Modularity in Total Hip Arthroplasty

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The Benefits of Modularity

Restoration of Femoral Anatomy
- Leg Length
- Offset
- Version

Stability

Diaphysis ➔ Metaphysis
Modularity Works…

Head–Neck Modularity for Total Hip Arthroplasty

William J. Hozack, MD,*† Joseph J. Mesa, MD,†
and Richard H. Rothman, MD, PhD*†
The Journal of Arthroplasty Vol. 11 No. 4 1996

- 19% of cases had a change in neck length to optimize leg-length

Modular versus Nonmodular Neck Femoral Implants in Primary Total Hip Arthroplasty: Which is Better?


Paul J. Duwelius MD, Bob Burkhart PA, Clay Carnahan PA, Grant Branam BSc,
Laura Matsen Ko MD, YingXing Wu MD, Cecily Froemke MS,
Lian Wang MS, Gary Grunkemeier PhD

- Less leg length discrepancy with neck modularity
- Less offset differences with neck modularity
But Do We NEED It?

Paul J. Duwelius MD, Bob Burkhart PA, Clay Carnahan PA, Grant Branam BSc, Laura Matsen Ko MD, YingXing Wu MD, Cecily Froemke MS, Lian Wang MS, Gary Grunkemeier PhD

- No difference in HHS or complications at 3 years

Midterm Results of a Femoral Stem With a Modular Neck Design: Clinical Outcomes and Metal Ion Analysis The Journal of Arthroplasty 29 (2014) 1768–1773
Craig D. Silverton, DO\(^{a,1}\), Joshua J. Jacobs, MD\(^b,1\), Jeffrey W. Devitt, MD\(^{a,1}\), H. John Cooper, MD

- 9% revision rate for Profemur Z stem-related failures at 8 years

Camilo Restrepo, MD, David Ross, BA, Santiago Restrepo, Snir Heller, MD, Nitin Goyal, MD, Ryan Moore, MD, William J. Hozack, MD

- Mean 17 months to symptoms with the ABG-II
- All revisions had evidence of corrosion between neck and stem
Stryker
ABG II (CoCr)
Rejuvinate (CoCr)

Wright Medical
Profemur-Z (Ti)
## Corrosion

<table>
<thead>
<tr>
<th>Corrosive Mode</th>
<th>Cause</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galvanic</td>
<td>Dissimilar Metals</td>
<td>Avoid Dissimilar Metals Passivation Layer</td>
</tr>
<tr>
<td>Fretting</td>
<td>Micromotion</td>
<td>Avoid Micromotion</td>
</tr>
<tr>
<td>Crevice*</td>
<td>Microscopic Isolation</td>
<td>Improved Tolerances Passivation Layer</td>
</tr>
<tr>
<td>Pitting*</td>
<td>Surface Defects</td>
<td>Polish Surfaces Passivation Layer</td>
</tr>
<tr>
<td>Intergranular</td>
<td>Carbide-Grain Boundaries</td>
<td>Molybdenum Alloys Low Carbon Alloys</td>
</tr>
</tbody>
</table>
Fretting Corrosion

Contact Pressure

Fretting Pad

Slip Region

Stick Region

Wear Debris

Crack

Fretting Fatigue Specimen

Cyclic Loading Direction
Fretting Corrosion

Fretting Corrosion - 4% head-neck and 94% dual modular

Collier+ 1995, AAOS+ 2014
Crevice Corrosion

MOH $\rightarrow$ $M^+ + OH^-$

Head - Female
Crevice Corrosion – Chromium (III) Phosphate Precipitation
30% at mixed-alloy junctions
10% of all-titanium-alloy junctions
6% of all-cobalt-alloy junctions

