Institute of Medical & Biological Engineering

Damage and wear of polyethylene hip replacements subjected to edge loading during hip simulator testing

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Background

- Wear, degradation and fatigue of polyethylene acetabular cups have been reported to play a role in the failure of total hip replacements.
- In vitro hip simulator tests replicate standard walking with optimally positioned implants[1]. However, edge wear has been observed clinically when cups have been highly inclined or where joint centres were mismatched[2,3,4].
- Edge wear is of concern, particularly when the mechanical properties have been reduced, it is known that this is an effect of ageing[5].
- A requirement for pre-clinical testing that replicates these adverse edge loading conditions has been identified[6].

Aims

- To develop a hip simulator protocol to replicate edge-loading conditions and use this to evaluate aged and non-aged polyethylene acetabular liners for wear and fatigue behaviour.

Materials & Methods

Materials:

- Two types of UHMWPE liner were tested (Fig. 1; Pinnacle®, DePuy Synthes):
  - Artificially aged Gamma Vacuum Foil PE aged at 70°C and 70psi for 2 weeks (Aged PE, n=4)
  - Marathon® moderately crosslinked PE (XLPE, n=4)
- Cobalt chromium femoral heads (DePuy Synthes, UK)

Fig. 1 Assembled Pinnacle liner and shell

Fig. 2 Single station of the ProSim hip simulator (Simulator Solutions, UK) showing the mounted femoral head and the PE acetabular cup

Simulator: Ten station ProSim hip simulator (Fig. 2)

Motions and loading: flexion/extension -15°/+30°; internal/external rotation ±10°; max. load 3kN; min. load 300N

Lubrication: 25% new born calf serum with 0.03% sodium azide

Test duration: 5 million cycles standard gait conditions then 5 million cycles edge loading conditions

Edge loading: dynamic microseparation of head and cup to reflect a mismatch in the centres of rotation (Fig. 3): *0.5mm to 1mm of lateral displacement*

Volume change/wear: gravimetric (Balance, Mettler Toledo) and geometric (CMM, Mitutoyo) assessment

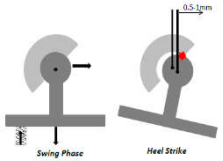

Fig.3 Schematic of femoral head and acetabular cup showing forces and motions during swing phase and heel strike

Results

- Three types of fatigue damage were observed on the aged PE liners (Fig. 4)
  - Cracking at the inner rim (A)
  - Circumferential cracks at anti-rotation tabs (B)
  - Radial cracks on the backside (C)

Fig. 4 Images of damage observed on aged PE liners. Orientation with respect to edge loading also shown.

- All liners exhibited rim deformation after edge loading, most likely consisting of wear and creep (Fig. 5)

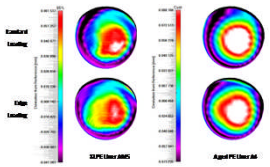

Fig. 5 Geometric volume change images (Redlux, UK) of XLPE and aged PE liners after standard and edge loading

- Both types of liner were lower wearing under edge loading conditions than standard loading (Fig. 6)

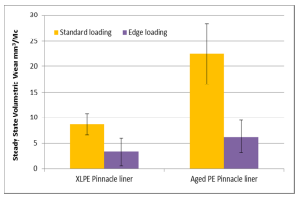

Fig. 6 Steady state volumetric wear for XLPE and aged PE liners measured gravimetrically

Discussion

- A hip simulator edge loading protocol was developed that caused rim damage in aged PE acetabular liners.
- A dynamic microseparation of 0.5mm-1mm was used but larger separations of greater than 1mm may occur clinically and may cause increased wear rates and greater damage and deformation under edge loading[2].
- **SIGNIFICANCE:** This study developed and evaluated a simulator protocol that can be used to help predict the wear and fatigue behavior of PE acetabular components when they are subjected to edge loading conditions.

References

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