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Articulation and Edge Loading Affects Taper Wear and Corrosion in Total Hip Replacement

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Introduction

- Modular implants are frequently used in total hip replacements. They provide surgeons with flexibility to restore the joint centre in patient populations with variable anatomy.
- The disadvantage of this design feature is the introduction of another interface which is potentially susceptible to wear and corrosion.
- Taper wear and corrosion have been observed on retrievals [1] and the cause of such phenomena has been reported as multi-factorial, with taper design and material combinations as well as surgical and patient factors contributing.
- The clinical significance of these observations are as yet unclear.

Edge loading due to dynamic separation in hip joint replacement.

Aim

The aim of this study was to determine the effect of joint articulation, component positioning and the occurrence of edge loading on the amount of corrosion at head-neck taper under physiological conditions.

Materials and Methods

- The Leeds II hip joint simulator [2] was used in this study.
- Titanium alloy femoral stems (Corail®, DePuy Synthes, Leeds, UK) and 36mm (diameter) ceramic-on-ceramic bearings (n=3, BIOLOX® *delta*), mounted in Titanium alloy shells (Pinnacle®), (DePuy Synthes, Leeds, UK) were used where the stem and shell were cemented into holders using PMMA and sealed with silicone (Figure 1).
- The femoral head was impacted on the stem using a hand held hammer.
- A series of test conditions were considered which were run sequentially using hip simulator input profiles as summarised in Table 1.
- Throughout the test, the output current was monitored using a potentiostat (VersaStat, 4 with VersaStudio software version 2.42.3, Princeton Applied Research, Farnborough, UK).
- The femoral stem acted as the working electrode (WE) alongside a carbon fibre counter electrode (CE) and Ag/AgCl reference electrode (RE).
- New-born calf serum (25% v/v) diluted using phosphate buffered saline (PBS) was used as a lubricant.

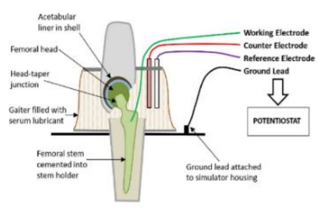

Figure 1: Schematic of the three electrode test cell on one station of the Leeds II anatomical and physiological simulator

Table 1: A matrix of test conditions considered in this study.

	Experimental Condition						
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
Kinematics and kinetics	At rest	At rest	Dynamic loading only	Standard gait with articulation and concentric head and cup			Standard gait with articulation and 2mm of dynamic separation and edge loading
Potential	Open circuit	Fixed -50mV	Fixed -50mV	Fixed -50mV			Fixed -50mV
Swing phase load	N/A	N/A	70N	70N	70N	70N	70N
Peak load	N/A	N/A	1kN	1kN	2kN	3kN	3kN
Flexion-extension	N/A	N/A	N/A	+30°/ -15°	+30°/ -15°	+30°/ -15°	+30°/ -15°
IE rotation	N/A	N/A	N/A	±10°	±10°	±10°	±10°
Duration (secs)	100	100	100	100	100	10,800	10,800

Results

- The potentiostat data recorded showed that at rest, the open circuit potential of approximately -150mV was reached (Figure 2, test No. 1).
- When the voltage was fixed at -50mV, the current increased to approximately 50μA which then decreased down to the level it was at under the open circuit potential conditions (Figure 2, test No. 2).
- As the motion was applied and the load increased, the current increased initially then decreased as the test progressed (Figure 2, tests No. 3, No. 4 and No. 5).
- Under the standard gait cycle, the current initially increased to approximately 10μA, then started decreasing reaching 2-3μA after 10,800 cycles of testing (Figure 2, test No.6).
- However, under edge loading caused by 2mm of dynamic separation driven by component translational mismatch of the centres of rotation of the head and cup, the current stayed at a higher level (>5μA) throughout the 10,800 cycles of testing (Figure 2, test No. 7).

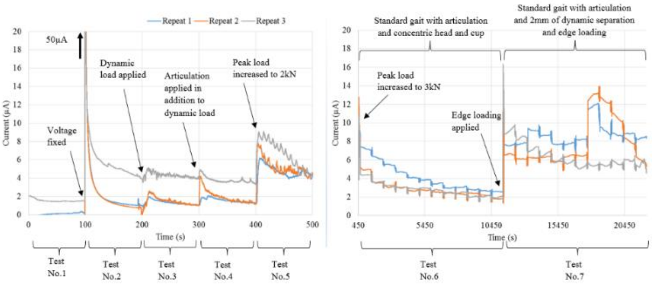

Figure 2: The output current obtained throughout the seven conditions considered (n=3) for ceramic on ceramic bearings on titanium stem at -50mV of fixed voltage.

Discussion

- By fixing the voltage in the test cell, the current measurements became an indicator to the corrosion potential of the working electrode which in the current setup was the femoral stem taper.
- This study has shown that motion and increased loading may lead to higher potential for corrosion of the taper which may be due to higher level of micro-motion at the taper-head junction.
- Moreover, this study has shown that a mismatch in the centres of rotation between the head and cup which might lead to large dynamic separation during gait and edge loading at the rim of the cup, can cause higher potential for corrosion at the head-neck taper interface. This may be due to larger degrees of motion at the taper interface driven by higher torques.

Significance

- A preclinical simulation method was developed to assess the performance of the head-neck taper interface *in vitro* taking into account for the first time the contribution of dynamic hip separation.
- This study showed that edge loading driven by variations in component positioning may affect the corrosion rate at the head-neck taper junction.

References

1. Kocagoz SB et al CORR 2016;474(4):985-994. 2. O'Dwyer Lancaster-Jones O et al. ORS, Orlando, USA, 2016.

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