Combined Meeting:
Australian Knee Society, &
Australian Arthroplasty Society
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Alternative Bearings in TKA:

Oxinium (Oxidized Zirconium)
--The Science behind the Ceramic--

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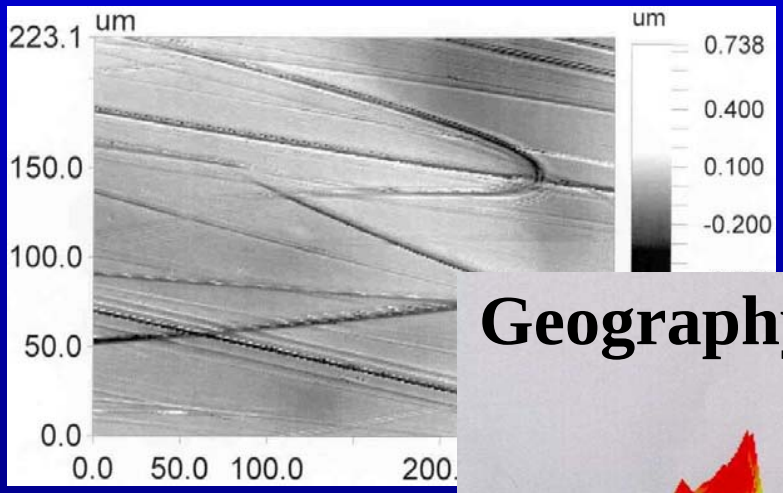
CoCr TKA Surface Roughens

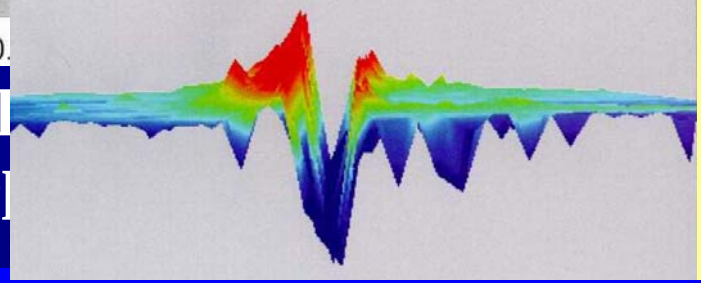
(Levesque et al., ORS 1998)

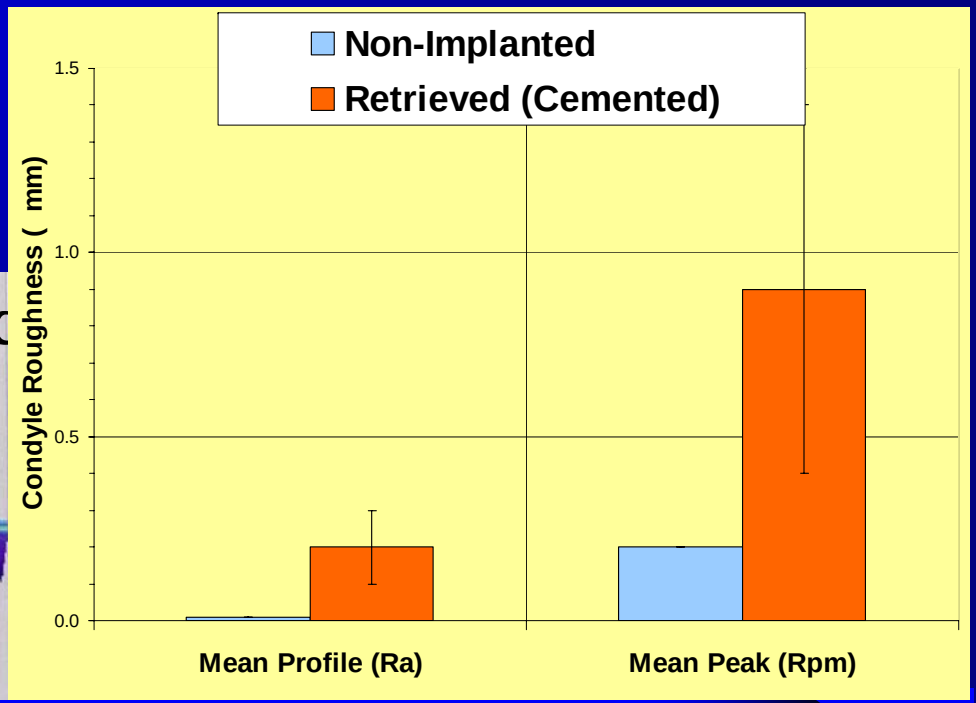
- Thirteen consecutively retrieved CoCr clinical components
- All condyles had scratches, some oblique to articulation
- Condyle roughness increased, especially the peaks



Scratches on I
Condyl

Geography of a Scratc





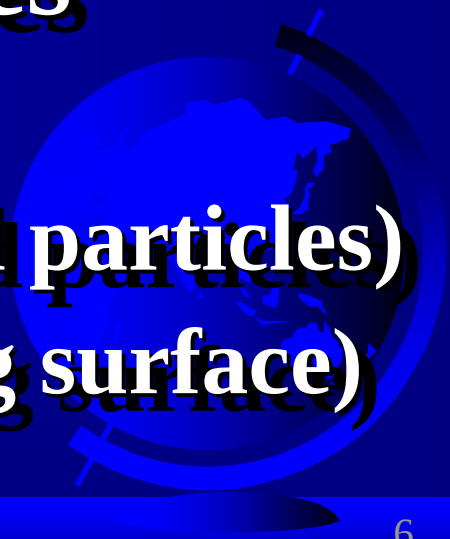
Cobalt Chrome

Oxinium

Roughening Increases Wear

(Fisher et al., Proc IME, 1995)

- "…a single scratch 2 μm deep (with 1 μm adjacent peak height) on a metal counterface can cause a dramatic increase in the wear rate of UHMWPE"
- How do metal bearing surfaces roughen?
  - Abrasive wear (scratching by hard particles)
  - Oxidative wear (shearing of sliding surface)

