SIMULATION OF POLYETHYLENE WEAR IN ANKLE JOINT PROSTHESSES

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INTRODUCTION
Historically, fusion of the joint has been the primary mode of treatment for most disabling conditions of the ankle. Overall results of total ankle replacement (TAR) have not been comparable to those of the other major joints of the lower extremity, but some mobile bearing prostheses have been successful. This is due to their ability to provide for complex ankle motion while maintaining low contact stress with a congruent contact, throughout the gait cycle. The aim of this work was to develop a new simulator test to compare the wear of a new mobile bearing TAR with one with a good clinical history, the Buechel Pappas.

METHODS
The wear of three Buechel Pappas (BP), size 3 titanium nitride (TiN) coated total ankle components was investigated along with three of a new DePuy mobile bearing ankle (Mobility) design. The BP polyethylene insert was machined from extruded bar (GUR 1150) and sterilised using gamma irradiation (3.5 MRad, 35Gy minimum) under vacuum.

Testing was performed in a six station simulator (ProSim Simulation Solutions, Manchester, UK), which has previously been used to test total knee replacements. Samples were tested in two banks of three, and each design was rotated round the stations in each bank, every million cycles, to minimise station variability. Components were tested in an inverted position. The BP tibial plate was implanted with a 7° tilt and the Mobility tibial plate with a 5° tilt.

All components were tested using kinematic inputs derived from the literature and are shown in Figure 1. All inputs were displacement controlled to ensure no excessive motions occurred, that could result in dislocation of the ankle joint. The force profile was taken from work by Stauffer et al. The basic force profile was used, with a maximum load of 3.1kN. Stance phase was assumed to be 60% of the gait cycle and a minimum load was applied during swing phase. The profiles for plantar/dorsi flexion and internal/external rotation were taken from the design paper by Caldarella, who republished the results of Lamoreux. The mean value of plantar/dorsi flexion from the data of Lamoreux was used as the input cycle for the simulator. The internal/external rotation profile followed the basic shape of the Lamoreux profile, with a range of motion from 2° internal to 8° external rotation. This range is similar to that stated by Raikin et al. The first five million cycles of the test were run without an anterior/posterior (AP) displacement, as no precise information on AP translation in the ankle could be found in the literature. From 5-6 million cycles a limited AP displacement was included. The general literature consensus is that there is some anterior motion during dorsiflexion and posterior motion during plantarflexion, however the magnitude is unknown. A maximum AP displacement of 3mm was chosen, to prevent dislocation of the plastic insert. The AP input cycle had the same profile as the flexion curve, but reduced in magnitude, thus following the consensus of direction of motion during gait.

Testing was performed at 1Hz using a 25% (v/v) newborn calf serum (Harlan Serlah, Loughborough, UK) with 0.1% (m/v) sodium azide solution in de-ionised water. Wear measurements taken were every 0.5 million cycles to three million cycles, then every million cycles subsequently. Gravimetric analysis was performed using a Mettler AT201 microbalance (Leicester, UK) with unloaded soak controls to adjust for moisture uptake. Volumetric wear was calculated from the weight loss of the insert using a density of 0.934mg/mm³. Digital images of the wear scars on the upper bearing surface of the UHMWPE inserts were analysed using Image-Pro Plus software (Media Cybernetics, MD, USA). Talar and tibial tray surface damage was analysed using a Form Talysurf (Taylor Hobson, Leicester, UK) stylus profilometer at the start, middle and end of the test. Wear rates stated as mean ± 95% confidence intervals. Data plotted as mean ± standard error bars (SE). Results analysed for statistical significance using one-way ANOVA with individual differences determined using the T-method.

RESULTS
The wear rate was after 5 million cycles (MC) for the BP ankle was 10.4 ± 11.8 mm³/MC and for the Mobility was 3.4 ± 10.0 mm³/MC. The mean wear rate from 5-6M cycles for the BP ankle was 16.4 ± 17.4 mm³/MC and for the Mobility components was 10.4 ± 14.7 mm³/MC. The Mobility had lower wear than the BP at all time points but this was not statistically significantly (p=0.05). Both sets of components showed an increase in wear with the increase in kinematics (figure 2), however these increases were not statistically significant (p=0.05).

DISCUSSION
The wear rate for the Mobility components was lower than that for the Buechel-Pappas ankles at all time points. However the results were not statistically significant different, probably due to the small sample size (n=3). The wear rate for both sets of components increased with the addition of an AP displacement. This was expected as the components are subjected to higher kinematic demands and the AP motion coupled with rotation introduced multidirectional wear at the tibial interface.

There is little published literature on the wear of ankle joints and no previous published simulator studies. This study has shown that it is possible to study wear of total ankle replacements in a simulator designed for total knee replacements. It was also shown that the new DePuy Mobility ankle compares favourably with the Buechel Pappas ankle, which has a successful clinical history, under the simulator test conditions described.

REFERENCES

** DePuy International (a Johnson & Johnson Company), Leeds, UK.