Difficulty of Performing Activities of Daily Living with the Michelangelo Multigrip and Traditional Myoelectric Hands

Andreas Kannenberg, MD PhD
on behalf of the
Strategic Consortium for Upper Limb Prosthetic Technologies (SCULPT)
Introduction

Rejection rates are relatively high in upper limb prostheses*

- passive hands 53%
- body-powered hooks 50%
- myoelectric hands 39%

Main reasons for rejection of prosthetic hands:

- missing out on the "golden window"**
- poor dexterity
- glove durability
- lack of sensory feedback

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Drives of the Michelangelo® hand

The **thumb drive** enables the user to use opposition or lateral grip.

The **main drive** is responsible for grasping movements and grip force.

**Ring finger** and **little finger** are moved passively by the finger moving unit.
Michelangelo® multigrip hand: 3 modes and 7 hand positions
Methodology

Patient sample

16 unilateral transradial amputees using regular myoelectric prosthetic hands gave informed consent and participated in this study.

- average age $41 \pm 14$ years
- mean time since amputation: $12.8 \pm 16.1$ years
- all male
- amputation etiology: 6 congenital deformities, 8 trauma, 1 malignancy, 1 sepsis
- amputation side: 11 left hands, 5 right hands
- dominance of amputation side: 4 dominant hands (all right), 12 non-dominant hands
Study design

Patients filled out two self-reported questionnaires

- OPUS-UEFS
- PUFI

for their existing myoelectric hands

as well as after a mean use of the Michelangelo® multi-grip hand of 12.4 ± 7.3 weeks.
Outcome measures

**Basic challenge**

There is no one gold standard outcome measure identified that covered all related components [of outcome] and would work in all fields of application (i.e., research or patient care).

One recommendation of the ULPOM group was to build a toolkit of validated procedures for the entire development cycle [of a prosthesis] to be developed and promoted within the appropriate professions.


Outcome measures: OPUS-UEFS

Orthotics & Prosthetics User Survey – Upper Extremity Functional Status (OPUS-UEFS)

Patients rate the perceived difficulty to perform 23 activities of daily living (ADL):

- very easy 3 points
- easy 2 points
- difficult 1 point
- cannot perform activity 0 point


Outcome measures: PUFi

The Prosthetic Upper Extremity Functional Index (PUFI) is well validated for children of various age groups to measure the

- way of using the prosthesis
- perceived difficulty to perform activities with and without the prosthesis
- perceived usefulness of the prosthesis

with age specific activities but no PUFi questionnaire for adult prosthesis users exists.

An adult PUFi was created by using the 23 ADLs of the OPUS-UEFS with the scaling scheme of the PUFi.

Adult-PUFI: Way of using the prosthesis

*How do you usually do this activity?*

- both arms together with prosthetic hand used actively to grasp the (object)
- both arms together with the prosthesis used passively to position or stabilize (the object) on a surface or against (another object)
- with assistance of the residual limb
- non-prosthetic hand alone
- with some help from another person
- other way (please describe)

Adult-PUFI: Perceived difficulty and usefulness

**How well do you do this activity with / without the prosthesis?**

- with no difficulty
- with some difficulty
- with great difficulty
- with some help from another person
- cannot do it with/without the prosthesis

**How useful is the prosthesis for this activity?**

- very useful
- somewhat useful
- not useful

Previous hand prostheses

- Sensor Hand Speed: 10 patients
- VariPlus Speed: 3 patients
- DMC Plus: 1 patient
- Motion Control: 1 patient
- Greifer: 1 patient

One patient used both a Sensor Hand Speed and a Greifer.
Results:
Perceived ease of performing ADLs (OPUS-UEFS)

- All (23) activities: p=.03
- 19 activities: p=.07
- monomannual: p=.01

Results:
Perceived ease of performing ADLs (OPUS-UEFS)

- All (23) activities: +37%
- 19 activities: 54%
OPUS-UEFS difficulty rating per individual ADLs

➢ 5 ADLs were significantly easier to perform with Michelangelo®
  ▪ wash face  p=.04
  ▪ put on socks  p=.03
  ▪ tie shoe laces  p=.03
  ▪ cut meat with knife and fork  p=.03
  ▪ carry laundry basket  p=.01

➢ 16 ADLs were easier to perform with Michelangelo®, but differences did not reach statistical significance

➢ 2 ADLs were easier to perform with the previous hands, but differences did not reach statistical significance
OPUS-UEFS: Prosthesis use