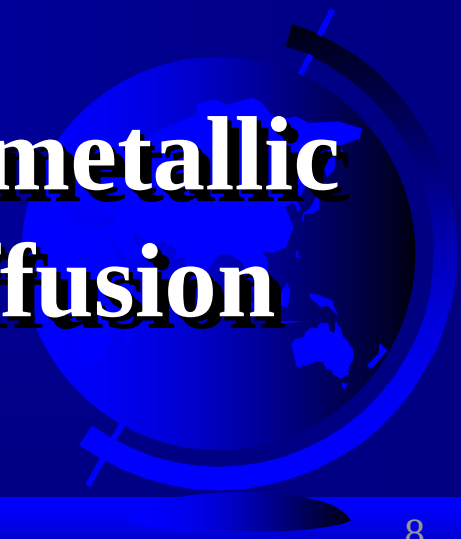


Limited Alternatives to CoCr

- Hardened Metals (ion implanted; diffusion hardened)
  - Benefit inferior to ceramics and short-lived at best
- Ceramic Coatings (titanium nitride; diamond)
  - Limited durability, especially if damaged
- Monolithic Ceramics (zirconia; alumina)
  - Risk for brittle fracture
  - Not available commercially

Oxinium (Oxidized Zirconium)

- **Capability**
  - **Reduce polyethylene wear by using a low-friction counterface that resists roughening and avoids brittle fracture**
- **Method**
  - **Form a ceramic surface on a metallic zirconium alloy by oxygen diffusion**



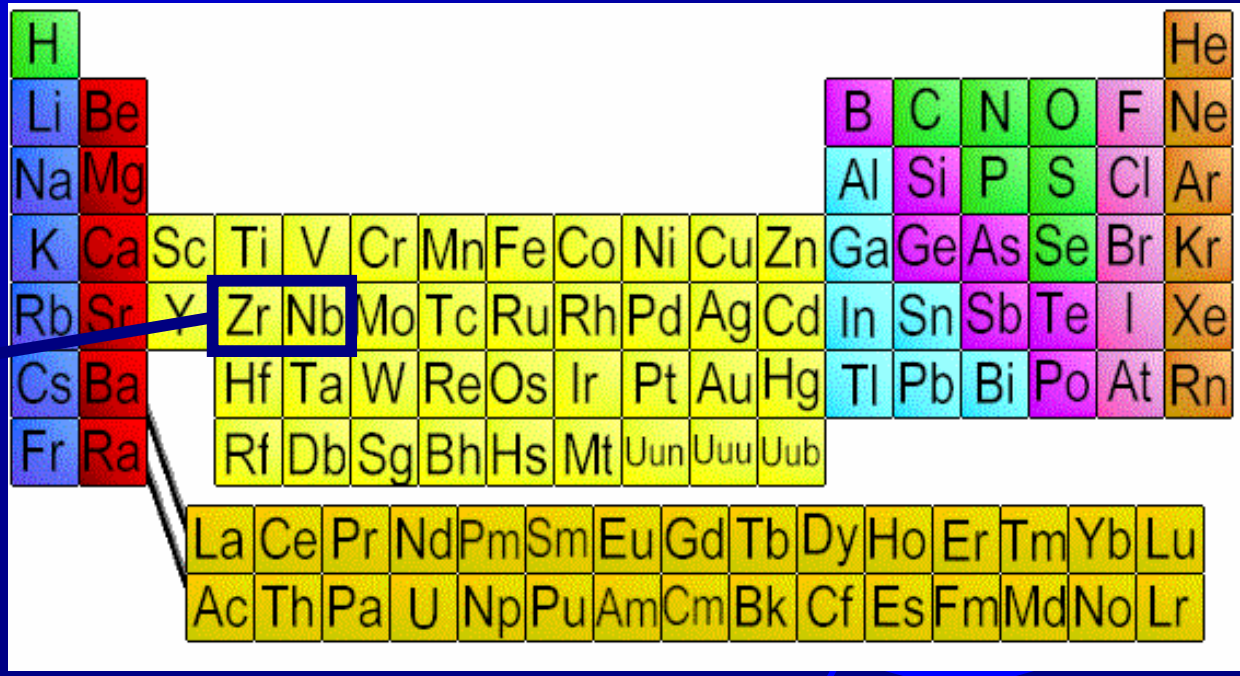
Materials

- Metallic element--Zirconium
  - Same family as titanium; very biocompatible
- Metallic alloy by combining with Niobium--Zr-2.5Nb
  - Niobium and oxygen strengthen zirconium
- Oxidize to form ceramic--Zirconia (zirconium oxide)
  - Low-friction and resists roughening
  - Brittle; low fracture toughness

Two Highly Biocompatible Metals

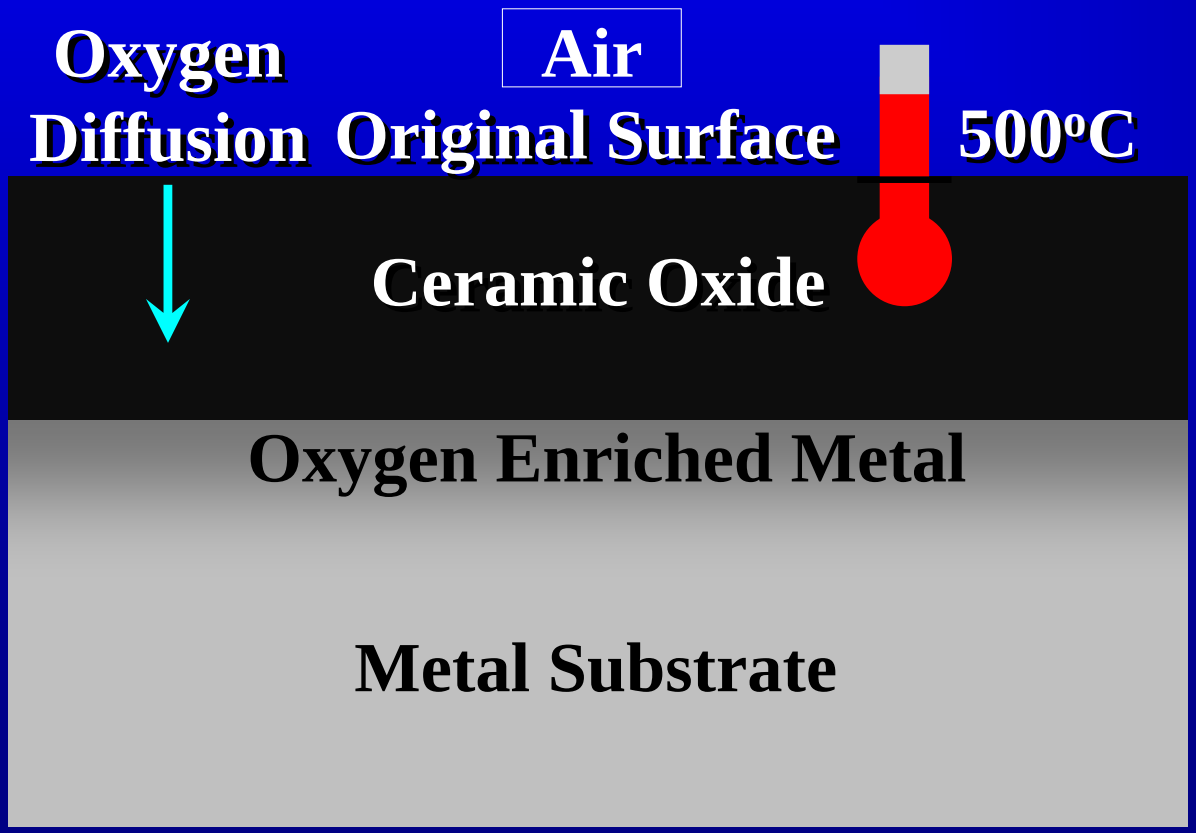
97.5% Zirconium
+ 2.5% Niobium
+ Oxygen and Heat
= Oxinium

