The Hinnant Prosthetics Quarterly

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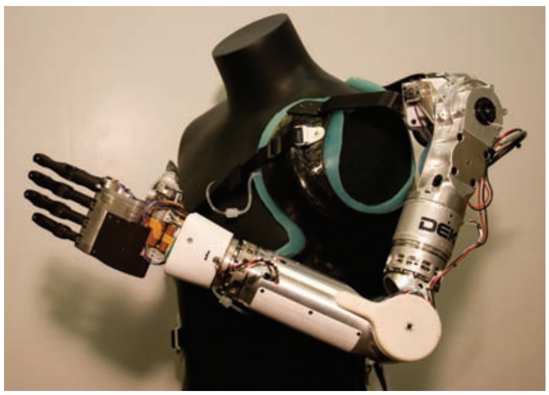
'Bionic Man' Reality Now at Hand

Hard to believe, but it was fully 38 years ago that bionic man Steve Austin made his first appearance in American living rooms in the popular The Six Million Dollar Man TV series and quickly became a pop culture icon. The premise that bionic components could replace disabled human limbs was pure science fiction at the time, but not anymore: An 'out there" story line is fast becoming reality.



DEKA "Luke" arm

Courtesy DEKA Research and Development Corp.

Credit the Defense Advanced Research Projects Agency's (DARPA) *Revolutionizing Prosthetics* program for much of this progress. Determined to provide a better prosthetic solution for military upper-extremity (U-E) amputees injured in Iraq and Afghanistan, DARPA in 2006 commissioned two distinct programs to create a prosthetic limb that would allow motivated U-E amputee soldiers to return to active duty if they so choose. That outcome would require a quantum leap beyond existing technology, which had lagged recent developments in lower-limb prosthetics.

What's New

Specifically, DARPA challenged innovators to "create a fully functional (motor and sensory) upper limb that responds to direct neural control." Among the limb's attributes would be a five-fingered hand with independent powered articulation for each digit, a powered elbow capable of lifting a significant weight, a powered movable wrist, and a shoulder joint. In other words the prosthesis would be capable of providing meaningful function for even a shoulder disarticulation amputee.

Courtesy DEKA Research and Development Corp.

The "Luke" Arm

When noted inventor (e.g. the Segway) Dean Kamen, president of DEKA Research and Development Corporation, was first presented this set of expectations, he responded, "You're nuts." He then set about to prove himself wrong, and in two years his team of experts produced the "Luke" arm, named after Luke Skywalker's sophisticated U-E prosthesis in the Star Wars movie series.

The Luke arm is modular (and therefore customizable to each amputee's needs), lightweight at roughly 8 pounds, the size of a typical female arm, and capable of 14 degrees of freedom, far more than any previous arm prosthesis. It also provides sensory feedback through small motors that produce vibration proportional to grip force. DEKA "test pilots," who have logged more than 3000 hours with Luke prototypes, are capable of picking up a grape or a raisin and gently placing it in their mouth.

DEKA was so successful with the Luke arm that the initial DARPA two-year funding window was extended to carry the research into clinical studies. The company hopes to move the system into commercial production soon.

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Hinnant Prosthetics Quarterly is a professional newsletter published since 1998 by Hinnant Artificial Limb Co. to keep physicians, therapists and other rehabilitation professionals abreast of the latest trends and technology in prosthetics.

Hinnant has been serving the needs of amputees and patients with congenital limb deficiencies for more than 79 years. We specialize in applying the latest proven technology commensurate with each patient's capabilities, lifestyle and personal desires.

We hope you find our newsletter to be interesting and professionally relevant and encourage your comments, questions and referrals. We also encourage you to visit our website at

www.hinnantprosthetics.com

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Restoring Upper-Limb Function—Great Challenges, Greater Rewards


Courtesy Otto Bock Health Care

Restoring manipulation and grasping functions lost to upper-limb amputation (or creating those abilities where none previously existed in instances of congenital defect) is regarded as one of the most fascinating and challenging aspects of rehabilitative medicine.

Every patient has distinct capabilities, needs and desires and therefore requires a unique, highly customized prosthetic system. Creating a new prosthesis requires consideration of many factors, including the type and construction of the socket, method of suspension, control mechanism, terminal (hand-substitute) device, and cosmetic finishing. The process is as much art as science.


Courtesy Motion Control Inc.

Patients referred to our practice for evaluation, prosthesis design, component selection, fabrication, fitting and follow-up go through a detailed process designed to provide the most functional and practical prosthesis for their individual situation, needs and desires. The degree of difficulty is usually high, but the rewards of a successful outcome are far greater.

Management

Experience has shown that the longer an upper-extremity amputee has to become accustomed to the idea of being one-handed, the less his/her motivation to put forth the effort to learn to use a functional prosthesis. Therefore, early fitting is generally recommended, other factors permitting. A preparatory system provided soon after surgery encourages the new amputee to develop a positive outlook before despair or resignation can set in.

