Preliminary assessment of three new designs of prosthetic prehensors for upper limb amputees

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Abstract
At present, upper-limb amputees have a basic choice of a hook or a hand for the prosthetic prehensor. In the USA about two-thirds of upper-limb amputees wear hooks and about one-third wear hands. Either of these options represents a compromise. The hook is more functional and the hand is more cosmetic. Some amputees solve the dilemma by having one of each and interchanging them as work and social situations dictate. However, they would prefer to have one acceptable prehensor, and they want one which is functional, is attractive, and does not necessarily have to look like a hand.

In an attempt to meet the desires of upper-limb amputees, three prosthetic prehensors or "terminal devices" have been designed and developed into models. This article describes the preliminary assessment of these new designs.

Description of new designs

The concept is to have a prehensor which is neither hook nor hand to satisfy the desires of upper-limb amputees (LeBlanc et al, 1987 ab). One notable attempt has been made to accomplish this. That is the work of the creative prosthetist Carl Sumida and his evolution of the CAPP I prehensor for children and the CAPP II prehensor for adults.

The authors took a three-pronged approach to the challenge of designing new prehensors based on (a) the anatomy of the human hand, (b) function of grasping, and (c) appearance.

Prehensor A
This prehensor (Fig. 1, top left) is derived from study of the anatomy of the human hand. It is voluntary closing (VC), uses primarily three-jaw-chuck grasp, has curvatures for multi-point grasp of cylindrical objects and has a cut-out in the dorsum for use of pencils and utensils.

Prehensor B
This prehensor (Fig. 1, top right) is based mainly on aesthetics. It is unique in that it has a rotary thumb which, when positioned for fingertip grasp is VO, and when rotated for palmar grasp is VC.

Prehensor C
This prehensor (Fig. 1, bottom left) is based mainly on functional considerations and has two modes of operation, fingertip grasp in the VO position and palmar grasp in the VC position. The fingertips handle objects up to 1½ inches in diameter and the proximal area handles 1½-3 inches in diameter. Prior work has indicated that 90% of activities can be handled with a 1½ inch opening or less.

Prehensor D
Standard Homer-Durrance 5X hook for comparison (Fig. 1, bottom right).

The operation of the Prehensor A design is conceptualized as normally closed, thumb opening completely with a slight pull on the cable, and thumb closing with further pull on the cable.

The Prehensors B and C designs are unique in that they offer different grasping surfaces and the option of using VO or VC prehension. That is, one could hold objects in the VO position with fixed prehension force and no harness pull, or could hold objects in VC position with variable prehension proportional to harness pull.

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Fig. 1. Prosthetic prehensors.
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Fig. 2. Ranking of the four prehensors.

All three models were made of hard plastic painted grey with a grey fabric covered forearm and a white dress shirt sleeve to the wrist.

Method of assessment

A questionnaire was developed to help ascertain if any of the three models appeared worthy of further development. Three major areas of importance were addressed: appearance, function and acceptance.

The questionnaire was administered face-to-face to a cross section of 18 people as follows:
- 4 below-elbow amputees
- 4 prosthetists
- 5 occupational therapists
- 5 lay persons

18 total

Each person was shown models of the three prehensor designs and asked for their reactions to them.

The questionnaire was in two parts. The first part elicited responses to the three new designs. The second part included the common, "standard" Hosmer-Dorrance 5X Hook for comparison and re-examination of preferences with the three new designs. A ranking system was used to determine 1st, 2nd and 3rd choices.

In addition, subjective comments were solicited on design features that were felt to be positive or negative, including ideas of modification for improvement.

Of the 18 people participating in completion of the questionnaire, nine were women and nine were men. The five lay people included (1) the father of a 19-year-old boy with a below-elbow congenital amputation, (2) the wife of a man with a below-elbow amputation for 43 years, (3) a special education teacher of 25 years experience, (4) a hospital recreation therapist with 15 years experience, and (5) a psychology counselor with minimum exposure to upper-limb amputees.

Results

Figure 2 shows the ranking of all four prehensors by the different groups of people.

