Current and Future Bearing Surfaces in Total Hip Arthroplasty

David Fabi, MD
Chief of Orthopaedic Surgery,
Scripps Mercy Hospital
Joint Replacement Specialist
Smith and Nephew Speaker, Instructor
Medtronic Speaker
Fletch Wisdom/ Truths
C'MON FELLAS,

IT'S ALL BALL BEARINGS NOWADAYS!
Bearing Surfaces
- Tough
- Minimal wear
- Cost effective
- Easy to implant
- Bioinert

Ideal Surface
• Charnley 1950s
  ◦ Polytetrafluoroethylene (PTFE) against stainless steel
  ◦ Failed in a few years
• 1962 ➔ Charnley introduced HMWP
• Conventional Polyethylene
  ◦ Charnley 1950s
    ◦ Polytetrafluoroethylene (PTFE) against stainless steel
    ◦ Failed in a few years
  • 1962 → Charnley introduced HMWP
• Charnley 1950s
  ◦ Polytetrafluoroethylene (PTFE) against stainless steel
  ◦ Failed in a few years
• 1962 → Charnley introduced HMWP
Polyethylene
- Long chain hydrocarbon
- Radiation $\rightarrow$ C-H and C-C bonds can be broken
- Oxygen can bind to free radical $\rightarrow$ oxidation
- Oxidation can have negative consequences for wear and mech properties
• 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
• 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
• Wear reduced by 95%
• Yearly femoral head penetration < 6µm
• Crosslinked UHMWPE
  ◦ Decreased mechanical properties
  ◦ No Free lunch!
• Inverse relationship b/w radiation dose and crack propagation
- 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
Shia DS, Clohisy JS, Schinsky MF, Martell JM, Maloney WJ: THA with highly cross-linked polyethylene 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

- CT scans at 5 yrs postop
- Incidence osteolysis significantly higher w/ conventional poly (28% vs 8%)
- Lesions significantly smaller
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

**Crosslinked UHMWPE**
- 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
Metal on Poly VS Ceramic on Poly
Mayweather Vs Pacquiao
Filipino Pride!!!!
• 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

Ceramic on Poly and Metal on Poly
- **Semlitsch et al**
  - 20:1 reduction in wear

- **Oonoshi et al 1989**
  - CoP $\rightarrow$ 0.1mm/yr
  - MoP $\rightarrow$ 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**
Metal on Metal

• First used in 1930s
  ◦ Stainless steel components

• 1940s-1950s
  ◦ Cobalt-chrome alloy
- First used in 1930s
  - Stainless steel components
- 1940s-1950s
  - Cobalt-chrome alloy
Metal on Metal

- Modern MOM THAs introduced in 1990s
- Revival d/t increased stability, decrease wear, hip resurfacing
- Improved metallurgy
- Low- wear option
  - Weber et alm CORR 1996
Metal on Metal

- Modern MOM THAs introduced in 1990s
- Revival d/t increased stability, decrease wear, hip resurfacing
- Improved metallurgy
- Low- wear option
  - Weber et al CORR 1996
- Modern MOM THAs introduced in 1990s
- Revival d/t increased stability, decrease wear, hip resurfacing
- Improved metallurgy
- Low- wear option
  - Weber et al CORR 1996
• Modern MOM THAs introduced in 1990s
• Revival d/t increased stability, decrease wear, hip resurfacing
• Improved metallurgy
• Low- wear option
  ◦ Weber et alm CORR 1996
• Modern MOM THAs introduced in 1990s
• Revival d/t increased stability, decrease wear, hip resurfacing
• Improved metallurgy
• Low- wear option
  ◦ Weber et al CORR 1996

Metal on Metal
- “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
• 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?
• Localized effects
  ◦ Metal sensitivity
  ◦ ALVAL/ALTR
  ◦ Metallosis
  ◦ Pseudotumors
  ◦ Effusion
- Localized effects
  - Metal sensitivity
  - ALVAL/ALTR
  - Metallosis
  - Pseudotumors
  - Effusion

Metal on Metal
Rev THAs being performed for unique reasons

Risk factors:
- Females
- Known poor functioning implants
- Head size
- Cup position
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.
<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Metal sensitivity; stable, well-aligned acetabular component, elevated metal ions, and pain</td>
<td>Revise bearing only to metal-poly or ceramic-poly; if modular cup, revise cup with metal-poly or ceramic-poly bearing</td>
</tr>
<tr>
<td>2</td>
<td>Malpositioned cup; stable, malaligned acetabular component, elevated metal ions, and pain</td>
<td>Revise cup with metal-poly or ceramic-poly bearing</td>
</tr>
<tr>
<td>3</td>
<td>Loose cup</td>
<td>Revise cup with metal-poly or ceramic-poly bearing</td>
</tr>
<tr>
<td>4</td>
<td>Early failure cups; acetabular components with known high early failure rates</td>
<td>Revise cup with metal-poly or ceramic-poly bearing</td>
</tr>
<tr>
<td>5</td>
<td>Hip flexor impingement; ion levels within normal limits, cup reoriented</td>
<td>Hip flexor release or revise cup to optimal position with metal-poly or ceramic-poly bearing</td>
</tr>
</tbody>
</table>

Abbreviations: THA, total hip arthroplasty.
Fabi-Levine Classification

Table 2

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

Abbreviations: THA, total hip arthroplasty.
IMMORTALITY!!!!
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%
• 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%
• 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

- No squeaking
- No liner fx
- No metal debris
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

Multiwalled carbon nanotube reinforced poly

Mult concentric nanotubes precisely nested within one another

Improves mechanical characteristics

Superior wear behavior compared to UHMWPE
• 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
- Simulator study $\rightarrow$ 45% less wear than smooth CoCr heads
- w/ roughened heads, ox 61% less wear
  - Good et al. JBJS 2003
- Australian registry $\rightarrow$ excellent survival
- Lewis et al
  - No diff b/w CoCr and Ox at 2 yrs
  - Retrieval $\rightarrow$ loss of ox layer with extensive damage to poly
    - Jaffe et al. JOA 2009
• Superior mechanical properties, biocompatibility and inertness
• In vivo study → 46% of 101 heads against poly revised due to aseptic loosening
• Retrieved heads → delamination and corrosion
• Simulator study
  ◦ Metal-poly 50-100mm/yr
  ◦ Metal on metal 5-10mm/yr
  ◦ Diamond 0.001mm/yr
- 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
Carbon Based Composite Materials

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

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

- 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
Thank You!

Michigan
Questions?