InMotion Article:

Advances in Arm Prosthetics by Harold H. Sears, Ph.D.

A recent survey of prosthetics practice in the U.S. revealed that upper-limb prosthetics represents a mere 5% of the work performed by the typical U.S. prosthetist. Knowing that research efforts (and dollars) will tend to be spent in a similar proportion, arm amputees might well be discouraged that their needs could be overlooked in favor of the needs of larger disabled populations. Especially when we consider that the loss of an arm to these amputees is no less traumatic, and their rehabilitation no less important, than the lower limb amputee's.

Their small population notwithstanding, this is a very exciting period for arm amputees hoping for improvements in their prostheses. Technologies developed for the electronics and communications industries (batteries, miniature electronics, etc.) are allowing many new devices for both adult and child upper extremity amputees. New materials (composite plastics, silicones, etc.) are allowing lighter weight designs and more natural-looking covers for modern arm prostheses.

Media attention is drawn to "high-tech" devices like myoelectric arms, but progress in body-powered developments continues also. There have been some significant new products introduced lately, and the future will see more advancement in body-powered devices, offering benefits of lower cost and simplicity.

In this article, we will show some of the most recent developments, and try to point out the benefits that exist in these new technologies for consumers.

New electronic components:

The trend is very clear in new electric hands - the microprocessor is here to stay! The latest controllers for electric hands from Motion Control, Otto Bock, and Liberty Technology (the three main players) all utilize small micro computers, and they have more automatic functions than ever before. Their size is also smaller than ever, and they consume less power , all big pluses for the electric arm wearer.

Proportional control is now accepted as the preferred method of control of myoelectric hands, because of the improved precision it affords the electric hand wearer. ["Proportional" means that the hand power is in proportion to the size of the muscle contraction]. All the new microprocessor controllers provide proportional control. Formerly requiring a sacrifice in component space, the new microcomputers simply implement proportional control in their software, all within the small space of the microprocessor.

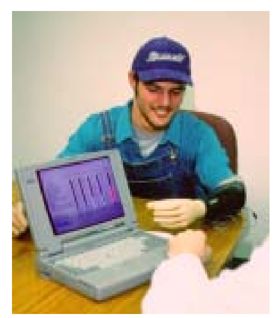

Figure 1- The new ProControl 2 from Motion Control - microcomputer for electric hand and wrist control. The patented AutoCal(r) feature automatically adjusts to the strength of the wearer's signals during the first few seconds after it is turned on. When muscles get tired at the end of the day, the wearer can adjust for the change in muscle strength. (Photo courtesy of Motion Control, Inc.)

Hands and Hooks ("Terminal devices" in the prosthetics vernacular) have also evolved greatly. A much wider variety in shapes and sizes is available. For adults, in addition to the OttoBock hands, the Ultralite Centri Hand is available at one-third less weight than the OttoBock version. Hand weight is especially important because it hangs at the end of the arm prosthesis. The lighter hand, although reducing the weight at the end of the forearm provides far less pinch force. Work-type devices like the Otto Bock Greifer and Hosmer Synergetic Prehensor can be interchanged with the hand for rugged environments, or where the tool-like gripping shapes better suit the task.

Children's electric hands have proliferated widely, and are used quite commonly in most clinics, although the body-powered hooks will always have a place for kids' rugged activities. The Flexi-Wrist (by Liberty Technology) allows a hand to bend at the wrist, which is useful when grasping a handle bar on a tricycle or other play activities.

Figure 2 Children's' electric hands now feature several control modes, to suit the age and muscular abilities of the patient, and more convenient wrists, which bend to grasp a device more conveniently. (Photo courtesy Liberty Technology).

In combination with the electric terminal devices, electric wrist rotation is now used much more commonly, and much more effectively, with the new controllers allowing easy control of both hand and wrist. The Utah ProControl introduced cocontraction switching, which allows the wearer to turn on the electric wrist with a quick "snap" of the two control muscles. Now utilized by other systems also, cocontraction requires some training for the new wearer, but has proven to be the most convenient method for wrist control, and has led to much wider usage. The benefit to the wearer is the freedom to reposition the hand without the trouble of reaching over with the sound hand (for unilateral amputees) or awkward knee manipulation (by bilateral amputees). The result is a much more "natural" movement for the wearer.

