INTRODUCTION:

Unicondylar Knee Arthroplasty (UKA) has increased in popularity for faster recovery time, preserving ligaments, restoring normal knee kinematics, and prolonging the time before Total Knee Arthroplasty (TKA) is needed. It is reported that misalignment of the knee implants could severely affect the success of unicondylar arthroplasty. Published Finite Element (FE) analysis reports have recommended some inclination of the uni-tibial component with respect to the tibial bone in the coronal and sagittal planes [1],[2] for optimum duty and fixation life.

It is known that the accuracy of an FE analysis in orthopaedic biomechanics improves with bone geometry and material distribution extracted from imaging data. Using optimized bone mesh and bone material distribution extracted from Computer Tomography (CT), FE bone models were developed to study the effect of misalignment of a uni-tibial component in the coronal and sagittal planes. To compare to the findings of Sawatari et al [1], our 3D FE study had a similar bone model and similar misalignments [1]. Our solution was also made to directly compare with the results of Iesaka et al [2] (same laboratory as [1]), who earlier presented a 2D FE study with regionalized bone material model under varying varus-valgus inclinations [2]. These studies recommended slight valgus angle for lower bone stress and that too much posterior tilt could increase the bone stress. They reported that the maximum bone stress was observed in the proximal end of the diaphyseal cortex and that this bone stress could lead to bone fracture.

Our current fully-distributed bone material properties in a 3D FE analysis was found to produce interesting and somewhat contradictory results to the ones referred to above.

METHODS:

The proximal tibial bone model was extracted from the female’s dataset of the Visible Human Project® by the process of segmentation and reconstruction. The bone model was resected in 13 different configurations to fit the novel unicondylar knee replacements (uni-tibial tray and uni-plastic insert). These 13 configurations represented the 13 configurations involved in the present study; every element had a different modulus assigned in the present case; every element had a different modulus value from the CT data. The bone material model used by Sawatari et al [1] involved distributed material properties for the cancellous and the bone marrow region, but the cortical bone was regionalized into 2 parts only, with two different properties. The stress concentration observed in their FE study might be due to the (too) abrupt a change in the strength of the bone. In the present study, the stress patterns showed that the load transferred from the keel of the tibial tray into the diaphyseal cortex (Fig. 1). Further investigation proved that the difference was due to the bone density distribution.

For the misalignment along the sagittal plane, bone stress increased by 20% for 10° posterior tilt and by 7% for 2.5° and 5° posterior tilt. It is known that increased posterior tilt would promote increased flexion and femoral rollback. To strike a balance a posterior tilt in the range of 2.5° to 7.5° seems the best. Similar ranges were reported by other published clinical and experimental studies [3],[5]. Our results suggest (if anything) that a slight varus tilt would reduce the bone stress. Although higher varus tilts could yield lower bone stresses but in the long run the high shear stresses would not be useful for the implant. This finding contradicts the earlier reports of recommendations towards slight valgus tilting, which was interesting at best, and now perhaps invites a more thorough examination.

RESULTS:

The maximum von Mises stress in the bone was found on the medial side of the diaphyseal cortex, with concentration towards the distal side. We speculate that the numerical value of the bone stress would be lower if the complete tibia was simulated. The majority of the load was transferred through the keel of the tibial tray into the cortex (Fig. 1).

With the increase in the posterior tilt, the maximal bone stress increased from 39.5 to 49.6 MPa (Table 1). For the variation in tibial inclination along the coronal plane, the maximum bone stress decreased from 57.8 to 25.2 MPa (Table 2).

REFERENCES: