Current and Future Bearing Surfaces in Total Hip Arthroplasty

SAN DIEGO ORTHOPAEDIC ASSOCIATES MEDICAL GROUP, INC.

sdoa

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Disclosures

- Smith and Nephew Speaker, Instructor
- Medtronic Speaker

Fletch Wisdom/ Truths

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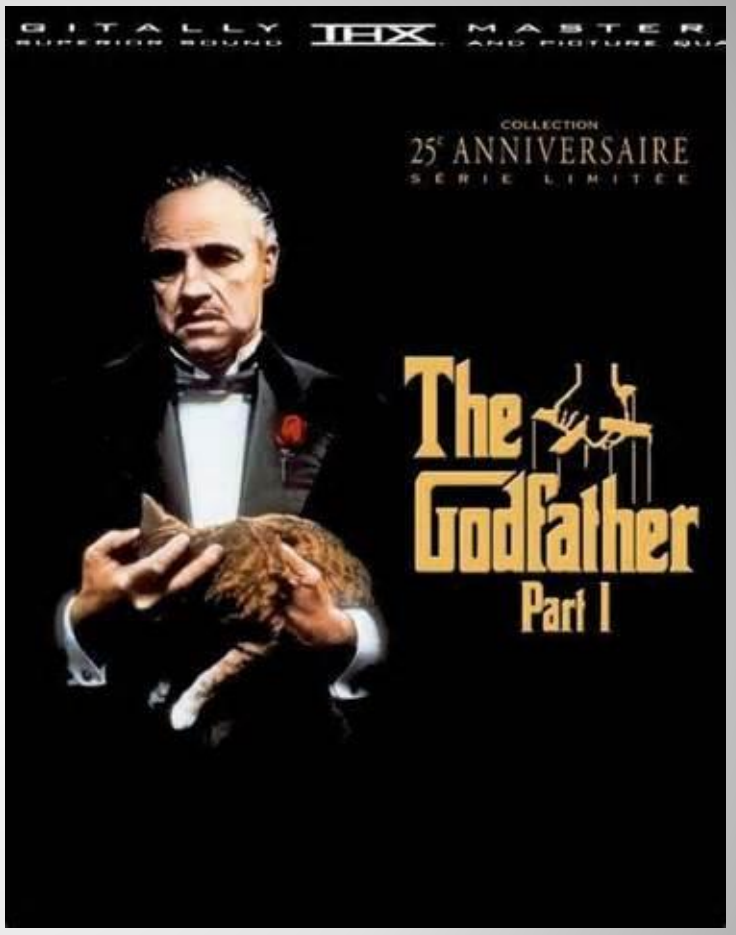
Bearing Surfaces

- Tough
- Minimal wear
- Cost effective
- Easy to implant
- Bioinert

Ideal Surface

Conventional Polyethylene

- Charnley 1950s
  - Polytetrafluoroethylene (PTFE) against stainless steel
  - Failed in a few years
- 1962 → Charnley introduced HMWP



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Background

- Polyethylene
  - Long chain hydrocarbon
  - Radiation → C-H and C-C bonds can be broken
  - Oxygen can bind to free radical → oxidation
  - Oxidation can have negative consequences for wear and mech properties

Cross Linking

- Formation of C-C bond b/w adjacent molecules
- Two steps
  - Irradiation → free radicals → react to cross link polymer chains
- Heating
  - Reduces free radicals
  - Prevents oxidation
  - Below melting point → annealing
  - Above melting point → remelting

Crosslinked UHMWPE

- Marked reduction in wear compared to conventional
  - Estok, Harris et al, J Arthroplasty 2007
  - Muratolglu, Rubash, Harris et al J Arthroplasty 2007
  - Mahoney, Crowninshield

Crosslinked UHMWPE

- Insensitive to femoral head size in terms of volumetric wear compared to std poly
- More resistance to third body wear and rough femoral heads
  - Ito, Crowninshield, Maloney et al, J Arthroplasty 2010

