

# Material Problems on the Cup Side

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Material problems in total hip arthroplasty  
*Belgian Hip Society*  
Orthopaedica Belgica 25<sup>th</sup> April 2019

# CUP MATERIALS



## ACETABULAR SHELL

Polyethylene  
CoCrMo  
Ti-alloy (TiAlV)  
Ta-alloy  
Al<sub>2</sub>O<sub>3</sub>  
ZTA

Coatings: Ti porous, HA, TiN, ...

## ARTICULATING SURFACE

Inside of cup or as liner (inlay)  
Non-XL UHMWPE (PE)  
XLPE  
CoCrMo (M)  
Al<sub>2</sub>O<sub>3</sub> (Biolox forte)  
ZTA (Biolox delta)

Coatings: TiNbn, ...

## Non-cemented fixation: Porous Ti +/- HA: attractive to osteoblasts OSTEOINTEGRATION

Journal of INTERNATIONAL MEDICAL RESEARCH  
Apostu et al. 2017

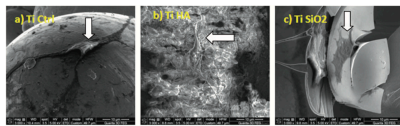
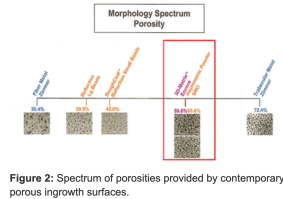
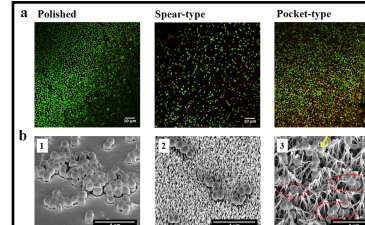


Figure 2. Scanning electron microscopy images of titanium implants seeded with osteoblast cells (a) Ti6Al4V implants as a control (Ti6Al4V) seeded with osteoblast cells (arrow shows cells surrounded by bone matrix). (b) Titanium implants coated with hydroxyapatite (TiHA) and seeded with osteoblast cells (arrow shows a strong matrix deposition with cells surrounded by bone matrix). (c) Titanium implants with bioactive silicofluoride coating (TiSiO<sub>2</sub>) seeded with osteoblast cells (arrow shows a large flattened cell with numerous extensions) (magnification, >3000)<sup>12</sup>

www.nature.com/scientificreports  
Yunyi Cao et al. 18 January 2018



**BIOFILM:**  
bacteria attracted to  
- hydrophobic  
- rough surfaces  
- deep pores

Adherence of *S. epidermidis* on different titanium surfaces after 2 hours incubation.  
J Biomed Mater Res A. 2014 Jan;102(1):215-24. doi: 10.1002/jbm.a.34688. Epub 2013 May 10.

## Staphylococcal biofilm growth on smooth and porous titanium coatings for biomedical applications.

Braem A<sup>1</sup>, Van Meilaeert L, Mattheys T, Hofmans D, De Waelheyns E, Geris L, Anné J, Schrooten J, Vlieghe J.

The results also show that a further expansion of the porosity with over 15% and/or the pore size up to 150 µm is correlated to a significant increase in the roughness parameters resulting in an ascent of bacterial attachment.

## ARTICULATING SURFACES / BEARING COUPLE CUP - HEAD



Cumulative Percent Revision of Primary Total Conventional Hip Replacement by Bearing Surface (Primary Diagnosis OA) AOAJRR

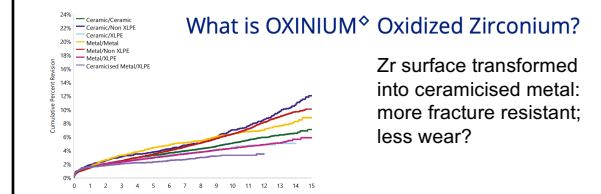


Table H2B Cumulative Percent Revision of Primary Total Conventional Hip Replacement by Bearing Surface (Primary Diagnosis OA)

