BIO-TRIBOLOGY

TRIBOLOGY OF TOTAL HIP ARTHROPLASTIES

C.B. Rieker, PhD
Zimmer Biomet EMEA
CH – 6300 Zug

ZIMMER BIOMET

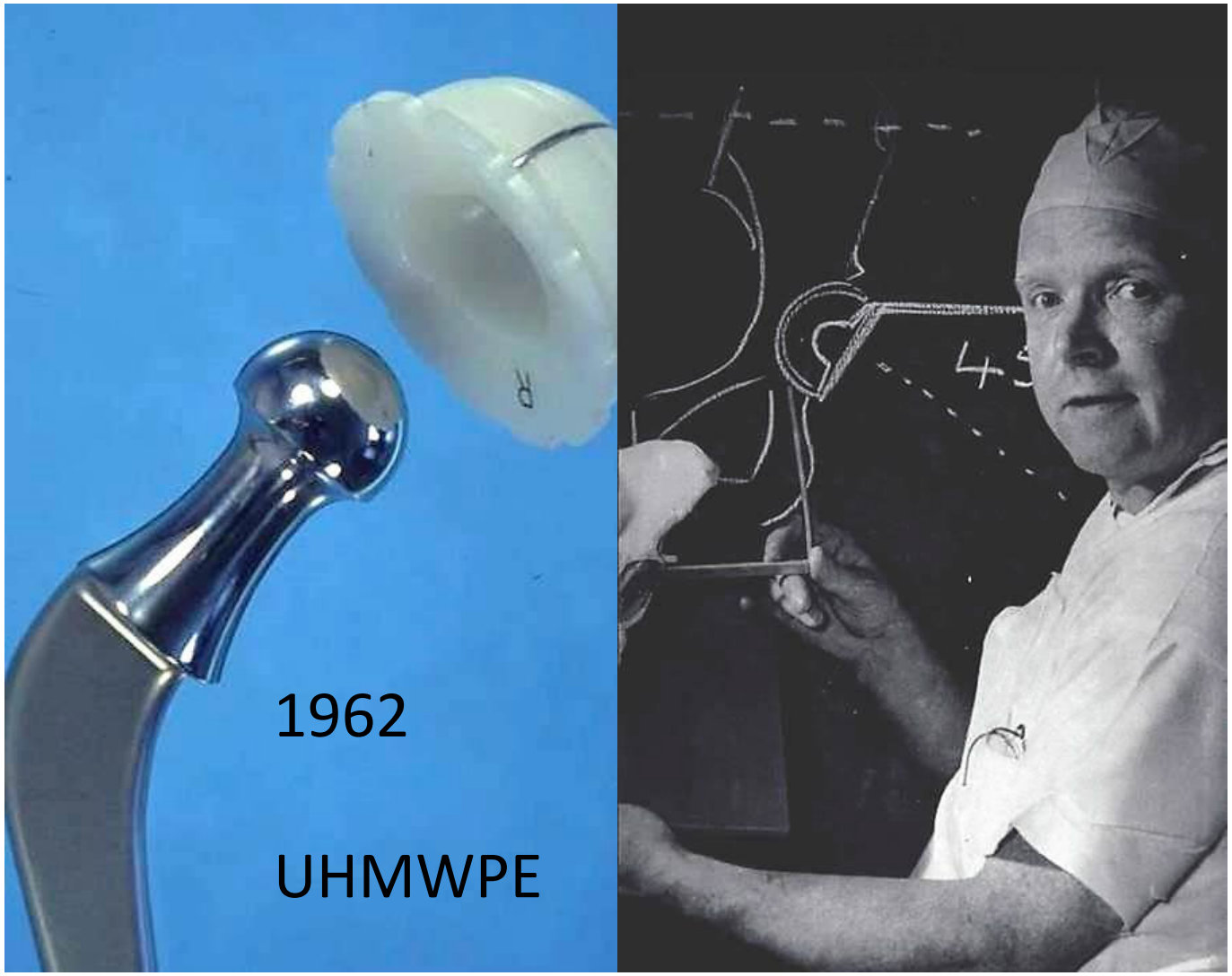
TRIBOLOGY OF TOTAL HIP ARTHROPLASTIES

- Introduction
- Why is tribology important
- Materials
- Possible methodology
- Other aspects
- Conclusions

EPFL

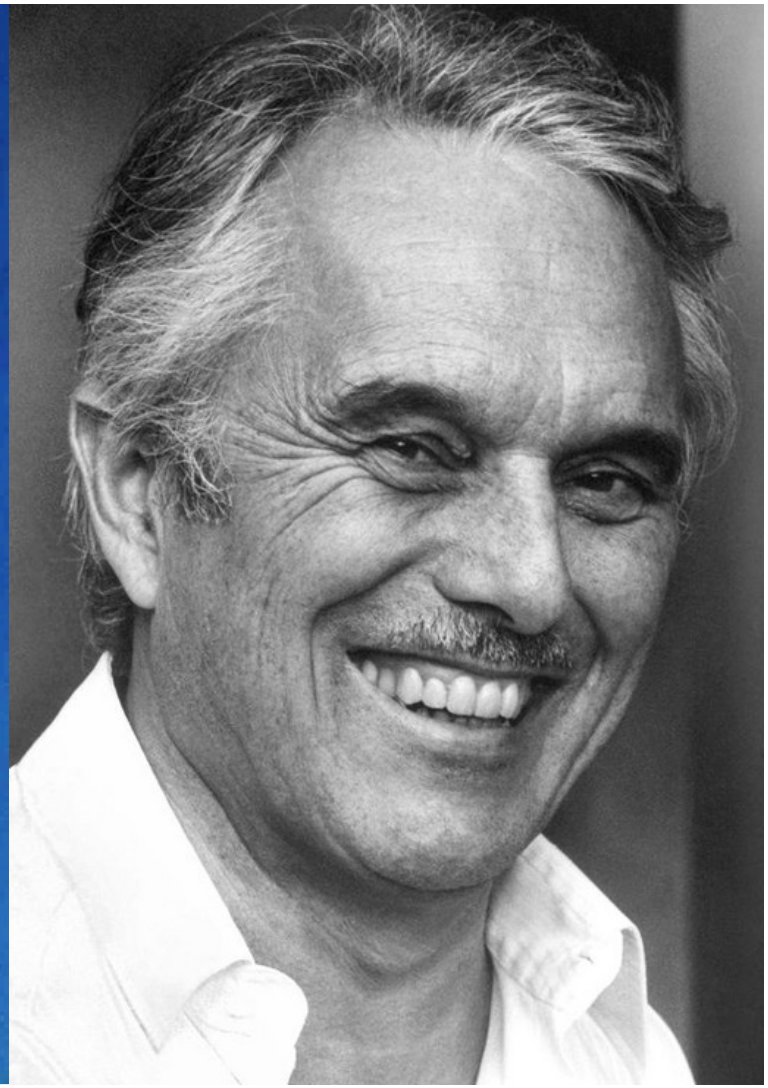

Tabac
Besson
swatch
Le Myosotis
Le Robun


SAMPLE - DO NOT



Sir John Charnley
1911 - 1982

NHS
Wrightington,
Wigan and Leigh
NHS Foundation Trust



Maurice Müller
1918 – 2009

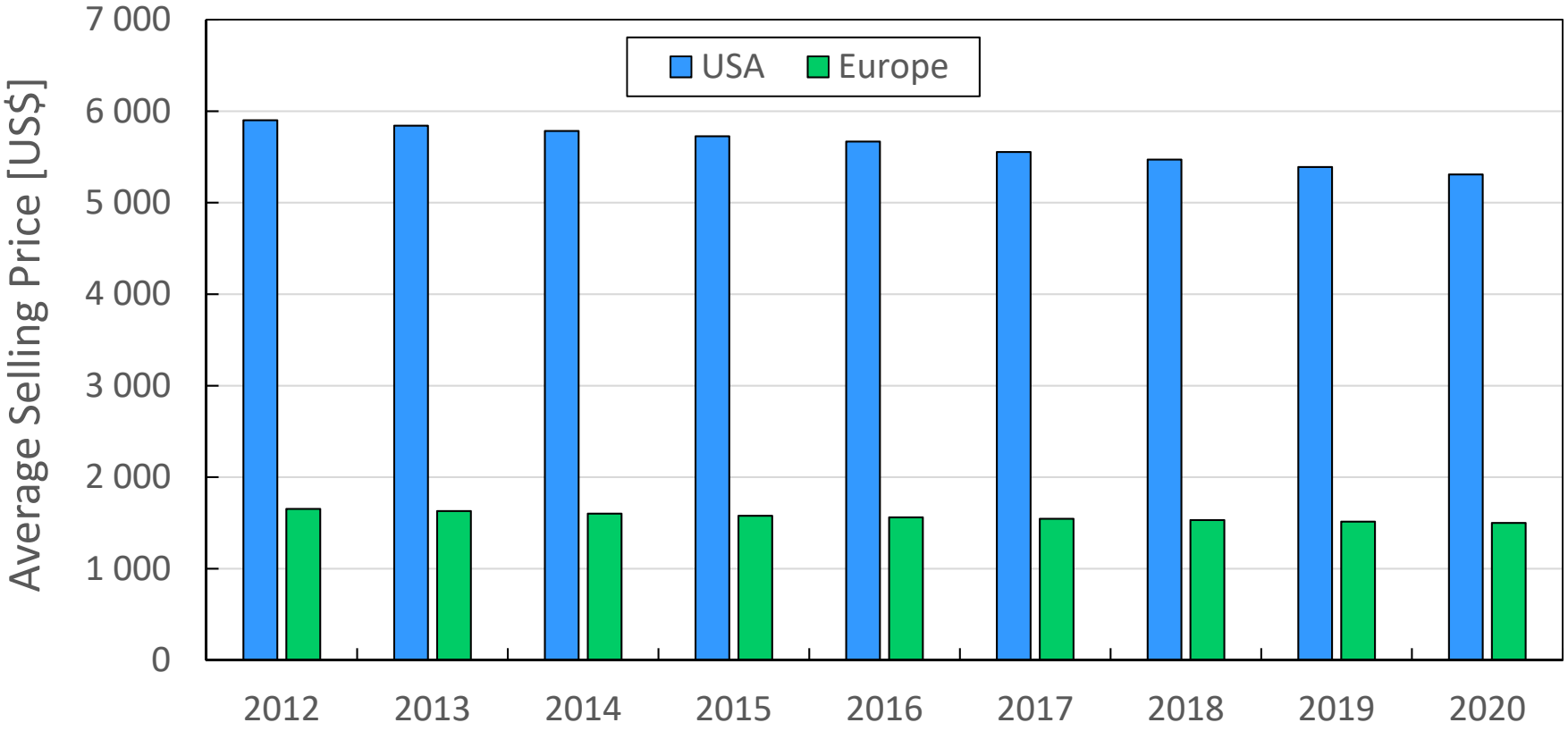
Surgeon of the century

INSELSPITAL
UNIVERSITÄTSSPITAL BERN
HOPITAL UNIVERSITAIRE DE BERNE
BERN UNIVERSITY HOSPITAL

TOTAL HIP PROSTHESES

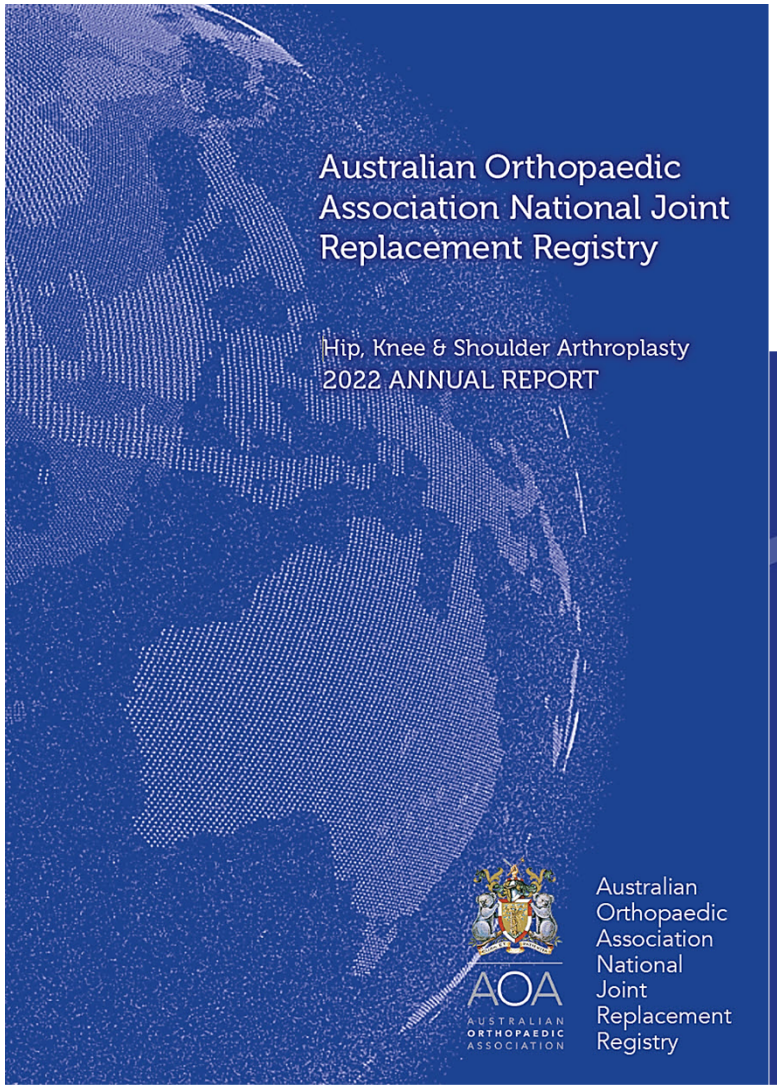
- More than 2’000’000 implantations per year
- Costs of a hip implant: About 1’500 €
About 5’300 US$
- Operation time: 45 – 90 minutes
- Number of steps per year: 500’000 – 10’000’000
- Life expectancy: 5’000’000 ➔
200’000’000 cycles

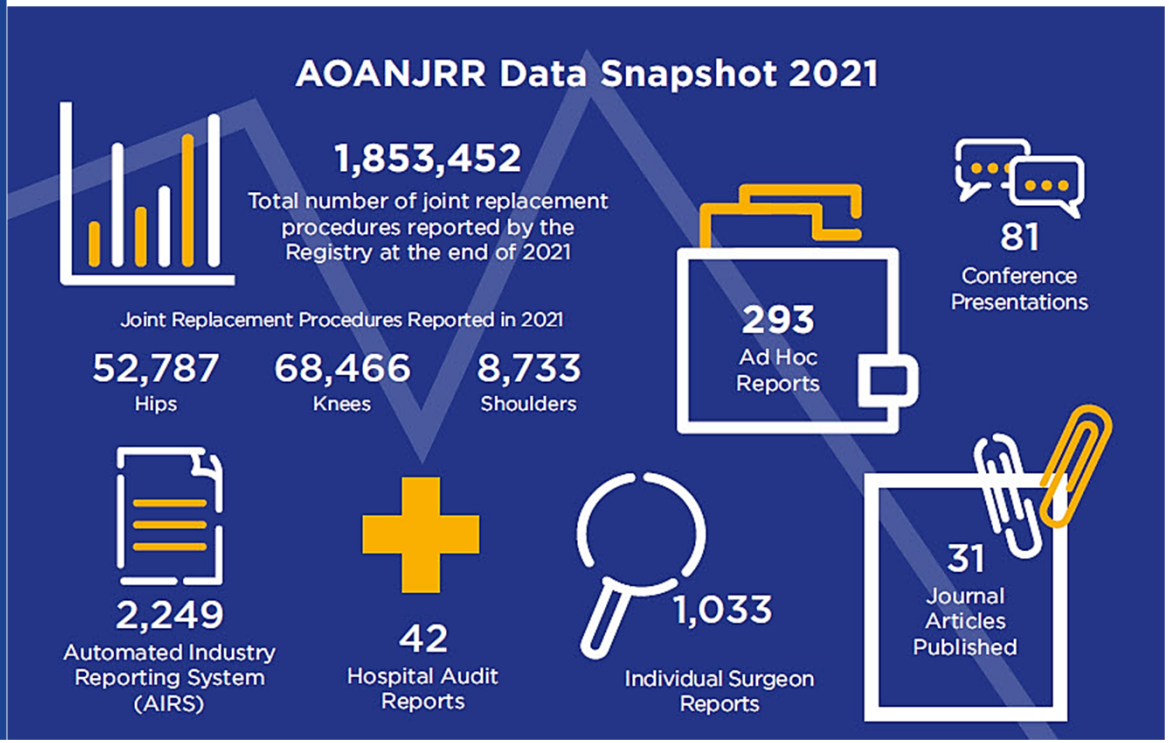
TOTAL HIP PROSTHESES

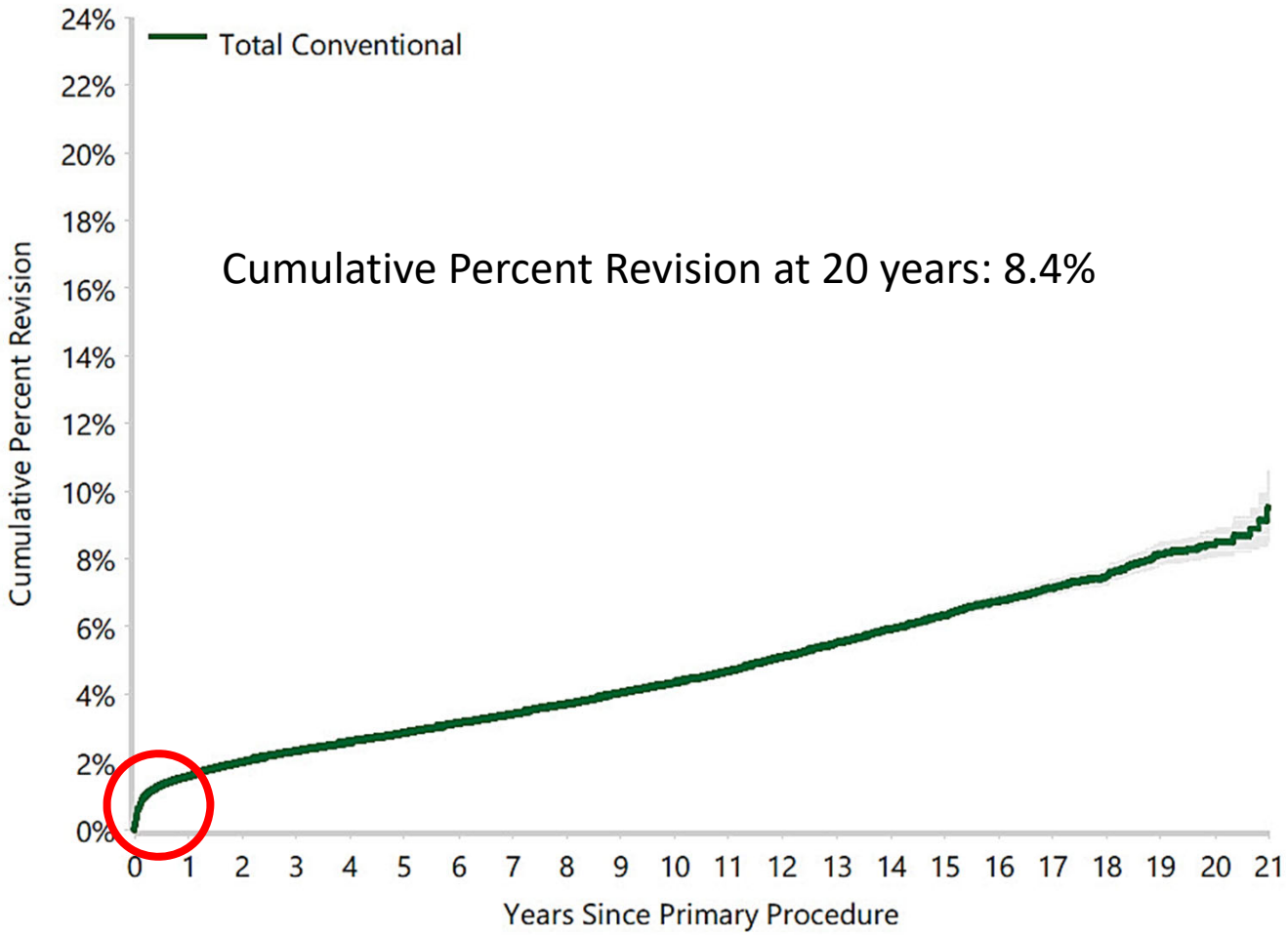


TOTAL HIP PROSTHESES

CLINICAL RESULTS SURVIVAL RATES

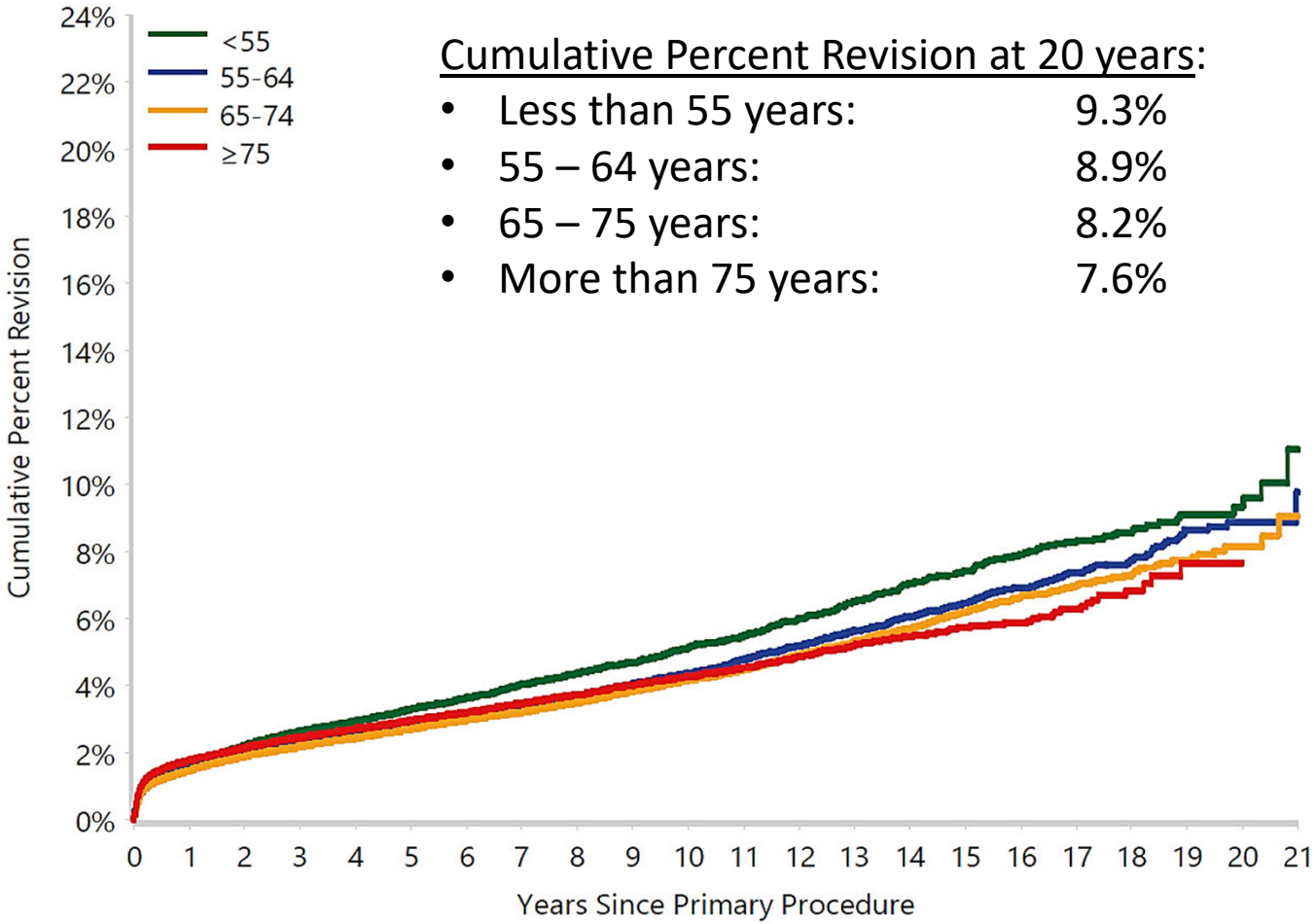





Total Conventional
Cumulative Percent Revision at 20 years: 8.4%
Cumulative Percent Revision
24%
22%
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Years Since Primary Procedure

THE OPERATION OF THE CENTURY: TOTAL HIP REPLACEMENT

- I. Learmonth et al, The Lancet, 370, 2007, p. 1508

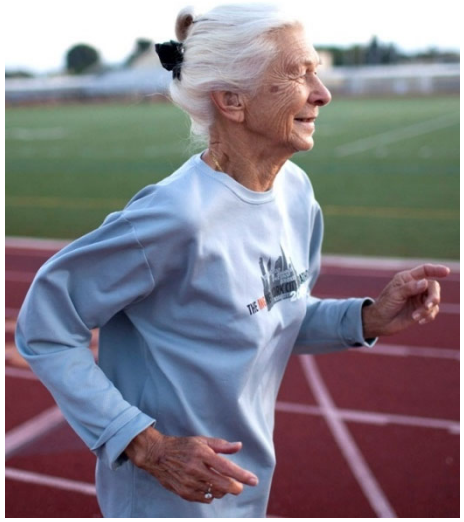


Cumulative Percent Revision at 20 years:

- Less than 55 years: 9.3%
- 55 – 64 years: 8.9%
- 65 – 75 years: 8.2%
- More than 75 years: 7.6%

PATIENT ACTIVITY

- As the mean age of the patients is steadily decreasing, the mean activity of the patients is increasing.



