CPOJ OPEN ACCESS

ABSTRACT (POSTER PRESENTATION)

AOPA'S 101 ST NATIONAL ASSEMBLY ABSTRACTS, SEPTEMBER 26-29, VANCOUVER, CANADA, 2018

THE EFFECT OF MATERIAL CHOICE AND PROCESS PARAMETERS ON THE MECHANICAL STRENGTH OF 3D-PRINTED TRANSTIBIAL PROSTHETIC

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DOI: https://doi.org/10.33137/cpoj.v1i2.32160

INTRODUCTION

The most important aspect of a lower extremity prosthesis is the socket. The socket is the interface between the human and the mechanical support system[1]. There are different methods for producing prosthetic sockets. The traditional method requires a skilled prosthetist and is time consuming [2, 3]. Using 3D printing technology for manufacturing prosthetic sockets promises to speed up the fabrication process and reduce materials and time cost significantly. 3D Printed prosthetic sockets have to potential to increase socket strength and durability. This paper investigates the effect of material choices and printing process parameters on the mechanical strength of 3D printed trans-tibial sockets.

METHODS

First available printable materials with excellent structural characteristics were identified. Nylon 12, recycled Nylon 12, and PLA were selected. The appropriateness of 3D Printed prosthetic sockets lies in its strength and durability of the sockets. 3D printing parameters that have impact on the mechanical properties of printed sockets were explored as well. Two additive manufacturing methods, namely Fused Deposition Modeling (FDM) and Selective laser sintering (SLS) were selected. Based on selected materials and manufacturing methods seven prototype sockets were fabricated. A standard socket attachment block and orthocryl sealing resin was used to connect the socket and pylon. ISO standard 10328 was used to statically evaluate the strength of printed sockets. As specific guidelines for trans-tibial socket testing had yet to be stablished the loading parameters and offset values for lower limb prostheses were used. A Tinius Olsen universal testing machine was used to test the seven sockets by applying vertical loads under static condition during early stance phase of gate cycle for an 80 kg trans-tibial male amputee patient. Each socket was tested for a proof test and ultimate strength test and then loaded to failure in accordance with the ISO standard 10328.

RESULTS

After applying the loads for loading condition I and load level P4 specified in the standard, all sockets were loaded until failure. The maximum load reached in every socket can be seen in figure 1. Both of the unrecycled Nylon 12 sockets resulted in the failure of the socket attachment system.

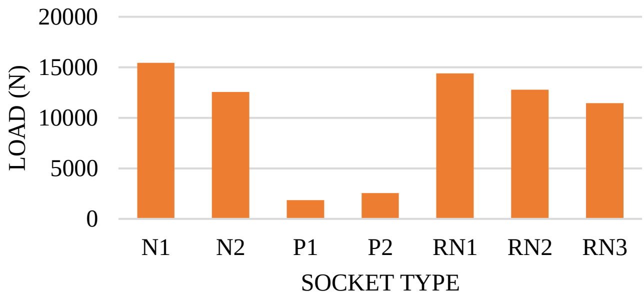

Figure 1: Ultimate strength at failure for different socket types. N: Nylon12, P: PLA, RN: recycled Nylon 12.

In general, all the unrecycled and recycled Nylon 12 printed sockets met the minimum ISO standard for ultimate strength. However, recycled Nylon 12 performed with lower ultimate strength than did unrecycled Nylon 12. The remaining two systems, the PLA sockets that was printed in xz direction, resulted in the failure of the socket before reaching the ultimate strength specified in ISO standard.

CONCLUSION

This pilot study results showed that the PLA socket tested do not meet the minimum requirement of the ISO 10328. All Nylon 12 printed socket tested exceeded ultimate strength for ISO 10328. For two of the socket tested the attachment block failed before the socket failed. Therefore, it's recommended that additional study for determining a suitable method for attaching adaptor to socket are needed.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance of Barber Prosthetic Clinic, Wiivv Wearables, and Yamagata University, who contributed their time and materials to make this project successful.

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