Quantifying the Effect of Ankle Posture on the Positions of Bones of the Foot/Ankle Complex for Injury-Prediction Studies

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INTRODUCTION

- The ankle is one of the most common sites of injury for an occupant during a frontal vehicular collision [1] and damage to this region can result in a high level of impairment, accompanied by long-term healthcare costs and emotional distress.
- Understanding the factors which cause ankle injury will help in the design of suitable protective systems.
- Risk of ankle injury in different loading scenarios has been studied experimentally and numerically, with most of the emphasis being on the ankle in a neutral posture (*e.g.* [2]). However, the ankle can assume a wide variety of postures during injurious events.
- A concern with this type of experimental testing is the variability in joint alignment required to control the load path during impact, with fractures occurring in the tibia, talus and calcaneus.
- At the wrist, during falls, the orientation of the scaphoid and lunate has been shown to affect both the location of fracture and fracture load in the radius [3].

PURPOSE

- To determine the effect of ankle posture on the positions of the bones of the foot/ankle, which, in the event of a frontal vehicular collision, may alter the fracture threshold and location.
- To use strain gage data from the ankle loaded in different postures with the intention of generating a finite element model of the ankle.

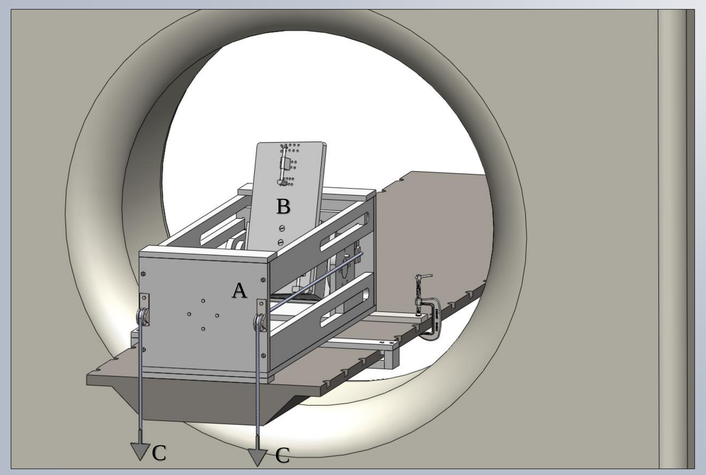

Figure 1: Test Frame Mounted on CT Scanner Bed: A) Test Frame, B) Ankle Positioner, C) Weights

METHODS

- A CT-compatible test frame (Fig. 1) was developed, which can adjust the angles of the ankle independently to varying degrees of flexion/extension, internal/external rotation and inversion/eversion (Fig. 2) and can apply force to a cadaveric lower leg fixed at the proximal tibia through pulleys and hanging weights.
- Soft tissues are removed only where necessary, from a 50th percentile male leg, in order to apply 5 strain gages to the specimen – 3 on the calcaneus bone and 2 on the talus bone (Fig. 3). For the gage attached to the medial talus, the tibiospring and tibionavicular ligaments are to be removed. For the gage attached to the posterior talus, some cartilage is removed, as well as part of the posterior talofibular ligament.
- The proximal tibia is potted and proper axial alignment is ensured. The potted tibia is then fixed to the test frame so that it is parallel with the CT bed.
- The ankle is attached to the ankle positioner at a neutral posture and is subject to two preconditioning cycles, in which loads are applied from 0 to 100 lbs in 20 lb increments.

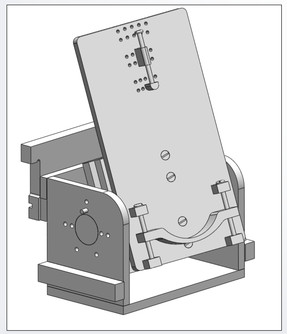

Figure 2: Ankle Positioner

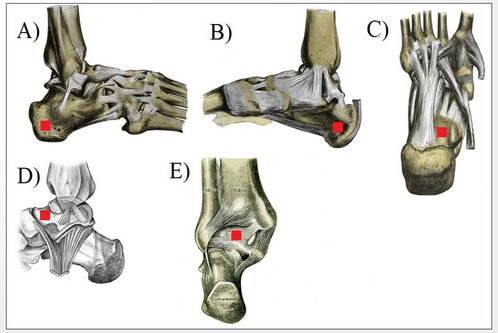

Figure 3: Strain Gage Locations: A) Lateral Calcaneus, B) Medial Calcaneus, C) Plantar Calcaneus, D) Medial Talus, E) Posterior Talus

- The postures to be tested are shown in Table 1. These postures correspond to some of the most vulnerable ankle positions [4,5].
- A CT scan is taken while the leg is unloaded in each of the postures (Table 1). Then in each posture, the leg is loaded from 0 to 100 lbs in 20 lb increments (minimizing inertial effects due to rapid loading) and strain readings are acquired. The specimen is removed from the ankle positioner and then reattached. The leg is then loaded again. This process is performed a total of 4 times for each posture to ensure repeatability of strain measurements. Another CT scan of the ankle is taken while it is loaded at 100 lbs. Scans are taken in the loaded configuration so that any changes in the positions of bones due to loading can be quantified and compared to the deflections of the bones in the finite element model of the ankle. This maximum load of 100 lbs was chosen to limit stresses to below failure levels [2,6].
- The difference in the position of the bones between the neutral and repositioned ankle will be quantified by the change in location of the center of gravity, as well as the change in absolute distance of any point.

EXPECTED RESULTS

- It is anticipated that the posture of the ankle will affect the positions of the associated bones, and ultimately the load pathway and injury tolerance of the foot/ankle complex. To our knowledge, this effect has not been previously investigated in the literature

Table 1: Ankle Postures to be Tested

Ankle Postures	Eversion (°)	Inversion (°)	Dorsiflexion (°)	External Rotation (°)
Neutral	0	0	0	0
Combined Eversion/ External Rotation	20	n/a	0	5
Combined Inversion/ External Rotation	n/a	20	0	5
Combined Dorsiflexion/ Inversion	n/a	20	20	0

FUTURE WORK

- The locations of the attached strain gauges will be recorded in the CT scans so that a finite element model of the ankle in various positions can be developed and validated.
- The results from this study will be useful for research in determining injury limits of the ankle and for developing postural guidelines to minimize injury.

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AWKNOLEDGEMENTS

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