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- Why is tribology important
- Materials
- Possible methodology
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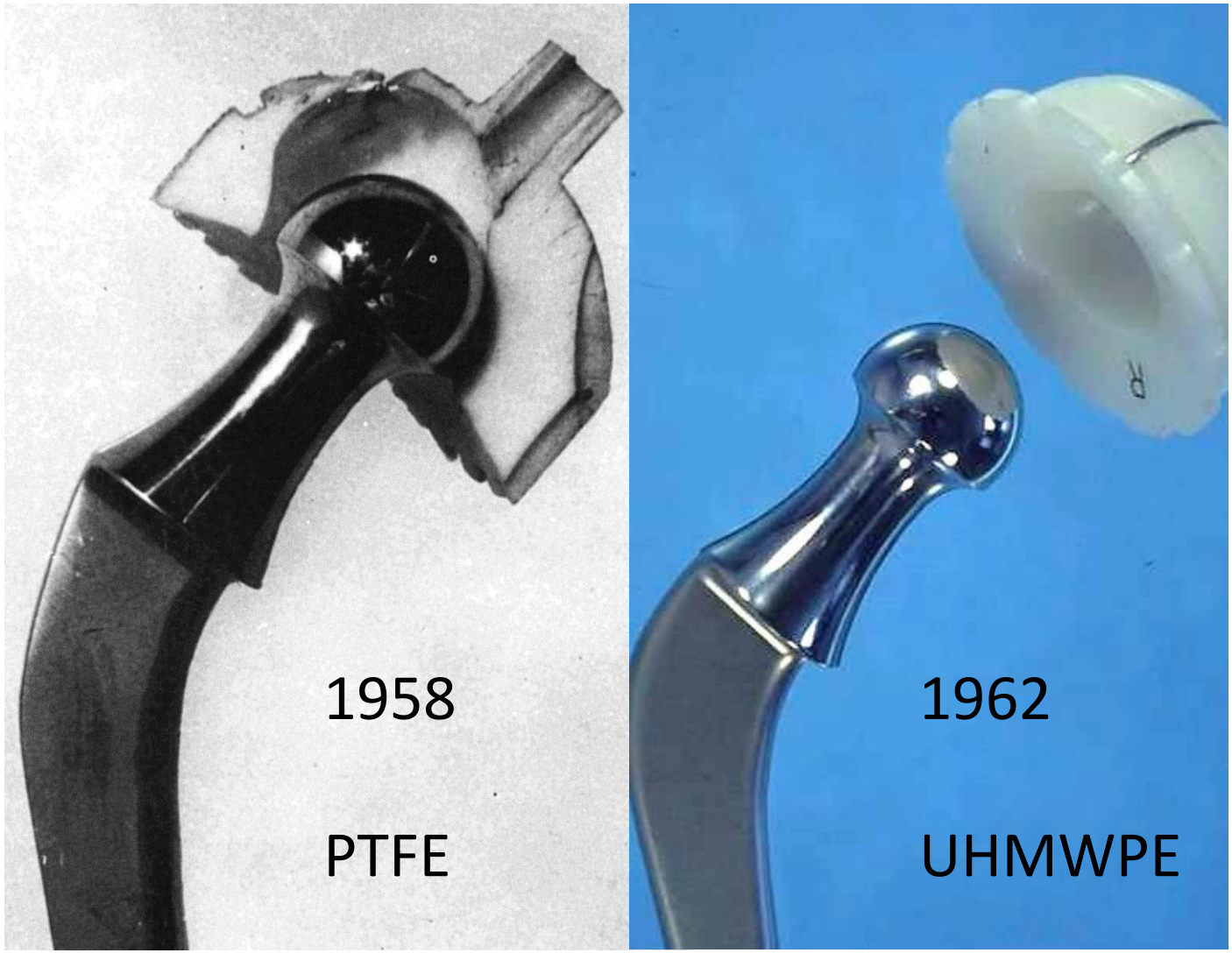
- Conclusions

EPFL



Sir John Charnley
1911 - 1982

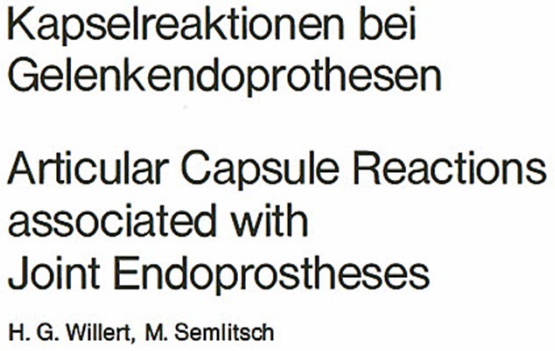
NHS
Wrightington, Wigan and Leigh
NHS Foundation Trust

PARTICLE DISEASE

SULZER

- The first description of this phenomenon was published in 1974 by Prof. H.G. Willert (Germany) and Dr. M. Semlitsch (Sulzer Orthopaedic)

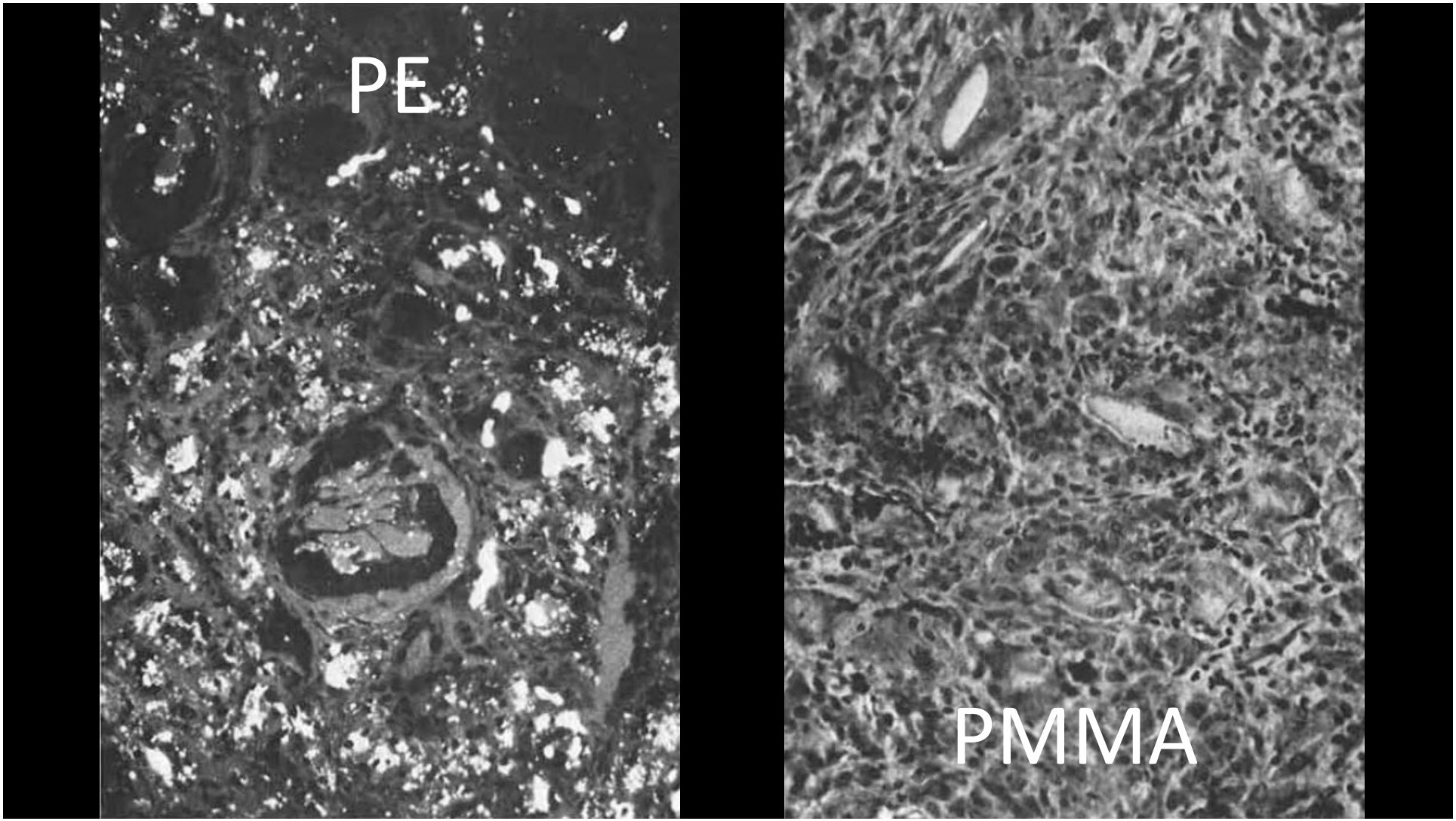
- Dutch-Swiss Orthopaedic Societies, Lausanne, 1974

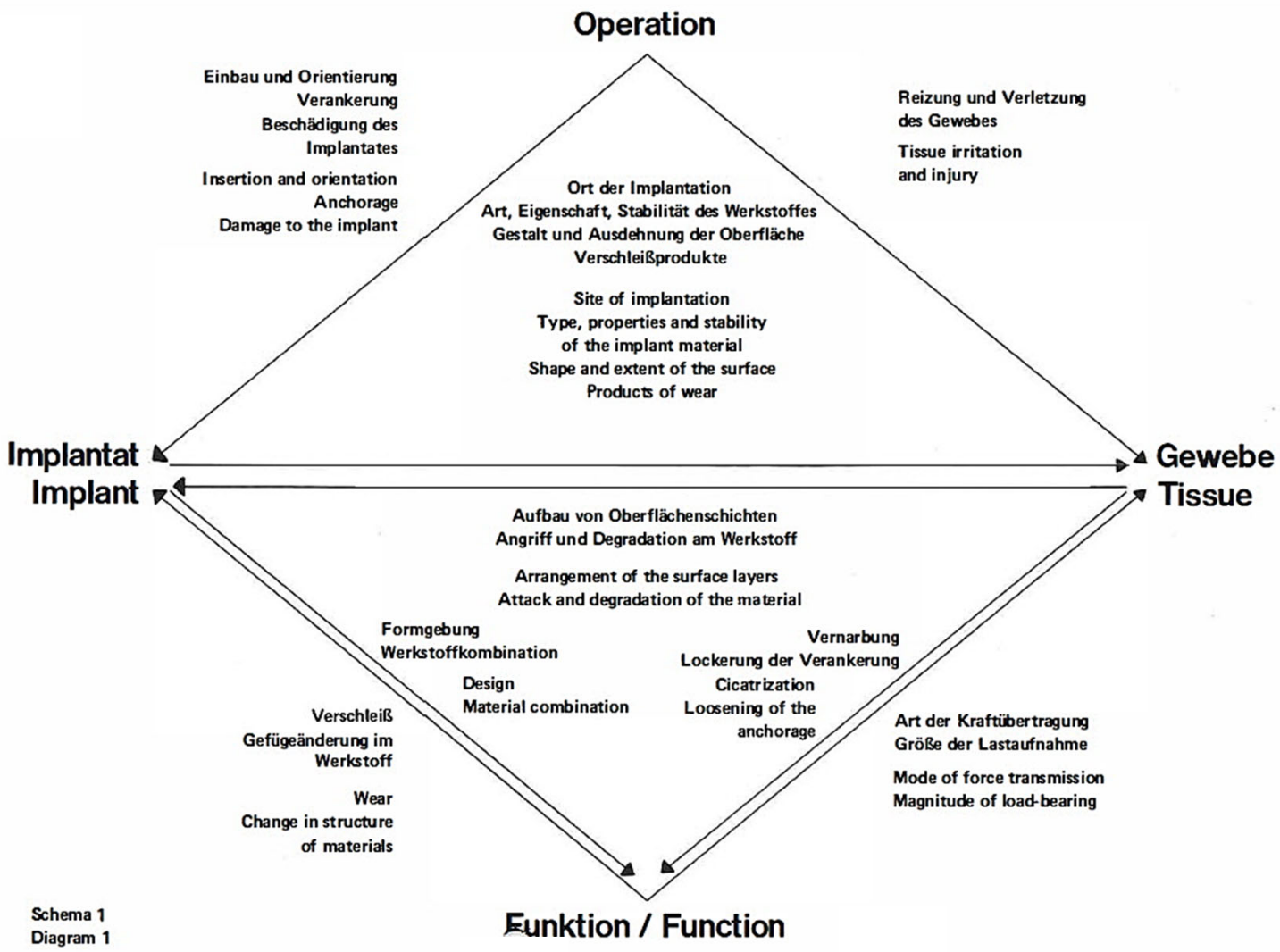


Kapselreaktionen bei Gelenkendoprothesen

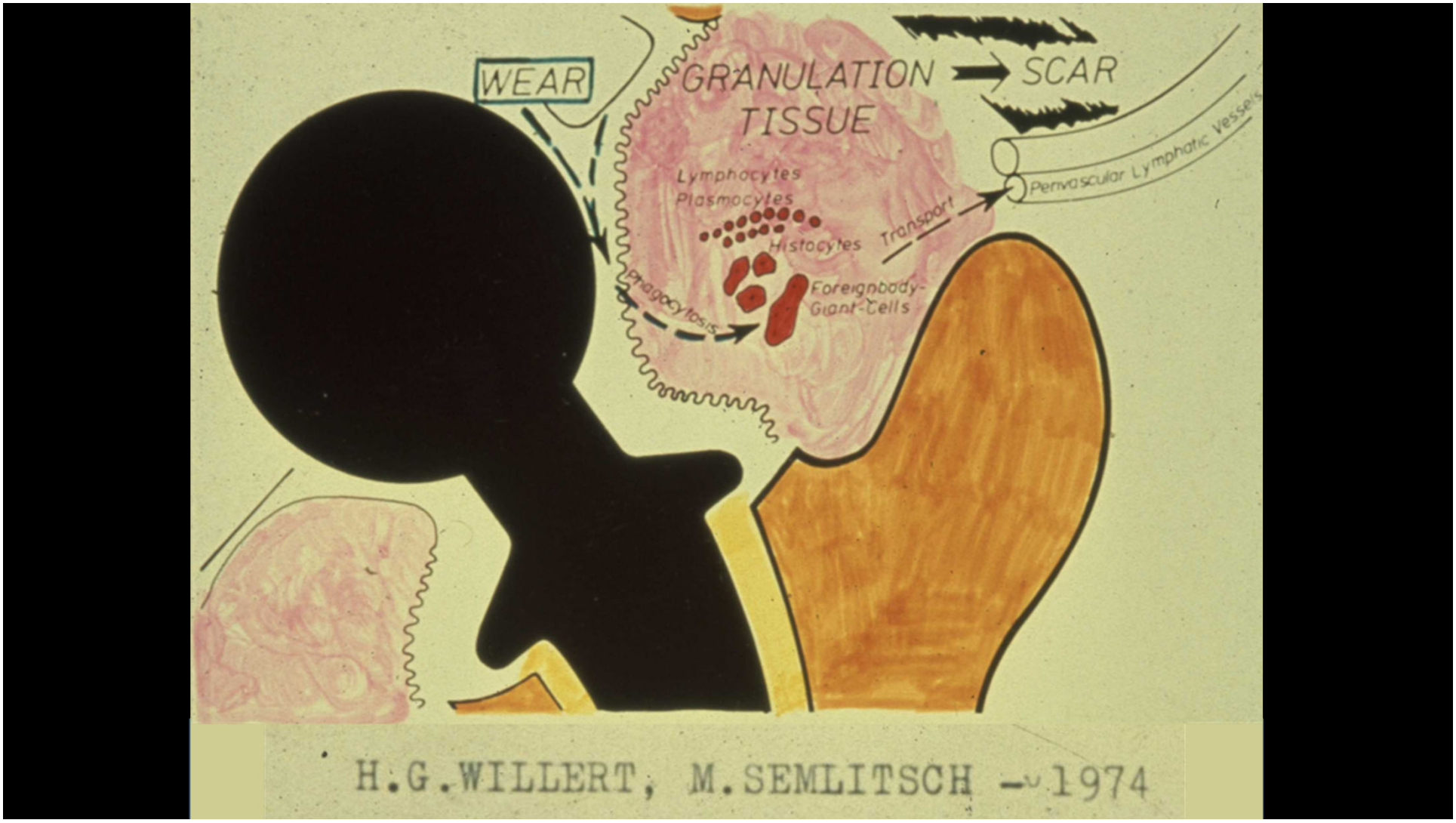
Articular Capsule Reactions associated with Joint Endoprostheses

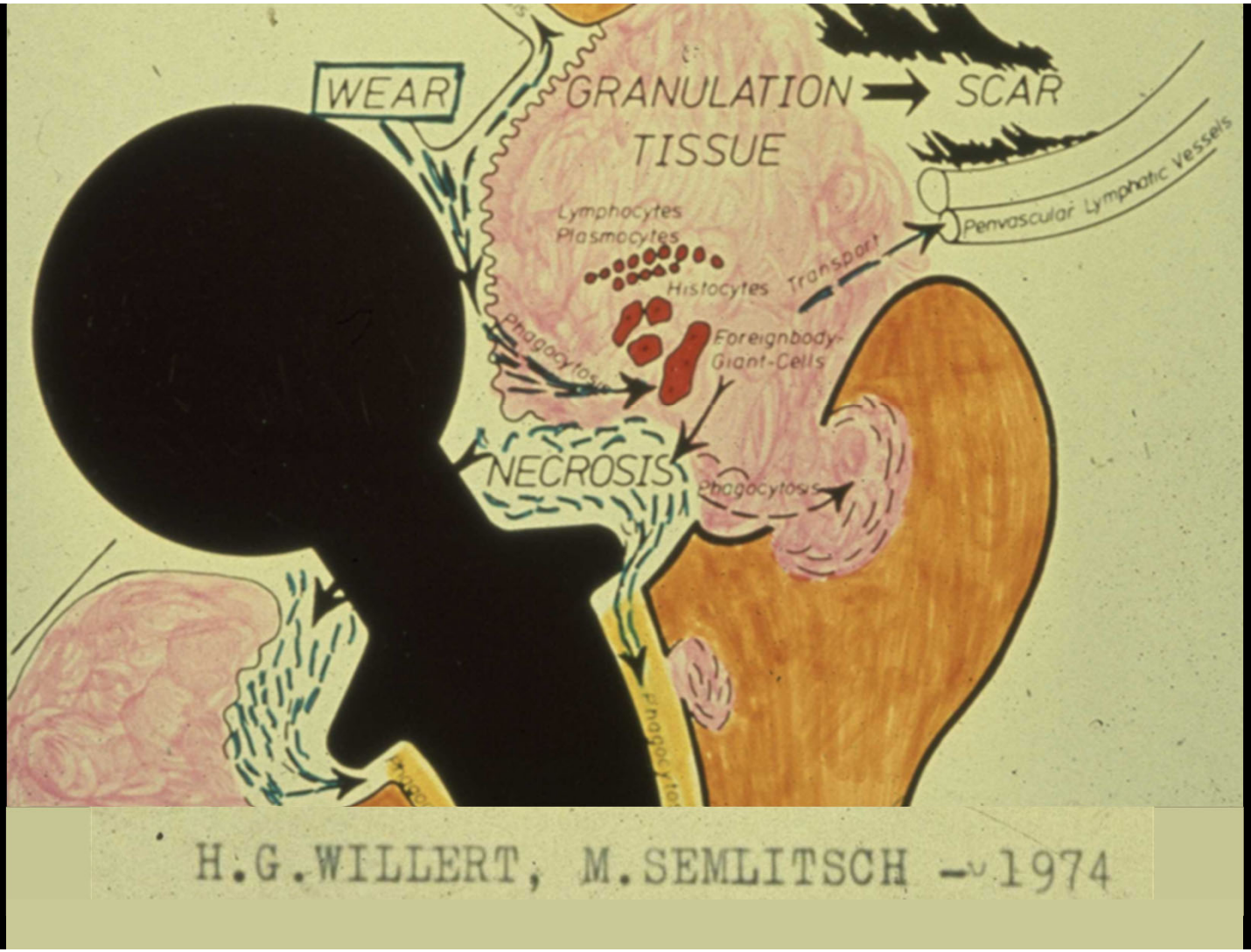
H. G. Willert, M. Semlitsch


PE
PMMA

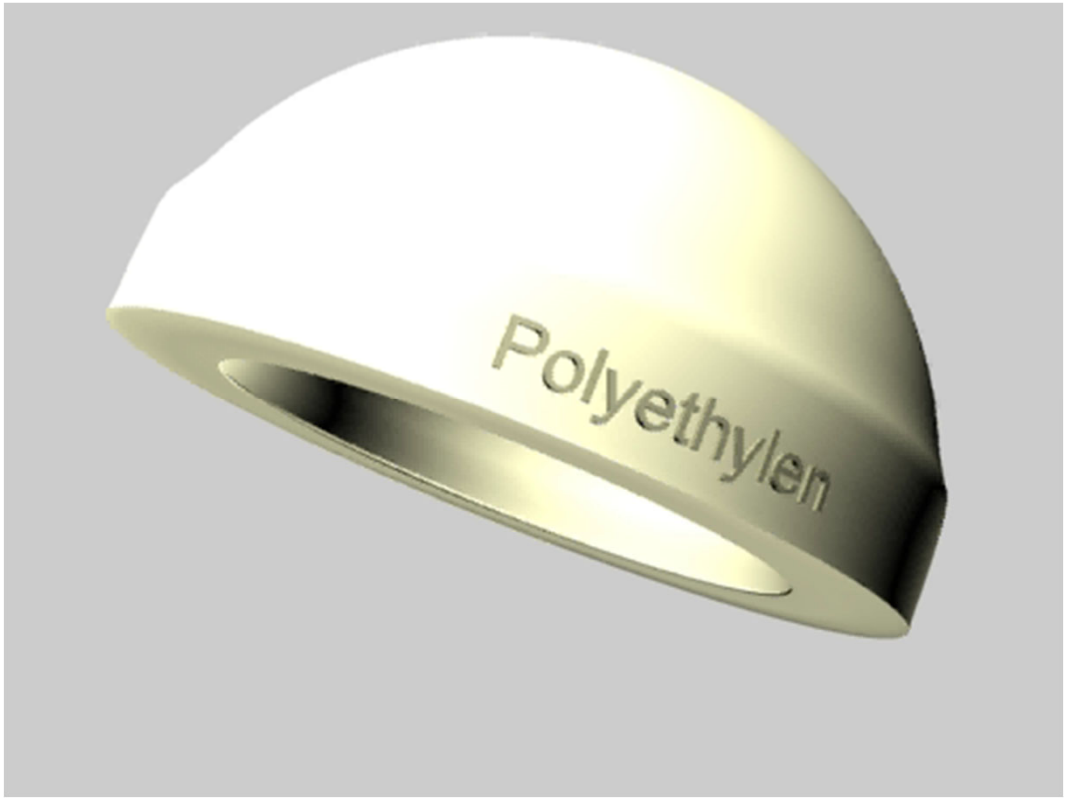


Schema 1
Diagram 1


WEAR
GRANULATION TISSUE
SCAR
Lymphocytes
Plasmocytes
Histocytes
Transport
Foreignbody-Giant-Cells
phagocytosis
Pervascular Lymphatic Vessels
H.G.WILLERT, M.SEMLITSCH - 1974

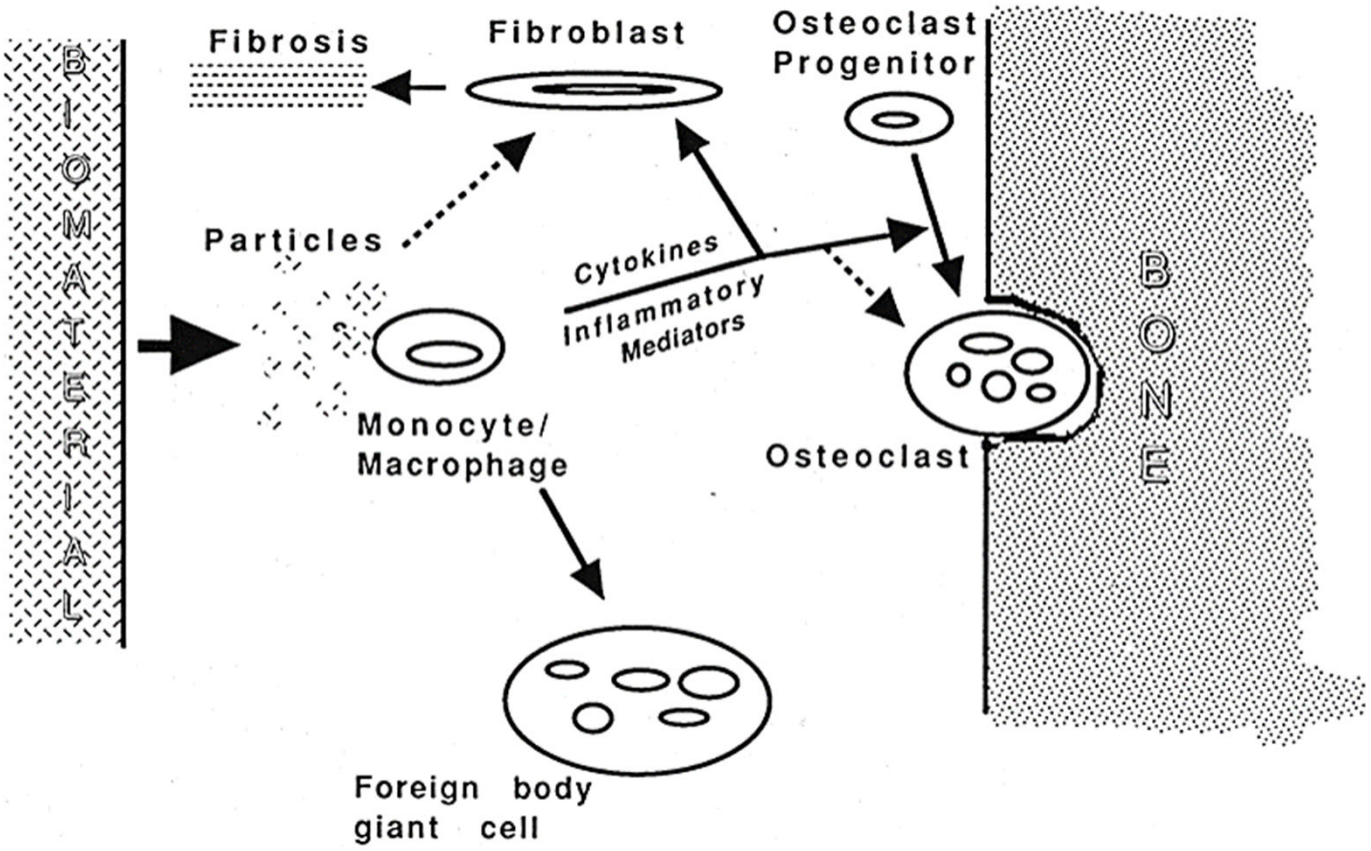

WEAR
GRANULATION TISSUE
SCAR
Lymphocytes
Plasmocytes
Histocytes
Transport
Perivascular Lymphatic Vessels
Phagocytosis
Foreignbody-Giant-Cells
NECROSIS
Phagocytosis
H.G.WILLERT, M.SEMLITSCH - 1974