Prosthetics Today

Ideally, the new amputee can be managed by a rehabilitation team consisting of the amputating surgeon or alternatively a physiatrist as team leader; certified prosthetist for component selection, fabrication and fitting; physical therapist for residual limb care; occupational therapist for prosthetic training; other professionals as needed, and the patient's family. Of course, the most important member of the team is the patient.

Body-Powered Components—Conventional or body-powered systems use movement of the residual limb and shoulders to power a terminal device, prosthetic joint or locking mechanism. The force and motion necessary for movement are delivered by a cable and harness, which crosses the chest or shoulders. Each level of limb absence presents different prosthetic challenges. In most cases the higher the level, the greater the challenge.

Advantages of body-powered prostheses are their relatively light weight, lower cost and high reliability. Disadvantages include the sometimes-exaggerated movements and high energy needed to operate the system. Also, the harness system may constrict movement of the affected side or the side opposite the amputation.

Externally Powered Components—Prostheses whose function is enabled by an external power source, typically a battery, are most often controlled by electromyographic signals generated by muscle contraction in the residual limb and sensed by electrodes in the socket. An alternate method of actuating externally powered components involves one or more touch pads strategically built into the socket for actuation by residual limb musculature.


Courtesy Otto Bock Health Care

Advantages of myoelectrically controlled systems include more natural function, which does not require a cable or gross body action to generate movement, and more natural appearance, making them particularly popular among women amputees. Drawbacks include higher cost and sometimes the need for more complicated maintenance or adjustments.

Socket Design

The interface between residual limb and the prosthesis is vitally important to ensure patient acceptance of a particular system. Contemporary socket design incorporates flexible and lightweight materials, which provide secure skin contact while preserving sufficient protection for soft tissues.

The challenge with body-powered system sockets and their associated harness and cables is to sufficiently convey the physical movements needed to power the prosthesis. For externally powered systems the task is to secure electrodes against the skin covering muscle areas to convey signals and allow muscle contraction at the same time.


Courtesy Hosmer Dorrance Corp.

Increasingly common today are self-suspending sockets with roll-on liners made of silicone or similar material. These liners provide the high levels of traction necessary to increase suspension strength while maintaining secure skin contact.

Wrist and Elbows Joints

Prosthetic wrist and elbow units allow amputees to adjust a terminal device for optimal functioning; both manual and myoelectric joints are available.

The simplest wrists are friction units that maintain the terminal device in position under load while preventing undesired rotation; however, the amputee can still rotate the hand or hook component manually. Quick-release wrist units are useful for amputees who require frequent changes of tools to perform work or hobby activities.

Depending on the level of amputation, an elbow component may be necessary even when the elbow joint remains intact. Patients with high forearm amputation may not have the residual strength to perform the movements necessary to support a terminal device. For that reason, body-powered systems incorporate various types of elbow hinges to help support the prosthetic device and allow for the motion necessary to power it.

Electric-powered elbows include a friction or alternative turning mechanism to permit rotation, as well as a locking feature to assist in positioning the terminal device. The ability to lift objects of some weight is critical, thus elbow component design is focused on providing reasonable lift capacity for functional use.

Shoulder-Level Prostheses

Because considerable strength is required for operation of a body-powered prosthetic system for amputations at the shoulder level, an electric powered system or a passive prosthesis is often advisable. Myoelectric systems have somewhat limited application at this level because the possible sites for electrode placement may be compromised; therefore, after careful review of prosthetic options with their therapeutic team, high-level amputees may choose to wear a passive prosthesis, which serves primarily to provide a more natural appearance.

Body-powered systems at this level, for patients who have the strength and residual function to power them, employ a harness and cable system with elbow, wrist and generally a hook-type terminal device. In addition, hybrid systems can be designed, incorporating electrically powered terminal devices and/or elbow joints.

Terminal Devices

Regardless of the type and mechanism of an upper limb prosthetic system, most are designed to replace the intricate manipulation and grasping functions of the normal hand. A hand substitute or terminal device (hands, hooks and work or recreational tools) is adapted to the prosthetic system as needed by the patient.

Passive Devices—Passive, lifelike hands are appropriate for some patients. Some have bendable or spring-loaded fingers, allowing patients the ability to grip objects. Others are specially fitted with a wide array of options to allow for the performance of household chores, gardening, sports or manual work.

Active Prehensile Devices—Active components, incorporating the ability to voluntarily open or close a hook by means of a cable, deliver a much higher level of function than more passive devices. Voluntary opening and closing hands provide a more acceptable cosmetic solution for some patients, while affording a mild-to-moderate degree of grip and movement.


Electric Terminal Device.
Courtesy Motion Control Inc.

Externally Powered Hands and Prehensors—Fulfilling the need for ever more precision in replacing the manipulative power of the natural hand, researchers have developed a wide range of electric hands, hooks and grippers (or greifers) to enhance grip and functional capabilities.

Cosmetic gloves and sleeves are available with some hands to give a more natural appearance for patients who express that preference. The use of silicone-based gloves and sleeves has made them more lightweight and thus more acceptable for patients of all ages.

