PATELLAR TRACKING: RELATIONSHIP WITH DISTAL FEMORAL GEOMETRY

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INTRODUCTION

Despite a large number of in-vitro and in-vivo studies, the description of patellar motion relative to the femur has been variable (1). This is because the different methods employed make comparison difficult. Different coordinate systems can lead to differing descriptions for the same patellar motion.

The aim of our study was to examine the tracking behavior of the patella in normal knees with physiological loading of the quadriceps in particular:

1) To see if a more constant relationship exists after the patella enters the femoral trochlear groove
2) To look at the motion of the patella in relation to the previously established femoral axes and to establish the rules governing its excursion on the trochlea in full extension.

METHOD

Seven fresh-frozen cadaveric knees with no prior history of knee surgery or disease were used in this study. The quadriceps was separated into six components. Five fiducial screws were placed into the femur and four each into the patella and tibia. The knee specimens were imaged with computerised tomography scans.

A Polaris optical system was used to measure the kinematics of the patellofemoral and tibiofemoral joints during active, resisted, knee extension in response to 175N quadriceps tension (2); it was also used to digitize the fiducial screws. Custom software was used to reconstruct 3D images and determine the coordinates of fiducials and landmarks used for the construction of the femoral, tibial and patellar coordinate system. The proximal-distal midpoint and the distal end of the median ridge of the patella, and the proximal point of the trochlear groove were also determined. The condylar spherical axis was defined as a line connecting the centers of these spheres. Using the digitized fiducial markers, the motion and geometry of the knee joint were co-registered.

The kinematic data was processed with Visual3D (C-Motion Inc., Maryland, USA) software and results were reported as patellar shift, tilt and rotation in relation to anatomic, epicondylar, spherical and trochlear axes. The distance between the patella ridge points and the proximal entrance of the femoral trochlear groove were calculated during knee motion. These values were used to determine the flexion angle when the distal end and the center of the patellar median ridge crossed the proximal beginning of the femoral groove.

RESULTS

In five out of seven of the knees there was an initial medial translation in early flexion (0° to 15°-20°), followed by a progressive lateral translation in relation to the trans-spherical axis. For these five knees the initial medial translation was on average 2.2mm (S.D. 2.8) from 0° to 20° knee flexion. In one knee, there was medial translation (2.9mm) for the first 16° and minimal translation after that. Last knee had a minimal translation in the 10 degrees, followed by progressive lateral translation (6mm). For the 7 knees, the translation relative to the position in the extended knee was 2.2mm medial (S.D. 2.9) at 20° increasing to 1.3 mm lateral (S.D. 1.7) at 100° flexion.

The patella was laterally tilted (lateral patella more posterior then medial patella) on average by 6.9° (S.D.3.4) relative to the femoral spherical axis in the extended knee. This increased with flexion to 13° (S.D. 3°) at 100° flexion. Patellar flexion increased with knee flexion and the lateral rotation decreased with knee flexion. The knee flexion angles at which the distal end and midpoint of the patellar median ridge crossed the proximal limit of the femoral trochlear groove were 7° (S.D. 2.8) and 22° (S.D.5.3), respectively.

The path of the center of the patella was circular (RMS 0.3) and uniplanar from approximately 16° flexion. The radius of the circle fitted to the center of the patella was on average 44mm (S.D. 2.7). The average angle between the circle fitted to the center of the patella and the femoral anatomical axis in the coronal plane was on average 6.4° (S.D. 1.6°).

The average angle between this circle and the epicondylar, spherical and trochlear axes in the coronal plane were 91.2° (S.D. 3.4°), 88.9° (S.D. 2.4°) and 88.3° (S.D. 3°) respectively. The average measurements for the same angles in the transverse plane were 92.3° (S.D. 4.6°), 88.8° (S.D. 3.8°) and 89.4° (S.D. 3.2°) respectively.

Discussion

In early knee flexion, the patella moved medially to engage the trochlear groove. The trajectory of the center of the patella then became circular and uniplanar after the distal patella but before the center of the patellar median ridge entered the trochlear groove. This study accurately identified the center of the patella and the orientation of the femoral, tibial and patellar coordinate systems were visualized on CT scans.

This study makes it easier for surgeons to visualize the motion of the patella by describing it in relation to the femoral axes. Knowing the relationships between the different femoral axes, it is possible to reconcile some differing published results. In particular, we have shown that the patellar motion is uniplanar for most of the arc of flexion, and have measured the relationship between this plane and the femoral axes. More complex descriptions in past papers have looked at the motion using axes not aligned to the plane of patellar motion.

References:

(1) Katchburian et al., Clin Orthop 412; 241-9, 2003
(2) Amis et al, JOR 24; 2201-11, 2006