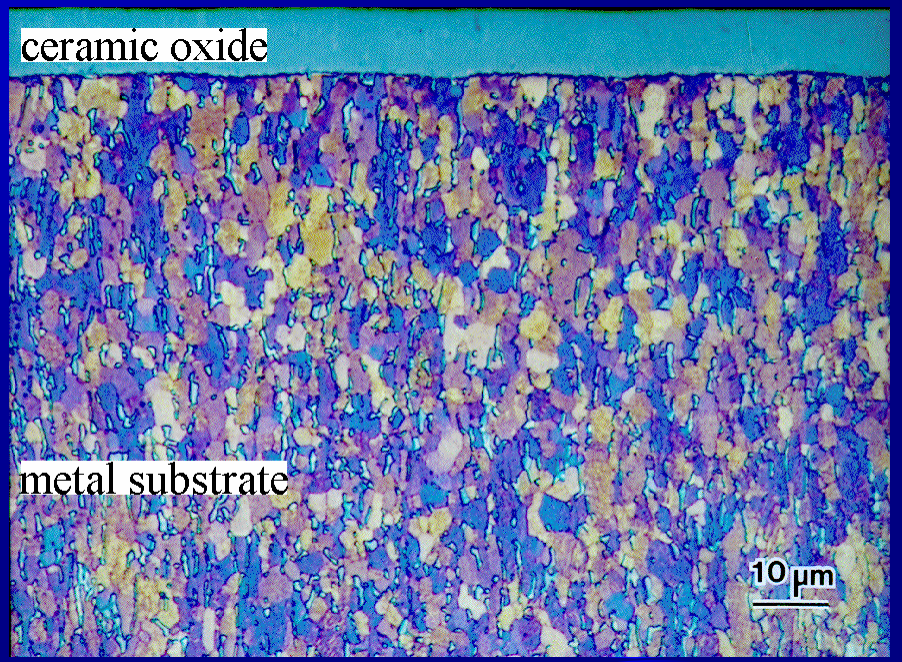
	IV B	V B	
	22 47.90 **Ti** Titanium 4.5 3130 1812 (Ar) $3d^2$ $4s^2$	23 50.94 **V** Vanadium 5.96 3530 1730 (Ar) $3d^3$ $4s^2$	
	40 91.22 **Zr** **Zirconium** 6.4 3580 1852 (Kr) $4d^2$ $5s^2$	41 92.91 **Nb** **Niobium** 8.4 3300 1950 (Kr) $4d^4$ 5s	



Oxidation Process

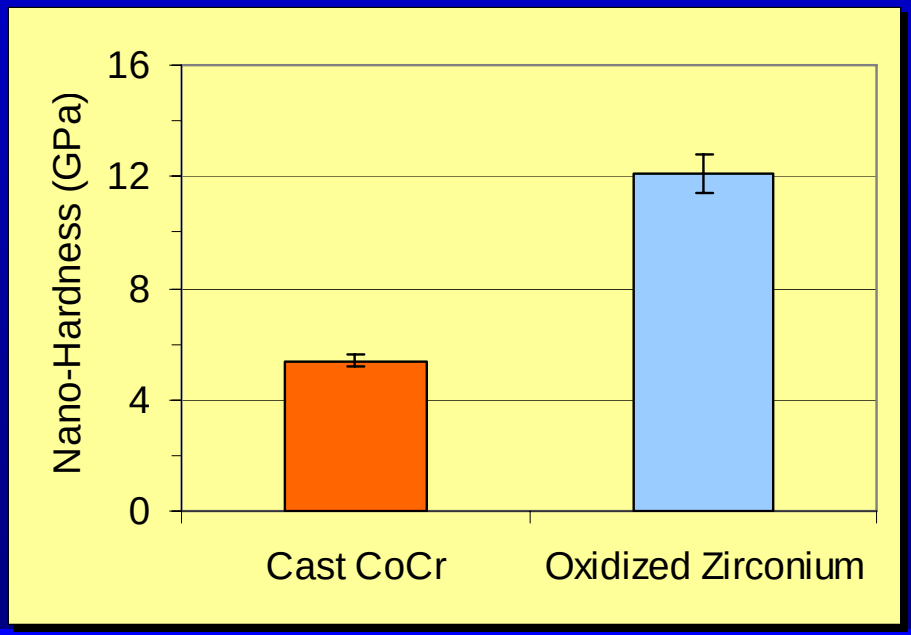
- Wrought zirconium alloy component is heated in air
- Metal surface transforms to ceramic; not a coating
- Ceramic oxide is uniformly about 5 μm thick

