Introduction

There are many factors that can affect the wear and deformation of polyethylene in the hip prosthesis. Edge loading and contact may occur due to a translational mismatch between the head and cup bearing centres and/or steep cup inclination angles [1, 2] (Fig. 1). This may lead to an increase in deformation, damage, cracking and wear, at the rim of the cup [3].

Rotational surgical position
Translational surgical position

Figure 1. Variations in component positioning.

Aim

The aim of this study was to assess the occurrence and severity of edge loading of metal-on-polyethylene bearings, then to assess the wear and deformation of polyethylene at different medial-lateral translational and rotational positions.

Materials and Equipment

Metal-on-modernly crosslinked polyethylene (UHMWPE, Marathon™, DePuy Synthes Joint Reconstruction, Leeds, UK) hip replacements were set up on the ProSim electromechanical hip joint simulator (Fig. 2, EM13, Simulation Solutions, Stockport, UK).

Figure 2. ProSim EM13.

Methods

- Biomechanical tests (stage one) were carried out at 45° and 65° cup inclination angles with 1, 2, 3 and 4 (mm) medial-lateral translational mismatch between the centres of the head and cup (n=3 under each condition, Fig. 3).
- For the wear study (stage two), different conditions were considered, conditions with 0, 2 and 4 (mm) translational mismatch for three million cycles for cups inclined at 45° (n = 6) and 65° (n = 6).
- For all tests, a gait cycle consisting of a twin peak input load of 3 kN and swing phase load of 70 N was applied along with three axes of rotation conditions.
- Gravimetric analysis was carried out at one, two, three and five million cycle intervals (n=6) and 65° cup inclination angles.

Results

- The largest level of dynamic separation occurred at 4 mm mismatch & 65° cup inclination angles (p<0.01, Fig. 4).
- The wear rate increased as the level of translational mismatch increased. There was no significant difference in the wear rates for the same level of translational mismatch at 45° and 65° cup inclination angles (p=0.14, Fig. 5).
- The maximum mean penetration depth at the edge of the cup was 0.03 ± 0.01 mm at 45° and 0.22 ± 0.02 mm at 65° cup inclination angles (p<0.01). At 4 mm translational mismatch the maximum mean penetration depth at the edge of the cup was 0.10 ± 0.05 mm at 45° and 0.28 ± 0.04 mm at 65° cup inclination angles (p<0.01, Fig. 6).

Figure 3. Rotational and translational positioning of the cup.

Figure 4. Dynamic medial-lateral separation (mean ± 95% confidence limits) of metal-on-polyethylene bearings at different levels of translational mismatch at 45° (n=3) and 65° (n=3) cup inclination angles.

Figure 5. Wear of polyethylene (mean ± 95% confidence limits) for concentric, 2 mm and 4 mm translational mismatch at 45° (n=6) and 65° (n=6) cup inclination angles.

Discussion

A two stage method was used to firstly assess the effects of component positioning on the occurrence of edge loading, then to determine the wear and deformation of polyethylene liners.

- 4mm translational mismatch between the head and the cup resulted in approximately twofold increase in wear at highest inclination angle.
- 4mm translational mismatch between the head and the cup resulted in substantial deformation of the cup rim for both inclination angles, with three fold more deformation with 65° compared to 45° cup inclination angles.

Significance

Rotational and translational positioning of the acetabular cup are important factors in the long term clinical success of hip joint implants. Good component positioning which will reduce the magnitude of dynamic separation and reduce the occurrence and severity of edge loading in vivo may reduce the potential for deformation, fatigue damage and failure of polyethylene.

References


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