Crosslinked UHMWPE

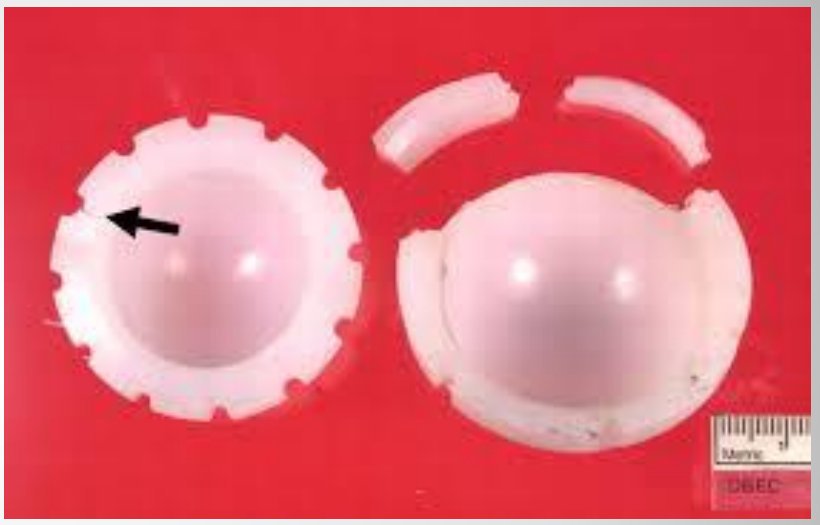
- Wear reduced by 95%
- Yearly femoral head penetration <6µm
  - Rohrl et al, Acta Orthop 2007

Crosslinked UHMWPE

- Crosslinked UHMWPE
  - Decreased mechanical properties
  - No Free lunch!
- Inverse relationship b/w radiation dose and crack propagation

Crosslinked UHMWPE

- XL UHMWPE liner fracture
- Multifactorial in nature
  - Assoc'd with heads larger than 32mm
- Tower et al, JBJS 2007
  - Thin poly at the cup rim
  - Vertical cup alignment
  - Reduction in mechanical properties of UHMWPE



Crosslinked HMWPE

- Shia DS, Clohisy JS, Schinsky MF, Martell JM, Maloney WJ: THA with highly cross-linked polyehtylene in patients 50 years or younger. CORR 2009
  - Avg age 41 years
  - f/u mean 4 years
  - Post bedding in phase, femoral head penetration not detectable

- Leung SB, Egawa H, Stepniewski A, Beykirch S, Engh CA Jr, Engh CA Sr: Incidence and volume of pelvic osteolysis at early follow-up with highly cross linked and noncross-linked polyethylene. J Arthroplasty 2007
  - CT scans at 5 yrs postop
  - Incidence osteolysis significantly higher w/ conventional poly (28% vs 8%)
  - Lesions significantly smaller

Crosslinked UHMWPE

Crosslinked UHMWPE

- Bitsch RG, Loidolt T, Heisel C, S Ball, Schmalzried TP: Reduction in osteolysis with use of Marathon cross-linked polyethylene: A concise follow-up, at a minimum of five years, of a previous report. JBJS 2008.
  - Min 5 yr f/u
  - XL UHMWPE lower femoral head penetration rates, volumetric wear, activity adjusted wear
  - No osteolysis in XL UHMWPE
  - 33% (8/24) osteolysis in conventional poly

Vitamin E Poly

- Adding antioxidant vitamin E
  - Oxidation resistance
  - Improved fatigue strength
- Simulator studies
  - Low wear
  - High oxidation strength
  - Micheli et al JOA 2012
- Longer term studies needed
- Increased cost

VS

Metal on Poly

Ceramic on Poly

Mayweather Vs Pacquiao

Filipino Pride!!!!