Bearing Surface	N	N	1 Yr	3 Yrs	5 Yrs	7 Yrs	10 Yrs	15 Yrs
	Revised	Total						
Ceramic/Ceramic	14029	72139	1.5 (1.4, 1.6)	2.4 (2.3, 2.5)	3.1 (3.0, 3.3)	3.9 (3.7, 4.1)	5.0 (4.8, 5.3)	7.1 (6.4, 7.8)
Ceramic/Non XLPE	388	5836	1.8 (1.5, 2.2)	3.0 (2.6, 3.5)	3.7 (3.2, 4.3)	4.7 (4.2, 5.4)	7.0 (6.3, 7.8)	12.0 (10.7, 13.5)
Ceramic/XLPE	973	39349	1.6 (1.5, 1.7)	2.5 (2.3, 2.6)	3.0 (2.8, 3.2)	3.6 (3.3, 3.8)	4.4 (4.0, 4.8)	
Ceramic/Metal	18	299	1.7 (0.7, 4.0)	3.7 (2.1, 6.6)	4.4 (2.6, 7.4)	8.3 (4.9, 13.9)		
Metal/Metal	223	5147	1.5 (1.2, 1.9)	2.3 (2.0, 2.8)	4.4 (3.8, 5.0)	5.1 (4.5, 5.8)	6.4 (5.7, 7.2)	8.9 (7.6, 10.1)
Metal/Non XLPE	2127	34267	1.4 (1.3, 1.5)	2.4 (2.3, 2.6)	3.4 (3.2, 3.6)	4.3 (4.3, 4.7)	6.3 (6.1, 6.6)	10.0 (9.5, 10.6)
Metal/XLPE	3399	118862	1.5 (1.5, 1.6)	2.3 (2.2, 2.4)	2.9 (2.8, 3.0)	3.4 (3.3, 3.6)	4.3 (4.1, 4.5)	5.8 (5.2, 6.5)
Ceramised Metal/Non XLPE	35	288	1.7 (0.7, 4.1)	3.9 (2.2, 7.0)	4.3 (2.5, 7.5)	7.8 (5.1, 11.8)	13.0 (9.2, 18.2)	
Ceramised Metal/XLPE	253	16078	1.5 (1.3, 1.7)	2.0 (1.8, 2.2)	2.5 (2.0, 3.5)	2.6 (2.3, 2.9)	3.2 (2.9, 3.7)	
TOTAL	10023	292385						

Note: Excludes 169 procedures with unknown bearing surface, one procedure with Ceramised Metal/Ceramic bearing surface and 10 procedures with Metal/Ceramic bearing surface. All procedures using metal/metal prostheses with head size larger than 32mm have been excluded.

Clin Orthop Relat Res (2018) 476:182-192  
DOI 10.1007/s11999-018-0000-0

2017 Hip Society Proceedings

Clinical Orthopaedics and Related Research  
Published online: 17 January 2018  
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### Polyethylene Wear Increases in Liners Articulating With Scratched Oxidized Zirconium Femoral Heads

Alberto Carli MD, Chelsea N. Koch BS, Christina I. Esposito PhD, Timothy M. Wright PhD, Douglas E. Padgett MD

6 OxZr Grade 3 (dislocators)  
Sa = 2220 nm, Sa = 6075 nm, Sa = 1088 nm, Sa = 5916 nm, Sa = 1111 nm, Sa = 1111 nm

3 OxZr Grade 2 (nondislocators)  
Sa = 383 nm, Sa = 373 nm, Sa = 1023 nm

3 BIOLOX® delta Grade 3 (dislocators)  
Sa = 113 nm, Sa = 162 nm, Sa = 247 nm

TiNbn

### Case report

#### Oxidized zirconium on ceramic; Catastrophic coupling

V.E. Ozden<sup>a,\*</sup>, N. Saglam<sup>b</sup>, G. Dikmen<sup>a</sup>, I.R. Tozun<sup>a</sup>

**Fig. 6.** A 55-year-old female who underwent right total hip arthroplasty seven years ago complained of left hip squeaking for four months. A. At seventh years' AP radiography showing metallosis around cup. B. During revision; extracted cup, ceramic liner and debris bony material.

