Institute of Medical &
Biological Engineering

UNIVERSITY OF LEEDS

Wear Performance of an All-Polymer Total Knee Replacement

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WHY PEEK OPTIMA?

A More Natural Solution to Knee Replacement

- Non-metallic solution
- Bone-like modulus[1]
- Bone-like weight[2]

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[1] *independently tested modulus for PEEK falls within the accepted range of trabecular and cortical bone moduli (1.15-5.44GPa) - Choi et al (1990), The elastic moduli of human subchondral, trabecular, and cortical bone tissue and the size-dependency of cortical bone modulus, Journal of Biomechanics, Volume 23, Issue 11, 1990, Pages 1103-1113.*

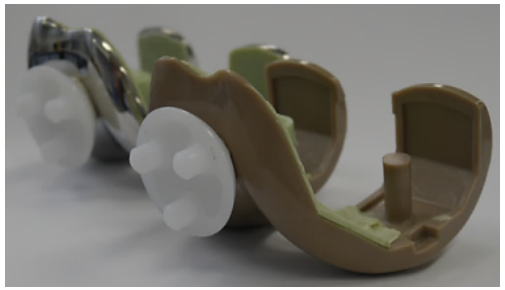
[2] *Measured density of PEEK-OPTIMA® Natural lies within the accepted density of trabecular bone (1.02-1.20 according to Stendig-Lindberg et al. 1993).*

AN ALL POLYMER TOTAL KNEE REPLACEMENT – EXPERIMENTAL SIMULATION STUDIES OVERVIEW

Fundamental pin-on-plate studies to better understand the tribology of UHMWPE-on-PEEK

1. **Influence of** protein **lubricant** concentration and **temperature on the wear** and friction **of a UHMWPE-on-PEEK OPTIMA™ bearing couple**[4]
2. **Influence of cross-shear and contact pressure on the wear of UHMWPE-on-PEEK**

- Third body wear performance



Whole joint wear simulation studies of TFJ and PFJ

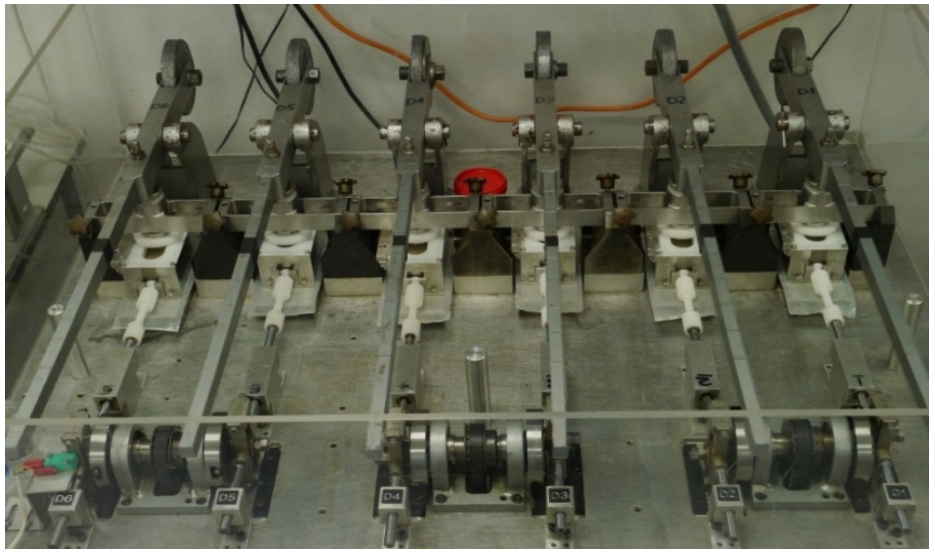
3. **Experimental wear simulation of the tibiofemoral joint (TFJ)**
4. **Experimental wear simulation of the patellofemoral joint (PFJ)**

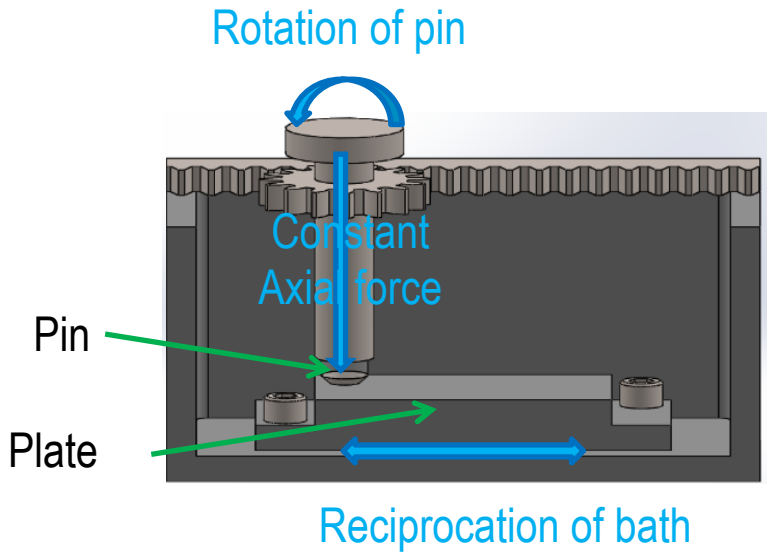
- Influence of input kinematics on the wear of the TFJ[3]

[3]*Cowie R.M. 2016 JEIM 230(11):1008-1015*
[4]*Cowie R.M. 2019 JMBBM 89:65-71*

METHODS PIN-ON-PLATE WEAR SIMULATION

- Simple geometrical configuration 6-station pin-on-plate wear simulator
- Lubricant protein concentrations 25% bovine serum
- Compared to UHMWPE-on-CoCr
- N=6
- Wear of UHMWPE pins assessed gravimetrically





PIN-ON-PLATE STUDY: INFLUENCE OF LUBRICANT TEMPERATURE ON WEAR OF UHMWPE-ON-PEEK

1. Influence of lubricant temperature on the wear of a UHMWPE-on-PEEK OPTIMA™ bearing couple

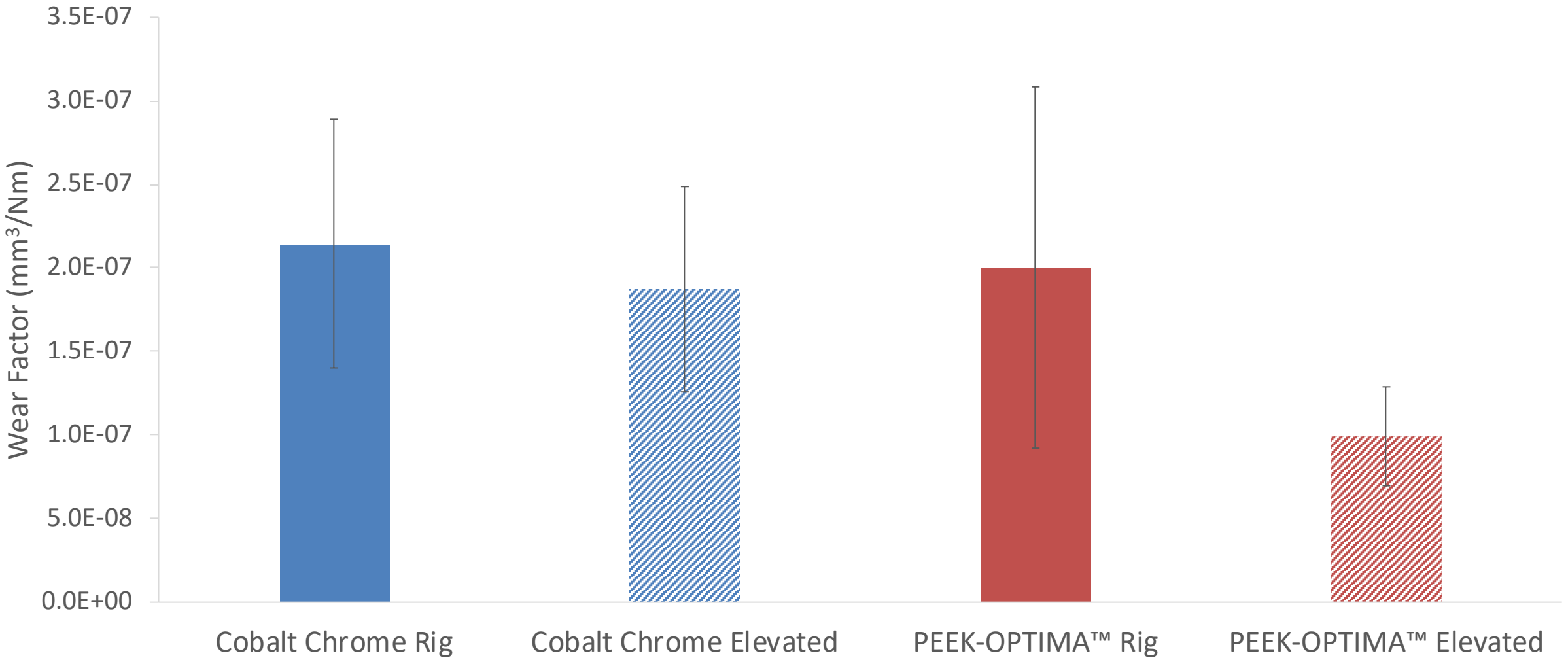
Test Conditions

- Frequency 1Hz
- Stroke length 20mm
- Rotation ±20°
- Load 160N
- 1Million cycles

Protein lubricant temperature:

- Rig running temperature (~24°C)
- Elevated temperature (~35°C)

