Design of a new total knee replacement

An estimated 1.3 million artificial knee joints are implanted annually around the world. Southampton researchers in bioengineering are working with one of the world's leading manufacturers of total knee replacements to support them in developing new and better implants. They have developed advanced computer simulations for use in the early design phases which are helping to assess wear, taking account for differences in patients and surgical procedures.

Advances in medicine mean more people are living longer and will need joint replacements in later life. It is essential both for the well-being of these individuals and the financial cost to health services that artificial joints are well-designed, robust and long lasting.

Millions of artificial knee joints have now been implanted in patients worldwide and have transformed their lives. However, problems with wear after surgery mean some have to be replaced through 'revision' operations. According to the National Joint Register for England and Wales, 6.2 per cent of all knee replacements were revision procedures in 2010.

Manufacturer DePuy, which makes around a third of total knee replacements, is constantly looking to improve the quality of its implants. Practical experiments to test the wear of the components that make up the artificial joints are essential but also time-consuming and expensive. In 2000, the company signed a technology partnership with the Bioengineering Sciences Research Group at the University of Southampton to use computational tools to assess existing products and suggest ways of making improvements during the early stages of product development.

In a total knee replacement, the damaged surfaces of the joint are replaced by a metal component at the end of the femur moving against a polyethylene insert at the top of the tibia. In use, the plastic part of the artificial joint can wear and loosen, a problem that can only be resolved by more surgery.

Previous research into wear had suggested that multi-directional movements of the joint, or 'cross-shear' could cause particular problems. Southampton's Bioengineering group was the first to develop computerised techniques to model a person's movements in this way and investigate their effect on wear. This model was later amended to take account of different types of implant as well as movements.

Southampton's advanced computer simulations have enabled manufacturers to explore many different options in the early design stages and improve their understanding of how small changes can result in very different outcomes. This can save years in the development process of complex devices for implantation into patients.

DePuy has used the results of its technical collaboration with Southampton to develop an entirely new knee implant that will give an improved quality of life to people who receive it. In addition, the company can now demonstrate that the final design of its new knee joint should be more robust to patient and surgical variability than other artificial replacements.

DePuy’s new knee implant will be the company’s flagship brand for the future and its success is critical. It has invested tens of millions of dollars in this innovative product and estimates that the new joint will represent 80 per cent of this division’s sales in years to come.

Senior managers acknowledge the techniques developed at Southampton have been key in the design evaluation process allowing the company to distinguish between designs and be selective over features.