Surface Damage Mechanisms, In Vivo Oxidation, and Reasons For Revision for Highly Crosslinked Tibial Inserts for TKA

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Remelted Highly Crosslinked Polyethylene

- Introduced in the late 1990’s
  - Reduces wear rates in total hip arthroplasty
- Elevated radiation and remelting reduces fracture toughness
- Increasingly used in TKA
- Little known on the *in vivo* damage mechanisms and oxidative stability of HXLPE in TKA.
The purpose of this study was to investigate the damage mechanisms and oxidative stability of remelted polyethylenes in a series of retrieved tibial components.
Drexel University Implant Repository

- 10 Surgical Centers
- 2 Retrieval Laboratories
## Patient Demographics

<table>
<thead>
<tr>
<th>Cohort</th>
<th>n</th>
<th>Age (years)</th>
<th>Gender (%F)</th>
<th>BMI (kg/m²)</th>
<th>Implantation Time (y)</th>
<th>Max UCLA Score (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma Inert</td>
<td>41</td>
<td>66 ± 10</td>
<td>55%</td>
<td>30.3 ± 3.7</td>
<td>2.7 ± 2.1</td>
<td>5 (2 – 9)</td>
</tr>
<tr>
<td>Remelted Highly Crosslinked PE</td>
<td>69</td>
<td>65 ± 10</td>
<td>53%</td>
<td>31.6 ± 5.4</td>
<td>1.4 ± 1.2</td>
<td>6 (1 – 10)</td>
</tr>
</tbody>
</table>
Reasons for Revision

- Loosening
- Infection
- Instability
- Stiffness
- Periprosthetic Fracture
- Pain
- Other

Gamma Inert vs HXLPE
Methods
Damage Scoring

• Semi-quantitative Scoring Method
• 7 Damage Modes
  – Burnishing, Pitting, Delamination, Abrasion, Embedded Debris, Scratching, and Surface deformation
## Methods

### Damage Scoring

<table>
<thead>
<tr>
<th>Score</th>
<th>Area Damage Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Not Present</td>
</tr>
<tr>
<td>1</td>
<td>&lt; 10%</td>
</tr>
<tr>
<td>2</td>
<td>10 – 25%</td>
</tr>
<tr>
<td>3</td>
<td>&gt; 50%</td>
</tr>
</tbody>
</table>

![Diagram showing condyles and backside with areas marked for damage scoring]
Results
Damage Scoring

![Box plot showing damage scoring for Gamma Inert and HXLPE materials with different damage mechanisms indicated.](image)
Methods
Oxidation Analysis

- 200 μm sections taken:
  - Medial Condyle
  - Central Spine
Methods
Oxidation Analysis

- Boiled for 6h in heptane to avoid interference of absorbed lipids
- Scanned at 0.1 mm increments
  - 32 repeat scans per location
- Maximum Oxidation Index in accordance with ASTM F2102-01

\[
OI = \frac{A_{1850-1650}}{A_{1396-1330}}
\]
Methods
Hydroperoxide Analysis

• Expose UHMWPE to nitric oxide (NO) gas in the absence of oxygen
  – Hydroperoxides → nitrates
  – Alcohols → nitrites
• Hydroperoxide index measured using FTIR

\[ HI = \frac{A_{1670-1600}}{A_{1396-1330}} \]
Results
Oxidation

*\(p<0.001\)
Results

Oxidation

![Graph showing Oxidation results with various samples and statistical significance markers.](image)
Results

Oxidation

- HXLPE (Spearman’s Rho = 0.36; p = 0.003)
- Gamma Inert (Spearman’s Rho = 0.38; p = 0.02)
Results
Oxidation

Oxidation

HXLPE (Spearman’s Rho = -0.09 : p = 0.48)

Gamma Inert (Spearman’s Rho = 0.47: p = 0.003)

HXLPE (Spearman’s Rho = -0.09 : p = 0.48)
Results
Hydroperoxide Index

*\( p < 0.0001 \)
Case Study #1

- 62 year old male
  - BMI: 30.3 kg/m²
- Implanted: 2005
  - Osteoarthritis
- Explanted: 2010
  - Tibial Loosening
  - $\text{UCLA}_{\text{Max}}$: 5
- Low Oxidation (<0.3)
- Pitting, scratching, and Burnishing

*in vivo: 4.2 years*
Case Study #2

- 48 year old male
  - BMI: 28.4 kg/m²
- Implanted: 2005
  - Osteoarthritis
- Explanted: 2009
  - Tibial Loosening
    - UCLA_{Max}: 10
- Moderate Oxidation (1.1 at the bearing surface)
- Pitting, scratching, and Burnishing

in vivo: 3.9 years
Discussion

- Remelted HXLPE exhibited lower oxidation levels than gamma inert implants.
- In gamma inert components, AP Face and Bearing Surface had the highest oxidation.
- In HXLPE components, the bearing surface had the highest oxidation.
Discussion

• Pitting, Scratching and burnishing were the main damage modes
  – No delamination in HXLPE Cohort
  – 1 Case of Delamination in the gamma inert cohort

• Longer-term studies necessary to determine stability of remelted HXLPE in total knee replacement
Thank You For Your Attention