



# Comparison of *in vivo* wear of ceramic, metal and titanium nitride coated total hip arthroplasty heads



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## BACKGROUND

- In vivo scratching of conventional metal (MET) heads of total hip replacements (THR) accelerates polyethylene (PE) wear leading to osteolysis and loosening<sup>1</sup>
- To minimize this effect heads from alumina ceramics (CER) and heads with titanium nitride (TIN) coatings were introduced to clinical practice<sup>2,3,4</sup>

## AIM OF STUDY

- This retrieval study compared *in vivo* wear of conventional CoCrMo, second generation ceramic (Bilox Forte), and TiN coated heads

## MATERIALS

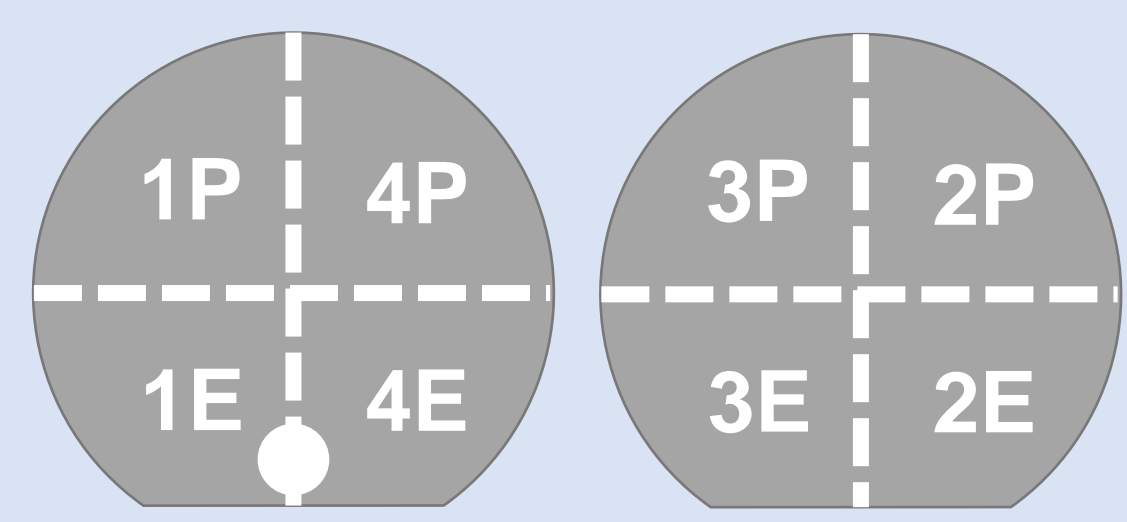
- 75 retrieved heads from failed primary total hip replacements : 25 TiN coated (Implantcast ic-head) samples with matched\* ceramic (Bilox Forte) and metal heads (CoCrMo, various manufacturers); unused heads of each type were included as controls

*matching criteria (in order of importance)	TIN	CER	MET
Implantation time (months)	3-72	3-75	3-72
THR fixation: cemented/uncemented/hybrid	1/23/1	1/24/0	1/23/1
Cause of revision: aseptic/septic/pain	22/2/1	22/3/0	20/2/3
Head diameter : 28/32/36 mm	22/2/1	25/0/0	21/2/2

## METHODS

### 1. Evaluation of bearing surface wear (BSW) using the semiquantitative Hothi scoring system<sup>4</sup>

#### Following features were examined :



Heads were divided into eight equatorial (E) and polar (P) sectors relative to (dot – manufacturers logo)

- Light/Moderate/Heavy scratching/metal deposits
- Haziness
- Discolouration
- Embedded particles
- Pitting
- Wear scars

Each feature was scored as 0..3 depending on the area it covered (0-25%...75-100%)

### 2. Subsequent examinations

- Surface roughness (Ra) was measured in the most (weight-bearing; W.B.) and least (non weight-bearing; non W.B.) damaged sector using contact profilometry (Turbowave 8000, Hommelwerke)
- Results of BSF scoring Ra measurements were analyzed statistically using Shapiro-Wilk and Kruskal-Wallis tests
- Qualitative examination using scanning electron microscopy (SEM) with Energy-dispersive (EDS) spectroscopy for elemental composition

