A NOVEL APPROACH TO MEASURE TIBIOFEMORAL KINEMATICS IN HUMAN CADAVERIC KNEES WITH INTACT CAPSULE

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Introduction

Using the same definitions while describing and comparing kinematics is crucial since the choice of coordinate systems can lead to markable differences in the resulting curves and thus to different interpretations of normal kinematics [1, 2]. For this reason, landmark-based coordinate systems are recommended for measuring tibiofemoral kinematics [1]. However, accurate placement of landmark-based coordinate systems in native knees with intact capsule is challenging since the necessary landmarks cannot be directly accessed and are only estimated. Therefore, the aim of this study was to develop a workflow that allows accurate tracking of landmark-based femoral and tibial coordinate systems and their associated bone geometries in human cadaveric knees with intact knee capsule during dynamic testing.

Methods

This in vitro study used 15 fresh-frozen human cadaveric knees from hip center to malleoli with intact capsule and soft tissue approximately 10 cm superior and inferior to the knee joint space. Landmark-based femoral and tibial coordinate systems were generated by using segmented CT scans of the specimens. During preparation, the proximal and distal segments of the joint were skeletonized and measuring points were attached to the bones. 3D fittings of femur and tibia were then performed by aligning the segmented CT scans to previously acquired 3D point clouds of each bone (ARAMIS 12M, GOM Metrology GmbH, Braunschweig, Germany). To ensure accurate alignment, visual and quantitative inspections of the 3D fittings were conducted from different perspectives. Subsequently, 3D fitting information were saved and femur and tibia were transected and embedded to allow fixation in a six degrees of freedom joint motion simulator (Advanced Mechanical Technologies Inc., Watertown, USA). After mounting the specimen, the previously generated 3D fitting information of the segmented CT scans were again projected onto the residual bones using the measuring points. In this way, the 3D information of the complete femur and tibia was available even after the bones were cut. Based on this information, the relative position of the femoral and tibial coordinate systems was recorded and transferred to the joint motion simulator. Afterwards, the specimens were subjected to dynamic testing. During testing, the relative position of femoral and tibial coordinate systems was recorded by the joint motion simulator.

Results

Quantitative inspections of the 3D fittings using a tactile measuring instrument resulted in a mean deviation of 0.27 ± 0.21 mm between the real bone and the 3D fitted, segmented CT scan (Fig. 1).

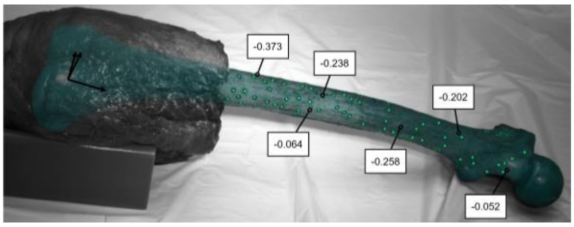

Figure 1: Cadaveric femur with measuring points (green), 3D fitted, segmented CT scan (blue) and deviations between the real bone and the 3D fitted, segmented CT scan at specific points.

Discussion

The high accuracy of the 3D fitting demonstrates that this novel approach enables accurate measurement of tibiofemoral kinematics using landmark-based coordinate systems with intact knee capsule. Furthermore, knowledge of the relative positions of femoral and tibial bone geometries, rather than just their coordinate systems, also allows multiple analyses such as the projection of the flexion axis and flexion facet centers (FFC) onto the tibial plane. This enables the measurement of condylar motion [3] with intact knee capsule (Fig. 2). In addition, this novel approach allows subsequent transformation to kinematics of different landmark-based femoral and tibial coordinate systems, what is necessary when comparing data with different underlying definitions [2].

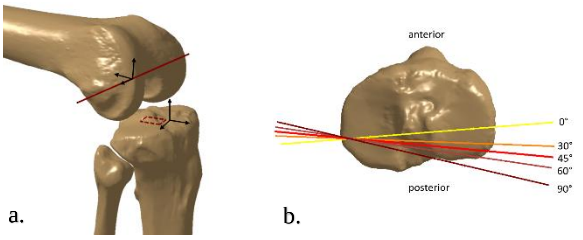

Figure 2: Projection of the femoral flexion axis and the FFCs onto the tibial plane (a) at different flexion angles (0°, 30°, 45°, 60°, 90°), showing condylar motion (b).

References

1. Wu et al., J Biomech, 28(10) :1257-61, 1995.
2. Sauer et al., Materials, 7644, 2021.
3. Iwaki et al., J Bone Joint Surg, 82-B:1189-95, 2000.