### WEAR PRODUCTS: PARTICLES

Wear rate in  $\text{mm}^3/10^6$  cycles

Combination	Wear Rate
CoCr-PE	55.7
CoCr-XPE	8.1
Al <sub>2</sub> O <sub>3</sub> -PE	17.1
Al <sub>2</sub> O <sub>3</sub> -XPE	4.7
CoCr-CoCr	1
Al <sub>2</sub> O <sub>3</sub> -CoCr	0.04
ZrO <sub>2</sub> -CoCr	0.018
Al <sub>2</sub> O <sub>3</sub> -Al <sub>2</sub> O <sub>3</sub>	0.052
ZrO <sub>2</sub> -ZrO <sub>2</sub>	0.05

nonXL PE: >wear with >diameter head

### Figure HT24 Cumulative Percent Revision of Primary Total Conventional Hip Replacement by Polyethylene Type (Primary Diagnosis OA)

AOAJRR 2018

HR, adjusted for age and gender

- Non-XLPE vs XLPE: 0.3688, HR=0.81, 0.74, 0.94, p=0.002
- 32mm: 0.9488, HR=1.09, 0.81, 1.52, p=0.304
- 33mm: 0.8488, HR=1.09, 0.81, 1.52, p=0.001
- 15yr: 2.99, HR=1.31, 0.81, 1.54, p=0.002
- 23yr: 4.05, HR=1.71, 1.01, 3.79, p=0.001
- 43yr: 9.99, HR=2.91, 1.54, 2.66, p=0.001
- 9yr: HR=2.14, 1.24, 3.78, p=0.001

"XLPE has a lower rate of revision than non XLPE regardless of the femoral head used."

Polyethylene Type	Head Size	N Revised	N Total	1 Yr	3 Yrs	5 Yrs	7 Yrs	10 Yrs	15 Yrs
Non-XLPE	<32mm	2548	40391	1.5 (1.3, 1.6)	2.5 (2.4, 2.7)	3.5 (3.3, 3.7)	4.5 (4.3, 4.8)	6.5 (6.2, 6.8)	10.5 (10.0, 11.0)
	32mm	185	4432	1.6 (1.3, 2.0)	3.0 (2.3, 3.9)	3.7 (3.1, 4.4)	4.9 (4.2, 5.8)	5.9 (5.0, 6.9)	10.5 (9.5, 11.6)
	>32mm	23	295	3.8 (2.1, 6.7)	6.3 (3.9, 9.9)	8.7 (5.6, 13.2)	10.6 (6.9, 16.0)		
XLPE	<32mm	4725	174409	1.5 (1.5, 1.6)	2.3 (2.2, 2.4)	2.8 (2.8, 2.9)	3.4 (3.3, 3.5)	4.2 (4.1, 4.4)	5.6 (5.1, 6.1)
	32mm	1648	46263	1.5 (1.4, 1.6)	2.3 (2.2, 2.5)	2.9 (2.8, 3.1)	3.5 (3.3, 3.7)	4.4 (4.1, 4.6)	5.8 (5.2, 6.3)
	>32mm	1675	71991	1.5 (1.4, 1.6)	2.2 (2.1, 2.3)	2.6 (2.5, 2.7)	3.1 (3.0, 3.3)	3.8 (3.6, 4.1)	
TOTAL		13402	56155	1.6 (1.5, 1.7)	2.4 (2.2, 2.5)	3.1 (2.9, 3.2)	3.5 (3.3, 3.8)	4.4 (4.0, 4.8)	

