The Effect of the Swing Phase Load under Head and Cup Centre Mismatch on the Severity of Edge Loading and Wear of Ceramic-on-Ceramic Hip Joint Replacements

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Stratified Approach For Enhanced Reliability (SAFER)

Significance

Patient and surgical variability should be taken into account during pre-clinical testing of hip replacement bearings. This study has shown that the level of swing phase load in hip simulator testing associated clinically with soft tissue tensioning affects the occurrence and severity of edge loading under conditions where a mismatch between the centres of rotation of the femoral head and acetabular cup exists.

Introduction

Pre-clinical testing of hip joint replacements is important for the evaluation of the performance, safety and reliability of existing and new devices. Patient and surgical variability need to be accounted for, as they may lead to scenarios which affect the occurrence and severity of edge loading conditions. Clinically, edge loading has been associated with increased wear and revision of hip replacements [1]. Clinical biomechanical studies show a variation in the swing phase load applied to hip prosthesis [2]. Thus, it is important to widen the set of conditions to be considered for pre-clinical testing.

Aim

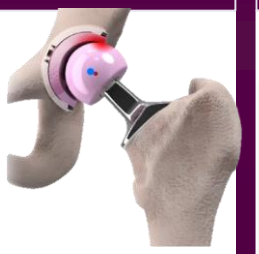
The aim of this study was to determine the effect of varying the swing phase load on the occurrence and severity of edge loading and the wear of ceramic-on-ceramic bearings when a medial-lateral translational mismatch (offset deficiency) of the centres of the head and cup was present under different cup inclination angles in a hip joint simulator.

Materials

36 mm BIOLOX® delta ceramic-on-ceramic (DePuy Synthes, UK)

Method

Edge loading was replicated in a hip joint simulator by applying a translational mismatch between the centre of the head and the centre of the cup during the set-up of components.
Different levels of swing phase loads were applied along with different levels of mismatches and cup inclination angles to determine the dynamic separation and severity of edge loading, and wear (study A and B).



The severity of edge loading is the time during the cycle where the head is in contact with the rim (duration of separation) and the magnitude of the forces applied [3].

Test study	Translational mismatch between the head and cup centres	Swing phase load	Inclination angle (in-vivo equivalent)	Study output assessed
[A] Biomechanical study (96 combinations), n=3 per combination	1, 2, 3 and 4 mm	50, 70, 100, 150, 200, 250, 300, and 450 N	45°, 55° and 65°	Dynamic separation, severity of edge loading
[B] Wear study (n=6)	4 mm	70, 150 and 300 N	65°	Wear rate (determined gravimetrically)

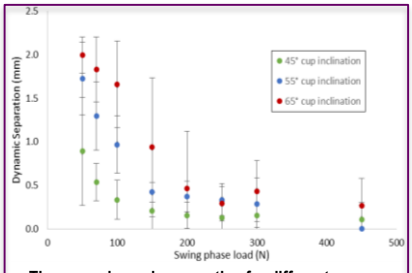
- Leeds Mark II Physiological Anatomical Hip Joint Simulator

Test conditions:
- Walking gait cycle kinematics
- Lubrication: 25% new-born calf serum + 0.03% sodium azide

Statistical analysis was performed using one way ANOVA (significance at 0.05)

Results and Discussion

The magnitude of dynamic separation decreased as the swing phase load increased for all the cup inclinations angles.

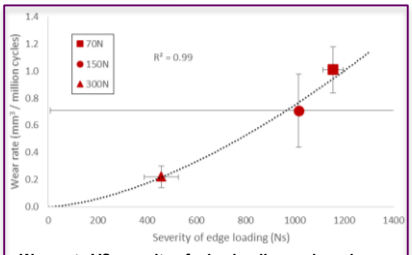


The mean dynamic separation for different cup inclination angles under a 4 mm translational mismatch.

The magnitude of dynamic separation also decreased under different level of mismatches applied as the swing phase load increased.

The severity of edge loading also decreased as the swing phase load increased. This led to lower wear rates at higher swing phase loads.

Previous tests demonstrated that the level of dynamic separation, severity of edge loading and wear in ceramics-on-ceramic bearings increased with high cup inclination angle and mismatch [3]. This study showed a reduction in dynamic separation, severity of edge loading and wear with increased swing phase load.



Wear rate VS severity of edge loading under a 4 mm translational mismatch and 65° cup inclination angle condition

The wear rates correlated positively with the severity of edge loading obtained from the biomechanical tests.

This study provides further evidence under a wider range of conditions that wear associated with edge loading, can be predicted from biomechanical tests which determine the severity of edge loading.

Acknowledgement

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References

[1] Nevelos et al., Biomaterials 20, 1999. [2] Bergmann et al., JBiomech 34, 2001. [3] O'Dwyer Lancaster-Jones et al., ORS, 2016.

Disclosure

J. Fisher is an NIHR senior investigator, a paid consultant to DePuy Synthes, Invibio, Tissue Regenix Group plc and a share holder of Tissue Regenix Group plc; E. Ingham is a paid consultant to DePuy Synthes, Stryker, Tissue Regenix Group plc and a share holder of Tissue Regenix Group plc; S. Williams is a paid consultant to DePuy Synthes; Jonathan Thompson, Oscar O'Dwyer Lancaster-Jones and Graham H. Isaac are employees at DePuy Synthes

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