Ceramic on Poly and Metal on Poly

- Wyles, Sierra, Trousdale et al. CORR 2014
- Meta-analysis of RCTs
  - Min of 2 yr followup
  - Avg age <65 yrs
  - Direct meta-analysis → No differences in rev rates
  - 779 THAs
  - Network meta-analysis → 2599 THAs
  - No differences in survival

- Semlitsch et al
  - 20:1 reduction in wear
- Oonoshi et al 1989
  - CoP → 0.1mm/yr
  - MoP→ 0.25mm/yr
- Wroblewski et al
  - Head penetration of 0.019 mm/yr at 17 yr followup C on XLPE
  - Demonstrated in wear simulator studies
- **Potentially cost effective in younger patients**

Ceramic on Poly and Metal on Poly

Metal on Metal

- First used in 1930s
  - Stainless steel components
- 1940s-1950s
  - Cobalt-chrome alloy

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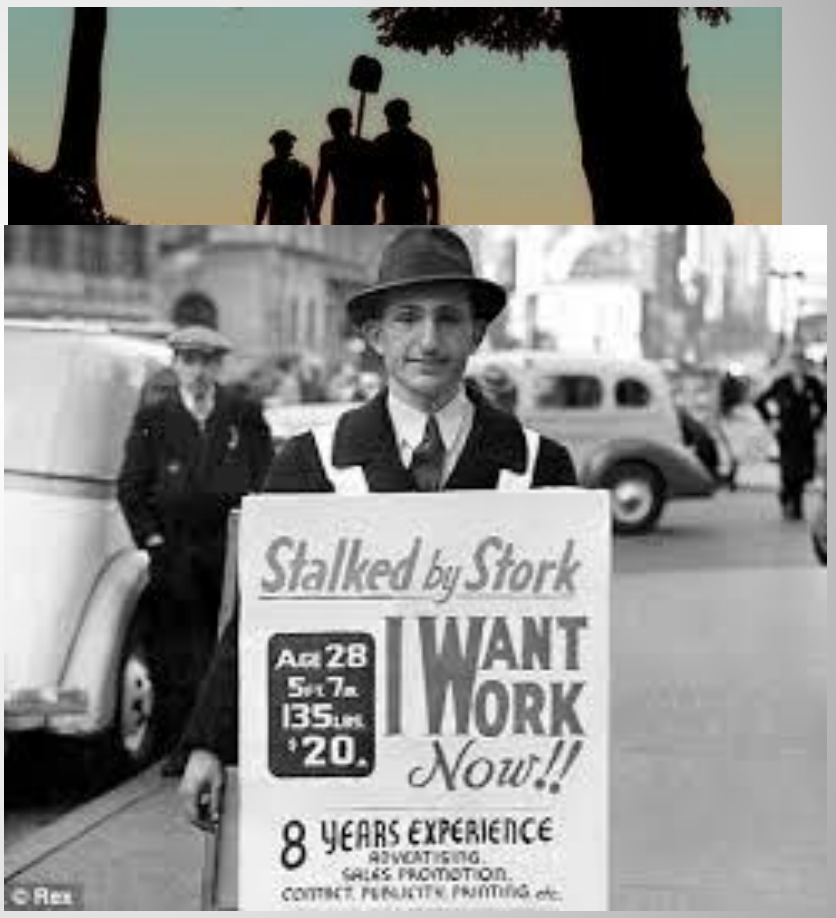

Metal on Metal

Metal on Metal

- Modern MOM THAs introduced in 1990s
- Revival d/t increased stability, decrease wear, hip resurfacing
  - Bozic et al JBJS 2009, Chan et al CORR 1999, Rieker et al 2001
- Improved metallurgy
- Low- wear option
  - Weber et alm CORR 1996

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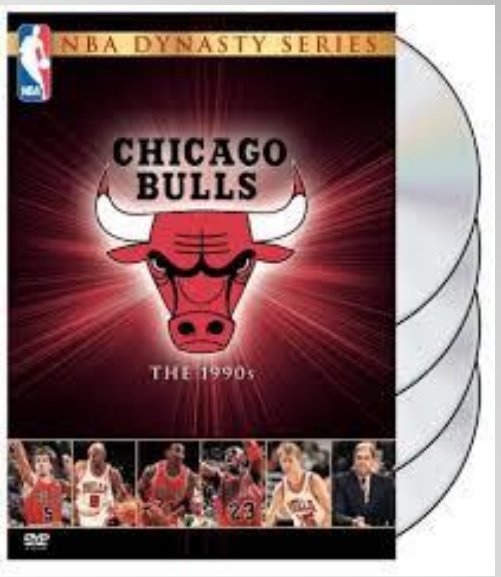