### HARD BEARINGS

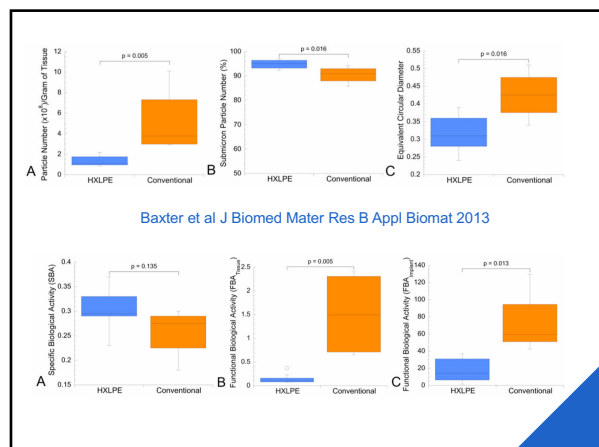
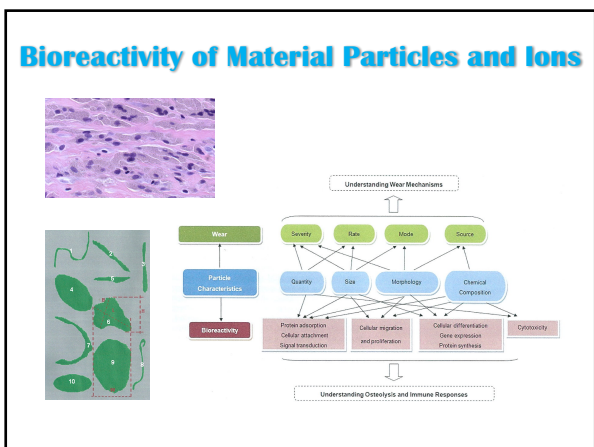
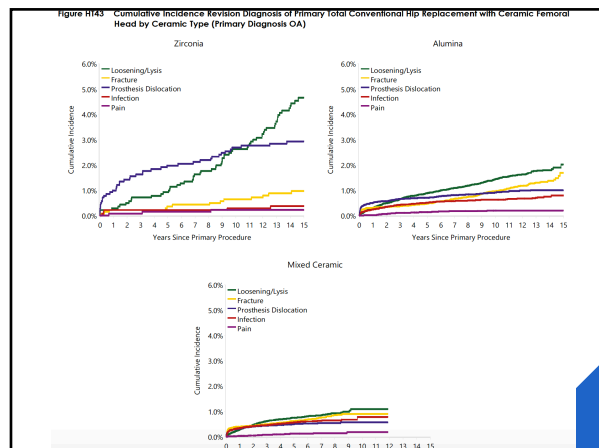
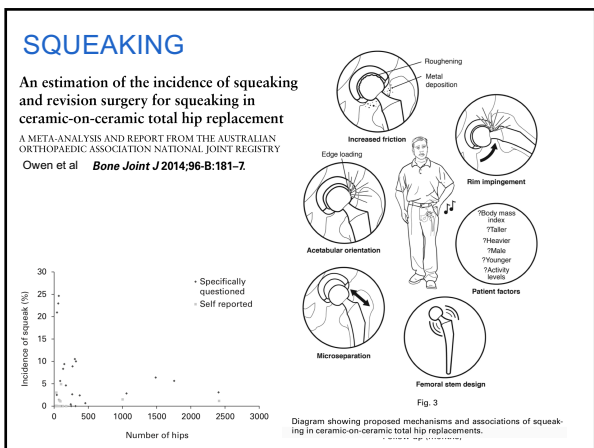
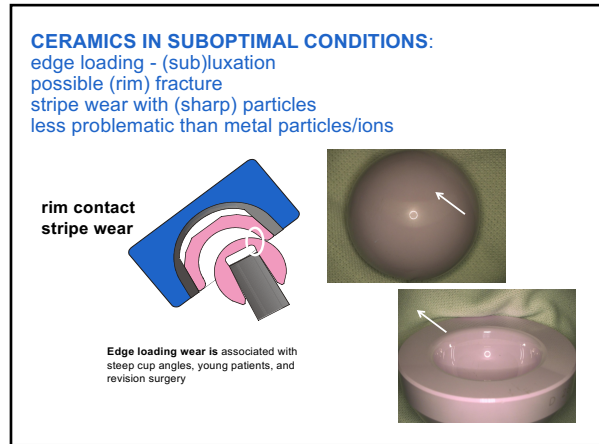
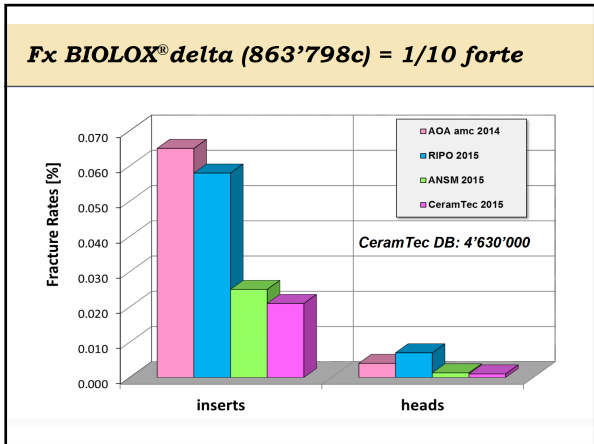
#### High performance biomaterials

- Hydrophilicity ⇒ lubrication
- Surface roughness ⇒ PE abrasion
- Hardness ⇒ scratch resistance

### Properties of ceramics in THA

- High scratch resistance
- Long lasting smoothness
- Low friction
- Low wear in-vivo, independent of head diameter

Piconi C et al., Ceramics in THR bearings: behavior in off-normal conditions. Key Eng Mater 631:1-7 (2015)  
Lee et al., Scratch and wear performance of prosthetic femoral head components against crosslinked UHMWPE sockets. Wear, 267, 11, 2009, 1915-1921.