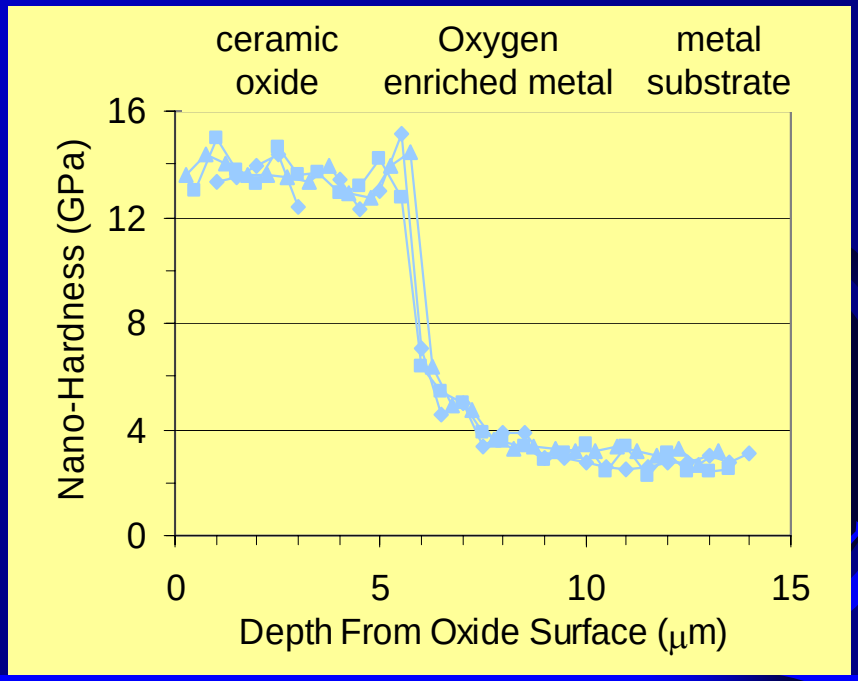




Hardness
(Long et al., SFB 1998)

- Oxidized Zirconium surface is over twice as hard as CoCr
- Underlying oxygen-rich zone promotes adherence to substrate

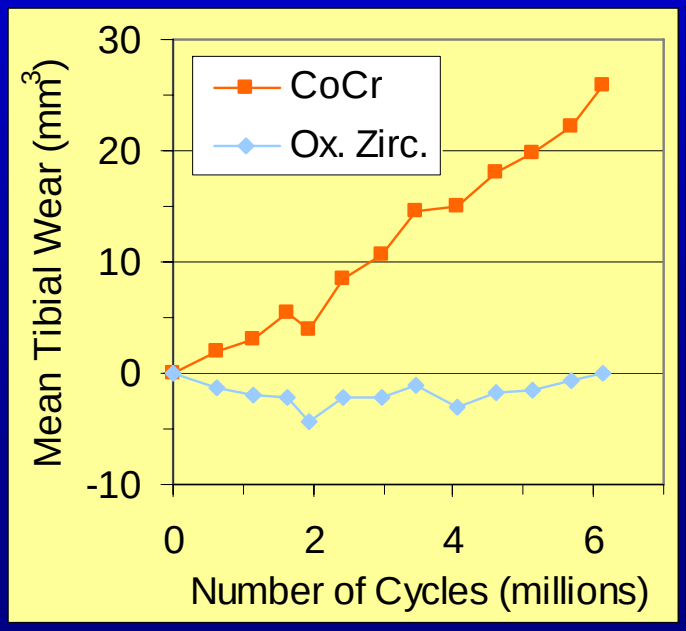


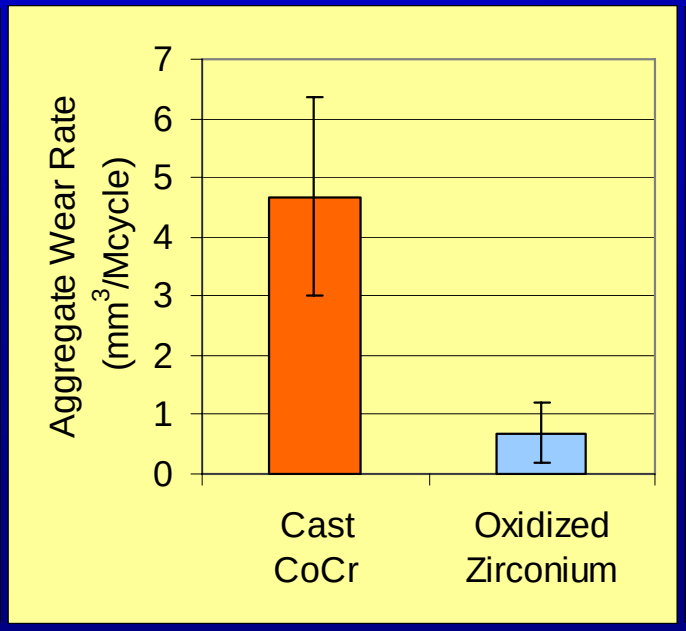


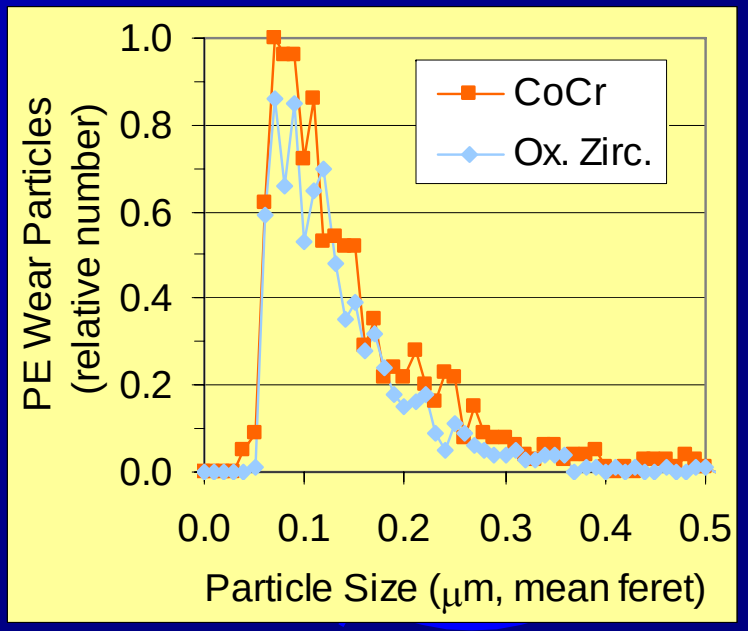
Polyethylene Wear against Oxinium (Spector et al., AAOS 2001)

