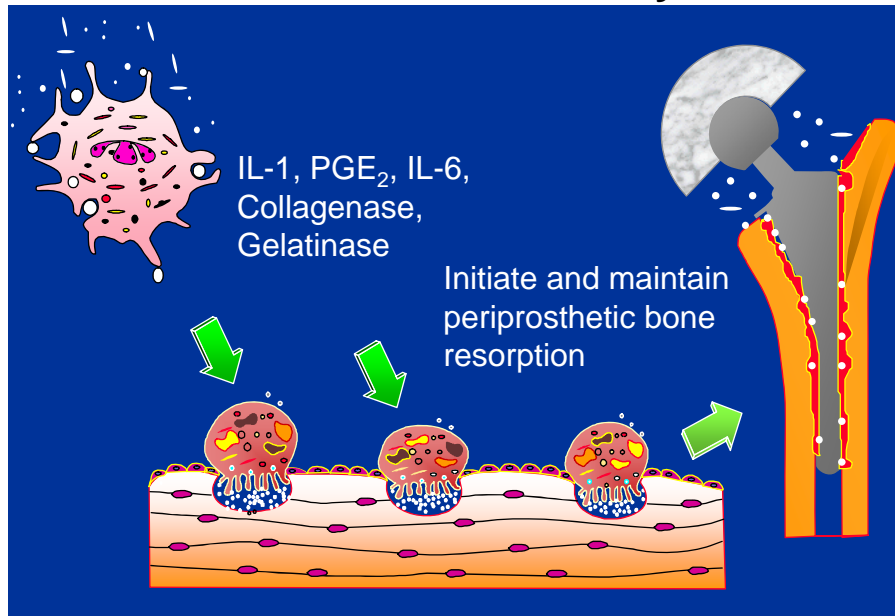


Particle Disease - Osteolysis **CTQ**



Particle induced osteolysis

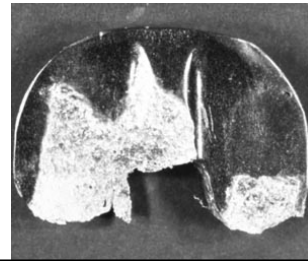
CTQ

- Increased VEGF expression
- Increased RANK expression
- Increased RANKL expression
- Macrophages produce VEGF

Old, failed poly technology= BAD

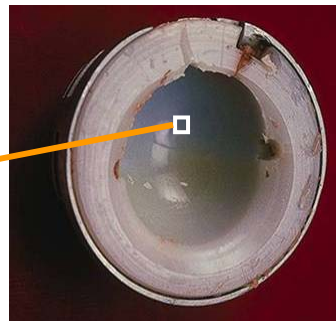
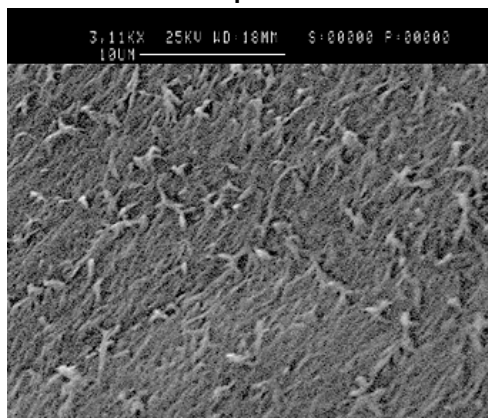
CTQ

- Ram extruded (calcium stearate)
- Heat pressed
- Hylamer (crystalline crosslinked poly)
- Carbon reinforced (Black Plastic)



Wear Mechanisms in vivo - THR

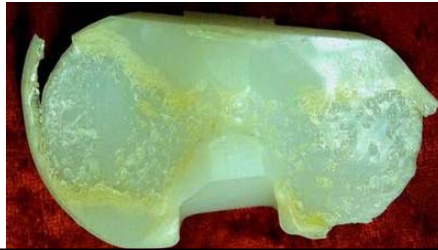
SEM analysis of 138 clinical
and autopsy retrieved
acetabular components