INFLUENCE OF LUBRICANT TEMPERATURE ON WEAR FACTOR OF UHMWPE PINS



Cowie R.M. 2019 JMBBM 89:65-71

PIN-ON-PLATE STUDY: INFLUENCE OF CROSS SHEAR AND CONTACT PRESSURE ON WEAR OF UHMWPE-ON-PEEK

2a. Influence of contact pressure on wear of UHMWPE-on-PEEK

- Contact pressures ranging from 2-25MPa, created by changing the area of the contact face of the pin
- High contact pressures at 30, 40 and 80MPa
- Cross-shear ratio maintained at 0.087

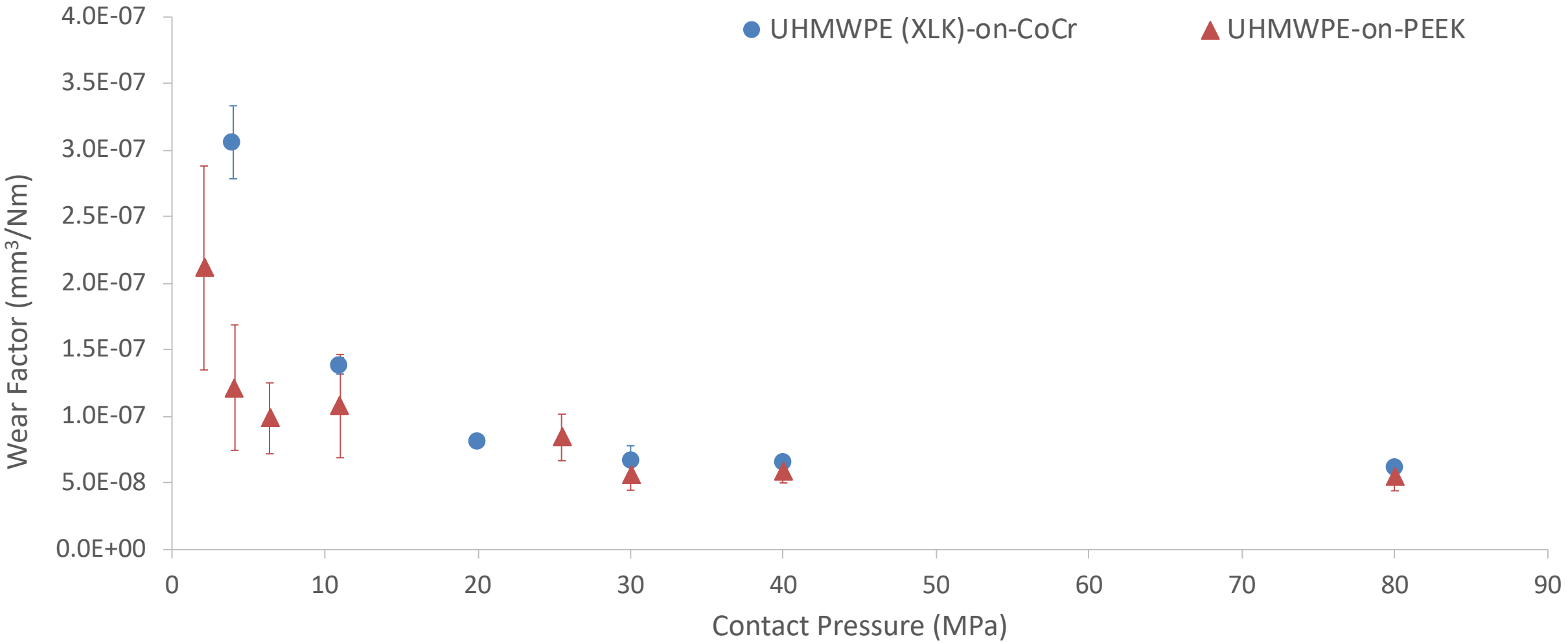
2b. Influence of cross-shear ratio on UHMWPE-on-PEEK

- 5 conditions investigated from 0 to 0.18
- Contact pressure maintained at 6.4MPa

Wear of UHMWPE-on-PEEK compared to XLK-on-CoCr[5]