Using knee simulator, Oxinium reduced PE wear rate by 85% with fewer particles

- **Three femorals each for 6M cycles of physiological motion**
- **Polyethylene wear measured by weight-loss and by particle analysis**



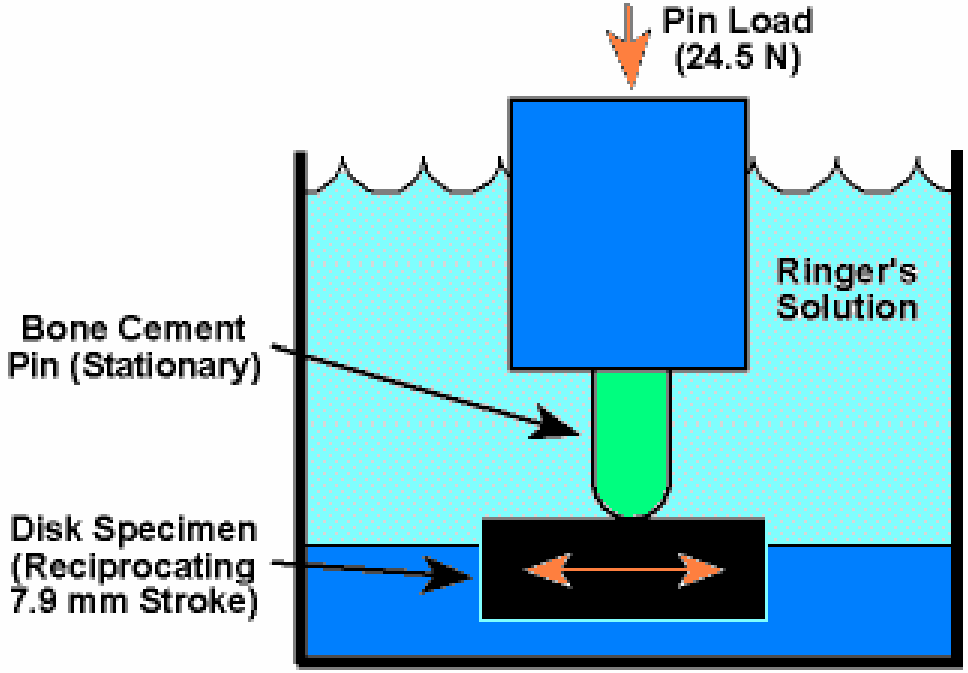


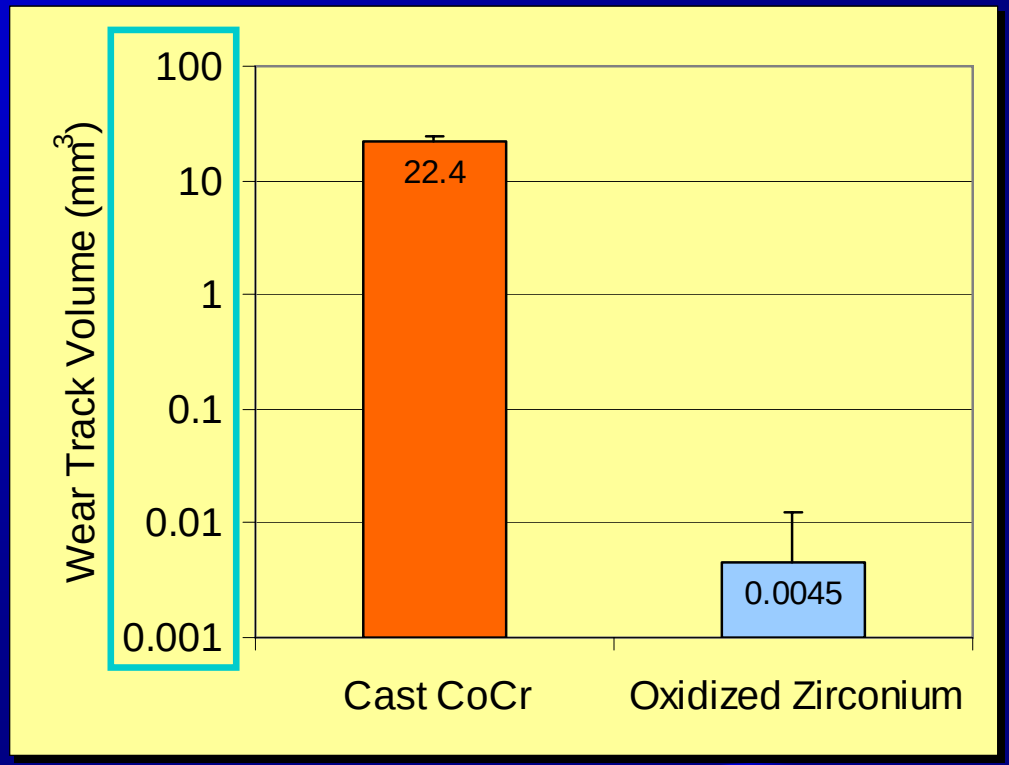


Abrasion Resistance

(Hunter and Long, WBC 2000)

- Oxinium reduced abrasion against bone cement by over 4900X
- Oxidized Zirconium post-test roughness was over 160X less
  - 10 million cycle pin-on-disk test represents 10 years of cement debris in joint

