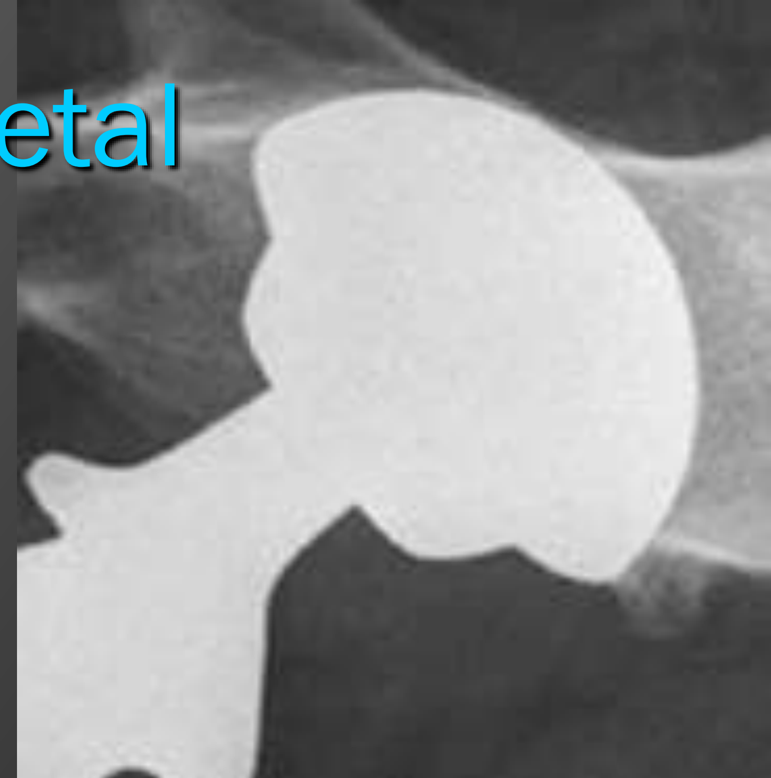
Polyethylene

- Benefits
  - Durable/versatile for most lifestyles
  - Long clinical history
  - Not toxic
- Limitations
  - Wear
    - Inflammation/small particle disease
    - Bone loss

Liao, *et al*, Effects of resin and dose on wear and mechanical properties of cross-linked thermally stabilized UHMWPE, Society for Biomaterials, the 7th World Biomaterials Congress, Sydney, Australia, 2004.

Metal on metal





- Benefits
  - Durable/long lasting
  - Low level of wear particles
  - Younger/active patients
- Limitations
  - Adverse reaction to metal debris

Muller, M.E., The Benefits of Metal-on-Metal Total Hip Replacements, *Clin Ortho and Rel Research*, 311: 54-59, 1995.

Ceramic

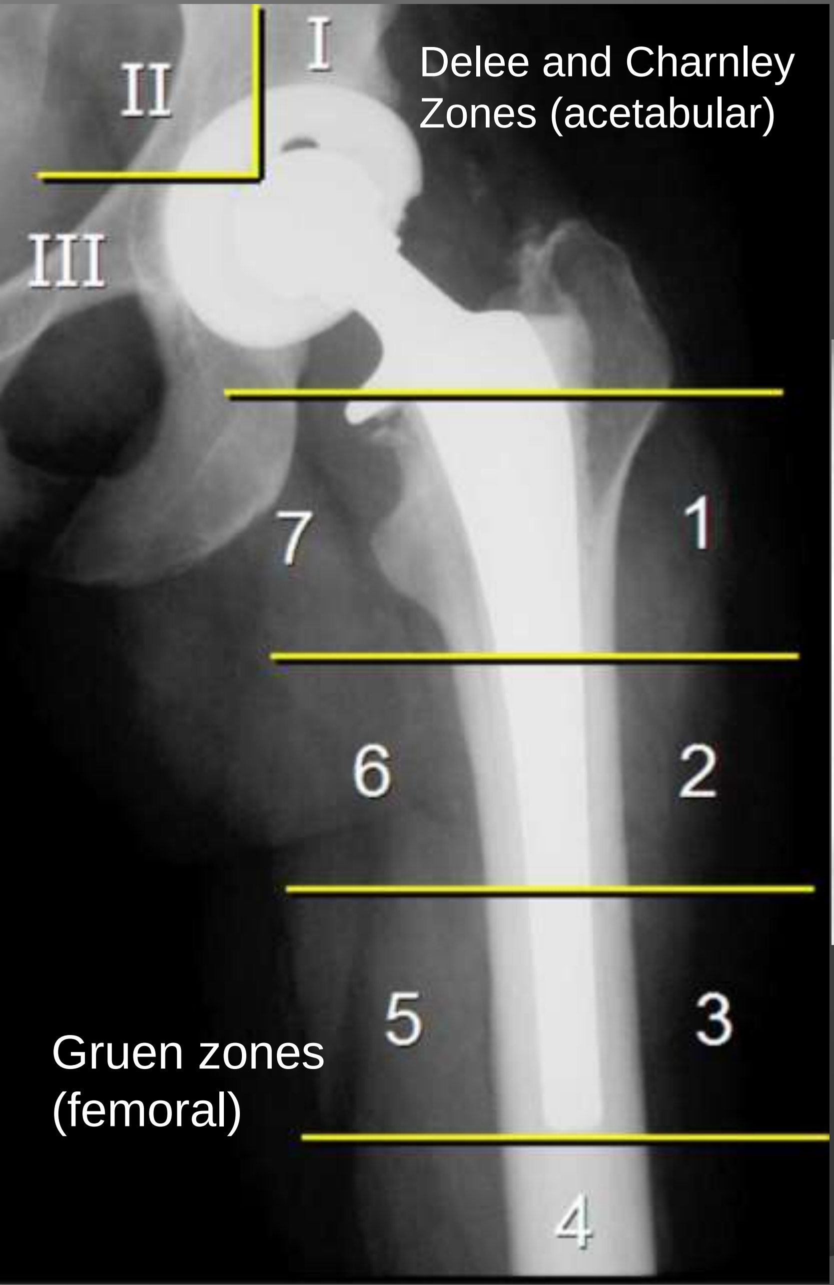
- Benefits
  - Reduced wear
  - Improved lubrication
  - Reduced friction
- Limitations
  - More prone to fracture
  - Less forgiving in surgery
  - Chance of squeaking

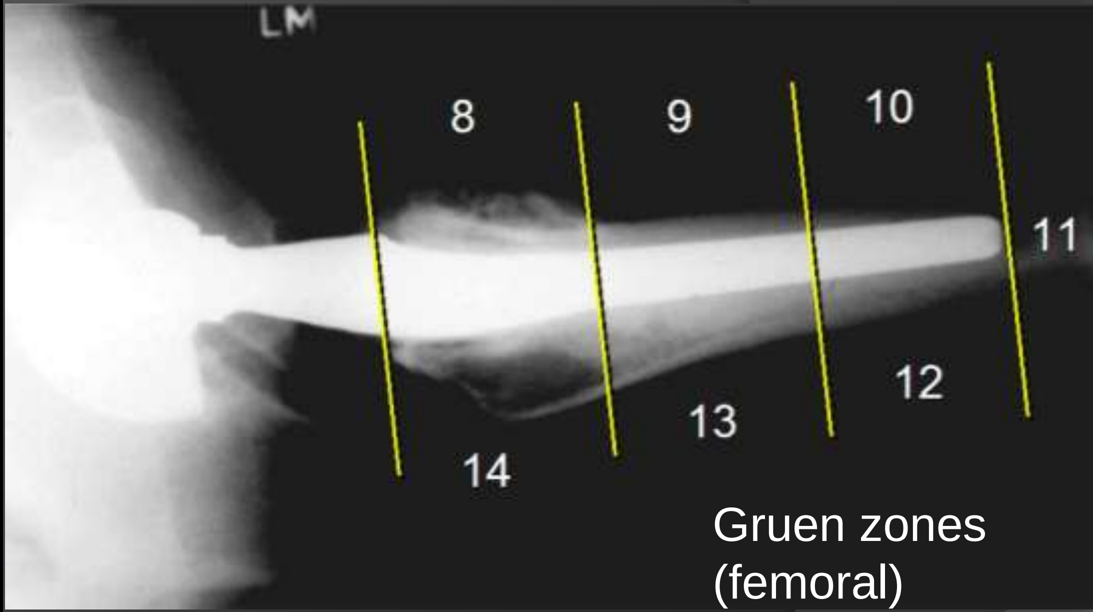
Hsu, J.E., *et al*, Ten year follow-up of patients younger than 50 years with modern ceramic-on-ceramic total hip arthroplasty, *Sem Arthro*, 22: 4;229-233, Dec 2011.

Postoperative Evaluation

- Normal Findings
  - Early
  - Late
- Pathologic considerations
  - Early
  - Late

Anatomic considerations





Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall

Immediate postoperative considerations

- Leg length
- Acetabular inclination/version
- Femoral stem inclination/version
- Femoral tip position
- Material interface/cement mantle

Leg length

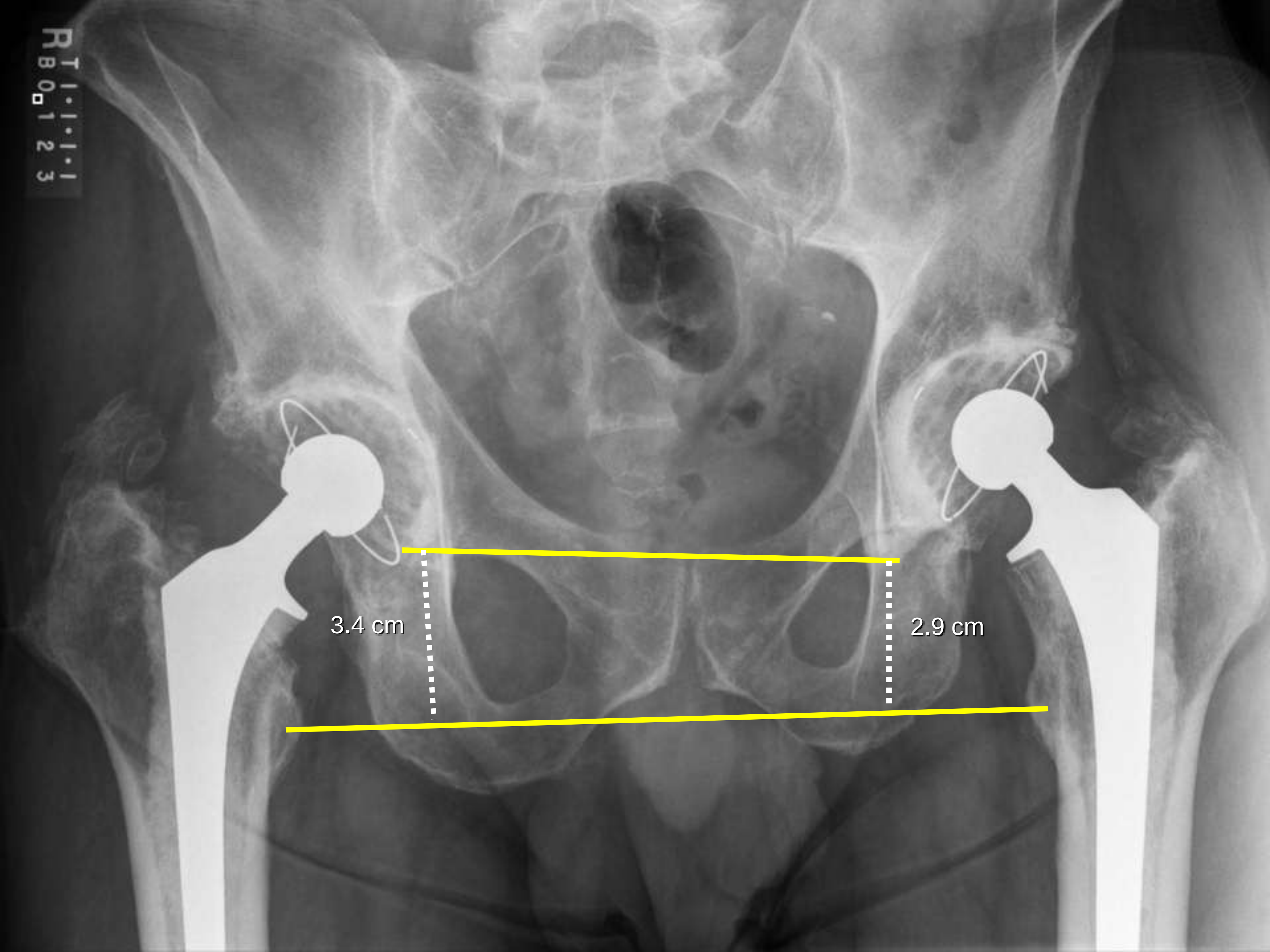
- Leg length inequality common after THA
- Up to 27%
- Mean discrepancy 15.9mm
- Up to 10mm thought to be acceptable, but may still be noticeable by patient; may require shoe orthotic
- High source of malpractice

McBride, TJ, *et al*, How to read a postoperative total hip replacement radiograph, *Postgrad Med J*, 2010.

How to measure leg length

- Hips positioned in neutral
- Draw transverse line connecting inferior borders of acetabular teardrops (transverse pelvic axis)
- Lesser trochanter often used as femoral reference point
- Perpendicular line from femoral reference to pelvic reference compared side to side
- Bi-ischial line also described as pelvic reference → rotation of film can make this inaccurate

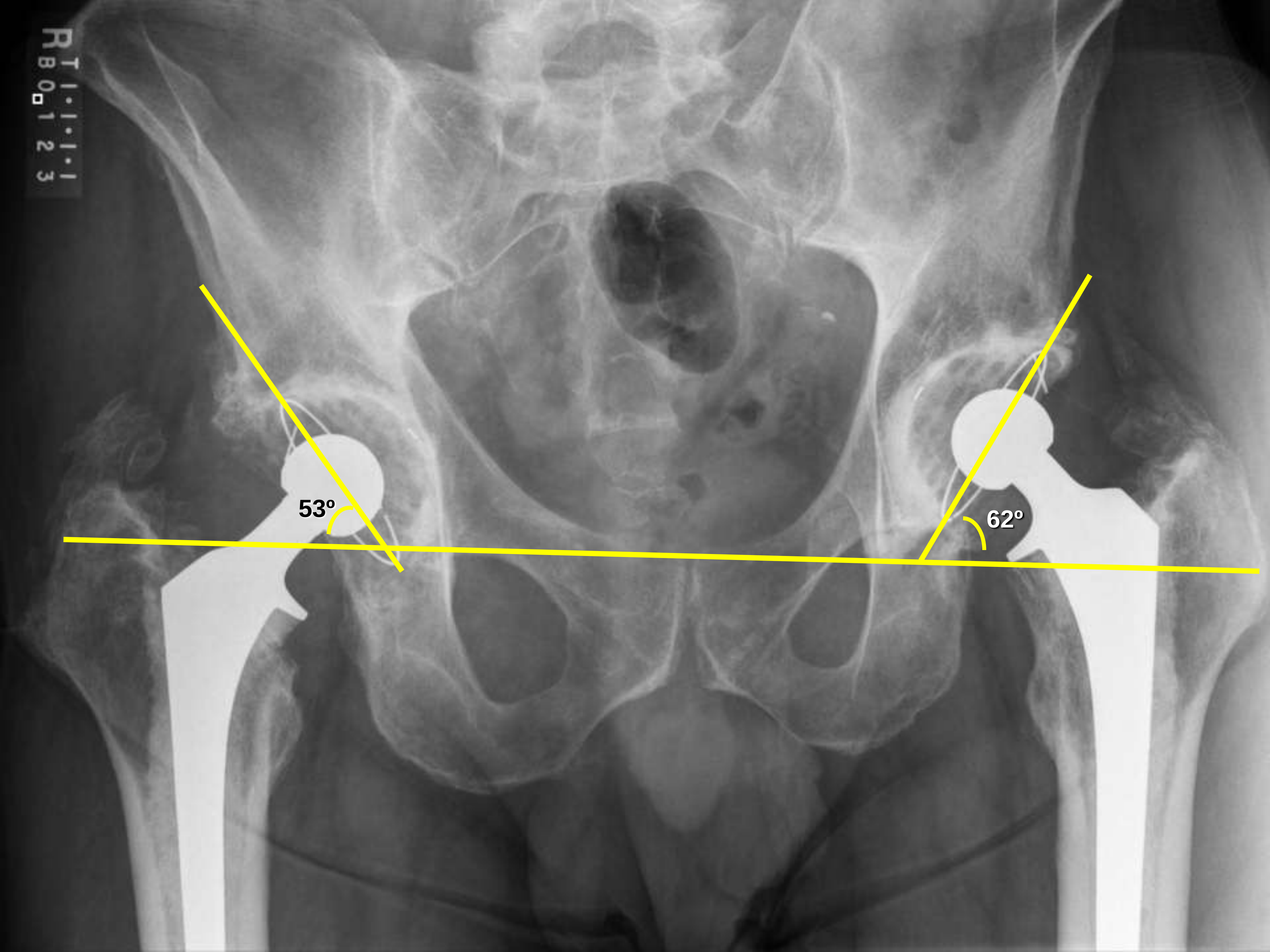
Woolson ST, *et al*, Results of a method of leg length equalization for patients undergoing primary total hip replacement, *J Arthroplasty*, 1999;14:159-64.


