A 3D Printed Wrist-Driven Orthosis with Expanded Thumb Range of Motion

Diepenbrock, D.M. 1, Steele, K.M. 2
Oklahoma Christian University, Edmond, OK, University of Washington, Seattle, WA

INTRODUCTION
Wrist-driven orthoses (WDOs) facilitate a pinch grip for people who are capable of wrist flexion/extension but have limited finger control. Current designs for WDOs are difficult and time-consuming to fabricate. Further, many users do not like wearing them due to poor comfort, function, and aesthetics (House, Gwathmey and Lundsgaard, 1976). These challenges were the inspiration for using 3D printing to improve fabrication and function of custom WDOs. 3D printing creates models from digital files by printing numerous layers of very thin horizontal slices of the model, one on top of the other. The advantages of 3D printing include rapid prototyping, cost-effective manufacturing, and high levels of customizability. These advantages can be especially useful when dealing with custom medical devices and complex geometry, such as orthoses.

METHOD
SolidWorks, a 3D modeling software, was used to recreate the form of traditional WDOs. The WDO was made up of a forearm piece, a hand piece, pieces that go above and below the hand, the thumb, a four-bar linkage, and a fingertip piece. These pieces were printed on a MakerBot Replicator using an affordable and widely available bioplastic commonly used in 3D printing, polylactic acid (PLA). After printing, the pieces were connected using post screws. Padding was added at the wrist, thumb, and top and bottom of the hand to improve subject comfort. Velcro straps were used at the thumb and two places on the forearm to secure the WDO to the individual.

This design recreated the motion and function of the traditional WDO. An advantage of 3D modeling and printing is that the design can be quickly modified and tested. To improve upon the traditional WDO, design modifications were made to increase the range of motion (ROM) by allowing the thumb to move with the fingers and create a more natural grasping action. To enable this function, a four-bar linkage was added between the thumb and the finger that allows the thumb to move in conjunction with the fingers with wrist flexion and extension.

The ROM of both the original WDO and the modified design were tested using a goniometer to measure the angle between the tips of the thumb and the index finger at fully closed and open positions.

RESULTS
The 3D printed WDO took 6-6.5 hours to print (Figure 1). The total material costs were approximately $9.50 for the PLA, screws, padding, Velcro, Instamorph, and Loctite. The modified WDO design increased the ROM by 20° by engaging both the fingers and thumb in motion during wrist flexion and extension (Table 1). This improvement will allow users to pick up a wider range of objects.

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<th>Table 1. ROM of Original and Modified WDOs</th>
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<td>Fully Closed</td>
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<td>Fully Open</td>
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<td>ROM</td>
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DISCUSSION
The modified WDO design enabled greater hand aperture with minimal increases in device complexity or weight. Future work will evaluate the device with individuals with spinal cord injury to determine if it provides a more natural grip.

CONCLUSION
3D printed orthoses have the potential to ease fabrication, enhance aesthetics, reduce cost, and improve function. New designs, such as the modified WDO created in this study, can be customized to meet the unique needs and functional ability of each individual.

CLINICAL APPLICATIONS
The low cost of materials, enhanced aesthetics, and easier customizability of 3D printed orthoses have the potential to improve WDOs and other orthoses for individuals with spinal cord injury and other neurological disorders.

REFERENCES

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