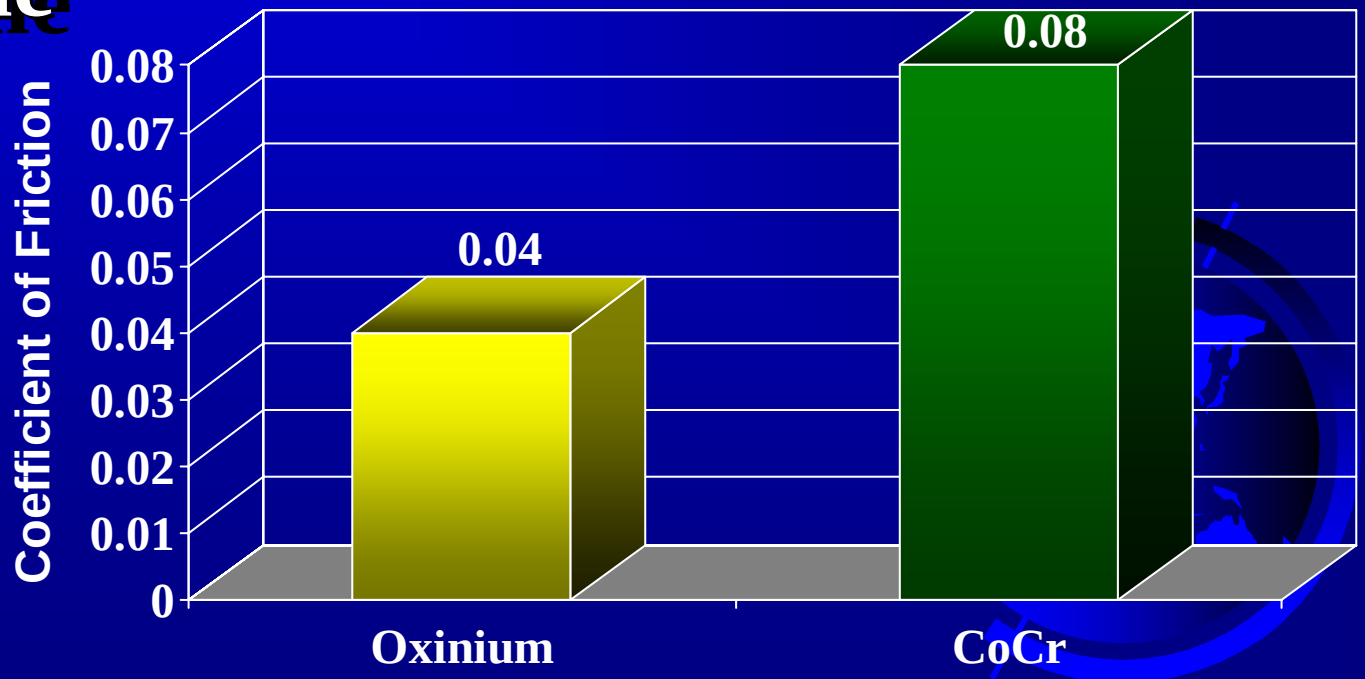




Why Low Wear?

Lower Friction reduces adhesive wear

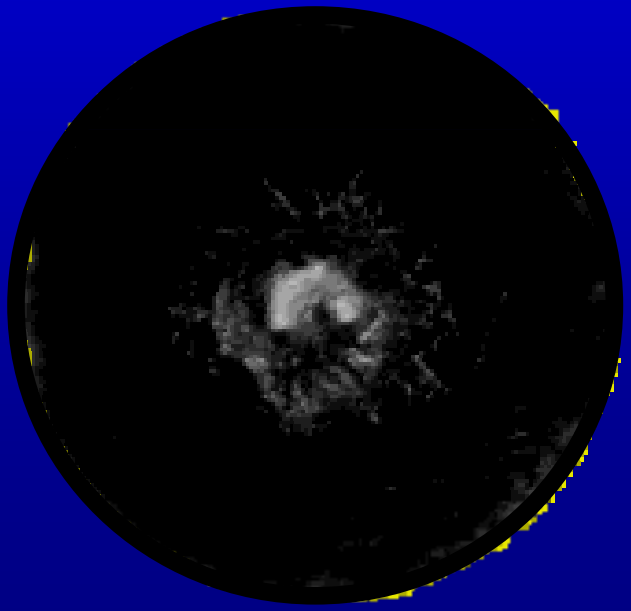
- Lower coefficient = increased sliding efficiency which may reduce wear
- Oxinium coefficient of friction is 1/2 that of cobalt chrome

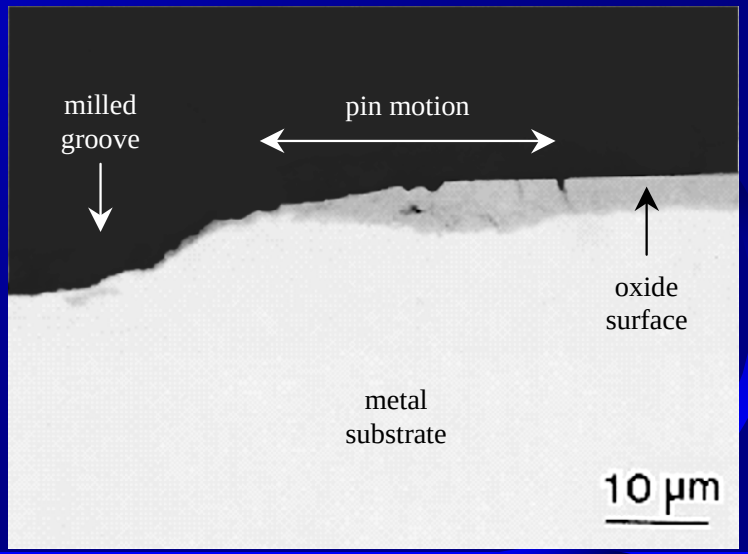


Damage Tolerance

(Hunter, SFB 2001)

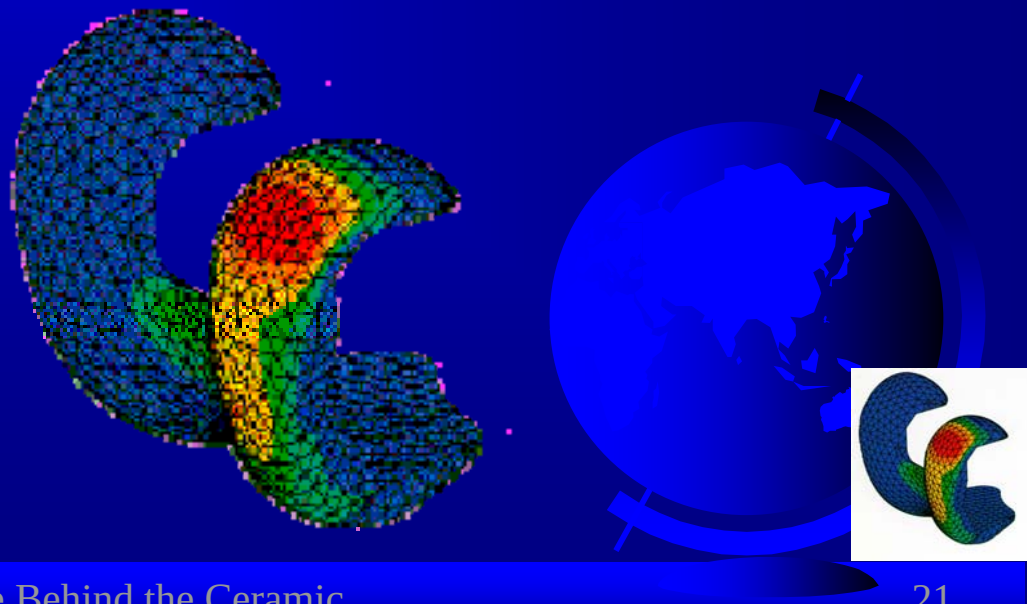
- Ceramic oxide surface adheres even if damaged by:
  - Punching crater through oxide, with adjacent heaving -up of substrate (hardness test)
  - Abrading bone cement pin for 10 Mcycle across line milled through oxide (modified abrasion test)





