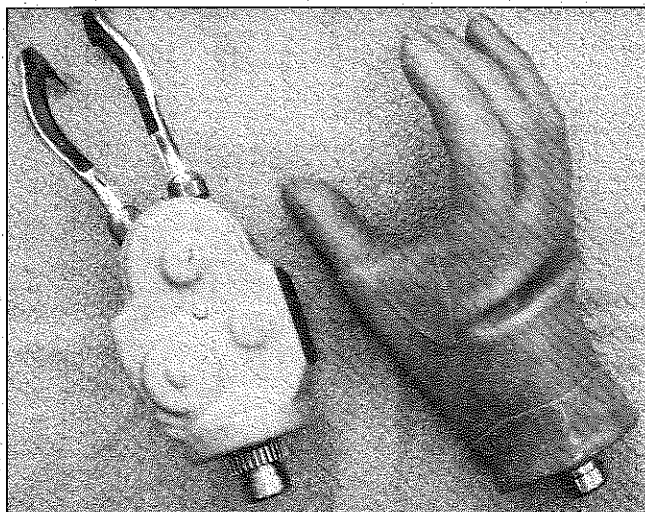




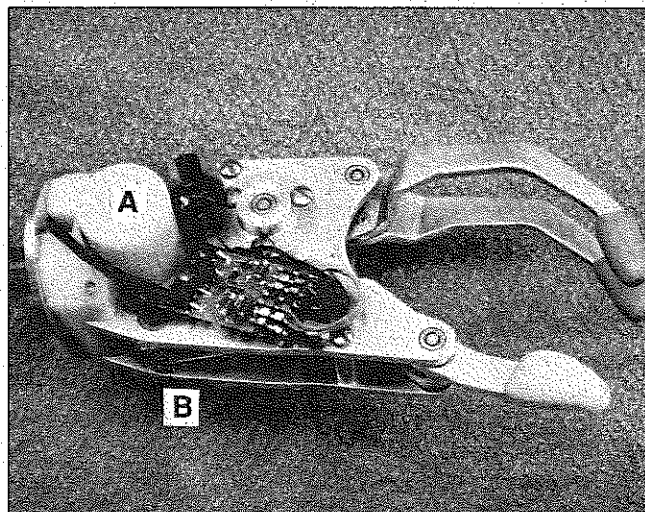
Capabilities

Communicating the Science of Prosthetics and Orthotics

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Left, Synergetic Prehensior. Right, Synergetic Hand.



Inside the Synergetic Hand: A. Fast motor drives fingers at high rate. B. Slow powerful motor drives thumb to high force.

A New Synergetic Hand Prototype

Prosthetics Research Laboratory

Northwestern University/VA Lakeside Medical Center, Chicago, Illinois

We recently completed the first prototype of a new electric hand that will be the companion hand for the Synergetic Prehensior (a hook-like powered prehensior developed earlier by our lab). We call the new prehensior the Synergetic Hand.

The Synergetic Hand uses the synergetic principle—developed in our laboratory—of two drive actuators (motors): one motor produces the fast movement of the fingers and the other creates high pinch forces. Closing time for the new hand is on the order of 0.25 seconds, while the pinch force is around 23 lbf. This means the new hand has a maximum operating speed that is three to four times faster than existing electric prosthetic hands, yet it maintains a gripping force of comparable

magnitude. The closing and opening rate for the new prosthetic hand is similar to typical working speeds of the average human hand.

You may wonder why another electric hand was developed. There are at least two reasons. First, there is a need for a prosthetic hand that is both much faster than existing hands, and that complements the fast Synergetic Prehensior, which is already commercially available. The fast Synergetic Hand makes it possible for people to move between use of the Hand and use of the Synergetic Prehensior without experiencing a change in high dynamic performance. The second reason for a new hand was recently suggested by Mr. John Billock at the 1992 AAOP Annual Meeting in Miami. He lamented the fact that there is currently only one electric hand for adults on the market. He pointed out that there are several electric hands for children and that the availability of several hands has been advantageous in providing superior prosthetic services to children. He believes this may also prove true for adults. ♦ *Dudley S. Childress, Ph.D.*

Dudley S. Childress is Director of Northwestern University's Prosthetic Research Laboratory and Rehabilitation Engineering Program.