PARTICLE DISEASE

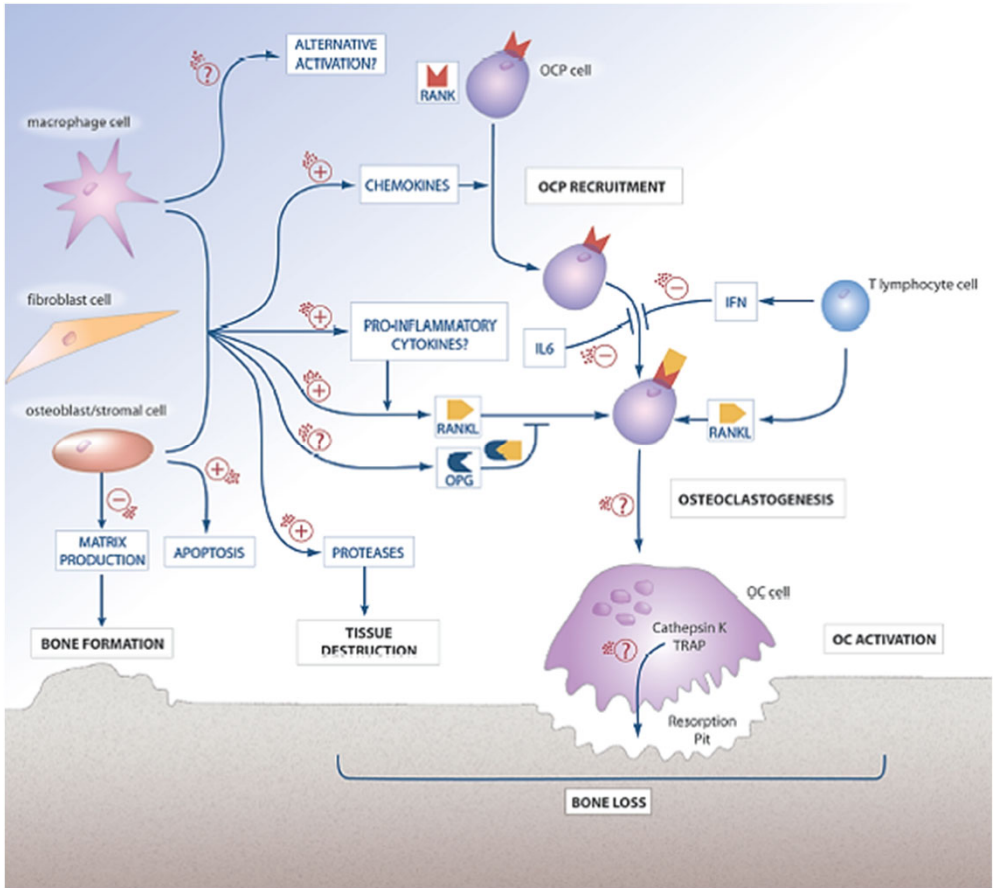


Courtesy of CeramTec

PARTICLE DISEASE



PARTICLE DISEASE

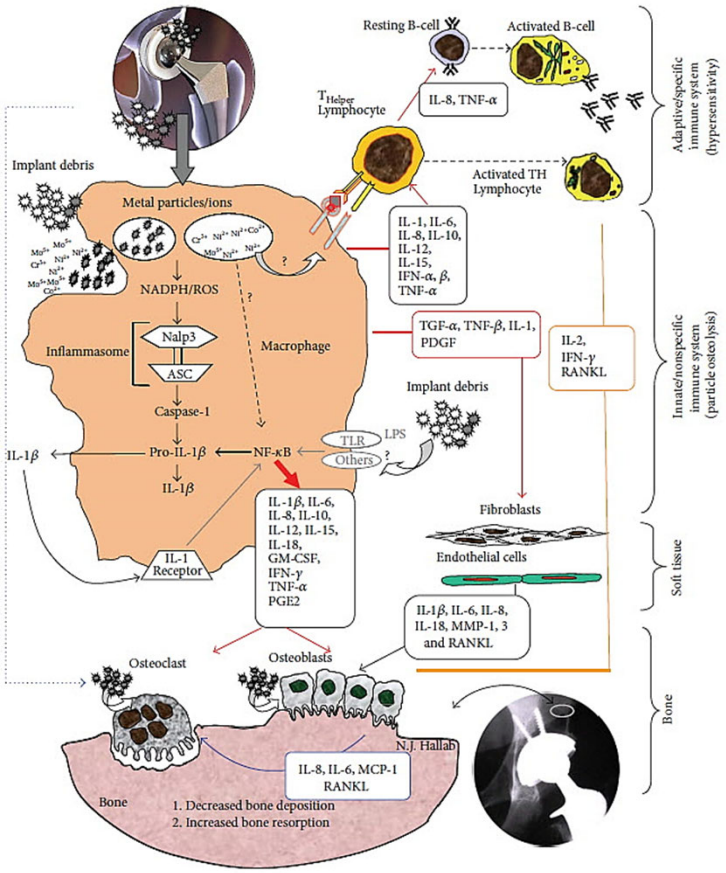


The Cellular and Molecular Biology of Periprosthetic Osteolysis

P.E. Perdue et al

CORR, 454, 2006, p. 454

PARTICLE DISEASE



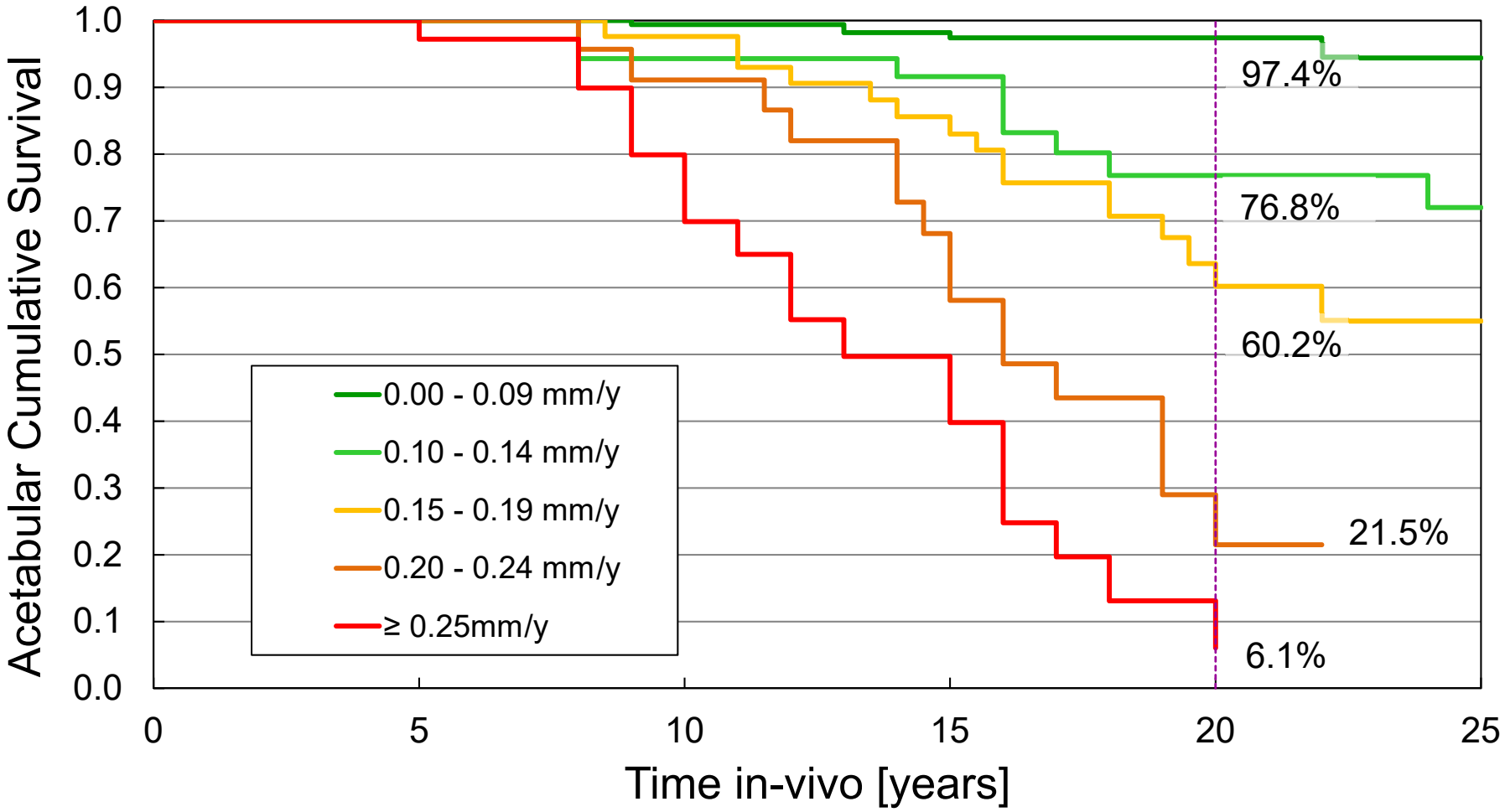
The Pathology of Orthopedic Implant Failure Is Mediated by Innate Immune System Cytokines

S. Landgraeber et al

Mediators Inflamm. 2014:185150

RELATIONSHIP OF ACETABULAR WEAR TO OSTEOLYSIS AND LOOSENING IN THA

- “Increasing annual acetabular wear correlated strongly with aseptic loosening, failure, and revision of the acetabular component.”
- “Increasing annual acetabular wear correlated strongly with aseptic loosening, failure, and revision of the femoral prosthesis.”
- D.H. Sochart, CORR, 363, 1999, p. 135


Acetabular Cumulative Survival
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
5
10
15
20
25
Time in-vivo [years]
0.00 - 0.09 mm/y
0.10 - 0.14 mm/y
0.15 - 0.19 mm/y
0.20 - 0.24 mm/y
≥ 0.25mm/y
97.4%
76.8%
60.2%
21.5%
6.1%

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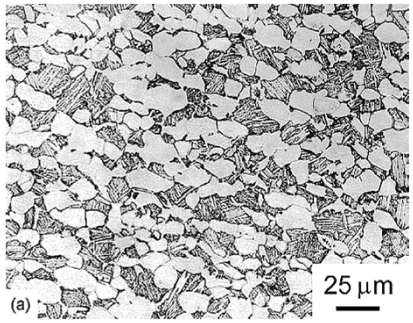
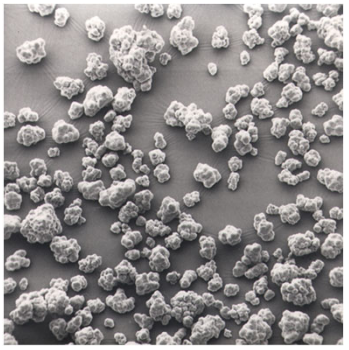
EPFL

- Stem
  - α/β titanium alloy
  - Titanium – 6% aluminium – 4% vanadium



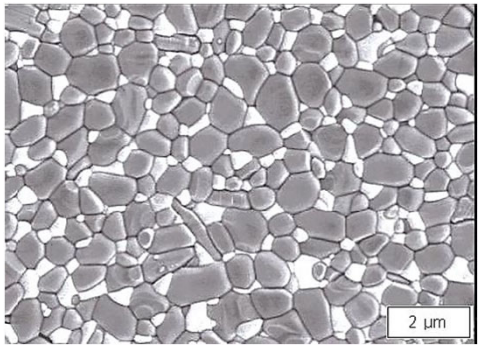
  - ISO 5832-3
    First edition in 1983

- Insert
  - Ultra High Molecular Weight Polyethylene



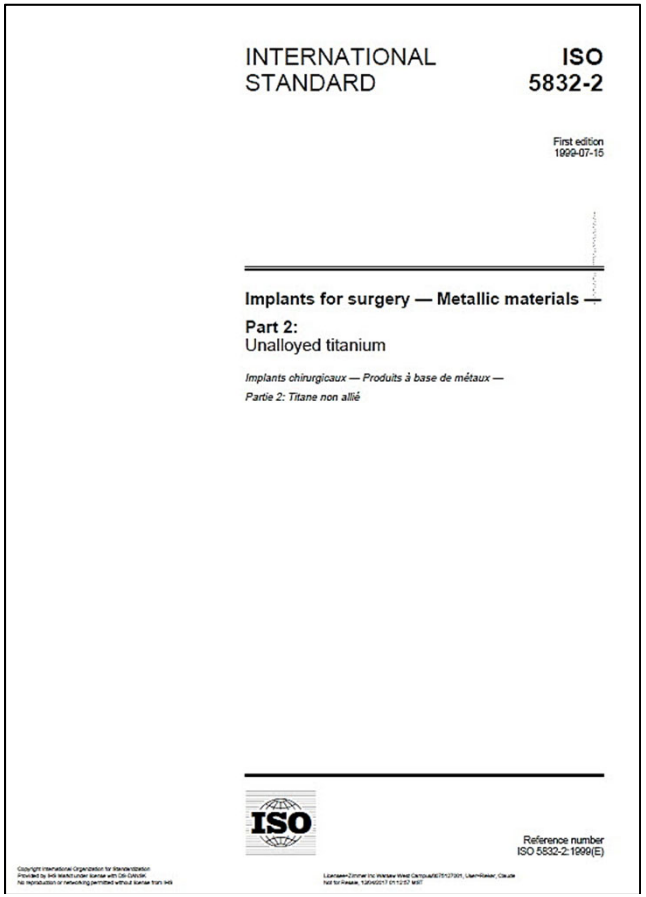
  - ISO 5834-2
    First edition in 1985

- Head
  - 82% alumina – 17% zirconia – 1% different oxides



  - ISO 6474-2
    First edition in 2012

MATERIAUX



INTERNATIONAL STANDARD

ISO 5832-2

First edition
1999-07-15

Implants for surgery — Metallic materials —

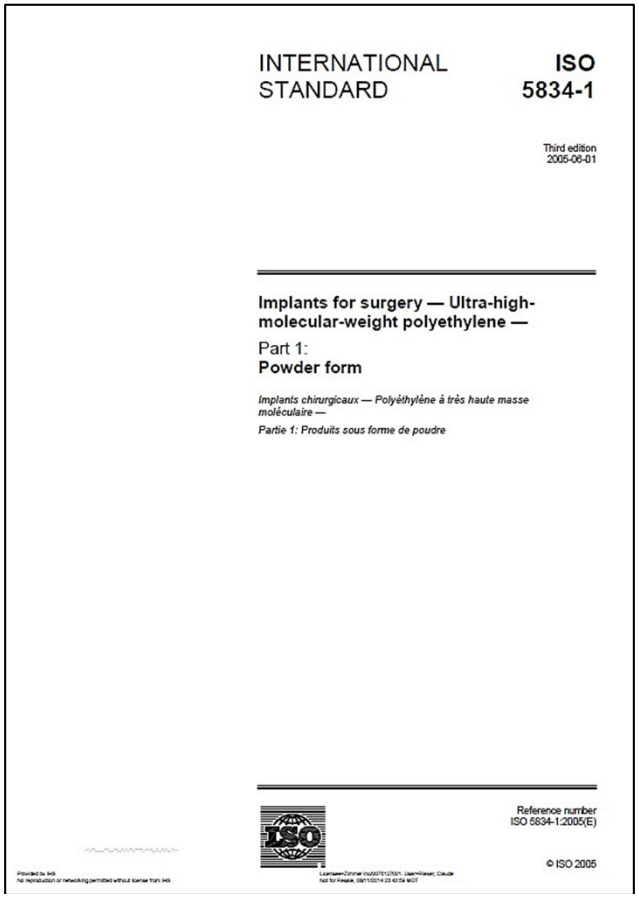
Part 2:
Unalloyed titanium

Implants chirurgicaux — Produits à base de métaux —

Partie 2: Titane non allié

ISO

Reference number
ISO 5832-2:1999(E)



INTERNATIONAL STANDARD

ISO 5834-1

Third edition
2005-06-01

Implants for surgery — Ultra-high-molecular-weight polyethylene —

Part 1:
Powder form

Implants chirurgicaux — Polyéthylène à très haute masse moléculaire —

Partie 1: Produits sous forme de poudre

ISO

Reference number
ISO 5834-1:2005(E)

MATERIAUX

- ISO 5832-1: Stainless steel
- ISO 5832-2: Unalloyed titanium
- ISO 5832-3: Ti6Al4V alloy
- ISO 5832-4: Cast CoCrMo alloy
- ISO 5832-9: Stainless steel (high nitrogen)
- ….

MATERIAUX

- ISO 5834-1: UHMWPE powder
- ISO 5834-2: Moulded UHMWPE
- …
- ISO 6474-1: Alumina
- ISO 6474-2: Zirconia-toughened alumina
- ISO 13356: Zirconia

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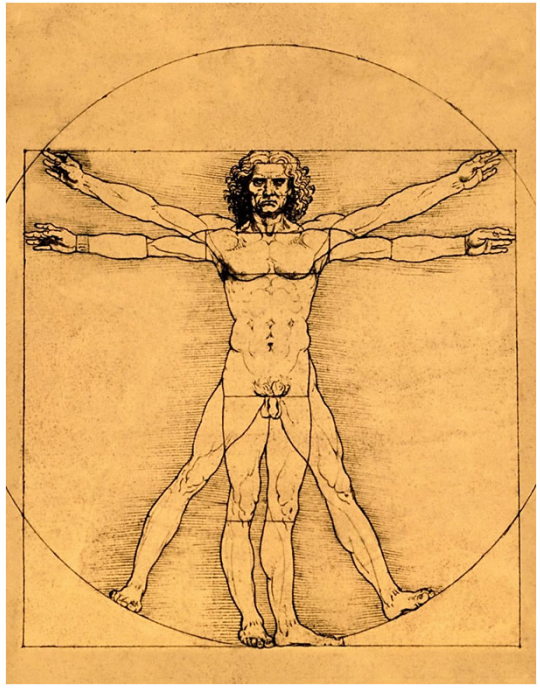
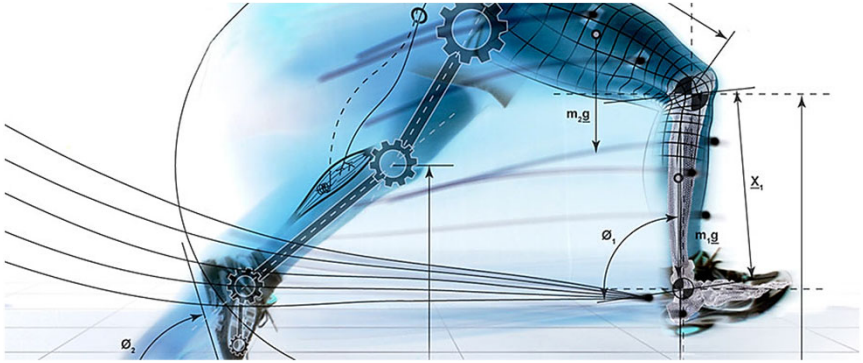
IN-VIVO SITUATION?



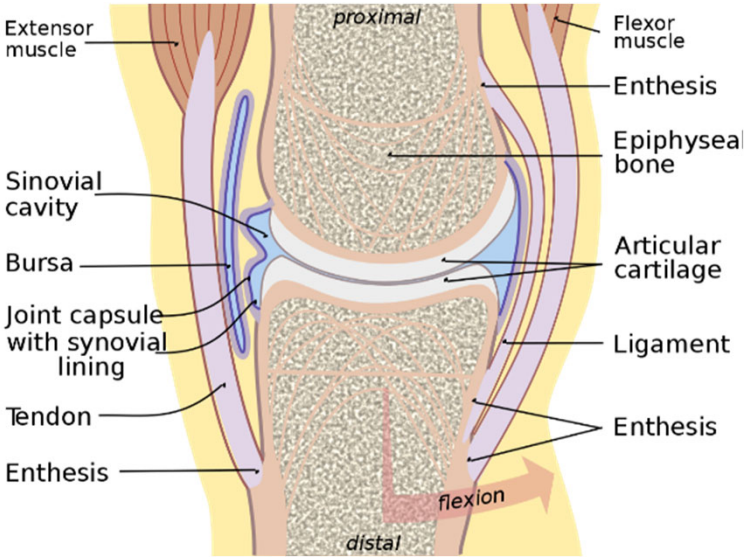
Anatomy

Temperature



Biomechanics

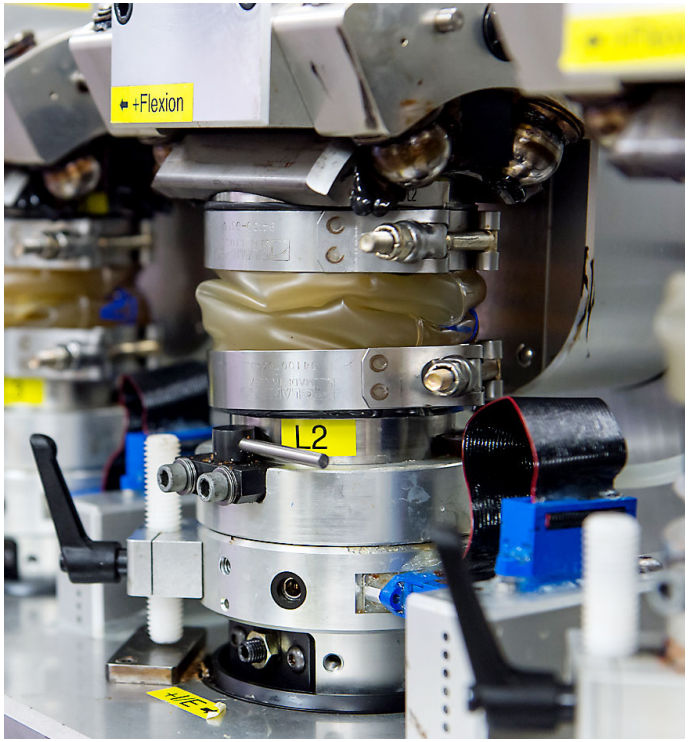
IN-VIVO SITUATION?



Synovial fluid

- Composition:
  - Proteins: 1.8 g/dl
    Albumin 60%
    Globulin 40%
  - Hyaluronate: 0.3 g/dl
  - Glucose: 90 mg/dl
  - Uric acid: 5 mg/dl

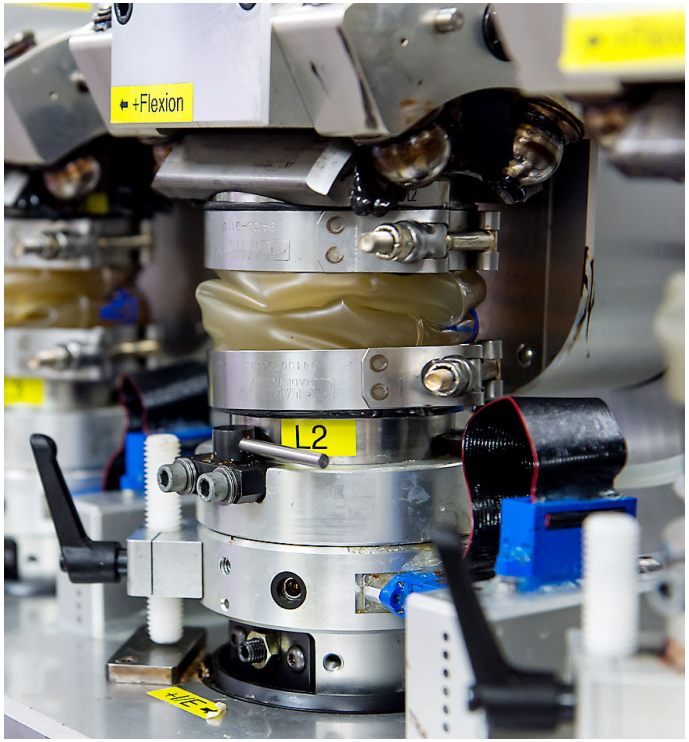
IN-VITRO SITUATION?



Hip simulator

- Composition:
  - 33% Calf serum
  - 67% Ringer solution
  - Proteins concentration: 2 g/dl
  - Filtration by a 0.2 µm filter
  - pH: 7.2

IN-VITRO SITUATION?



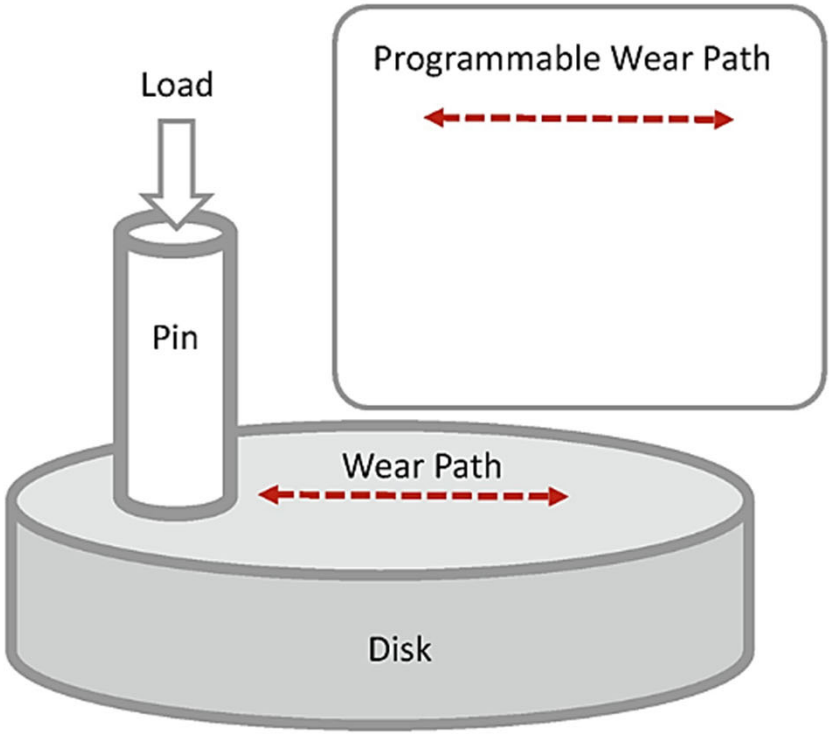
Hip simulator

- Composition:
  - Diluted calf serum
  - Deionized water
  - Proteins concentration: 3 g/dl
  - Filtration by a 0.2 µm filter
  - Antimicrobial reagent: Sodium azide

PIN-ON-DISC

- For a first material evaluation, there is a need for screening tests with the following characteristics:
  - Same wear mechanism
  - Same amount of wear
- First standardized tests were developed in the early 80's (ASTM F-732).

PIN-ON-DISC



ABRASIVE / ADHESIVE WEAR
ARCHARD EQUATION

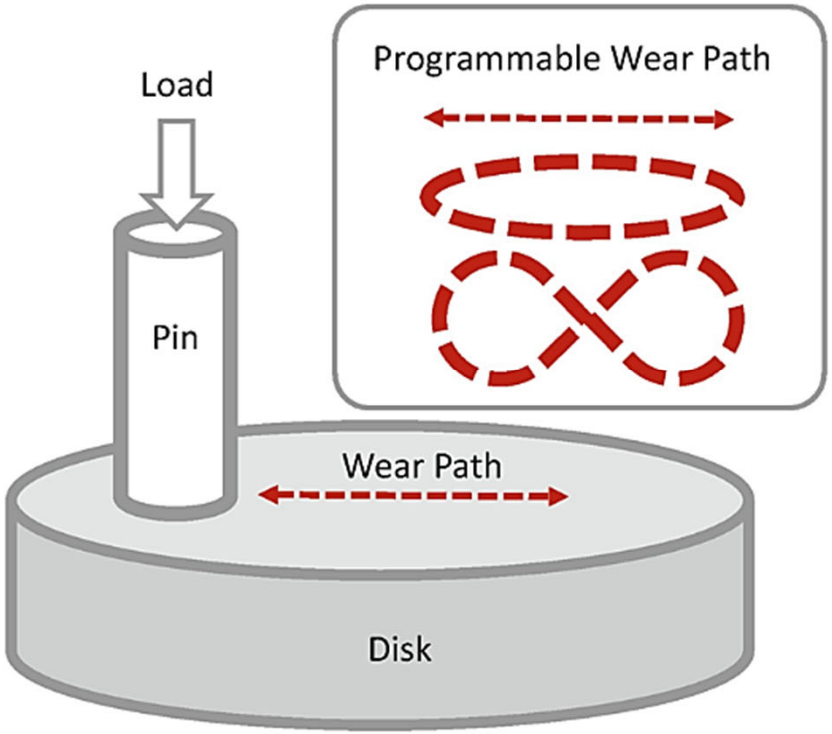
- V: Wear Volume
- L: Normal load
- W: Distance
- H: Hardness
- K_{Wear}: Wear Factor
  Abrasive: $10^{-4} – 10^{-1}$
  Adhesive: $10^{-7} – 10^{-2}$

$$V = K_{Wear} \cdot \frac{WL}{3H}$$

COMPARATIVE STUDY OF THE WEAR OF UHMWPE WITH ZRO_2 AND STAINLESS STEEL FEMORAL HEADS IN ARTIFICIAL HIP JOINTS

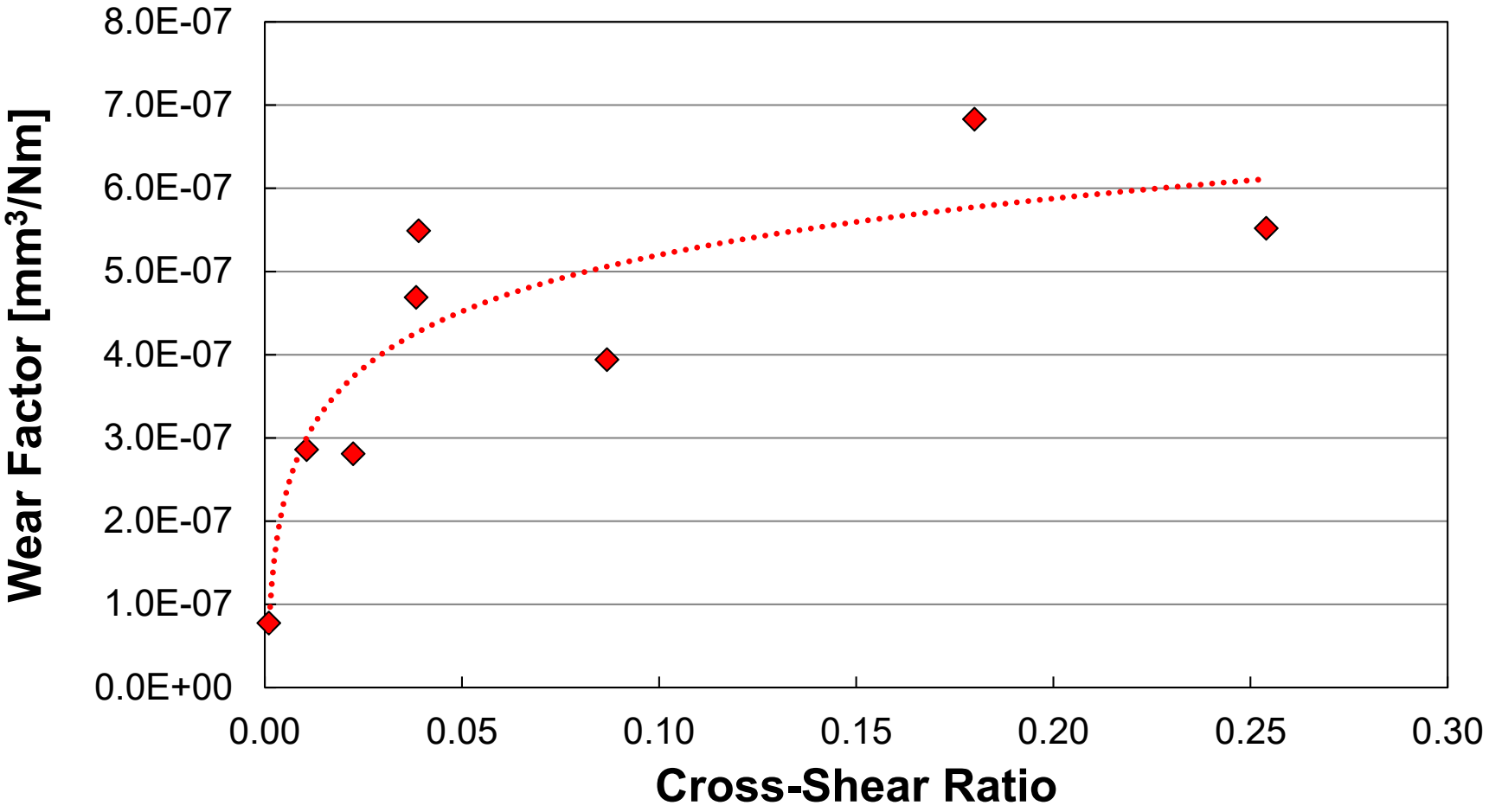
- In-vitro wear factors: about 10^{-8} mm^3/Nm
- In-vivo wear factors: about 10^{-6} mm^3/Nm
- B. Derbyshire et al, Med Eng Phys, 16, 1994, p. 229