3.4 cm
2.9 cm

Acetabular component position

- Inclination: angle between the acetabular axis (line through medial and lateral cup margins) and the transverse pelvic axis
  - Associated with risk of dislocation
  - Affects range of motion
- McCollum and Grey: safe range 30-50º
- D'Lima: best range of motion: 45-55º

1. McCollum DE, *et al*, Dislocation after total hip arthroplasty: causes and prevention, *Clin Orthop*, 1990;261-159-70.
2. D'Lima D, *et al*, The effect of orientation of the acetabular and femoral components on the range of motion of the hip at different head-neck ratios, *JBJS* 2000;82-A:315-21.

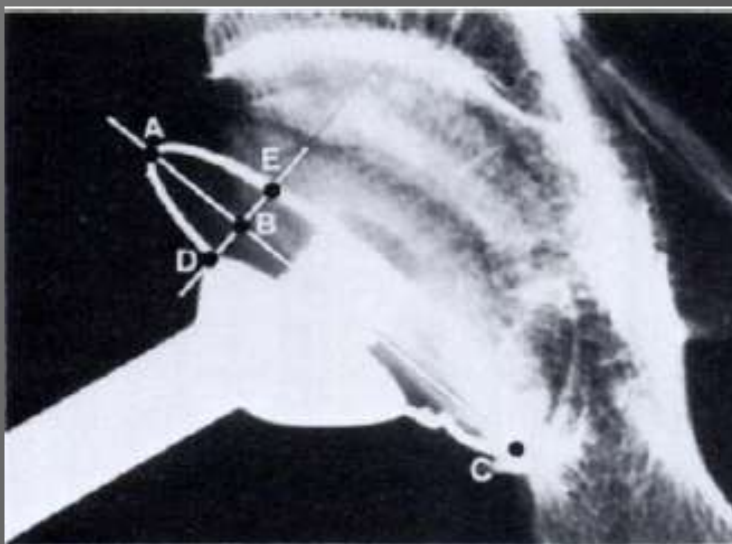

53º
62º

Acetabular component position

- Anteversion: angle between the acetabular axis and the coronal plane
  - Associated with risk of dislocation
  - Affects range of motion
- Rarely calculated by radiologists in day-to-day clinically practice
- Lateral view: exact measurement not possible → degree of angulation affected by pelvic or thigh rotation
- AP view often only view provided
- CT best modality
- Normal range: 5-25º

http://www.radiologyassistant.nl/en/431c8258e7ac3.

Anteversion calcuation



$$\frac{AB}{AC}=\frac{14}{56}=0.25 \quad \text{and} \quad \frac{DE}{AC}=\frac{11}{56}=0.20.$$

Anteversion of the Acetabular Cup

Angle of planar anteversion according to the ratios AB/AC and DE/AC (where AB = X' and DE = Y')

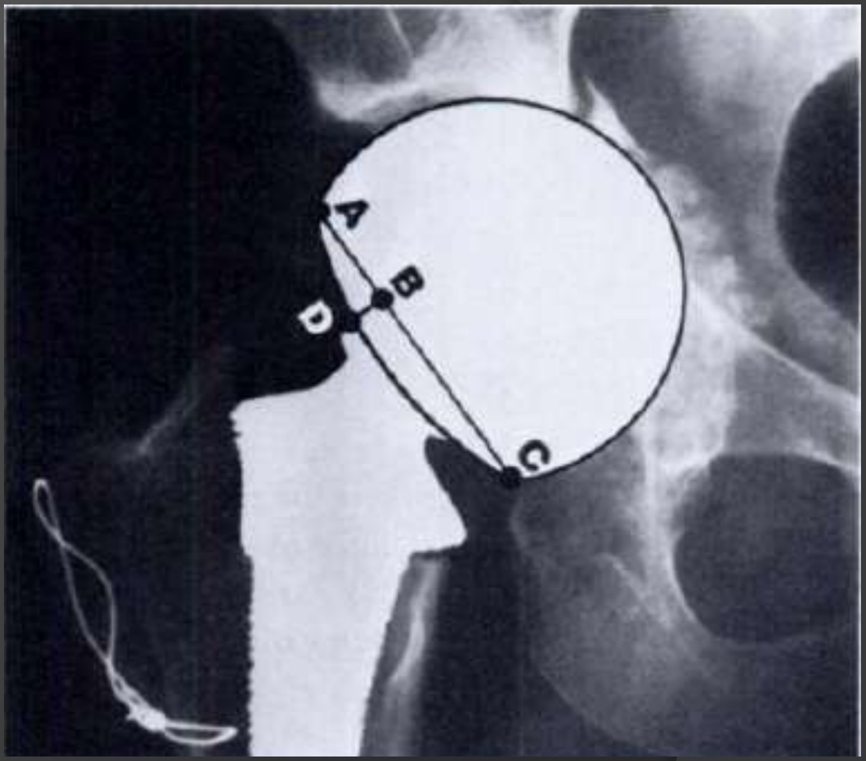
	X'/AC																
Y'/AC	0.38	0.36	0.34	0.32	0.30	0.28	0.26	0.24	0.22	0.20	0.18	0.16	0.14	0.12	0.10	0.08	0.06
0.02	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2
0.04	2	2	2	2	2	3	3	3	3	3	3	3	3	3	4	4	4
0.06	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	6	6
0.08	5	5	5	5	5	5	5	5	5	6	6	6	6	7	7	8	8
0.10	6	6	6	6	6	6	6	7	7	7	7	7	8	8	9	10	11
0.12	7	7	7	7	7	8	8	8	8	8	9	9	9	10	11	12	13
0.14	8	8	8	8	9	9	9	9	9	10	10	10	11	12	12	13	15
0.16	9	9	10	10	10	10	10	11	11	11	12	12	13	13	14	15	17
0.18	11	11	11	11	11	11	12	12	12	13	13	14	14	15	16	17	19
0.20	12	12	12	12	12	13	13	13	14	14	14	15	16	17	18	19	22
0.22	13	13	13	13	14	14	[illegible]	[illegible]	15	15	16	17	17	18	20	22	24
0.24	14	14	14	15	15	15	16	16	16	17	17	18	19	20	22	24	26
0.26	15	16	16	16	16	16	17	17	18	18	19	20	21	22	24	26	29
0.28	17	17	17	17	17	18	18	19	19	20	20	21	22	24	26	28	31
0.30	18	18	18	18	19	19	20	20	21	21	22	23	24	26	27	30	34
0.32	19	19	19	20	20	20	21	21	22	23	24	25	26	27	29	32	36
0.34	20	21	21	21	21	22	22	23	23	24	25	26	28	29	32	35	39
0.36	22	22	22	22	23	23	24	24	25	26	27	28	29	31	34	37	42
0.38	23	23	23	24	24	24	25	26	26	27	28	30	31	33	36	39	44
0.40	24	24	25	25	25	26	26	27	28	29	30	31	33	35	38	42	47
0.42	25	26	26	26	27	27	28	29	29	30	32	33	35	37	40	44	51
0.44	27	27	27	28	28	29	29	30	31	32	33	35	37	39	43	47	54
0.46	28	28	29	29	30	30	31	32	33	34	35	37	39	42	45	50	58
0.48	29	30	30	30	31	32	32	33	34	35	37	39	41	44	48	53	62
0.50	31	31	31	32	32	33	34	35	36	37	39	41	43	46	50	56	67
0.52	32	32	33	33	34	35	35	36	38	39	41	43	45	49	53	60	73
0.54	33	34	34	35	35	36	37	38	39	41	42	45	47	51	56	64	84
0.56	35	35	36	36	37	38	39	40	41	43	44	47	50	54	60	69	
0.58	36	37	37	38	38	39	40	41	43	44	46	49	52	57	63	75	
0.60	38	38	39	39	40	41	42	43	45	46	49	51	55	60	67	90	
0.62	39	40	40	41	42	43	44	45	47	48	51	54	58	63	73		
0.64	41	41	42	42	43	44	45	47	49	51	53	56	61	67	80		
0.66	42	43	43	44	45	46	47	49	51	53	56	59	64	72			
0.68	44	44	45	46	47	48	49	51	53	55	58	62	68	78			
0.70	46	46	47	48	49	50	51	53	55	58	61	66	73				
0.72	47	48	49	49	51	52	53	55	57	60	64	70	79				
0.74	49	50	50	51	52	54	55	58	60	63	68	74					
0.76	51	52	52	53	55	56	58	60	63	67	72	82					
0.78	53	53	54	55	57	58	60	63	66	70	77						
0.80	55	55	56	58	59	61	63	66	69	75	90						

Planar anteversion = 13º

Ackland MK, *et al*, Anteversion of the acetabular cup. Measurement of angle after total hip replacement, *JBJS*, 1986;68B:409-13.

Anteversion calcuation from AP view

- Metal-backed cup
  - AC unchanged
  - BD is half of Y'

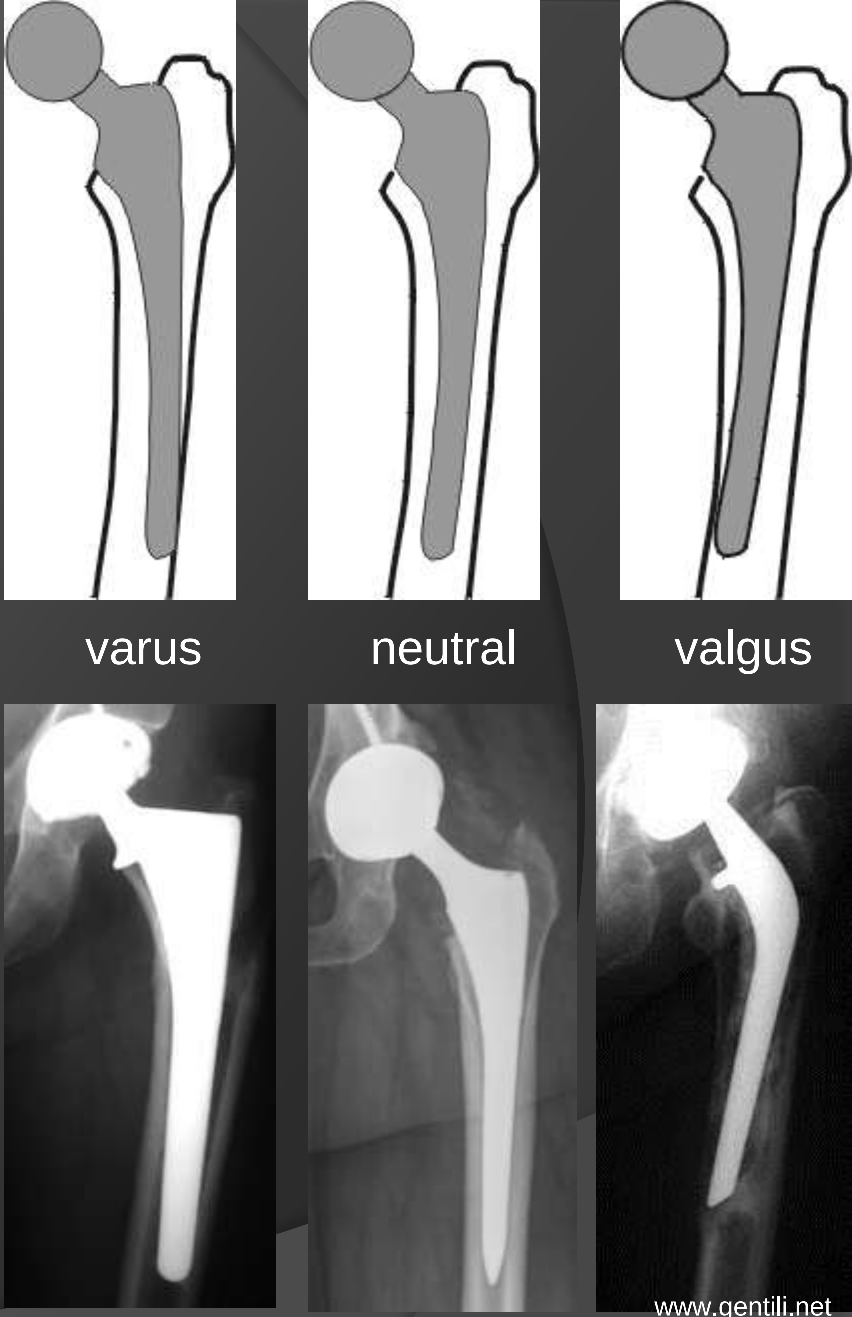


In day-to-day clinical practice, inclination angle most commonly assessed.

Ackland MK, *et al*, Anteversion of the acetabular cup. Measurement of angle after total hip replacement, *JBJS*, 1986;68B:409-13.

Femoral component position

- Goal: stem in neutral position within femoral shaft
- AP view: stem tip should be in center
- Malposition of stem associated with failure
  - Up to 46% failure w/ 16 yr f/u of cemented
  - Correlated with loosening in cementless prostheses



McBride, TJ, *et al*, How to read a postoperative total hip replacement radiograph, *Postgrad Med J*, 2010.

Femoral component position

- Anteversion of neck best assessed on lateral view, but often difficult to evaluate
  - Positioning in elderly or post operative patient
  - Affected by pelvic and thigh rotation
- Femoral anteversion important factor allowing adequate flexion of hip
- Suggested range: 10-15º
- Over-anteversion associated with dislocation
- CT best modality

McBride, TJ, *et al*, How to read a postoperative total hip replacement radiograph, *Postgrad Med J*, 2010.

Material interface (cemented prostheses)

- Assess prosthesis--cement and cement—bone interfaces
  - Thickness
  - Gaps/lucencies
- Deficient cement mantles associated with aseptic loosening and failure of components
- Acetabular mantle 3 mm yield best strain characteristics and reduced loosening risk
  - Sandhu, *et al*: 78% acetabular components are eccentrically placed with increasing mantle thickness from Delee and Charnley zones I—III (superomedial—inferolateral)
  - Achieving ideal/uniform mantle difficult
- Femoral cement mantle 2-3 mm yield good long term radiographic and clinical outcomes

McBride, TJ, *et al*, How to read a postoperative total hip replacement radiograph, *Postgrad Med J*, 2010.
Sandhu, HS, *et al*, Acetabular cement mantles and component position: are we achieving "ideal" results?, *J Arthroplasty* 2006;21:841-5.

Material interface (cemented prostheses)

- Assessment of lateral view for cement defects paramount due to common posteriorly angulated prosthesis → thin mantle at posterior tip
- Centralizer may reduce risk of thin mantle around tip

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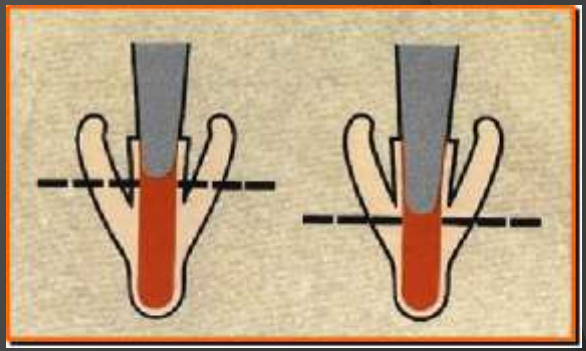
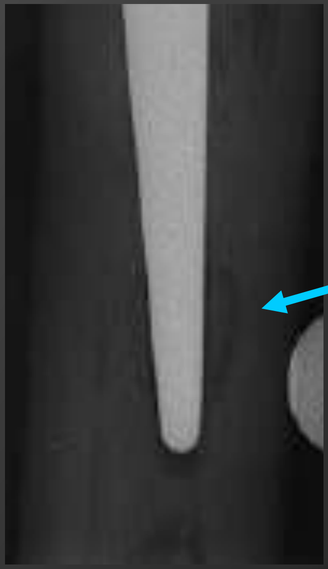


Exeter stem with distal centralizer



Accolade C femoral stem

McBride, TJ, *et al*, How to read a postoperative total hip replacement radiograph, *Postgrad Med J*, 2010.

