EARLY CLINICAL RESULTS OF A NEW AESTHETIC HEAVY-DUTY ELECTRIC TERMINAL DEVICE

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ABSTRACT

Over the last decade, a heavy-duty Electric Terminal Device (ETD1) has been adopted widely by Upper Extremity (UE) amputees, featuring a water-resistant housing, combined with simple but functional hook fingers, motor-driven by a 2-speed transmission.

A new version was sought with goals to: 1) shorten the overall length 2) implement body-powered grip shapes to improve grip security (developed in an earlier project) [1], 3) improve aesthetics so that wearers could use a hook-style TD in a wider range of workplaces and social situations.

A new design, ETD2, using metal and plastic structure, achieves the goal of shorter length, and a smoother aesthetic, while retaining high durability, water and dirt resistance, low weight, quick response, and high pinch force, as in the legacy device. The grip surfaces are replaceable in the field, an important convenience.

The on-board electronic controller allows interchange-ability with almost all other terminal devices, Bluetooth® wireless communication, and Force Limiting Auto Grasp (FLAG) [2].

The field trial subjects (n=8) were unilateral UE prosthesis wearers. Results indicate equivalent function to the ETD1 in most areas, with interesting divergence of opinion in areas. All field trial subjects signed an Informed Consent form approved by Motion Control's IRB, Ethical & Independent Review.

The usage period (from 2-18 mo.) yielded a wealth of information, guiding the design process. Summarizing the comparisons to ETD1:

- Cylindrical and flat gripping surfaces were uniformly rated superior.
- Rubber areas on lateral fingertip surfaces aided in pushing down and holding firmly, etc., for most wearers.
- Field-replaceable gripping surfaces promise to reduce the current area of highest maintenance.
- Speed and responsiveness for many was quicker than ETD1.
- Shorter overall length was valued, and produced lighter perceived weight for some.
- The aesthetics of ETD2 are appreciated, but not consistently by all. Color choices strongly favored black.
- The wider hook fingers of ETD2 meant a loss of visibility for some (but not all).

Generalizations

- UE prosthetic wearers as a group are enthusiastic to have more choices – as long as they do not represent a major compromise in function.
- The varieties of TD functions are different for each wearer – ensuring that opinions are very seldom consistent across all wearers.

BACKGROUND & AIMS

Over the last decade, the first generation of the heavy-duty Electric Terminal Device (ETD1) has been successfully used by thousands of UE amputees. Its success in large part may be attributed to the combination of functional hooks with a light weight motor-driven 2-speed transmission in a water-resistant housing.

Figure 1: the ETD1, using 50's era APRL hook fingers, to create a combination of simple body-powered hook shapes, with a modern motor drive in a water-resistant package.

The slender hook design provides users with the ability to reach tight places and provides high manipulation as well as visibility of objects grasped. The 2-speed transmission provides a fast closing speed and high pinch force. Water resistant housings made the ETD1 highly functional working in wet and dirty environments, e.g., the kitchen, out-of-doors occupations from auto mechanic to farming, in addition to familiar Activities of Daily Living (ADLs).

A new version was sought, with goals to 1) shorten the overall length (for equivalent length between interchangeable hand and work TDs), 2) improve grip security with wider gripping surfaces (using earlier work with body-powered TD designs), and add high-friction coatings on outside surfaces

for passive functions, and, 3) allow field maintenance of the rubber gripping surfaces so highly used devices did not require frequent returns, and 4) improve aesthetics so that wearers from a broader demographic could use a heavy-duty TD in a wider range of work and social situations. All this, and importantly, retain all the functional aspects of the ETD1.

METHODS

The development process evolved a new device, the ETD2, which uses advanced integrated metal and plastic manufacturing methods contributing to an integrated aesthetic, with a strong structural core, of aluminium or optionally, steel.

The electronic features maintained from the ETD1 were:

- "Plug and play" compatibility for interchangeability with almost all other terminal devices,
- Bluetooth® wireless communication using Apple® handheld devices with an iOS operating system
- AutoCal, a built-in feature within the on-board microprocessor
- Force Limiting Auto Grasp (FLAG), an electronic method enabling the wearer to limit pinch force- which requires an internally mounted, sensitive force sensor, which at the same time is very rugged.
- A new method to allow convenient field replacement of the Gripping Pads (rubber surfaces) has been developed.
- A new splash resistant cover has been designed for the ETD2. This cover is easier to don and doff and is more aesthetic than the current system.

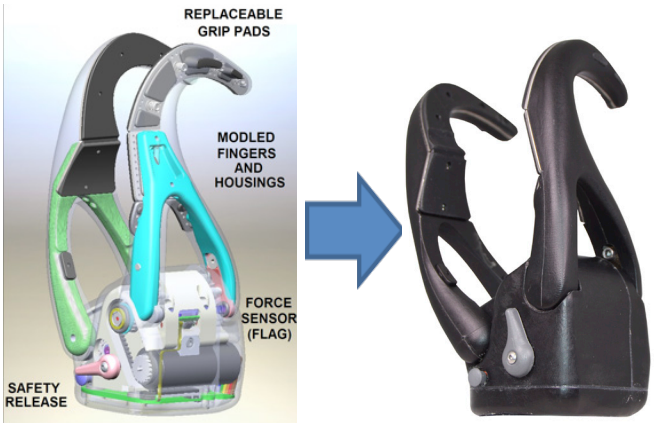


Figure 2 – The ETD2 has transitioned from the ETD1 to a shorter length, with internal structural inserts, and integrated overmolded tough exterior. Gripping Pads are replaceable in the field, for maintenance convenience.