PIN-ON-DISC



QUANTIFICATION OF THE EFFECT OF CROSS-SHEAR ON THE WEAR OF CONVENTIONAL AND XLPE UHMWPE

- Cross-shear increased the apparent wear factor for both polyethylenes by more than fivefold compared to unidirectional wear.
- L. Kang et al, JoB, 14, 2008, p. 340


8.0E-07
7.0E-07
6.0E-07
5.0E-07
4.0E-07
3.0E-07
2.0E-07
1.0E-07
0.0E+00
Wear Factor [mm³/Nm]
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Cross-Shear Ratio

AMTI – HIP SIMULATOR

AMTI – HIP SIMULATOR

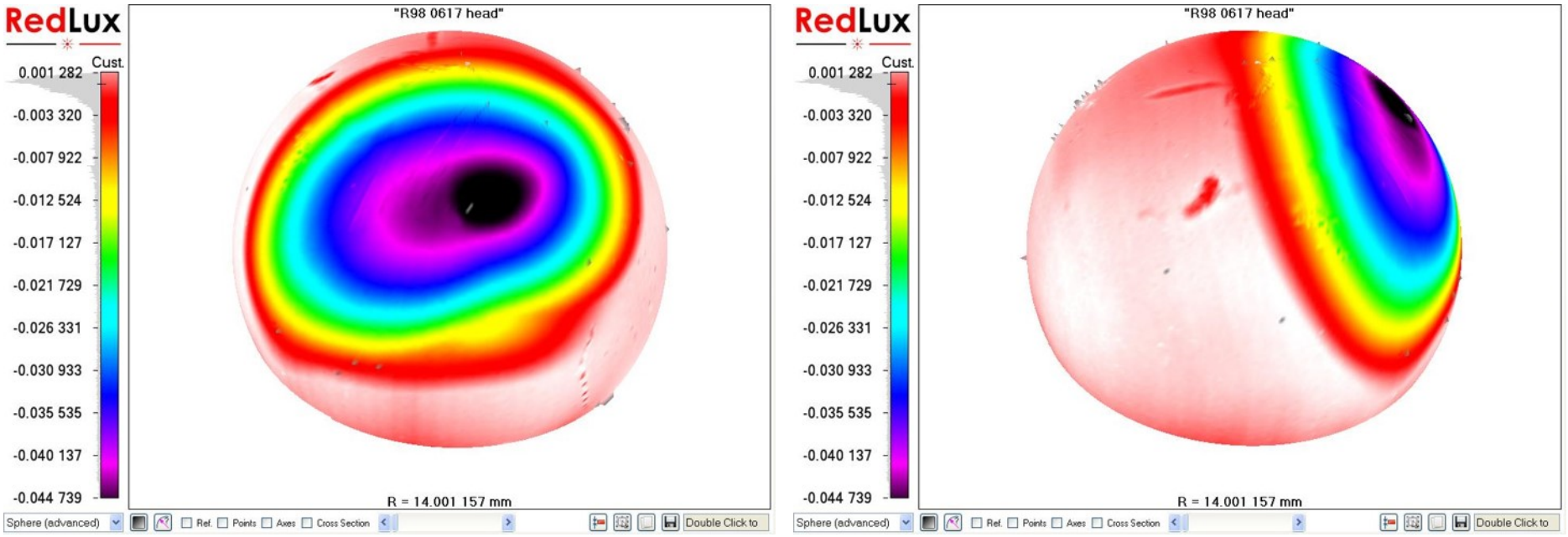
HIP SIMULATOR

- AMTI – ISO 14'242-1:
  - Flexion - Extension: 25° - 18°
  - Abduction - Adduction: 7° - 4°
  - Int. - Ext. Rotation: 2° - 10°
  - Maximum load (double peak): 3'000 N
  - Temperature: 37 °C
  - Frequency: 1.0 Hz

HOW TO MEASURE THE WEAR?

- Gravimetric method:
  - High resolution balance (better than 0.2 mg)
  - Fluid absorption
  - Material transfer
- Dimensional method:
  - High resolution method (better than 1 µm)
  - Volume of measurement: 12 – 8 – 8 cm
  - Creep

OPTICAL SENSOR



800’000 measuring points / 20 nm resolution

ELSEVIER
SAUNDERS

Orthop Clin N Am 36 (2005) 135 – 142

ORTHOPEDIC
CLINICS
OF NORTH AMERICA

Influence of the Clearance on In-Vitro Tribology of Large Diameter Metal-on-Metal Articulations Pertaining to Resurfacing Hip Implants

Claude B. Rieker, PhD[a,*], Rolf Schön[a], Reto Konrad[a], Gernot Liebentritt[a], Patric Gnepf[a], Ming Shen[a], Paul Roberts, MA(Oxon), MB, FRCS[b], Peter Grigoris, FRCS, FACS[c,d]

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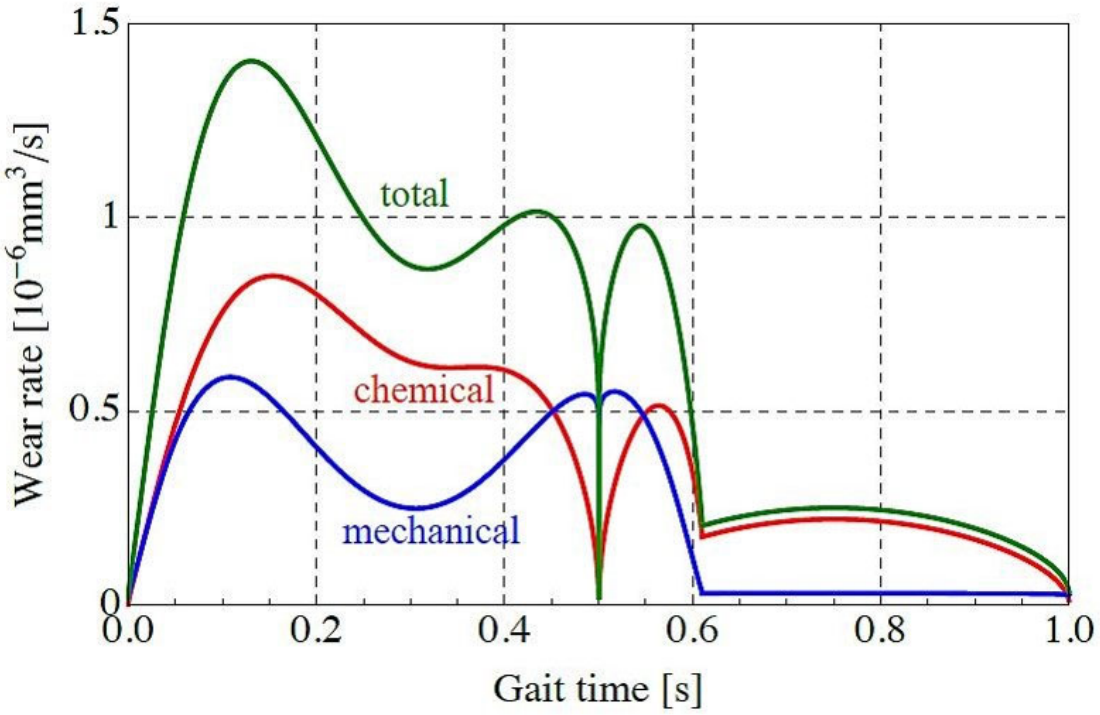
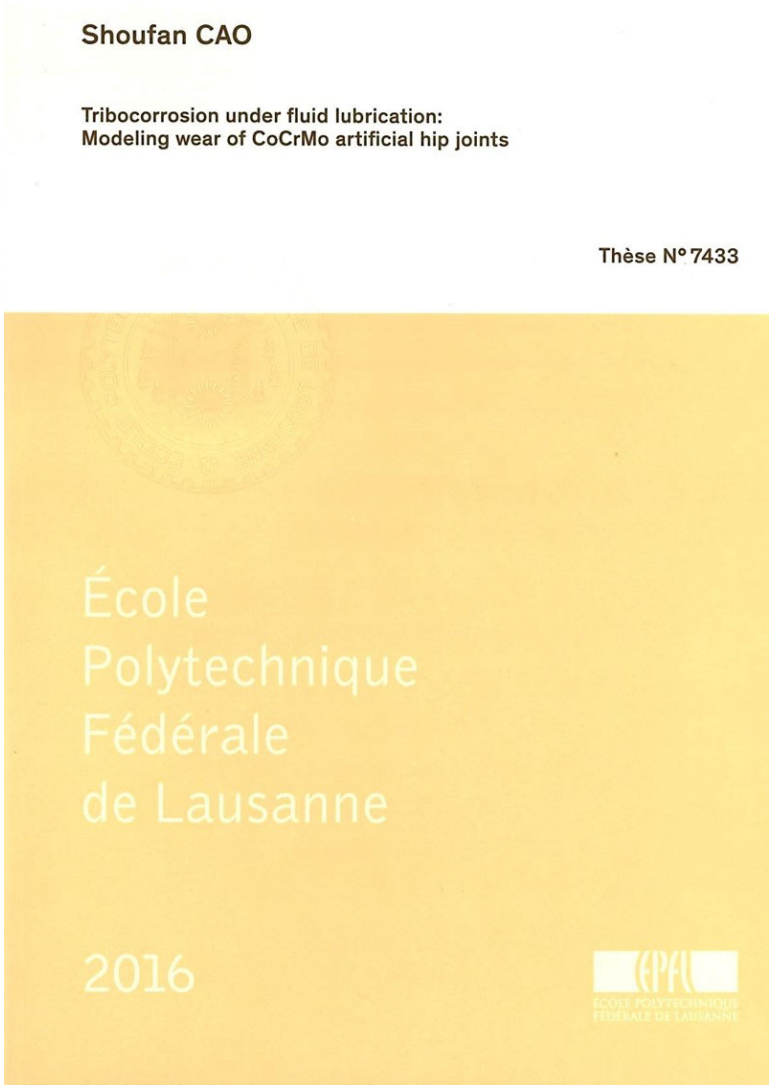
[b]*Department of Orthopaedics and Trauma, Royal Gwent Hospital, Cardiff Road, Newport NP9 2UB, Wales, UK*
[c]*2nd Orthopaedic Department, University of Athens, Ag. Olga Hospital, 142 33 N. Ionia, Athens, Greece*
[d]*Department of Medical Engineering, School of Engineering, Design, and Technology, University of Bradford, Richmond Road, Bradford, West Yorkshire BD7 1DP, UK*

TRIBOCORROSION





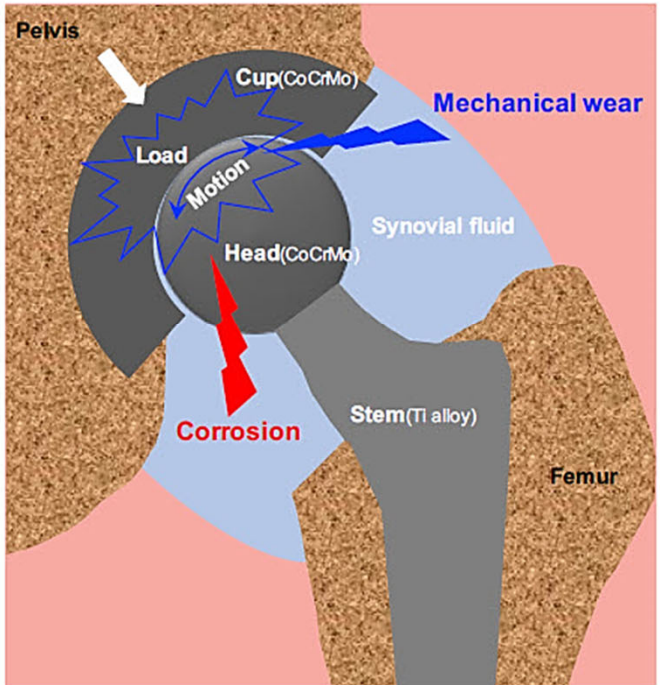
Rationalizing the in-vivo degradation of metal-on-metal artificial hip joints using tribocorrosion concepts

Shoufan Cao,[1]* Anna Igual Muñoz[1,2], and Stefano Mischler[1]

[1] *Ecole Polytechnique Fédérale de Lausanne (EPFL), Tribology and Interface Chemistry Group (SCI-STI-SM), Station 12, CH-1015 Lausanne, Switzerland*

[2] *Universitat Politècnica de València (UPV), Research Institute for Industrial, Radiophysical and Environmental Safety (ISIRYM), Camino de Vera s.n. 46022, Valencia, Spain*

*Corresponding author. Telephone: +41 21 6932948. E-mail: shoufan.cao@epfl.ch.



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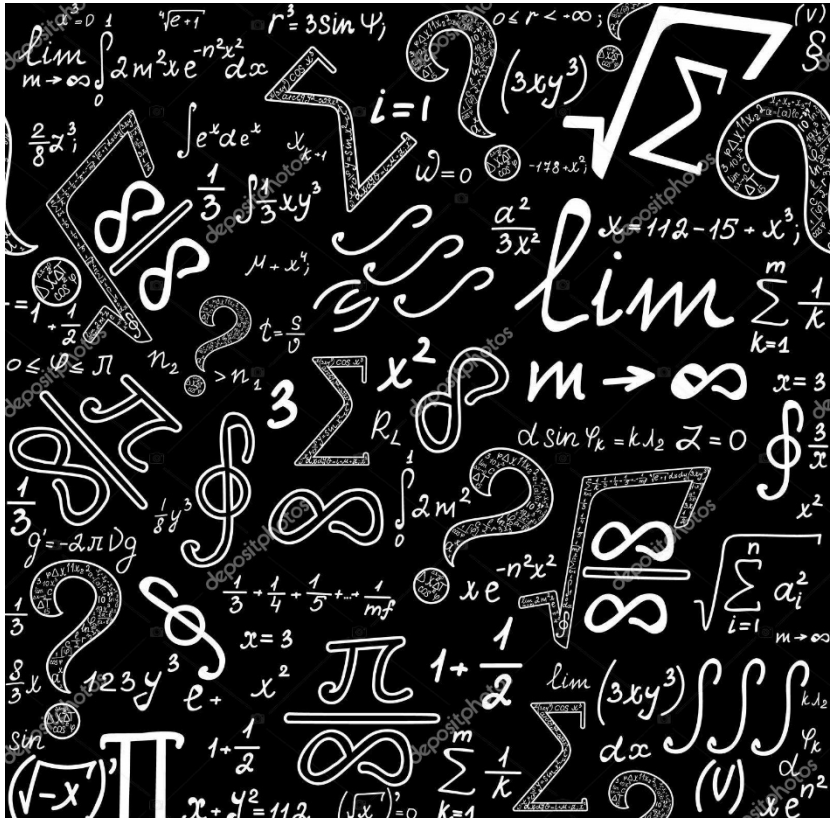
Accepted Day Month Year
Available Day Month Year

HIP SIMULATOR

- Open questions:
  - Acetabular Liner/Shell Angle
  - Third Body Particles
  - Changing Load Parameters
  - Stop-Dwell-Start (Stiction)
  - Microseparation
  - Corrosion
  - …

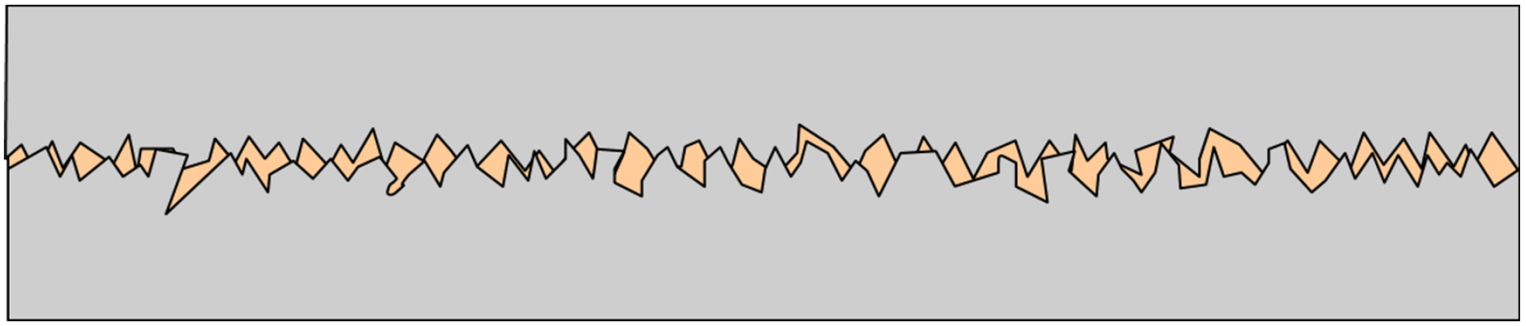
ANALYTIC APPROACH?

- Difficult to the (too) large number of parameters
- The wear and the friction are controlled by the whole system



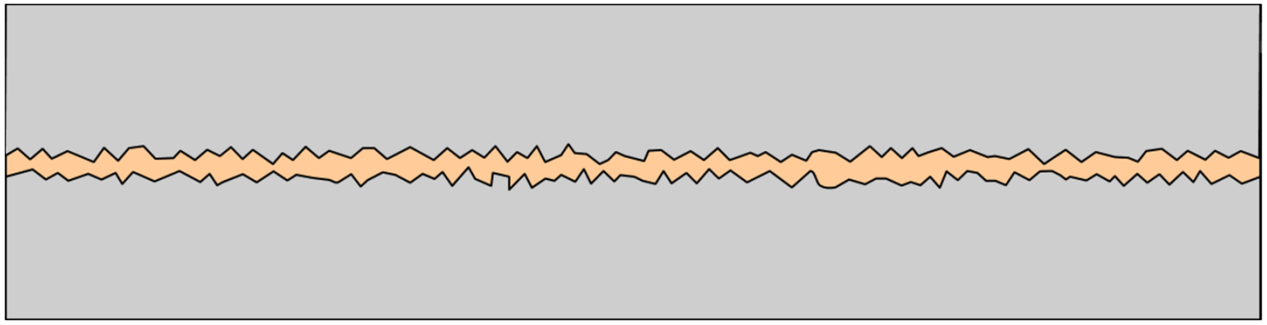
BOUNDARY LUBRICATION

- The thickness of the lubricant is not high enough to avoid a contact between the head and the cup.



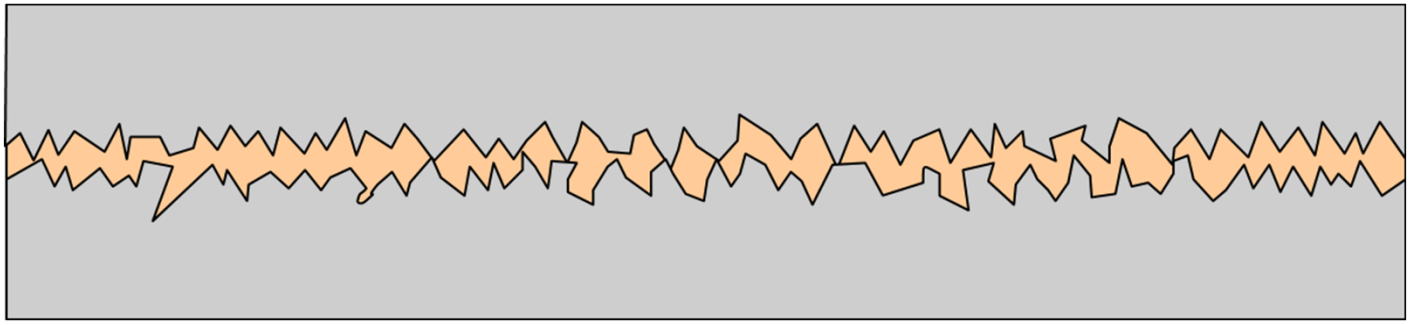
FLUID FILM LUBRICATION

- The thickness of the lubricant is high enough to avoid a contact between the head and the cup.



MIXED LUBRICATION

- Intermediate situation between the boundary and fluid film lubrication.



LUBRICATION OF HARD-ON-HARD ARTICULATIONS

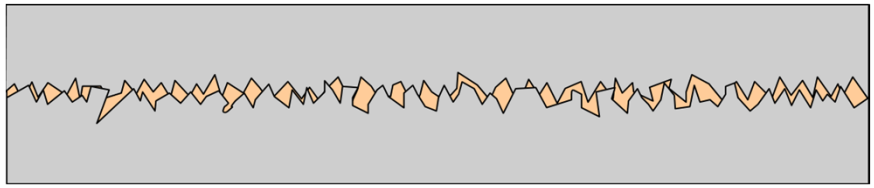
- The lambda coefficient λ describes the lubrication mode:

$$\lambda = \frac{h_c}{\sqrt{R_{q_{Cup}}^2 + R_{q_{Head}}^2}}$$

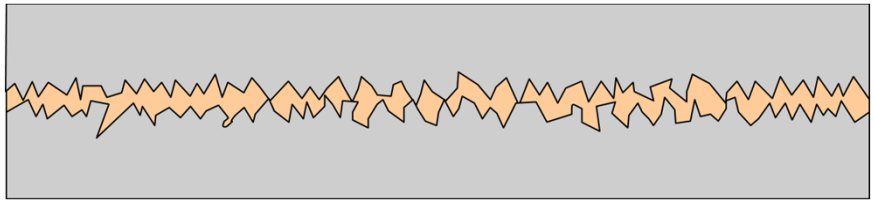
  - h_c: Central film thickness
  - R_q: Root mean square roughness

MODE OF LUBRICATION

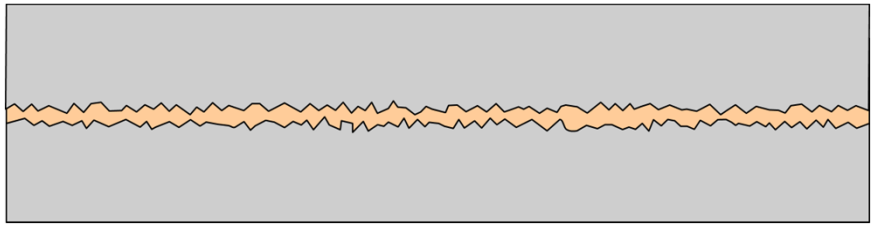
- Boundary lubrication
  Lambda < 1



- Mixed lubrication
  1 < Lambda < 3



- Fluid film lubrication
  Lambda > 3



LUBRICATION OF HARD-ON-HARD ARTICULATIONS

- The lambda coefficient λ describes the lubrication mode:

$$\lambda = \frac{h_c}{\sqrt{R_{q_{Cup}}^2 + R_{q_{Head}}^2}}$$

  - h_c: Central film thickness
  - R_q: Root mean square roughness

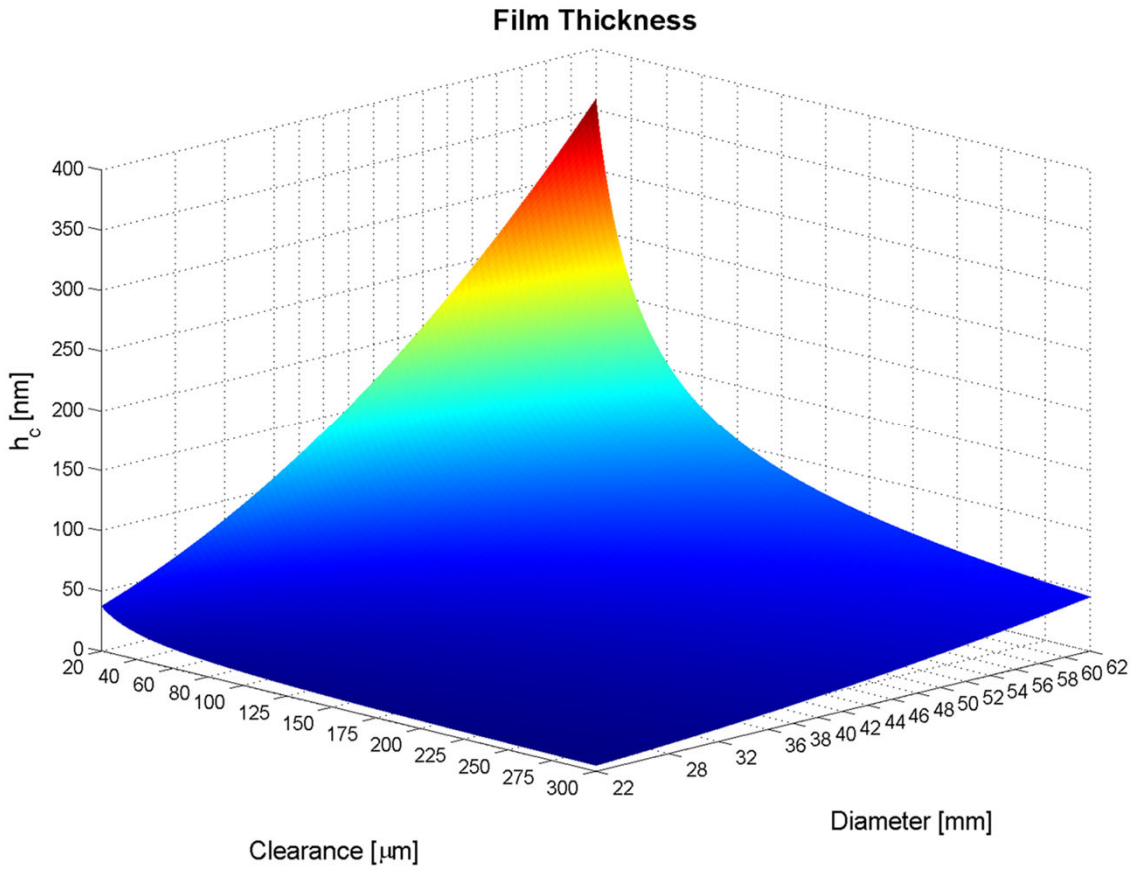
FILM THICKNESS

- Hamrock - Dowson equation (1978):

$$h_c = 2.80R\left(\frac{nu}{E'R}\right)^{0.65}\left(\frac{w}{E'R^2}\right)^{-0.21}$$

