Technical, Clinical and Functional Considerations for the Development of 3D Printed Upper-Limb Prostheses

Keaton Young[1], Jean L. Peck[2], Rakesh Srivastava[3], James Pierce[1], Nicholas Stergiou[1], Jorge M. Zuniga[1].
1. University of Nebraska at Omaha, Department of Biomechanics, USA; 2. CHI Health Creighton University Medical Center, Omaha, USA; 3. Innovative Prosthetics & Orthotics, USA.

INTRODUCTION

The development of 3D printing for the manufacturing of prostheses and orthoses has resulted in cost reduction strategies, better accessibility and customization of prosthetic designs. The current paper describes the technical and clinical considerations for the implementation of these devices in rehabilitation and research settings. Specifically, considerations on fitting procedures, assembly, durability, regulatory implications, and patient functional outcomes are discussed.

METHODS

Subjects: Eleven children participated in this study and were fitted with a 3D-printed transitional wrist-driven and elbow-driven prosthesis.

Apparatus and Procedures: Gross manual dexterity was assessed using the Box and Block Test and wrist strength was measured using a dynamometer.

Data Analysis: Separate two-way repeated measures ANOVAs were performed to analyze function and strength data. An alpha value of 0.05 was considered statistically significant for all comparisons.

RESULTS

There was a significant hand by time interaction for the function [$F(1,10) = 6.42$; $p = 0.03$, $\eta p2 = 0.39$], but not for the wrist flexion strength [$F(1,7) = 0.67$; $p = 0.44$, $\eta p2 = 0.02$], or for the wrist extension strength [$F(1,7) = 0.05$; $p = 0.40$, $\eta p2 = 0.1$]. There were significant main effects of function for the hand [$F(1,10) = 52.41$; $p = 0.01$, $\eta p2 = 0.84$] and the time [$F(1,10) = 37.31$; $p = 0.01$, $\eta p2 = 0.79$]. There were significant main effects of strength for time [$F(1,7) = 6.56$; $p = 0.38$, $\eta p2 = 0.48$].

	Box & Block Test (blocks per min)*				Flexors Strength (Kg)**			
	Non-affected		Affected		Non-affected		Affected	
ID	Before	After	Before	After	Before	After	Before	After
1	24	25	0	5	10	11.6	8.46	14.6
2	22	26	3	3	11.8	13.46	11.7	13.2
3†	26	27	0	3	---	---	---	---
4	36	38	13	19	4.2	10	5.2	7.6
5†	36	38	0	9	---	---	---	---
6	50	54	40	47	27.53	33.13	17.43	18.9
7†	60	66	0	3	14.8	14.7	25.2	22
8	60	62	13	16	15.7	17.8	12.3	19.46
9	53	53	0	17	24.4	19.4	20.46	22.46
10	69	68	0	9	10.8	10.1	8.3	12.16
11	75	75	0	12	---	---	---	---
M	**46.45**	**48.36**	**6.27**	**13.00**	**14.90**	**16.27**	**13.63**	**16.30**
SD	**18.67**	**18.34**	**12.31**	**12.70**	**7.70**	**7.62**	**6.83**	**5.24**

Table 1. Mean (±SD) for function and strength measurements before and after one to six months of using the 3D-printed hand prosthesis.

DISCUSSION & CONCLUSION

The increase in manual gross dexterity suggests that the 3D printed prosthesis can be used as a transitional device to improve function in children with traumatic or congenital upper-limb differences.

REFERENCES

1) Zuniga JM, Peck J, Srivastava R, Katsavelis D, Carson A. An Open Source 3D-Printed Transitional Hand Prosthesis for Children. JPO: Journal of Prosthetics and Orthotics. 2016;28(3):103-108.

2) Zuniga JM, Carson AM, Peck JM, Kalina T, Srivastava RM, Peck K. The development of a low-cost three-dimensional printed shoulder, arm, and hand prostheses for children. Prosthetics and orthotics international. Apr 26 2016.

3) Zuniga JM, Katsavelis D, Peck J, et al. Cyborg beast: a low-cost 3d-printed prosthetic hand for children with upper-limb differences. BMC research notes. Jan 20 2015;8(1):10.

4) Ten Kate J, Smit G, Breedveld P. 3D-printed upper limb prostheses: a review. Disability and rehabilitation. Assistive technology. Feb 02 2017:1-15.