Number of ADLs performed with the prosthesis

- Traditional myo: 9.5 ± 3.7
- Michelangelo: 11.1 ± 4.2

p = .04
PUFI – Way of using the prosthesis

- Prosthetic hand used actively to grasp
- Prosthetic hand used passively
- With assistance of the residual limb
- Non-prosthetic hand alone

p = .04
PUFI: Usefulness of the prosthesis

Average number of activities for which prosthesis is rated "very useful"

- Traditional myo: 6.4 ± 4.1
- Michelangelo: 9.1 ± 4.3

p = .01
Discussion

Thus far only case reports on the use of multigrip prosthetic hands have been published with mixed results.

This is the first bigger observational study to compare a multigrip with traditional single-grip myoelectric hands.
Discussion

When using the Michelangelo® multigrip hand individuals with a unilateral transradial amputation

- perceive it easier to perform ADLs
- use the prosthesis in more activities
- use the prosthesis more often to actively grasp objects
- perceive the prosthesis more useful

than when using traditional myoelectric hands.
Limitations and future research directions

Limitations

- no standardized follow-up period and occupational training ("real world scenario")
- use of self-reported outcome measures only
- OPUS-UEFS is still work in progress; adult PUFI not validated

Future research should

- use performance-based outcome measures
- study compensatory movements
- compare multigrip prosthetic hands
Conclusions

Multigrip myoelectric hands such as Michelangelo® are a promising technological progress towards improved prosthetic hand function.

Patients with a transradial amputation perceive multigrip hands more useful than traditional single-grip myoelectric hands.

The gap between prosthetic hands and a sound human hand is still huge with lots of room for further improvement.
Acknowledgements

Strategic Consortium for Upper Limb Prosthetic Technologies (SCULPT)

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Wolfgang Gröpel, CPO
Novavis, Germany
Biomechanical study of compensatory movements

- 8 patients with a unilateral transradial amputation
- previous hands: Myohand Variplus or DMC plus
- psychosocial assessments
- performance-based and self-reported functional outcomes
- motion capture at baseline and after 3 months of Michelangelo use
Psychosocial assessment

**Baseline Assessment**

- **Semi-structured Interview**
- **Self-report Questionnaires**
  - MSPSS - Multidimensional Scale of Perceived Social Support
  - CISS - Coping Inventory for Stressful Situations (CISS)
  - EPQR-SF - Eysenck Personality Questionnaire Revised-Short Form
  - HADS – Hospital Anxiety and Depression Scale
  - EQ-5D-3L – Euro QoL Questionnaire
  - ABIS - Amputee Body Image Scale
  - TAPES - Trinity Amputation and Prosthesis Experience Scales

**3-month follow-up**

- **Semi-Structured Interview (Short Form)**
- **Self-report Questionnaires**
  - HADS + EQ-5D-3L + ABIS + TAPES

**6-month follow-up**

- **Semi-Structured Interview (Short Form)**
- **Self-report Questionnaires**
  - HADS + EQ-5D-3L + ABIS + TAPES
Functional assessment – tests & scales

MMDT-P – Minnesota Manual Dexterity Test - Placing

BBT – Box & Block Test

SHAP – Southampton Assessment Procedure

DASH: Disability of the Arm, Shoulder and Hand (self-report)


OPUS – UEFS_{CFR}: Hand Comparison Questionnaire (self-report)
Biomechanical assessment – tasks

Shoulder & Elbow analysis

- execution of simple movements (upright posture)
  - Elbow flexion-extension
  - Shoulder flexion-extension
  - Shoulder abduction-adduction in scapular plane

Execution of standardized ADLs
(generally seated in reference posture)

- Disk task
- Plate task
- Jar task
- Carton pouring task (from SHAP protocol)
- Drinking task
- Tray task
Patients

- **8 patients recruited**
- **6/8 experienced a failure**
- **6 3-month follow-up**