Collier+ 1995, Kop+ 2009
Any Modular Junction Can Be Affected

<table>
<thead>
<tr>
<th>Modularity</th>
<th>Stem Design</th>
<th>Manufacturer</th>
<th>Junction</th>
<th>Failure Mode(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metaphyseal</td>
<td>S-ROM</td>
<td>DePuy-Synthes</td>
<td>Ti/Ti</td>
<td>Fracture</td>
</tr>
<tr>
<td>Dual Taper</td>
<td>Kinectiv, Profemur-Z</td>
<td>Zimmer, Wright</td>
<td>Ti/Ti, Ti/Ti (1st Gen), CoCr/Ti (2nd Gen)</td>
<td>Fracture, Corrosion</td>
</tr>
<tr>
<td></td>
<td>ABG II, Rejuvinate, Adaptor GHE, Bionik, M-series, Apex</td>
<td>Stryker, Eska, Exacttech, Eska, Global</td>
<td>CoCr/Ti, Ti/Ti</td>
<td>Corrosion, Damage</td>
</tr>
<tr>
<td>Diaphyseal</td>
<td>ZMR, Link, MRP-Titanium</td>
<td>Zimmer, Microport, Peter Brehm</td>
<td>Ti/Ti, Ti/Ti, Ti/Ti</td>
<td>Fracture, Damage</td>
</tr>
<tr>
<td>Multiple</td>
<td>Margron, GMRS</td>
<td>Portland, Stryker</td>
<td>CoCr/Ti, CoCr/Ti</td>
<td>Corrosion, Corrosion</td>
</tr>
</tbody>
</table>
Risk Factors for Taper Corrosion

1) Taper Design/Geometry

- NO STANDARD (V40, C-taper, 14/15, 12/13, etc.)
- Taper Length: Short Tapers (Increased Corrosion)
- 3D Topography: 64% have Peaks and Troughs (Increased Corrosion)

Gilbert+ 2009, Bernstein+ 2011, Meyer+ 2012, AAOS+1014
Risk Factors for Taper Corrosion

2) Mechanical Environment

Less Rigidity of the Femoral Neck Increased Micromotion
Wet or Contaminated Assembly Increases Micromotion
Off-Axis Impaction Increases Micromotion
Femoral Head Offset Increases Torque
Highly Cross-linked or Vitamin E Polyethylene Increases Friction
Increased Head Size Remains Controversial

Gilbert+ 2009, Bernstein+ 2011, Meyer+ 2012, AAOS+1014
Clinical Presentation Similar to MOM

History: s/p THA
± Pain at Rest
± Pain with Loading

Physical: ± Palpable Mass
± Fluid Collection
± Loss of Abduction

Labs: ± Negative for Infection
Aseptic Lymphocyte-dominated Vasculitis-associated Lesion (ALVaL)

Fibrinous Exudate

Perivascular Infiltration

Macrophages

B-Cells

T-Cells

T-Cells+

Osteolysis

Trochanteric → Calcar → Peri-Acetabular

Korovessis+ 2006, Huber+ 2009
Pseudotumor
Management Algorithm

Risk Stratification Algorithm for Management of Patients with Metal-on-Metal Hip Arthroplasty
Consensus Statement of the American Association of Hip and Knee Surgeons, the American Academy of Orthopaedic Surgeons, and The Hip Society

Young-Min Kwon, MD, PhD, Adolph V. Lombardi, MD, FACS, Joshua J. Jacobs, MD, Thomas K. Fehring, MD, Courtland G. Lewis, MD, and Miguel E. Cabanela, MD

### TABLE II MoM ‘Low’ Risk Group

<table>
<thead>
<tr>
<th>'Low' Risk Group Stratification</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient factors</strong></td>
<td><strong>Patient with low activity level</strong></td>
</tr>
<tr>
<td>Symptoms</td>
<td>Asymptomatic (including no systemic or mechanical symptoms)</td>
</tr>
<tr>
<td>Clinical examination</td>
<td>No change in gait (i.e. no limp, no abductor weakness)</td>
</tr>
<tr>
<td></td>
<td>No swelling</td>
</tr>
<tr>
<td><strong>Implant type</strong></td>
<td>Small-diameter femoral head (&lt;36 mm) modular MoM THA; hip resurfacing in males &lt;50 with osteoarthritis</td>
</tr>
<tr>
<td>Radiographs (2 views ± serial for comparison when available)</td>
<td>Optimal acetabular cup orientation (40° ± 10° inclination for hip resurfacing)</td>
</tr>
<tr>
<td></td>
<td>No implant osteolysis/loosening</td>
</tr>
<tr>
<td>Infection work-up (ESR, CRP, ± hip aspiration)</td>
<td>Within normal limits</td>
</tr>
<tr>
<td>Metal ion level test (if available)</td>
<td>Low (&lt;3 ppb)</td>
</tr>
<tr>
<td>Cross-sectional imaging (if available); these studies include MARS MRI; ultrasound or CT when MRI contraindicated or MARS protocol not available</td>
<td>Within normal limits</td>
</tr>
<tr>
<td>Treatment recommendation</td>
<td>Annual follow-up</td>
</tr>
</tbody>
</table>
## Moderate Risk