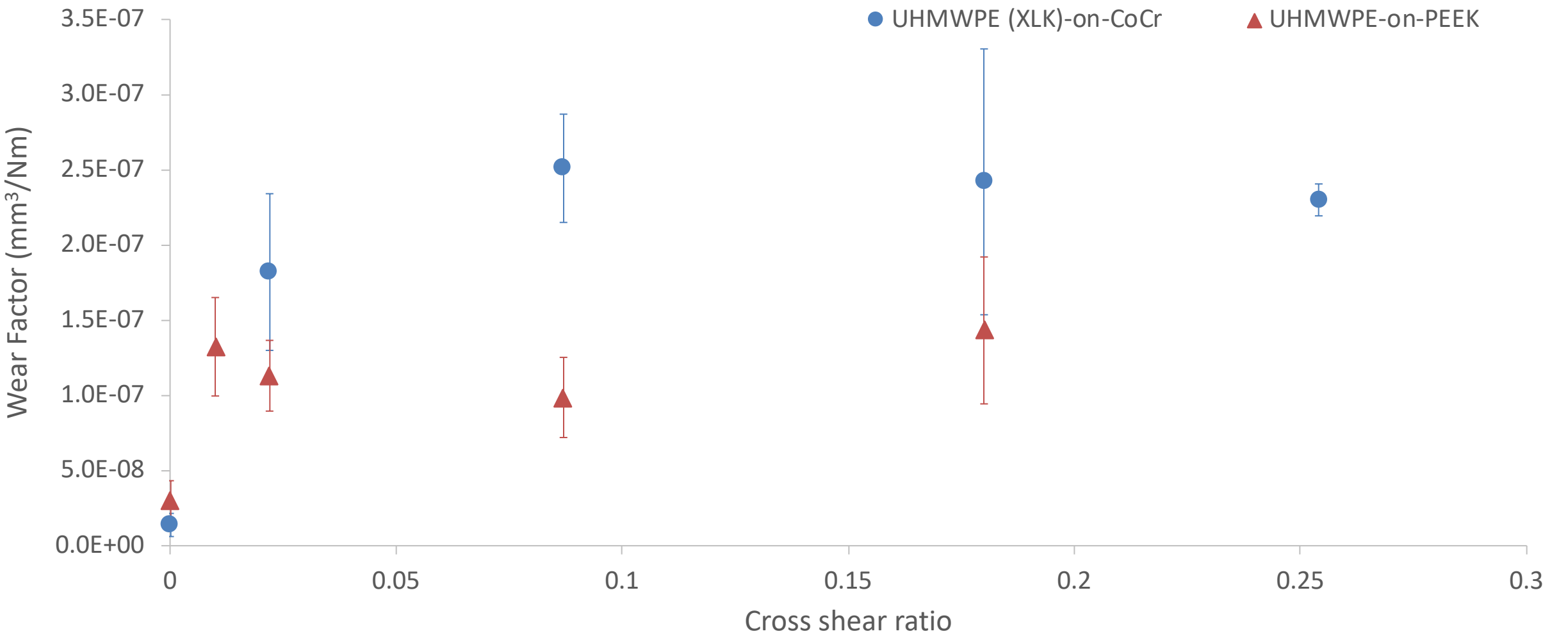
[5]*Abdelgaied A, et al. 2012. JEIM 227(1):18-26*

INFLUENCE OF CONTACT PRESSURE ON WEAR FACTOR OF UHMWPE



Comparison data from: Abdelgaied A, et al. 2012. JEIM 227(1):18-26

INFLUENCE OF CROSS SHEAR RATIO ON WEAR FACTOR OF UHMWPE



Comparison data from: Abdelgaied A, et al. 2012. JEIM 227(1):18-26

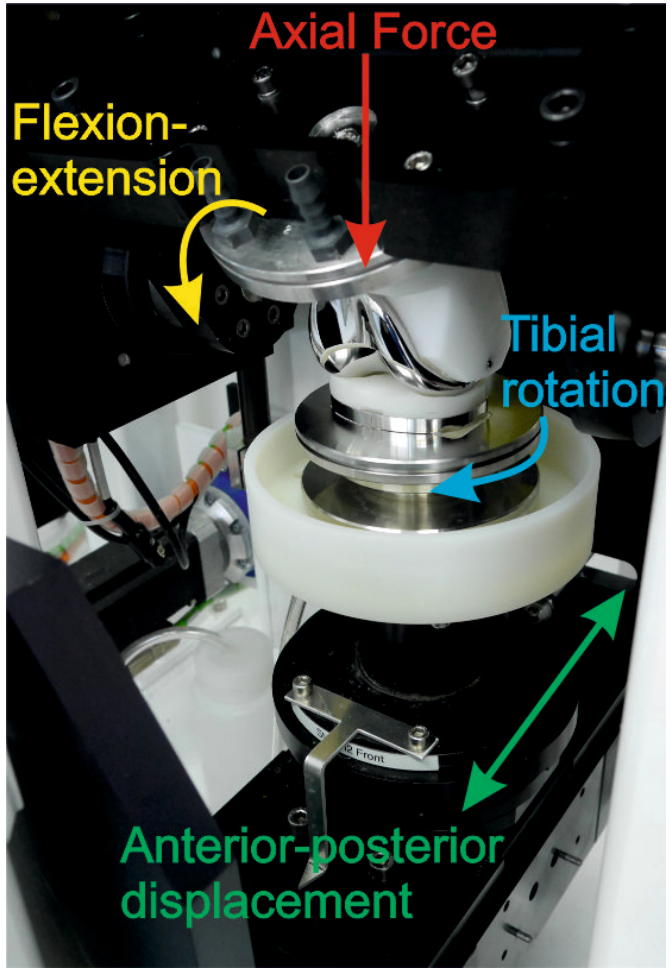
PIN-ON-PLATE SUMMARY

- Pin-on-plate studies showed the importance of the selection of appropriate test conditions when investigating the wear of different materials, in order to minimise test artefacts such as polymer transfer, and protein precipitation and deposition
- Wear factor of UHMWPE followed a similar trend against PEEK and CoCr with changing cross-shear ratio and contact pressure
- The variation in the data was larger for pins with a larger diameter contact face articulating against PEEK