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My Dual Role as Consumer and Research Reviewer

*by Johnnie P. Pearson, Member, Consumer Advisory Panel/
Northwestern Rehab Engineering Program*

My personal consumer awareness role began in March, 1970 when wounds received in Viet Nam necessitated the amputation of my left leg above the knee. What I thought would only be a few months in the hospital turned into an eight month stay.

At the end of my hospitalization, I was given a list of prosthetists in my geographical area who could fabricate my limb. I visited them all, asking questions, with the exception of one facility in a "seedy" part of town. In the end, I also paid this prosthetist a visit. It was this last prosthetist who eventually fabricated my first limb. I chose him because he was the only practitioner who wanted to see my stump. He was interested in what he had to work with and how he could best fill my need, based on the residual limb. Even now, after 22 years as a consumer, I still ask questions.

My advice to consumers is to ask questions and to ask lots of them, both of vendors and of other consumers. What works? What does not work? What products are on the market? Why is the product better than another? How does a product work? What maintenance is required? Can I try it out? Who can I talk to who already uses the product? Just because a product has all the latest "lights and bells" does not mean it is the best product for a particular consumer. I found this out with a limb that was without question the best looking limb I had ever seen—but it never fit the way it should. In a year's time I had to replace this limb.

Early in 1985, I was contacted by the American Legion and asked to serve on the Department of Veterans Affairs Merit Review Board for Rehabilitation Medicine Research and Development. Shortly after my acceptance as an Ad Hoc member of the Amputation, Prosthetics and Orthotics Panel of the VA Rehab R&D Board, I was asked to formally review two research proposals for the July 1985 Merit Review meeting. I had neither education nor training in a science field, but at the time, I could offer 15 years' experience as a consumer of prosthetic appliances plus eleven years of veteran's service work (where I had come in contact with veterans of all ages and disabilities.) I knew first-hand how the VA disability system worked and how veterans in need of prostheses and sensory aids received these services.

My experience as a consumer and as a Merit Review Board member has served me well since 1985. VA re-

quirements of the Rehab R&D Service do not differ from what I, as a consumer and disabled veteran, require and expect: the VA recommends and funds projects which have a clinical application which will improve or maintain as high a quality of life for the disabled veteran as possible. If a project has both program and scientific merit, it will receive a positive recommendation. Each member of the panel provides input during the review process, not just those who do the formal review. In this way, each project is discussed in depth as to its strengths and weaknesses. This in-depth discussion is the hallmark of the VA Rehab R&D Merit Review: no project is at the mercy of only three or four formal reviewers.

As a panel member, I not only look at the science, but I also question the project's clinical application and ask how soon the project will be available to the veteran consumer. Is the research group aware of what other groups are doing in the same area? Resources available to the applying research center are also considered, both in personnel and equipment. Does the research group have the experience and background to successfully complete the project? Is available equipment sufficient to support the project? Is there sufficient support from the VA Medical Center involved? Budget for the project is also a concern in my review. Is the project heavy in personnel? Are outside contracts taking a great portion of the budget? Most importantly, during my review I am mindful of what affect the project will have on the population the research group is targeting. After all, this population will determine how successful and meaningful the project really is. Therefore, I not only look at the scientific and program merit of the project, but I am also very concerned as a potential customer of the project's clinical application.

Currently, projects which receive a positive recommendation are funded for a maximum of three years. At the end of this three-year funding period, the research group must resubmit their project for review if they wish to be considered for an additional funding period. At that time, the panel determines what has been accomplished in the prior period. If good progress has been

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made and the current submission has scientific and program merit, an additional funding period can be recommended. During these subsequent reviews, VA Central Office staff informs the panel of any information they have which might have an impact on the current review. Any shortcomings or, for that matter, any positive comments brought out by staff are discussed during the review process. Any site visits which may have taken place during the funding period are also discussed.