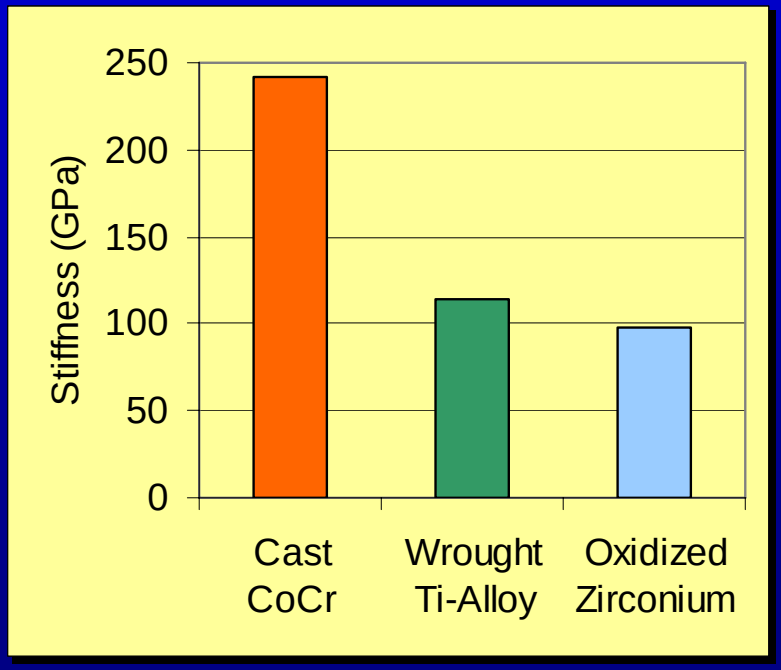
Strength
(Tsai et al., SFB 2001)

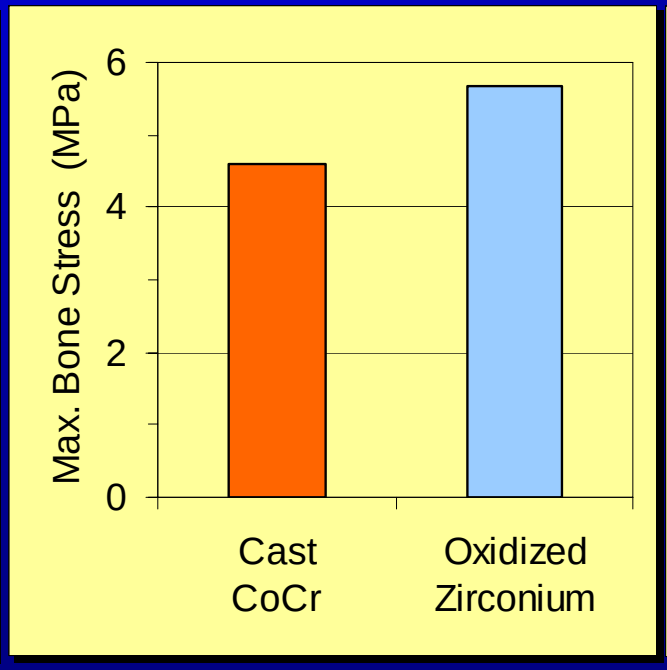
- **Ox. Zirconium device strength is equivalent to CoCr**
  - **Supported 4.4 kN (1000 lbf) in 10 Mcycle fatigue test**
  - **Physiological worst-case: single condyle, no bone support, full flexion**

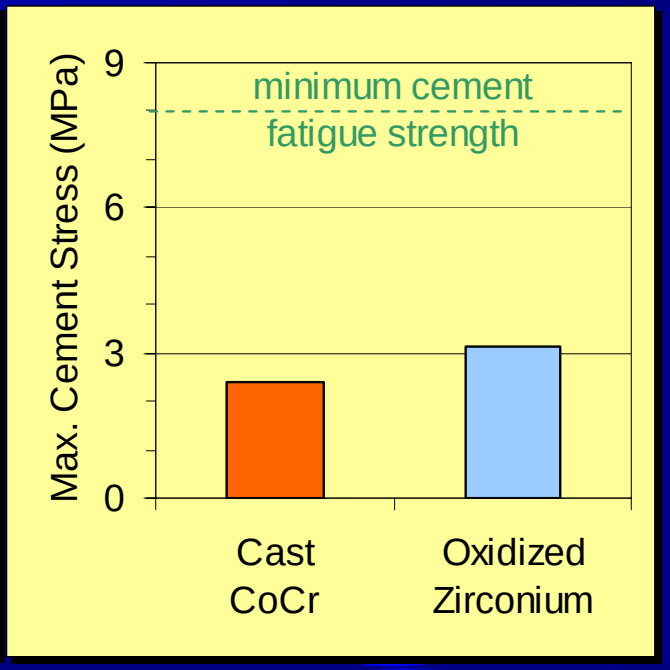


Stress Shielding

- **Ox. Zirconium is less stiff than CoCr; less stress shielding of bone**
  - **Simulated load of 6X body weight in full flexion**
  - **Stresses in cement remain below the minimum fatigue strength**







Biocompatibility

(Kovacs and Davidson, ASTM STP 1272)
(Davidson et al., Bioceramics 5)