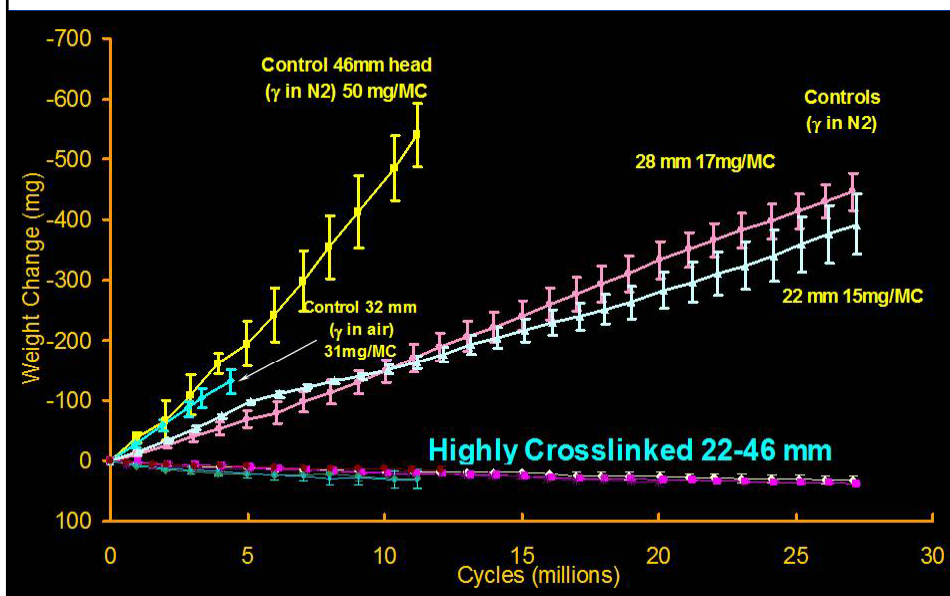
Jasty et al., JBJS 1994

Wear Mechanisms **CTQ**

- Adhesion- hips (most important for osteolysis)
- Abrasion- hips
- 3rd Body
- Subsurface delamination- knees
- Fatigue- knees
- Oxidation- both



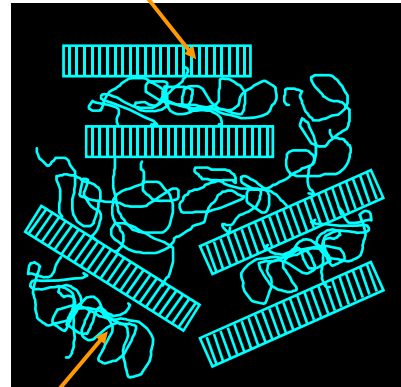
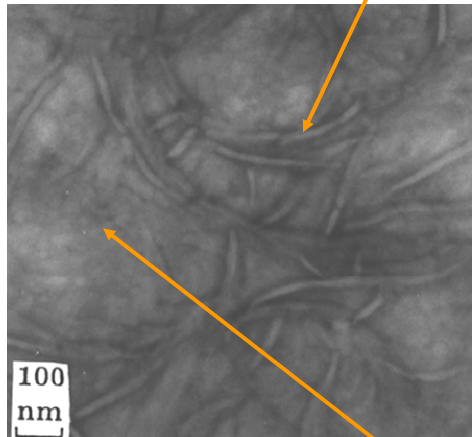
1st Generation Highly Crosslinked Polyethylene - Simulated Hip Gait



UHMWPE Microstructure

CTQ

Crystalline lamellae=STRENGTH



Amorphous
Regions- **CROSSLINKING=WEAR RESISTANCE**

Crystallinity

- Only amorphous segment can crosslink
- Crystalline phase associated with mechanical strength
- Optimum crystallinity 45-65 % **CTQ**
 - Too high : oxidation
 - Too low: weak poly

