KINEMATICS OF THE KNEE AT HIGH FLEXION ANGLES

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Introduction

Restoration of knee function after total ligament reconstruction or meniscus surgery requires an understanding of knee behavior throughout the entire range of knee motion. However, there is little data available regarding the kinematics and kinetics of the knee at flexion angles greater than 120° (high flexion) [1, 2]. We hypothesize that knee kinematics at higher flexion angles cannot be extrapolated from the patterns observed at lower flexion angles.

Materials and Methods

Thirteen cadaveric human knee specimens (62~78 years old) were tested using an in-vitro robotic experimental setup. Each knee was tested with the femur rigidly fixed to a base and the tibia fixed to the robot through a 6 degrees-of-freedom load cell. The robot applied external loads to the tibia through the load cell and measured the resulting motion. All soft tissues around the knee were kept intact during the test. A passive flexion path of the knee (path where minimal load was applied to the knee) was determined first from 0° to 150°. Using the passive path as a reference, the resulting knee motion under simulated muscle loads was measured at selected flexion angles: 0°, 30°, 60°, 90°, 120° and 150°. Three muscle loads were applied in this study: a 400 N quadriceps load, a medial and lateral hamstring load of 100N each, and the combined quadriceps/hamstring load of 400N/200N. The anterior-posterior tibial translation (ATT and PTT) and the internal-external tibial rotation (ITR and ETR) in response to the muscle loads were analyzed using a repeated measure ANOVA of within factors. The statistical significance level was set as p<0.05.

Results

Muscle loads caused substantial tibial translation up to 120° flexion (Fig. 1a). Under the quadriceps load, the tibia translated anteriorly in the first 60° (maximum at 30°) and then posteriorly until 120°. The combined muscle load caused ATT in the first 30°, and PTT from 60° to 120°. The isolated hamstring load caused posterior tibial translation from full extension till 120°. Interestingly, at high flexion, the application of muscle loads had little effect on translation of the tibia. At 150°, the anterior tibial translations were 0.3±1.2 mm, 0.2±1.2 mm, and 0.1±1.4 mm, respectively, under the three muscle loads and were not significantly different from each other.

The simulated muscle loads influenced tibial rotation between 0° and 120° of knee flexion (Fig. 1b). The quadriceps load caused ITR in the first 60°, and ETR at 90° and 120°. The combined muscle load caused ITR in the first 30°, and ETR thereafter, until 120°, while the hamstring loads caused ETR between full extension and 120°. The tibial rotations at 150° of flexion under the three muscle loads were 0.4±2.2°, −0.9±1.8°, and −1.5±2.4°, respectively. The tibial rotations were small and statistically similar to each other at 150°.

Discussion

The kinematic behavior of the knee at 150° was markedly different from that measured at other flexion angles. Muscle loads appear to play a minimal role in influencing tibial translation and rotation at maximal flexion. The results imply that the knee is highly constrained at high flexion. This stability may be due in part to the effects of soft tissues (posterior capsule and menisci) contact into the concave surface of the femoral condyles (Fig. 2). The stability of the knee at high flexion will result in high stresses in the surrounding soft tissues. Therefore, patients with meniscal or capsular repair should avoid high flexion during their early healing phase. The results of this study also indicate that knee arthroplasty designs aimed at high flexion may need design modifications that will provide strong posterior stability while allowing sufficient femoral rollback at high flexion angles.

References


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