DEVELOPMENT AND EVALUATION OF POINTDEXTER – AN INTEGRATED PREHENSOR FOR PROSTHETIC FINGERS

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ABSTRACT

Current prosthetic terminal devices require a compromise between form and function. Pointdexter is a retrofittable miniature gripper that is integrated into the index finger of multi-articulating hands to allow for an additional, selectable, grasp to assist in the manipulation of small objects. Pointdexter is an all-mechanical design that does not require additional actuators and is controlled using existing prosthesis control signals. Testing on able-bodied and amputee test subjects was performed using the Jebsen Taylor Hand Function test using three terminal devices: an unmodified Bebionic hand, the Bebionic with Pointdexter, and a Motion Control ETD. The results demonstrate that Pointdexter improved small object manipulation time over an unmodified multi-articulating hand by >35%, while not impacting normal hand function. Additionally, take home testing was performed to identify additional areas of improvement and to evaluate robustness of the device.

INTRODUCTION AND BACKGROUND

The Problem

Current prosthetic terminal devices (TDs) each have their advantages and disadvantages, which requires a compromise between form and function (Figure 1). Some individuals will carry multiple TDs and swap them out based on the environment and task being performed.

The Solution

A dexterous fingertip terminal device, Pointdexter, (Figure 2) was designed to optimally combine the advantages of multi-articulating prosthetic hands (e.g., conformal grasp) and hooks/grippers (e.g., small object manipulation) in a single upper-limb terminal device. Pointdexter adds function within the form and aesthetics of multi-articulating hands, as appearance is often as important as function in adoption of the prosthesis by the user [1].

Pointdexter adds an additional, selectable, dexterous grasp option focused on manipulating small objects. In this approach, the pointer finger on the hand is replaced with the self-contained and retrofittable Pointdexter to provide a tonged end-effector at the fingertip. The current, all-mechanical design is an add-on to existing multi-articulating hands that does not require additional actuators.

Pointdexter is driven with standard control signals. It is activated during 'trigger' grip via a selectable mechanical mode switch (Figure 3). When the Pointdexter is locked, the jaws are closed and finger is free to flex and extend as it normally would. When Pointdexter is unlocked, the finger actuator opens and closes the tines of the gripper instead of flexing and extending the finger.

After development of the prototype, functional outcomes measures were used to quantify the change in small object grasping ability created by Pointdexter and also confirm that Pointdexter does not interfere with standard hand function.

	Grasps Large Objects	Grasps Small Objects	Conformal Grasp	Multiple Grip Patterns	Cosmetic
Split Hook	✓	✓	✗	✗	✗
Electric Gripper	✓	✓	✗	✗	✗
Conventional Electric Hand	✓	✗	✗	✗	✓
Multi-Articulating Hand	✓	✗	✓	✓	✓
Multi-Articulating Hand + Pointdexter	✓	✓	✓	✓	✓

Figure 1: Commercially available TDs (top) and a feature comparison matrix (bottom).

Figure 2: Pointdexter features.

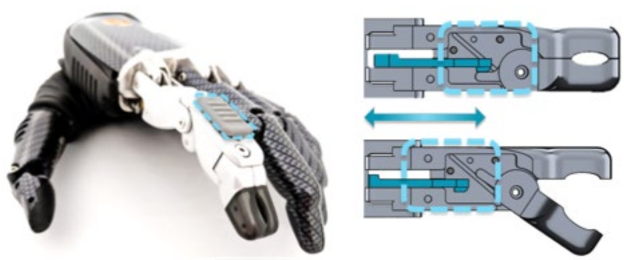

Figure 3: The 'top lock' mode switching mechanism.

METHODS

LTI conducted an initial clinical evaluation of functional outcome measures to compare Pointdexter (Liberating Technologies), a Bebionic hand (Otto Bock), and a powered split-hook ETD (Motion Control) (Figure 4). The ETD was selected to serve as the 'gold-standard' for function. IRB approval and participant informed consent was obtained.

A first round of testing for protocol development included subjects conducting three repetitions of the Jebsen-Taylor Hand Function (JTHF) test, 9-hole peg test, and common bimanual tasks. However, during this testing it was discovered that fatigue was substantial and was likely affecting the results. Therefore, the second round of testing that is described here focused solely on performing three repetitions of the JTHF test.

Figure 4: The 3 terminal devices used for testing: standard Bebionic hand (left), Bebionic with Pointdexter (center), and ETD (right).

<u>Subjects</u>

Two persons with transradial limb absence and two able-bodied subjects using prosthesis simulators (Figure 5) have participated in this study to date. Amputee subjects were experienced (>6 months) users of myoelectrically controlled multi-articulating hands.

Figure 5:A photograph of the able-bodied simulator.

<u>Procedures</u>

Participants practiced with each device to reduce the potential for learning effects. Subjects then conducted three timed trials of each sub-task of the Jebsen-Taylor with each of the three terminal devices. The terminal devices were presented in random order. Before the start of each task, subjects were allowed to select the desired grasp pattern in the standard Bebionic condition. During the Pointdexter condition, the subjects also had the option of selecting to use the Pointdexter or not. The selection of whether or not to use Pointdexter was consistent across all subjects. Every subject chose to use Pointdexter for turning cards, lifting light cans, stacking checkers, and manipulating small objects, but not use it for simulated feeding, writing, and lifting heavy cans (Figure 6).

<u>Data Analysis</u>

Mean and variance data of the able-bodied and amputee subjects were similar, so the results were pooled. Full statistical analyses were not conducted due to the small number of patients in this pilot study.

