QUANTIFICATION USING FLUOROSCOPIC RSA OF SYNDESMOTIC MOTION IN THE INTACT STATE AND FOLLOWING SIMULATION OF HIGH ANKLE SPRAIN

Angela E. Kedgley and Thomas R. Jenkyn

Wolf Orthopaedic Quantitative Imaging Laboratory and Department of Mechanical and Materials Engineering, University of Western Ontario, London, ON, Canada
tjenkyn@eng.uwo.ca

INTRODUCTION

The distal tibiofibular syndesmosis lies between the tibia and fibula at the ankle. Four ligaments maintain the stability of this articulation. Sprains of the syndesmosis are fairly rare, but are frequently misdiagnosed (Lin et al, 2006) with the range of disability and time to recovery being highly variable (Amendola et al, 2006). This may be because these injuries are not being diagnosed correctly and consequently are not receiving optimal treatment. A better understanding of syndesmosis sprain kinematics should assist clinicians in proper differential diagnosis.

Non-invasive *in-vivo* studies are commonly confounded by skin motion artefact (Benoit et al, 2006). In this study, two techniques were utilized to quantify syndesmosis kinematics—optical skin-mounted markers and beaded fluoroscopic radiostereometric analysis (RSA). The aims of this study were 1) to quantify the range of motion present in the syndesmosis and 2) to determine whether skin-mounted markers accurately measure syndesmosis kinematics in intact and injured states.

METHODS AND PROCEDURES

Motion at the syndesmosis was manually simulated in a fresh-frozen cadaveric foot and ankle. Four 0.8mm tantalum beads were implanted into both the tibia and fibula. Two fluoroscopic units (SIREMOBIL Compact-L, Siemens, Malvern, PA) were positioned nearly orthogonally with the specimen in both fields of view. RSA reconstruction of bead locations was performed with custom-coded software (MatLab, MathWorks, Natick, MA). From these, bone-fixed reference frames were created on the tibia and fibula and relative rotations and translations were calculated with an Euler angle analysis.

Auto-reflective markers were affixed to the skin on the medial and lateral malleoli, heel, distal second ray and anterior tibial ridge to approximate the shank and foot portions of the Helen Hayes marker set (Kadaba et al, 1990). Rigid marker triads were affixed to the tools used for manual manipulation of the specimen to capture the applied bone displacements. The markers were tracked optically with a 4-camera motion capture system (Hawk cameras, EvaRT system, Motion Analysis Corp, Santa Rosa, CA).

Passive full-range ankle dorsi- and plantar-flexion and medial-lateral separation of the tibia and fibula via inferiorly applied forces were performed. Motions were first carried out with all ligaments intact, then repeated after complete sectioning of the anterior tibiofibular ligament. The kinematics recorded by the skin-mounted markers were compared to the kinematics obtained from the bone-fixed coordinate systems using RSA.

RESULTS

The kinematics measured with RSA were different from those obtained from optical motion analysis of skin-mounted markers,
particularly the change in distance between the two malleoli during plantar- and dorsiflexion (Figure 1A). RSA was considered the gold standard with which to compare the skin-mounted marker measurements. During plantar-flexion the tibia and fibula incorrectly appeared to move approximately 1.3mm closer together with the optical system. During dorsi-flexion the tibia and fibula incorrectly appeared to move about 1.3mm further apart with the optical system.

Differences were also noted between the intact and injured states, especially upon the application of the inferiorly-directed forces on the tibia and fibula. Using the RSA measurements, in the intact state these forces had almost no effect on the distance between the malleoli (Figure 1B). However, once the anterior tibiofibular ligament was sectioned, the application of the forces increased the separation of the tibia and fibula.

**Figure 1.** Change in the distance between the medial and lateral malleoli as measured (A) by RSA and by optical surface markers during full plantar flexion and full dorsiflexion and (B) by RSA during medial-lateral separation via inferiorly applied pressure

**DISCUSSION**

The ‘extra’ motion observed when using skin-mounted markers and an optical motion capture system during plantar- and dorsiflexion is most likely the result of skin motion relative to the underlying bone. If this is the case, this artefact in the observed motion would represent an error of similar magnitude to the bone kinematics under investigation. In standard gait analysis the foot and lower leg are treated as rigid bodies that articulate at the ankle joint. This variation in relative optical marker positions would usually be treated as error in the rigid body assumption and corrected by smoothing. Therefore, optical motion analysis with skin-mounted markers is inadequate for quantifying syndesmosis motion *in-vivo.*

The results of this work suggest there is a poor correlation between motion observed by skin markers and the actual kinematics of the underlying bones. They do however suggest that RSA is an appropriate modality for investigating these kinematics, as it is able to accurately track the motions of the bones. Ultimately, the goal is to determine whether distinct modes of syndesmotic injury exist which result in differing abnormal kinematics. The next step is to apply this approach *in-vivo* to more accurately characterize the kinematics of the distal tibiofibular syndesmosis in the normal state and following a high ankle sprain.

**REFERENCES**