Material interface (noncemented prosthesis)

- Assessing initial fixation more difficult
- Initial postoperative radiographs
  - Alignment evaluation
  - Fixation better assessed with serial follow-up radiographs

McBride, TJ, *et al*, How to read a postoperative total hip replacement radiograph, *Postgrad Med J*, 2010.

Radiographic follow-up of THA

- Periprosthetic lucency
- Component subsidence
- Stress shielding
- Stress loading

Periprosthetic lucency--cemented

- Bone—cement interface a thin fibrous layer forms as response to local necrosis from exothermic cement polymerization—stable by 2 yrs
- Acetabular (Delee-Charnley) zone I: 1-2mm lucency frequent
- Lucency at metal—cement interface initially not uncommon, but should remain stable

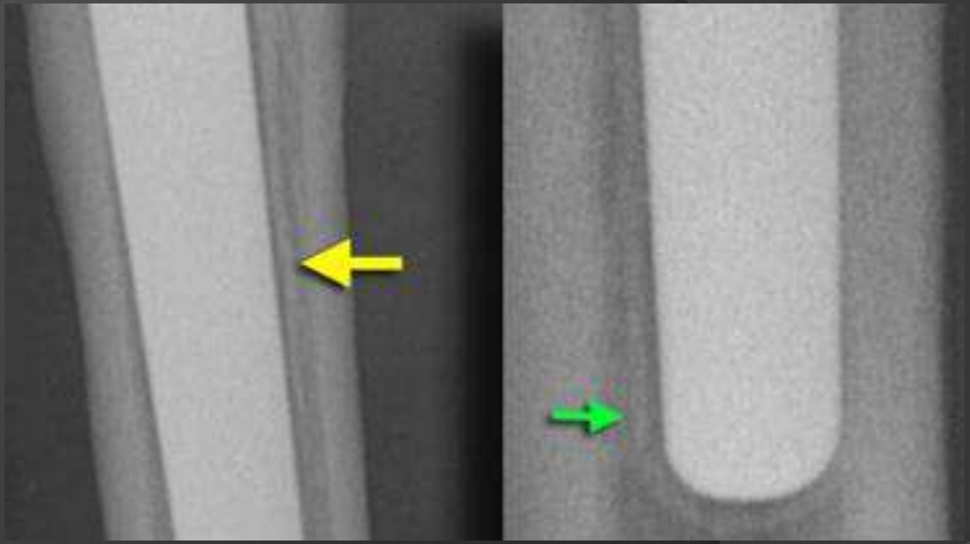
General Rules:

- Lucency ≤2mm
- Stability over 2 years

-McBride, TJ, *et al*, How to read a postoperative total hip replacement radiograph, *Postgrad Med J*, 2010.
-http://www.radiologyassistant.nl/en/431c8258e7ac3
-Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall

Periprosthetic lucency--noncemented

- Lucencies at metal—bone interface occur typically as combination of bone and fibrous tissue attachment
- Often accompanied by parallel sclerotic line
- Common—80%
- 1-2 mm thickness



General Rules:

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http://www.radiologyassistant.nl/en/431c8258e7ac3

Component subsidence

- Uncemented stems during initial post operative months
  - Beyond 2 years or 10 mm considered abnormal
- Certain cemented stems
  - Exeter: specifically designed to subside into cement mantle
  - 1-2 mm, seen superolaterally

McBride, TJ, *et al*, How to read a postoperative total hip replacement radiograph, *Postgrad Med J*, 2010.

Stress shielding

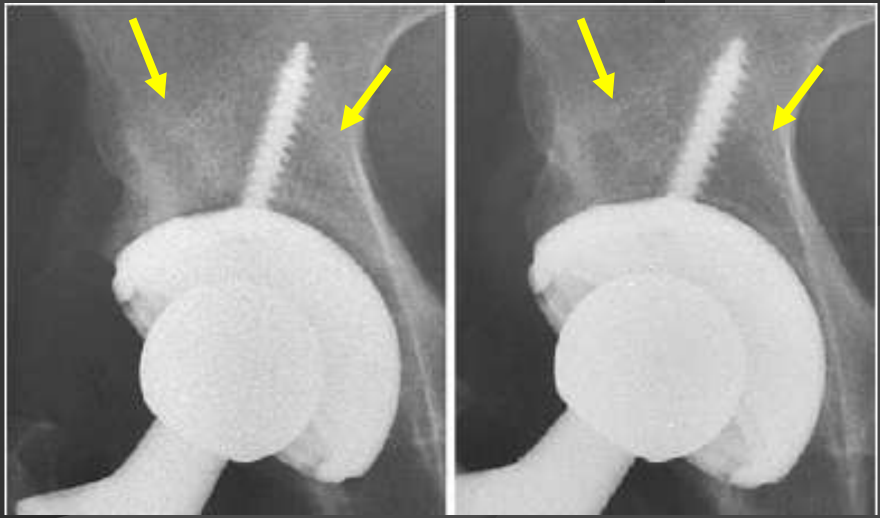
- Wolf’s Law: Bone will biomechanically remodel and adapt according to the load placed on it.
- THA:
  - Altered forces about hip lead to areas of decreased mechanical load
  - Decreased osteoblastic activity
  - Areas of relative osteopenia—stress shielding
- Generally occurs in first 2 years following surgery
- Implies prosthesis is well fixed
- Long term implications unknown

Wolf, J, *The Law of Bone Remodeling*, Berlin Heidelberg New York: Springer, 1986 (translation of the German 1892 edition).
McBride, TJ, *et al*, How to read a postoperative total hip replacement radiograph, *Postgrad Med J*, 2010.

Stress shielding

- Often seen at proximal—medial femur
  - Calcar resorption/round off
- Also commonly seen at superomedial acetabulum and about the trochanters

Post op 2 year follow-up



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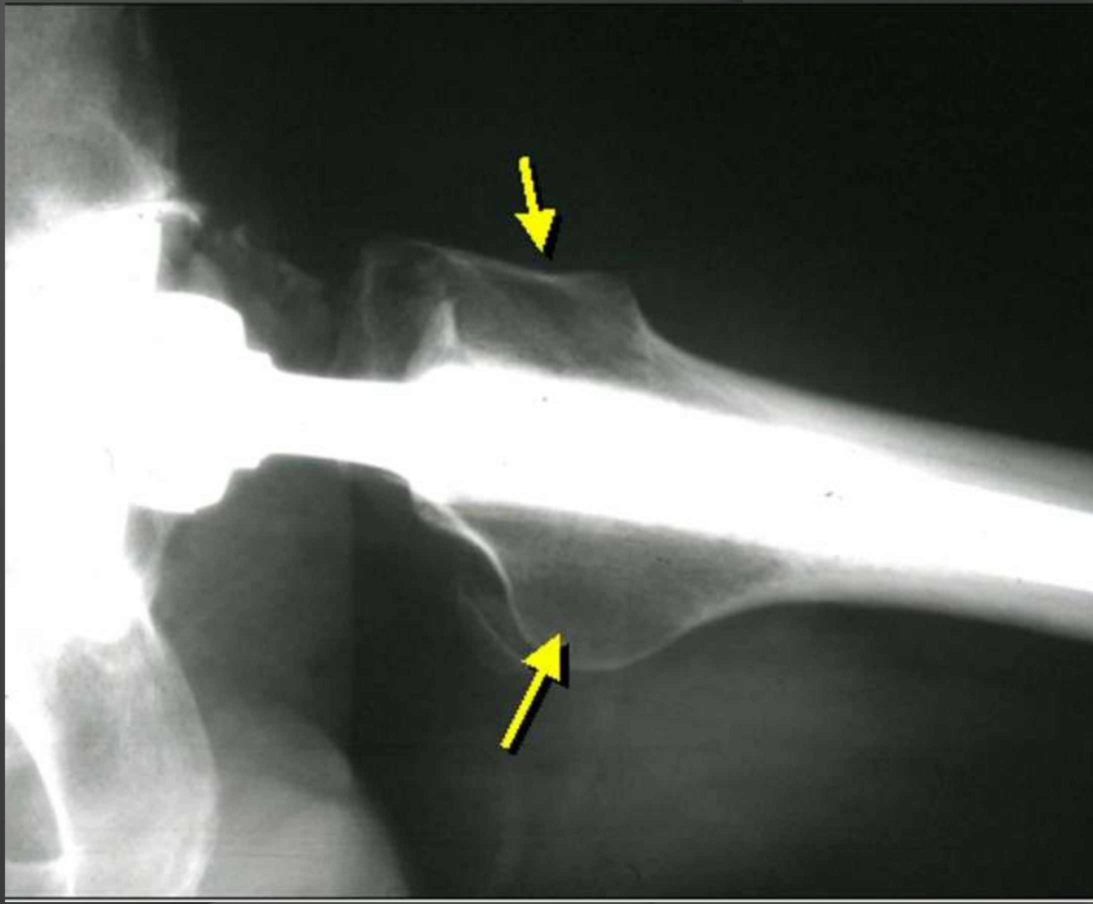
Stress shielding



Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall

Sinha, RK, *JBJS*, 2004;86:1254-61.

Stress loading

- Wolf’s Law similarly applies
- Spot welds: small areas of sclerosis originating from endosteal surface and abutting the femoral stem
  - Strong indicators of stability
- Cortical thickening of femoral shaft indicates good fixation

McBride, TJ, *et al*, How to read a postoperative total hip replacement radiograph, *Postgrad Med J*, 2010.

Dumbleton, J, *JBJS*, 2004;86:2526-40.

Stress loading—pedestal

- Bridging sclerosis at the tip of the cementless femoral stem
- Unclear significance
  - Can be associated with loosening
  - Careful evaluation and sequential review of follow-up radiographs recommended

Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall

McBride, TJ, *et al*, How to read a postoperative total hip replacement radiograph, *Postgrad Med J*, 2010.

Pathologic considerations

- Early postoperative setting
  - Improper placement/alignment
  - Fracture/dislocation
  - Cement migration
  - Limb length discrepancy
  - Nerve palsy: sciatic, femoral, peroneal
  - Hemarthrosis
  - Vascular injury
- Subacute to remote sequelae
  - Fracture/dislocation
  - Loosening/component migration
  - Polyethylene wear
  - Particle disease
  - Infection
  - Adverse reaction to metal debris
  - Heterotopic ossification

Close to Home, John McPherson

"Mr. Simms, I think you have a very strong case for malpractice regarding your hip replacement."

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  - Infection ←
  - Adverse reaction to metal debris ←
  - Heterotopic ossification ←

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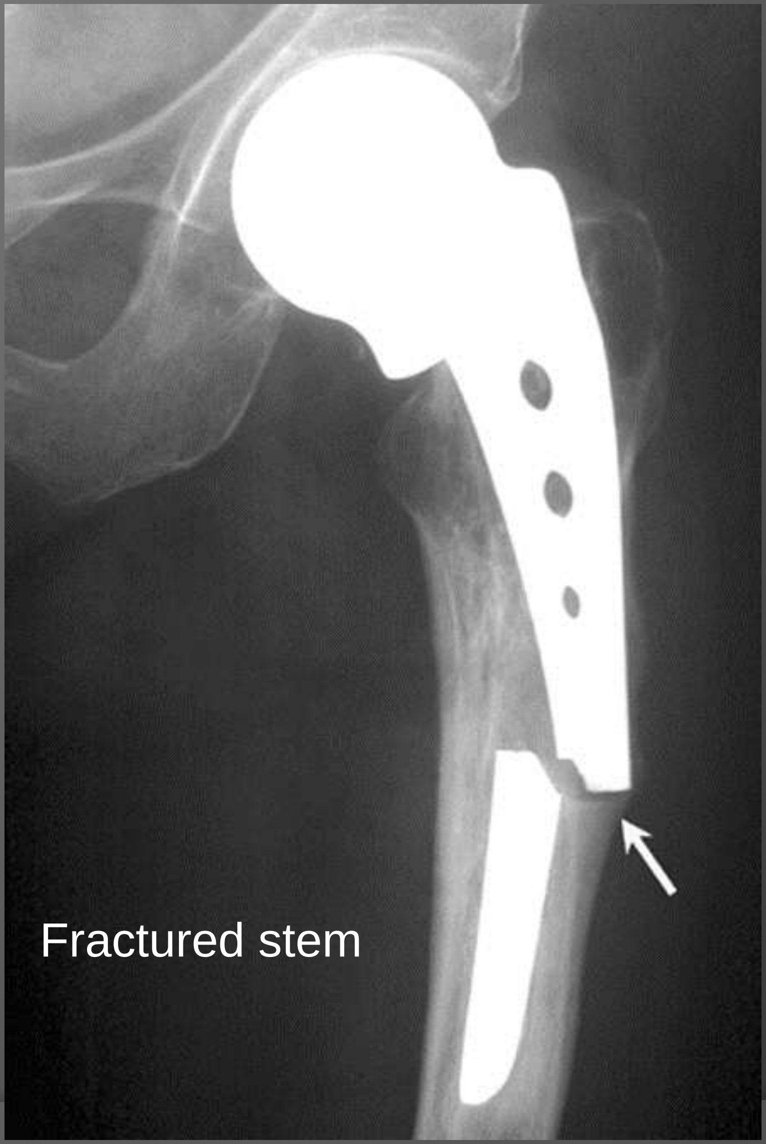
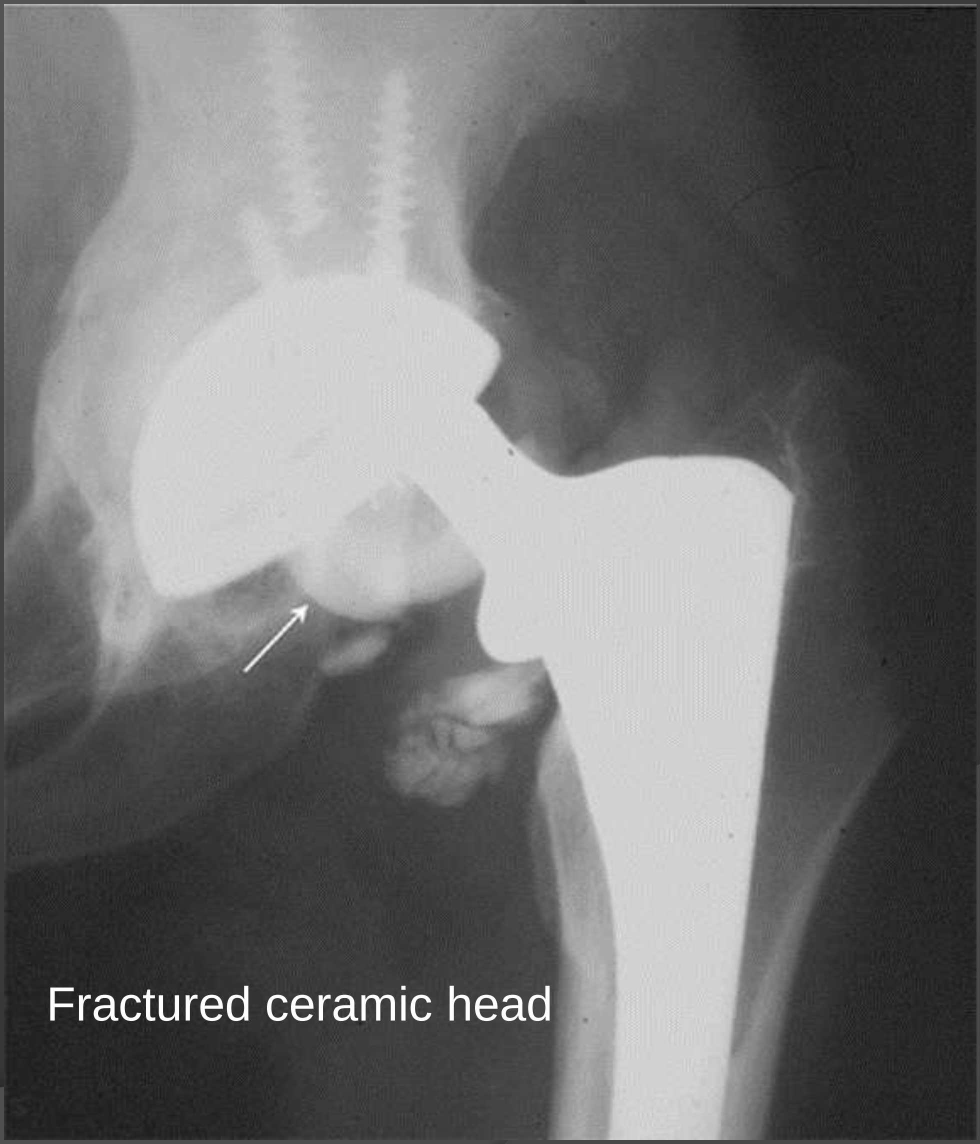
Fracture—prosthesis

- Hardware failure may consist of metal, ceramic, or polyethylene component fracture/displacement
- Failure of supporting hardware (screws)
- May be related to:
  - Trauma
  - Stress shielding
  - Loosening

Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall

Fracture—prosthesis





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Fracture—prosthesis

Broken, frayed, and disintegrating cerclage cables

Side plate placed for periprosthetic fracture, now broken with loss of reduction of femur fracture

http://www.gentili.net/thr/hardware.htm

Fracture—prosthesis

- Phalanged acetabular cup with interval fracture of the medial phalange.

