TOWARDS THE DEVELOPMENT OF BENCH TESTING FOR LOWER-LIMB PROSTHETIC SOCKETS

Francesca Gariboldi[1], Mattia Scapinello[1], Nicola Petrone[1], Gian Luca Migliore[2], Gregorio Teti[2], Andrea Giovanni Cutti[2]

[1]University of Padova, Italy; [2]Centro Protesi INAIL, Italy
E-mail: francesca.gariboldi@phd.unipd.it

INTRODUCTION

Prosthetic sockets are the custom element connecting the residual limb of a person with lower-limb amputation to their prosthetic foot and (possibly) prosthetic knee through distal attachment modules. The socket has to guarantee good fit and function while being lightweight and structurally sound during the activities of daily living relevant to the patient. However, given the absence of widely accepted guidelines or standards dedicated to socket construction and structural testing, its mechanical properties remain unknown, which may lead to negative consequences such as socket under-dimensioning and failure. The purpose of this study was to design a mechanical testing system for lower-limb prosthetic laminated sockets and conduct preliminary mechanical tests on alternative socket layups. This will help understand to which extent socket design can influence its ultimate strength.

METHODS

The literature regarding structural testing of lower-limb prosthetic sockets is very limited (16 articles)[1] and most of the authors that performed socket testing were guided by ISO 10328[2], the reference standard for off-the-shelf lower-limb prosthetic componentry. This standard does not apply to the socket as a whole, and the researchers had to apply adaptations to deal with a series of knowledge gaps, such as socket alignment within the test machine, load transfer from test machine to the socket, etc. Despite these limitations, ISO 10328 seemed a viable starting point for socket testing, as it describes testing factors that can be applied to the socket, such as critical test configurations and load levels normalized to body weight.
In this study, the authors assumed the ISO 10328 adaptation proposed by Gerschutz et al. [3] in toe-off condition. To this aim, a socket testing machine was built at the University of Padua (Figure 1).

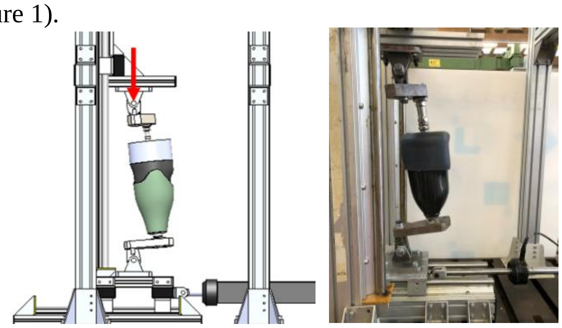

Figure 1: Test machine for structural testing of lower-limb prosthetic sockets.

Load was applied vertically on the upper lever arm by an actuated sliding cylinder, and it was transferred to the socket using a hard-resin custom-made mock residual limb with a 9mm styrene liner to assure proper press-fit. Top and bottom lever arm sizes were chosen to comply with ISO 10328 P5 configuration in test condition II (toe-off) and the socket was positioned as low as possible inside the test machine, to generate the highest bending moment.
Thirty carbon-fiber laminated transtibial sockets were manufactured from the same residual limb shape, i.e. a template developed by Gerschutz et al., and differed solely for material layup, lamination resin and distal attachment hardware.
The sockets were subjected to static loading according to ISO 10328 requirements up to failure. The ultimate load at failure was compared with the thresholds reported in the ISO 10328 standard ("P" levels).

RESULTS

Figure 2 displays the load-displacement curve for three sockets with different combinations of layup, resin and distal modules.

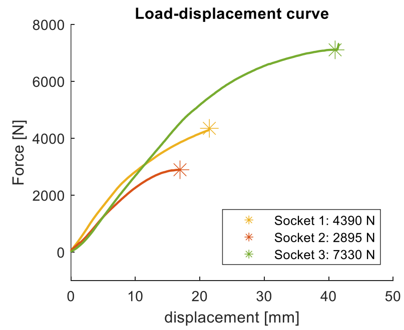

Figure 2: Load-displacement curves and ultimate load at failure three sockets.

As showed by the graph, the maximum load reached by the three sockets is very different: Socket 3 exceeds ISO 10328 P8 threshold (5250N), Socket 1 is just below P6 threshold (4425N) and Socket 2 barely overcomes P4 threshold (2790N).

CONCLUSION

Different combinations of layup, resin and distal module can lead to very different results in terms of mechanical properties, which highlights the importance and need to perform socket testing.

SIGNIFICANCE

This work might help support the definition of widely accepted guidelines for socket structural testing.

REFERENCES

1. Gariboldi F, et al. *Med Eng Phys*. 2021;99:103742.
2. ISO. *Int Organ Stand*. 2016;10328:2016.
3. Gerschutz MJ, et al. *J Rehabil Res Dev*. 2012;49(3):405.

DISCLOSURE

None.

ACKNOWLEDGEMENT

Authors intend to thank INAIL for funding the study through the OLIMPIA Project.