RESULTS

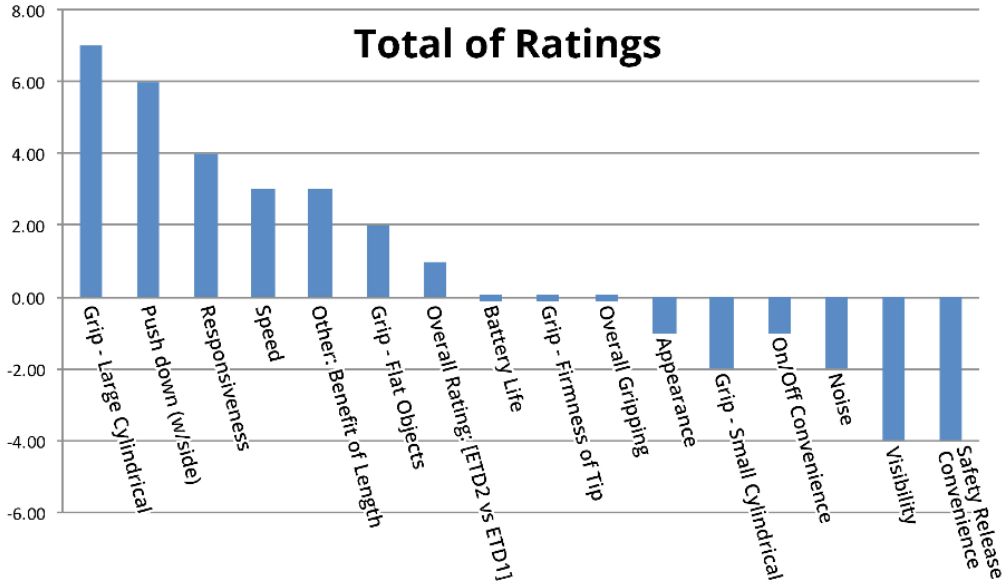
The main targets have been achieved in the ETD2 design (Figure 2). Compared with ETD1, overall length is 30 mm shorter, weight is equivalent, and strength and speed have been maintained, as has water and dirt resistance. There are two options of hook structural metal, those with lightweight aluminium inserts and those with heavy duty steel inserts.

The electronic features found in the ETD are also available in the ETD2. The FLAG feature was successfully integrated into the design.

Field Trial Results

The initial field trial (n=8) has been surveyed to obtain device feedback (Table 1).

Table 1: Summation of Ratings from field trial wearers of ETD2 (n=8). Wearers rate each feature between -2 and +2



For a quick comparison, the survey ratings are summed in Table 1, but the individual ratings were realistically evaluated for each field trial subject. For example, some subjects found the shorter length quite significant, while others did not particularly care about the length. This does not mean the shorter length was irrelevant – obviously, the importance is an individual difference. To the design team, this feature was worth the effort, especially since the shorter length was never a negative feature.

The survey results indicate improvements in some areas over the ETD1 (see Table 1). Security in gripping with the large cylindrical grip was generally highly rated. Also, greater convenience in passively pushing with outside surfaces ("Push Down w/Side"), the speed and responsiveness, flat gripping surfaces, and appreciation of shorter length all were rated positively overall. Interestingly, some subjects noted that the reduced length produces a slightly lighter perceived weight. Summation of the Overall Rating was positive for ETD2 overall (all in comparison to ETD1).

Anecdotally, from the prosthetists whose clients were in the field trials, the field-replaceable gripping surfaces generated positive feedback as well.

The survey also indicated that the visibility, noise, and small cylindrical grip ratings of the ETD2 sum slightly lower than the ETD1. Interestingly, the appearance rankings summed slightly lower than the ETD1, but again there was great individual variation, since some subjects prefer the slenderness of the ETD, despite the increased length, over the more bulky (but shorter) shape of the ETD2. Beauty, as always, is in the eye of the beholder.

Device color is another aesthetic factor, noted anecdotally. Initial field trials units were grey. However, most field trial subjects desired a different color, predominantly black. A variety of colors and/or custom coatings may be offered for the ETD2 product, when released.

CONCLUSION

ETD2 retains many of the features of the ETD1, such as rugged function, high speed and pinch force, and integration of the FLAG feature, and improves large diameter gripping, and flat grips for most wearers. In summation, ETD2 is rated slightly higher overall than the ETD1. However, hook object visibility and small diameter gripping of the ETD2 were not as functional for a few wearers.

The aesthetics of the ETD2 device are improved for some, but others find the bulky base less desirable than the slenderness of the ETD. In balance, field trials confirm the benefits of lower overall ETD2 length, and strength achieved through advanced manufacturing processes.

REFERENCES

[1] H. Sears, "Evaluation and development of a hook type terminal device," *PhD Dissertation,* University of Utah, 1983.

[2] E. Iversen, H. Sears, "Force Limiting Auto Grasp (FLAG)," *AAOP Annual Assembly* presentation, 2015.