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HOW INFILL PERCENTAGE AFFECTS THE ULTIMATE STRENGTH OF A 3D-PRINTED TRANSTIBIAL SOCKET

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INTRODUCTION

3D printing for non-weight-bearing upper extremity prostheses is becoming increasingly popular as a method of fabrication.[1] Some clinics in North America have begun using 3D printing to fabricate lower extremity diagnostic sockets (Figure 1). The strength requirements for upper extremity prostheses are not as rigorous as the strength requirements for lower extremity prostheses. Therefore, strength testing on 3D-printed lower extremity sockets is one of the first steps that needs to be conducted to ensure patient safety. 3D-printed prosthetic sockets are becoming an alternative option to traditional methods because it is possible to customize different parameters to create a strong structure. Infill percentage is an important parameter to research as this can have an influence on the strength of 3D printed sockets.[2] As both prosthetists and healthcare professionals, there is a need to become more involved in the process of designing and testing 3D printed sockets. The purpose of this study is to test how changing the infill percentage affects the ultimate strength of a 3D printed transtibial socket during initial contact.

Figure 1. 3D printed transtibial socket

Figure 2. Testing jig with socket.

METHODS

A total of nine transtibial sockets were printed using a Fused Deposition Modeling (FDM) printer. Three different infill percentages were chosen because they represent realistic percentages that clinicians may decide to print. Three sockets were printed at 30% infill, three sockets at 40% infill and three sockets at 50% infill. All the sockets were printed from a white polylactic acid (PLA) filament and from the same data file to maintain shape consistency (Table 1). The sockets were tested for ultimate strength in a Tinius Olsen universal testing machine (Figure 2) located at the British Columbia Institute of Technology. The International Organization for Standardization (ISO) standard 10328 outlines the process and procedures of structural testing in lower limb prostheses.[3] The standard determines whether the sockets can withstand the minimum static load at initial contact and how much additional load it can withstand.

Table 1. Characteristics of the 3D-Printed sockets before structural tests.

Socket #	Infill %	Length (cm)	Unfinished Weight (g)	Finished Weight (g)
1	30	20.8	291	531
2	30	20.8	304	543
3	30	20.8	304	543
4	40	20.8	297	527
5	40	20.8	296	538
6	40	21	302	543
7	50	20.8	325	564
8	50	20.9	324	574
9	50	20.5	326	575

RESULTS

In all nine sockets, the amount of force that resulted in socket failure exceeded the ISO 10328 threshold of 4480N (Figure 3). The infill percentages (30% - 50%) do not appear to impact the ultimate strength of the socket. Observational analysis of socket failure show that all sockets broke in two areas: 1) lateral mid socket or 2) medial popliteal area with the latter region being the most common.

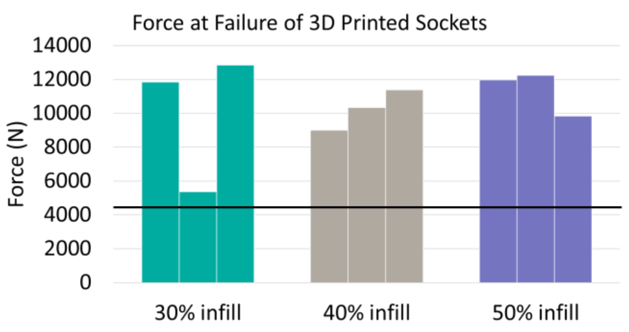

Figure 3. Force of failure of 3D Printed transtibial sockets. Horizontal line represents the strength threshold set by ISO Standard 10328 (4480N).

Table 2. Areas of socket failure and failure types

Socket #	Infill %	Failure point	Failure Type
1	30	medial popliteal	crack
2	30	lateral mid socket	crack
3	30	medial popliteal	complete
4	40	medial popliteal	crack
5	40	lateral mid socket	crack
6	40	medial popliteal	crack
7	50	medial popliteal	complete
8	50	medial popliteal	crack
9	50	medial popliteal	crack

Figure 4. Socket broken in the medial popliteal area.

Figure 5. Socket broken in the middle lateral area.

CONCLUSION

3D printing technology is currently being used in many different industries. The field of prosthetics and orthotics needs to demonstrate how it can successfully use the technology in clinical practice. A logical first step is testing the strength of 3D-printed prosthetic sockets to determine if it is safe for patient use. Using the specific criteria (static testing, initial contact and P5 weight class) and procedures of ISO Standard 10328, this research project demonstrated that the ultimate strength of the 3D-printed sockets exceeded the minimum required 4480N threshold set by the standard. Furthermore, infill percentages ranging from 30% to 50% did not seem to affect the ultimate strength of the sockets.

FUTURE DIRECTIONS

This project focused on specific conditions whereas the standard outlines additional conditions.3 It is important that these other conditions are tested to fully deem a 3D printed socket safe for patient use. 3D printing technology is advancing quickly. It would be beneficial to investigate how different printers, materials, and methods of printing can affect the strength of a socket. Further research should test multiple parameters (e.g. layer height and wall thickness) to see their combined effect on the strength of a prosthetic socket. This project is a small part of a much larger research initiative involving collaboration among clinicians and technicians. The hope is that the findings from this project contribute to the understanding and awareness of 3D printing in the Prosthetics and Orthotics field.

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