Polyethylene in Orthopaedics Today

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Disclosures

- Consulting
 - Corin
 - Stryker
 - Heron Therapeutics
- Educational Honorarium
 - Depuy
 - Convatec
- Institutional Support
 - Zimmer
 - Smith and Nephew
 - NIH
 - Depuy



I Routinely Use







The Epidemiology of Revision Total Hip Arthroplasty in the United States

By Kevin J. Bozic, MD, MBA, Steven M. Kurtz, PhD, Edmund Lau, MS, Kevin Ong, PhD, Thomas P. Vail, MD, and Daniel J. Berry, MD

- Most common reasons for revision:
 - Instability/Dislocation : 22.5%
 - Mechanical Loosening: 19.7%
 - Infection: 14.8%

TREND TOWARDS USING LARGE HEADS



Figure 26: Polyethylene Usage in Acetabular Liners (N=367,590)



AJRR Annual Report 2018





Figure 25: Enhanced Liner Use and Head Composition (N=40,910)

Figure 24: Percentage of Cobalt Chrome (CoCr) and Ceramic Heads Used with Cross-Linked Polyethylene (XLPE) and Antioxidant Polyethylene Acetabular Liners (N=332,203)



Figure 28: Frequency and Percentage of Dual Mobility Cups Implanted in Hip Arthroplasty by Year (N=35,063)



AJRR Annual Report 2018



The Problem Still: Wear and Osteolysis







HIP The rates of wear of X3 highly cross-linked polyethylene at five years when coupled with a 36 mm diameter ceramic femoral head in young patients

Table II. Steady state wear rates shown after the first year

	2D linear wear rate (mm/year)	3D linear wear rate (mm/year)	Volumetric wear rate (mm³/year)
Mean steady state wear after one vear	0.11	0.11	29.61
Pearson correlation coefficient (r)	0.92 (p = 0.030)	0.92 (p = 0.033)	0.72 (p = 0.218)
2D. two-dimensiona	I: 3D, three-dimensional		

Osteolysis Threshold 0.1mm/year

Selvarajah E, et al. Bone Joint J 2015



Clin Orthop Relat Res DOI 10.1007/s11999-015-4319-5



CrossMark

SYMPOSIUM: 2015 HIP SOCIETY PROCEEDINGS

Wear and Osteolysis of Highly Crosslinked Polyethylene at 10 to 14 Years: The Effect of Femoral Head Size

Paul F. Lachiewicz MD, Elizabeth S. Soileau BSN, John M. Martell MD

Table 2. Volumetric wear rate by femoral head size			
Head size (mm)	Number of hips	Median volumetric wear rate (mm ³ /year [95% confidence intervals]	
26	10	3.1 [0.7–12.3]	
28	31	12.3 [3.0–19.3]	
32	30*	12.9 [6.6–16.8]	
36/40	12	26.1 [11.3-47.1]	

* One hip excluded as a result of missing value; p = 0.020.



SMALL OSTEOLYTIC LESIONS (1CM) VISIBLE



HXPE Can Also Fail As Well



Tower ST, JBJS-A 2007

Bates M, JBJS Case Connect 2015



2006 OTTO AUFRANC AWARD PAPER

Significance of In Vivo Degradation for Polyethylene in Total Hip Arthroplasty

Steven M. Kurtz, PhD^{*,†}; William J. Hozack, MD[‡]; James J. Purtill, MD[‡]; Michele Marcolongo, PhD^{*}; Matthew J. Kraay, MD[§]; Victor M. Goldberg, MD[§]; Peter F. Sharkey, MD[‡]; Javad Parvizi, MD[‡]; Clare M. Rimnac, PhD^{||}; and Avram A. Edidin, PhD^{*}



Fig 7. The superior rim of retrieved Hexloc liners was worn through in 16 of 47 cases (34%).

CORR 2006





- Successful
- Durable
- Reproducible

Not Perfect For Everyone!





Why Are Total Knee Arthroplasties Failing Today—Has Anything Changed After 10 Years?



