Institute of Medical & Biological Engineering

Influence of kinematic and setup conditions on the wear of three total knee replacement bearings

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Background

- Wear of polyethylene continues to be a significant factor in the longevity of TKR [1] Cross-linked and anti-oxidant polyethylene materials have been introduced to enhance stability and wear resistance
- Experimental studies aim to assess TKR devices under conditions that enable prediction of clinical wear. However, variation in experimental setup, and kinematic conditions may have a significant impact on the results
- The aim of this study was to examine the effect of kinematic and setup conditions on the wear performance of total knee replacements, comparing a novel TKR design with an established TKR tested with two bearing materials

Materials

Three different TKR/bearing materials studied (n=6)

- Sigma CR fixed bearing TKR (DePuy Inc, USA)
  - Curved conventional UHMWPE inserts (GVF)
  - Curved moderately cross-linked UHMWPE inserts (XLK)
- Attune CR fixed bearing TKR (DePuy Inc, USA)
  - Anti-oxidant moderately cross-linked UHMWPE (AOX)

All mid-size, with composite thickness of 10mm

Methods

Figure 1: Prosim Knee Simulator

- Six station Prosim knee simulator (Fig 1)
- Femoral bearing setup on distal radius, dependent on device design, or ISO specification (Table 1)
- Leeds kinematic conditions [2]
  - High kinematics with 10mm AP disp.
  - Intermediate kinematics with 5mm AP disp.
  - Modified high kinematics used for ISO test setup – direction of AP displacement reversed
- Lubricated with 25% bovine serum
- Wear assessed gravimetrically

Table 1: Kinematic and setup conditions

Centre of rotation	Distal Radius		ISO [3]
Kinematic condition	High kinematics [2]	Intermediate kinematics [2]	Modified high kinematics
Peak load/N	2600	2600	2600
Anterior-posterior displacement/mm	10	5	-10
Internal-external rotation/°	±5	±5	±5
Flexion-extension/°	0-50	0-50	0-50

Results

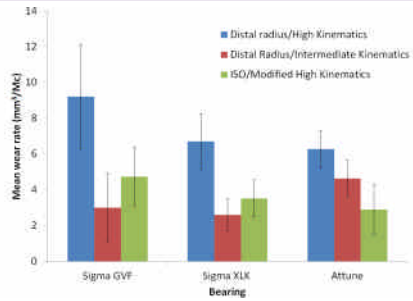

Figure 2: Mean wear rates for bearings under all conditions (±95% confidence limits indicated)

- Significant reduction in wear rate for all bearings under ISO/Modified high kinematics compared with Distal/High kinematics (Figure 2, ANOVA, $p<0.05$)
- Comparable wear rates between Sigma XLK and Attune bearings under high kinematics Wear scars of ISO setup studies were smaller and more anterior for both designs (Figure 3)

Figure 3: Comparison of wear scar size and location

Discussion

- Experimental test setup and kinematic conditions were shown to have a significant and similar effect on both Sigma and Attune TKRs (ANOVA, $p<0.05$)
- ISO/modified high kinematics condition resulted in significantly lower wear rates than distal/high kinematics due to the altered relative motion at the femoral-tibial interface
- The relative motion and contact mechanics of the TKR were altered by changing the femoral centre of rotation
- The novel Attune TKR had comparable wear rates to the Sigma XLK under distal/high and ISO/modified high kinematics, but significantly higher wear under intermediate kinematics

Significance

- This study demonstrates the significant effect test setup and input kinematics has on the outcome of wear studies on total knee replacements.
- Additional research should be conducted to determine the appropriate setup and kinematic input to provide physiologically relevant relative motion between the femoral and bearing surfaces
- This study highlights the need to assess the wear performance of TKR bearings under a range of kinematic inputs, rather than one test condition

References
[1] Ingham and Fisher Biomaterials 2005
[2] McEwen et al Biomechanics 2005
[3] ISO 14243-3

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