INTRODUCTION:

Femoral components used in knee arthroplasty are primarily designed on the basis of kinematics and ease of fixation. The mechanical environment due to different implant designs and fixation methods has received relatively less attention. This study considers issues associated with micromotion at the bone-implant interface of the distal femur due to different implant geometry variations (based on current industry standards for fixed single radius femoral components). Three dimensional finite element (FE) models representing both primary and revision scenarios subject to physiological type loading based on a normal walking cycle are considered.

METHODS:

The femur model used for these studies is the third generation composite femur available in the public domain. The femur model used for these studies is the third generation composite femur available in the public domain. The modification of each femur model was carried out in accordance with the surgical protocols for a cruciate retaining (CR) implant and a total stabilising (TS) implant respectively. TS implant with a long diaphyseal stem was also considered. Implant geometries and FE models used for these analyses are shown in Fig. 1.

![Fig. 1: a) CR implanted femur b) TS implanted femur and c) TS implanted femur with long diaphyseal stem.](image)

In-vivo force data from telemetry was used to apply realistic loading to the distal femur. Three flexion angles (0°, 22°, and 48°) from a normal walking cycle were modeled in three static steps. The vertical force (appropriately split over the medial and lateral condyles), the anterior-posterior shear force, the internal-external moment and the patellar-femoral force were included in each step. These loads were applied over realistic contact areas rather than as concentrated forces.

To capture the effect of femoral component micromotion contact between the bone-implant interfaces was modeled using Coulomb friction with a coefficient of friction μ = 0.3. In the case of revision analyses based on the TS implanted femur with long diaphyseal stem frictional interaction was again used at the bone-implant interface.

RESULTS:

Typical results of the analyses (at 48° flexion) are shown in Fig. 2. The micromotions of the implants are displayed as three separate components: the first (COPEN) indicates separation between the implant and bone surface, the second (CSLIP1) and third (CSLIP2) represent micromotions tangential to the contact surface in two orthogonal directions. Figure 2 shows that both CR and TS implants are subject to similar magnitudes of micromotion with only the location of maxima being slightly different.

The second part of this study deals with the revision TS implant and how better implant stability can be achieved through the addition of a long diaphyseal stem (with proximal fixation). Figure 3 shows that under the same loading and boundary conditions as the previous analyses, the addition of a long stem can be beneficial in significantly reducing levels of implant micromotions for TS implants.

![Fig. 2: Levels of micromotion at 48° flexion. The CR implant motions are displayed on top row and TS on bottom row.](image)

![Fig. 3: Levels of micromotion at 48° flexion for TS with fixed 150mm stem.](image)

The analysis showed that if proper fixation of the stem is not achieved proximally micromotion of the stem tip can be around 80µm. It was also found that the stem tip exerts high concentrated stresses on the surrounding bone (Fig. 4). However, if the stem is fully bonded with the bone then the stem tip micromotion and stress concentration is found to be absent.

![Fig. 4: Stress distributions for frictional and fully bonded stems at 0° flexion.](image)

DISCUSSION:

Investigations into implant micromotion have shown that motions at the bone-implant interface are within acceptable limits (<100µm) for both primary implants and for all flexion angles. The addition of a long diaphyseal stem with proximal fixation was seen to significantly lower the levels of femoral component micromotion in the distal region in all directions. However in practice a proximal fix of the stem is hard to achieve due to the length of the stem and the natural bow in the shape of the femur. In the absence of complete proximal fix the subsequent micromotion of the stem tip is within acceptable limit but leads to high localized stresses. These can cause end of stem pain as reported by patients in clinical situations.

REFERENCES: