Comparison of Three Myoelectrically Controlled Prehensors and the Voluntary-Opening Split Hook

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Key Words: hand function • myoelectrics prosthesis

The literature includes several comparisons of prosthetic hands and hooks (see Appendix). None of the studies has compared the Otto Bock System Electric Greifer prehensor and the Hosmer NU-VA Synergetic Prehensor to the myoelectrically controlled hand or to the body-powered hook. This study compares the Otto Bock System Electric Hand (hereafter called the Electric Hand) and the Otto Bock System Electric Greifer prehensor (hereafter called the Greifer prehensor) by all subjects. This is the system most frequently used by persons with unilateral below-elbow amputations using Otto Bock System Electric prehensors (R. Schmierer, personal communication, July 7, 1994). The Hosmer NU-VA Synergetic Prehensor (hereafter called the Synergetic Prehensor) uses an alternative myoelectric control system, proportional, which allows the user to grade the speed of movement of the prehensor fingers and the rate at which force can be increased or decreased (see Table 1).

Body-powered split hooks are classified according to their mode of operation (Fryer & Michael, 1992). Voluntary-opening split hooks open when the control cable is pulled; voluntary-closing split hooks close when the control cable is pulled. The voluntary-opening split hook is the most commonly prescribed terminal device in North America (Fryer & Michael, 1992). It is the body-powered prehensor used in this study.

It has been standard rehabilitation practice to prescribe at least two different interchangeable prehensors for each patient, in an attempt to meet the versatile demands of a dexterous person. Options have previously been limited to handlike prehensors and the body-powered split hook. However, the Greifer prehensor and the Synergetic Prehensor differ markedly from the Electric Hand and from the body-powered split hook in that the former are both myoelectrically controlled non-hand prehensors. An assessment of these new prehensors was

1Manufactured by Otto Bock Orthopedic Industry, Inc., 3000 Xenium Lane North, Minneapolis, Minnesota 55444.
2Manufactured by Bionics Corporation, 561 Division Street, Campbell, California 95008. Designed by Northwestern University's Prosthetics Research Laboratory with support from the Veterans Administration Rehabilitation Research and Development Service.
3Manufactured by Otto Bock Orthopedic Industry, Inc., 3000 Xenium Lane North, Minneapolis, Minnesota 55444.
4Manufactured by Hosmer Dorrance Corporation, 561 Division Street, Campbell, California 95008.
needed to develop guidelines for patients with amputations and clinicians who work with them.

The objective of this study was to compare the effectiveness of four prehensors with quantitative standardized hand function tests and qualitative bimanual activities of daily living. The effectiveness of each prehensor for each subject was evaluated, along with the effectiveness of prehensors for the group as a whole (see Table 1).

**Method**

**Subjects**

The three subjects were all full-time prosthetic users who had been fitted with both a body-powered split hook and a myoelectrically controlled Electric Hand soon after their traumatic amputations. Their amputations had occurred a minimum of 2 years before their participation in this study.

Subject 1 was a right-handed, 73-year-old man with a right below-elbow amputation who had been wearing a myoelectric hand for 20 years. He had rarely worn his body-powered split hook since his injury. He sustained his injury while using a brush cutter in his yard. He was a
Hand Function Obsen, Taylor, Trieschmann, Trotter, Kashman, & Volland, 1985), the Jebsen-Taylor Test of body-powered split hook since his injury 3 years ago. He Berg, Iversen, while using a chopper shredder on his lawn. He chose to retire as an office worker after his injury. He wore his myoelectric hand. He sustained his injury to a meat cutter and returned to the same job. He wore his prehensor during all waking hours.

Subject 2 was a right-handed, 38-year-old man with a right below-elbow amputation who had been wearing his body-powered split hook for 2 years. He rarely wore his myoelectric hand. He sustained his amputation at work as a meat cutter and returned to the same job. He wore his prehensor during all waking hours.

Subject 3 was a left-handed, 61-year-old man with a right below-elbow amputation who had been wearing his body-powered split hook since his injury 3 years ago. He rarely wore his myoelectric hand. He sustained his injury while using a chopper shredder on his lawn. He chose to retire as an office worker after his injury. He wore his prehensor during all waking hours.

Instrumentation

Standardized measures. Standardized hand function tests were used to compare the prehensors. These included the Nine Hole Peg Test (Kellor, Frost, Silberberg, Jversen, & Cummings, 1971; Mathiowetz, Weber, Kashman, & Volland, 1985), the Jebsen-Taylor Test of Hand Function (Jebesen, Taylor, Trieschmann, Trotter, & Howard, 1969) and the Box and Block Test (Buehler & Fuchs, cited in Mathiowetz, Volland, Kashman, & Weber, 1985). The Nine Hole Peg Test is a coordination test scored according to the time required to place nine pegs in a pegboard and then remove them, one by one (Mathiowetz, Weber, Kashman, & Volland, 1985). The Jebesen-Taylor Test has several subtests that simulate daily unilateral functional tasks (Jebesen et al., 1969). These tasks include stacking checkers, grasping and releasing small objects such as coins and paper clips, holding a spoon and scooping up items, turning over index cards, picking up 1 lb. cylindrical cans and releasing them, and picking up empty cylindrical cans and releasing them. Performance is evaluated by speed and is scored according to the number of seconds required to complete each task. The Box and Block Test measures the number of blocks transferred from one side of a partition in a box to the other side, one at a time, in 1 min (Mathiowetz, Volland, Kashman, & Weber, 1985). These tests all involve timing, testing one side against the contralateral side, and use of functional tasks. The reliability and validity of the tests are described in the above cited references. These tests were chosen because they are objective and quantitative.

Activities of daily living (ADL) measures. A variety of bimanual ADLs was also tested with each prehensor. The activities selected were likely to be equally familiar to all subjects and involved a minimum of problem solving so as to reduce the effect of this variable on the results. They included cutting meat and pouring soda from a can to a glass.

Three occupational therapists who had at least 1 year of experience working with persons with amputations rated the effectiveness of each prehensor for the three subjects, who were videotaped while performing the ADL. The raters were uninformed as to which were the familiar prehensors for each subject. They were given qualitative criteria to judge the most and two least effective prehensors for each of the three activities performed by each of the three subjects.

Raters were instructed that the first criterion was the most important, followed by the second, then the third. The three qualitative criteria were as follows:

1. Functional outcome: Task is completed (specifically, food is cut in at least two pieces, glass is

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### Table 1

**Comparison of Three Myoelectric Prehensors and the Body-Powered Voluntary-Opening Split Hook (As Tested)**

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Mechanism</td>
<td>Single motor</td>
<td>Single motor</td>
<td>Two motors</td>
<td>Mechanical cable-activated moveable finger and stationary finger</td>
</tr>
<tr>
<td>Function and appearance of fingers and their coverings</td>
<td>Rigid hook distally, hook fingers parallel through opening range, built-in passive wrist providing flexion-extension</td>
<td>Soft compliant glove over motorized thumb, index, middle fingers, and non-motorized ring and little fingers</td>
<td>Primarily offers palmar prehension and cylindrical grip</td>
<td>Primarily offers tip and lateral pinch, cylindrical and hook grip</td>
</tr>
<tr>
<td>Control of the action of the prehensor</td>
<td>Nonproportional (digital): myoelectric signal must cross threshold to activate</td>
<td>Nonproportional (digital): myoelectric signal must cross threshold to activate</td>
<td>Proportional: user can grade speed of movement of prehensor fingers and rate at which force can be increased or decreased</td>
<td>Proportional force and speed but much lower forces than myoelectrics</td>
</tr>
<tr>
<td>Closing speed at “finger-tips” at operating voltage</td>
<td>120 mm/sec at 6V</td>
<td>110 mm/sec at 6V</td>
<td>295 mm/sec at 9V</td>
<td></td>
</tr>
</tbody>
</table>

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university photographer and wore his prehensor during all waking hours.

Subject 2 was a right-handed, 38-year-old man with a right below-elbow amputation who had been wearing his body-powered split hook for 2 years. He rarely wore his myoelectric hand. He sustained his amputation at work as a meat cutter and returned to the same job. He wore his prehensor during all waking hours.

Subject 3 was a left-handed, 61-year-old man with a right below-elbow amputation who had been wearing his body-powered split hook since his injury 3 years ago. He rarely wore his myoelectric hand. He sustained his injury while using a chopper shredder on his lawn. He chose to retire as an office worker after his injury. He wore his prehensor during all waking hours.

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Raters were instructed that the first criterion was the most important, followed by the second, then the third. The three qualitative criteria were as follows:

1. Functional outcome: Task is completed (specifically, food is cut in at least two pieces, glass is
filled at least one third full with soda) without error (i.e., without dropping objects, spilling, or sliding food off plate).

2. Ability to grip with prehensor: Utensil or object does not slip, slide, or become disengaged from the prehensor.

3. Ability to perform task in coordinated manner: Subject performs upper body movements in a smooth, coordinated manner without noticeable dysfluencies with the flow of the movement pattern and uses a minimum of awkward or unnatural body contortions in an apparent attempt to compensate for movements that cannot be achieved with the prostheses (i.e., forearm pronation-supination, wrist flexion-extension).