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- "run-in period"
  - First million cycles in vitro
  - First 1-2 years in vivo
  - Then lower steady-state wear
- Chan, Bobyn et al. CORR 1999
  - cup position in vitro → anteverted and vertical → increased wear rate, metal ions

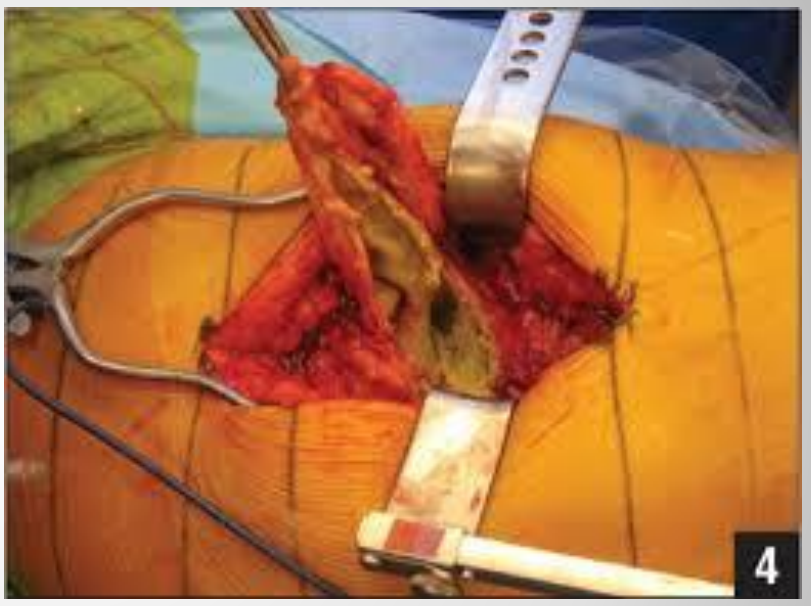
Metal on Metal

Metal on Metal

- Unique complications
  - Increased metal ion levels
    - Macdonald SJ, CORR 2004; Clarke et al, JBJS Br 2003
- Systemic issues?
  - Case reports of renal failure and neuro issues
- Crosses placenta
- Malignancy?

Metal on Metal

- Localized effects
  - Metal sensitivity
  - ALVAL/ALTR
  - Metallosis
  - Pseudotumors
  - Effusion



Metal on Metal

- Localized effects
  - Metal sensitivity
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  - Effusion

- Rev THAs being performed for unique reasons
- Risk factors:
  - Females
  - Known poor functioning implants
  - Head size
  - Cup position

High Incidence of Revision THAs

- Fabi, Levine, Paprosky, Della Valle, Sporer, Klein, Levine, Hartzband . Orthopedics 2012
- **Metal-on-metal total hip arthroplasty: causes and high incidence of early failure.**
- **Abstract**
- A review was performed of 80 patients who underwent revision of a failed metal-on-metal THA for any reason.
- The most common reason for metal-on-metal failure was aseptic acetabular loosening, with a rate of 56.25% (45/80 patients).
- Early failure of metal-on-metal THAs was noted, with 78% of these revisions being performed within 2 years of the index operation and 92.5% within 3 years.
- Mean preoperative Harris Hip Score was 42.35 ± 14.24 and mean postoperative Harris Hip Score was 66.5 ± 23.2 (range, 9.55-95.4), with an average follow-up of 438 ± 492 days (range, 40-2141), or 1.2 years.
- This article proposes an algorithm to aid in diagnosing the etiology of a painful metal-on-metal THA, as well as 2 classification schemes regarding metal-on-metal THA complications to help direct treatment.