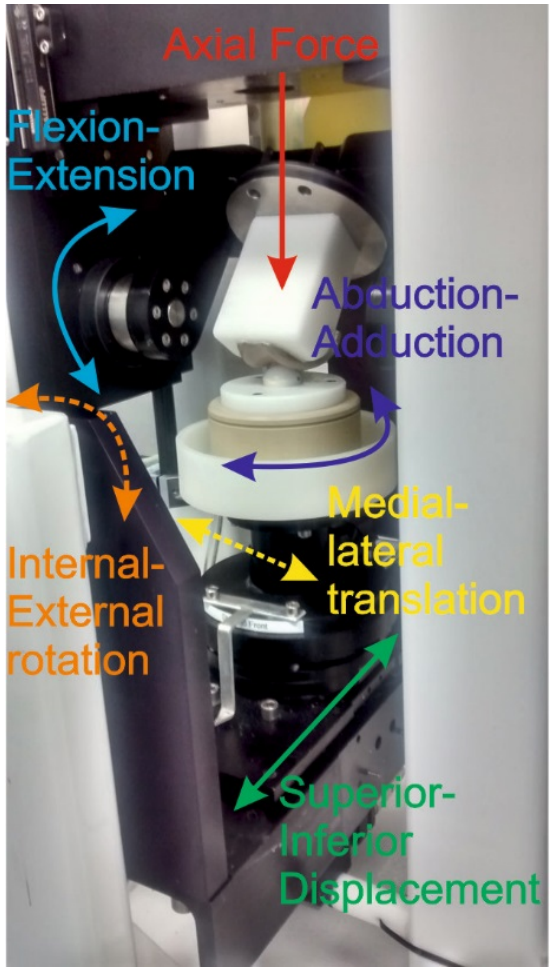
- Caution must be taken when interpreting these studies as POP results do not always directly translate to whole joint simulation

