COMPUTER MODEL OF THE KNEE WITH TWO FIXED OFFSET REVOLUTES FOR TIBIOFEMORAL MOTION

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Recent publications have suggested that knee motion occurs about two fixed offset axes of rotation. The flexion-extension axis is in the femur under the epicondyles and is directed distal and posterior from medial to lateral. The longitudinal rotation axis is fixed relative to the tibia and exits through the anterior cruciate ligament insertion. These axes are not perpendicular to the bones or to each other and do not intersect.

Bearing surfaces of mechanisms which move about axes of rotation are surfaces of revolution of those revolutes. The revolutes of most man made mechanisms are perpendicular to each other and parallel to the surfaces. With modern computer aided design (CAD) and engineering (CAE) technology, it is possible to produce surfaces of revolution for offset revolutes. Surfaces of revolution for the two tibiofemoral revolutes and the patellofemoral axis were made using a HP 9000 series workstation and Structural Dynamics Research Corporation's Ideas Master Series CAD/CAE software. The femoral surface includes a tibiofemoral surface, a patellofemoral surface and a transition zone between the patellofemoral and tibiofemoral joints. The lateral femoral condyle is smaller than the medial and the posterior condyles are circular when sectioned perpendicular to the FE axis. The tibia has a swept surface including motion about both tibiofemoral revolutes and an anterior portion to articulate with the femoral transition zone when the knee is in extension. This surface resembles a combination of both tibial bone and menisci.

CAE analysis of the joint model shows a range of FE from -5 to 120° . There is no internal (IR) or external (ER) rotation in extension and 20° IR to 10° ER at 60° of knee flexion. Movements of the tibia on the femur include varus and valgus, internal and external rotation as well as flexion and extension. The screw home mechanism described by Grood occurs as the joint is extended. The joint has AP and lateral stability in both flexion and extension and is very congruous. Bezier curvature analysis of the medial femoral condyle sagittal plane curvature give similar results to anatomic studies. The surface of the medial condyle includes the tibiofemoral and patellofemoral curves. Both of these curves are elliptical since their rotation axes are not perpendicular to the sagittal plane.

This mathematical representation of the knee should aid in understanding knee joint mechanics and the functions of its anatomic structures.

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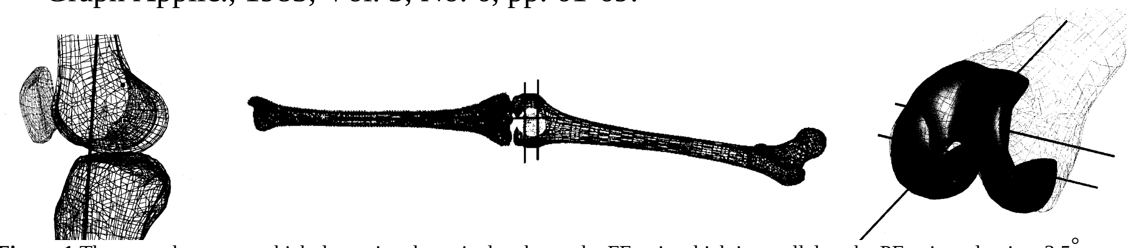
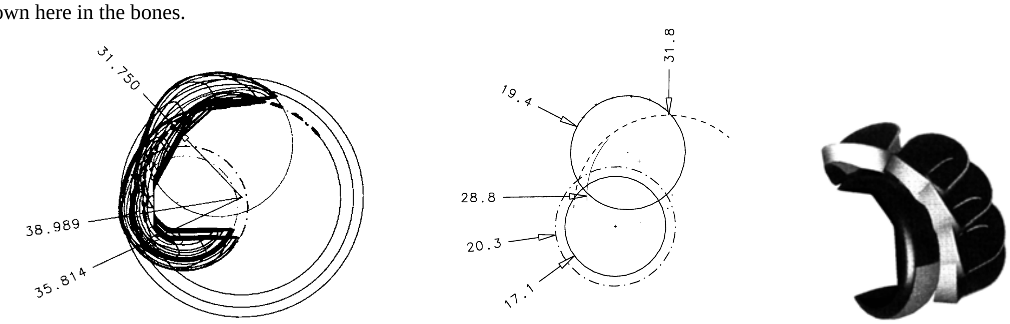
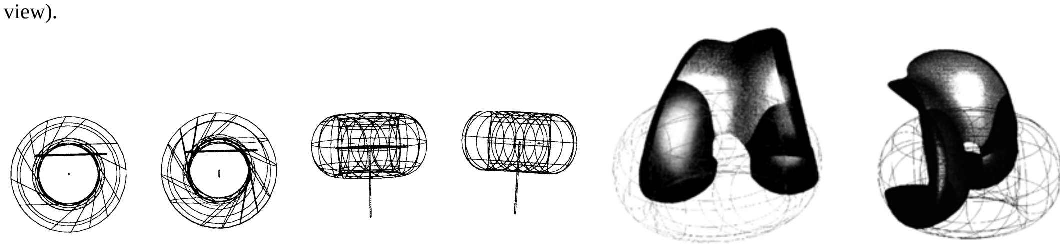


