Custom 3D-Printed Assistive Devices Improve Functional Independence in Cervical Spinal Cord Injury

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Introduction

• In the face of disability, the inability to interact with objects and devices around us can severely limit our functional independence.

• There are currently more than 200,000 people living with SCI in the United States, of whom half are quadriplegic.

• Through recent developments, such as 3D-printing, custom assistive devices for this disabled population have become a reality.

• The goal of this study is to measure whether 3D-printed assistive devices, in tandem with an upper extremity orthosis, can improve functional independence for people living with SCI.
Methods

- A 23-year-old male with cervical quadriplegia (C5 ASIA Impairment Scale) as a result of a motor vehicle accident 6 years prior was recruited to participate in this study.
- After interviewing the patient subject based on his needs, 3 conceptual models were designed for 3 distinct tasks using Computer Aided Design (CAD) Software (Solidworks).
- An external orthosis (Neomano) was used in tandem with the 3D-printed assistive devices.
- To assess changes in functional independence, the Spinal Cord Independence Measure (SCIM) was administered at the initiation and conclusion of the 6-week study.
Results – Overall Tasks

- Over a six-week period we compared the time taken to complete (TTC) each task using only the external orthosis versus using the orthosis together with the 3D-printed assistive devices.
- The results throughout the study are summarized as mean TTC and top and bottom bars indicate 95% confidence interval for the mean.
- On the SCIM, there was a slight increase from 27 to 28 over the course of the study due to an increase from 1 to 2 on Question 1 (Self Care – Feeding).

Average time taken to complete (TTC) door opening, writing and self-feeding task for most recent trial. Blue – orthosis only (O); Orange – orthosis + 3D-printed assistive device (O+3D).
Results – Self Feeding

Time taken to complete (TTC) self feeding task with the orthosis plus 3D-printed assistive device (O+3D).

Accuracy of Self Feeding task performance. The high accuracy was coupled with a corresponding decrease in time for each of the sessions.

- Implementation of 3D-printed assistive devices gave the subject the opportunity to feed himself – a task he could not simply do before the study.
Results – Door Opening

• Time taken to complete (TTC) door opening task was observed over six sessions.
• In all sessions, implementation of 3D-printed assistive devices decreased the time taken to complete the task.
• As evidenced by the decrease in mean TTC in both the orthosis only and orthosis + 3D-printed assistive device, there was significant learning effect across trials.

Time taken to complete (TTC) door opening task. Blue – orthosis only (O); Orange – orthosis + 3D-printed assistive device (O+3D). Time was compared for O vs. O + 3D. Time difference between O and O+3D increased over duration of experimentation.
Results – Writing

• Time taken to write a certain phrase was observed over six sessions.
• In all sessions, implementation of 3D-printed assistive devices decreased the time taken to complete the task.

Time taken to complete (TTC) writing task. Blue – orthosis only (O); Orange – orthosis + 3D-printed assistive device (O+3D). Time was compared for O vs. O + 3D. Subject wrote “Hello” during sessions 1-3 and “Brain” during sessions 4-6.
Discussion

- 3D-printed assistive devices, working in tandem with an external orthosis, can effectively reduce the time taken to perform certain tasks.
- 3D-printing assistive devices allow for rapid prototyping and full customizability to each user and their unique needs.
- These devices can provide the subject with the ability to perform new tasks and gain independence.
- A library of open source 3D-printed assistive devices can be created to reach a greater population of those affected with SCI.
Summary Points

• Increasing functional independence in spinal cord injury is of utmost importance in rehabilitation for this patient population.

• After interviewing the patient subject, we identified three tasks that the patient considered most beneficial to their recovery to full independence.

• 3D-printed assistive devices were created to work alongside an external orthosis to assess increased levels of functional independence in a single patient study.

• Implementation of 3D-printed assistive devices decreased the time taken to perform all three tasks studied: self-feeding, door opening, and writing.

• Surveys were taken pre and post intervention and results showed increase in perceived functional independence along with an increase in SCIM measure over the course of the study with the implementation of 3D-printed assistive devices.