Device for Collecting Stress Images of the Subtalar Joint

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Abstract

The subtalar joint is located at the boundary between the talus and calcaneus. It allows for inversion, eversion, and assists in pronation and supination. At the joint, the lateral talocalcaneal ligament and calcaneofibular ligament provide lateral stability of the ankle. Subtalar joint instability often goes undetected and can be a primary cause of foot and ankle disability. It is often overlooked by doctors who currently perform exploratory surgery to correct instability of the ankle. A detailed and accurate analysis of the subtalar joint has historically proved difficult to produce. It is challenging to determine if the subtalar joint is unstable through current methods of examination due to the cost and difficulty of use of the equipment necessary to make reliable measurements. The objective is to utilize the research of the medical literature gathered and translate the findings to design a device to position the ankle that will allow for improved visualization of the subtalar joint.

Introduction

Radiographic views have been developed to allow for improved visualization of the subtalar joint. Two radiographic views in particular have been examined in detail to determine the effectiveness of analysis on subtalar joint stability; the hindfoot alignment view and the long axial view. The both views were based on a radiographic method pioneered by James Cobey [1]. The hindfoot alignment view was developed by Salzman, El-Khoury [2] and consists of the X-ray beam located 40 inches behind the foot, and positioned along the axis of the medial forefoot, approximately 15-20 degrees from the horizontal. The long axial view is similar, except positioned along the axis of rotation of the subtalar joint, approximately 45 degrees from the horizontal. Each view has its advantages, but the long axial view has been observed to have a better correlation between the data. Reilingh, Beimers Et al. [3] performed a study in which the two radiographic views were compared. They collected two sets of the same measurements for each view, one set for a unilateral stance, and the other for a bilateral stance; both weight-bearing. Their results showed that the long axial view yielded better correlation coefficients between the unilateral and bilateral stances. The hindfoot alignment view (Figure 1) resulted in bilateral intra- and interclass correlation coefficients of 0.72 and 0.58, and of 0.93 and 0.49 for unilateral.

![Figure 1- Hindfoot Alignment View](image-url)
The long axial view (Figure 2) produced correlation coefficients of 0.93 and 0.79 for the bilateral stance, and 0.91 and 0.58 for unilateral.

At the request of the supervising party, the Cobey method will be utilized for this research. The desired device will apply stress to open the subtalar joint so that a Cobey radiograph may be used to closely examine its stability. The device will be applied to the ankle so that a Cobey radiograph will give a repeatable, high-quality image of the subtalar joint for analysis purposes.
Proposed Approach

The device for collecting stress is being designed for the simplest means of manipulating the foot and subtalar joint for radiographic purposes. The device will not be constrained to radiographic positioning, as the X-ray machine can be easily moved and held in desirable locations. Through various literature researches, it has been determined that the most effective method of analyzing the joint is by applying a stress on the subtalar joint. The stress will be applied by simply having the patient hold a weight bearing stance on the ankle. The goal is to have a basic device which will hold the foot in place, and allow for inversion and eversion of the foot, exposing the subtalar joint.

The preliminary designs have been based off of previous ankle/foot manipulation devices found through literature research. One such device is the DYNASTAT. Although it is not tailored for subtalar joint stability analysis, the DYNASTAT is an all purpose device which inverts and everts the foot at specific angles, and allows for multiple analyses of the ankle with radiographic imaging. It is shown below in Figure 3.

![Figure 3 - DYNASTAT](image)

Another device [4] was a simple hinge and platform used in the study of subtalar instabilities. It allowed for analysis of the subtalar tilt angle, and the results can help detect instabilities within the joint. The device was non-weight bearing, but the ease of construction and application make it desirable to incorporate into the design of the stress collecting device. Simply converting this design into a form that can handle weight-bearing stresses will fulfill the need for stress application on the subtalar joint. The device is shown below in Figure 4.
With these design considerations, a preliminary model has been constructed in Solidworks. Solidworks will allow for ease of construction and material selection, and simplify the failure analysis for the device. The preliminary device will allow for weight-bearing stresses with the foot secured, and a simple hinge to allow for inversion and eversion of the foot. The goal is to have specific angular intervals that can be locked in, to allow for various radiographic views of the subtalar joint. The locking mechanism is still being researched and analyzed, but a simple bar and pin assembly is preferred for ease of construction and cost. The initial design model from Solidworks is shown below in Figure 5.
Further refinement of the preliminary design will continue after meetings with surgeons from The Ohio State University as well as Naval Medical Center Portsmouth. Discussions will be carried out in order to design the device for optimal positioning and radiography of the subtalar joint.

The design and analysis phase should conclude approximately around February 17, 2011. After the design phase has concluded, the construction phase will commence. At this time the specifications and material selection should be almost final, and a prototype shall be built and analyzed. The conclusion of the construction phase on approximately March 11, 2011 should allow for field testing and adoption of the device in the medical field. The gantt chart shown below in Figure 6 will provide additional scheduling details.

Figure 6 – Gantt Chart
Cost Consideration

All parts necessary for this device will be manufactured in-house, therefore cost will be minimal. The full list of materials that will be used are still under discussion, but aluminum will most likely be the primary material. The aluminum cost will range from $50-$150, and the miscellaneous material cost will range from $50-$100. The total cost of the project will be a maximum of $250.

Summary

The objective is to utilize the research of the medical literature gathered and translate the findings to design a device to position the ankle that will allow for improved visualization of the subtalar joint. Various designs are under discussion with PhD supervisors from the Mechanical Engineering Department at Old Dominion University in addition to surgeons from Ohio State University and Naval Medical Center Portsmouth. An optimal design will be created to provide the best possible solution to the problem.
References

[1-4]


