BIOMECHANICS, KINEMATIC ANALYSIS OF ANKLE PROSTHES

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Introduction

Injuries and diseases affecting the ankle can cause significant discomfort and hinder regular activities, negatively impacting joint function and movement [1]. Various therapies have been developed to alleviate pain and restore mobility, including total ankle replacement (TAR), which is a promising option that is continuously evolving. To determine the effectiveness of different prosthetic designs, robotic simulators are commonly utilized to mimic natural ankle joint movements and compare the performance of various prosthetic designs [2]. Thus, the objective of this thesis was to develop a universal robotic simulator that could test both ankle and knee prostheses. In particular, the robot was utilized to assess the effectiveness of a PLA prototype ankle prosthesis during walking.

Methods

Initially, the robot experienced multiple mechanical and electrical problems that had a significant impact on its functionality. Despite being a metal frame with four motors that offered four degrees of freedom, it was unable to move synchronously, with the axial motor being particularly affected. Nevertheless, the current advanced robotic system can accurately replicate natural ankle movements by executing a variety of synchronous instructions outlined in ISO 22622:2019. These instructions, such as Plantar/Dorsiflexion (P/D), Internal/External rotation (I/E), Anterior/Posterior displacement (A/P), and Axial load, are controlled by a C++ application that was developed as a part of this thesis.

In addition, motors calibration has been performed. To accomplish this, an Optoelectronic system from OptiTrack was utilized, consisting of three cameras aimed at the motion of three rigid bodies equipped with three markers each. Using this advanced system, the movement of each motor can be precisely controlled, enabling the evaluation of motor performance one at a time.

Tekscan 4000 Pressure sensor was used to acquire data on the contact area and force applied over two tests.

Comparative research was performed over ten different configurations of the Tibial and Talar interface, including changes to the Tibial part's position angle with respect to the Transverse Plane [0°,6°,10°] and the use of a mobile bearing. Afterward, a repeatability test checked the robot's ability to replicate the same gait cycle multiple times with the same characteristics, seven cycles were performed on the TAR configuration with 0-degree Eversion and mobile bearing.

Results

Regardless of using only half the axial load specified in the ISO standard, the 3D-printed PLA part did not perform well under testing, causing failure after prolonged use.

Calibration indicate that motors have high accuracy and minimal error, with maximum errors of 1.25°, 0.94°, and 1.13 mm for P/D, I/E, and A/P, respectively.

Moreover, from comparative research, the best configuration was found to be a neutral position of 0 degrees with a mobile bearing, showing higher values of the contact area, as shown in Figure 1.

Finally, from the repeatability test standard deviation was calculated over cycles, showing a good repeatability, as reported in Table 1.

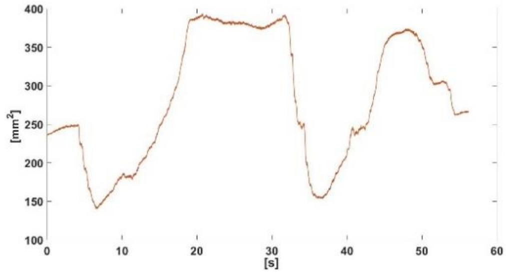

Figure 1: Area of contact data coming from the repeatability test with their standard deviations.

Cycle	1	2	3	4	5	6	7
Std	0.17	0.10	0.13	0.07	0.11	0.13	0.12

Table 1: Mean standard deviation for each cycle during the repeatability test.

Discussion

Despite mechanical issues, solutions were developed, and the robot performed well during testing. Calibration and repeatability tests confirmed its high accuracy and repeatability.

On the other hand, this study is anticipated to make a valuable contribution to ankle prosthetics and establish the foundation for future advancements.

References

1. Bonasia, Davide Edoardo, et al. "Total ankle replacement: why, when and how?." The Iowa orthopaedic journal 30 (2010): 119.
2. Natsakis, Tassos, et al. "Foot–ankle simulators: A tool to advance biomechanical understanding of a complex anatomical structure." Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine 230.5 (2016): 440-449.