

ANKLE PROSTHESIS DESIGN

Introduction

Since early 70's ankle prosthesis have been implanted, however, ankle arthroplasty has not been successful in establishing itself as a standard procedure as did hip or knee arthroplasty. Literature review on different medical company's ankle prostheses is studied. These include popular STAR prosthesis, ESKA ankle prosthesis and Agility Ankle. Of all, it is understood that the prostheses are constrained in the dorsi-plantar flexion plane but almost absence of inversion-eversion motion allowance in the medial and lateral plane.

The ankle consists of the ankle joint, between tibia and talus surface, and the subtalar joint, between talus and calcaneous. Subtalar joint is mostly responsible for the inversion-eversion motion but it is normally fused during the surgery. Problem is reflected by surgeons that the prosthesis tends to be tilted about the quasi-sagittal plane after prolong implantation of the prosthesis in the patient's ankle joint. The tilting is suspected to be caused by the intention of the ankle to perform inversion-eversion motion during daily activities.

Hence, this forms the inspiration and motivation of NTU project team to develop and investigate further in this area. For the purpose of this project, ten cadavers were successfully obtained to carried out this project smoothly.

Objectives

The main objective of this project is to overcome the problem mentioned in the 'Introduction' section. To be more specifically, this project aims to produce an innovative value-added ankle prosthesis design that allows not only dorsi-plantar flexion but also inversion-eversion motion.

Scope

Testing and design work concentrates on achieving satisfactory range of ankle motion with respect to the constraint as will be mentioned in the 'Hypothesis'. Materials are yet to be of much concern in the design. Two basic designs will be produced, which are the 'two-component' design and the 'three-component' design.

Hypothesis

Hypothetically, the range of motion of the prosthetic design must be close but may not be exact to the real ankle joint. It is no way to mimic the exact ankle joint motion, as ankle joint is complex. Its instantaneous center of motion varies during every instant. The complex ankle motion includes different degrees of translation and rotation at every instant.

Method

As a control of the project throughout, kinematic analysis is done on the ten unimplanted cadaver by incrementally displacing the foot with respect to the shank while the motion of the articulating bones was measured through a three dimensional position data acquisition system. Four landmarks – LM, MM, HF and TT shown in Figure 1, are digitized to made up the two coordinate reference frames. An electromagnetic tracking device – 'Flock of Birds' is used to assist data acquisition. The output data are analysed and quantified using Dual Euler method with the help of the Matlab programming. These output data serve as a control later for justification of output data of the implanted cadaver.

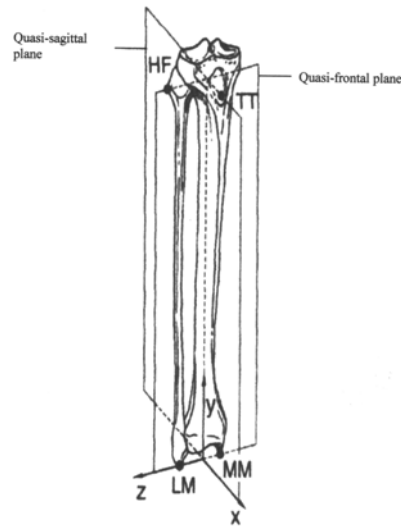


Figure 1. Location of landmarks

To design a prosthesis, design dimensions are important. This is obtained by digitizing the surface of tibia and talus longitudinally and laterally with respect to the surface using the same device and software. The average dimensions are then used as the rough guide of the length and width of the prosthesis. The cad modeling of the prosthesis will be done and sent to fabricate as a prototype for testing on the cadavers.

Kinematic analysis are performed again using implanted cadavers. The output data obtained will be studied and analyses with reference to the output data obtained earlier for unimplanted cadavers. Design modification will be done where necessary. Testing will be repeated to get satisfactory result.

