A major challenge in the development of terminal device (TD) and UE prosthetic devices is to add to the functional benefits to the wearer, without greatly increasing the weight, or complexity, or the cost of the prosthesis.

Using existing TD designs, the opportunity existed to increase the function by increasing the degree of freedom available at the wrist, in several ways. Since the existing hands and electric terminal devices (ETD) were both single degree-of-freedom TDs, improving the positionability of the TD can logically improve the gripping orientation and grip security.

Our goal was therefore, to improve positionability of TDs via improved wrist flexion/extension devices, and an improved wrist rotation device, which could be added in a modular fashion to the existing MC Hand, and ETD already developed and used extensively in the field.

Specifically, three wrist components have been developed to increase function of myoelectric TDs:

1. Flexion/Extension Wrist, with manual reposition to three or four positions integrated into both hand and electric hook.

![Figure 1 - Wrist flexion in a Hand TD (left) allows flexion to 30 degrees, and extension to 30 degrees. The button for the manual lock engage/disengage may be pushed or bumped on the side of the locking wrist. Wrist flexion in the Electric Terminal Device (ETD) allows a total of four locking positions, at 52 degrees and 30 degrees of flexion, neutral, and 30 degrees of extension.](image)

Evaluation Methods:
Evaluation of the benefits of the Flexion Wrist involved a questionnaire administered by telephone interview. The functional pros and cons were evaluated by rated versus the device used previously by the wearer, so a simple “A vs. B” type comparison could be obtained, with minimal variables. That is, variables are reduced, since the wearer and the prosthesis are nearly...
the same for the test device and the comparison device, except for the single component of the flexion wrist. 17 prosthesis wearers were surveyed who had been fitted with the Flexion Wrist in either a Hand or ETD for over two months previously. Some of the most significant ratings obtained are shown below:

RATING OF “USEFULNESS OF FLEXION” (n = 17)

![Bar chart showing the rating of usefulness of flexion](image)

Figure 2 – The 17 patients in the survey were asked to rate the usefulness of flexion in their test prosthesis, compared with their previous prosthesis. The majority (8/17) found the usefulness “better” or “much better” than the prostheses they had used previously, without flexion.

Result #2: DOES THE FLEXION WRIST ALLOW YOU TO:

USE THE PROSTHESIS IN A MORE NATURAL WAY

![Pie chart showing use in a more natural way](image)

USE THE PROSTHESIS FOR MORE ACTIVITIES

![Pie chart showing use for more activities](image)

Figure 3 – In another important result, the 17 wearers were asked to simply respond “yes” or “no” to the question, “Do you use your prosthesis in a more natural way?” (left pie chart), and “Do you use your prosthesis for more activities?” (right pie-chart).
2. Multi-Flex Wrist, adds comfort and versatility to the earlier Flexion/Extension joint, by implementing a spring-retumed mechanism to the neutral position, while still allowing the wearer to lock the wrist passively in 30 degrees of flexion and extension, as well as the neutral position. The goals of the Multi-Flex device were to reduce reaction forces in the socket, and maintain security of grip on objects that are moved throughout the work space gripped by the TD. The ability to manually lock in three positions is retained, in much the same fashion as with the Flexion/Extension wrist.

Figure 4 – MultiFlex wrist allows free motion up to 30 degrees of flexion in all directions. Springs return the wrist to the neutral position, and locking is optional at 30 degrees of flexion or extension, and at neutral position. The lock is activated by pushing the locking button.

Data collected for the Multi-Flex Wrist was similar to that collected from Flexion Wrist wearers. Two interesting preliminary results demonstrated that the goals of the development are being met, by showing that wearers can use the Multi-Flex wrist generally unlocked, and that the comfort is generally considered much better.

Figure 5- Preliminary results from wearers of the Multi-Flex wrist show that the percent of wearing time that the wrist is locked is quite low (left chart), indicating that the security of grip must be acceptable in most occasions, even with the flexible wrist. Comfort was also rated “better” (+1 rating), or “much better” (+2 rating), by 3 out of 4 wearers surveyed, indicating that reaction forces in the socket are reduced.
3. In-Hand electric wrist rotator.

Powered pronation/supination of the wrist has long been acknowledged as an important contribution to function of the electric TD especially. In earlier evaluation by the authors (Ref.1), the contribution to function has been documented, but the use of earlier electric rotation devices was nearly completely restricted to pre-positioning of the TD, with a much lesser number of tasks utilizing “active” rotation (functionally rotating the device in the TD, for instance, pouring from a bottle).

Also, earlier rotation devices increase the length of the electric prosthesis, so that anatomical-matching of the length of the prosthesis is not possible (earlier pro/supination devices required ~7.5 cm, in addition to the length of the TD).

Therefore it was felt that a shorter component, which could provide greater torque and speed to the wearer, would increase the functional capabilities of an electric TD.

The device which has been developed by Motion Control is a high-torque and high-speed rotator (3x greater than earlier devices) giving the wearer greater manipulation force in active rotation, and quicker pre-positioning. Since the rotator and hand are built into the same device, both distal to the quick-disconnect wrist, there is much less space occupied in the forearm.

Field trials of the InHand Wrist Rotator have begun, but sufficient data has not been collected to this date. However, the few wearers of the device have used it extensively and it appears that it will make a very positive contribution to function for Hand + Wrist electric TD wearers, as well as ETD + Wrist wearers (although).

**Figure 6** Electric Hand + Wrist length, compared with Hand alone (left). An example of higher torque of the InHand Wrist – a 1.0kg elbow prosthesis is rotated easily by a wearer, a difficult task with earlier components.

**CONCLUSION:**

Wrist function is clearly an important contributor to function of the Terminal Device, and thus the prosthesis. When even modest numbers of field trial wearers can be surveyed, quite specific pros and cons can be identified of new these new components.