Shameless Self Plug

Table 1

Fabi-Levine Metal-on-Metal THA Failure Classification

Type	Description	Treatment
1	Metal sensitivity: stable, well-aligned acetabular component, elevated metal ions, and pain	Revise bearing only to metal–poly or ceramic–poly if modular cup; if monoblock cup, revise cup with metal–poly or ceramic–poly bearing
2	Malpositioned cup: stable, malaligned acetabular component, elevated metal ions, and pain	Revise cup with metal–poly or ceramic–poly bearing
3	Loose cup	Revise cup with metal–poly or ceramic–poly bearing
4	Early failure cups: acetabular components with known high early failure rates	Revise cup with metal–poly or ceramic–poly bearing
5	Iliopsoas impingement: ion levels within normal limits, cup retroverted	Iliopsoas release or revise cup to optimal position with metal–poly or ceramic–poly bearing

Abbreviation(s): THA, total hip arthroplasty

Fabi- Levine Classification

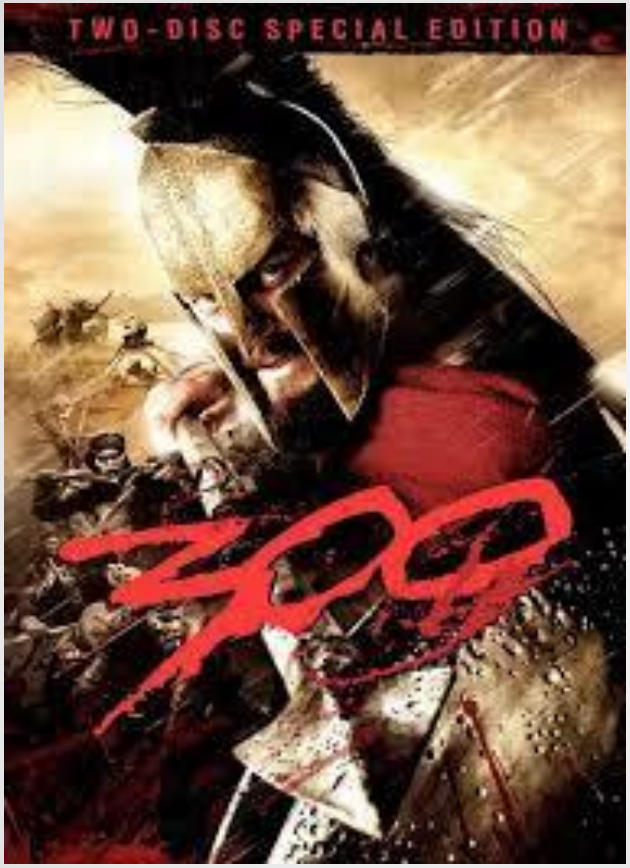
Table 2

Fabi-Levine Metal-on-Metal THA Soft Tissue Complication Classification

Type	Description	Treatment and Implications
I	Intracapsular effusion, capsule intact	Revise bearing and/or cup if needed, stability less of an issue
II	Extracapsular effusion, capsule affected, abductors intact	Revise bearing and/or cup if needed, stability more of an issue
III	Capsule affected, abductors affected	Revise bearing and/or cup if needed, stability severely compromised; consider constrained liner, other salvage options

Abbreviations: THA, total hip arthroplasty.

Fabi-Levine Classification



IMMORTALITY!!!!

Ceramic on Ceramic

Ceramic on Ceramic

- First seen in 1970s
- Femoral head and/or liner fracture
  - 13.4% in ceramic heads manufactured before 1990
  - Willmann G. CORR 2000
    - Current generation femoral head fx 0.004%

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Squeaking

- Squeaking
  - 0.7-20.9%
  - Mai K, Ezzet KA, Copp SN, Walker RH, Colwell CW. CORR 2010
  - d/t?
    - Edge-loading, stripe wear, component malposition, altered fluid mechanics

Newer Surfaces

- Ceramic on metal
- Diamond on poly
- Oxinium on poly
- Ox-ox
- Silicone nitride
- Sapphire
- Multiwalled carbon nanotube reinforced poly
- Dual mobility

Ceramic on Metal

- Ceramic on metal
  - No squeaking
  - No liner fx
  - No metal debris

Literature

- **Isaac et al. JBJS Br 2009. Ceramic-on-metal bearings in total hip replacement: whole blood metal ion levels and analysis of retrieved components.**

- This study reports on ceramic-on-metal (CoM) bearings in THA
- The median increase in chromium and cobalt at 12 months was 0.08 microg/1 and 0.22 microg/1, respectively, in CoM bearings.
- Comparable values for metal-on-metal (MoM) were 0.48 microg/1 and 0.32 microg/1.
- The chromium levels were significantly lower in CoM than in MoM bearings ($p = 0.02$).
- The cobalt levels were lower, but the difference was not significant.