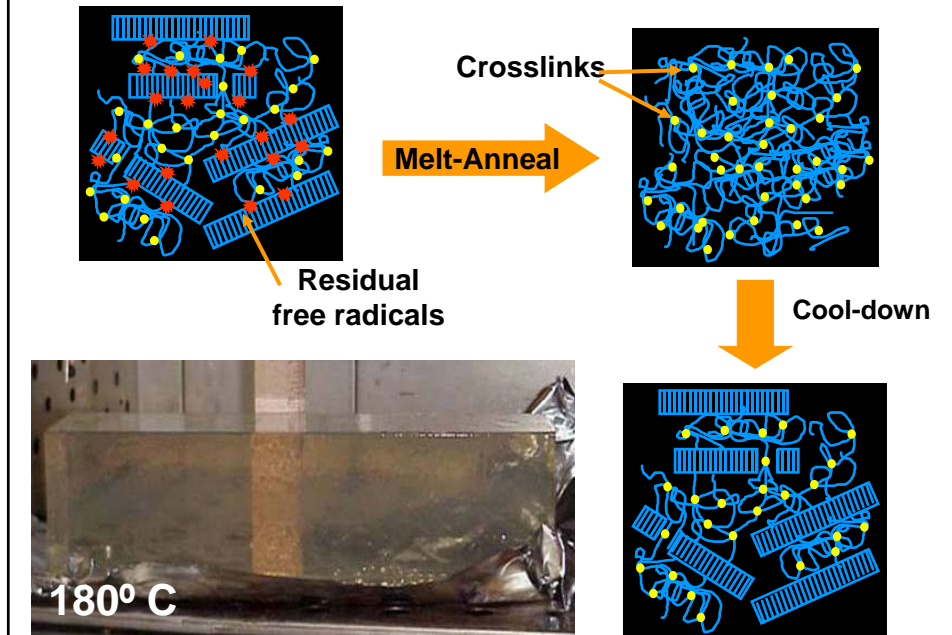
Crosslinking

- Irradiate with gamma rays
- Quench remaining free radicals
 - Melt
 - Anneal (almost melt)
 - Use radical absorber like alfa tocopherol (vit E)

Radiation Cross Linking

- Increased radiation
 - Increased crosslinking
 - Increased wear resistance
 - **Decreased** mechanical properties **CTQ**
- **Crosslinked poly has decreased SIZE and NUMBER of particles** **CTQ**

Irradiation and Melting



Why eliminate free radicals?

- Free radicals combine with Oxygen over time
- Oxidized material has very poor wear performance!

1st generation free radical elimination tradeoffs

- **Annealing: heat to below melting**
 - Less loss of crystallinity and mechanical strength
 - More residual free radicals
- **Melting: Heat to above melting point**
 - Better free radical elimination
 - Lower crystallinity, weaker mechanical properties