## Review studies particles from TJA

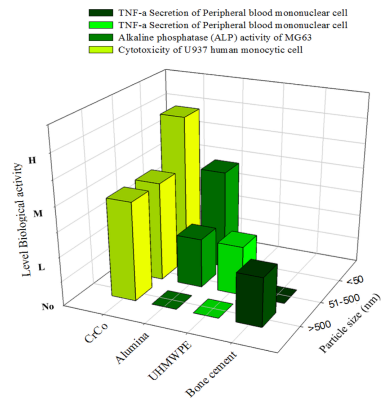
Nine et al. Materials 2014

- different materials with different wear mechanisms in hips and knees
- correlate findings with debris morphology/disintegration

- 1) Many: inappropriate process isolation/characterization → Tipper et al: 'Lifelong Joints': European standard
- 2) Particles not uniform in size/shape nor homogeneous in distribution, *in vivo* and *in vitro*.
  - Variability in: size, shape, volume,
  - depends on: type of joint, material combination, wear mechanism,
- 3) **Smaller debris (PE, M, ceramic): higher inflammatory response to living cells**
  - phagocytosis is size-dependent: nanosized particles from any material stimulate cells at high volumetric dose.
  - the size-dependent response rate weakens with lower doses.

**BUT:** Liu et al *acta Biomaterialia* 2015

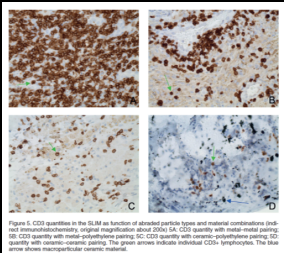
µm -size UHMWPE wear particles (0.1–1.0 µm) caused significantly elevated osteolytic cytokine release from PBMCs compared to <50nm size particles



Nine et al. 2014

## Immune Response: quantity of CD3 Ly

Metal - Metal



Metal - PE

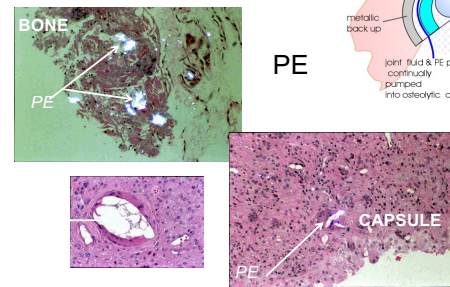
Ceramic - PE

Ceramic - Ceramic

Figure 5. CD3 quantifies in the SLIM as function of abraded particle type and material combinations (indicated in the corresponding original magnification above CD3). A: CD3 quantity with metal-metal pairing. B: CD3 quantity with metal-ethylene pairing. C: CD3 quantity with ceramic-ethylene pairing. D: CD3 quantity with ceramic-ceramic pairing. The green arrows indicate individual CD3+ lymphocytes. The blue arrow shows macrophages around metal.

## Analysis of tissue reactions

Foreign body reaction to debris → Osteolysis



## Local adverse reactions to metal wear debris

METALLOSIS and 'PSEUDOTUMOURS' +/- SOFT TISSUE AND BONE DAMAGE



## Metal Allergy as cause of TJA failure

**Metal Reactivity:**  
Innate Immunity: non-specific 'foreign body' reaction  
Normal response to a large amount of metal particles