6/1997

11/2002

http://www.gentili.net/thr/hardware.htm

Fracture—prosthesis

Progressive subsidence with subsequent transcortical screw fracture

http://www.radiologyassistant.nl/en/431c8258e7ac3

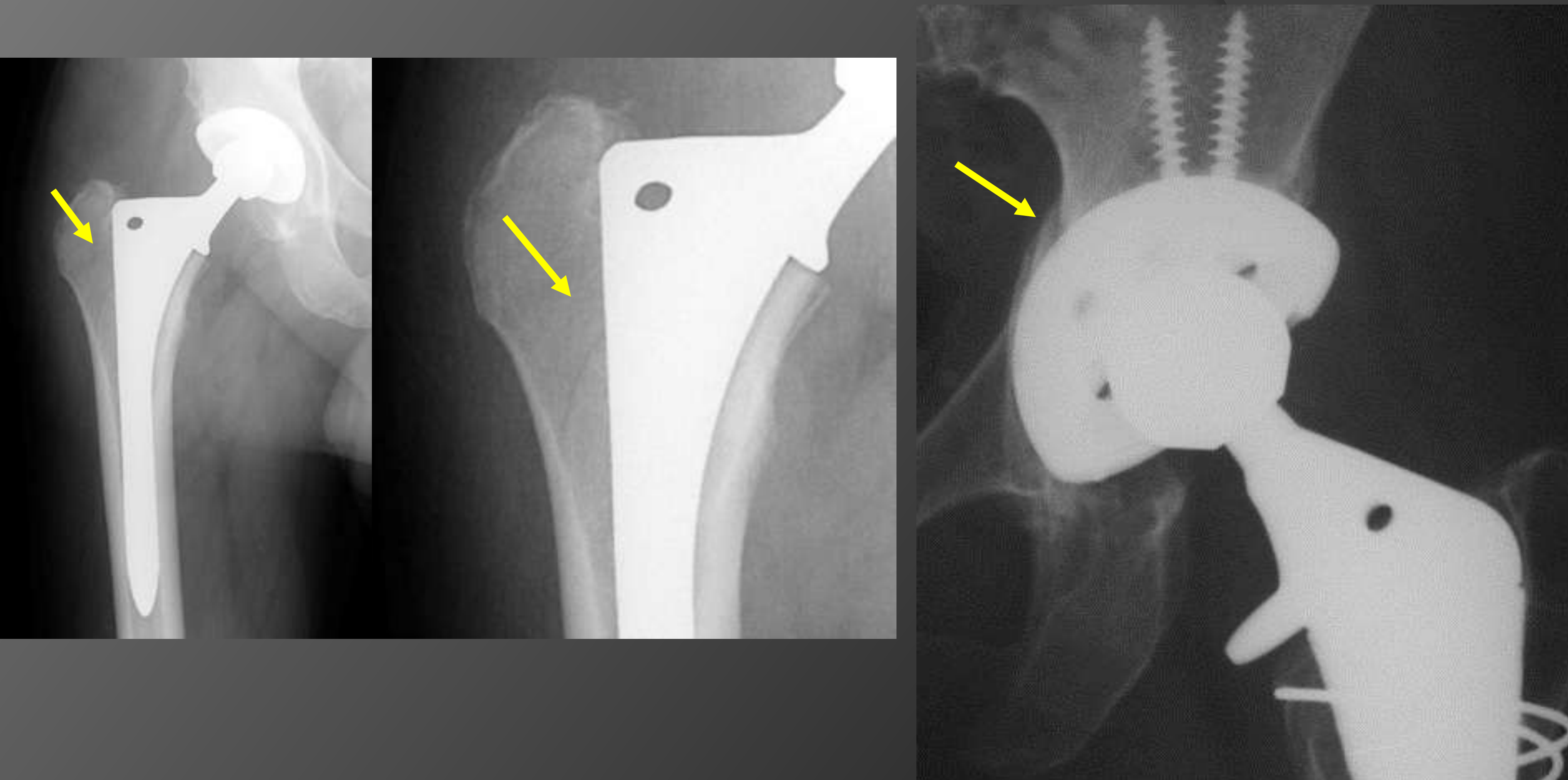
Fracture—periprosthetic

- Intraoperative
  - Femoral shaft most common
    - 2º to pounding femoral component in position
    - Rarely displaced
    - Cerclage cables
  - Pelvis rare
  - DDX:
    - Nutrient foramen; compare w/ preop
    - Controlled perforation during surgery/revision
- Subacute/remote
  - Femoral shaft most common
    - Greatest torque
  - Osteopenia from inactivity (pre/post op pain/disability) predispose to insufficiency fractures

Intra-op periprosthetic fracture

http://www.gentili.net/thr/intraopfx.htm

Intra-op periprosthetic fracture



http://www.gentili.net/thr/intraopfx.htm

Intra-op periprosthetic fracture

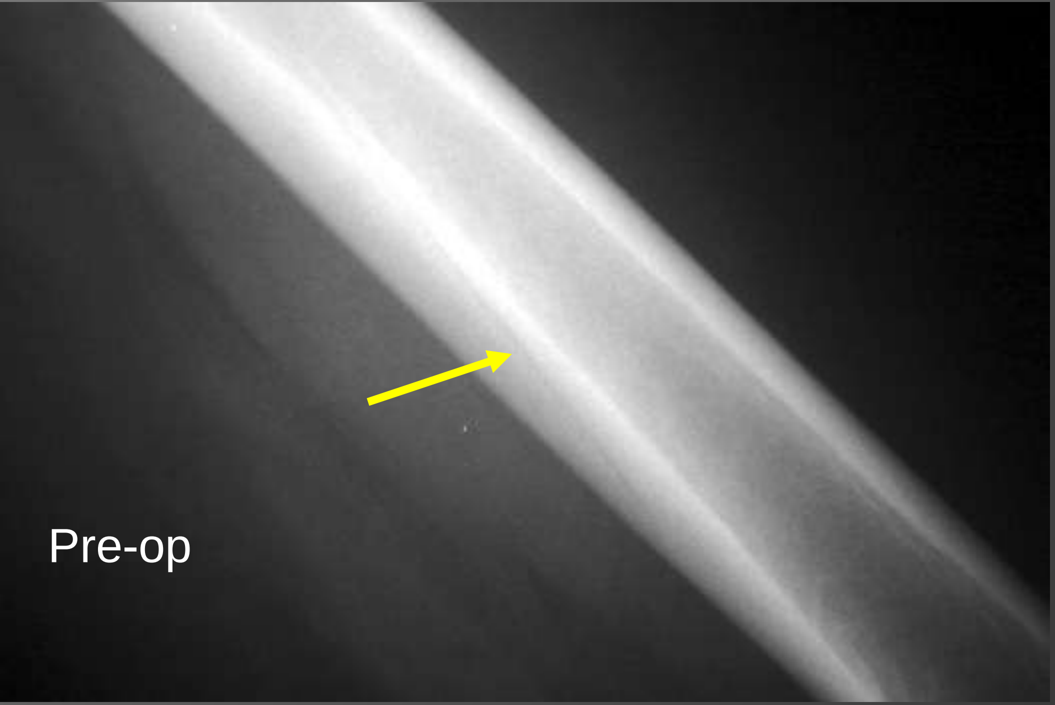
-Differential diagnosis

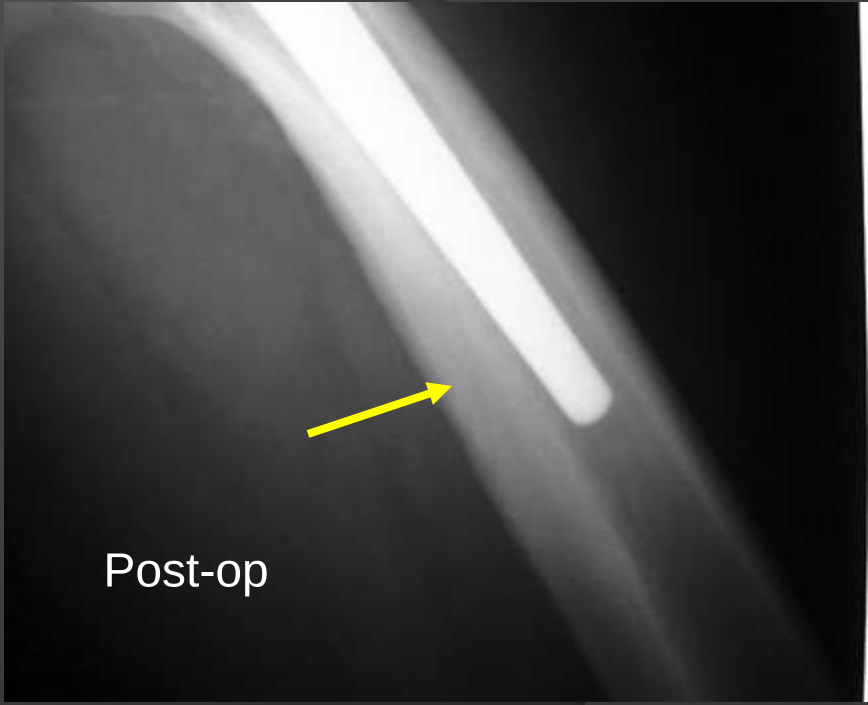
- Controlled perforation of the lateral femoral cortex to facilitate removal of old femoral prosthesis

http://www.gentili.net/thr/intraopfx.htm

Intra-op periprosthetic fracture

-Differential diagnosis





- Vascular channel
  - Best seen on lateral, entering femoral cortex distally and traveling proximally
  - “To the elbow I go, from the knee I flee” – direction of channel

http://www.gentili.net/thr/intraopfx.htm
http://www.bonepit.com/Lectures/The%20Growing%20Physis%20John%20Stassen.pdf

Periprosthetic fracture at follow-up

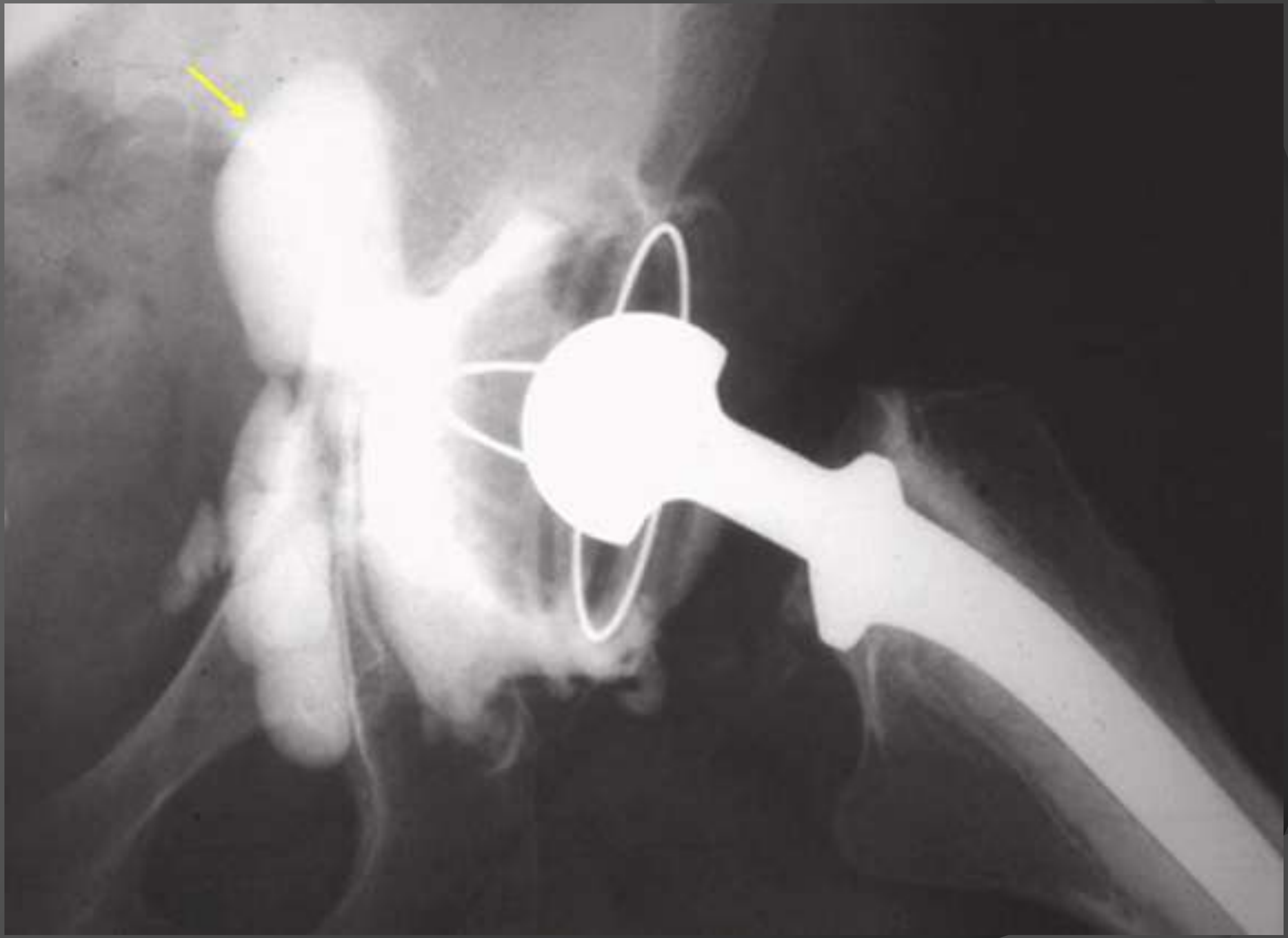
Commonly about the tip of the stem

http://www.gentili.net/thr/fracture.htm

Cement migration

- Intrapelvic through defect in acetabulum most common
- Usually asymptomatic
- Rare complications
  - Bowel fistula
  - Neurovascular encasement
  - Bladder wall burn (exothermic cement polymerization)