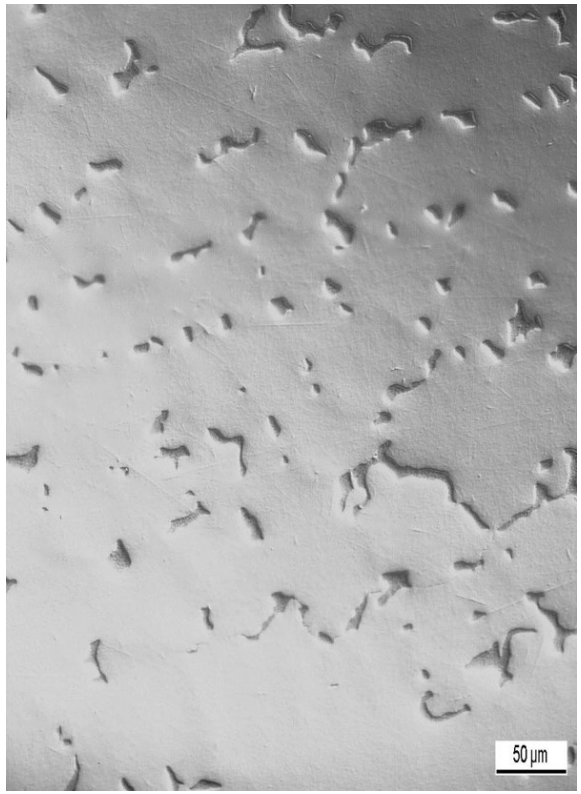
- h_c: Central film thickness
- R: Relative radius
- n: Viscosity
- u: Relative velocity
- E’: Equivalent elastic modulus
- w: Load

LUBRICATION

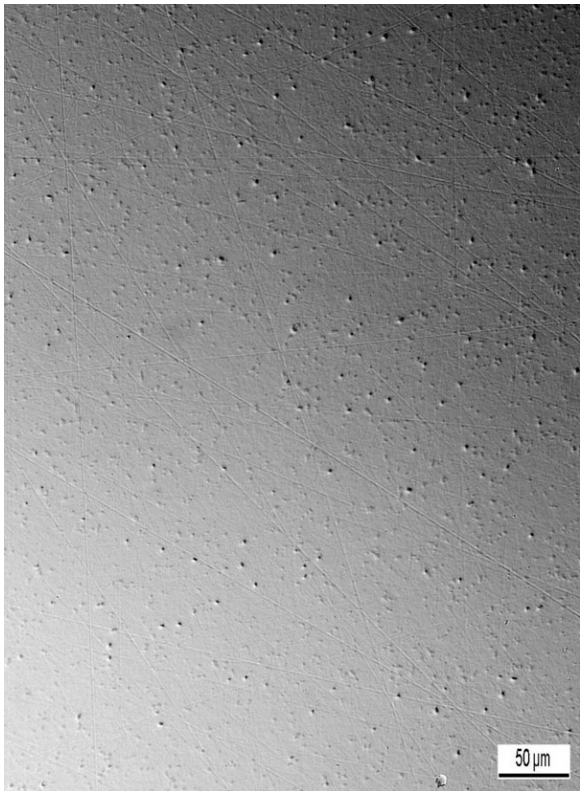


Load: 3000 N
Viscosity: 0.005 Pas

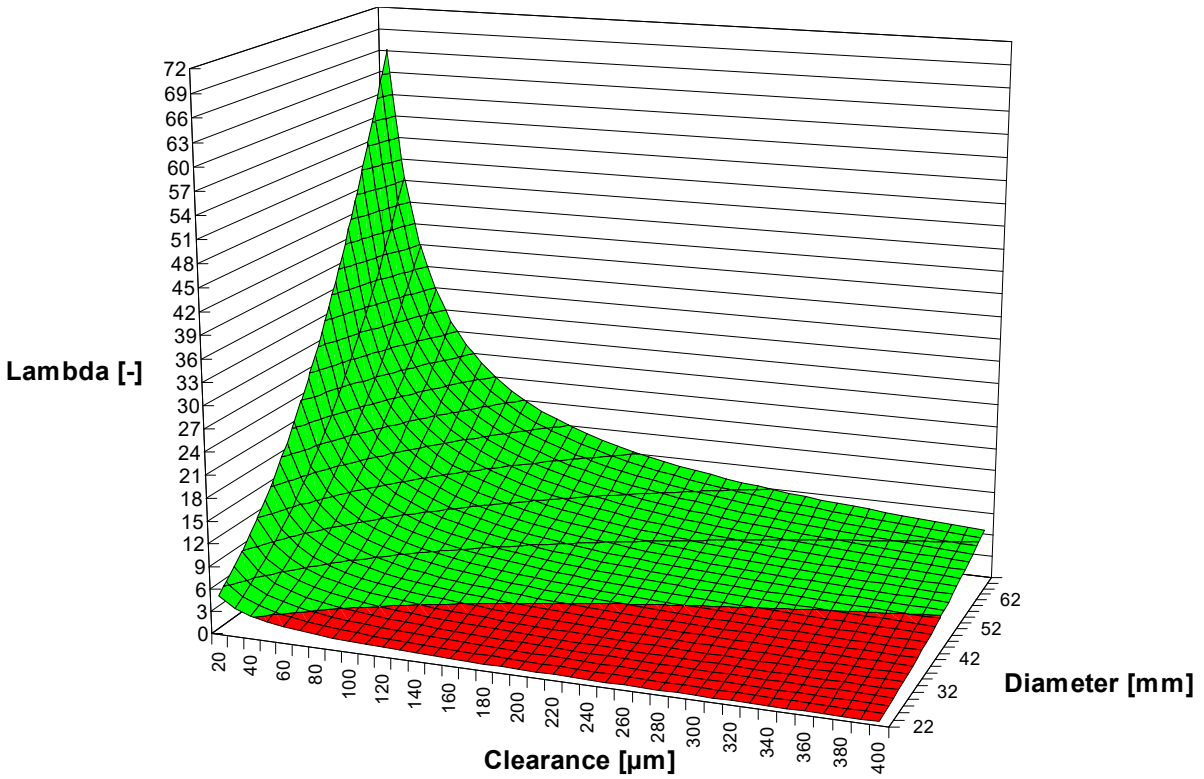
CAST CoCrMo ALLOY



WROUGHT CoCrMo ALLOY



LAMBDA COEFFICIENT

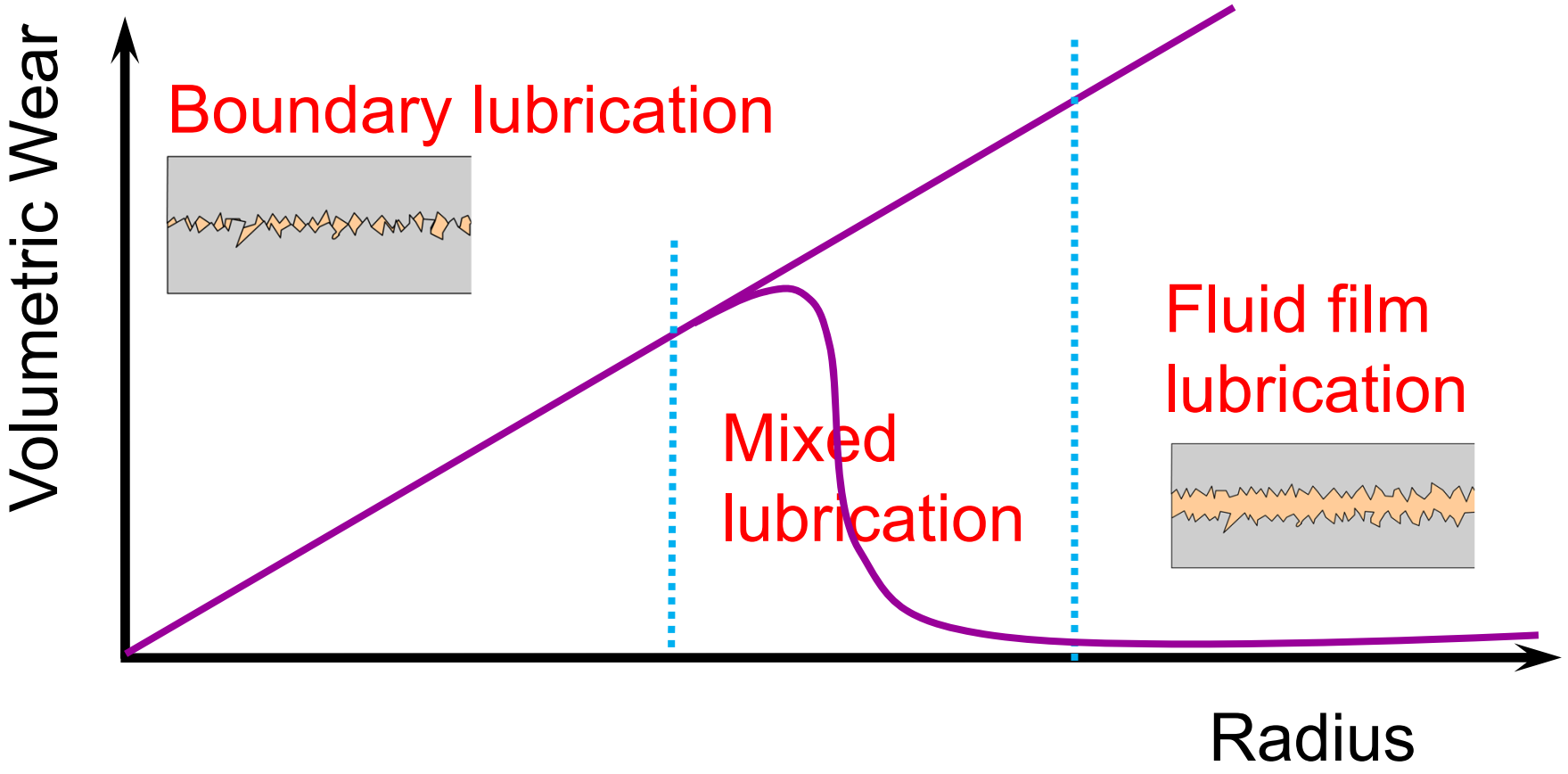


Roughness R_a: 4 nm

Roughness R_q: 5 nm

THE EFFECT OF FEMORAL HEAD DIAMETER UPON LUBRICATION AND WEAR OF METAL-ON-METAL THR

- “This study has demonstrated that the application of sound tribological principles to prosthetic design can reduce the wear of metal-on-metal joints, using currently available materials, to a negligible level.
- S.L. Smith et al, IMechE 215, 2001, p. 1


Volumetric Wear
Boundary lubrication
Mixed
lubrication
Fluid film
lubrication
Radius

LARGE DIAMETER MOM BEARINGS

THE SUNDAY TIMES

April 18, 2010

Tumour fear over metal hip replacements

In a group of more than 1,200 patients who had hip resurfacing over an eight-year period, 4% required a further operation because of this reaction, described as “pseudotumours”. The Nuffield study said 13% of women under 40 required a new operation.

Justin Cobb, professor of orthopaedic surgery at Imperial College London, said metal-on-metal hip procedures were effective and there was an adverse tissue reaction in only a small number of cases. “It’s like a Formula One car. If you don’t get the wheels perfectly aligned, you will shed them on the first lap,” he said.

The New York Times

September 15, 2011

Metal Hips Failing Fast, Report Says

By BARRY MEIER

In a troubling development for people with all-metal artificial hips, a registry that tracks orthopedic implants in Britain reported on Thursday that the failure rate of the devices was increasing.

Le Monde

Après les implants mammaires, des prothèses de hanche défectueuses

Le Monde.fr avec AFP | 28.02.2012 à 13h36 • Mis à jour le 09.03.2012 à 11h53

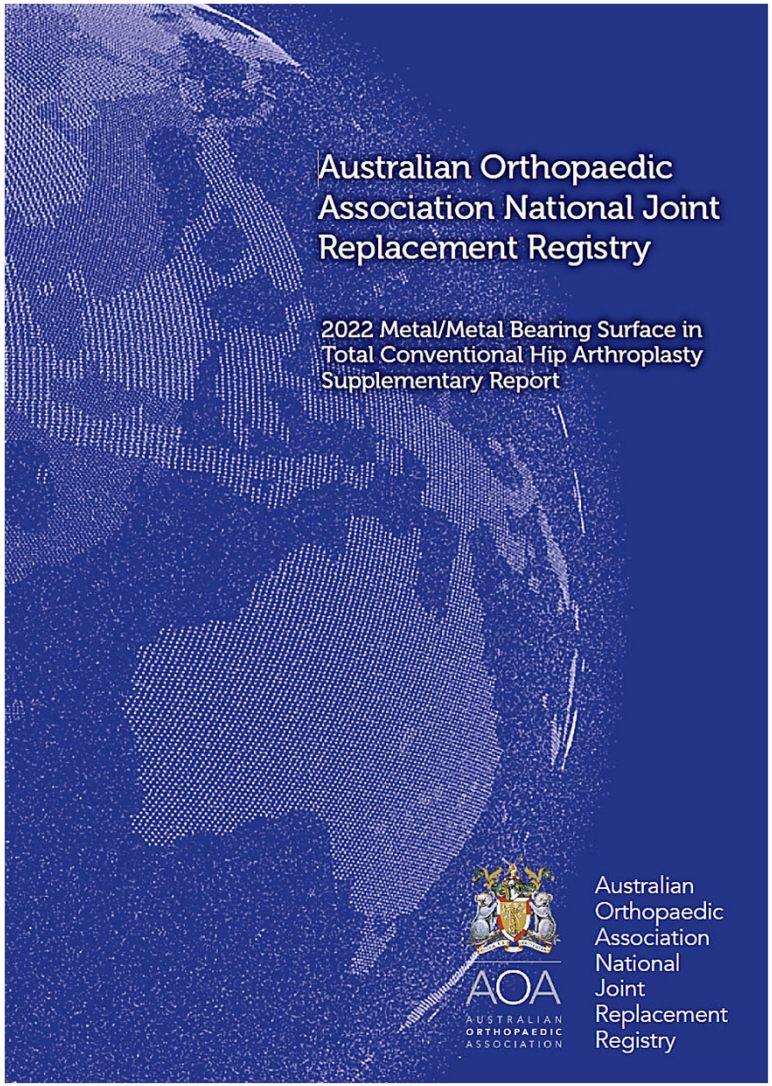
Des centaines de milliers de patients dans le monde pourraient avoir été exposés à des taux importants de métaux toxiques dus à des prothèses de hanche défectueuses, alors que le risque était connu, s'alarment, mardi 28 février, dans une enquête commune le *British Medical Journal* (BMJ) et la BBC.

Süddeutsche Zeitung

5. März 2012 17:13 Hüftprothesen in der Kritik

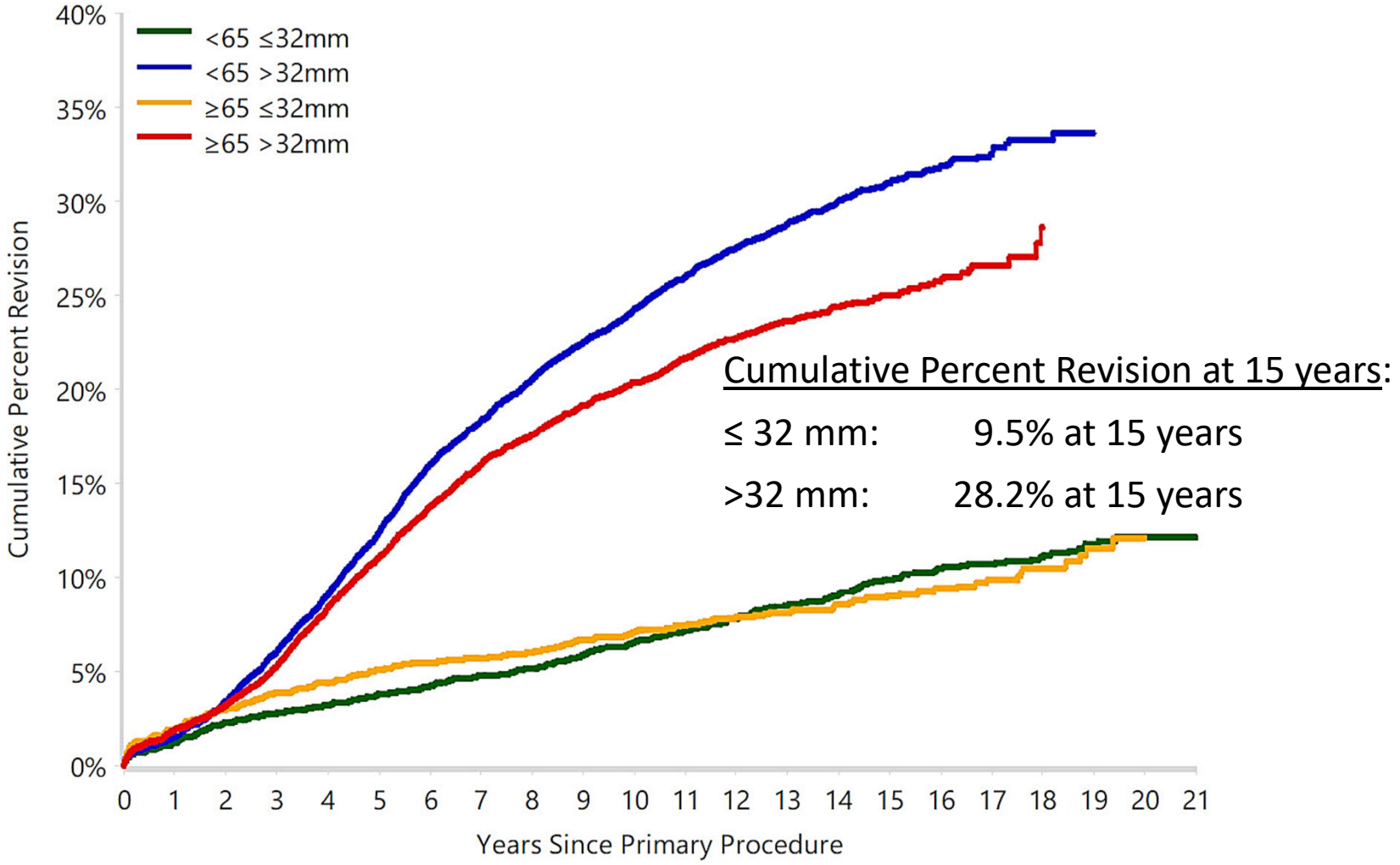
Giftige Gelenke

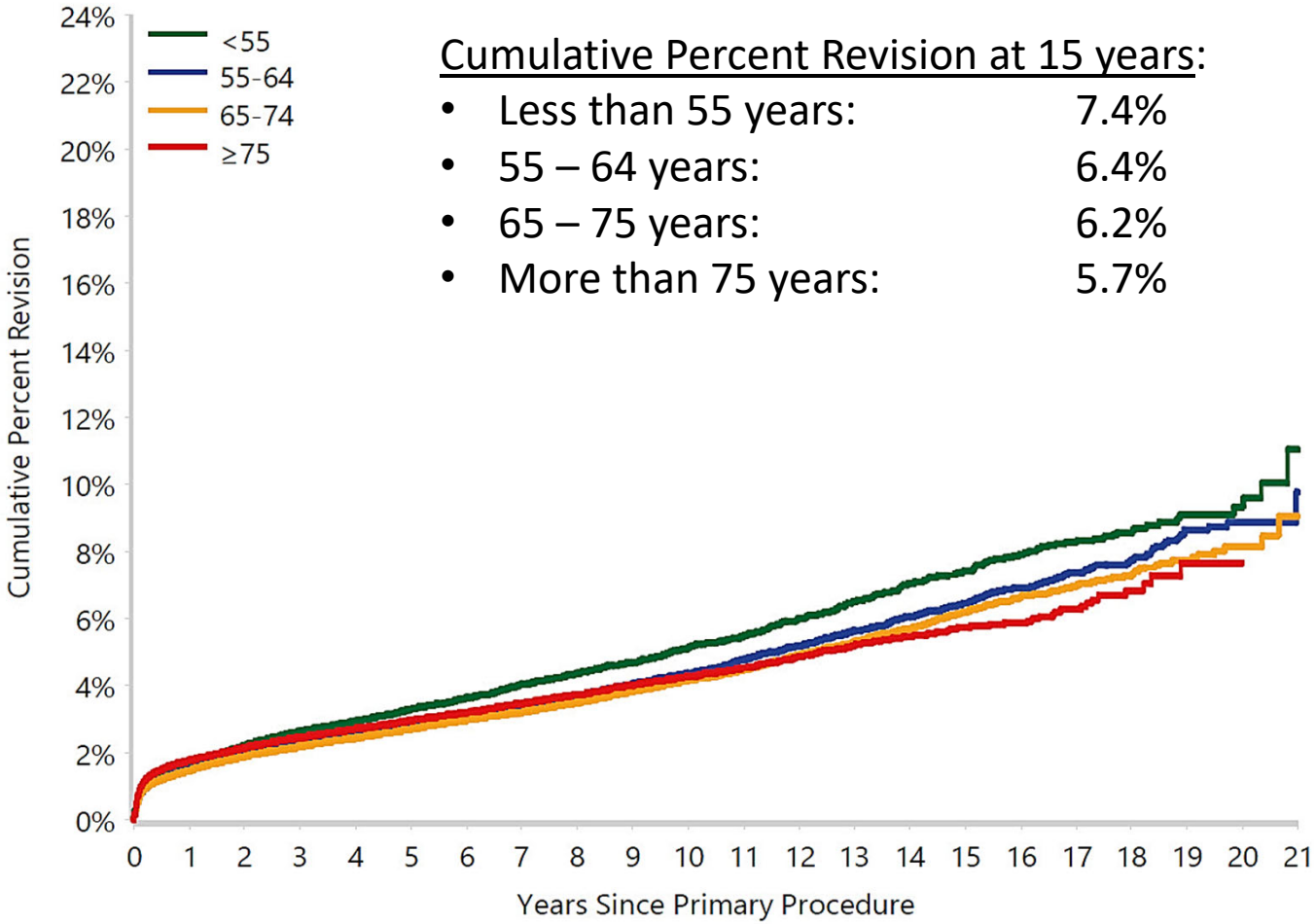
Mehr als eine Million Patienten mit künstlichen Hüftgelenken sind von einem neuen Medizinskandal betroffen. Ihre Metall-Prothesen können Ionen freisetzen, die Schmerzen auslösen, Organe schädigen und das Krebsrisiko erhöhen. Skandalträchtig ist vor allem: Die Gefahren sind seit Jahrzehnten bekannt.



AUSTRALIAN REGISTRY 2022

Figure MM3:
Cumulative Percent Revision of Metal/Metal Primary Total Conventional Hip Replacement by Head Size


40%
35%
30%
25%
20%
15%
10%
5%
0%
Cumulative Percent Revision
<65 ≤32mm
<65 >32mm
≥65 ≤32mm
≥65 >32mm
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Years Since Primary Procedure
Cumulative Percent Revision at 15 years:
≤ 32 mm: 9.5% at 15 years
>32 mm: 28.2% at 15 years

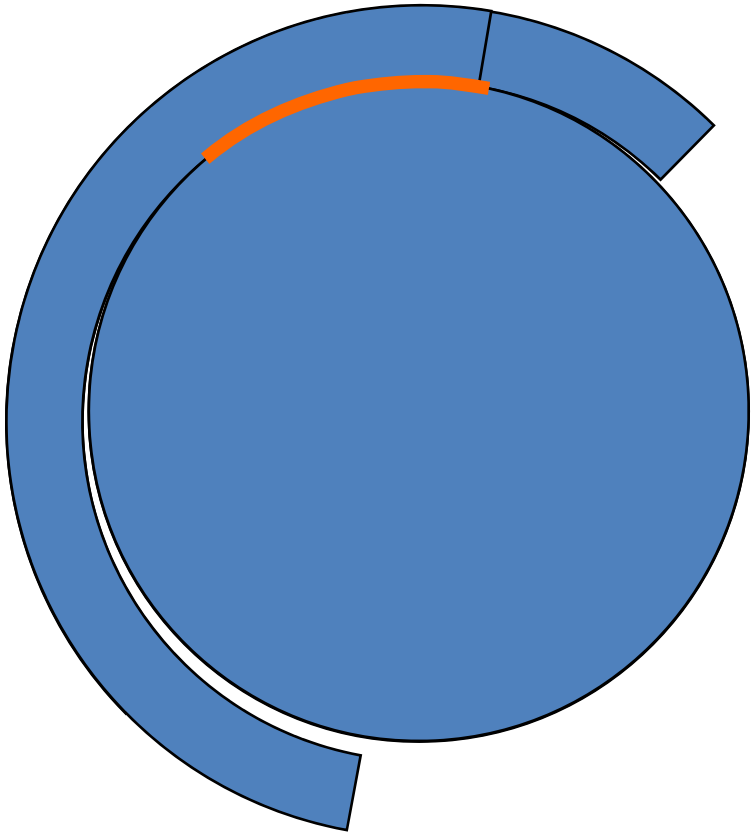


Cumulative Percent Revision at 15 years:

- Less than 55 years: 7.4%
- 55 – 64 years: 6.4%
- 65 – 75 years: 6.2%
- More than 75 years: 5.7%

LARGE DIAMETER MOM BEARINGS

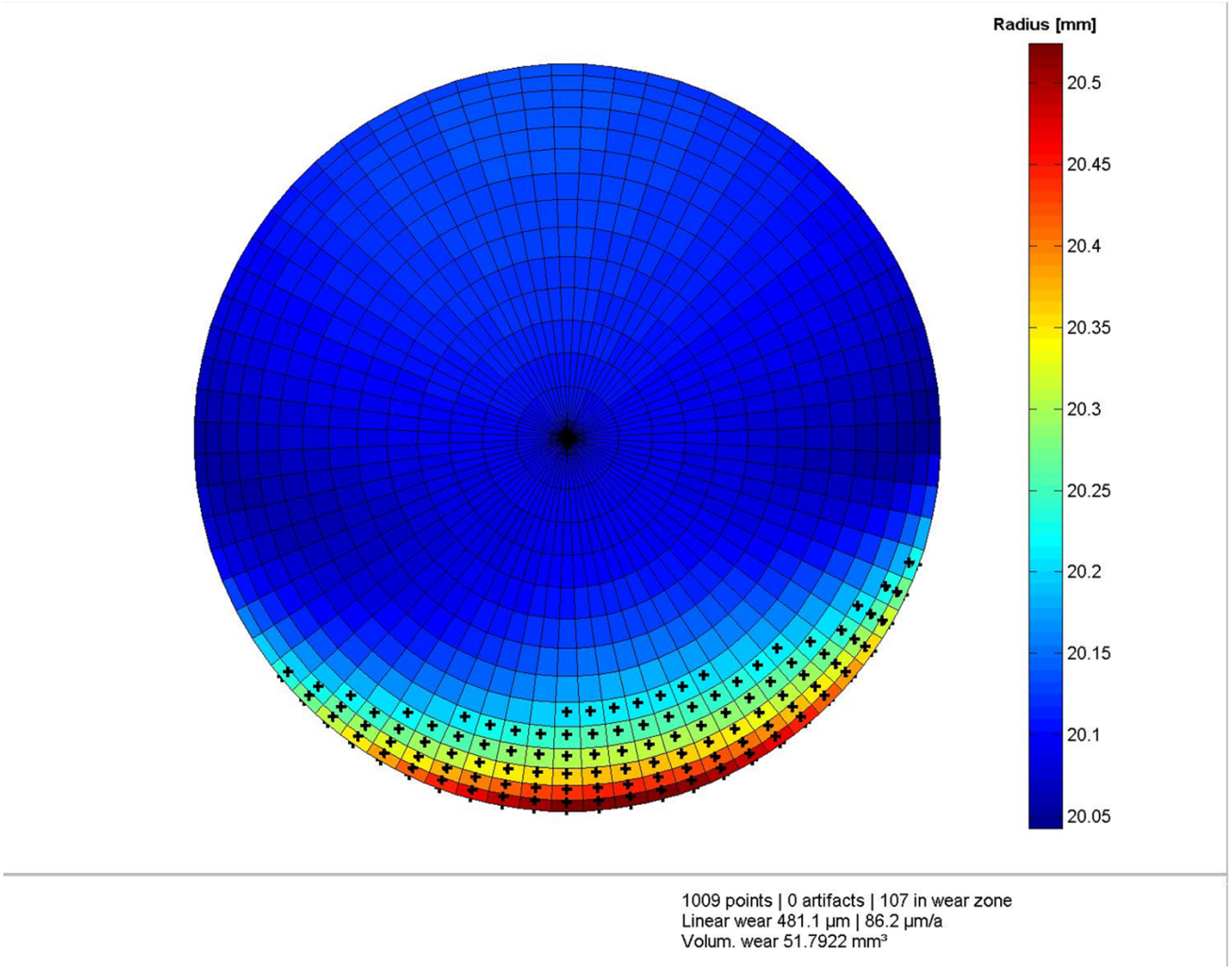
Loss of fluid lubrication?