Progress in these technologies, as well as the fitting techniques of prosthetists have changed the traditional attitudes toward electric hands. Only a decade ago, electric hands were considered a very specialized prosthesis, only to be prescribed for the rare patient. Now, in the up-to-date clinics serving arm amputees in the U.S. and Europe, the majority of arm prostheses utilize electric hands.

In another relevant trend, a new breed of prosthetic specialists has emerged, who fit upper limb prostheses predominately. These new "Upper Limb Specialists" usually travel to the patient's location, allowing patients anywhere in the country to receive the highest level of prosthetic technology, fitted by an experienced practitioner. The large prosthetic "chains" have such specialists, but smaller independent prosthetic laboratories can contract with either a manufacturer's specialist, or a free-lance specialist if their own experience is lacking. (Insert Fig 3)

Figure 3 The electric hand and the Synergetic Prehensor may be used together effectively, as in this example, the hook providing better purchase

on the small cap, while the hand grasps the larger bottle more firmly. No one terminal device meets every need yet, so they are often interchanged using a quick-disconnect wrist system. For bilateral amputees especially, the electric wrist allows much easier positioning of the hand, although the force generated by the electric wrist is not enough to actually twist off the bottle cap. (photo courtesy of Motion Control, Inc.)

Figure 4 The Otto Bock SensorHand. The hand can be set to automatically increase the grip force when special shear sensors in the finger tips detect an object slipping from the fingers. (Photo courtesy of Otto Bock Orthopedic.)

Other new electric prostheses include the Utah Arm 2 (U2) by Motion Control, which reworks the sophisticated prosthesis with new sturdier circuit technology, stronger plastics for more rugged use, and new nickle-metal-hydride batteries for faster charging and longer wear. New technologies like the U2 offer consumers dependability and high performance, with a very low effort to operate compared to body-powered arms.

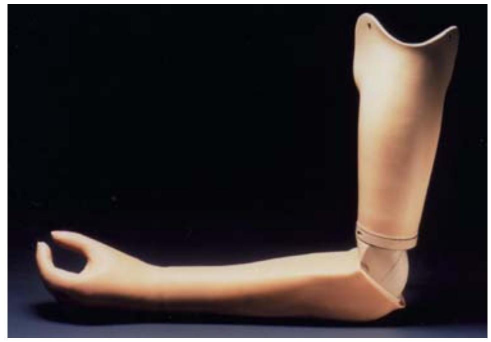

Fig 5- The Utah Arm 2. The most sophisticated of the new generation of electric prostheses, the new U2 features much sturdier and simplier electronics, and high-strength plastics. The new battery pack can last wearers several days, and recharge in 2 1/2 hours. (Photo courtesy of Motion Control, Inc.)

Body-Powered Developments and Cosmetic Covers

As mentioned previously, progress is being made in body-powered prosthetics. Though its progress is not celebrated as much as the high-tech electric arms, advances in this technology have the potential to reach many more amputees worldwide. The lightweight Advantage Arm by Sarcos, Inc., pictured in Figure 5 below, features internal cables, so the cables go directly from the harness into the top of the elbow unit. Flexible polymer cables are utilized which pull much more smoothly than steel cables. Then, a mechanism inside the elbow allows “cable recovery”, that is, after locking the elbow (with a second cable) the wearer relaxes the pull on the elbow cable, then pulls again to open the hook or hand terminal device.

Figure 6The lightweight Advantage Arm, featuring internal control cables, and cable recovery. (Photo courtesy Sarcos, Inc.)

Figure 7 The Friction-Free cable system by Rimjet, Inc., for body-powered elbow and hook systems. The cables are used without the heavier housings, and routed directly to the hooks, thus reducing the friction. The wearer also has control over humeral rotation (bringing the forearm into the body and out).
(Photo courtesy Rimjet, Inc.)