Peter F. Sharkey, MD, Paul M. Lichstein, MD, MS, Chao Shen, MD, Anthony T. Tokarski, BS, Javad Parvizi, MD, FRCS



J Arthroplasty 2014





















Polvethylen	Table I. Summary of retrieval studies.		
Where are	Study	Findings	
	Liu et al.6	No difference in surface damage between matched HXLPE and CPE inserts of the same designs.	
Spencer K Wilhel Drew Moore ² and	Willie et al. ⁴⁰	No difference in surface damage between the retrieved Durasul and conventional PE tibial components.	9
	Muratoglu et al. ⁴¹	No difference in articular and backside surface morphology of HXLPE and CPE tibial inserts	
	Macdonald et al. ⁴²	Remelted HXLPE reduced oxidation as compared to gamma inert sterilized controls.	
	Liu et al. ⁴³	HXLPE crosslink density decreases over time	
	Rowell et al. ⁴⁴	All retrievals, except vitamin E-stabilized components, showed significant oxidative degradation	
	Rowell et al. ⁴⁵	Vitamin E prevents in vivo and ex vivo oxidation for short durations and reduces free radicals	
	HXLPE: highly cross-l	inked polyethylene; CPE: conventional polyethylene.	

J Orthopedic Surg 2018

Table 3. Revision rates studies.

Study	Procedures	Follow-up (years)	HXLPE revisions and causes	CPE revisions and causes
Kim et al. ⁵⁶	638	Mean 5.9	l infection	No revisions
Kindsfater et al. ⁵⁷	938	Min. 5	 6 in total—2 arthrofibrosis, 1 infection, I tibial component loosening, I hemarthrosis, 1 patella/femoral dislocation 	 10 in total—4 infections, 3 tibial component loosening, 1 arthrofibrosis, 1 hemarthrosis, 1 flexion instability
Meneghini et al. ⁵⁸	114	Mean 5	No revisions	l infection
Lachiewicz and Soileau ⁵⁹	132	Mean 4.5	3 total reoperations—3 infections	5 total reoperations—2 infections, I femoral loosening, I instability, I periprosthetic fracture
Minoda et al. ⁶⁰	202	2	No revisions	No revisions
Hodrick et al. ⁵⁹	200	Mean > 6	HXLPE: 0	3 loose tibial components
Meneghini et al. ⁶¹	307	Min. 4	I patella fracture unrelated to the PE	2 in total—I aseptic loosening unrelated to the PE, I arthrofibrosis
Long et al. ⁶²	120	Mean 4	2 in total—1 multidirectional instability, 1 aseptic loosening	
Kim et al. ⁶³	366	Mean 6	I cause not listed	I cause not listed

PE: polyethylene; HXLPE: highly cross-linked polyethylene; CPE: conventional polyethylene.



Table 4. Joint registry studies.

Study	Registry	Procedures	Revision rate
Inacio et al. ⁶⁵	Not listed	62,177	HXLPE: 2.1% at median 1.8 years; CPE: 2.2% at median 3.0 years
Paxton et al. ⁶⁶	Kaiser Permanente Total Joint Replacement Registry	77,084	HXLPE: 3.1% at 5-year follow-up; CPE: 2.7% at 5-year follow-up
de Steiger et al. ⁵⁴	Australian Orthopaedic Association National Joint Replacement Registry	386,104	HXLPE: 3.5% at 10-year follow-up; CPE: 5.8% at 10-year follow-up

HXLPE: highly cross-linked polyethylene; CPE: conventional polyethylene.

Data may be confounded by manufacturers only offering HXLPE in certain TKA designs.



Cross-linked versus conventional polyethylene for total knee arthroplasty: a meta-analysis

Bin-feng Yu, Guo-jing Yang^{*}, Wei-liang Wang, Lei Zhang and Xi-peng Lin



Fig. 4 Forest plot diagram showing reoperation for prosthesis loosening between two groups



Five cases of tibial post fracture in posterior stabilized total knee arthroplasty using Prolong highly cross-linked polyethylene*

Owen J. Diamond *, Lisa Howard, Bassam Masri





Knee 2018



The Effect of Alternative Bearing Surfaces on the Risk of Revision Due to Infection in Minimally Stabilized Total Knee Replacement

An Analysis of 326,603 Prostheses from the Australian Orthopaedic Association National Joint Replacement Registry

> Christopher J. Vertullo, MBBS, FRACS(Orth), FAOrthA, Peter L. Lewis, MBBS, FRACS(Orth), FAOrthA, Yi Peng, MMed(Epi&Stats), Stephen E. Graves, MBBS, DPhil, FRACS, FAOrthA, and Richard N. de Steiger, MBBS, DipBiomech, FRACS, FAOrthA

JBJS-A 2018

Conclusions: In this registry analysis, CoCr-XLPE had a 26% lower risk of revision for infection than CoCr-NXLPE, suggesting a reduction of wear particle-induced immunomodulation with XLPE. Oxinium-XLPE had the same risk as CoCr-XLPE. Overall, Oxinium did not reduce the infection risk.