- Multiwalled carbon nanotube reinforced poly
- Mult concentric nanotubes precisely nested within one another
- Improves mechanical characteristics
- Superior wear behavior compared to UHMWPE

Multiwalled carbon nanotube reinforced poly

Oxinium

- Oxidized layer of metallic zirconium alloy
- Not a coating but a transformation of surface that is 5-10mm thick
- Much harder and more scratch resistant

Oxinium

- Simulator study → 45% less wear than smooth CoCr heads
- w/ roughened heads, ox 61% less wear
  - Good et al. JBJS 2003
- Australian registry → excellent survival
- Lewis et al
  - No diff b/w CoCr and Ox at 2 yrs
  - Retrieval → loss of ox layer with extensive damage to poly
    - Jaffe et al. JOA 2009

Diamond

- Superior mechanical properties, biocompatibility and inertness
- In vivo study → 46% of 101 heads against poly revised due to aseptic loosening
  - Hauert et al. Acta Biomater 2012

Diamond

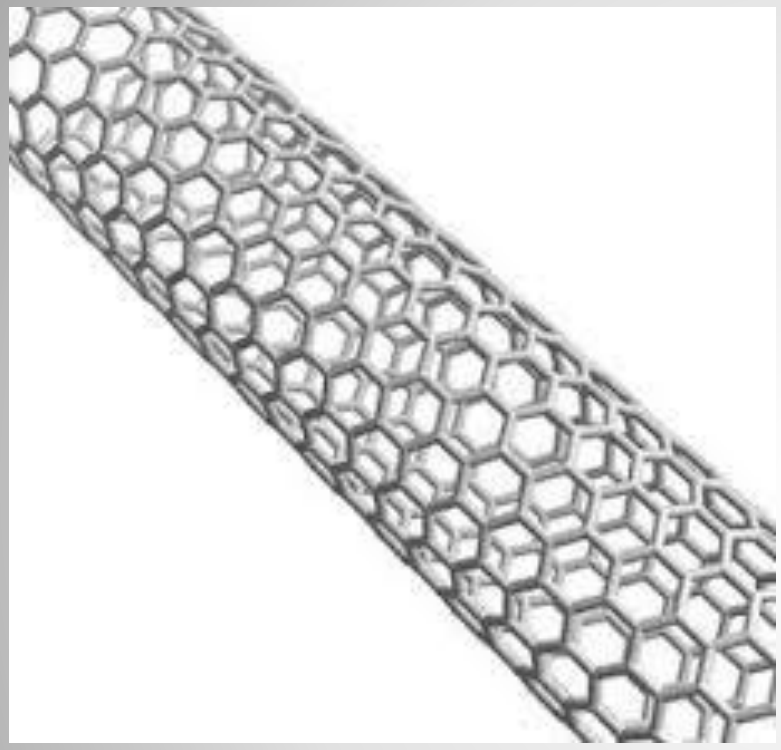
- Retrieved heads → delamination and corrosion
- Simulator study
  - Metal-poly 50-100mm/yr
  - Metal on metal 5-10mm/yr
  - Diamond 0.001mm/yr
    - Lappalainen et al. J Biomed Mater Res B Appl Biomater 2003

Sapphire

- Aluminum oxide in the purest form
- No porosity or grain boundaries
- Low and stable coeff of friction

Sapphire

- Inert, low cost
- 5 patients → no complications at 5 years
- Studied in ukraine
  - Mamalis et al. J Biol Phys Chem 2006



- Low wear
- Inert
- Less biologically active wear particles
- Lower wear rates than UHMWPE
- Less cytotoxic

Carbon Based Composite Materials

Silicon Nitride

- Biocompatible
- High wear resistance
- Good osteoconductive properties
- Inhibits biofilm formation and bacterial contamination
- Semi-radiolucent