EDGE WEAR

- 40 mm metal-on-metal bearing
- Inclination: ≈ 55°
- Women: 48 years old
- Time in-vivo: 5.6 years

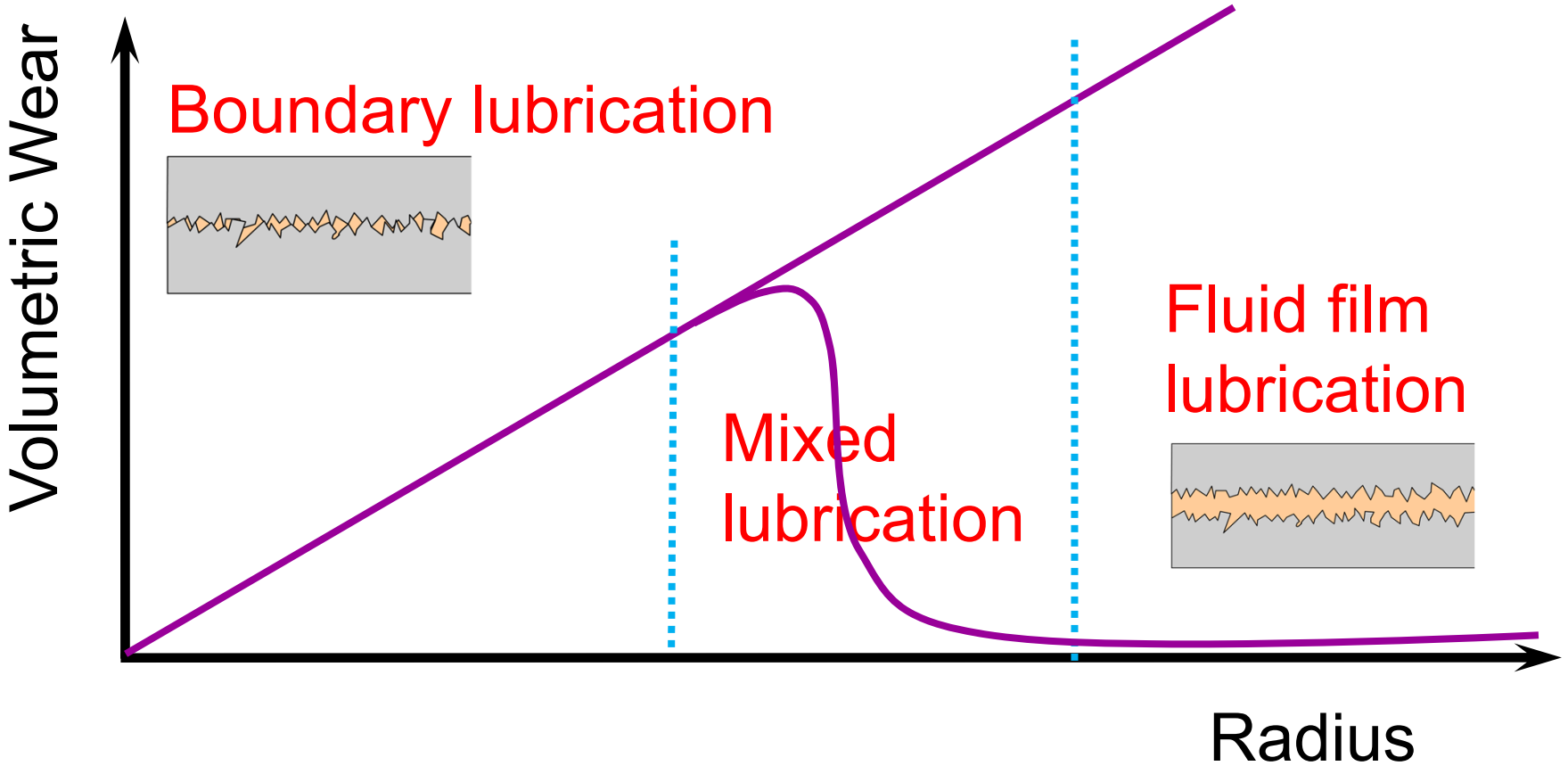

11_2762
2 mm
11_2763
2 mm



1009 points | 0 artifacts | 107 in wear zone
Linear wear 481.1 µm | 86.2 µm/a
Volum. wear 51.7922 mm³

EDGE WEAR

- Volumetric wear of the head:
  58.8 mm^3
- Volumetric wear of the cup:
  51.8 mm^3
- Volumetric wear rate:
  19.8 mm^3/year

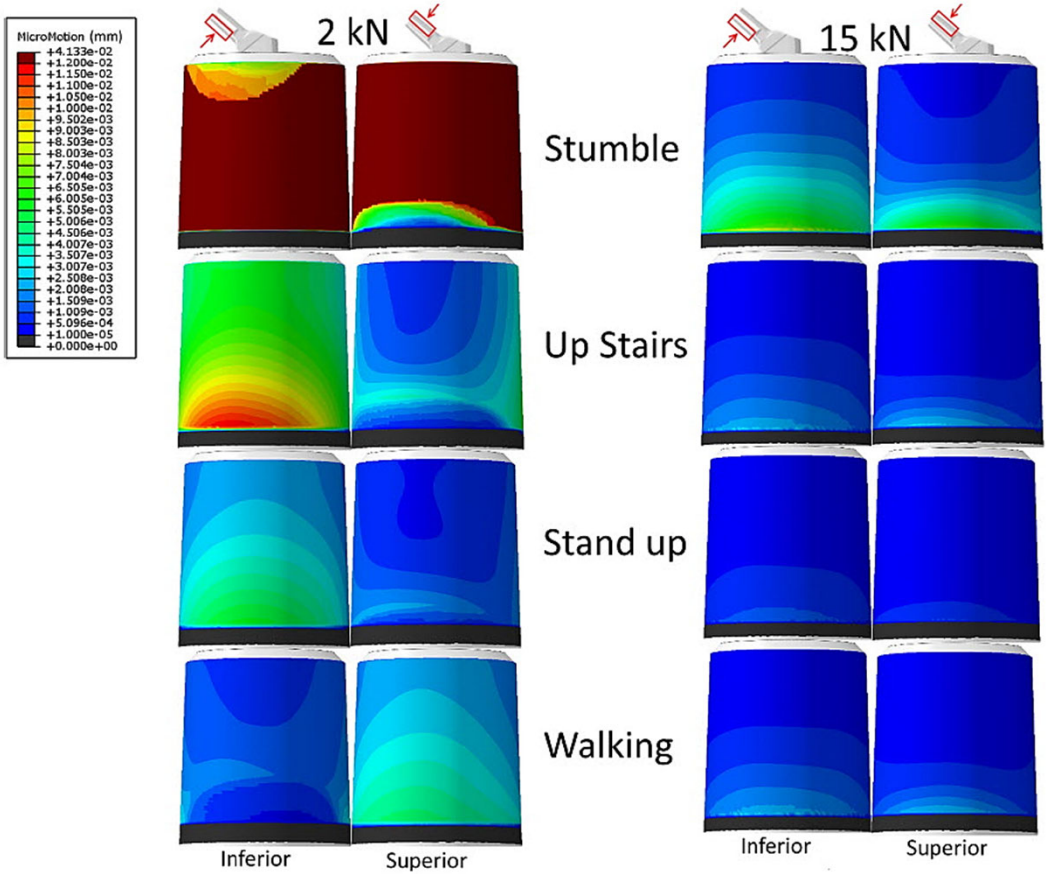

Volumetric Wear
Boundary lubrication
Mixed
lubrication
Fluid film
lubrication
Radius

BIOLOGIC REACTIONS

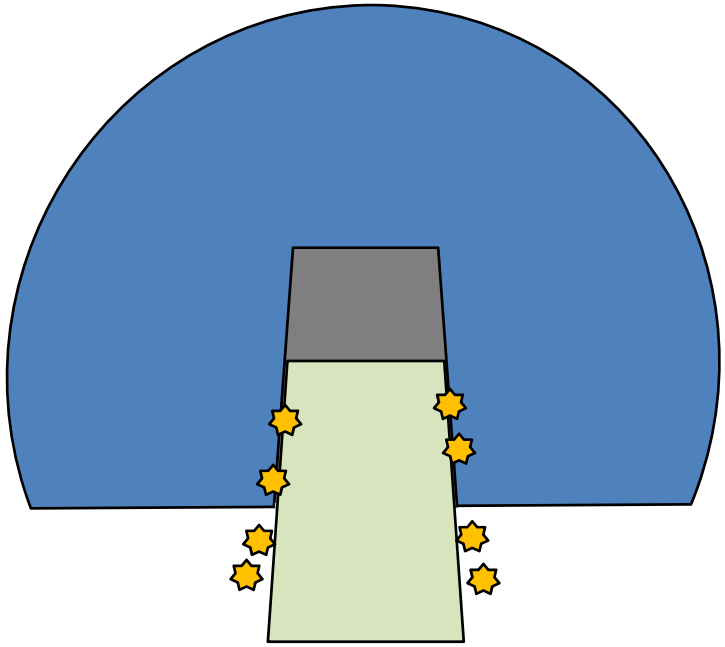
- Loss of fluid lubrication

- Without a fluid lubrication, the amount of volumetric wear / friction are increasing with large diameter bearings.

TAPER CONNECTIONS

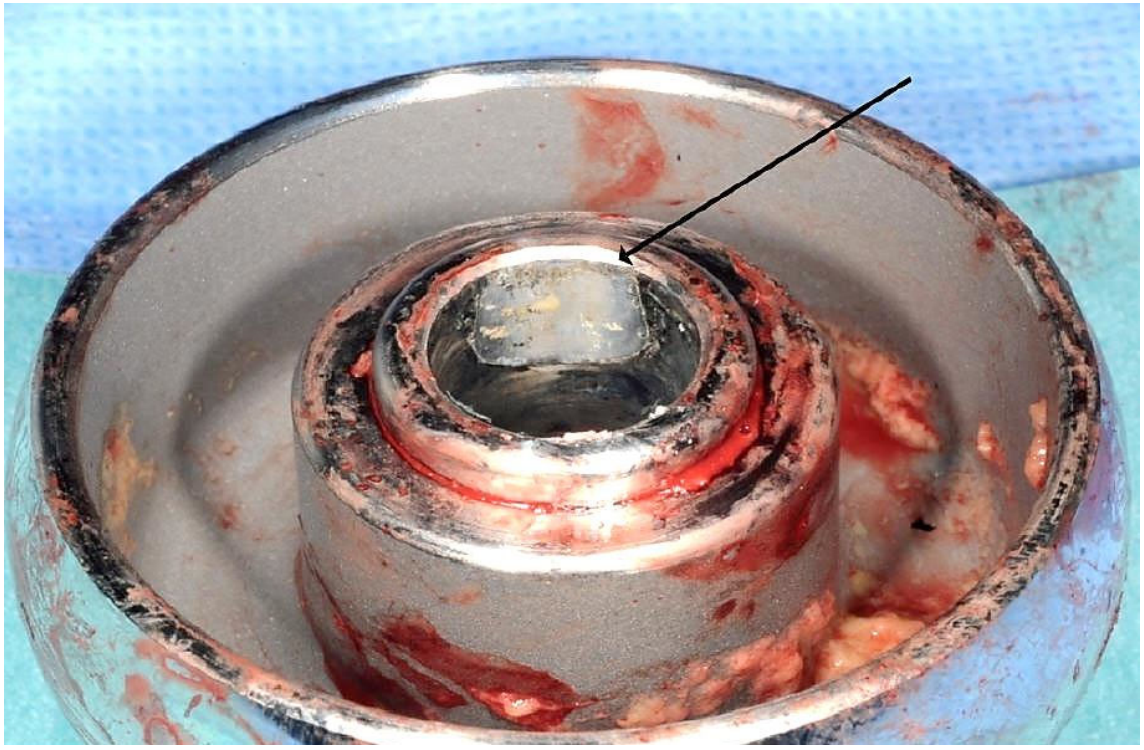


TAPER CONNECTIONS



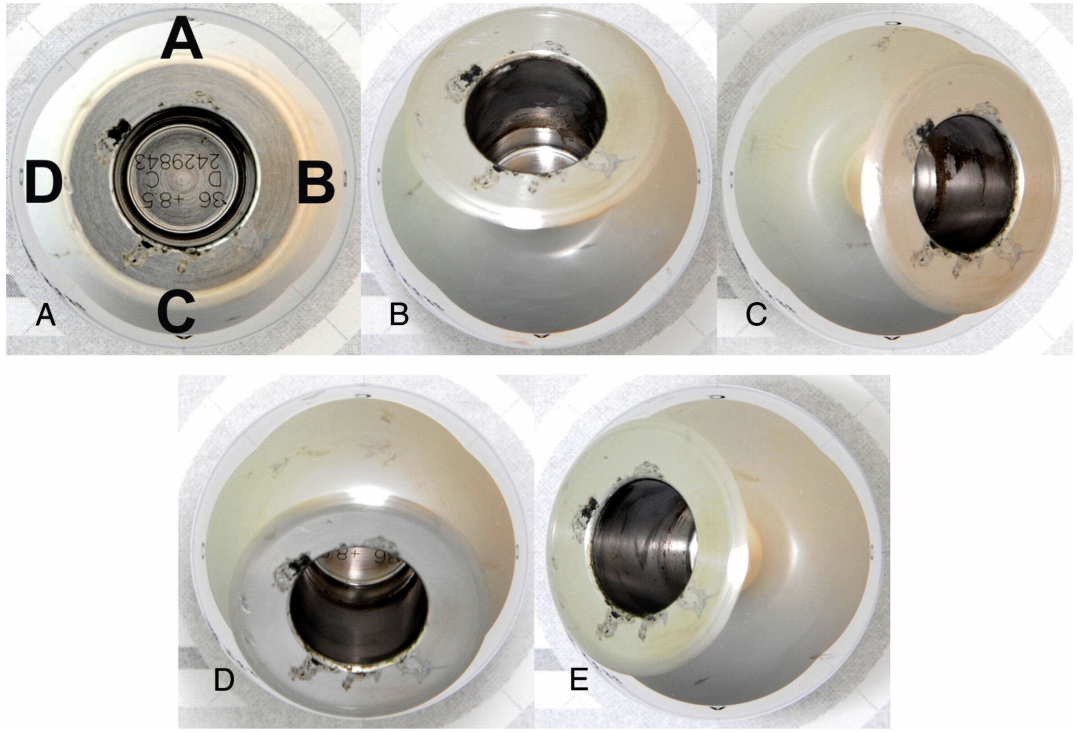
- Impaction forces
  - Mallet
  - Direction
  - Number of impacts
  - …
- Cleanness of the taper?
- Wet or dry?
- Geometry
- Head size
- Roughness
- …

LARGE DIAMETER MoM BEARINGS



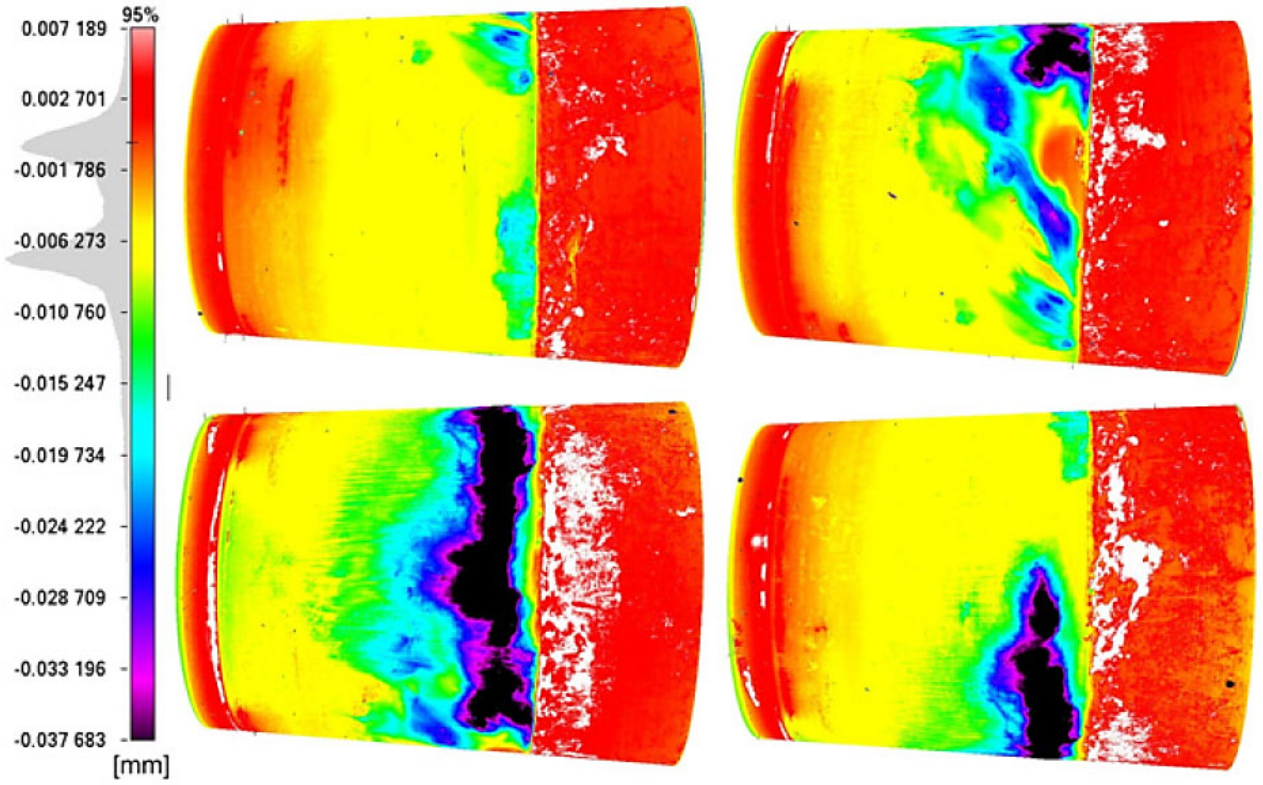
F.S. Haddad et al, JBJS 93B, 2011, p. 572

SMALL DIAMETER MoM BEARINGS



K.B. Fricka et al, JoA, 27, Suppl 8, 2012, p. 26

LARGE DIAMETER MoP BEARINGS



R.B. Cook et al, JoA, 2013, 28, p. 1430

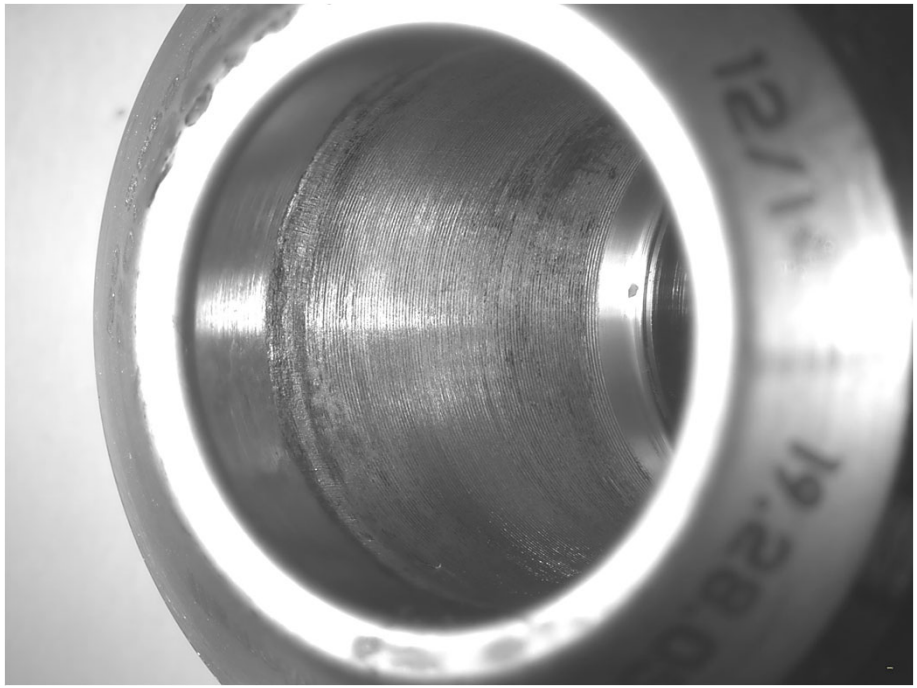
SMALL DIAMETER MoP BEARINGS

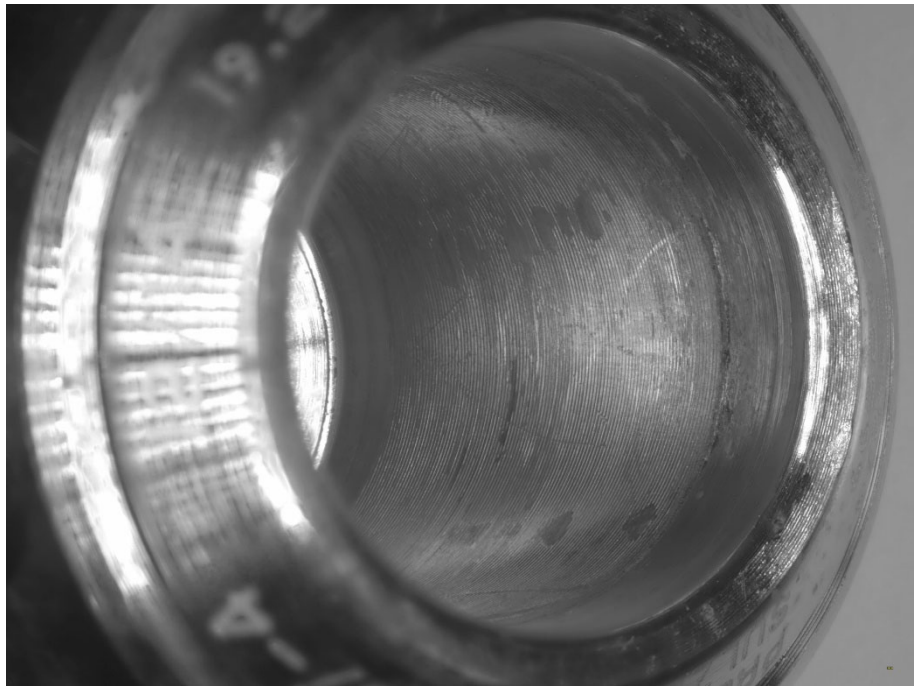
M. Kiran et al, JoA, 30, 2015, p. 277

MODULAR NECKS

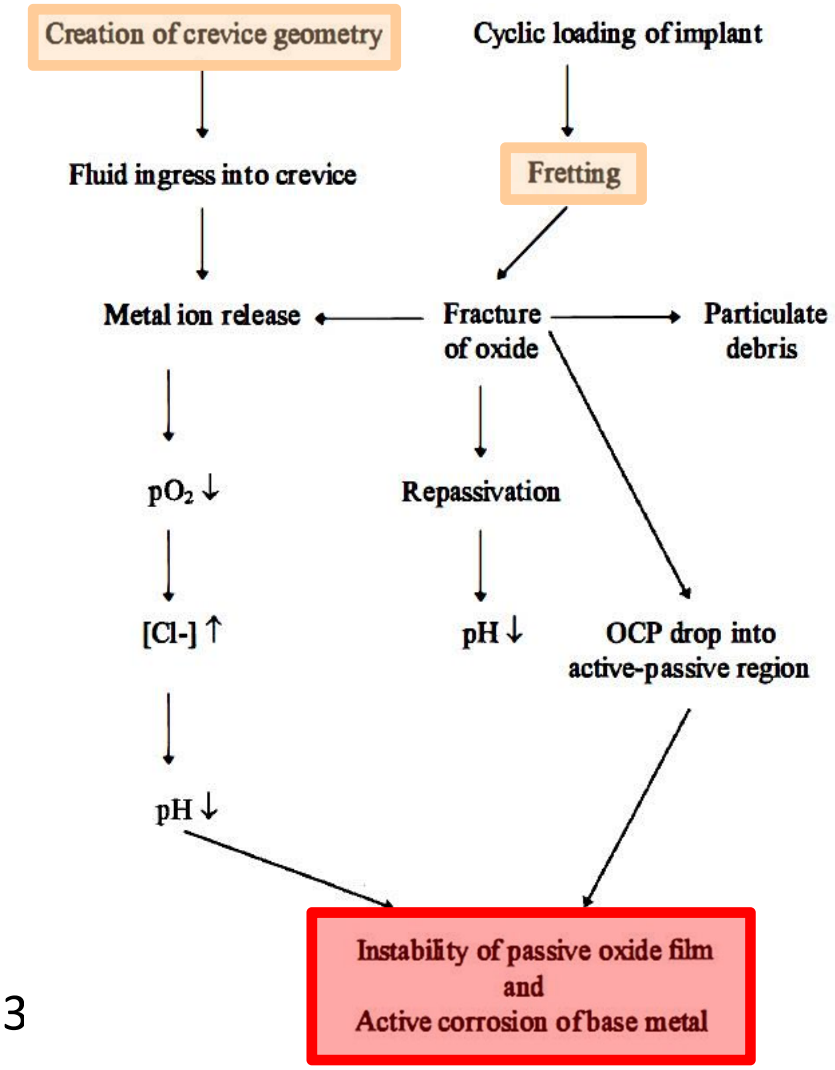
D.O. Molloy et al, JBJS, 2014, 96A, p. 488

“IMPRINTING”





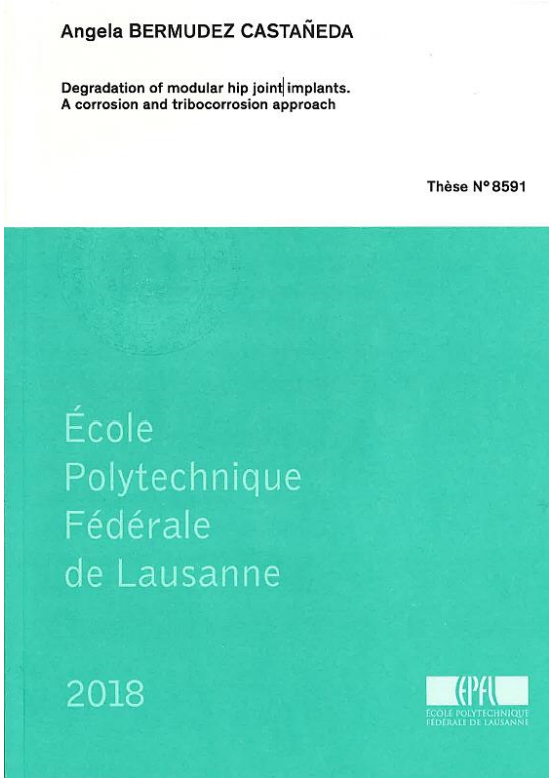
MACC
MECHANICALLY ASSISTED CREVICE CORROSION



J.L. Gilbert, JBMR, 27, 1993, p. 1533

FRETTING CORROSION OR CREVICE CORROSION?