Establishing a short funding period has two purposes. First, it forces the research group to focus on a particular area of concentration. Second, it allows the Merit Review Panel to ensure that the research is headed in the direction of clinical application. Each research group is also given a summary statement from the review panel. These summary statements not only inform the research group of approval or disapproval, but are also intended to guide and encourage the research group. Great effort is taken by the panel to ensure that these summary statements are a positive response to the research group.

For example, several years ago a project was submitted to our panel from a very capable group; however, I felt the project had no scientific or program merit. During the panel review and discussion I could sense the difficulty the panel was also having with the project. The project was eventually disapproved because the research group had failed in two areas: first, there would never have been any clinical application of the project, and second, they had failed to consider the potential consumer.

In a more positive example, our panel recently reviewed projects from three centers dealing with CAD/CAM. During the first funding period a software package was developed to be used with a milling machine for the fabrication of below the knee prosthetic sockets. This same software package is now being used in a project for footwear. It is expected to be used by other groups investigating shape-sensing devices. As a consumer, I saw these projects as enabling amputees to receive a properly fitting limb in a timely manner, with a consistent fit which would equate to comfort. I could also see the advantages of a shape-sensing device which would be accurate and which could quickly sense the shape of a residual limb.

In 1970, my goals were to get out of the hospital as quickly as possible and to get on with my life. I had no idea in the years to come as to the part I would play in the lives of amputees and disabled persons. My association with the VA Rehab R&D Board has been most rewarding for it has allowed me, a consumer, to have a voice in products and clinical applications coming to market. ♦

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Amputation as a New Challenge

The following publications can serve as resources for new or prospective amputees. This is only a partial listing of publications in the RU database. Please call or write for a more complete listing.

AAF National Resource Directory. American Amputee Foundation, P.O. Box 250218, Little Rock AR 72225.

Pre-Prosthetic Program for the Amputee. FM Rutan. Orthopedic Nursing 14, May/June 1982.

What to Expect When You Lose a Limb. RH Barja & RA Sherman. US Gov't Printing Office #634-2241, 1986.

Questions and Answers about Life as an Amputee. Amputee Assn. of Maryland, Inc., 2200 North Forest Park Ave., Baltimore, MD 21207.

Choosing a Prosthetist. COAST, Inc., 1991. COAST, P.O. Box 1701, Columbus OH 43216.

Things to Know about Amputation and Artificial Limbs. National Amputation Foundation, 1980. NAF, 12-45 150th St., Whitestone, NY 11357. ♦ EMT

Cable-actuated Position Control of Children's Electric Elbows: A Joint U.S.-Sweden Evaluation

by Craig W. Heckathorne, M.Sc. and Lennart Philipson, Ph.D.

In the July 1991 issue of this newsletter, Dudley Childress described our laboratory's efforts to develop and implement a new type of controller for electric prosthetic components, such as electric elbows. This electronic controller provides "boosted" cable activation and is based on D.C. Simpson's concept of extended physiological proprioception (e.p.p.). The implementation of the controller uses a control cable harnessed to body motion in the same fashion as for a body-powered mechanical elbow. The electronic controller, however, allows the force and excursion required to operate the elbow to be independently adjusted to the user's capabilities. The cable linkage to the body provides the rich proprioceptive awareness inherent in cable-actuated prostheses but without the effort and range of motion typically required by purely mechanical systems. At the time of the July article, three adults (one with an above elbow amputation and two with shoulder disarticulations) had evaluated the system for control of the NY-Hosmer Electric Elbow.

Since last summer, our laboratory has been engaged in a cooperative project with the Arm Prosthetics Unit (APU) of the Medical Center in Örebro, Sweden, to evaluate this controller with children. The project developed from the initiative of Lennart Philipson, a Research Engineer, with the APU. Lennart had worked in our laboratory, as an exchange engineer, for a year in the 1979-1980 period. It was at this time that James Doubler, a doctoral candidate in our laboratory, and Dudley Childress were conducting an evaluation of e.p.p.-type position control and of velocity control, as used in myoelectric and switch-operated systems. Lennart was intrigued by Doubler's results, which showed the superiority of position-controlled systems. He kept informed of our e.p.p. research after returning to the APU, and, following our clinical evaluation by adults using e.p.p.-controlled elbows, invited one of our engineers, Craig Heckathorne, to Örebro to work with the APU team.