WHOLE JOINT WEAR SIMULATION STUDIES

3. TFJ wear simulation

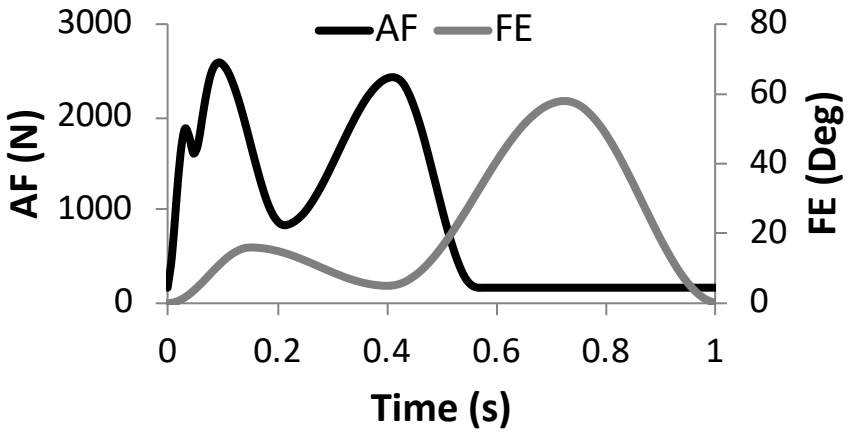


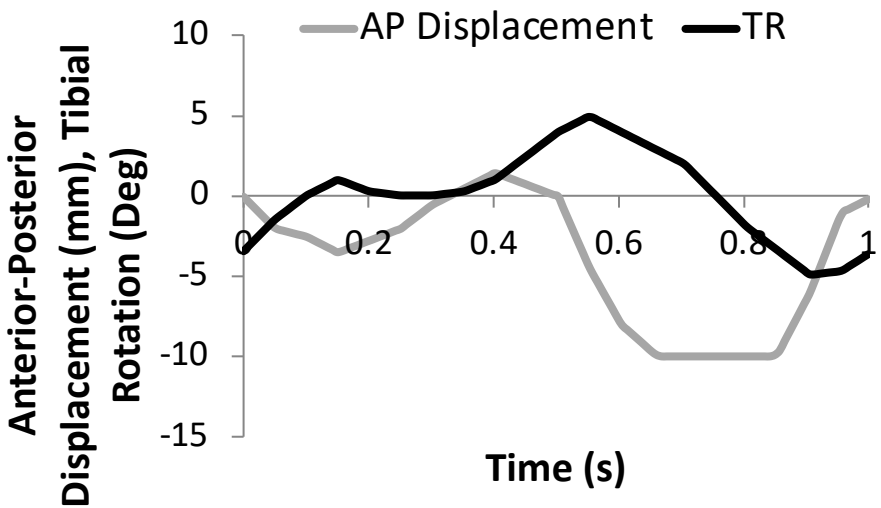
4. PFJ wear simulation



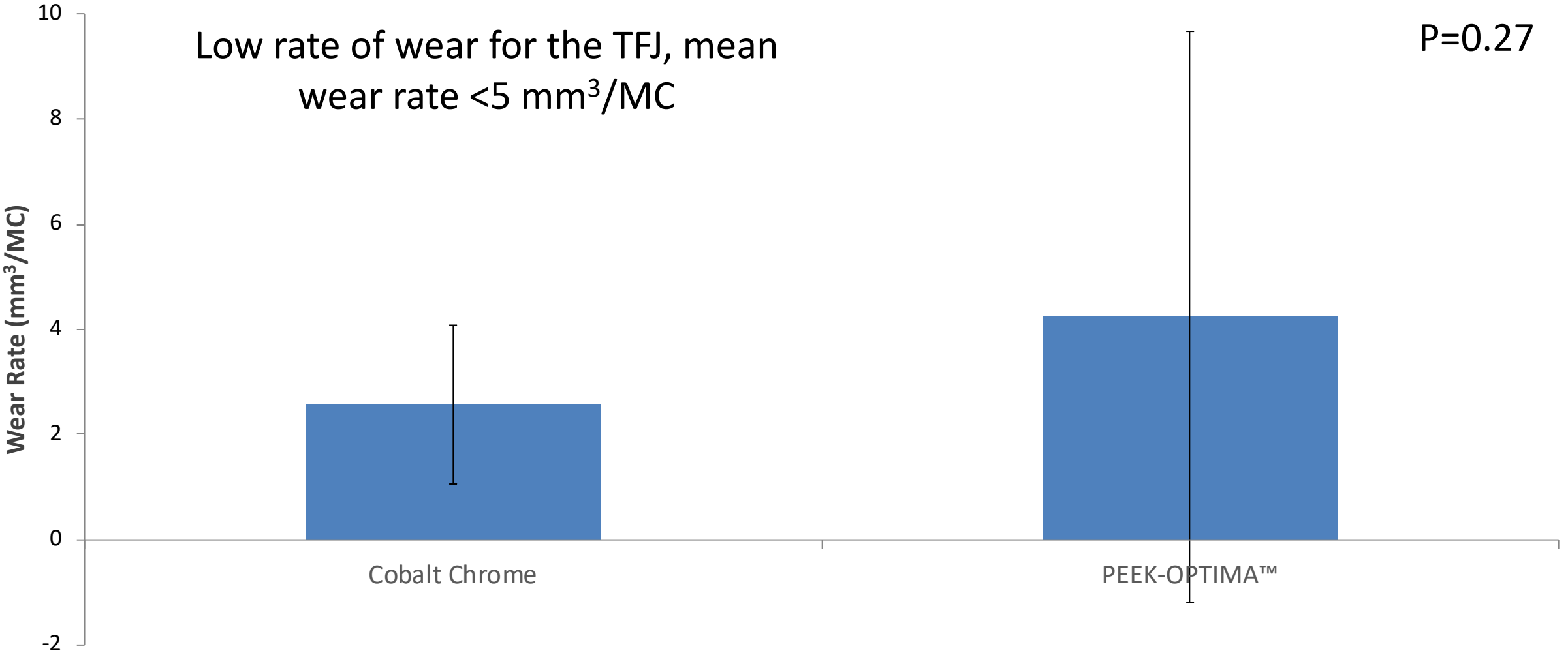
EXPERIMENTAL WEAR SIMULATION OF THE TIBIOFEMORAL JOINT

- Aim: Investigate the wear performance of the all-polymer knee implant compared to conventional materials
- n=3 PEEK-PE, n=3 CoCr-PE
- 5 million cycles, 25% bovine serum
- Leeds High Kinematics (displacement control)
- Wear of UHMWPE tibial components determined by gravimetric analysis
- Surface topography analysed pre- and post-test





