The Effect of Insert Conformity on The Wear of Total Knee Replacements

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Introduction:
The demand for joint replacements in young patients is increasing, and therefore there is a need to increase the lifetime of the prostheses. To fulfill this requirement, new replacements’ designs and materials are being introduced. One of the design parameters that may affect wear of total knee replacements, and hence the predicted lifetime of such prostheses, is the insert conformity [1].

Computational models have been used extensively for wear prediction and optimisation of artificial knee designs. The object of the present study was to use a previously validated non-dimensional wear coefficient based computational wear model [2] to investigate the effect of insert conformity on the predicted wear in total knee replacement (TKR).

Materials and Methods:
To investigate the effect of insert conformity on the wear predicted in TKR, four different insert designs, with different conformity, were tested against the same femoral geometry. The DePuy TKR Sigma fixed femoral (DePuy International Limited, UK) was run against custom Flat, Partial flat, Lipped and Curved inserts (Figure 1). Two different kinematic inputs, intermediate kinematic and high kinematic inputs [3], were used. The difference between intermediate and high kinematics was the level of anterior-posterior translation, being maximum 5mm in the intermediate condition and 10mm in the high kinematic condition. Each design and kinematic input were run for three million cycles in a computational model. The inserts were Sigma curved and lipped inserts, based on a size 3 geometry with a thickness of 10mm (DePuy International, UK). The partial flat geometry was based on the Sigma High Performance Partial Knee, and size matched to the total knee geometries. The custom Flat insert was created by flattening the contact surface of the Partial flat insert.

The computational framework used in the present study was validated against the experimental results, for the Curved and Flat inserts, elsewhere [2]. The computational wear model for the knee implants was based on the contact area and an independent experimentally determined non-dimensional wear coefficient. The effects of cross-shear and creep on wear predictions were also considered. The UHMWPE was modelled as an elastic-plastic material, using the true stress-strain data (DePuy International Limited, UK) [4], with a modulus of elasticity of 463 MPa [5] and a Poisson’s ratio of 0.46 [6].

Results:
The predicted average wear rate for the different inserts and intermediate kinematic inputs is shown in Figure 2-a. The predicted average wear rates were 1.7, 1.9, 3.2, and 6.0 mm/million cycles, for the Flat, Partial flat, Lipped, and Curved inserts respectively. When tested under high kinematic inputs (Figure 2-b) the predicted wear rates were 2.5, 2.7, 5.8, and 8.7 mm/million cycles, for the Flat, Partial flat, Lipped, and Curved inserts respectively.

Discussion and Conclusions:
This study investigated the effect of insert conformity on predicted computational wear rates. The results showed that, under both intermediate and high kinematics, the less conforming geometries had the lower predicted wear. The predicted wear rate for the curved insert was more than three times that for the flat insert, under both intermediate and high kinematic inputs. In addition, contrasting the predicted wear rates under different kinematics; the predicted wear rates under high kinematics were approximately 1.5 times the corresponding predicted wear rate under intermediate kinematics, for the same insert.

Significance:
The current study showed that a potential method for increasing the expected total knee replacement lifetime may be to introduce less conforming knee replacements.

Conflict of Interest Statement:
J. Fisher is a consultant to DePuy International Ltd, UK, a Director and share holder of Tissue Regenix plc and BITECIC Ltd and a Director of Medlink. C. Brockett is a consultant to DePuy International Ltd, UK.

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