Comparison of Wear Particles

Conventional poly

- **More in number**
- **Larger**
- **More pointed**

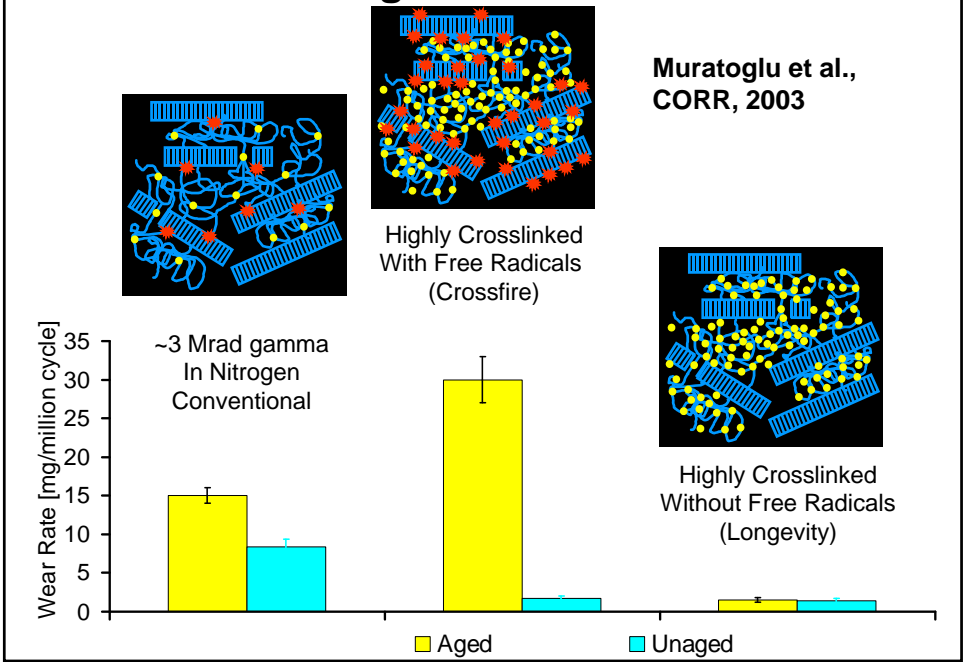
Crosslinked poly

- **Fewer**
- **Smaller**
- **Rounder**

Comparison of Wear Particles

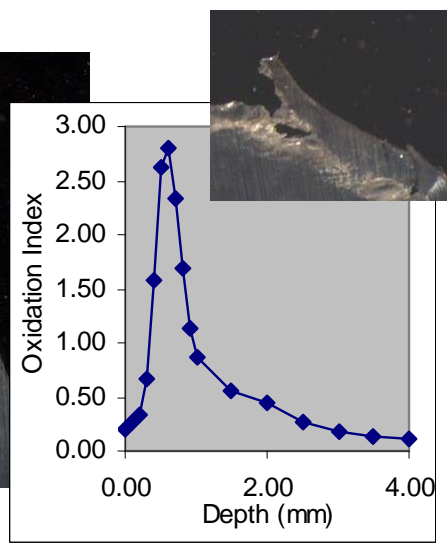
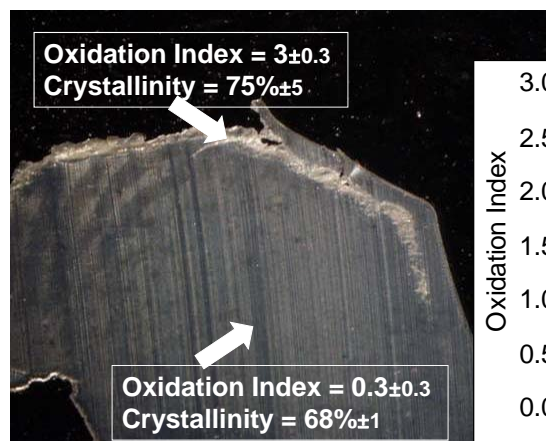
Conventional	Cross linked	Metal/Metal
<ul style="list-style-type: none"> - More in number - Larger - More pointed 	<ul style="list-style-type: none"> - Fewer - Smaller - rounder 	<ul style="list-style-type: none"> - Even more in number - Much smaller in size

Crosslinking And Free Radicals



ANNEALED=CROSSFIRE=BAD

Case Study: Crossfire™ explant (33 months in vivo)



**CROSSLINKED+MELTED=
REDUCED MECHANICAL
STRENGTH**

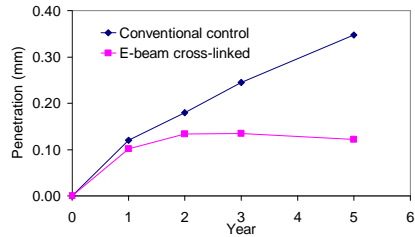


REDUCED MECHANICAL STRENGTH

- **CRACKED ELEVATED RIMS (HIPS)**
- **BROKEN LOCKING MECHANISMS (KNEES)**
- **BROKEN POSTS (PS KNEES)**

Summary

- **In vivo wear rates of 1st generation materials corroborate in vitro wear results**



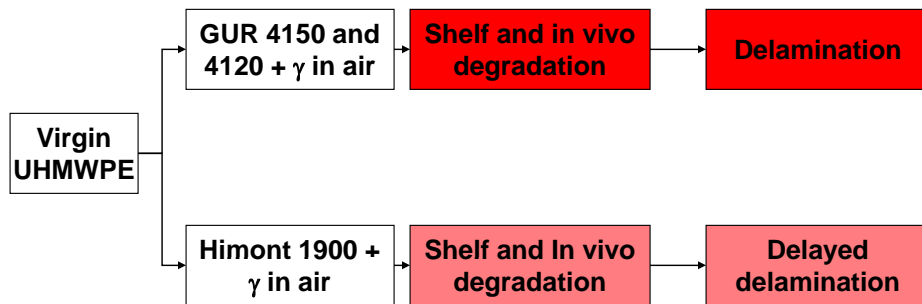
- **Irradaiton and annealing results in oxidation in vivo**



Key Features of any poly system

- **Wear resistance**
- **Oxidative stability**
- **Mechanical strength**

Gamma in Air sterilization= Oxidation and Delamination (important for TKR)



Longer shelf life associated with more oxidation!

What method of terminal polyethylene sterilization results in the greatest number of remaining free radicals within the polyethylene?