The march of technology continues to improve prospects and outcomes for upper-limb amputees. We welcome your inquiries about possibilities for your patients.

Will Amputees Use Their Prosthesis?


Courtesy Fillauer LLC

Observations over the years have revealed adult amputees' acceptance of upper-limb prostheses to be relatively low. On the other hand, practitioners have noted that children fitted with a prosthesis at an early age exhibit great potential for acceptance and success.

Optimal acceptance by adults seems to occur when the initial fittings are performed in the first week to 30 days after amputation by a specialized rehabilitation team. Adults appear to respond best to a comprehensive program wherein they are thoroughly introduced to the prosthetic options with the ability to touch and feel the devices and understand their capabilities.

Therapists on the team are instrumental in evaluating how the patient works, uses his or her hands and arms, learns, and applies new knowledge. When these findings are integrated into an overall therapeutic plan, adult upper-limb amputees can claim a stronger ownership of their prosthetic system and its use.

For the best prosthetic outcome, patients should undergo casting and test socket fittings as soon as feasible after their full evaluation and receive and begin training in their prosthesis shortly thereafter with regular follow-up and adjustments along the way.

Note to Our Readers

Mention of specific products in our newsletter neither constitutes endorsement nor implies that we will recommend selection of those particular products for use with any particular patient or application. We offer this information to enhance professional and individual understanding of the orthotic and prosthetic disciplines and the experience and capabilities of our practice. We gratefully acknowledge the assistance of the following resources used in compiling this issue:

Applied Physics Laboratory • DEKA • Fillauer LLC
Hosmer Dorrance Corp. • Motion Control Inc.
Otto Bock Health Care • RSL Sleeper • Touch Bionics

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Amputees to Be Well 'Armed' in the Future

(Continued from page 1)

Modular Prosthetic Limb

Meanwhile the Applied Physics Laboratory at Johns Hopkins University has been developing its Modular Prosthetic Limb (MPL) under a four-year DARPA commission with even more ambitious goals.

The APL multinational team has produced an MPL prototype capable of 25 degrees of freedom from fingertips through shoulder, including independent movement of all five fingers. Building on that progress, the team is now working on more advanced control and sensory feedback mechanisms, which will give users a sense of touch, temperature, pressure, and vibration, as well as a sense of where the limb is in space.

Modular Prosthetic Limb
Courtesy Applied Physics Laboratory

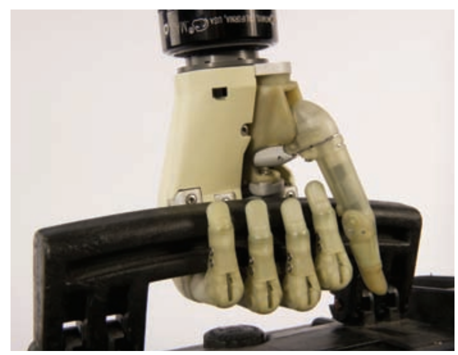
The MPL project also received additional DARPA funding to carry it into human testing. The first person to evaluate the system is, somewhat surprisingly, not an amputee but a quadiplegic patient with a high cervical spinal cord injury, suggesting the wide spectrum of disability for which the technology could be applicable.

Currently under development is full neural control of the MPL, using small wireless devices that can be surgically implanted (or injected) to allow access to intramuscular signals. In the near future researchers expect brain activity will fully control the MPL, just as it does a natural arm.

While these bionic arms currently reside solely in the testing lab, it won't be long before they are fit on war casualties and ultimately become commercially available to the general public. Of course, funding for these sophisticated systems will likely be problematic for some time, but the important thing is that this new technology will eventually raise the performance bar for all U-E prosthesis-wearers.

Advanced Myo Hands Available Now

In the meantime, some exciting advances in upper-limb componentry are available to patients right now. Probably the most exciting U-E innovation of the 21st century now in commercial production is a new generation of myoelectric hands featuring multi-articulating digits. Early to market was the iLIMB™ Hand, which has now been joined by the *bebionic* hand.



iLIMB Hand
Courtesy Touch Bionics

The *bebionic* features individual motors for each digit along with onboard microprocessors that keep track of each finger for maintaining accurate grip sequences. Should a gripped item begin to slip, the processors will detect the movement and tighten the grip accordingly.

Bebionic sensors also detect the position of the thumb, which the user can manually place in an opposed or non-opposed position — opposed for more powerful, clenched gripping, non-opposed for activities such as pointing or typing. The *bebionic* hand is capable of 14 different grip patterns.

Bebionic hand
Courtesy RSL Sleeper

The *bebionic* electric wrist, offers 135 degrees of rotation and 35 degrees of flexion and extension, significantly reducing the unnatural movements users would otherwise need to align the hand for different tasks.

The optional high-definition *bebionic* silicone glove, available in male or female versions and 19 colors with customized silicone nails, provides a good cosmetic result without compromizing hand function.