ABSTRACT

BIPLANAR FLUOROSCOPIC ANALYSIS OF IN VIVO HINDFOOT KINEMATICS DURING AMBULATION

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The overall goal of this project was to develop and validate a biplane fluoroscopic system and integrated software to assess hindfoot kinematics. The foot and ankle are comprised of 28 bones and 26 joints that allow complex tri-planar motion. Understanding the motion of these joints may lead to improved treatment methods in persons with foot and ankle pathologies. During gait analysis, skin markers are placed on the lower extremities, which are defined as four rigid-body segments with three joints representing the hip, knee and ankle. This method introduces gross assumption on the foot and severely limits the analysis of in depth foot mechanics. Multi-segmental models have been developed, but are susceptible to skin motion artifact error. Intra-cortical bone pins studies provide higher accuracy, but are invasive. This dissertation developed and validated a noninvasive biplane fluoroscopy system to overcome the skin motion artifacts and rigid-body assumptions of conventional foot motion analysis.

The custom-built biplane fluoroscopy system was constructed from two fluoroscopes separated by 60°, attached to a custom walkway with an embedded force plate. Open source software was incorporated to correct the image distortion and calibrate the capture volume. This study was the first that quantified the cross-scatter contamination in a biplane fluoroscopic system and its effects on the accuracy of marker-based tracking. A cadaver foot study was performed to determine the static and dynamic error of the biplane fluoroscopic system using both marker-based and model-based tracking algorithms. In addition, the study developed in vivo 3D kinematic models of the talocrural and subtalar joints during the stance phase of gait.

While the cross-scatter significantly increased the static tracking error in the three larger phantoms, there were negligible effects in the smallest, suggesting negligible motion tracking error due to cross scatter for distal extremities. Marker-based tracking error had a maximum absolute mean error of 0.212 (± 0.148) in dynamic trials. Model-based tracking results compared to marker-based had an overall dynamic RMS average error of 0.80 mm. The tracking error found in the present system, both marker and model-based, is within currently reported ranges. Models were developed to using custom algorithms to determine talocrural and subtalar joint 3D kinematics. The models offer viable a non-invasive method suitable for quantifying hindfoot kinematics. With the validation and model development completed, the next step will be human testing. In addition to the kinematic model presented here, a kinetic model of the joints will be added in a future study, utilizing the force plate embedded in the system. Patients with a variety of adult and pediatric conditions which affect foot and ankle dynamics during walking may benefit from this work.