- 1-Gas plasma
- 2-Ethylene oxide
- 3-Gamma irradiation
- 4-Gamma irradiation and annealing
- 5-Gamma irradiation and remelting

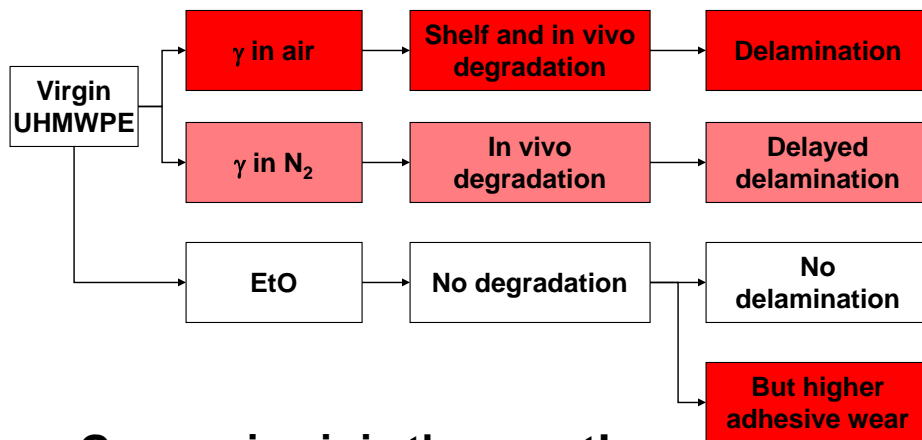
Preferred Response: 3

Reduce Delamination in TKR

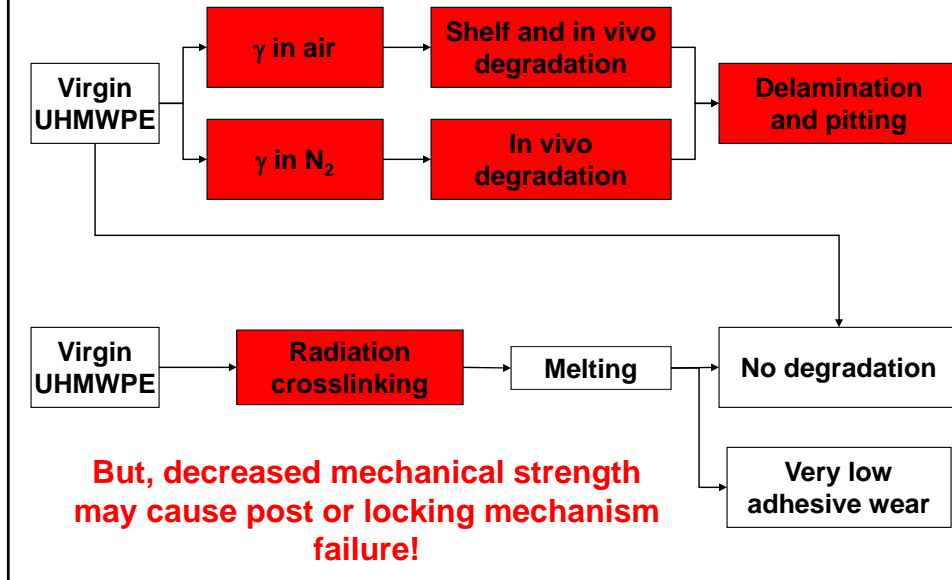
- Reduce contact stress (“round on round”)
- No gamma in air sterilization
- Thicker poly inserts
 - Min thickness= 6mm!