Another new mechanical elbow system from Otto Bock, the Automatic Forearm Balance (AFB), features an internal mechanism which provides a spring-assist to lifting the elbow. The wearer uses a "ballistic" motion to initiate lifting the elbow, i.e., from an extended position (hanging down) the wearer will swing the elbow forward, at which point the "forearm balance" kicks in and raises the elbow to a level position. One version of the AFB, called the Ergo Elbow, is designed to be used with the electric hand, commonly called a "hybrid" prosthesis.

Hybrid systems, i.e., combining mechanical elbow with electric hand, might offer lower weight, and the independence of elbow and hand function, i.e., both elbow and hand could theoretically be operated at the same time. However, good shoulder motion is required, and some training is usually required to learn to separate the control for the elbow from the control signals for the hand and wrist.

Figure 8 Otto Bock Ergo Elbow, designed to be combined with an electric hand, so no wires run outside the elbow.

Silicone Hand Covers

Silicone hand covers are now much higher in quality than previously available, and importantly, are now strong enough to be used with electric hands. Prior to just a few years ago, the natural-looking silicone covers were not durable enough to be used with electric hands, which could pinch through the glove with their high force. Now, several manufacturers make high strength silicones for the more functional electric hands, providing the best combination of high grip strength with near-natural appearance.

Figure 9 Silicone custom covers are much closer matched to the wearer's natural skin tone, and have the added advantage of resisting stains. Now strong enough to be used with electric hands, silicone covers are used much more widely and make the prosthesis practically unnoticeable.

Fitting improvements for high-level shoulder amputees

With the improvements in electric elbows, hands, wrists, etc., it has become possible to provide more function to the most-challenged of the arm amputees, those amputated at the shoulder level. Prosthetists are learning new ways to fit these difficult cases also, using new easily-formed yet strong plastic materials, which make new, innovative designs possible.

A new shoulder component, the MICA/Liberty locking shoulder joint also allows the wearer to securely lock the shoulder from moving in the front-to-back direction, but can then be unlocked with a lever (pushed with other hand, or chin) to freely move the arm to other positions, or for dressing more easily. Shoulder amputees are finding more success now with electric components, since better prosthetic techniques hold the prosthesis more securely on their body.

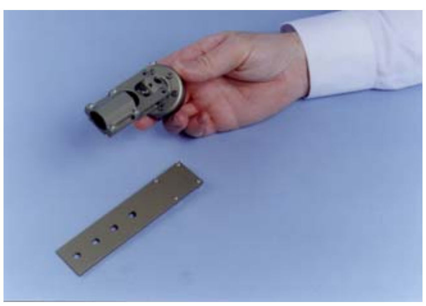

Figure 10 A moveable shoulder joint makes repositioning the prosthesis easier, while the locking function holds the arm firmly for holding an object securely.

Figure 11*New techniques for fitting shoulder amputees, combined with more comfortable materials (ProFlex with Silicone pictured, from Fillauer, Inc.) allow much more successful suspension to shoulder disarticulation amputees.* (Photo courtesy Advanced Arm Dynamics)

Summary

Arm amputees, who struggle to balance the needs of function, comfort, appearance, and cost of their prostheses, represent a great challenge to the manufacturers and prosthetists seeking to satisfy those needs. The fact that arm amputees represent a small fraction of the total prosthetic market further discourages advances for several reasons. Besides the obvious economic problem, there are also the difficulties of educating the decision-makers about benefits of new technologies, as well as prosthetists who need to learn and apply the new technology into a practical limb for the amputee.

However, two trends are working to the advantage of arm amputees:

1. New technologies developed for other industries allow new designs to improve the design and function of arm prostheses.
2. The trend toward specialization of prosthetic practice results in an elite group of arm specialists, prosthetists whose motto is “have tools -will travel”. Some are sponsored by manufacturers, some work for the major prosthetic service companies, and some are notable free-lance independents. They provide the link needed to disseminate modern fitting techniques, and the knowledge of the full range of electric and body-powered arm components.

Resources cited in the article, and others:

Motion Control
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