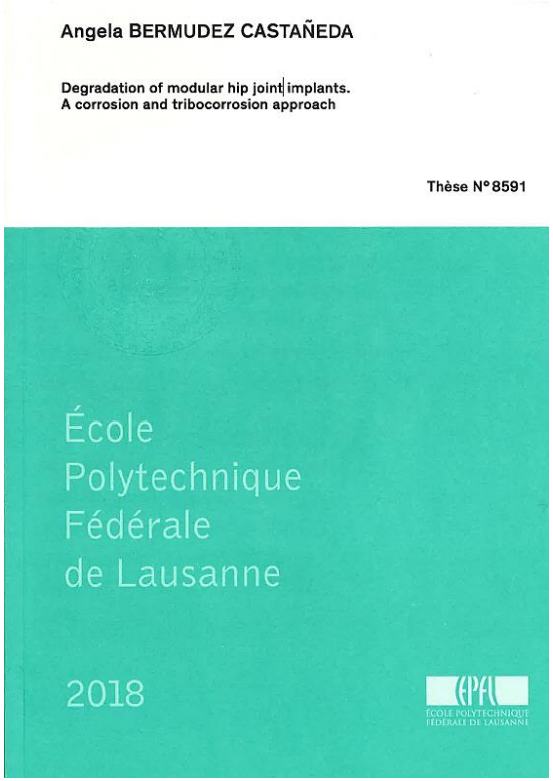
- “No deterioration evidence was found in Ti6Al4V and CoCr after crevice-corrosion experiments in several conditions using a geometry mimicking the femoral head-neck configuration.”
- A. Bermudez-Castañeda, Thesis 8591, EPFL, 2018



FRETTING CORROSION OR CREVICE CORROSION?

- “Therefore, based on these results, the attention should be focus on fretting-corrosion.”

- A. Bermudez-Castañeda, Thesis 8591, EPFL, 2018



materials

MDPI

Article

A Crevice Corrosion Model for Biomedical Trunnion Geometries and Surfaces Feature

Angela Bermúdez-Castañeda [1,2,*], Anna Igual-Muñoz [1] and Stefano Mischler [1]

[1] Tribology and Interfacial Chemistry Group, EPFL, École Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland; anna.igualmunoz@epfl.ch (A.I.-M.); stefano.mischler@epfl.ch (S.M.)

[2] Research Group in Sustainable Design in Mechanical Engineering, DSIM, Escuela Colombiana de Ingeniería Julio Garavito, 111166 Bogotá, Colombia

* Correspondence: angela.bermudez@escuelaing.edu.co; Tel.: +57-305-450-7048

Abstract: Modular hip joint implants were introduced in arthroplasty medical procedures because they facilitate the tailoring of patients' anatomy, the use of different materials in one single configuration, as well as medical revision. However, in certain cases, such prostheses may undergo deterioration at the head–neck junctions with negative clinical consequences. Crevice-corrosion is commonly invoked as one of the degradation mechanisms acting at those junctions despite biomedi-

The Journal of Arthroplasty 38 (2023) S274–S279

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Proceedings of The Hip Society 2022

Evaluation of Mechanically-Assisted Crevice Corrosion of Different Modular Dual Mobility Constructs

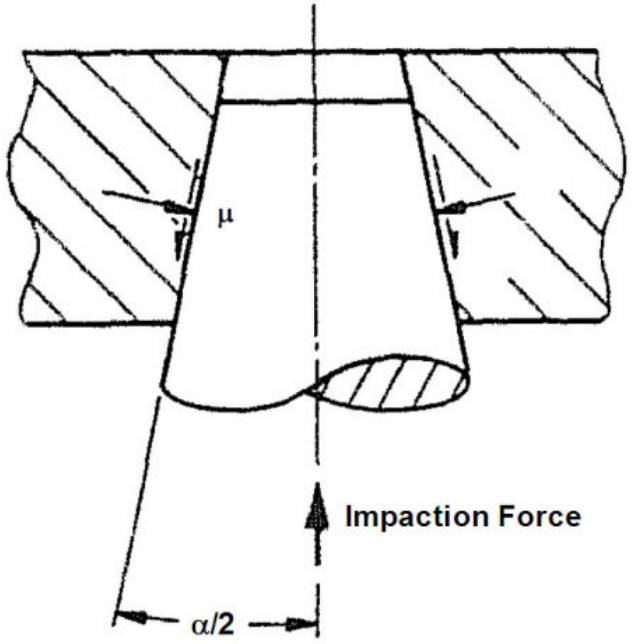
John R. Steele, MD [a, b, 1], Aarti A. Shenoy, PhD [c, *], Ashley Pekmezian [c], Timothy Wright, PhD [c], Douglas E. Padgett, MD [a]

[a] Adult Reconstruction and Joint Replacement Division, Hospital for Special Surgery, New York, New York
[b] Towson Orthopaedic Associates, Orthopaedic Institute at St. Joseph's Medical Center, Towson, Maryland
[c] Department of Biomechanics, Hospital for Special Surgery, New York, New York

INFLUENCE OF ASSEMBLY PROCEDURE AND MATERIAL COMBINATION ON THE STRENGTH OF THE TAPER CONNECTION

- “A stable fixation between femoral head and endoprosthesis taper is necessary to prevent relative motions and corrosion at the taper junction.”
- A. Rehmer et al, Clin Biomech, 27, 2012, p. 77

TAPER CONNECTIONS



$$F_{fixation} = F_{impact} \cdot \frac{\mu \cos(0.5\alpha) - \sin(0.5\alpha)}{\mu \cos(0.5\alpha) + \sin(0.5\alpha)}$$

H. Fessler et al, Journal of Engineering in Medicine, 203, 1989, p. 1

EXPERIMENTAL MEASUREMENT OF THE COEFFICIENT OF FRICTION AT THE Ti-Ti TAPER CONNECTION

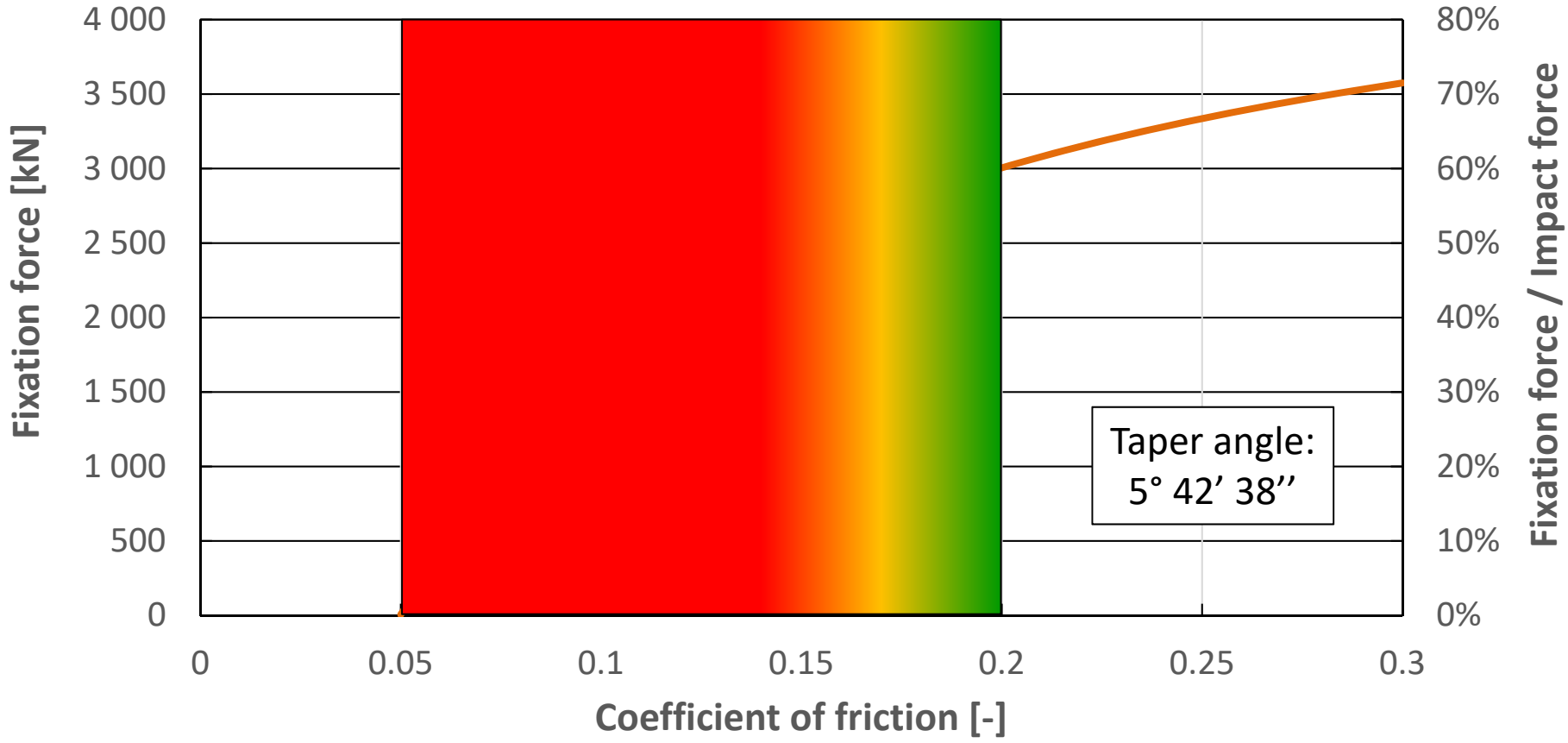
- “We found static coefficients of friction of 0.19 for the 12/14 stem-adaptor couples.”

- T. Bitter et al, JoBE, 138, 2016,

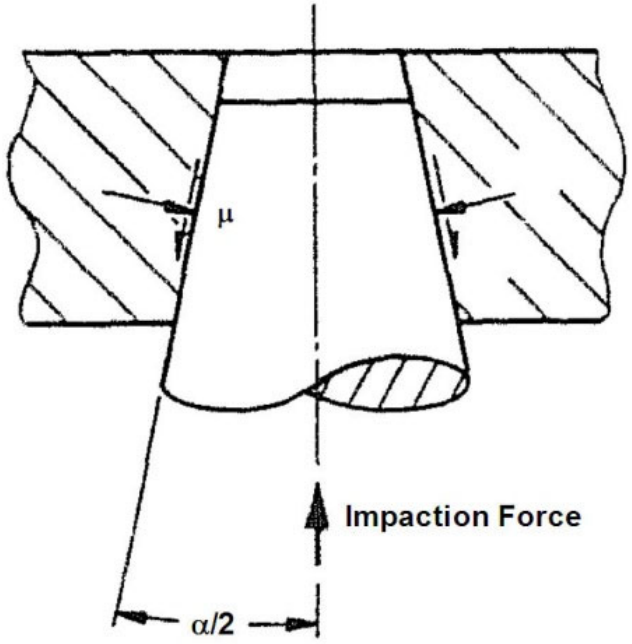
TAPER CONNECTIONS

- Taper angle: 5° 42’ 38’’
- Impaction force: 5’000 N – 100%
- Dry taper → coefficient of friction 0.2
  Fixation force: 3’004 N – 60.1%
- Wet taper → coefficient of friction 0.1
  Fixation force: 1’672 N – 33.4%
- H. Fessler et al, Journal of Engineering in Medicine, 203, 1989, p. 1

F_{IMPACT} - 5’000 N



TAPER CONNECTIONS



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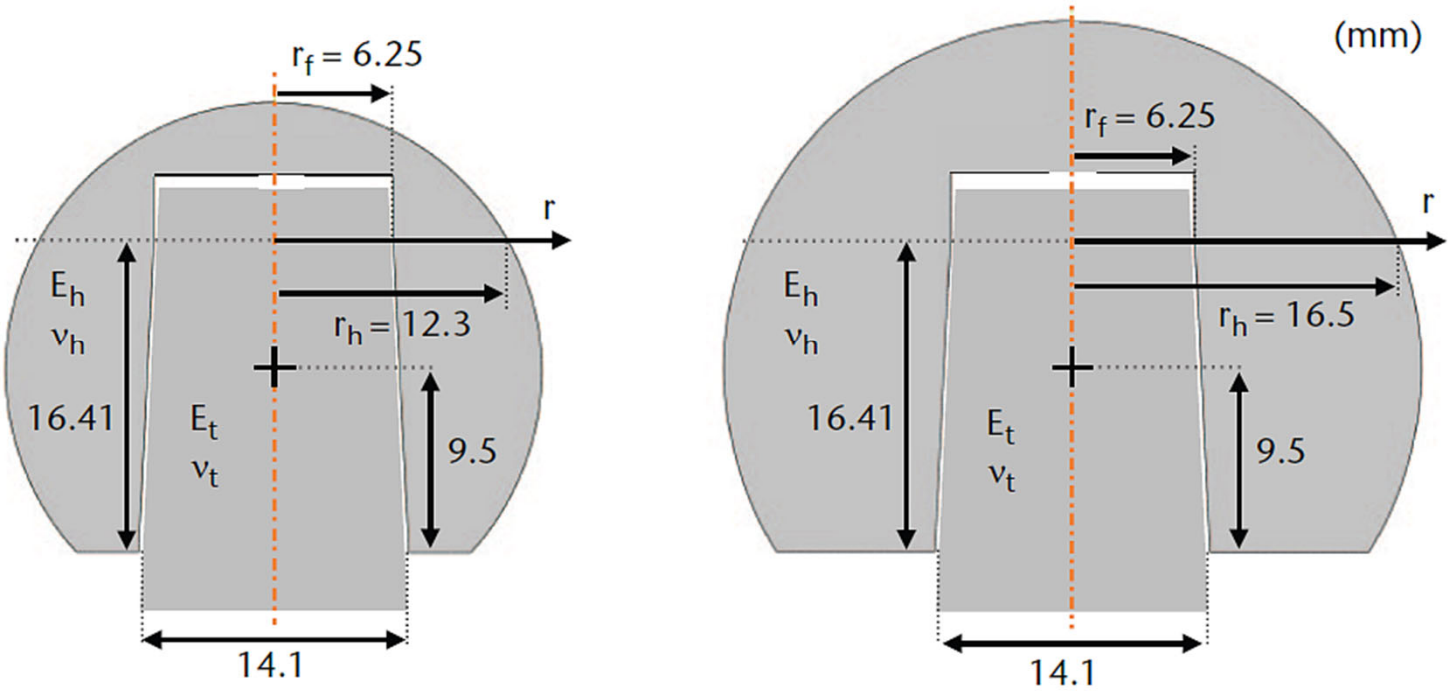
TAPER CONNECTIONS



A.R. MacLeod et al, BJR, 5, 2016, p. 338

TAPER CONNECTIONS

$$u_t = \frac{F_{impact}\left\{\frac{r_f}{E_h}\left[\left(\frac{r_h^2 + r_f^2}{r_h^2 - r_f^2}\right) + \nu_h\right] + \frac{r_f}{E_t}\left(1 - \nu_t\right)\right\}}{A\left(\sin\alpha + \mu\cos\alpha\right)}$$

$$F_{extract} = A\left(\mu\cos\alpha - \sin\alpha\right)\frac{E_h u_t r_f}{2r_h^2}\left(1 - \frac{r_h^2}{r_f^2}\right)$$

A.R. MacLeod et al, BJR, 5, 2016, p. 338

TAPER CONNECTIONS

Fessler's formula

$$F_{fixation} = F_{impact} \cdot \frac{\mu \cos(0.5\alpha) - \sin(0.5\alpha)}{\mu \cos(0.5\alpha) + \sin(0.5\alpha)} \cdot \frac{E_h r_f}{2{r_h}^2} \cdot \left(1 - \frac{{r_h}^2}{{r_f}^2}\right) \cdot \left[\frac{r_f}{E_h}\left(\left\{\frac{{r_h}^2 + {r_f}^2}{{r_h}^2 - {r_f}^2}\right\} + \vartheta_h\right) + \frac{r_f}{E_t}(1 - \vartheta_t)\right]$$

A.R. MacLeod et al, BJR, 5, 2016, p. 338

F_{IMPACT} - 5’000 N

Taper	**Head Diameter**	**Coefficient of Friction**	**$F_{fixation}$**	**$F_{fixation}$ / F_{impact}**
12/14 short	28 mm	0.20	3’855 N	77.1%
12/14 long	28 mm	0.20	3’855 N	77.1%
12/14 short	36 mm	0.20	3’986 N	79.7%
12/14 long	36 mm	0.20	3’986 N	79.7%

F_{IMPACT} - 5’000 N

Taper	**Head Diameter**	**Coefficient of Friction**	**$F_{fixation}$**	**$F_{fixation}$ / F_{impact}**
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12/14 long	28 mm	0.20	3’855 N	77.1%
12/14 short	36 mm	0.20	3’986 N	79.7%
12/14 long	36 mm	0.20	3’986 N	79.7%
12/14	36 mm	0.05	8 N	0.2%
12/14	36 mm	0.10	2’219 N	44.4%
12/14	36 mm	0.15	3’324 N	66.5%

F_{IMPACT} - 5’000 N

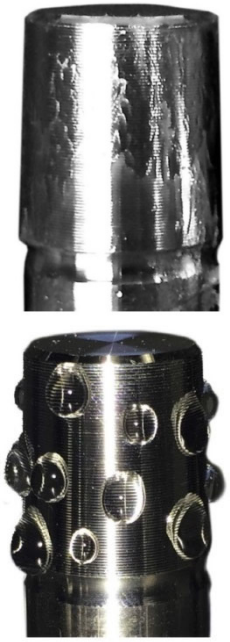
Taper	**Head Diameter**	**Coefficient of Friction**	**$F_{fixation}$**	**$F_{fixation}$ / F_{impact}**
12/14 short	28 mm	0.20	3’855 N	77.1%
12/14 long	28 mm	0.20	3’855 N	77.1%
12/14 short	36 mm	0.20	3’986 N	79.7%
12/14 long	36 mm	0.20	3’986 N	79.7%
12/14	36 mm	0.05	8 N	0.2%
12/14	36 mm	0.10	2’219 N	44.4%
12/14	36 mm	0.15	3’324 N	66.5%
10/12	36 mm	0.20	4’035 N	80.7%
14/16	36 mm	0.20	3’930 N	78.6%

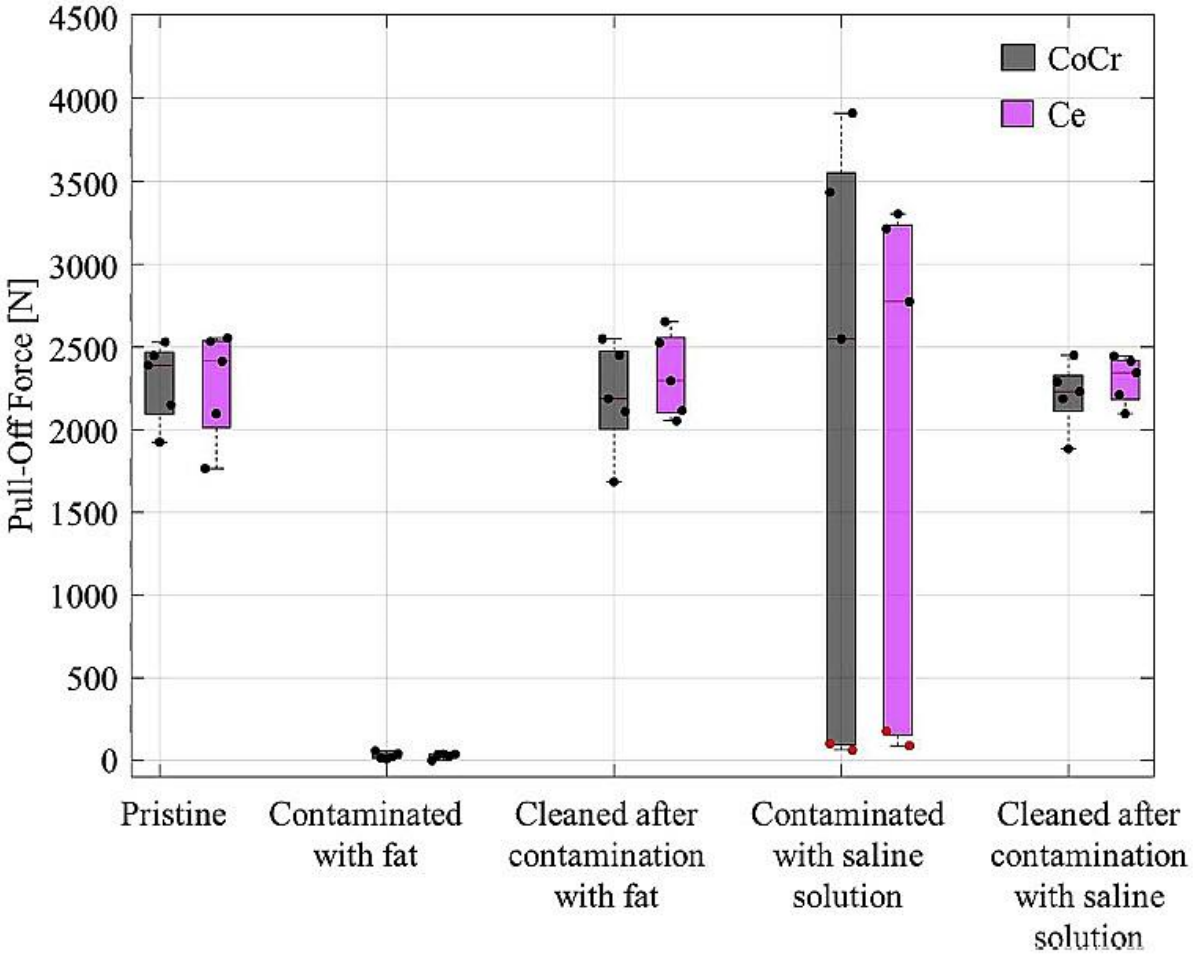
THE INFLUENCE OF CONTAMINATION AND CLEANING ON THE STRENGTH OF MODULAR HEAD TAPER FIXATION IN THA

- “Intraoperative interface contamination of modular head-stem taper junctions of hip implants can lead to poor fixation strength, causing fretting and crevice corrosion or even stem taper fracture. Careful cleaning before assembly should help to reduce these problems.”
- A. Krull et al, JoA, 32, 2017, p. 3200

THE INFLUENCE OF CONTAMINATION AND CLEANING ON THE STRENGTH OF MODULAR HEAD TAPER FIXATION IN THA

- “Metal or ceramic heads were impacted onto titanium alloy stem tapers with cleaned or contaminated (fat or saline solution) interfaces. The same procedure was performed after cleaning and drying the contaminated interfaces.”
- A. Krull et al, JoA, 32, 2017, p. 3200





A. Krull et al, JoA, 32, 2017, p. 3200

THE INFLUENCE OF CONTAMINATION AND CLEANING ON THE STRENGTH OF MODULAR HEAD TAPER FIXATION IN THA

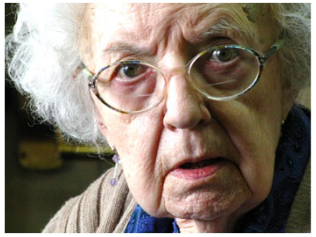
- “Cleaning of the stem taper with saline solution and drying with gauze directly before assembly allows the taper strength of the pristine components to be achieved. Not drying the taper results in a large variation in pull-off forces, emphasizing that drying is essential for sufficient and reproducible fixation strength.”
- A. Krull et al, JoA, 32, 2017, p. 3200

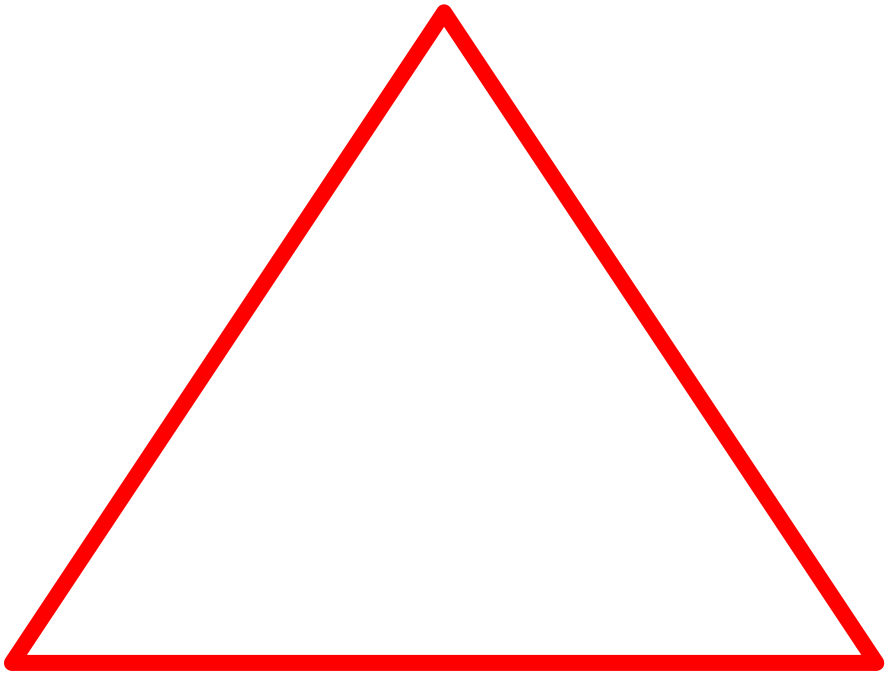
TRIBOLOGY OF TOTAL HIP ARTHROPLASTIES

- Introduction
- Why is tribology important
- Materials
- Possible methodology
- Other aspects
- Conclusions