WEAR RATE OF UHMPWE IN TFJ



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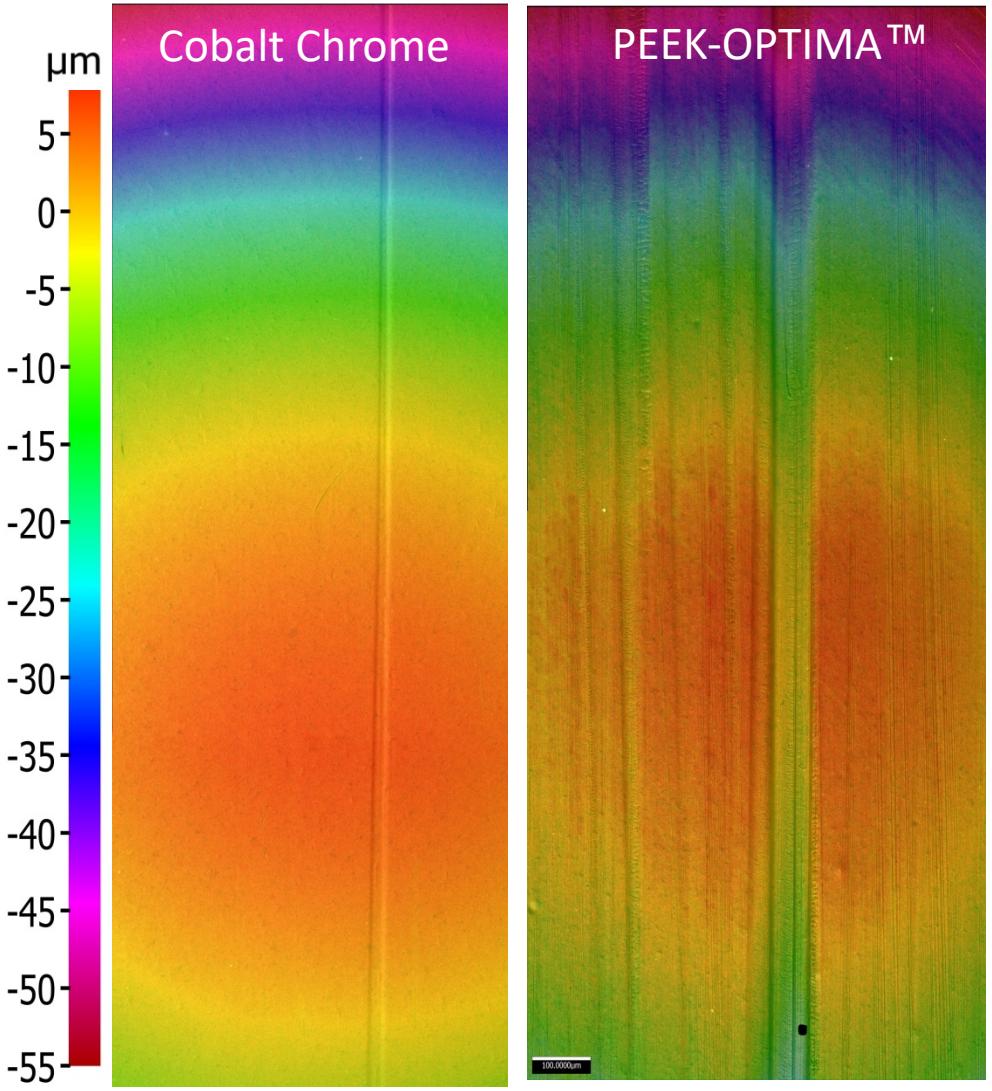
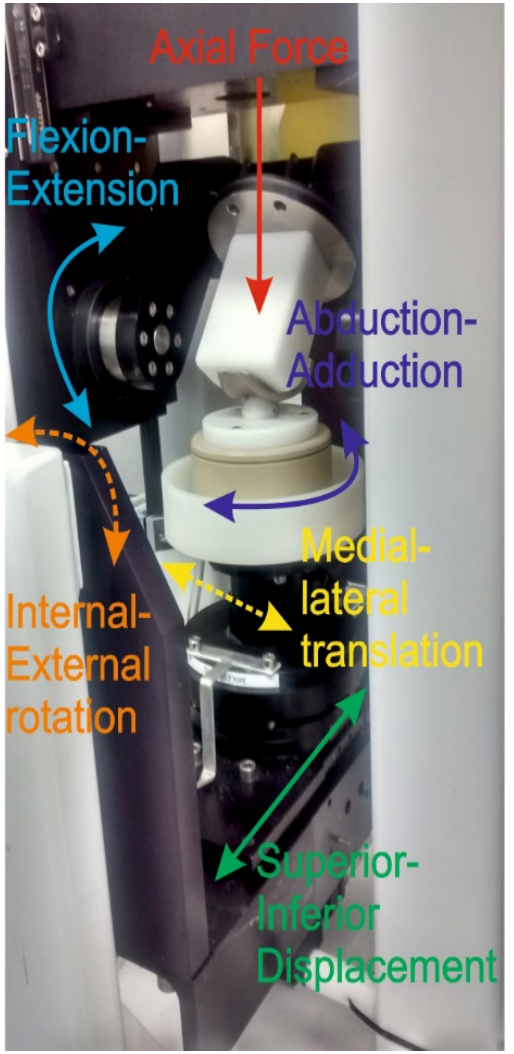


Images representative of the surface topography of the femoral components after 5MC