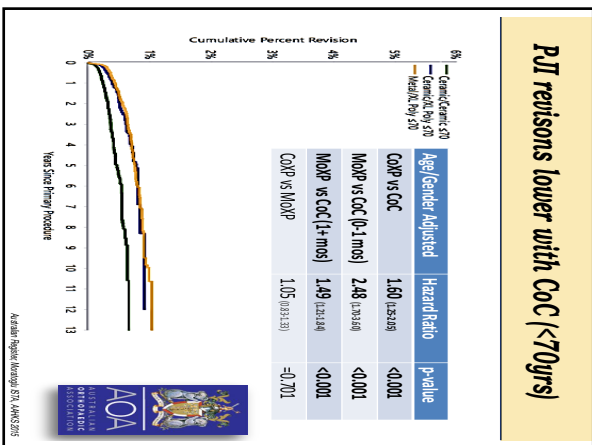
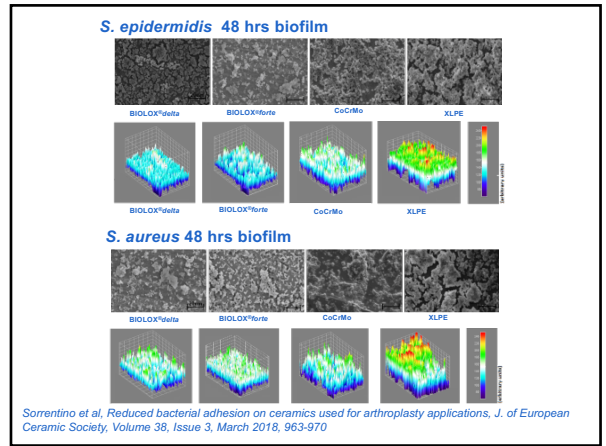
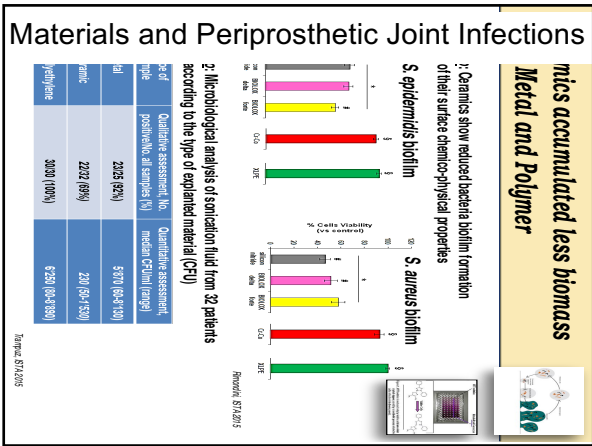
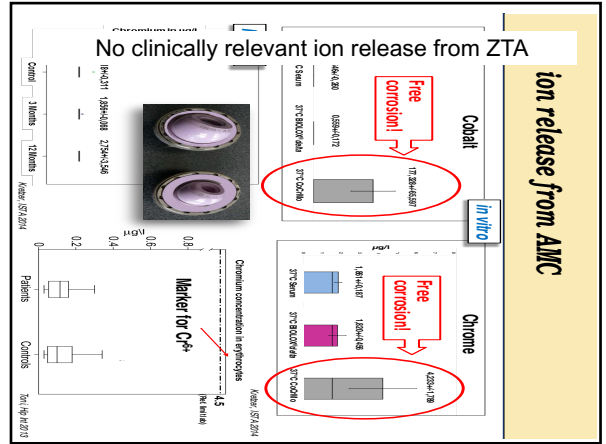
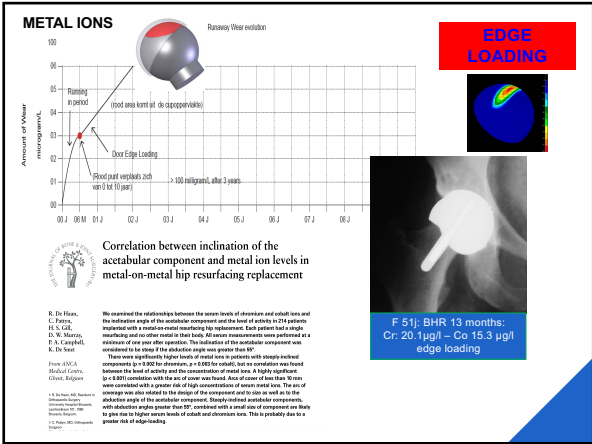
**Metal Allergy:**  
Adaptive Immunity: Type IV delayed hypersensitivity  
Abnormal response to a small amount of metal particles (genetic predisposition)



The association between metal allergy, total knee arthroplasty, and revision  
Study based on the Danish Knee Arthroplasty Register

Havvik J, MUNCH F, Sig S, JACOBSEN J, Jens T, OLESEN T, Toril MENNE, Kjetil SOBALLE, Joanne D, JOHANSEN, and Jacob P THYSEN

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Volg ons op