The Arm Prosthetics Unit of the Örebro Medical Center serves the majority of limb deficient children in Sweden. This service dates from 1971 when Dr. Rolf Sörbye, a neurophysiologist, arranged for a three-year-old girl to be fit with a below elbow prosthesis having a myoelectrically-controlled electric hand. This was the

first recorded effort to provide such a young child with this type of prosthesis. The success of this fitting and subsequent fittings to young children, referred to the Örebro Medical Center, greatly influenced the development and provision of myoelectric-controlled systems for children in the United Kingdom and North America, as well as in Sweden.

The majority of the approximately 100 children currently seen at the APU, now under the directorship of Dr. Pehr Leissner, have limb deficiencies below the elbow. For these children, a myoelectrically-controlled prehension device has proved to be a useful tool. For children with higher level deficiencies (requiring a prosthetic elbow), the usefulness of the prehension device is limited by the child's ability to actively position the prosthesis without assisting with the opposite hand and arm. Cable-actuated body-powered elbows have not been employed because of the high forces needed to lift a prosthetic forearm and electric hand. Electric elbows were applied experimentally in the late 1970s, but were not successful because of poor mechanical and controller performance.

Improvements in child-size electric elbows and the development of the e.p.p.-type electronic controller at NUPRL encouraged the team of the Arm Prosthetics Unit to re-evaluate the feasibility of electric-powered elbows for children. Of twelve children with transverse or longitudinal deficiencies appropriate for fitting with a prosthetic elbow, three children were selected for the initial study. All three of the children are users of prostheses and are skilled in the operation of their myoelectrically-controlled hands using their biceps and triceps muscles. Two of the children (ages 11 and 12) have been using mechanical manually-operated elbows. These elbows require the use of the opposite hand to unlock, position, and relock the elbow. The prostheses used by the third child (age 5.5) have not had a movable elbow but instead have a fixed bend of 45° at the "elbow" location.

The evaluation prostheses are being designed by Craig Heckathorne with fabrication assistance from the Medical Center's Prosthetic/Orthotic Department and technical support from the N.U. Rehabilitation Engineering Program in Prosthetics and Orthotics. Each prosthesis includes an electric elbow and electric hand. The type of electric hand and myoelectric controller is identical to what the child has been using. NY-Hosmer Electric Elbows (one "large" size and one "medium" size) are incorporated into the prostheses of the two older children. The VASI 8-12 electric elbow is used in the prosthesis of the youngest child. All elbows are cable-actuated using NUPRL e.p.p. controller, and the position and speed of the elbow movement is coupled to flexion of the residual limb at the shoulder.

At the time of the delivery of the definitive evaluation prosthesis, each child receives training by the Occupational Therapists of the APU. At this time the child is also evaluated in the operation of both prostheses: the type with the mechanical manually-operated elbow and the evaluation prosthesis with the e.p.p.-controlled electric elbow. These tests are administered by Liselotte Hermansson, chief Occupational Therapist of the APU, and include activities from the Skill Index Ranking Scale (SIRS) and other bimanual activities that typically incorporate elbow positioning. In addition to these tests, Lennart Philipson is conducting a blind positioning test, similar to the one developed by James Doubler, to determine if the proprioceptive feedback offered by the e.p.p. controller facilitates elbow positioning.

By the end of June 1992, all three children will have had their evaluation prostheses through the first follow-up testing (at four weeks). Results of the evaluation will be described at the ISPO Congress in Chicago and in a future *Capabilities* issue.

This work is supported by the Swedish National Board for Industrial and Technical Development and the Research Committee at the Örebro County Council. Application of the electronic e.p.p. controllers was supported in part by the National Institute on Disability and Rehabilitation Research, U.S.A.