Does not appear to be worse but may be better in certain instances.



Do Crosslinking and Vitamin E Stabilization Influence Microbial Adhesions on UHMWPE-based Biomaterials?

Giuliana Banche PhD, Pierangiola Bracco PhD, Valeria Allizond PhD, Alessandro Bistolfi MD, Michele Boffano MD, Andrea Cimino MD, Elena Maria Brach del Prever MD, Anna Maria Cuffini PhD





CORR 2015

Is Cross-Linked Polyethylene an Improvement Over Conventional Ultra-High Molecular Weight Polyethylene in Total Knee Arthroplasty?



Sequentially annealed highly cross-linked polyethylene reduced *in vivo* wear particle generation in total knee arthroplasty

J Orthopedic Surg 2017

Yukihide Minoda^{1,2}, Kanako Hata¹, Katsuko Goto², Tomonobu Itohara² and Hiroaki Nakamura¹

Table 2. Quantity, size, and shape of wear particles in conventional polyethylene and sequentially annealed HXLPE.

		Mean (and		
		Conventional PE	Sequentially annealed HXLPE	
Characteristics	Parameter	(n = 8)	(n = 8)	p Value
Quantity	Total number	(4.9 \pm 3.6) $ imes$ 10 ⁷	(2.1 \pm 1.0) \times 10 ⁷	0.036
Size	ECD (µm)	1.02 \pm 0.20	1.01 ± 0.26	0.674
Shape	Aspect ratio Roundness	$\begin{array}{r} 1.39 \ \pm \ 0.10 \\ 1.36 \ \pm \ 0.06 \end{array}$	$\begin{array}{r} 1.33 \ \pm \ 0.04 \\ 1.34 \ \pm \ 0.05 \end{array}$	0.462 0.600

HXLPE: highly cross-linked polyethylene; PE: polyethylene; ECD: equivalent circle diameter.



No Detectable Polyethylene Wear 15 Years After Implantation of a Mobile—Bearing Total Knee Arthroplasty With Electron Beam—Irradiated Polyethylene

Jean-Yves Jenny, MD ^{a, *}, Dominique Saragaglia, MD ^b



J Arthroplasty 2019





Current Economic Environment

- Shift from long term survivorship to 90 day outcomes.
- Cost cutting measures.
- Explore additional combinations that can potentially eliminate cobalt chromium from the equation.













Don't Forget the Other Joints!



Smart Implants

• Prevention

• Treatment







Peri-Apatite Coatings







- Tobramycin-periapatite implant
- Rabbit model prophylaxis model
- S. Aureus
- Significant reduction compared with controls (p=0.001)
- Viable as a clinician directed application

Moojen PA, et al: ORS presentation 2006



Clinical Applications

- Analgesics
- Anti-thrombolytic
- Antimicrobial
 - Spacers
 - Biofilm resistance





Research Article

The Effect of Absorbable Calcium Sulfate on Wear Rates in Ultra-high–Molecular-weight Polyethylene: Potential Implications for Its Use in Treating Arthroplasty Infections





Lewicki K, JAAOS 2017



What We Want....

- Polyethylene that does not wear.
- Polyethylene that is inert.
- Polyethylene that does not break.
- Polyethylene that is biofilm resistant.









We don't want....



FIG. 3

JBJS-A 1988



Wear of enhanced ultra-high molecular-weight polyethylene (Hylamer) in combination with a 22.225 mm diameter zirconia femoral head

B. M. Wroblewski, P. D. Siney, P. A. Fleming From Wrightington Hospital, Wigan, England







Fig. 2a

Summary

The current state of polyethylene and its future is bright.

Wear has essentially been solved in hips and knees.
 Fine tuning of formulations, processes, etc.

• Work in other joint arthroplasties continues.

 Interest in adjunct technologies that allow for drug deliveries and infection resistance.



Thank You



University of Pennsylvania Department of Orthopaedic Surgery