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Development of an Evaluation System for Magnetic Resonance Imaging Based Three-Dimensional Modeling of a Transfemoral Prosthetic Socket Using Finite Elements

Mohd Syahmi Jamaludin [1,*], Akihiko Hanafusa [1], Yamamoto Shinichirou [1], Yukio Agarie [2], Hiroshi Otsuka [3] and Kengo Ohnishi [4]

1 Department of Bio-Science and Engineering, Shibaura Institute of Technology, Tokyo 135-8548, Japan
2 Department of Supporting Prosthetic Orthotics, Niigata University of Health and Welfare, Niigata 950-3102, Japan
3 Department of Prosthetic and Orthotics, University of Human Arts and Science, Saitama 339-8539, Japan
4 Department of Science and Engineering, Tokyo Denki University, Tokyo 120-8551, Japan
* Correspondence: nb17107@shibaura-it.ac.jp; Tel.: +81-80-9285-0360

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Featured Application: Finite element theory was applied to determine the accuracy of a human anatomy model for potential use in the field of biomechanics. Furthermore, the proposed evaluation system can be applied in other prosthetic and orthotic research applications.

Abstract: Recent technologies have suggested the utilization of three-dimensional (3D) printing technology to enhance the fabrication accuracy of prosthetics. Accordingly, simulations are used to obtain precise parameters for subject-specified prosthetic socket. This study proposes an evaluation system to measure the accuracy of a subject-specific 3D transfemoral residuum model during the interaction with the socket in conjunction with the application of finite element methods. The proposed system can be used in future validations of socket fabrication. The evaluation is based on the measurement of the residuum's soft tissue deformation inside two types of prosthetic sockets. In comparison with other studies, the 3D models were constructed with magnetic resonance images (MRI) with the aid of computer-aided design (CAD) software. The measurement of soft tissue deformation was conducted based on the measurement of the volumetric value of fat, muscle and skin in the pre- and post-donning phases. The result yielded a promising correlation coefficient value between the simulation and the experiment in the soft tissue deformation evaluation. The relation of the muscle–fat ratio in the residuum is extremely important in the determination of the ability of the prosthetic to deform. The environment during the socket fitting session was similar to that defined by the set boundary conditions in simulations. In view of the promising results of this study, the evaluation system proposed herein is considered reliable and is envisaged to be used in future research.

Keywords: prosthetic socket; finite element method; finite element analysis; transfemoral residuum; biomechanics; bipedal stances; 3D model

1. Introduction

Prosthetic device manufacturing has increased tremendously owing to an increased demand in recent years. This demand has been driven by the increase of amputees that require the prosthetic device to perform their daily routines. In Japan, the proportion of amputees increased to 22.4%