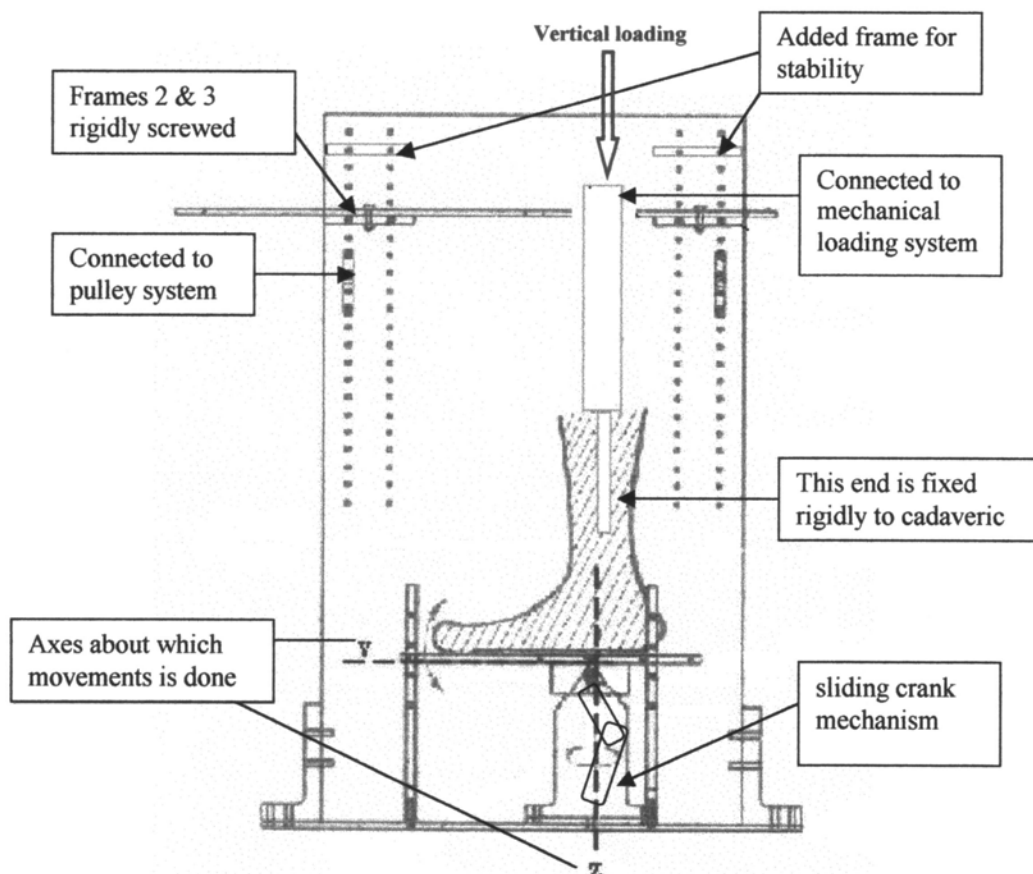


Figure 2. Experiment rig for in vitro laboratory investigation

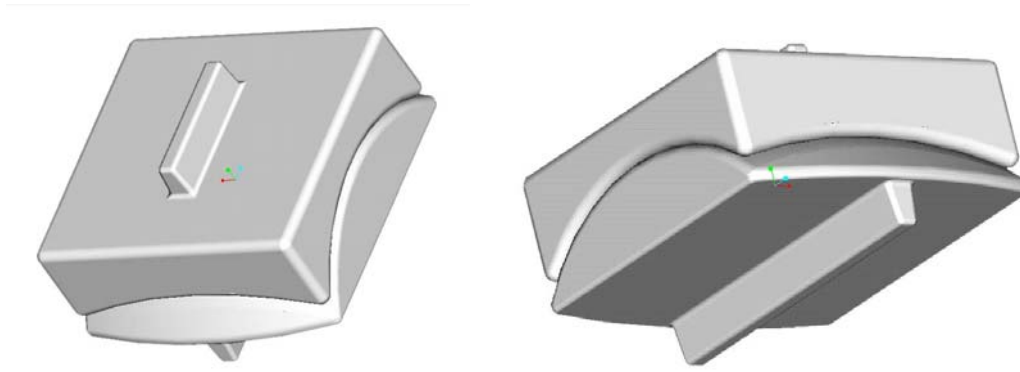


Figure 3. First generation ankle prosthesis design

Related Publication:

1. Wangdo Kim, Daryl Lim, Kin Seng Hong, "An evaluation into the effectiveness of the patella tendon bar in trans-tibial prosthetic patella tendon bearing sockets", SGH Proceedings, accepted as publication.
2. Wangdo Kim, Daryl Lim, Kin Seng Hong, "An evaluation into the effectiveness of the patella tendon bar in trans-tibial prosthetic PTB sockets", Prosthetic and Orthotics International, accepted as publication.
3. Ning Ying, Wangdo Kim, "Use of dual Euler angles to quantify the three-dimensional joint motion and its application to the ankle joint complex", Journal of Biomechanics, 2002, accepted as publication.
4. Ning Ying, Wangdo Kim, "Use of Dual Euler Angles to Describe General Spatial Movements of Human Joints", SGH Proceedings, 2001, 10(4), 262-272
5. George A. Arangio, MD, Chaorong Chen, and Wangdo Kim, "Effect of Cutting the Planta Facia on Mechanical Properties on the Foot", Clinical Orthopedics and Related Research, UK, 1997, 339, 227-231.
6. Wangdo Kim and Arkady S. Voloshin, "Role of Plantar Facia in the Load Bearing Capacity of the Human Foot," J. Biomechanics, Vol 28, No. 9, pp 1025-1033, 1995.
7. Wangdo Kim, Arkady S. Voloshin, Stanley H. Johnson, "Modeling of heel strike transients during running", Human Movement Science, Netherlands, 1994, 13, 221-244.
8. W. Kim, A.S. Voloshin, S.h. Johnson, A Simkin, "Measurement of the Impulsive Bone Motion by Skin-Mounted Accelerometers," Journal of Biomechanical Engineering, USA, 1993, Vol. 115, pp. 47-52.
9. Wangdo Kim and Arkady S. Voloshin, "Dynamic Loading during Running on Various Surfaces," Human Movement Science, Netherlands, 1992, 11, pp. 675-689.