Cementless Acetabular Fixation at 15 Years: Comparison to the Gold Standard Charnley

John L. Gaffey, B.S.
John J. Callaghan, M.D.
Douglas R. Pedersen, Ph.D.
Devon D. Goetz, M.D.
Patrick M. Sullivan, M.D.
Richard C. Johnston, M.D.
Procedure

All arthroplasties were performed using a Harris-Galante I acetabular component with two 5.1 mm dome screws. On line reaming was utilized.
Failure Scenario
Accumulated Damage

- Repetitive dynamic loading
- Microdamage
- Crack, nucleation, propagation
- Interface disruption
- Micromotion
- Bone resorption, fibrous interposition
- Gross loosening
<table>
<thead>
<tr>
<th></th>
<th>All Patients</th>
<th>Living Patients*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone I</td>
<td>40 hips (33.3%)</td>
<td>26 hips (36.1%)</td>
</tr>
<tr>
<td>Zone II</td>
<td>20 hips (16.7%)</td>
<td>14 hips (19.4%)</td>
</tr>
<tr>
<td>Zone III</td>
<td>35 hips (29.2%)</td>
<td>23 hips (31.9%)</td>
</tr>
<tr>
<td>Multiple Zones</td>
<td>26 hips (21.7%)</td>
<td>16 hips (22.2%)</td>
</tr>
<tr>
<td>Circum. w/out screws</td>
<td>13 hips (10.8%)</td>
<td>7 hips (9.7%)</td>
</tr>
</tbody>
</table>

*N=72
Failure Scenario
Particulate Reaction

• Most common finding
  – Bearing surface wear
  – Modular interface fretting

• Particles activate macrophages
  – Small particles are worse (sub-μm)
    • Normally, they can be engulfed by phagocytic cells, but depending on the particle burden, in some instances the patient’s phagocytic capabilities are overwhelmed.
  – Transport to remote locations

• Osteolysis

• Relative motion, loosening

3rd body debris
Biologically-induced enzymatic cascades
Osteolytic aseptic loosening
# Pelvic Osteolysis

<table>
<thead>
<tr>
<th>Zone</th>
<th>All Patients</th>
<th>Living Patients*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone I</td>
<td>2 hips (1.7%)</td>
<td>2 hips (2.8%)</td>
</tr>
<tr>
<td>Zone II</td>
<td>7 hips (5.8%)</td>
<td>6 hips (8.3%)</td>
</tr>
<tr>
<td>Zone III</td>
<td>3 hips (2.5%)</td>
<td>3 hips (4.2%)</td>
</tr>
<tr>
<td>Multiple Zones</td>
<td>4 hips (3.3%)</td>
<td>4 hips (5.6%)</td>
</tr>
<tr>
<td>Total:</td>
<td>9 hips (7.5%)</td>
<td>8 hips (11%)</td>
</tr>
</tbody>
</table>

*N=72
Fluid Ingress Studies
3rd Body Ingress?
Fluid Ingress
Polyethylene Cup Liner Wear

• Linear Wear Measurement Methods
  - Single-film
  - Livermore technique
  - Conventional Circular Templating
  - Digital Edge Detection
  - RSA
Linear Acetabular Wear

Single-film

Livermore
Wear Measurement in THA:
Digital Edge Detection versus Circular Templating
Complementary Techniques?

Douglas R. Pedersen, Ph.D.
Orthopaedic Biomechanics Laboratory
• Digital Edge Detection, DED
  – logic is more objective, and more consistent
  – improves accuracy, at 256 gray levels

• Conventional Circular Templating, CCT
  – only 32 gray levels, But! Wonderful integrator
  – Why compare DED with CCT?

CCT measures wear in all poly & metal-back cups

» What is the templating accuracy?
» More importantly, production-line reproducibility?
» Can we depend on template measured trends?
Circular Templating Technique

Post-operative film

Follow-up film
Overlay two films to determine the direction of polyethylene wear.

Mark the cup thickness from femoral surface to cup back.
What is the templating accuracy?

Digitize the cup opening and compare it to the nominal cup size.
The templating accuracy is 98.72% ± 0.86%

Interobserver Measures of Cup Diameter

Observer One [mm] vs. Observer Two [mm]

$y = 0.9954x$

$R^2 = 0.9256$
Circular Templating Technique

Post-operative film
Circular Templating Technique

Follow-up film
Interobserver Measures of Linear Wear

Linear wear difference
0.18 ± 0.14 mm (11%)

Wear rate disparity
0.012 ± 0.009 mm/year

\[ y = 0.9857x \]

\[ R^2 = 0.8591 \]
Intraobserver production-line reproducibility is $4.5 \pm 3.7\%$ 0.662 ± 0.521 mm

SigmaScan Production-line Reproducibility

$n = 28$ matched pairs

$y = 0.9922x$

$R^2 = 0.8765$
Digital Edge Detection

Shaver et al,
Digital Edge-Detection…
JBJS, 79A 5:690-700,1997
Digital Edge Detection
### DED and CCT Benchtop Validation