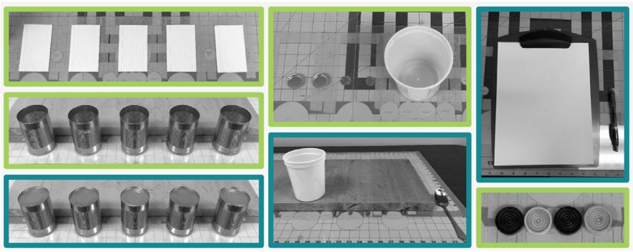

Figure 6: The subtasks of the Jebsen-Taylor test. When allowed, subjects chose to use the Pointdexter for those in green but not for those in teal.

RESULTS

Figure 2 shows the average completion times and 95% confidence intervals across test subjects for the Jebsen-Taylor Small Common Objects functional task conducted with each device. The standard multi-articulating hand was the slowest and the ETD the fastest, with the Pointdexter being >30 seconds faster (a >35% improvement) than the unmodified hand. As expected, both hand conditions were slower than the ETD on the small objects task.

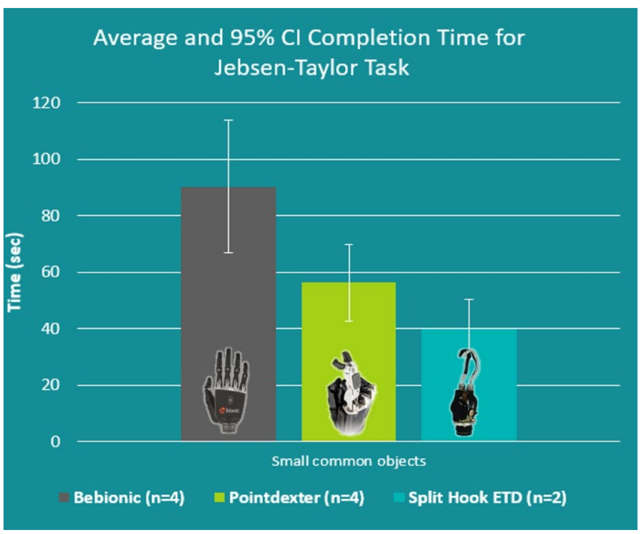

Figure 7: Jebsen-Taylor small objects test completion times for the tested terminal devices. Average across subjects with 95% confidence intervals.

Performance was found to be similar between the Pointdexter and the unmodified Bebionic hand for all other subtasks of the JTHF except card turning. More detail on this is provided below.

DISCUSSION

The Pointdexter design aims to combine the best aspects of various terminal devices and eliminate the need for users to frequently physically transition between terminal devices to accomplish various tasks/ADLs requiring dexterity.

As expected, the powered split-hook ETD performed the best across tasks and users as it is generally considered the most functional device we tested. However, the Pointdexter was able to emulate the precision of the split-hook ETD in manipulating small objects and improve the performance when compared to the standard multi-articulating hand. The variability was high and the sample size too small for statistical analysis, so further testing is required.

It was interesting the see how many tasks on the Jebsen-Taylor test individuals voluntarily chose to use Pointdexter. We believe that this has to do with the novelty of a new device or feature. For example, all subjects chose to try to pick up the large empty cans with the Pointdexter. However, we believe that, after using the device outside of the lab, it is likely that subjects would not choose Pointdexter for this task. Similarly, we believe that the increased time to complete the card turning task was due to the fact that the gripper on the Pointdexter was fairly small and therefore required more precise alignment to grip the card, while in full-hand mode there is a larger width of opening and therefore a larger margin for error. We believe that real-world practice would identify which tasks are best suited for Pointdexter and optimize its usage.

TAKE-HOME TRIAL

In addition to the in-lab testing described above, we conducted a one-month take home trial to identify:

- Areas of Improvement – more grip strength was the primary request.
- Tasks it was particularly useful for (Figure 8).
- Potential robustness issues – fortunately there were none.

Figure 8: A photograph of in-home use of the Pointdexter.

CONCLUSION

Initial functional tests with the Pointdexter are encouraging. Adding Pointdexter to a multi-articulating hand improved the user's ability to grasp small objects while retaining normal hand function and anthromorphic shape of the hand. Ideally, this design will increase prosthesis use and thus help to decrease overuse injuries in the intact limb from the relatively young UL amputee population.

ONGOING / FUTURE WORK

Additional research funding has been acquired to continue the project and implement various design changes and expand functional testing with human subjects. Anecdotal feedback from users highlighted a desire for more precise, secure, and strong grip patterns in the multi-articulating hand. Design efforts are underway to improve strength and security of grasp in order to gain even more functionality. Several changes have been implemented and initial functional tests with the improved design are encouraging. Also, while the Pointdexter was originally designed to work with the Bebionic hand, a new version has been developed to integrate with another popular multi-articulating hand, the iLimb from Össur (Figure 9).

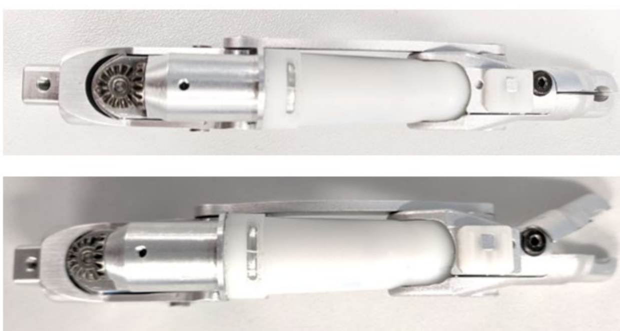

Figure 9: Photographs of the Pointdexter designed to integrate with the iLimb hand from Össur.

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