Figure 1 There are three axes which determine the articular shape, the FE axis which is parallel to the PF axis and points 3.5° posterior and inferior from medial to lateral. The tibiofemoral joint moves about the longitudinal rotation axis (LR) and the FE axis. The axes are shown here in the bones.



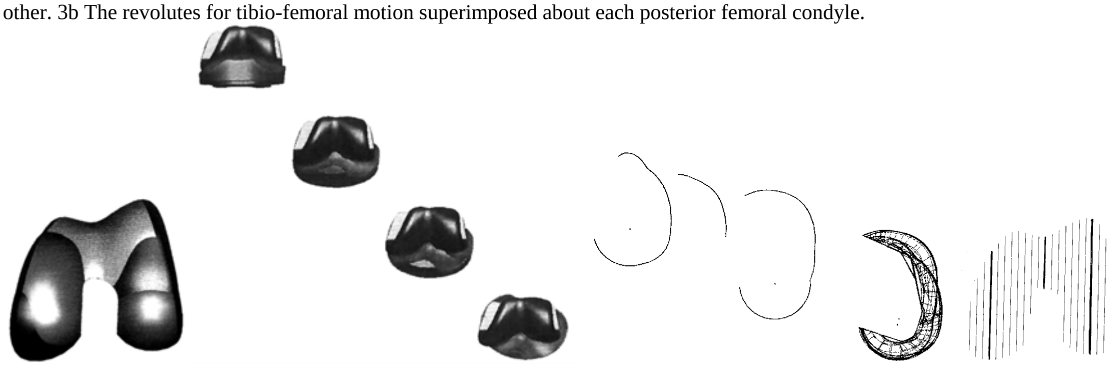
2a 2b 2c

Figure 2a & 2b The femoral surface includes curvatures of both the PF and the TF joints. These wire frames show projections of the primary curves (normal to the FE axis) in the femur. Note that the patella articulates with different regions of the femur, yet still maintains a fixed FE axis of motion as it dips into the intercondylar notch region during deep flexion maneuvers. 2c Patellar model transitioning from lateral and central articular contact to medial and lateral contact during flexion motion (medial-to -lateral isometric view).



3a 3b

Figure 3 Tibio-femoral spacial motion: 3a The tibio-femoral surfaces are torroidal, and reflect the revolutes for the joint shown here (4 views of medial revolute for left knee). The torriods are rather flat because the axes are nearly perpendicular to, and offset from each other. 3b The revolutes for tibio-femoral motion superimposed about each posterior femoral condyle.



4a 4b 4c

Figure 4 Femoral shape: 4a The joint surfaces are shown with the tibio femoral, patellofemoral and transition zones highlighted. Figure 4b The screw home mechanism with external rotation of the tibia with knee extension. 4c Bezier curvature analysis of the midportion medial femoral condyle in the sagittal plane shows good correlation with published data[2].