UHMWPEs for TKR: Effect of Sterilization

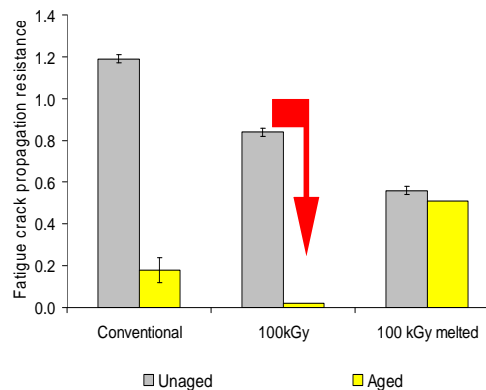


Highly Crosslinked UHMWPE for TKR



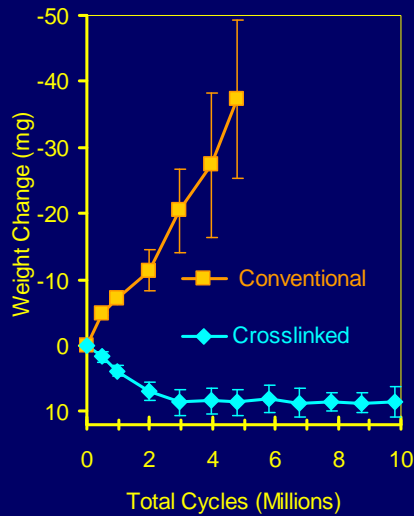
Poly aging: Aging causes oxidization

- Higher free radicals (annealing): worse oxidation
- Lower free radicals (melting): lower strength; better oxidative stability

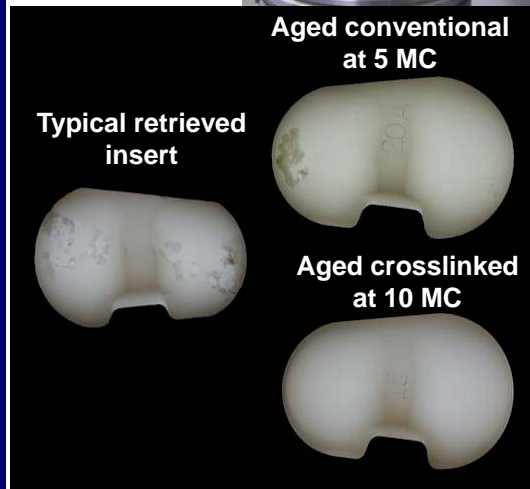


NKII Cruciate Retaining – Simulated Gait

Articular Wear

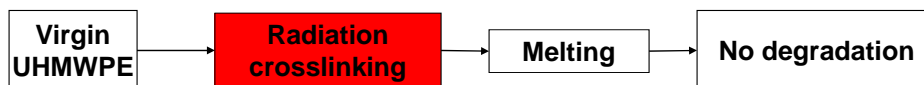


Delamination

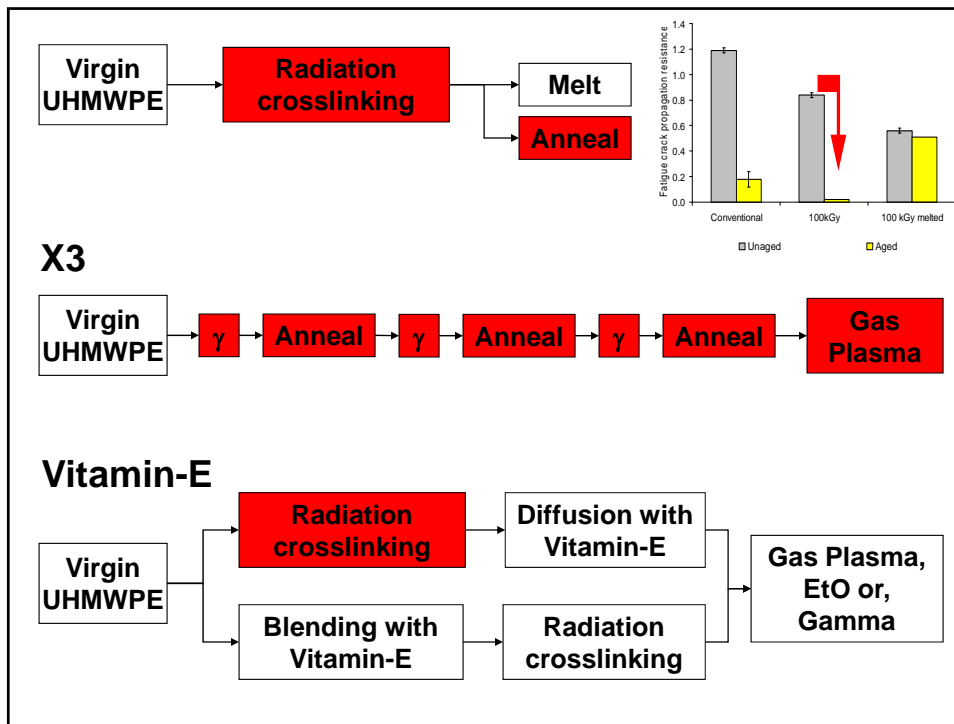


Summary

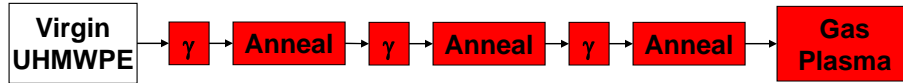
- **Highly crosslinked UHMWPE in TKR:**
 - Reduces articular wear
 - Reduces backside wear
 - Prevents oxidation related damage (delamination and pitting)



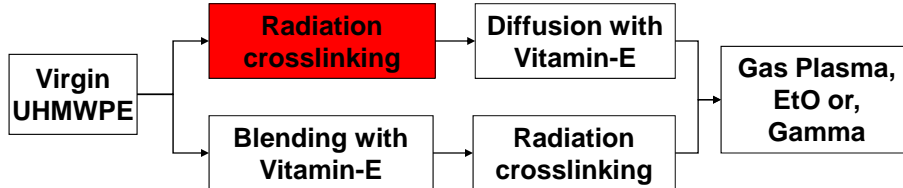
2nd Generation UHMWPE




X3





Vitamin-E

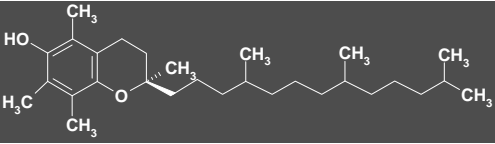


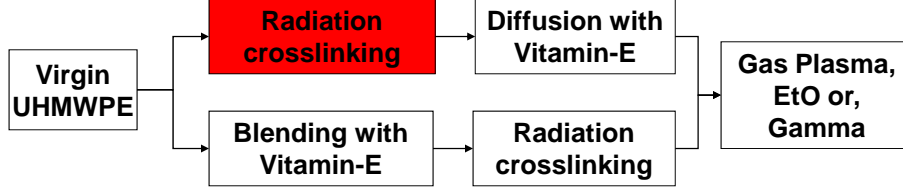


Vitamin-E

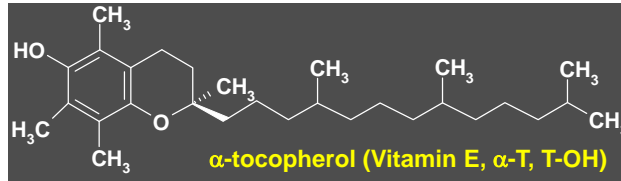




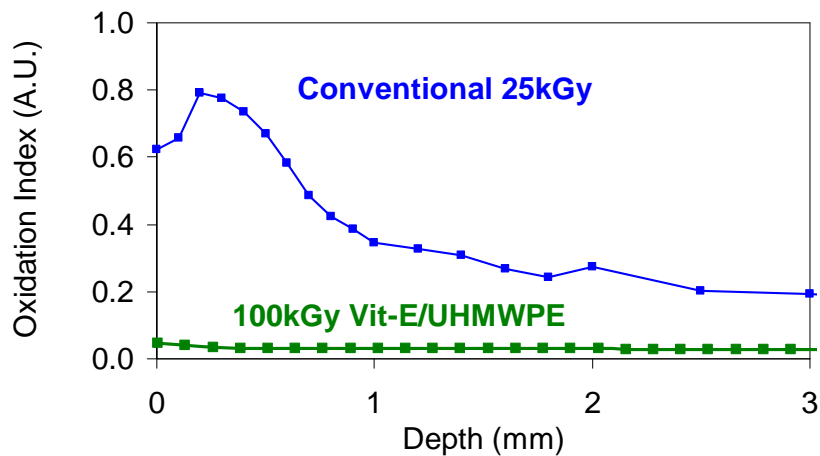




Vitamin-E Stabilization of Free Radicals



Accelerated Aging of Vit-E/UHMWPE



Comparison of 2nd Generation Polymers

- **In comparison to 1st generation, goals with 2nd generation were to achieve:**
 - Wear resistance equivalent to 1st generation
 - High oxidative stability
 - Better mechanical properties
 - Better fatigue strength