**Procedures**

The subjects had not used the Greifer prehensor or the Synergetic Prehensor before their participation in the study. Before testing, the subjects were trained with both the Greifer prehensor and the Synergetic Prehensor, concentrating on tasks to be performed in the test session. The subjects received at least 2 hr of training with each nonfamiliar prehensor before testing. Subjects then participated in a brief refresher session before testing. Because the goal of the study was to compare the prehensors, each subject was fully trained in the use of all 4 prehensors and was completely familiar with the tasks required in the tests. Each subject was tested using the Greifer prehensor, Synergetic Prehensor, the Electric Hand, and the body-powered split hook.

**Results**

A summary of the standardized measures is included in Table 2.

### Familiar Control Schemes Included

On the Nine Hole Peg Test, Subjects 1, 2, and 3 yielded the fastest performance with the Synergetic Prehensor. On the Box and Blocks Test, Subject 1 performed best on the Box and Blocks Test with the Greifer prehensor, Subject 2 with the body-powered split hook, and Subject 3 with the Synergetic Prehensor. On the Jebsen-Taylor Test, Subject 1 performed best with the Greifer prehensor, Subject 2 with the Synergetic Prehensor, and Subject 3 with the Greifer prehensor.

### Familiar Control Schemes Excluded

On the Nine Hole Peg Test, Subjects 1, 2, and 3 yielded the fastest performance with the Synergetic Prehensor. On the Box and Blocks Test, Subjects 1, 2 and 3 yielded the fastest performance with the Synergetic Prehensor. On the Jebsen-Taylor Test, Subjects 1 and 2 performed best with the Synergetic Prehensor; Subject 3 performed best with the Greifer prehensor.

### ADL Measures

A summary of the results for the ADL measures is listed in Table 3. The raters did not select a single consistent prehensor by using the qualitative criteria. Subjects 1 and 2, who lost their dominant hands, performed the three bimanual functional activities most effectively with the prehensor they were accustomed to using. Subject 3, who lost his nondominant hand, performed the pouring task and the holding task most effectively with the Synergetic Prehensor and cutting meat most effectively with the Electric Hand and body-powered split hook.

When the familiar control scheme was excluded, the Synergetic Prehensor was chosen as the most effective prehensor by the raters for all three bimanual activities, closely followed by the Electric Hand and body-powered split hook.

Each subject preferred a different prehensor. Subject 1 preferred the Electric Hand for cosmetic reasons. Subject 2 preferred the split hook because he was accustomed to using it as a meat cutter. Subject 3 requested a Greifer prehensor and Synergetic Prehensor as a result of his experience with the prehensors in this study.

### Table 2

<table>
<thead>
<tr>
<th>Measures</th>
<th>Subject 1</th>
<th></th>
<th>Subject 2</th>
<th></th>
<th>Subject 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B (S)</td>
<td>E (UA)</td>
<td>G (89)</td>
<td>S (69)</td>
<td>B (E)</td>
<td>G (127)</td>
</tr>
<tr>
<td>Nine Hole Peg</td>
<td>59</td>
<td>89</td>
<td>69</td>
<td>127</td>
<td>79</td>
<td>127</td>
</tr>
<tr>
<td>Box and Blocks</td>
<td>19</td>
<td>19</td>
<td>33</td>
<td>23</td>
<td>32</td>
<td>19</td>
</tr>
<tr>
<td>Jebsen-Taylor</td>
<td>161</td>
<td>121</td>
<td>81</td>
<td>125</td>
<td>127</td>
<td>177</td>
</tr>
<tr>
<td></td>
<td>125</td>
<td>127</td>
<td>107</td>
<td>125</td>
<td>102</td>
<td>125</td>
</tr>
</tbody>
</table>

Note: B = body-powered split hook, E = Electric Hand (Otto Bock System Electric Hand), G = Greifer prehensor (Otto Bock System Electric Greifer), S = Synergetic Prehensor (Hosmer NU-VA Synergetic Prehensor), UA = unable to prehend peg lying horizontally. Fastest performance is noted in **bold type** with familiar control schemes included and italicized type with familiar control schemes excluded. Familiar control schemes for Subject 1 = E and G, Subject 2 = B, and Subject 3 = B.

*Measurement = seconds.
*Measurement = blocks transferred in 1 min.
*Measurement = total number of seconds for the six subtests.
*Subject quit test after inserting 7 pegs.