MRI-BASED COMPUTER MODELING AND SIMULATION FOR 3-D KNEE JOINT MOTION ANALYSIS

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INTRODUCTION

In the past decade, knee joint motion analysis has been advanced from major joint angles to 3-D detailed joint motion by using Roentgen stereophotogrammetric analysis, single and biplane fluoroscopy. However, current radiographic techniques involve radiation and only offer small motion capture volume thus are not suitable for large subject population and daily activity research. By combining optical stereophotogrammetry and subject-specific MRI model together, this work explored the feasibility of a radiation-free approach to simulate and analyze 3-D knee joint movement.

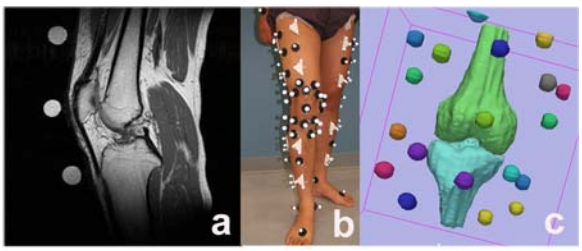

Fig.1 MRI based motion analysis

METHODS

One of the researchers was tested as the subject in this work. Special markers which can be identified by both MRI and optical stereophotogrammetry systems were developed. Nineteen these double-purpose markers were put on the right thigh and shank close to knee joint of the subject. The knee was MRI scanned using a T-1 weighted sequence (Fig.1 a). Immediately after the scan, the subject went to our motion analysis lab and 37 reflective markers were attached to his right thigh and shank (Fig.1 b). With all the regular and double-purpose markers, a static trial was captured using an 11-camera motion analysis system (MAC, Santa Rosa, CA) with the subject in a supine posture similar with during MRI scanning. After this, the subject's level waking data was collected.

An open-source software (www.slicer.org) was used to segment MRI images and construct 3-D models for femur, tibia and each double-purpose marker (Fig.1 c). Each double-purpose marker's position relative to bones was determined from the detailed 3-D models, then each regular marker' position in its bone coordinate systems can be calculated given all markers' position at the static posture. The 3-D knee joint motions were determined during level walking (Zheng *et al.*, 2007). Finally, using the 3-D MRI bone models, the knee joint motion was simulated during walking.

RESULTS & DISCUSSION

Generally, the simulation showed smooth and reasonable knee joint movement during the whole gait cycle. Even without any constrains applied between tibia and femur during the whole calculation process, overlap or lift-off between the tibia and femur was within a reasonable range (Fig.2). Based on the simulation results, the

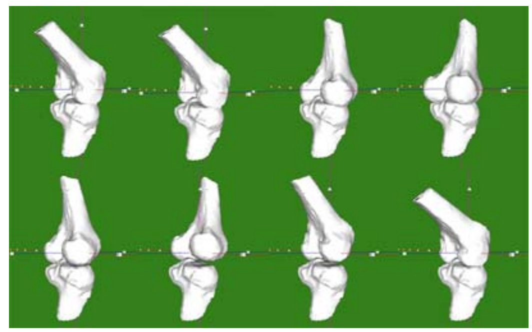

Fig.2 Simulation of knee motion during level walking

femorotibial contact (distant<0) areas at different instants were simulated (Fig.3).

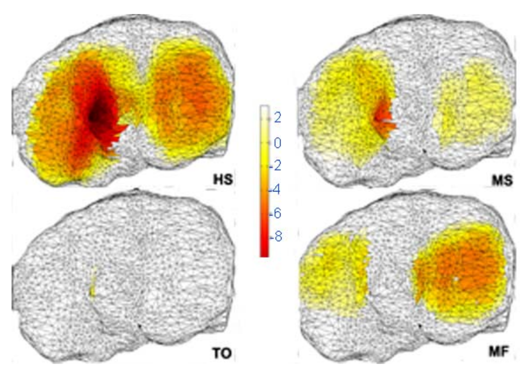

Fig.3 Contact areas during walking at heel strike (HS), mid-stance (MS), toe off (TO) and maximal flexion (MF)

This work shows the potential of combining optical stereophotogrammetry and subject-specific MRI model as a new approach to for 3-D knee joint motion analysis, which is radiation-free and suitable for large motion volume applications. By adding constrains, such as knee ligaments, to the 3-D knee joint motion determination the accuracy will be further improved.

REFERENCE

Zheng et al. (2007). *ORS annual meeting.*