PRE-PRINT: Strickland, M. A., L. A. Knight, et al. (2010). Ultra-Long-Term Knee Wear Testing: An In-Silico Perspective.
European Society of Biomechanics. 17th Congress, 5-8 July, 2010. Edinburgh, UK.

Ultra-Long-Term Knee Wear Testing: An *In-Silico* Perspective

Strickland A. M. [1]*, **Knight, L. A.** [2]* **Taylor M.** [3]*

[1]* University of Southampton, UK, mike.strickland@soton.ac.uk
[2]* University of Southampton, UK, l.a.knight@soton.ac.uk
[3]* University of Southampton, UK, m.tayor@soton.ac.uk

Introduction

Wear is one of the many factors which concern total knee replacement (TKR) designers. With younger patients & increasing life expectancy, new TKR designs face a longer service life[1]. This has implications for conventional wear testing, typical *in-vitro* tests of 10 million cycles (MCycles) may represent only a fraction of this extended lifespan. Ultra-long term wear tests may reveal the extent to which TKR mechanics adapt over time; e.g. kinematics, contact area (CA), contact pressure (CP) and cross-shear (CS). It is unclear to what extent this long-term adaptation would be dependent on the test design (e.g. control method or input waveforms), as well as implant geometry. A 50MCycle test would take >1year to run *in-vitro*; hence *in-silico* methods offer a valuable complementary 'screening tool', to determine whether such ultra-long-term tests would be justified.

Materials and methods

A rigid-body model of a TKR wear simulator[2,3] was used to run long-term adaptive wear simulations, based on previous finite-element models[4]. Both force-driven (FD) and displacement-driven (DD) tests were simulated, for a fixed cruciate-retaining implant. FD was based on the input conditions described in [5], but using a different implant design and no posterior tilt. DD was based on the 'standard' kinematics profile in [6]. Wear prediction was based on the A÷(A+B) model [7], with adaptive steps every 1MCycle, simulated to 50MCycles. Metrics monitored included FD kinematics, total CA, CP and CS surface distributions.

Results and Discussion

Results (Fig.1) exhibit the characteristic decay in linear wear rate seen in shorter-term studies[5]. However, there is also evidence of a decay in volumetric wear rate in the very long term: especially for the FD test, where kinematics adapt considerably.

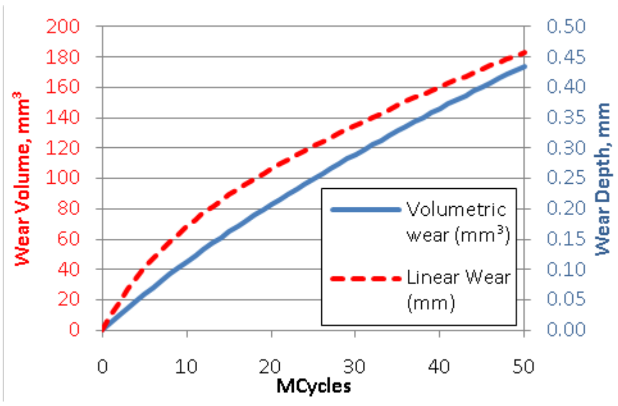

Fig.1: Comparison of FD linear and volumetric wear rates.

Fig.2 shows the final (50MCycles) results, normalized relative to the first cycle (before any surface profile adaptation). Whilst some metrics do not change, others alter substantially; the FD system at 50MCycles is essentially a different test to the case at the outset.

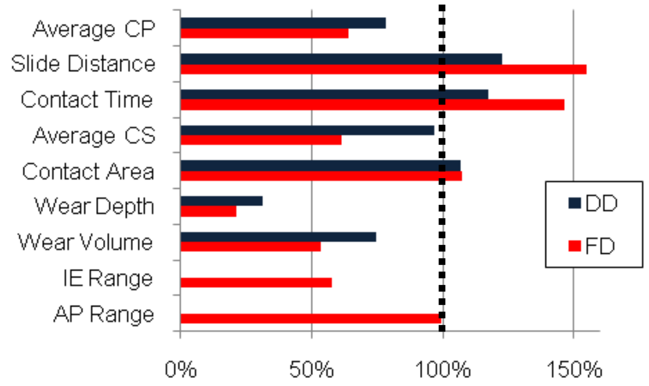

Fig.2: Final metrics, normalised relative to initial values.

The difference between FD and DD control also becomes more pronounced; the FD control adapts very significantly over the time-scale simulated here. Note that in the above figure, for every single metric listed, the change relative to the initial value (whether an increase or decrease) is of greater magnitude for FD than DD. In practice, for DD the conformity of the implant still increases over time (hence the increase in CA and decrease in CP); this has the potential to alter the kinematics on a pneumatically-driven DD wear test rig (since no *in-vitro* rig is truly 'displacement' driven).

Conclusion

Clearly, ultra-long-term TKR wear tests exhibit greater time-variations than shorter (~10MCycles) testing. These differences are much more pronounced for FD testing than for DD testing (where the implant kinematics are artificially restrained from adapting over time). This has important implications when selecting control strategies for long-term wear studies.

Acknowledgements

Funding for this research has been provided by the EPSRC (UK). Supporting data supplied by DePuy, a Johnson & Johnson company.

References

[1] Kurtz,S.M. *et al*, 2008 54th Meeting, ORS #1754
[2] Strickland,A.M. *et al*, 2009 J.Biomech 42(10) p1469
[3] Strickland,A.M. *et al*, 2009 CMBBE
[4] Knight,L.A. 2009, PhD Thesis
[5] Knight,L.A. *et al*, 2007 J.Biomech 40(7) p1550
[6] Barnett,P.I. *et al*, 2002 Proc IMechE H 216(1) p51
[7] Turell,M *et al*, 2003 Wear 255(7-12) p1034