- **Zirconium is one of five most biocompatible metals**
  - Other four metals: niobium, titanium, tantalum, and platinum
  - Based on self-passivation and lack of biological function
- **Alloy biocompatibility confirmed per ASTM F748**
  - Cytotoxicity (L929 MEM Mouse Fibroblast)
  - Sensitization (Kligman Maximization)
  - Genotoxicity (Ames Mutagenicity and Mouse Micronucleus Assay)
  - Implantation (Rabbit 90-Day Intramuscular and Rabbit 6-Month Transcortical)
  - Intracutaneous Reactivity (Rabbit Intracutaneous Injection)
  - Acute Toxicity (Mouse Systemic Injection and Rabbit Pyrogenicity)
  - Haemocompatibility (Rabbit Hemolysis)

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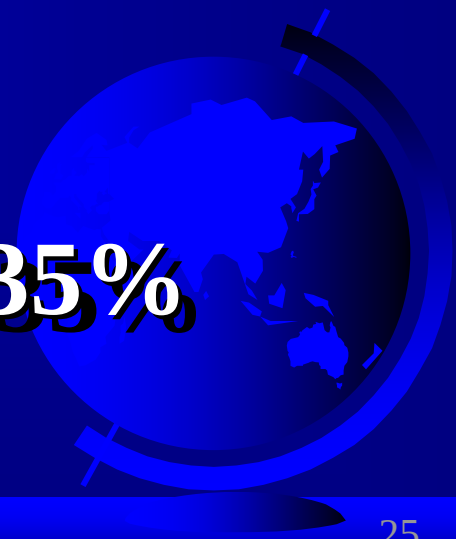
  - **Other four metals: niobium, titanium, tantalum, and platinum**
  - **Based on self-passivation and lack of biological function**

Metal Sensitivity

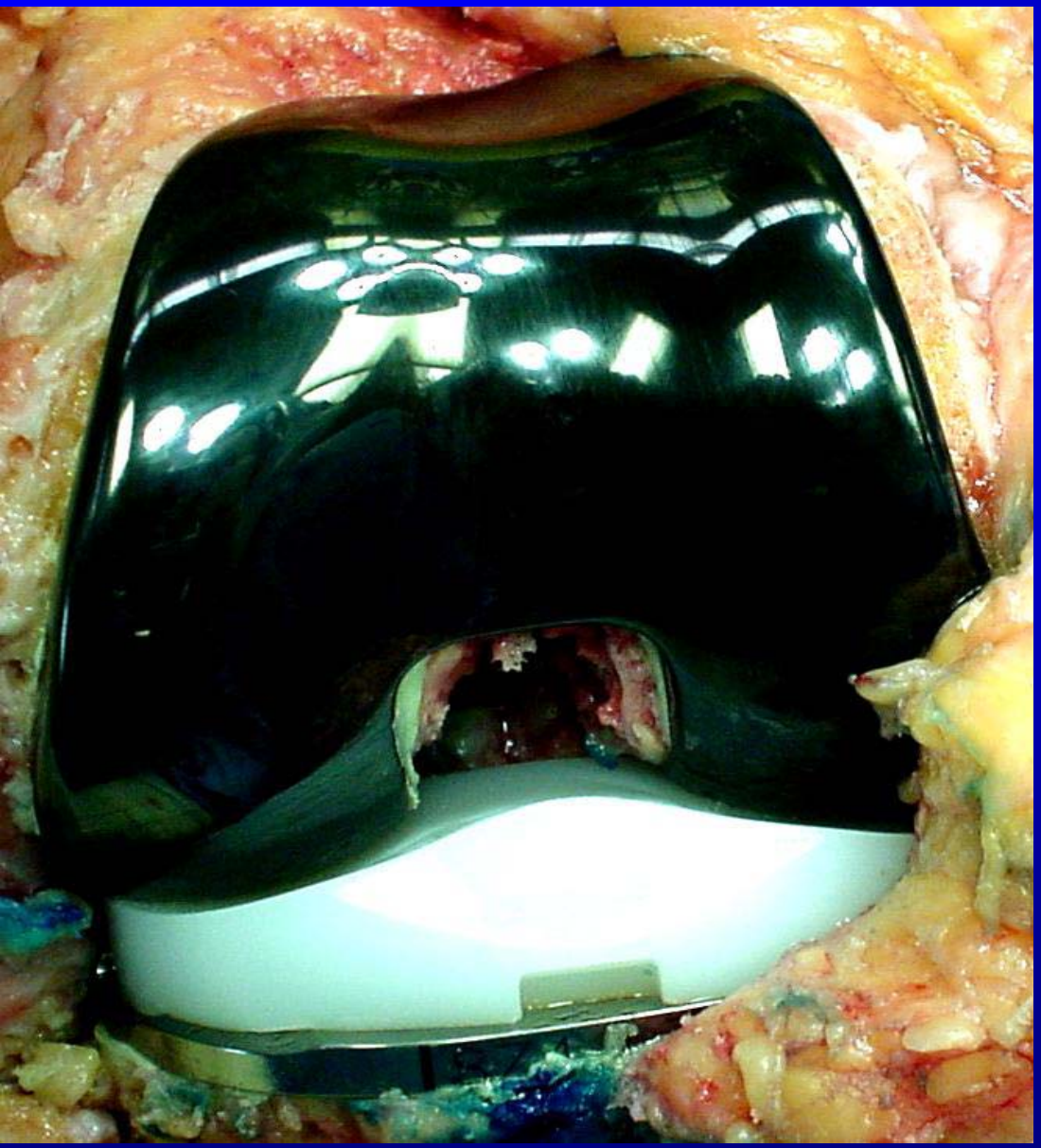
- Reports of metal hypersensitivity (especially nickel)
- Very low impurity content in Oxidized Zirconium
- Maximum specified impurity levels in alloys:
  - CoCrMo: 1% nickel
  - Ti-6Al-4V: 0.1% nickel
  - Zr-2.5Nb: Not detectable (0.0035% nickel)



Summary

- Less Polyethylene Wear Than CoCr
  - Harder Material
  - More Resistant to Scratching / Roughening Than CoCr
  - Less Friction Than CoCr
- Excellent Biocompatibility
- Strength of Metal; Tribology of Ceramic

And That's about as Good as it Gets!



Thank-you!

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