EPFL

Fixation
Positioning
Taper connection
…

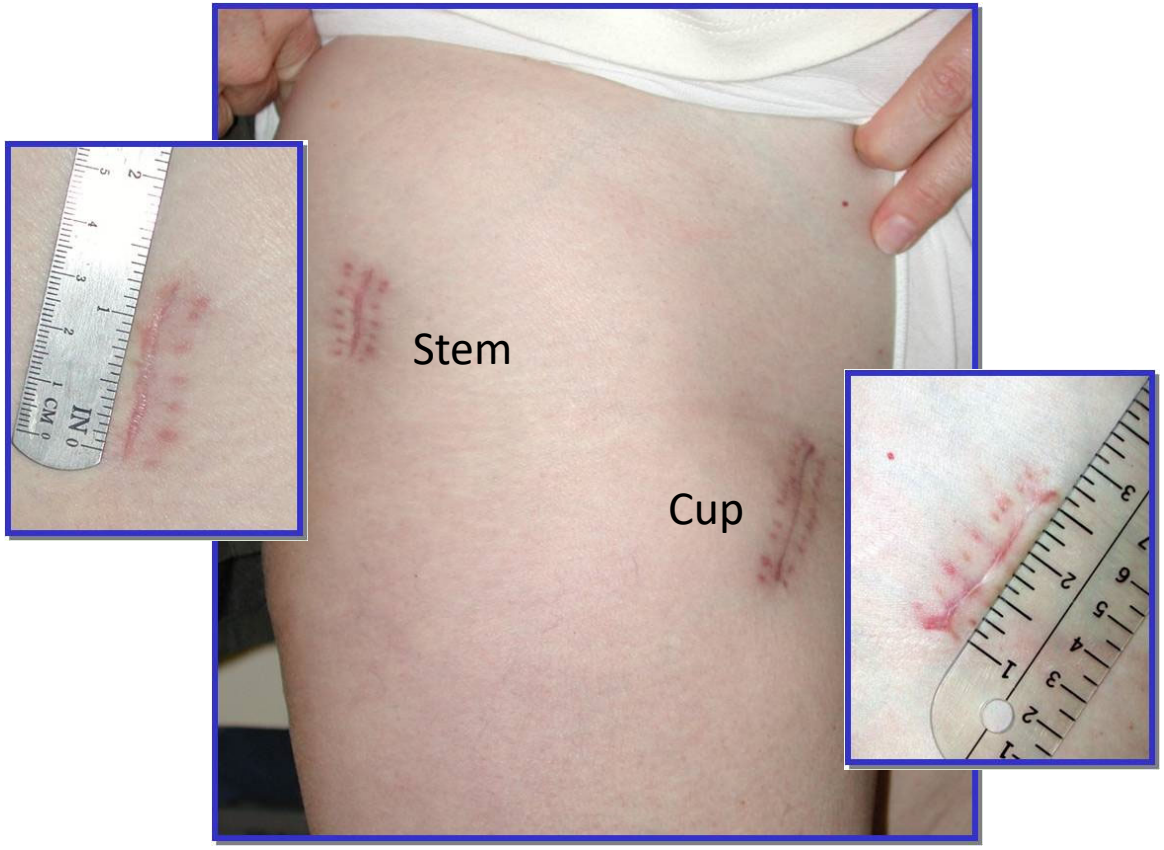




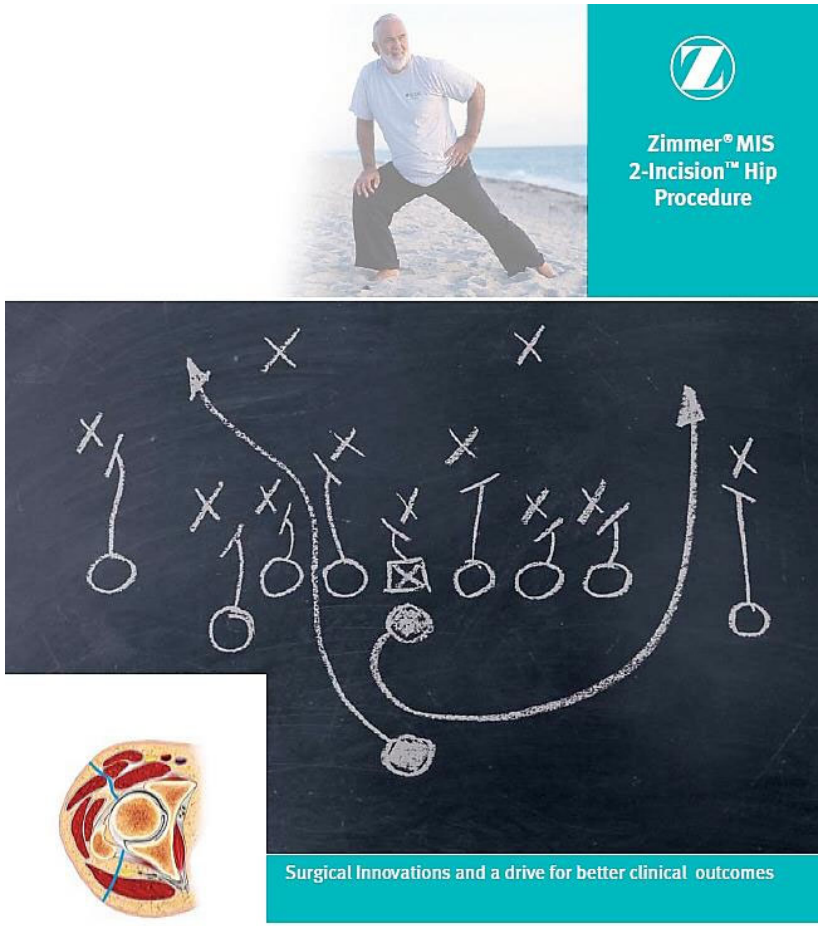
SURGEONS

DRIVERS

MIS TECHNIQUE - 2-INCISION



MIS TECHNIQUE
2-INCISION



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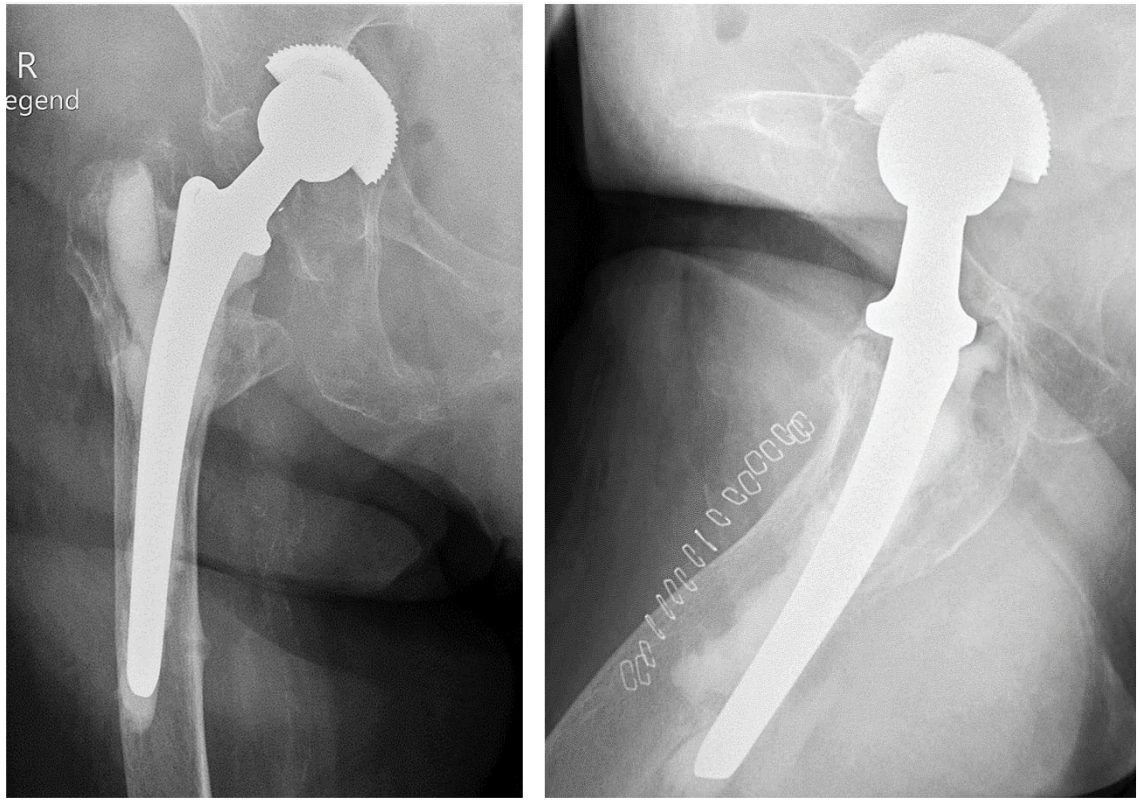
MIS TECHNIQUE - 2-INCISION

SURGEONS

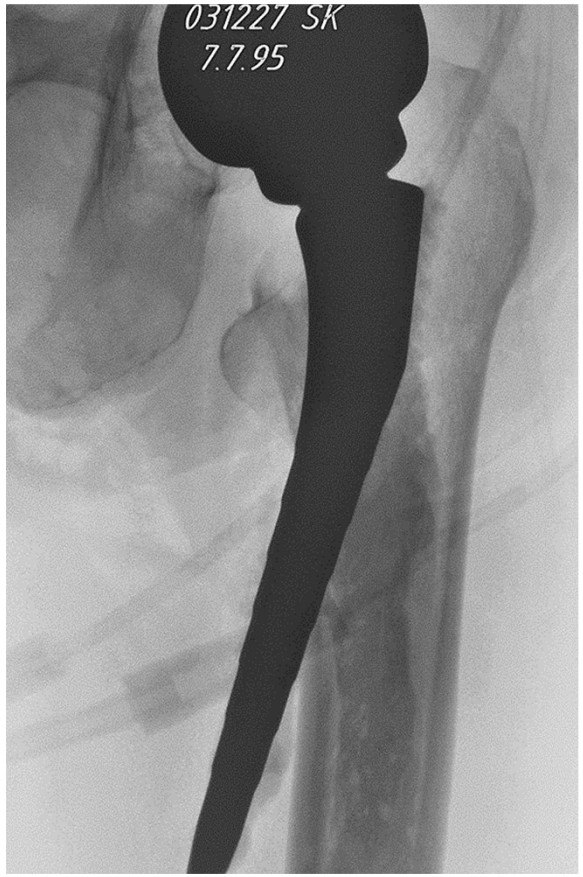
- Surgeons may have a bad day



Courtesy of
Prof. E. Gauthier

SURGEONS

- Surgeons may have a bad day



Courtesy of
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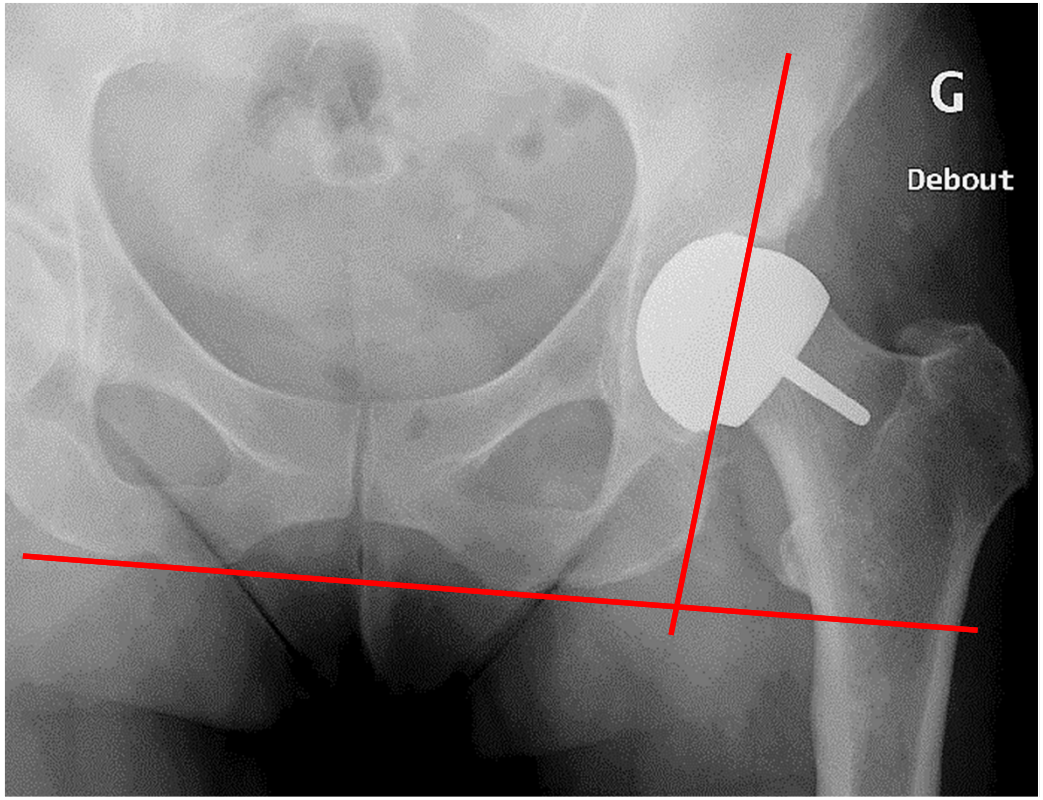
SURGEONS

- Surgeons may have a bad day



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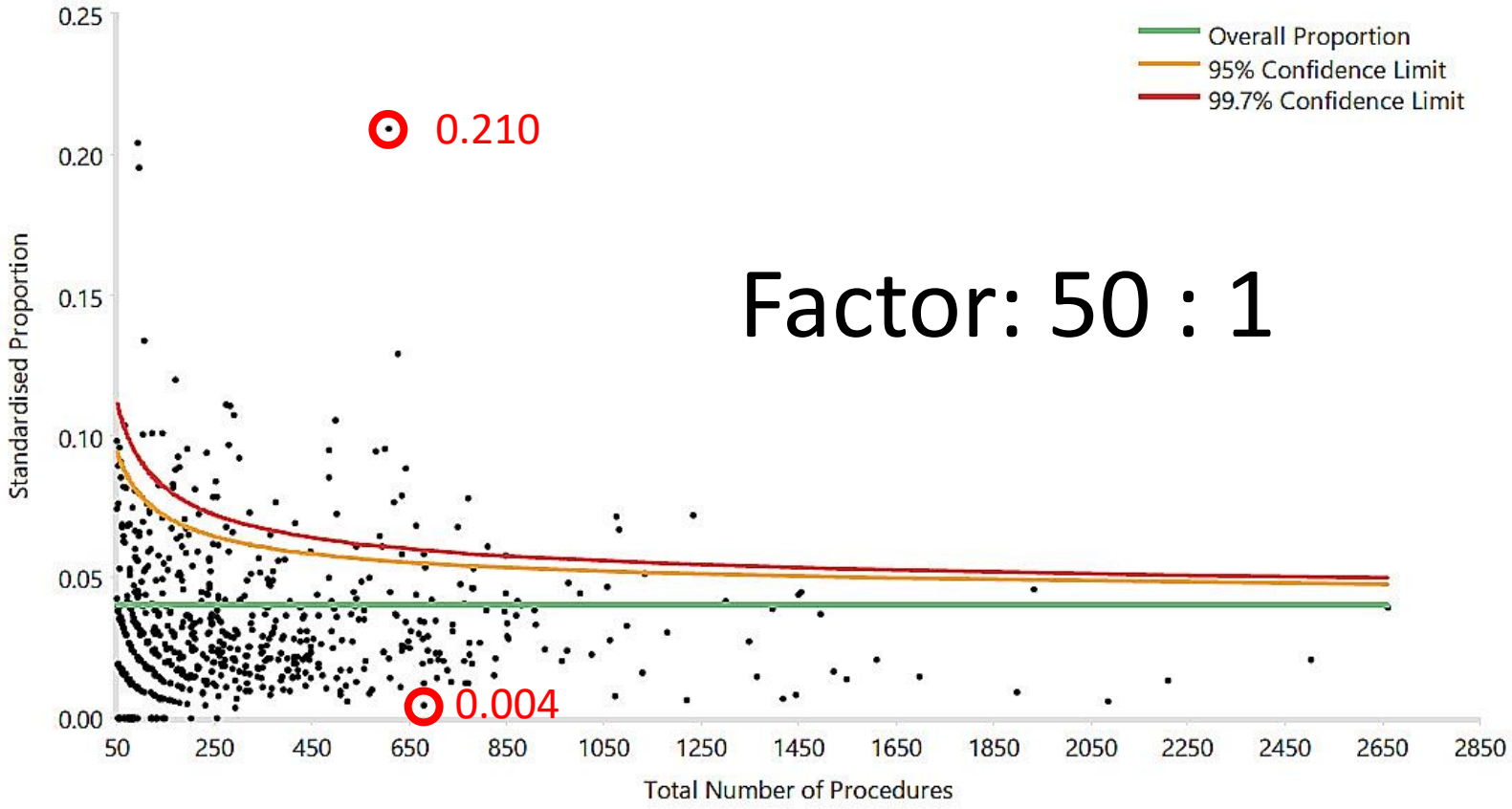
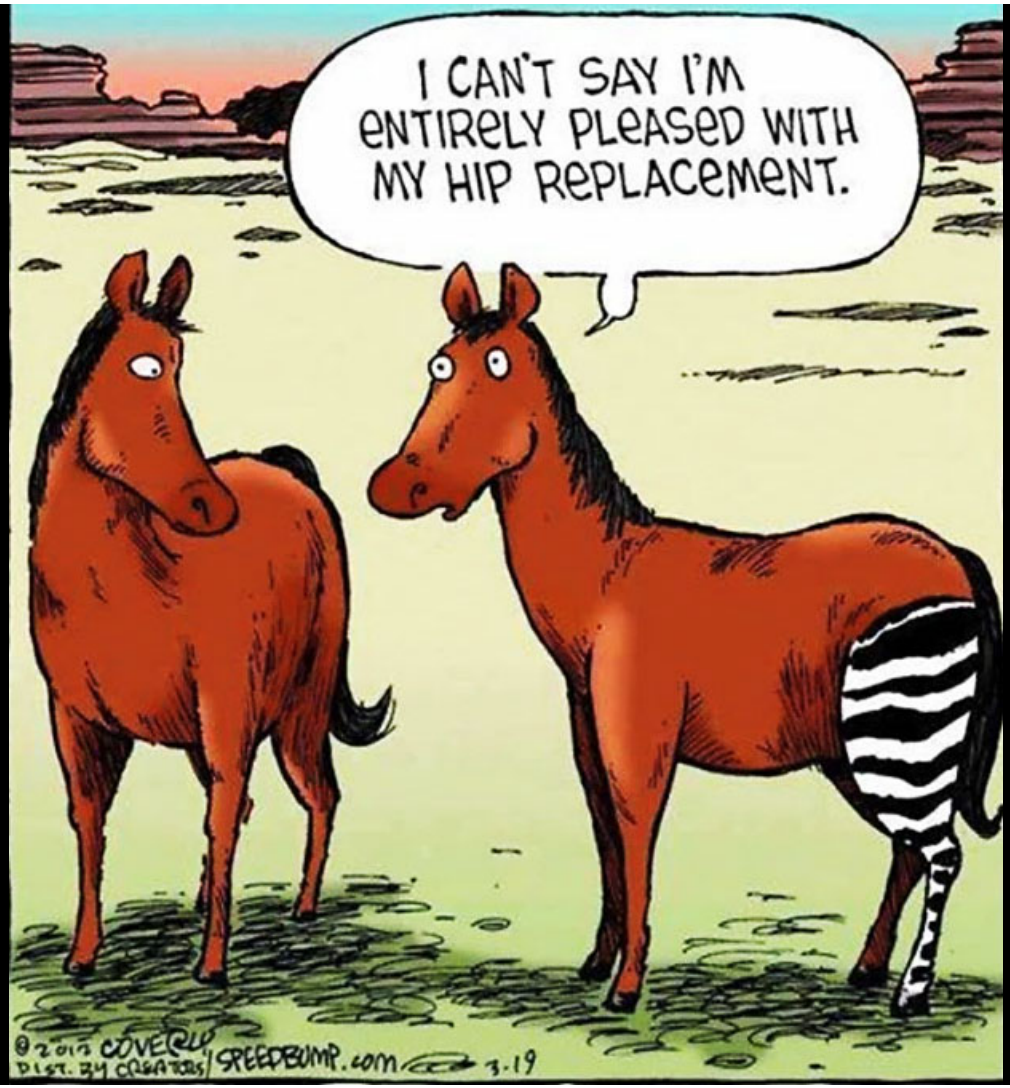
AUSTRALIAN REGISTRY 2017




I CAN'T SAY I'M ENTIRELY PLEASED WITH MY HIP REPLACEMENT.
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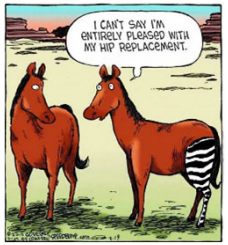
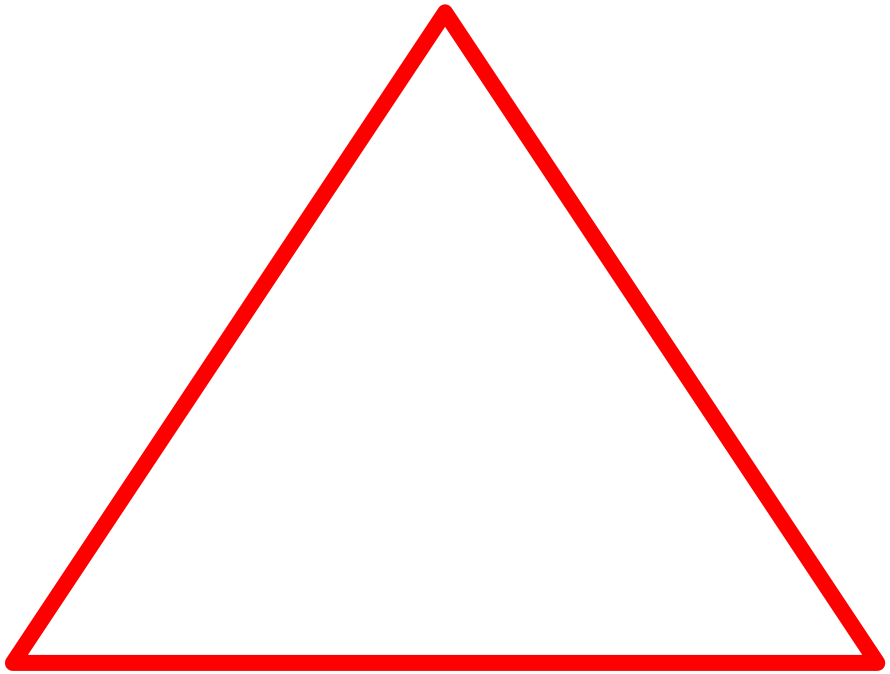
3.19

Fixation
Positioning
Taper connection
…

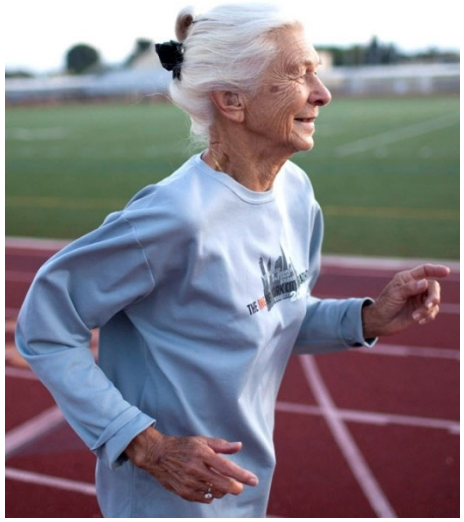
?





PATIENT ACTIVITY

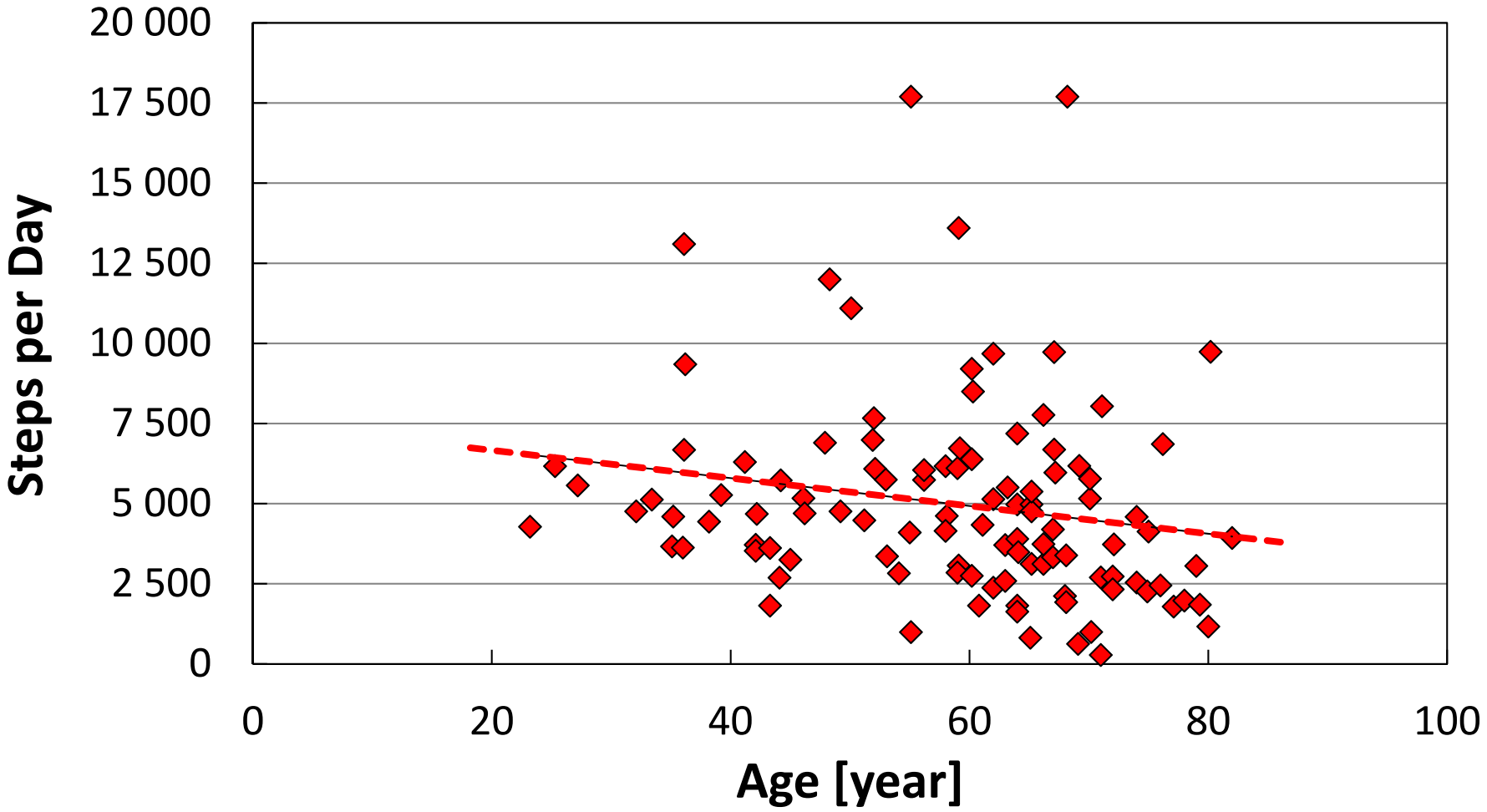
- As the mean age of the patients is steadily decreasing, the mean activity of the patients is increasing.



QUANTITATIVE ASSESSMENT OF WALKING ACTIVITY AFTER TOTAL HIP OR KNEE REPLACEMENT

- “The patients averaged 4,988 steps per day, which extrapolates to approximately 1.8 million cycles per year. Average activity ranged widely from 395 to 17,718 steps per day, an approximately forty-five-fold difference.”

- T. Schmalzried et al, JBJS, 80A, 1998, p. 54


Steps per Day
20 000
17 500
15 000
12 500
10 000
7 500
5 000
2 500
0
0
20
40
60
80
100
Age [year]

World Masters Athletics Championships 2019

Men 90 - 100

IN VIVO ELECTROCHEMICAL CORROSION STUDY OF A COCRMO BIOMEDICAL ALLOY IN HUMAN SYNOVIAL FLUIDS

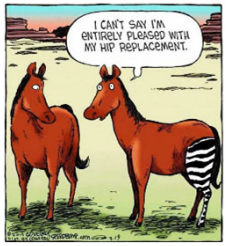
- “The corrosion behaviour of CoCrMo alloy in synovial fluids not only depends on material reactivity but also on the specific reactions of synovial fluid components. Depending on patients, corrosion rates varied significantly between 50 and 750 mg dm^{-2} $year^{-1}$.”
- A. Igual Munoz et al, Acta Biomat, 21, 2015, p. 228

IDENTIFICATION OF THE AT-RISK GENOTYPE FOR DEVELOPMENT OF PSEUDOTUMOURS AROUND MoM THAs

- “Among patients with a primary MoM THA, allelic variation within the HLA Class II loci may be a strong, independent risk factor associated with the need for subsequent revision surgery secondary to pseudotumour formation.”
- B.K.J. Kilb et al, CORR, 476, 2018, p. 230

COLLABORATION

COLLABORATION



Depuy's Pinnacle Lawsuits

After plaintiffs lost the first bellwether trial in the DePuy Pinnacle MDL, juries awarded verdicts to the people injured by hips in the next three trials. In January 2016, a jury awarded $502 million to five plaintiffs. Another jury awarded $1 billion to six plaintiffs in December 2016. The third trial resulted in a $247 million verdict for six plaintiffs.

Smith & Nephew

In April 2017, the Judicial Panel on Multidistrict Litigation combined 28 lawsuits over the company's BHR and R3 hip implants into a single MDL in Maryland. As of October 2017, the U.S. District Court for Maryland reported the MDL "encompasses more than 190 pending cases."

TRIBOLOGY OF TOTAL HIP ARTHROPLASTIES

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CONCLUSIONS

- Total hip prostheses is a standard operation than more than 2’000’000 operations per year
- Excellent clinical results / Operation of the century
- A good tribology is mandatory to assure good clinical results
- The in-vivo simulation is a real challenge:
  - Tribology tests allow only to exclude inappropriate solutions
  - Analytic approach may help

CONCLUSIONS

- Surgeon are the key players in the triangle
  Implant - Surgeon - Patient
- Patients are more and more demanding
- The understanding of the patient's biology will be an important area of research in the near future
- It's a real privilege to be active in this field for more than 32 years


THANK YOU