<table>
<thead>
<tr>
<th>Actual Wear§ (mm)</th>
<th>Estimated Wear (mm)</th>
<th>Error (%)</th>
<th>Coefficient of Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DED* (s.d.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.262</td>
<td>0.252 (0.019)</td>
<td>-3.8</td>
<td>DED 39.4</td>
</tr>
<tr>
<td>0.378</td>
<td>0.371 (0.012)</td>
<td>-1.9</td>
<td>41.8 15.5</td>
</tr>
<tr>
<td>0.582</td>
<td>0.652 (0.016)</td>
<td>12.0</td>
<td>33.0 43.5</td>
</tr>
<tr>
<td>0.914</td>
<td>0.906 (0.014)</td>
<td>-0.9</td>
<td>7.3 15.2</td>
</tr>
<tr>
<td>0.978</td>
<td>0.975 (0.021)</td>
<td>-0.3</td>
<td>35.0 11.5</td>
</tr>
<tr>
<td>1.544</td>
<td>1.594 (0.021)</td>
<td>2.7</td>
<td>2.0 7.2</td>
</tr>
<tr>
<td>2.047</td>
<td>2.116 (0.021)</td>
<td>3.4</td>
<td>-19.4 7.6</td>
</tr>
<tr>
<td><strong>Series Average</strong></td>
<td><strong>3.6</strong></td>
<td><strong>23.1</strong></td>
<td><strong>2.8 20.0</strong></td>
</tr>
</tbody>
</table>

§ - Measurements taken by the dial gage  
* - Mean value of six measurements taken by the DED technique on the paired digitized radiographs  
# - Mean value of four measurements taken by the CCT technique on the paired radiographs
DED versus CCT Linear Wear Measurements
n=166 hips

y = 1.0006x
R² = 0.5239

SigmaScan Wear [mm]
DED Wear [mm]
Matched CCT and DED Wear Rate Distribution

Frequency

Wear Rate [mm/year]

CCT
DED
Cumulative Distribution of Linear Wear Rates

<table>
<thead>
<tr>
<th>Linear Wear Rate [mm/year]</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mean</th>
<th>Median</th>
<th>Std.Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1276</td>
<td>0.1098</td>
<td>0.0939</td>
</tr>
<tr>
<td>0.1412</td>
<td>0.1313</td>
<td>0.0946</td>
</tr>
</tbody>
</table>

SS  DED
Wear Rate Distributions

Are the trends similar?
Conclusions

- Templating is capable of accurate length measurement
  Accuracy = 98.72% ± 0.86%

- Templating wear calculations suffer from subjectivity
  difference is 0.18 ± 0.14 mm (11%)

- Production-line repeat measures of post-op Cup thickness
  reproducibility is 4.5±3.7% 0.662±0.521 mm

» Can we depend on CCT measured trends? YES...
  » Provided cohort populations are respectably large, (e.g. >50)
  » and follow-up times are well into ‘steady-state’ (e.g. >5 years)
Are 22-mm Heads the Solution to Polyethylene Wear in Cementless Acetabular Components?

Douglas R. Pedersen, PhD
John J. Callaghan, MD
Richard C. Johnston, MD
Pedersen, et al: *Prediction of Long-Term Polyethylene Wear...*

The William Harris Award, ORS
1997
Digital Edge Detection

Shaver et al,
Digital Edge-Detection…
JBJS, 79A 5:690-700,1997
Linear Penetration

Bedding-in  
n=308

Longer-term  
n=218

Linear Wear [mm]

Years from Surgery

22-mm  28-mm
Group-average Penetration

Linear Wear [mm/yr]

Bedding-in

0.2986 mm/yr

0.1677 mm/yr

0.2737 mm/yr

Years from Surgery

0 1 2 3 4 5 6 7
Normal Wear Rate Distributions are Non-Gaussian

22-mm heads: 0.14 mm/year

28-mm heads: 0.18 mm/year
# Average at Last Follow-up

<table>
<thead>
<tr>
<th></th>
<th>Cup Angle [°] (±S.D.)</th>
<th>Wear Angle [°] (±S.D.)</th>
<th>Linear Wear (mm/yr) (±S.D.)</th>
<th>Wear Volume (mm³) (±S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22-mm</td>
<td>47 (±5.8)</td>
<td>1.5 (±31)</td>
<td>0.14 (±0.13)</td>
<td>129 (±154)</td>
</tr>
<tr>
<td>28-mm</td>
<td>47 (±6.8)</td>
<td>10.2 (±38)</td>
<td>0.18 (±0.14)</td>
<td>238 (±222)</td>
</tr>
<tr>
<td>All Polished</td>
<td>47 (±6.1)</td>
<td>4.1 (±34)</td>
<td>0.15 (±0.14)</td>
<td>161 (±183)</td>
</tr>
</tbody>
</table>
- Iowa polished femoral stem
  - Cemented
  - 105 modular heads 46

<table>
<thead>
<tr>
<th>Cementless Harris-Galante II Cup Outer Diameter [mm]</th>
<th>Number of Hips</th>
</tr>
</thead>
<tbody>
<tr>
<td>66</td>
<td>3</td>
</tr>
<tr>
<td>64</td>
<td>2</td>
</tr>
<tr>
<td>62</td>
<td>3</td>
</tr>
<tr>
<td>60</td>
<td>12</td>
</tr>
<tr>
<td>58</td>
<td>10</td>
</tr>
<tr>
<td>56</td>
<td>10</td>
</tr>
<tr>
<td>54</td>
<td>15</td>
</tr>
<tr>
<td>52</td>
<td>24</td>
</tr>
<tr>
<td>50</td>
<td>21</td>
</tr>
<tr>
<td>48</td>
<td>5</td>
</tr>
</tbody>
</table>

- Number of hips: 22-mm (blue) and 28-mm (red)
Conclusions

- Return to polished stems and 22-mm heads
  - reduced polyethylene linear wear
  - increased dislocations
    - A 22-mm head was twice as likely to dislocate from a cup over 56-mm in outer diameter as it was from one of 56-mm or less

- Change to polished stems and 28-mm heads
  - reduced dislocations
  - increased polyethylene linear wear
RSA
RSA
RSA