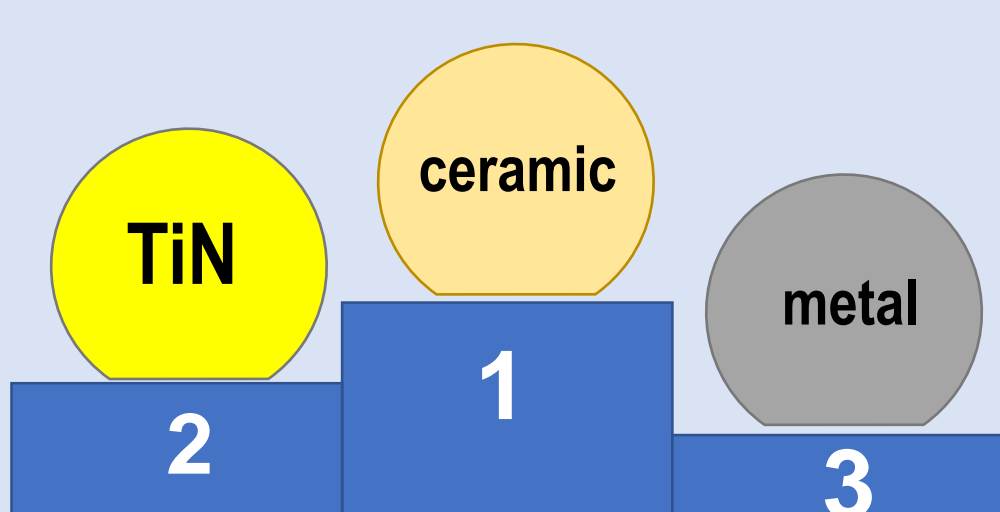
## RESULTS

	TIN	CER	MET
BWS Score	<b>34,2<sup>ns</sup></b> (range 12-57)	<b>10,7*</b> (range 5-21)	<b>40,7<sup>ns</sup></b> (range 15-86)
Mean surface roughness (W.B. areas)	<b>0,052*</b> (range 0,02-0,12) Non - W.B. parts 0,032	<b>0,028*</b> (range 0,02-0,05) Non - W.B. parts 0,028	<b>0,071*</b> (range 0,02-0,19) Non - W.B. parts
Unused reference sample	 Polished surface with multiple defects caused by the coating deposition process (in circles)	 Smooth surface with few areas with missing ceramic grains (arrows)	 Flat surface with few randomly oriented scratches (arrows)
Wear mechanisms of W.B. parts	 Abrasion by third bodies : scratching and removal of the TiN layer (2 cases)  Dislodgement of particles (arrow) from the coating – source of third bodies	 Localized pull-out of ceramic grains (in circle)  Transfer of Ti alloy debris <sup>5</sup> from metal components (arrow)	 Multidirectional scratches typically seen in W.B. areas (arrows)  Most scratches were caused by third bodies (in circles)
Other SEM findings	 Blister (arrows) formed by debonding of the coating due to corrosion  Massive coating debonding due to localized overload (impingement; 2 cases)	 Localized damage due to surgical tools (arrows); EDS spectra of metal deposits – presence of alloy containing iron (Fe) from surgical tools	 In patients with threaded, sandblasted Ti alloy cups alumina grains were common third bodies found on the heads, as confirmed by EDS analysis

ns – no statistical significance; \* statically significant difference

## CONCLUSIONS

- Ceramic heads had less *in vivo* surface damage in comparison to TiN and metal heads
- In Ceramic components damage was caused by transferred metal from implants<sup>5</sup> and surgical tools, while in metal and TiN coated abrasion caused by third bodies played an important role<sup>2,3,4</sup>
- Minimal wear rates of ceramic heads could potentially minimize PE wear and osteolysis<sup>1</sup>



## LITERATURE

- Mc Grory et al. J. Arthroplasty 2012
- Dahl wr K, Acta Orthopaedica 2013
- Łapaj et al. J. Mech Behav Biomed Mat. 2015
- Khatkhas et al., International Orthopaedics 2017
- Fredette et al. BioMed Research International 2015;

We are interested in cooperation :  
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