INTRODUCTION:

One of the primary advantages of unicompartmental knee replacement (UKR) is that the procedure can be performed using a minimally invasive approach. Because of the reduced surgical exposure and the desire to minimize cartilage damage, UKR intramedullary (IM) rods are typically shorter and thinner than total knee replacement (TKR) rods, and the rod placement is in the medial distal femur. From previous studies of TKR rods, it is known that rod length, thickness, and placement are critical factors determining alignment accuracy. This study was designed to evaluate the expected IM rod orientation for one set of UKR instrumentation.

METHODS:

CT scans of four frozen and sixteen dry cadaver femora were obtained using a Hi-Speed scanner (General Electric, Milwaukee, USA). The slice spacing and width were 1.25 mm and the pixel dimensions were less than 0.6 mm for all of the scans. Computer models, in the form of triangular meshes, of the canal and external cortical surfaces were derived from the CT scans using software based on an isosurface algorithm. There were approximately 100,000 and 400,000 triangles in each canal and femur model respectively. A model of the Oxford Phase 3 IM rod (4 mm diameter, 200 mm length; Biomet Merck Ltd., Bridgend, South Wales, UK) was also created. On each femur model we identified the relevant landmarks for defining the anatomic and mechanical axes, and the recommended IM rod insertion point (Figure 1). To account for deviations from the recommended rod site, we considered the nearby region by intersecting a cylinder (10 mm diameter, centered on the rod site, oriented parallel to the anatomic axis) with the distal femoral surface. The region of the femur clipped by the cylinder was typically comprised of less than 600 vertices and 1,000 triangles. Using every fifth vertex as a possible insertion point, we inserted the rod up to the insertion mark (161.5 mm) oriented parallel to the anatomic axis. We rotated the rod about the insertion point to every possible flexion/extension and varus-valgus (FE and VV) alignment between +/-15 degrees at intervals of 0.1 degrees for a total of 90,601 discrete rod orientations per femur. If the rod fit completely within the canal, the FE/VV angle pair was recorded; rod-canal interference was determined using a collision detection algorithm. This process resulted in the possible rod orientation distribution for each femur.

ESSENTIAL RESULTS:

Contour plots of the frequency of rod orientations showed that the distribution of expected orientation was unique for each femur. Figure 2 shows the results obtained from two of the femurs. Pooling all of the results produced the distribution of rod orientations shown in Figure 3. The mean rod orientation was 3.2 degrees flexion and 2.5 degrees valgus with standard deviations of 2.1 and 2.0 degrees respectively. The range of orientations was between 3.2 degrees extension and 9.7 degrees flexion, and 4.5 degrees varus and 8.9 degrees valgus. If we assume that the acceptable orientation of the femoral component is +/-5 degrees FE and VV, then 28.1% of the pooled distribution exceeded this range of values (19.9% greater than 5 degrees flexion, 10.3% greater than 5 degrees valgus, 2.1% both). Furthermore, it was possible to exceed this range in every femur. If we assume that the ideal orientation is +/-2.5 degrees in FE and VV, then only 21.4% of the pooled distribution was inside this range of values. For eleven femurs, it was impossible to achieve neutral rod alignment.

DISCUSSION:

Our results showed a bias towards flexion and valgus alignment when using a short, thin IM rod placed in the region surrounding the recommended insertion point. Bias towards valgus alignment will increase if the insertion point is moved medially, and bias towards flexion alignment will increase if the insertion point is moved posteriorly. With a minimally invasive approach, the patella cannot be everted, making it difficult to avoid excessive medial and posterior rod placement. The bias in rod alignment may affect the clinical outcome of a UKR patient, especially if the surgeon relies solely on the rod for alignment, but further research is needed to verify this hypothesis. If highly accurate alignment of the femoral unicompartmental component is desirable then a short, thin IM rod is inappropriate without extra guidance such as fluoroscopy or computer-assisted navigation. For more than half of the femurs we tested, we were unable to achieve neutral alignment with the distal anatomic axis. For every femur, it was possible to exceed 5 degrees of misalignment with a rod placement within 5 mm of the recommended insertion point. Our results are based on the assumption that the rod does not bend when it is inserted into the canal. Rod flexion cannot be ruled out completely when using a thin rod, and can either reduce or increase the amount of alignment error. Limitation of this study is the relatively small sample size. Also, we have not yet verified the provenance of the dry cadaver femora and thus cannot comment on whether or not the results are representative of any particular population.

REFERENCES:


Figure 1: Landmarks used for defining the anatomic and mechanical axes, and the recommended rod insertion point.

Figure 2: Contour plots of distribution of rod orientation for two femurs. The shape and location of the distribution is unique to each femur.

Figure 3: (left) Contour plot of the distribution of rod orientation after pooling the results from all twenty femurs. (right) Frontal and lateral images of the rod with mean orientation in one femur.

Figure 4: Flexion-extension and varus-valgus distributions of rod orientation after pooling the results from all twenty femurs.