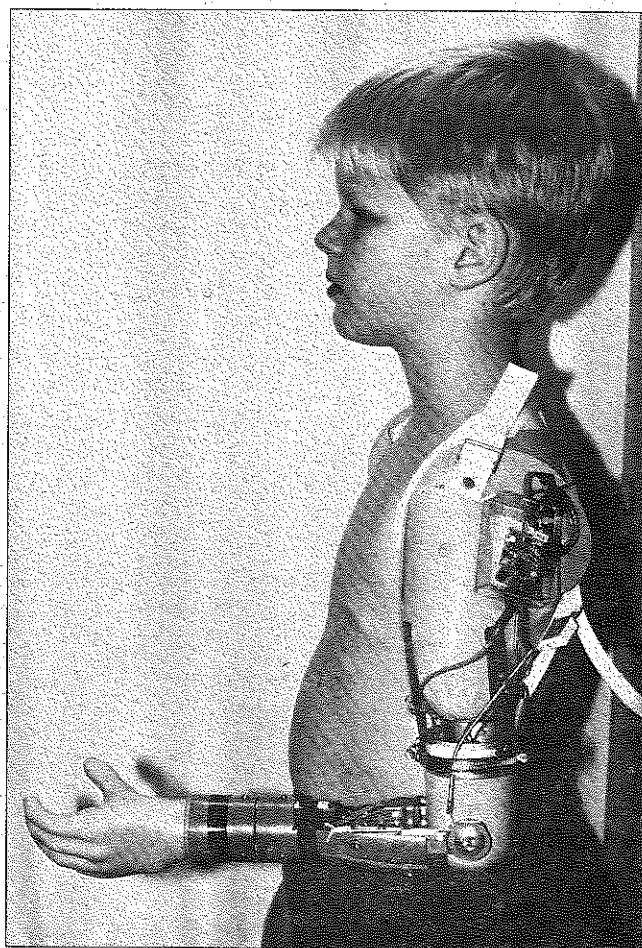
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Doubler, J.A. (1982). An analysis of extended physiological proprioception as a control technique for upper-extremity prostheses. *Ph.D. dissertation*, Northwestern University. (Chapters 5 and 7 describe the blind positioning tests.)

Heckathorne, C.W. (1990). Manipulation in unstructured environments: extended physiological proprioception, position control, and arm prostheses. *Proc. of the Int. Conf. on Rehabilitation Robotics*, Wilmington, Delaware, 25-40. (Includes references to Simpson's writings and all papers from our laboratory on e.p.p. theory and implementation.)

Hermansson, L.M. (1991). Structured training of children fitted with myoelectric prostheses. *Prosth. and Orth. Int.*, 15:88-92. (Describes the Skill Index Ranking Scale and training protocol generally used at the APU.)

Sörbye, R. (1977). Myoelectric controlled hand prosthesis in children. *Int. J. Rehabil. Res.*, 1: 15-25. (Describes the early work of the Arm Prosthetics Unit.) ♦



Twelve-year-old with preparatory prosthesis used during early evaluation of capability for cable-actuated control of electric elbow.

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Lennart Philipson, Ph.D. is a Research Engineer with the Arm Prosthetics Unit (APU) of the Medical Center, Örebro, Sweden.

Benefits of Early Upper Extremity Prosthetic Training

by Sandra Fletchall, OTR/L and Hector Torres, OTA

Without appropriate early therapeutic intervention, traumatic amputation of the upper extremity can result in multiple problems, i.e., contractures, limited range of motion and strength, depression and poor self-esteem, and a potential for reduction of wage earnings. Mendelson et al. (1) indicates that the traumatic upper extremity amputee may require a structured program to deal effectively with returning to pre-injury status because, "with traumatic amputation, the emotion is even more intense because the patient becomes a victim without any choice" (p. 581). Therapeutic intervention, ideally pre-amputation (otherwise, immediately following the upper extremity amputation) can produce a decrease in the delay of returning to pre-injury tasks and/or the work environment.