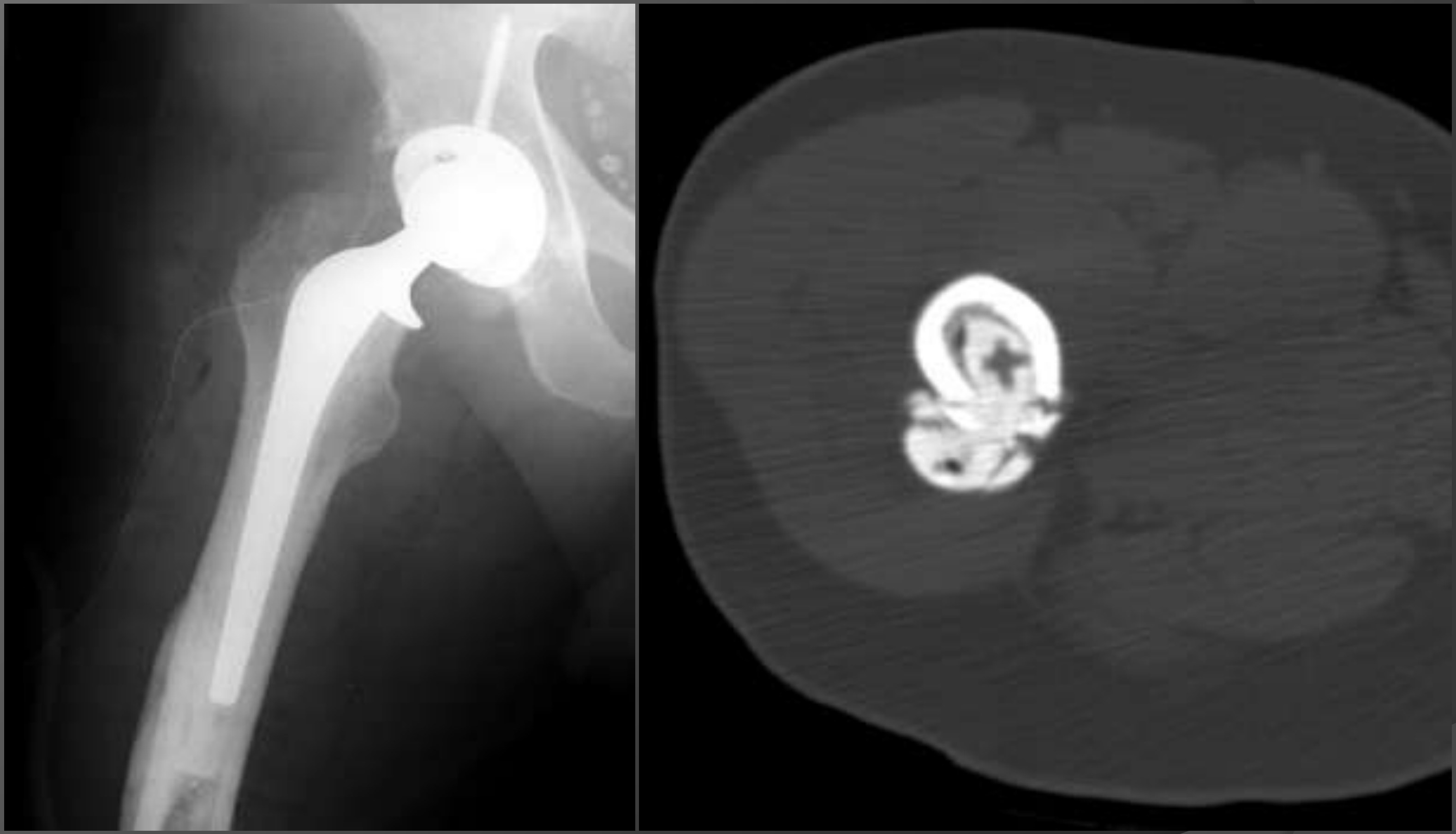
Cement migration



Medial extrusion through acetabular wall defect

Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall

Cement migration



Extravasation through intraoperative fracture at proximal femur

http://www.gentili.net/thr/cement.htm

Loosening/component migration -General concepts

- Always compare with baseline/post-op radiograph
- Interface assessment
  - >2 mm, loosening
  - 1-2 mm, acceptable if stable (6-12 mon) and asymptomatic
  - <1 mm acceptable
- Acetabular component
  - Delee-Charnley zone I (superolateral) 1-2 mm lucency at cement—bone interface common
  - Delee-Charnley zone III (inferomedial) lucencies more ominous
- Femoral component
  - Gruen zone I (superolateral) 1-2 mm lucency common and not significant
  - >2 mm abnormal

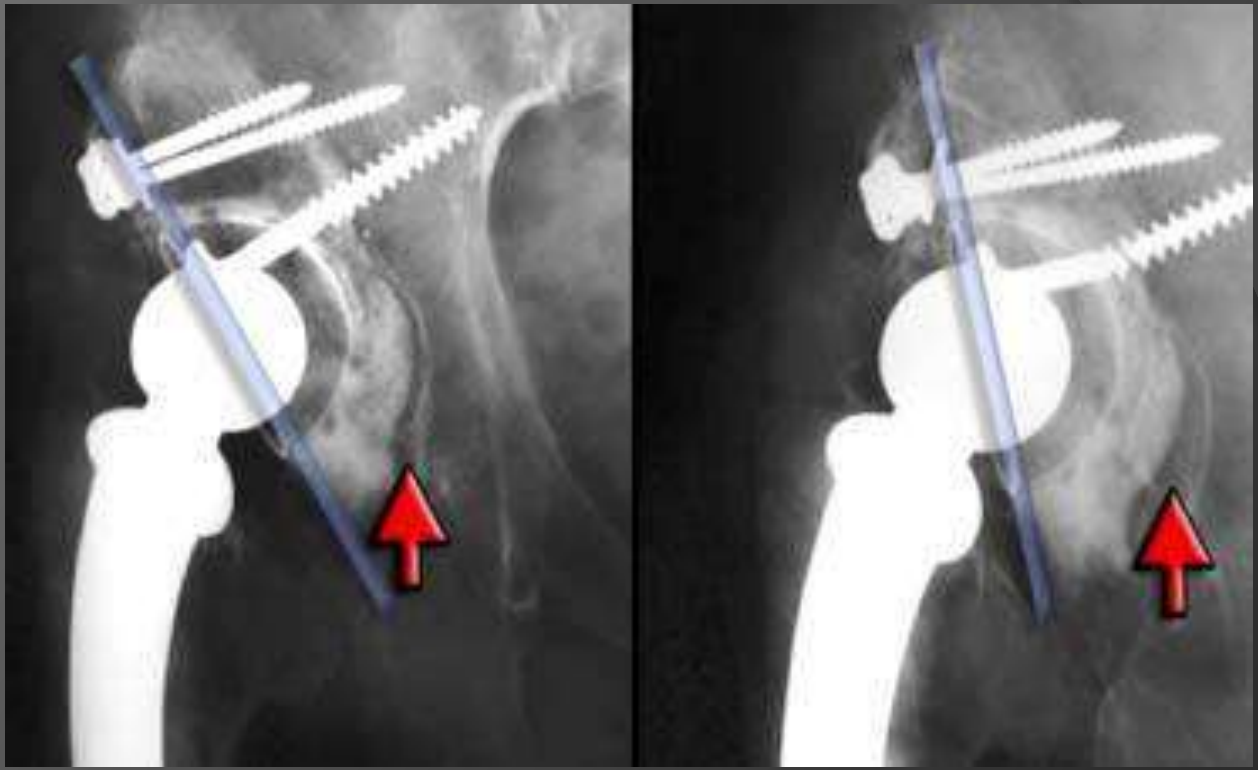
http://www.gentili.net/thr/loosenin.htm

Loosening/component migration -Cemented prosthesis

- 1-2 mm lucencies at cement interfaces common—if stable
  - Prosthesis—cement: minimal motion during cement hardening
  - Cement—bone: fibrous tissue at interface or minimal motion of prosthesis prior to polymerization
- Loosening:
  - Lucency >2 mm
  - Migration of cemented component/change in alignment
  - Progressive widening of radiolucent zone
  - Cement fracture

Manaster BJ, Total hip arthroplasty: radiographic evaluation, *Radiographics*, 1996;16:645-60.

Loosening/component migration—cemented prosthesis

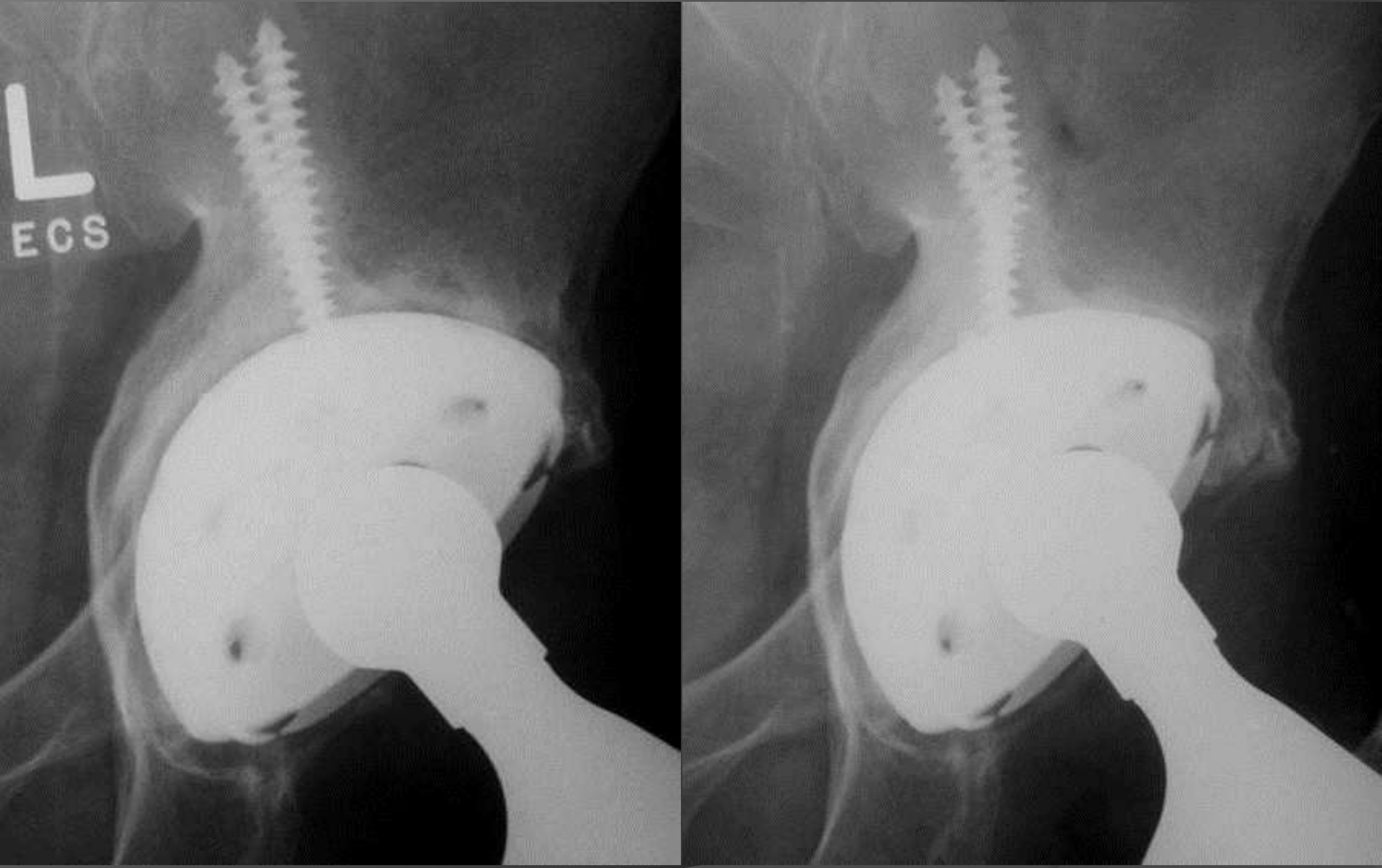


- Increased lateral inclination
- Lucency in Delee-Charnley zones II and III

- Upward migration/increased tilting
- Fracture of screw
- Increasing lucency zone II and III

http://www.radiologyassistant.nl/en/431c8258e7ac3

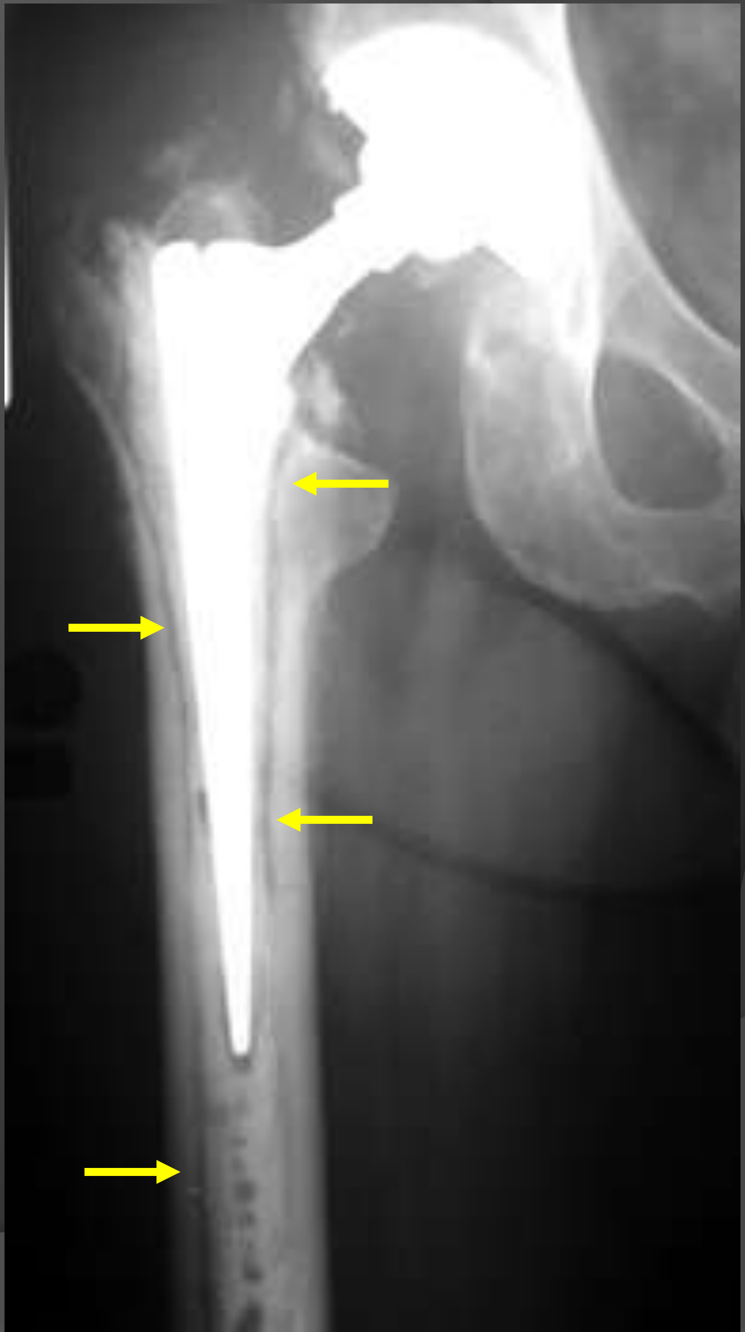
Loosening/component migration—cemented prosthesis



Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall

Loosening/component migration—cemented prosthesis

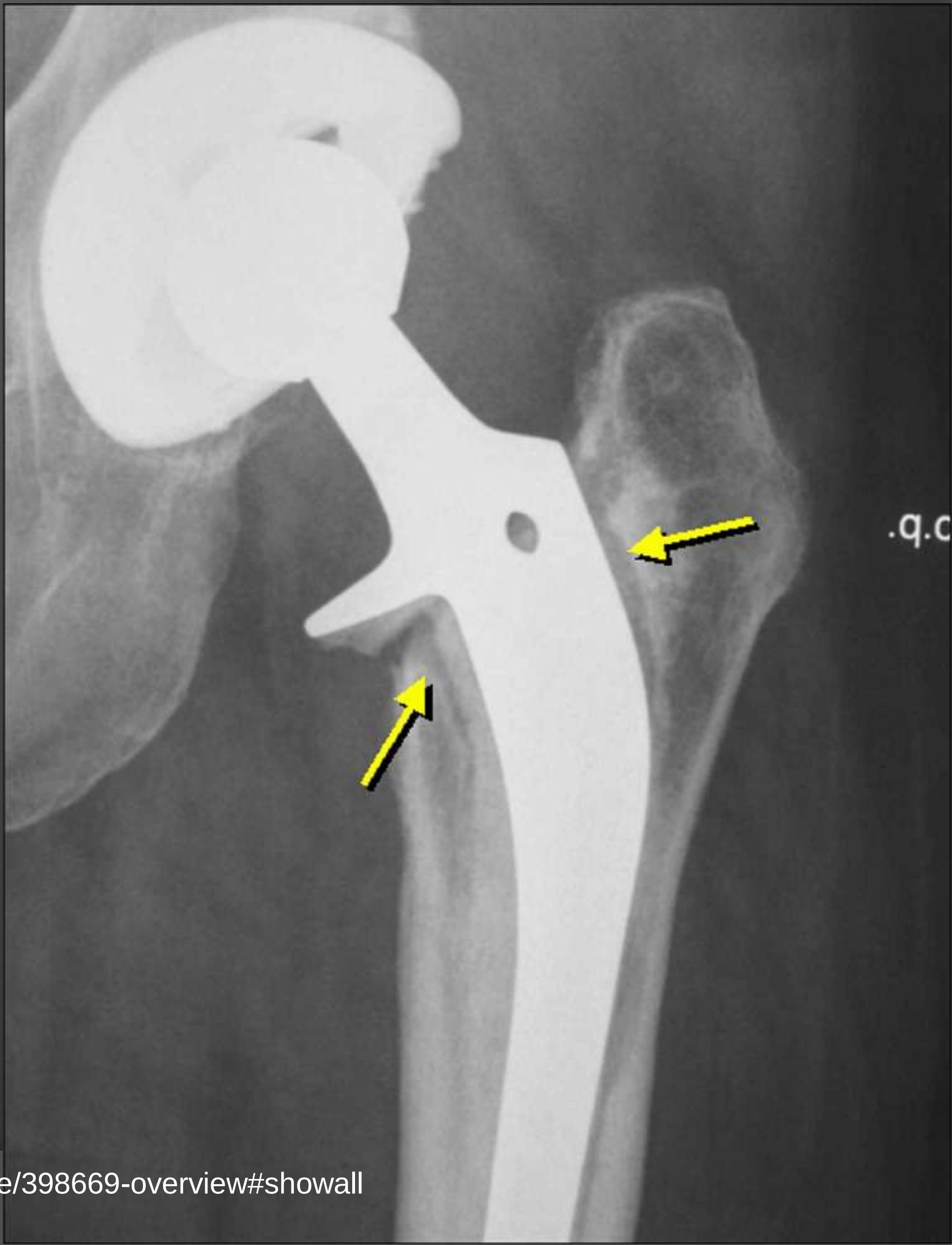
- Abnormal lucency at cement—bone interface surrounding entire femoral component



http://www.gentili.net/thr/loosenin.htm

Loosening/component migration—cemented prosthesis

- Abnormal (>2 mm) lucency at prosthesis—cement interface Gruen zone 1 and borderline (2 mm) lucency at zone 7



Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall

Loosening/component migration—cemented prosthesis

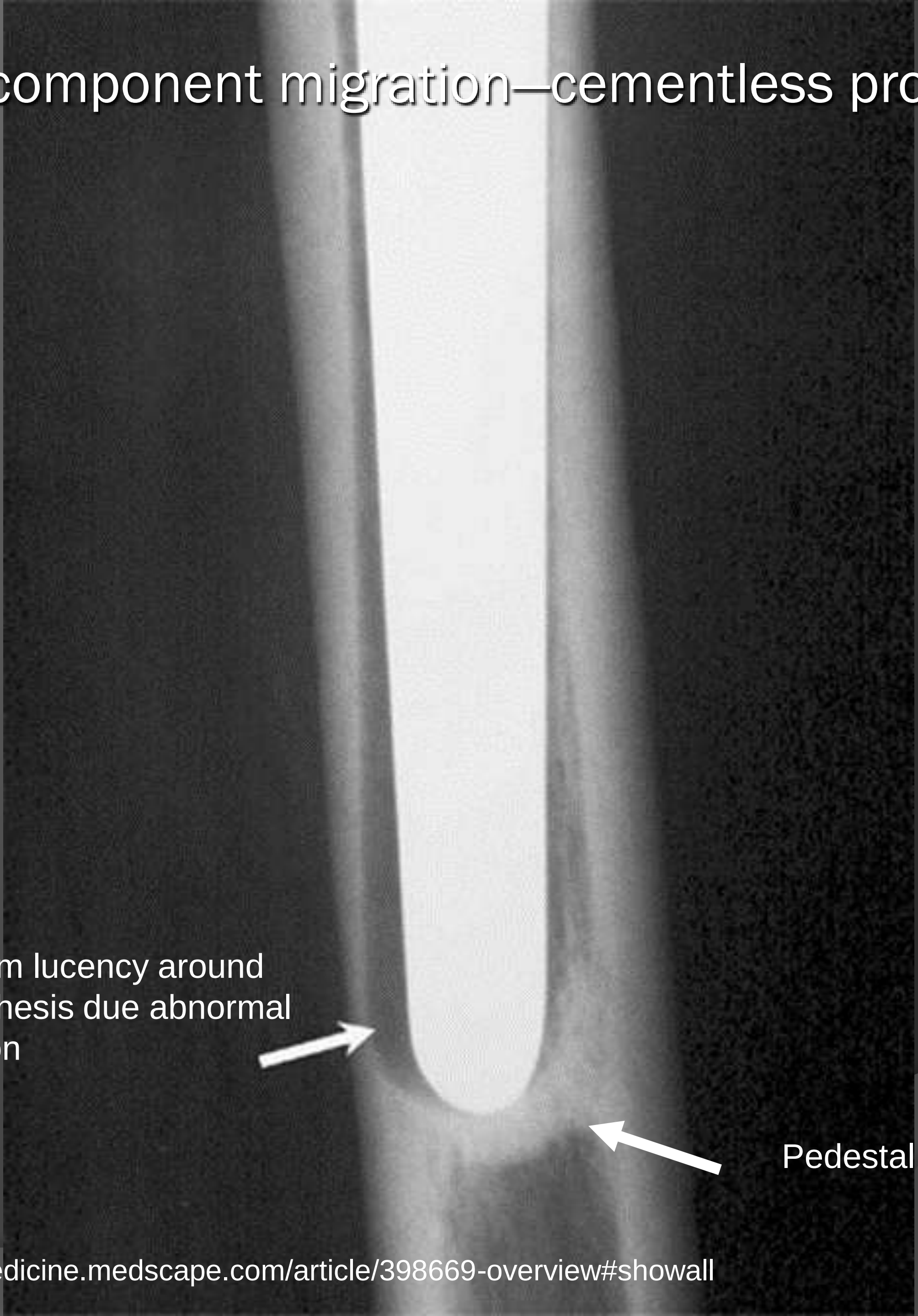
http://www.gentili.net/thr/loosenin.htm

Loosening/component migration -Cementless prosthesis

- Normal findings:
  - Stress shielding (calcar, trochanters)
  - Complete bone-prosthesis lucency (<2 mm) with sclerotic margin
  - Cortical thickening
  - Mild subsidence (<10 mm, nonprogressive)
- Most reliable signs of loosening
  - Progressive subsidence, migration, or tilt
  - May be subtle: serial radiographs and measurements often required
- Probable signs
  - Bone-prosthesis lucency >2 mm
  - Pedestal formation
  - Endosteal scalloping
  - Bead shedding (separation of microspheres on porous coated prostheses

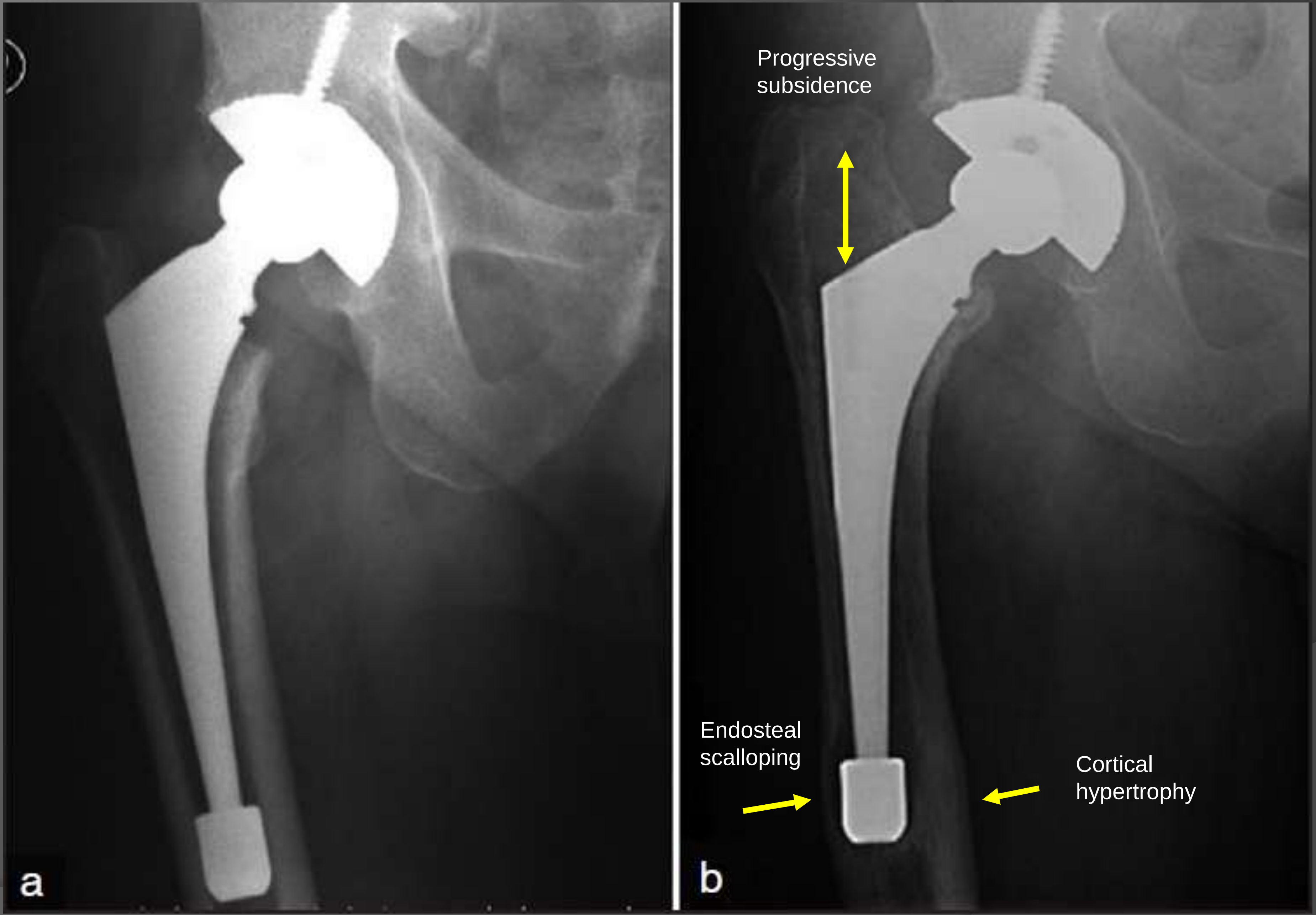
Manaster BJ, Total hip arthroplasty: radiographic evaluation, *Radiographics*, 1996;16:645-60.

Loosening/component migration—cementless prosthesis



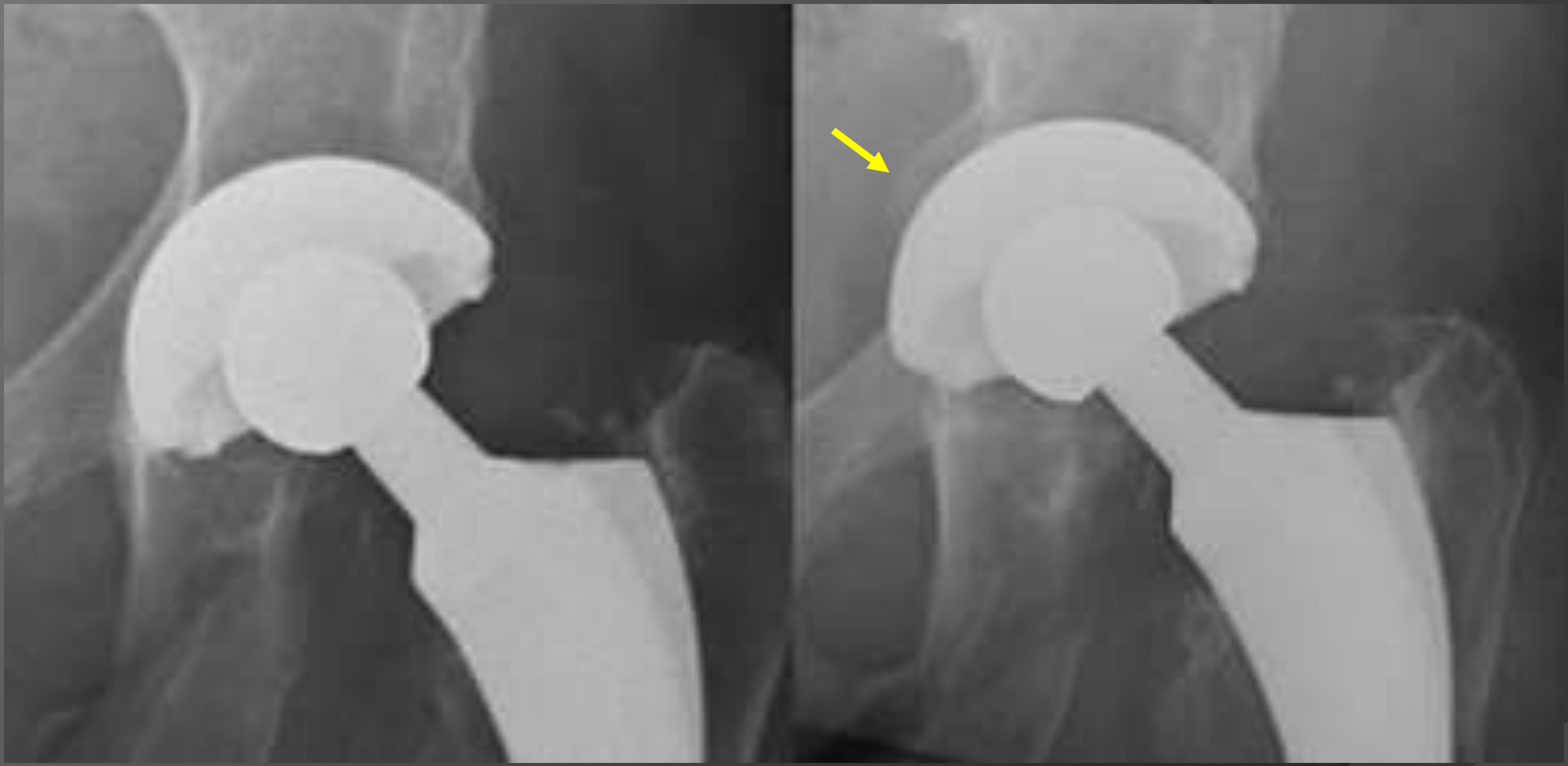
Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall

Loosening/component migration—cementless prosthesis



De la Torre, BJ, *et al*, 10 years results of an uncemented metaphyseal fit modular stem in elderly patients, *Ind J Ortho*, 2011;45-4:351-58.

Loosening/component migration—cementless prosthesis



- Increasing tilt of acetabular component and new acetabular fracture (arrow)

http://www.radiologyassistant.nl/en/431c8258e7ac3

Loosening/component migration—cementless prosthesis

- Bead shedding from the textured coating of femoral component

Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall

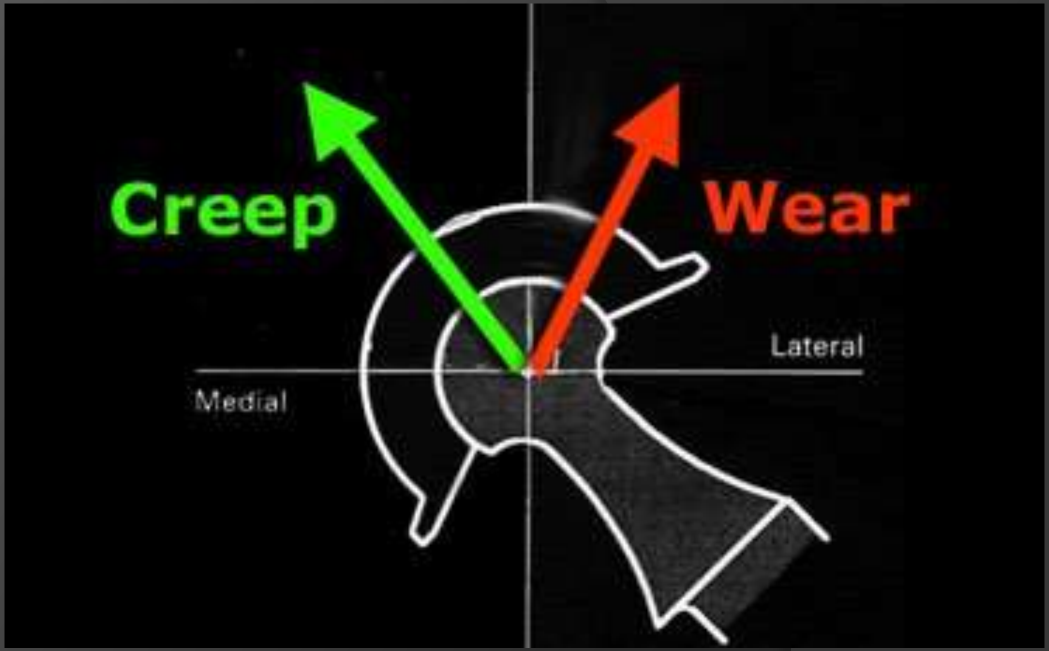
Loosening/component migration—cementless prosthesis

- Bead shedding from the textured coating of femoral component

Roberts CC, *et al*, Radiographic imaging of hip replacement hardware, *Seminars in Roentgenology*, 2005:320-32.

