STUDY OF MUSCULAR EFFECTS ON MEASUREMENT ACCURACY OF SKIN MARKERS

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INTRODUCTION

Bone markers have been extensively utilized in computer assisted orthopaedic surgery. However invasive installation of skeletal pins leads to additional incisions and increases the possibility of infection. In some occasions iatrogenic fracture or complications may also occur in patients. Therefore non-invasive skin marker has been considered as an alternative solution. However the achievable accuracy of skin marker measurement systems is still beyond the requirement. In this paper we investigate the errors sources of the measurement inaccuracy of the skin markers. We focus on the effects of muscular effects on the skin marker movement relative to the underlying bones.

MATERIALS AND METHODS

A fresh frozen cadaver was used to simulate an anesthetized patient. The muscles kept a relaxed condition without active contraction of the muscles. Three skin markers were placed (1) at the thigh near to the mass of adductor muscles, (2) at the half of the thigh closing to the gracilis, (3) near to the Sartorius. There were also two bone markers installed at femur and tibia for comparison purpose. The flexion and extension of the knee joint were conducted passively by the operation of surgeons. 10 cycles of passive cyclic knee flexion/extension was performed for each measurement. In every cycle, the knee was flexed from full extension to the full flexion and returned back to full extension.

RESULTS

Fig. 1 shows the trajectories of the skin markers relative to reference bone markers as the knee is at various flexion angles. The relative motion was up to about 30mm for skin marker I and II, about 20mm for skin marker III. For the locations with an underlying muscle, the relative motion of the skin markers (such as I, II) displays obviously. For the location without muscle underneath (such as III), the skin effect dominates the movement of the skin marker. In other words, the volume of the soft tissue of the segments determines the motion of the skin marker. When the skin marker is near to the distal end of the segment, or closed to the attachment of the muscles, the muscular effect will be minor.

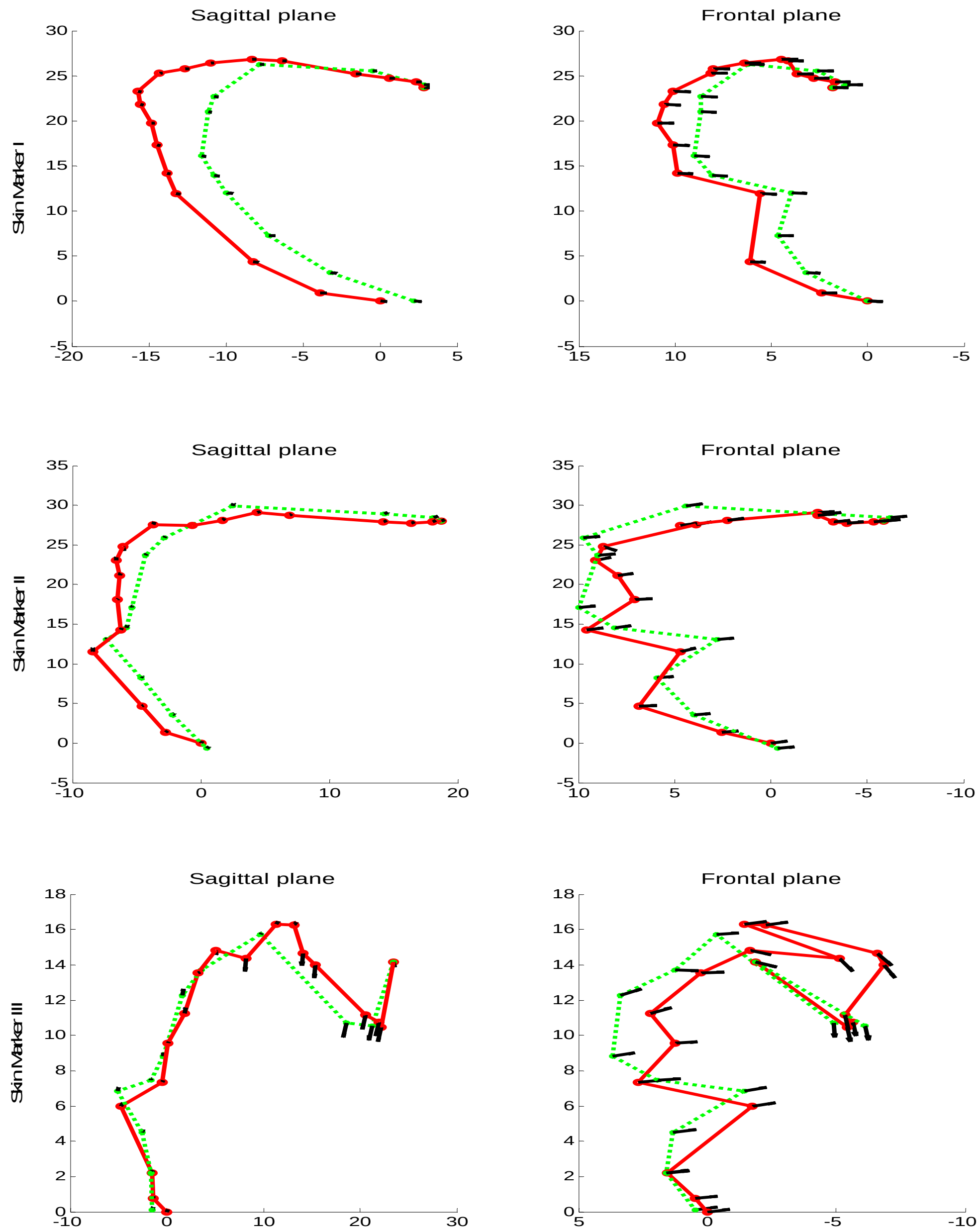

Fig. 1 Relative to the original position with no flexion, the typicle trajectories of skin markers which were installed on the thigh. The directions of the skin marker were identified by black arrows on the corresponding position.

If these skin markers were used to measure the flexion angle of the knee joint, the differences from the ground truth, the bone markers, may reach up to 7.2°~17° by average (Table 1). The results show the current non-invasive skin marker is still not feasible for computer assisted navigation surgery application no matter where the skin marker is located.

Table 1 the error between the flexion angles computed by the skin markers and the ones computed by the skeletal markers.

On the leg / On the thigh	SM1	SM2	SM3

SM1	8.0^{o}	7.2^{o}	7.2^{o}
SM2	8.2^{o}	7.6^{o}	7.8^{o}
SM3	17.0^{o}	15.9^{o}	15.8^{o}

DISCUSSION

The paper has analyzed the effects of soft tissue deformation on the measurement accuracy of skin markers. These skin markers were placed at different locations of the medial side of the lower limb. All the measured data were compared with the bone markers as the ground truth. Error sources of skin marker in measuring the bone spatial information have also been investigated. It is concluded that an innovative design of skin marker and the associate software, different from bone markers, may be needed before the skin marker can be applied in computer assisted orthopaedic surgery.

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