<table>
<thead>
<tr>
<th>Patient Code</th>
<th>Age (years)</th>
<th>Amputation side</th>
<th>Dominant Hand</th>
<th>Time since amputation (years)</th>
<th>Aetiology</th>
<th>Employment</th>
<th>Marital status</th>
</tr>
</thead>
<tbody>
<tr>
<td>02 (MA)</td>
<td>42</td>
<td>Right</td>
<td>Right</td>
<td>4</td>
<td>Trauma</td>
<td>Unemployed</td>
<td>Live-in partner</td>
</tr>
<tr>
<td>03 (GI)</td>
<td>53</td>
<td>Right</td>
<td>Right</td>
<td>35</td>
<td>Trauma</td>
<td>Office Worker</td>
<td>Divorced</td>
</tr>
<tr>
<td>04 (SA)</td>
<td>35</td>
<td>Right</td>
<td>Right</td>
<td>10</td>
<td>Trauma</td>
<td>Unemployed</td>
<td>Unmarried</td>
</tr>
<tr>
<td>05 (DE)</td>
<td>65</td>
<td>Left</td>
<td>Right</td>
<td>48</td>
<td>Trauma</td>
<td>Retired</td>
<td>Married</td>
</tr>
<tr>
<td>06 (DI)</td>
<td>43</td>
<td>Left</td>
<td>Right</td>
<td>20</td>
<td>Trauma</td>
<td>Business man</td>
<td>Married</td>
</tr>
<tr>
<td>07 (BO)</td>
<td>51</td>
<td>Left</td>
<td>Right</td>
<td>8</td>
<td>Trauma</td>
<td>Office Worker</td>
<td>Married</td>
</tr>
<tr>
<td><strong>MEDIAN</strong></td>
<td><strong>47</strong></td>
<td>-</td>
<td>-</td>
<td><strong>15</strong></td>
<td>-</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>
### Prosthesis use

<table>
<thead>
<tr>
<th>Patient Code</th>
<th>Days since fitting Michelangelo</th>
<th>Days of use at 3-FU</th>
<th>Cycles/day</th>
<th>% lateral grip</th>
</tr>
</thead>
<tbody>
<tr>
<td>02 (MA)</td>
<td>97</td>
<td>97</td>
<td>208</td>
<td>77</td>
</tr>
<tr>
<td>03 (GI)</td>
<td>134</td>
<td>96</td>
<td>337</td>
<td>70</td>
</tr>
<tr>
<td>04 (SA)</td>
<td>157</td>
<td>101</td>
<td>2168</td>
<td>59</td>
</tr>
<tr>
<td>05 (DE)</td>
<td>101</td>
<td>101</td>
<td>371</td>
<td>86</td>
</tr>
<tr>
<td>06 (DI)</td>
<td>94</td>
<td>94</td>
<td>456</td>
<td>74</td>
</tr>
<tr>
<td>07 (BO)</td>
<td>158</td>
<td>101</td>
<td>291</td>
<td>27</td>
</tr>
<tr>
<td><strong>MEDIAN</strong></td>
<td><strong>117.5</strong></td>
<td><strong>99</strong></td>
<td><strong>354</strong></td>
<td><strong>72</strong></td>
</tr>
</tbody>
</table>
### Analysis of the interviews transcripts [9]

**Patients’ experiences with the new prosthesis**

<table>
<thead>
<tr>
<th>Recurrent Themes</th>
<th>Extracts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functionality in everyday life</td>
<td>“I can do so many things, with different grips”, “… common things that are very important to me”, “it helps me especially at work”, “it is more important the functionality than the aesthetics … This prosthesis is really beautiful but it have to work!”</td>
</tr>
<tr>
<td>Like a “real hand”:</td>
<td></td>
</tr>
<tr>
<td>- Natural postures and gestures</td>
<td>“it seems a human hand”</td>
</tr>
<tr>
<td></td>
<td>“I never block the wrist … In this way I can take natural postures … like that … look!”, “I looked at a photo few days ago and I said - Oh my god! It seems a real hand! - … I am really satisfied!”</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>- Social meanings of the prosthesis</td>
<td>“though it was not a problem for me, I noticed that people pay less attention to the prosthesis”, “people look at me like a normal person”, “it improved the relationships with others”, “now, sometimes, I shake hands with the prosthesis”</td>
</tr>
<tr>
<td>Notes</td>
<td>Dissatisfaction emerged for some aspects: dimension [05(DE), 07(BO)], noise[03(GI), 05(DE)].</td>
</tr>
</tbody>
</table>

[9] Smith et al. 1999, Sage Publ (i.e., Interpretative Phenomenological Analysis, ideographic approach).
Results – Functional – driving

5/6 patients reported improvement in driving with Michelangelo (improved self-confident)
## Results – Functional – scales