<table>
<thead>
<tr>
<th>TABLE III MoM ‘Moderate’ Risk Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Moderate’ Risk Group Stratification</td>
</tr>
</tbody>
</table>

### Patient factors
- Male or female
- Dysplasia (for hip resurfacing)
- Patient with moderate activity level

### Symptoms
- **Symptomatic**
  - Mild local hip symptoms (e.g., pain, mechanical symptoms)
  - No systemic symptoms

### Clinical examination
- **Change in gait (i.e., limp)**
  - No abductor weakness
  - No swelling

### Implant type
- Large-diameter femoral head (≥36 mm) modular or nonmodular MoM THA
- Recalled MoM implant
- Hip resurfacing with risk factors (female with dysplasia)

### Radiographs (2 views ± serial for comparison when available)
- Optimal acetabular cup orientation
- No implant osteolysis/loosening

### Infection work-up (ESR, CRP, ± hip aspiration)
- Within normal limits

### Metal ion level test
- **Moderately elevated (3-10 ppb)**

### Cross-sectional imaging (MARS MRI; ultrasound or CT when MRI contraindicated or MARS protocol not available)
- Presence of abnormal tissue reactions without involvement of surrounding muscles and/or bone
- **Simple cystic lesions or small cystic lesions without thickened wall**

### Treatment recommendation
- Follow-up in 6 months
- Consider revision surgery if symptoms progress, imaging abnormality progresses, and/or there are rising metal ion levels over 6 months
# High Risk

## TABLE IV MoM ‘High’ Risk Group

<table>
<thead>
<tr>
<th>‘High’ Risk Group Stratification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient factors</strong></td>
</tr>
<tr>
<td>Female with dysplasia (for hip resurfacing)</td>
</tr>
<tr>
<td>Patient with high activity level</td>
</tr>
<tr>
<td><strong>Symptoms</strong></td>
</tr>
<tr>
<td>Symptomatic</td>
</tr>
<tr>
<td>Severe local hip and/or mechanical symptoms</td>
</tr>
<tr>
<td>Systemic symptoms</td>
</tr>
<tr>
<td><strong>Clinical examination</strong></td>
</tr>
<tr>
<td>Change in gait (i.e., limp)</td>
</tr>
<tr>
<td><strong>Abductor weakness</strong></td>
</tr>
<tr>
<td>Swelling</td>
</tr>
<tr>
<td><strong>Implant type</strong></td>
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<tr>
<td>Large-diameter femoral head (≥36 mm) modular or nonmodular MoM THA</td>
</tr>
<tr>
<td>Recalled MoM implant</td>
</tr>
<tr>
<td><strong>Radiographs (2 views ± serial for comparison when available)</strong></td>
</tr>
<tr>
<td>Suboptimal acetabular cup orientation</td>
</tr>
<tr>
<td>Implant osteolysis/loosening</td>
</tr>
<tr>
<td><strong>Infection work-up (ESR, CRP, ± hip aspiration)</strong></td>
</tr>
<tr>
<td>Within normal limits</td>
</tr>
<tr>
<td>High (&gt;10 ppb)</td>
</tr>
<tr>
<td><strong>Metal ion level test</strong></td>
</tr>
<tr>
<td>Presence of abnormal tissue reactions with involvement of surrounding muscles and/or bone</td>
</tr>
<tr>
<td><strong>Solid lesions</strong></td>
</tr>
<tr>
<td><strong>Cystic lesions with thickened wall</strong></td>
</tr>
<tr>
<td><strong>Mixed solid and cystic lesions</strong></td>
</tr>
<tr>
<td><strong>Treatment recommendation</strong></td>
</tr>
<tr>
<td>Consider revision surgery</td>
</tr>
</tbody>
</table>
Modularity is Here to Stay

Restoration of Femoral Anatomy
- Leg Length
- Offset
- Version

Stability

Diaphysis ➔ Metaphysis

It is up to us to use it Wisely
THANK YOU