Silicon Nitride

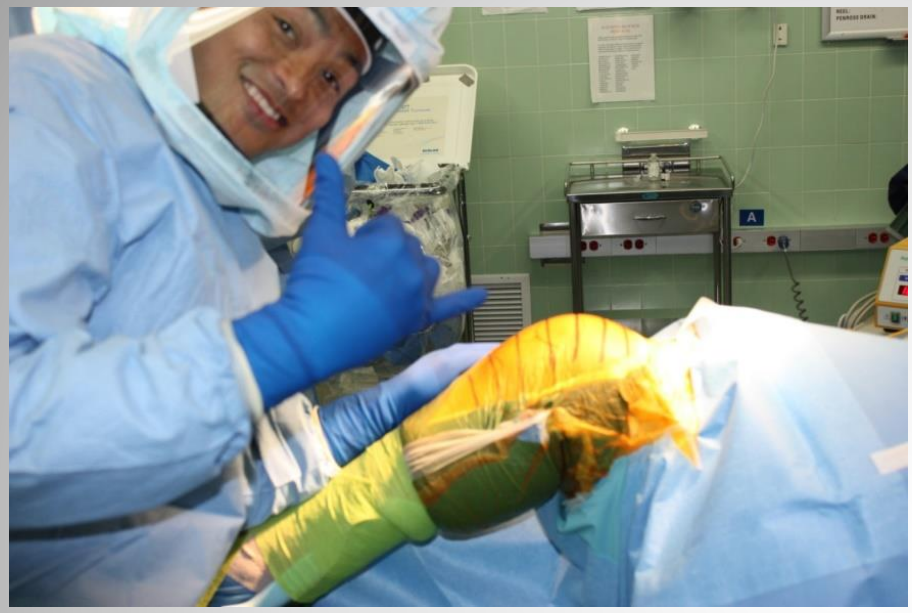
- Mechanical studies
  - Improved fx toughness and strength over ceramic
    - Bal et al. JOA 2009.
  - Wear products thought to dissolve in fluid → less aseptic loosening
    - Olofsson et al. Biomatter 2012.
- Feb 2011 → first Silicon THA

- Introduced in France in 1976
- Inner constrained femoral head and large poly insert
- Outer unconstrained poly insert and metal cup
  - Vielpeau et al. Int Orthop 2011
  - Guyen et al. CORR 2009

Dual Mobility

- Most motion within inner articulation
- Femoral neck eventually contacts poly insert and drives motion of outer articulation
- Unconstrained nature → decreased cup loosening
- Rev THAs for instability

Dual Mobility



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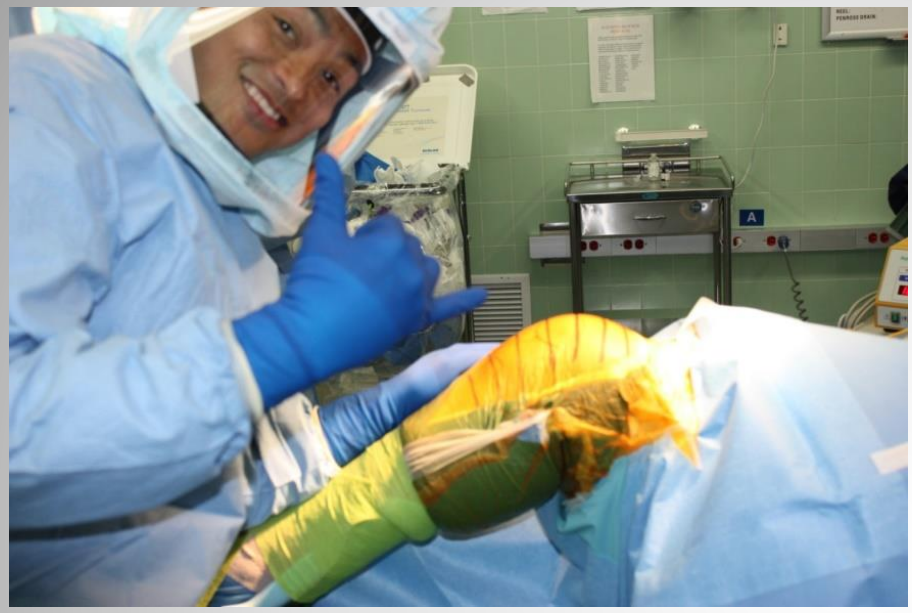

Questions?