<table>
<thead>
<tr>
<th>Scales</th>
<th>Tri-digital Median (min-max)</th>
<th>Michelangelo Median (min-max)</th>
<th>Minimum Detectable Change (MDC)</th>
<th># Patients &gt; MDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>DASH</td>
<td>4.5 (1 – 17)</td>
<td>9.5 (0-26)</td>
<td>10.70(^{[10]})</td>
<td>0</td>
</tr>
<tr>
<td>OPUS - UEFS</td>
<td>41 (11 – 46)</td>
<td>40 (24-48)</td>
<td>12.07(^{[11]})</td>
<td>1 better 1 worse 5/6 more activities with prosthesis</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scales</th>
<th>Michelangelo vs Tri-digital Median (min-max)</th>
<th>Reference</th>
<th># Patients &gt; ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPUS – CFR</td>
<td>124 (122 – 165)</td>
<td>99 &lt; X &lt; 165 → Easier with Michelangelo</td>
<td>6/6 preferred Michelangelo</td>
</tr>
</tbody>
</table>

\(^{[10]}\) Finch et al. 2002, Ed. Lippincott Williams & Wilkins  
\(^{[11]}\) Resnik et al. 2012, JPO 24(2), 192-201
### Results – Functional – scales

<table>
<thead>
<tr>
<th>Tests</th>
<th>Sound side Median (min-max)</th>
<th>Tri-digital Median (min-max)</th>
<th>Michelangelo Median (min-max)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MINN (s)</td>
<td>70.5 (60-82)</td>
<td>162.5 (130-297)</td>
<td>138.5 (120-165)</td>
<td>0.031*</td>
</tr>
<tr>
<td>SHAP</td>
<td>98.0 (96–101)</td>
<td>74.5 (43-84)</td>
<td>83.0 (75-89)</td>
<td>0.031*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tests</th>
<th>Sound side Median (min-max)</th>
<th>Tri-digital Median (min-max)</th>
<th>Michelangelo Median (min-max)</th>
<th>MDC</th>
<th># Patients &gt; MDS</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Scales</th>
<th>Michelangelo after OT Median (min-max)</th>
<th>Michelangelo 3MFU Median (min-max)</th>
<th>Difference Median (min-max)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MINN-PGC[s]</td>
<td>315 (235-445)</td>
<td>273 (230-330)</td>
<td>-43 (-180 ÷ 24)</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Results: Video DMC plus hand

Courtesy: Andrea Cutt, PhD, Italian Workers’ Compensation INAIL, Budrio/Italy, publication accepted by JRRD
Results: Video Michelangelo

Courtesy: Andrea Cutt, PhD, Italian Workers’ Compensation INAIL, Budrio/Italy, publication accepted by JRRD
Kinematics (1)

![Graphs showing kinematics](image)

- Scapula - Thx PR-RE (°)
- Scapula ME-LA (°)
- Scapula A-P TILT (°)
- Humerus - Thx FL-EX (°)
- Humerus - Thx AB-AD (°)
- Humerus - Thx IN-EX (°)

conventional myo hand
Michelangelo
able-bodied subjects

Courtesy: Andrea Cutt, PhD, Italian Workers’ Compensation INAIL, Budrio/Italy, publication accepted by JRRD
Kinematics (2)

[Graphs showing data comparison of conventional myo hand, Michelangelo, and able-bodied subjects.]

Courtesy: Andrea Cutt, PhD, Italian Workers’ Compensation INAIL, Budrio/Italy, publication accepted by JRRD
Compensatory movements

- with respect to Tri-dig, Michelangelo leads to a normalization in single joint angle range of 83% on average
- with respect to Sound, Michelangelo still requires an increase of 38% on average
Conclusion

Psychosocial results

H1 – all patients already adapted and satisfied with the prosthesis: “successful” prosthesis user share similar psychological characteristics

H2 – natural gesture and postures improves social relationships and self-presentation

→ points of improvement: reliability, noise, weight, length

Functional results

H1 – self-report scales do not detect significant changes, but direct comparisons show ease of execution of ADLs with Michelangelo

H2 – improved manipulation (Minnesota, BBT, SHAP)

H3 – slight improvement of reliance (OPUS # activities)

Biomechanical advantages?

H1 – Michelangelo reduces compensatory movements for fine manipulation tasks. No (at present) noticeable improvements in drinking and pouring.

H1 – allows the correct execution of tasks

H2 – closes the gap with the sound side, but not completely
Thank you very much for your attention!

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