Comments

Subjective comments made about all four prehensions are listed below.
Prehensor A

**Positive**
- Multifunctional;
- Versatile; large surface area for grasp; fits well in pocket; attractive;
- Resembles hand;
- Graceful contours;
- Good vision for grasp;
- Simplicity of design;
- Durable

**Negative**
- Beak nose; bird-like;
- Reptilian; claw-like;
- Too much bulk; no lateral grasp; problem holding large handles

Prehensor B

**Positive**
- Not threatening; nice contours; two function thumb; intriguing;
- Fascinating; presents additional options;
- Artistic, different; two types of grasp;
- Graceful; not weapon-looking; large, adaptable grasp; can be scoop or shovel

**Negative**
- Alien; turtle hand;
- Looks funny; one-sided; looks unstable;
- Awkward angles of grasp; large excursion required; science-fiction-like

Prehensor C

**Positive**
- V0 and VC grasp option; capacity for small and large tension; simple, streamlined in appearance; good vision for grasp; small bulk; not cumbersome; easy to use

**Negative**
- Too wide; too much open space; looks like R2D2; claw resembles a hook; limited approach to objects; robot-like; awkward use

Prehensor D

**Positive**
- Metal good for working around heat and chemicals;
- Durable; can be tool or weapon if necessary;
- Small point good for fine grasp; good vision for grasp; can get into small spaces; small bulk, low profile; hook around object for pulling; nicely machined; quality look to it

**Negative**
- External cable activation; Captain Hook stigma; metallic, shiny; cold-looking;
- Crush styrofoam cups or eggs; threatening, weapon-like; looks heavy; can tear clothes; dangerous in sports; too much weight during hot weather;
- Uncomfortable from perspiration

In addition to the positive and negative comments people suggested modifications to the prehensors for enhancement of quality.

**Modifications suggested**

**Prehensor A**
- Have thumb curving inward rather than outward for better appearance; make locking mechanism like APRL hand and hook; change alignment for improved grasp; VC should be actively researched; try different colours and materials; change scallops to flat surface with texture; less bulk

**Prehensor B**
- Good idea to have hole or slot for carrying handles, such as luggage; if made of stainless steel, could cut down on bulk; cant down (flex) the wrist slightly; make rotating thumb very strong; put ridges on flat surfaces; have “fingers” come to a point for fine grasp

**Prehensor C**
- Have flat versus curved surfaces for better grasp; have the stationary fingers pre-positional; have ends come to point for fine grasp; have less bulk

**Prehensor D**
- Have inside activation; make plastic for warmth and more social appearance; make light as possible and neutral in colour.

**Assessment of prosthetic prehensors**
A suggestion was made and supported by three raters for continued exploration of voluntary closing prehensors. The geriatric and very small child populations are unwilling to have voluntary closing prehensors currently. It was felt that focus on new technology with different materials and designs could promote the voluntary closing principle as a viable and practical answer to current problems.

**Conclusions**
Prehensor B was ranked the highest overall. It had the highest scores for appearance and acceptance.

Prehensors A and D (5X Hook) were close to one another for 2nd place. Both scored slightly higher in function than Prehensor B, but were
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lower in appearance and acceptance. It is the feeling of the authors that Prehensor B ranked lower in function because it is the biggest departure in design and the most unknown and untested functionally.

Prehensor C was clearly last as 4th choice among the four prehensors.

These conclusions suggest that (1) there are viable alternatives to the standard hooks and hands and (2) Prehensor B is worth pursuing.

Acknowledgements

This work is being supported in part by Field-Initiated Grant No. 133MH70021 from the National Institute on Disability Rehabilitation and Research, U.S. Department of Education and the Morris Stulsaft Foundation, San Francisco. Also significant was the opportunity to exchange ideas in Europe by means of a Fellowship to the secondary author from the international Exchange of Experts and Information in Rehabilitation, World Rehabilitation Fund, New York. The authors thank Douglas Williams, Ph.D., for assistance in data analysis.

REFERENCES


FURTHER READING