EXPERIMENTAL WEAR SIMULATION OF THE PATELLOFEMORAL JOINT

Aim: Investigate the wear of an UHMWPE patella articulating against a PEEK-OPTIMA™ femoral component under a walking gait cycle

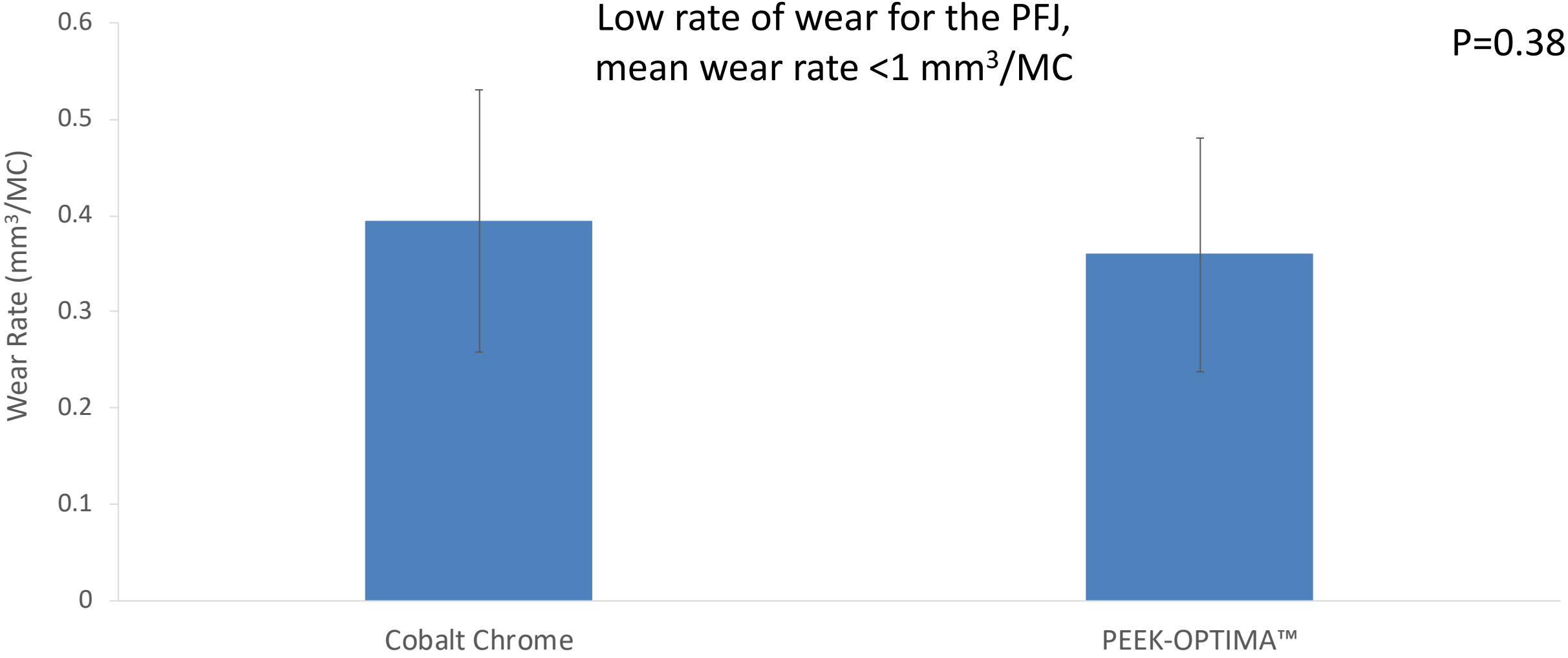
- n=6 PEEK-PE, n=6 CoCr-PE
- 5 million cycles, 25% bovine serum
- Input Kinematics adapted from Maiti *et al* (2014)
- Wear of UHMWPE patella buttons determined by gravimetric analysis
- Surface topography analysed pre- and post-test



WEAR RATE OF UHMPWE IN PFJ

Low rate of wear for the PFJ, mean wear rate <1 mm^3/MC

P=0.38



SUMMARY

- Low rate of wear (< 5 mm^3/million cycles for the TFJ and < 1 mm^3/million cycles for the PFJ) of UHMWPE against both PEEK and CoCr for a well positioned implant tested under walking gait conditions.
- No significant difference in the wear of UHMWPE articulating against the different implant materials after 5 million cycles of wear simulation.
- Scratching apparent on the surface of the PEEK femoral components but this did not influence wear rate, which remained linear over the duration of the 5 million cycle study.
- Elevated bulk lubricant temperature (~2.5°C) in all-polymer combination.

LIMITATIONS OF STUDIES

- Sample size of TFJ simulation studies limited by N=3
- No reliable method to determine whether wear of the PEEK occurs
- Lack of understanding of how the higher friction of UHMWPE-on-PEEK will affect joint motion

ACKNOWLEDGEMENTS

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