The pre-prosthetic program should emphasize wound care, edema control, stump shaping, scar control, upper extremity strengthening, range of motion, changing of hand dominance, general body strengthening and cardiovascular endurance. In addition, the therapist can explore the vocational and avocational areas, all of which will influence the prosthetic componentry. Functional goals should be discussed with the patient, with the Occupational Therapist establishing timeframes for return to pre-injury activities including return to work (2).

During the pre-prosthetic program, exposing the new amputee to others who are or have progressed through the prosthetic program can reinforce the concept that goals and timeframes that were established will be met. Mendelson et. al. (1) identified that "group interactions are of utmost importance in accepting the injury and acquiring positive goals" (p. 579). Structured group settings where individual treatment is emphasized can create an "awareness of functional abilities rather than disabilities..." (p. 579).

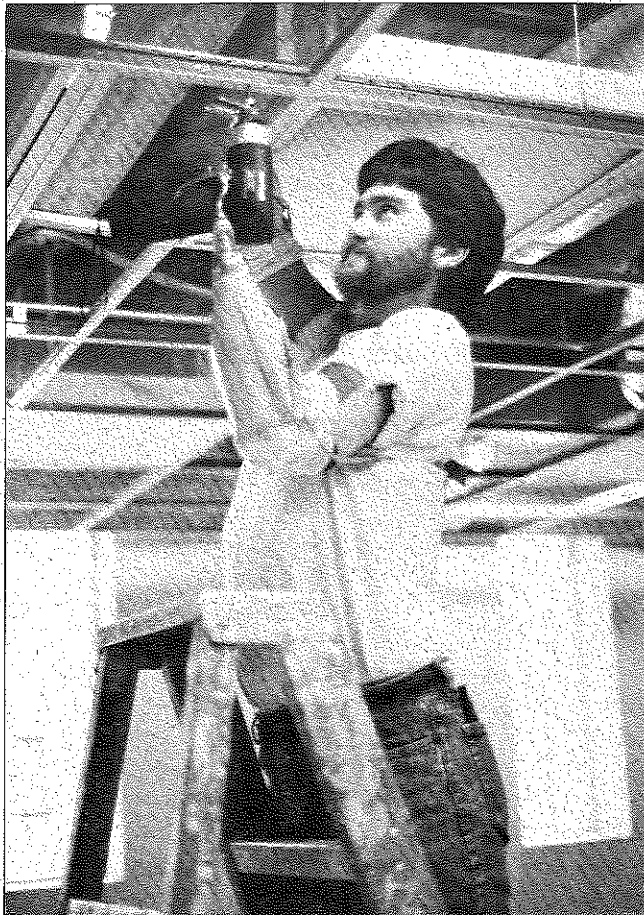
At UT Medical Group, Inc., Memphis, Tennessee, upper extremity amputees begin a full day, five day a week Occupational Therapy outpatient program immediately following their hospital discharge. The forementioned program is instituted with the staff providing physical rehabilitation and mental

health support. Prior to receiving a prosthesis, the Occupational Therapy staff provides education enabling the patient to become knowledgeable in the importance of edema control, stump shaping and the need for total body strengthening and endurance. Informal evaluation, and when necessary, formal evaluations of the patient's problem-solving and visual-motor skills, judgement, motor planning abilities and responsibilities within the home and work environment are compiled to assist in determining prosthetic componentry. The Amputee Team comprised of the Medical Director, Occupational Therapist, Prosthetist, patient and case manager for the health care provider meet monthly where the prosthetic componentry and the timeframe for fitting of a temporary or definitive prosthesis is identified. Temporary upper extremity prostheses are fabricated from thermoplastics, creating a lightweight, modular system that can quickly be modified, thus creating a cost-effective system for the health care provider (3).

Once the patient receives the prosthesis, Occupational Therapy establishes a structured wearing schedule. Within a week and a half of receiving the prosthesis, the patients are averaging a wearing and using schedule of six to eight hours a day. With no complications, the below elbow amputee will be utilizing six to seven bands on a body-powered prosthesis with a number 5X or 7 terminal device and a wrist flexion unit in two and one-half weeks.