Polyethylene wear

- Creep: normal remolding in a superomedial direction
- Wear: pathologic thinning in superolateral direction from abnormal loading
- Edge loading: highest loads extend beyond contour of cup; alignment critical
- DDX: polyethylene liner dislocation



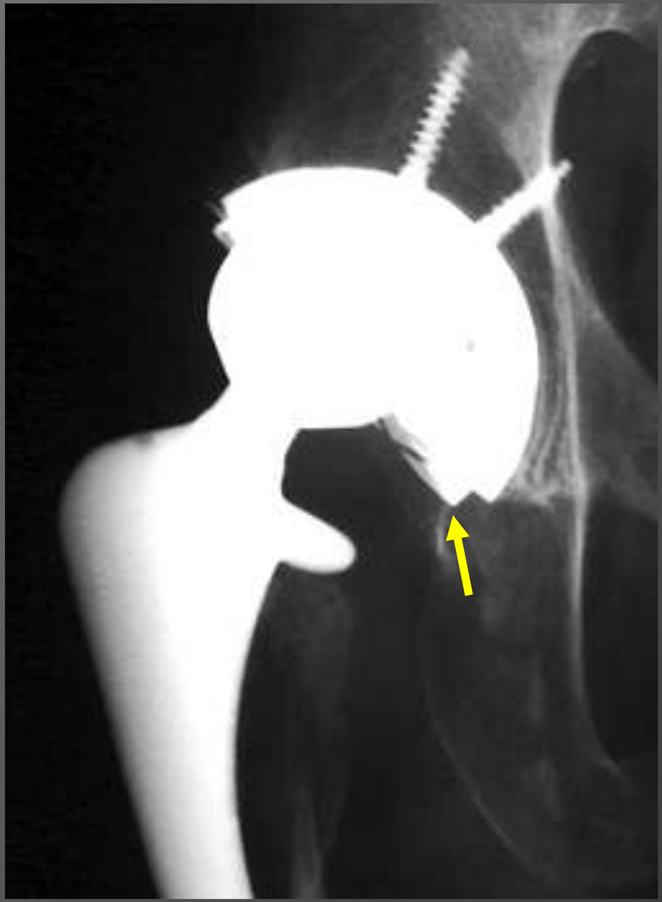
http://www.radiologyassistant.nl/en/431c8258e7ac3

Polyethylene wear

- Eccentric position of femoral heads in cups

Heisel C, *et al*, Bearing surface options for total hip replacement in young patients, *JBJS*, 2003;85:1366-79.

Polyethylene liner dislocation



- Note eccentric position of femoral head in cup and curvilinear density at inferior margin consistent with dislocated liner

http://www.gentili.net/thr/polyethi.htm

Particle disease

- AKA aggressive granulomatosis or osteolysis
- Particulate debris shed into joint fluid from wear of components
  - Typically bearing surfaces (polyethylene, cement, metal)
- Particles transported through small channels (along screws)
- Macrophages and multinucleated giant cells take up particulate and release cytokines initiating cascade reaction leading to osteolysis
- Tend to occur 1-5 yrs post-op, although may occur at any time

-http://www.radiologyassistant.nl/en/431c8258e7ac3
-http://www.gentili.net/thr/osteolys.htm

Particle disease

- Radiographs
  - Periprosthetic lucencies
    - May be large
    - Not necessarily indicative of instability
  - Smooth endosteal scalloping
  - No secondary bone response
  - Polyethylene wear (secondary finding)
- Relentlessly progressive → loosening, fracture, destruction of bone
- May necessitate revision, even in absence of symptoms, due to danger of fracture or additional loss of bone stock

-http://www.radiologyassistant.nl/en/431c8258e7ac3
-http://www.gentili.net/thr/osteolys.htm

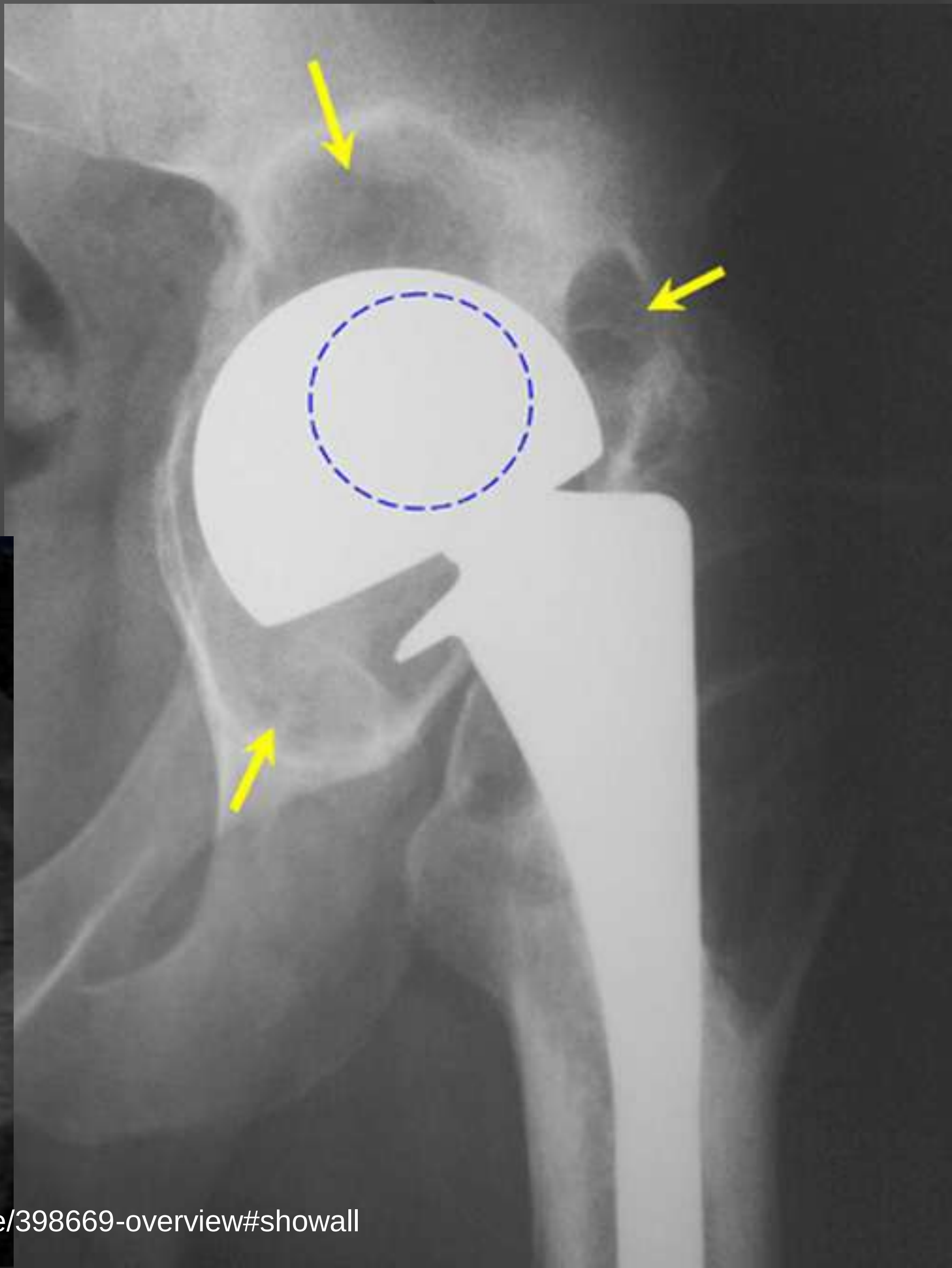
Particle disease

- Focal osteolysis with endosteal scalloping in Gruen zone 7
- Eccentric position of femoral head in cup—polyethylene wear

http://www.radiologyassistant.nl/en/431c8258e7ac3

Particle disease

- Eccentric position of femoral head in cup—polyethylene wear
- Focal osteolysis with endosteal scalloping in Delee-Charnley zones I—III with granulomatous soft tissue



Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall

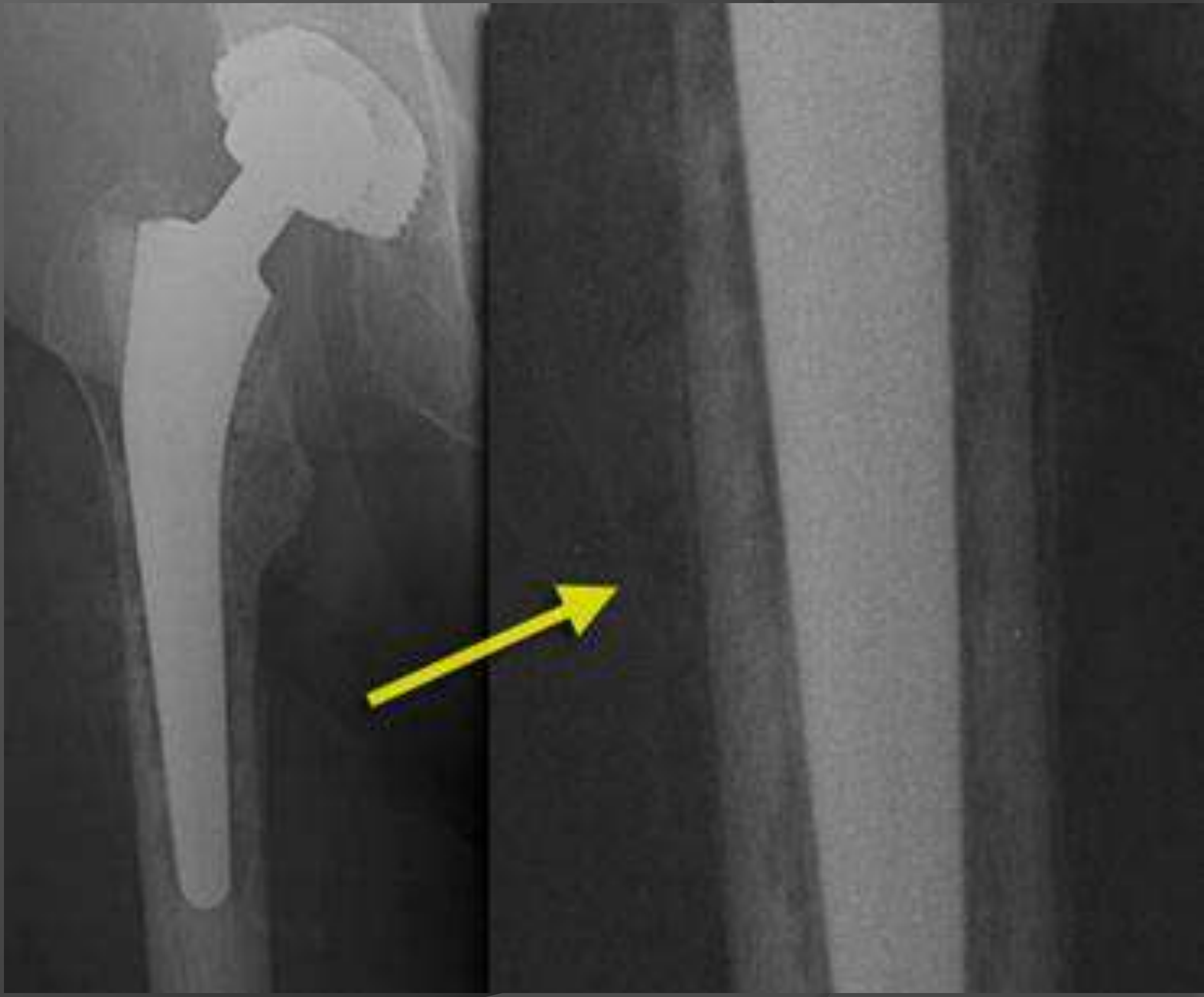
Infection

- Incidence: 1-2% primary, 3-4% revision
- Radiographic findings:
  - Ill defined bone resorption
  - Sinus tract/gas in soft tissue or joint
  - No sclerotic margin about lucency
- No definitive findings: can mimic loosening and particle disease
- Additional tests:
  - Blood tests
  - Nuclear medicine
  - Joint aspiration often required for diagnosis

-http://www.radiologyassistant.nl/en/431c8258e7ac3
-http://www.gentili.net/thr/infectio.htm

Infection

- Irregular periprosthetic bone resorption with periosteal reaction



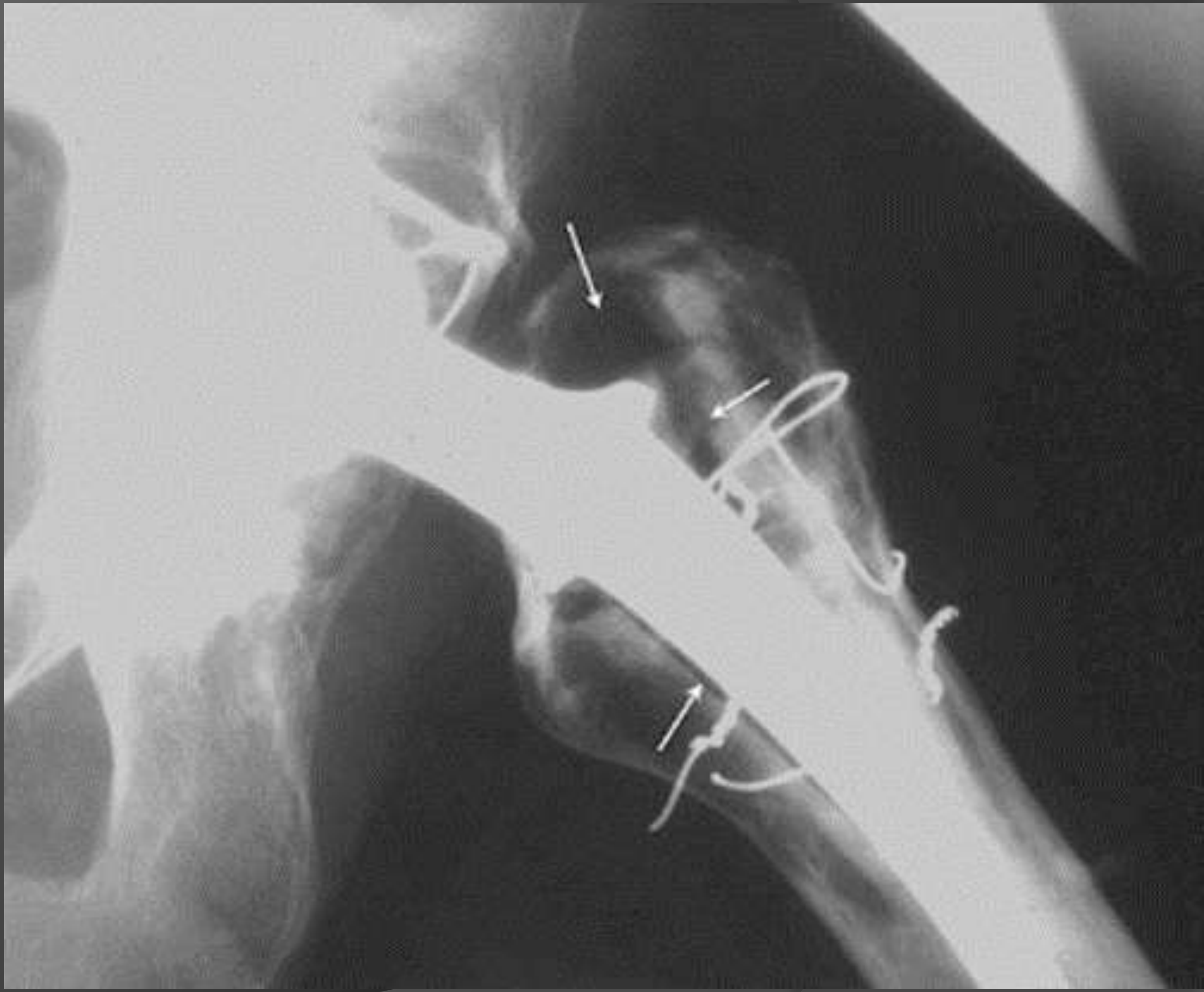
http://www.radiologyassistant.nl/en/431c8258e7ac3

Infection

- Periprosthetic soft tissue emphysema and gas in joint

http://www.gentili.net/thr/infectio.htm

Infection



- Abnormal lucency at cement—prosthesis interface

Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall

Differential diagnosis

Loosening vs. particle disease vs. infection

- Diffuse lucencies
  - Suggests loosening or infection
- Multifocal lucencies
  - Suggests particle disease or infection
- Polyethylene wear can suggest particle disease
- No specific finding for or against infection
- Normal radiograph does not exclude infection
- Aspiration required to exclude infection

Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall

Adverse reaction to metal debris

- Terminology:
  - Metallosis—macroscopic staining of soft tissues associated with abnormal wear
  - Aseptic lymphocytic vasculitis-associated lesions (ALVAL)—histologic appearance occurring with a range of changes from cellular level only to effusion, soft tissue necrosis, and pseudotumor
  - Pseudotumors—periprosthetic mass (solid and/or cystic), can be symptomatic, resemble neoplasms
  - Adverse reaction to metal debris (ARMD)—umbrella term including metallosis, ALVAL, and pseudotumor

No clear consensus in literature defining boundaries of each term

Haddad FS, *et al*, Metal-on-metal bearings: The evidence so far, *JBJS*, 2011;93-B:572-9.