The prosthetic training program encompasses all aspects of self care, homemaking, child care and when appropriate, yard and general home maintenance. Once everyday tasks are performed in a time appropriate manner, emphasis is focused on the job tasks within the work environment. Job responsibilities are simulated within





the Occupational Therapy treatment sessions where the previously identified goal of returning to work becomes a reality.

In determining the benefits of early occupational therapy and upper extremity prosthetic training, a retrospective study of 22 adults sustaining upper extremity amputations as a result of trauma was reviewed. All patients were treated by the staff of UT Medical Group, Inc., Memphis, TN. Twelve patients received immediate intervention following the upper extremity amputation with the initiation of the described pre-prosthetic and prosthetic program. Ten patients were delayed in being referred for treatment on an average of eight months (range, 5 to 12 months) from the date of amputation. Amputations were the result of burns (thermal and electrical), crush and/or mangle injuries.

The immediate group consisted of one female and 11 males with the average age being 35 years (range, 18-55 years); the delayed group had two females and eight males with the average age being 37 years (range, 28-56 years).

The types of amputations were as follows:

	<i>Immediate Group</i>	<i>Delayed Group</i>
Below Elbow	7	5
Bilateral Below Elbow	2	0
Above Elbow	2	4
Bilateral Above Elbow	1	0
Shoulder Disarticulation	0	1
TOTAL	12	10

Prior to receiving a prosthesis, the immediate group exhibited no upper extremity contractures, while 40% in the delayed group had contractures that required treatment.

The immediate group received a temporary prosthesis on an average of three weeks from the date of the last surgical procedure of the amputated extremity. The amputated extremity was ready for the definitive upper extremity prosthesis on an average of four months from the date of injury.

Two individuals in the delayed group were candidates for a temporary prosthesis, while eight were fitted with definitive prostheses; one patient chose not to be fitted with any prosthetic device.

Types of initial prostheses utilized were:

	<i>Immediate Group</i>	<i>Delayed Group</i>
Body Powered	9	7
Myoelectric	2	0
Electronic	1	2
None	0	1
TOTAL	12	10

Seventy-five percent of the patients in the immediate group had more than one terminal device, compared to 2% in the delayed group. In addition, 50% of the immediate group had more than one type of prosthesis, while only 1% in the delayed group had an alternative prosthetic device. The individuals in the immediate group expressed an interest in obtaining additional terminal devices and/or prostheses based upon the tasks and activities they were performing or attempting to perform. Re-evaluation of the individual's ability and use of the present prosthesis is continually performed by the Amputee Team. If additional terminal devices or types of prostheses are issued, the patient returns to Occupational Therapy for an intense training period to fully understand the potential of the new device. Findings from our patients coincide with Burrough and Brook's study (4) which stated, "the importance of training is related to the fact that training can increase the

capability of the recipient to make use of the prosthesis. This, in turn, increases the functionality of the prosthesis as a tool for living" (p. 46).

The immediate group exhibited 100% return to pre-injury activities using the prosthesis. In the delayed group, 30% used the prosthesis for pre-injury activities, 30% used the device occasionally, and 40% rarely used the prosthesis. Roeschlein et al. (5) and Fletchall (3) also found upper extremity amputees utilized the prosthesis for pre-injury activities a higher percent of the time if the device was received soon after the amputation.

Seventy-five percent in the immediate group returned to the work environment using the prosthesis on an average of four months from the date of injury (range, three to ten months), 16% remained unemployed due to community work trends, and one chose retirement. The delayed group had 60% returning to work with 40% unemployed. Millstein et al. (6) also found that "those subjects who reported frequent prosthetic use were more likely to be employed than less frequent prosthetic users" (p. 75).

It is tragic for an individual to sustain an upper extremity amputation; however, the benefits of initiating early, aggressive specialized Occupational Therapy intervention has been demonstrated at our facility, resulting in a functional prosthetic wearer in both the home and work environment.

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