Adverse reaction to metal debris

- Appeal of MoM
  - Decreased risk of dislocation due to larger head size
  - Higher levels of activity post-op
- ARMD etiology: deposition of metal wear particles in periprosthetic tissues induces spectrum of necrotic and inflammatory changes
  - 2 general theories:
    - Wear-related cellular cytotoxicity
    - Hypersensitivity
- Incidence: 6-18% at mean of 41 months
  - Higher incidence in women: not clear why, possibly smaller prosthetic size

Haddad FS, *et al*, Metal-on-metal bearings: The evidence so far, *JBJS*, 2011;93-B:572-9.

Adverse reaction to metal debris

- Local effects:
  - Metal particles released
  - Macrophages phagocytose particles
  - Particles corrode, release cobalt ions, cell death
- Systemic effects
  - Increased metal ion level in blood; grossly elevated when implant loose
  - Solid organ deposition
  - Concerns for long-term effects:
    - Immune mediated
    - Genotoxic
    - ? Teratogenic—insufficient data to date

Haddad FS, *et al*, Metal-on-metal bearings: The evidence so far, *JBJS*, 2011;93-B:572-9.

ARMD—Imaging

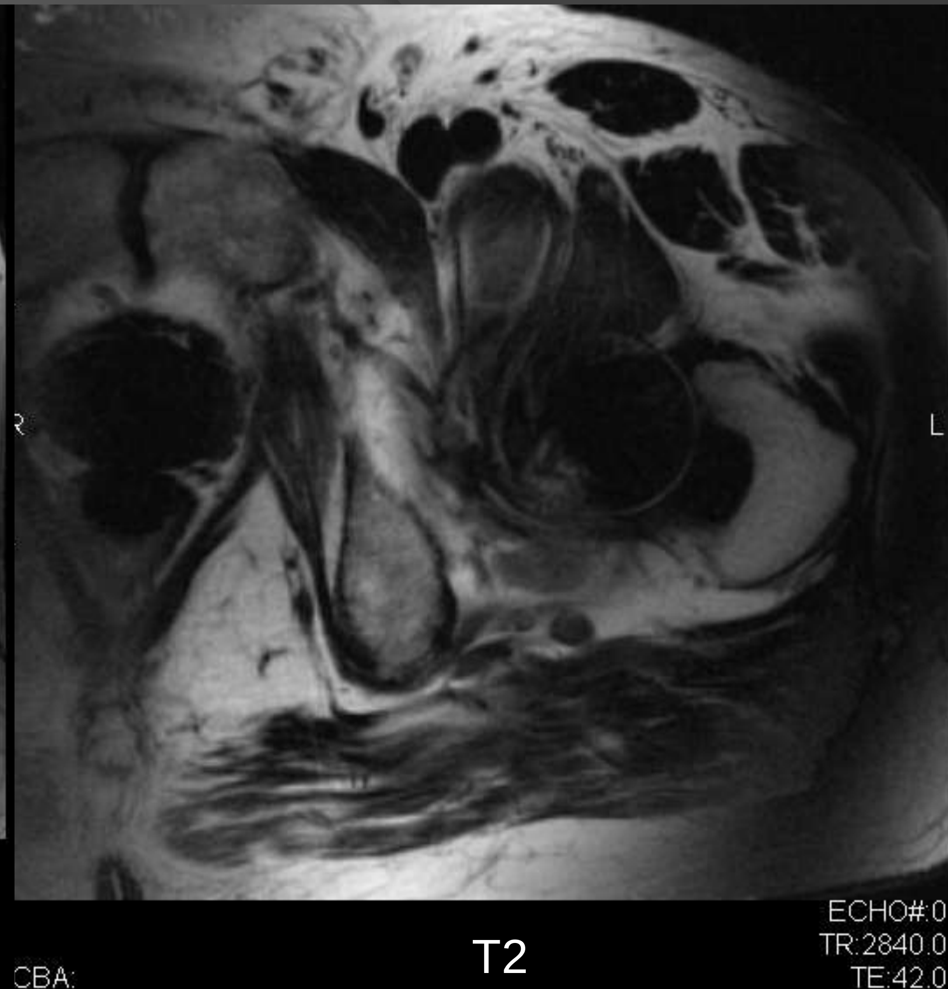
- Radiograph evaluation similar to other THA
- Cross sectional: required for imaging adjacent soft tissues/periprosthetic mass
  - MRI: metal artifact reduction sequences (MARS) required
  - US: useful due to absence of metal artifact

Ostlere S, How to image metal-on-metal prostheses and their complications, *AJR*, 2011;197:558-67.

ARMD—MRI

- Solid (occasionally cystic) lesions usually low T2 signal—metal deposition
- Gadolinium not required—low vascularity of solid components
- Solid lesions tend to be anterior (psoas muscle)
- Predominately cystic lesions tend to arise from posterior joint space
- Lateral lesions often involve trochanteric bursa

Ostlere S, How to image metal-on-metal prostheses and their complications, *AJR*, 2011;197:558-67.



57 yo male left hip MoM THA.

Adverse reaction to metal debris

- Incidence: 6-18% at mean of 41 months[1]
- However. . .
  - Recent nonpublished (submitted) evidence identifies 69% incidence of pseudotumor in Depuy recall imaging of both asymptomatic and symptomatic patients
  - Presence of symptoms was not correlated with presence or size of pseudotumors
  - Only bone marrow edema and tendon tearing were shown to be significant predictors of pain

1. Haddad FS, *et al*, Metal-on-metal bearings: The evidence so far, *JBJS*, 2011;93-B:572-9.

Heterotopic ossification

- Typically around femoral neck and greater trochanter
- Usually asymptomatic
  - Stiffness most common complaint
  - Pain rare
- Up to 39% THA
- May begin 2-3 weeks post-op with possible ankylosis by 12 wks

-Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall
-http://www.radiologyassistant.nl/en/431c8258e7ac3

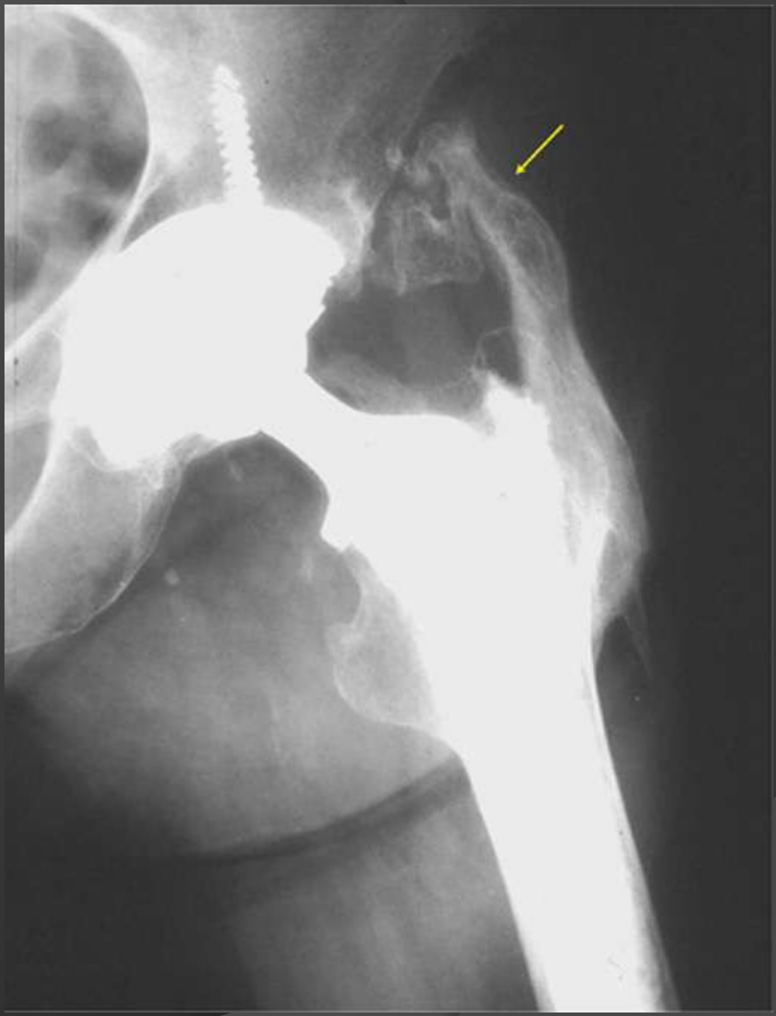
Heterotopic ossification

- Brooker and Bowerman classification
  - Class 1: Islands of bone in soft tissues
  - Class 2: >1 cm gap in HO between femur and pelvis
  - Class 3: <1 cm gap
  - Class 4: Bony ankylosis

-Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall
-http://www.radiologyassistant.nl/en/431c8258e7ac3

Heterotopic ossification

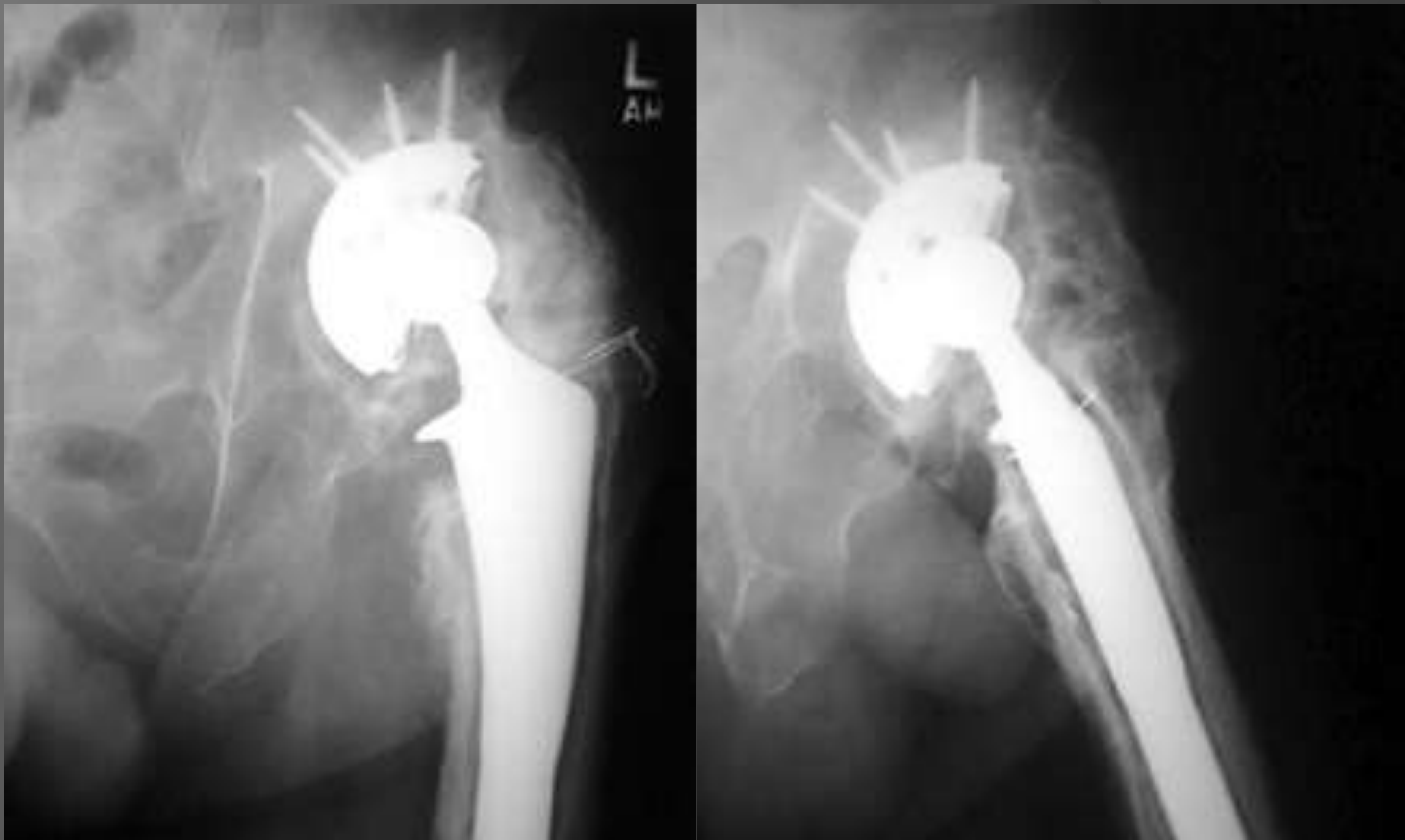
Class 3



Class 3-4

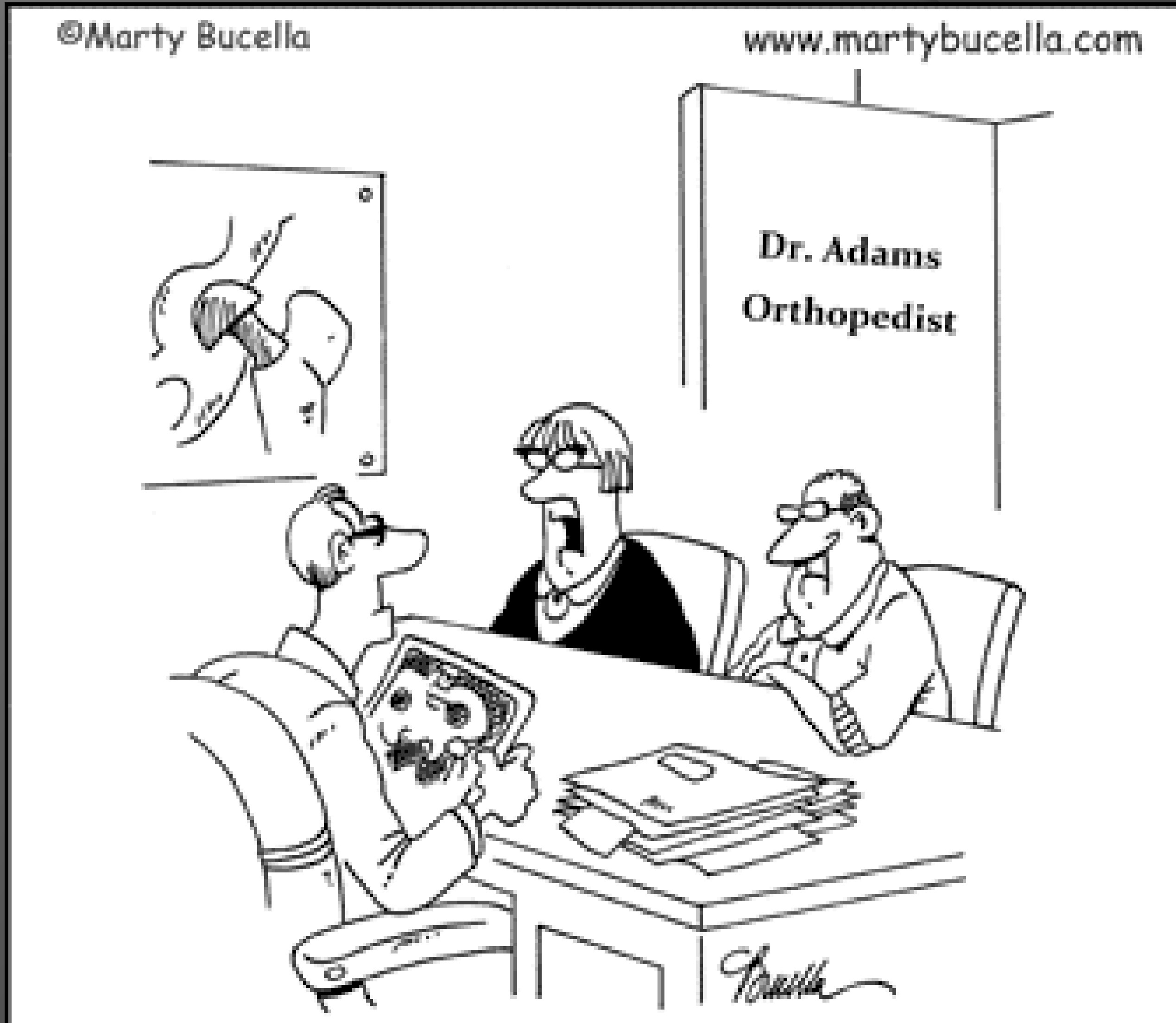
Jacobson JA, Chew FS, http://emedicine.medscape.com/article/398669-overview#showall

Heterotopic ossification



Class 4—complete ankylosis

http://www.gentili.net/thr/heteroto.htm



"Hip replacement? He was never hip to begin with."

Special thanks

- Eric Chang, MD

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