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Artificial Limbs

A Review of Current Developments

ADVISORY COMMITTEE on ARTIFICIAL LIMBS

National Academy of Sciences
National Research Council

Artificial Limbs

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ADVISORY COMMITTEE on ARTIFICIAL LIMBS

NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

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Artificial Limbs—Today and Tomorrow

F. S. Strong, Jr.[1]

Ours is an age of scientific research and development in almost every field of human interest. Some work to make man live longer, to make him more comfortable, more mobile, more informed. Some devise ways to maim or destroy him. This report and others to follow will tell the story of those who strive to replace what war, accident, or disease have removed, or what nature simply failed to provide. This is concerned with what modern science and engineering skill can do today-—and what may be expected in the future—for the person in need of a substitute for normally standard equipment—an artificial limb for a missing arm or leg.

From the dawn of history men have contrived replacements for lost extremities, particularly the lower. The loss of an arm, while causing inconvenience, has not resulted generally in serious handicap. But without a leg, a man becomes immobilized. Thus, over the years there has come about a considerable development until today some of the better types of artificial legs afford reasonably satisfactory service, always provided they are well fitted and aligned by qualified prosthetists. The same has not been true of upper-extremity devices. And so when young men returned from World War II with missing limbs, while the lower-extremity amputee could expect a replacement of some merit, the man who needed an arm was definitely in trouble. As a matter of fact, the entire field of artificial limbs needed serious attention to bring amputee service more in line with the scientific and engineering progress which has become synonymous with America in the modern world.

To meet this need, not only for the benefit of veteran amputees, but also to help all similarly handicapped individuals everywhere, a program was established at the end of the war under the sponsorship of the Armed Services and the Veterans Administration and was later implemented on a permanent basis by the Eightieth Congress through Public Law 729. This act authorizes the expenditure of $1,000,000 annually "to aid in the development of improved prosthetic appliances ..." and designates the Veterans Administration as the appropriate agency for the administration of the funds thus made available.

[1] Executive Director, Advisory Committee on Artificial Limbs, National Research Council.

The activities encompassed within the framework of these endeavors have come to be known as the Artificial Limb Program. And since the field, though serving less than a million persons, of whom only some 27,000 are veterans, involves the cooperation of several scientific disciplines as well as various organizations both civil and military, a special structure had to be contrived for successful operation. This was done through a contract between the Veterans Administration and the National Academy of Sciences, by means of which an Advisory Committee on Artificial Limbs of the National Research Council has been established for general supervision and coordination, and through other contracts between the Veterans Administration and various educational and industrial organizations for research and development. In addition, the Surgeons-General of the Army, Navy, and Air Force, and the Chief Medical Director of the Veterans Administration, have made available the services of certain laboratories and personnel in further support of the over-all program. While, in the early stages of this undertaking, it was necessary to proceed generally on a broad front in order to explore and define the complete problem so that at one time as many as sixteen contracts were in force, at present the number has been reduced to three only, and an operational structure has been evolved through which a long-range plan can be followed with reasonable hope of success.

The word "prosthetics" has been found a convenient term to define the general field of amputee service. Since the problems of replacement in the lower extremity are quite different from those in the upper, the field is divided into two parts. Lower-extremity research and development are centered at the University of California, Berkeley Campus, while upper-extremity studies are similarly covered at the University of California at Los Angeles, all under a contract between the Veterans Administration and the University. Assisting in lower extremities is the Oakland Naval Hospital Artificial Limb Department, while the Army Prosthetics Research Laboratory at Walter Reed Army Medical Center cooperates in the development of artificial arms and terminal devices. Finally, through a contract with New York University, and with the cooperation of the VA Prosthetic Testing and Development Laboratory in New York, well-defined methods of testing and field application assure that devices and techniques developed under the program are, before acceptance, in fact useful improvements in amputee rehabilitation.

For general technical guidance in these two branches, standing committees, in lower- and upper-extremity prosthetics respectively, have been constituted, each composed of specialists in the fields of medicine, engineering, prosthetics, and the like, and each under the chairmanship of the leader of the appropriate University of California research project. These groups meet annually, or more frequently if necessary, to review progress, define requirements, and recommend action to the Advisory Committee on Artificial Limbs, to the artificial-limb industry, or to others interested in amputee rehabilitation problems. In addi-

tion, smaller research and development panels have been appointed from these technical committees to supervise current activities between meetings of the larger groups. In this work, definite transition procedures have been adopted for orderly progress from the inception of ideas for improved devices and techniques to their final application in the limbshop or rehabilitation clinic.

By these methods the results of some eight years of research and development are now being channeled as directly as practicable to the service of amputees, rather than indirectly merely through the issuance of reports or through publication in scientific journals. In order that physicians, prosthetists, rehabilitation specialists, insurance carriers, and other interested individuals and organizations may be informed of advances in this field as promptly as possible, this series of reports is being undertaken. While the Advisory Committee on Artificial Limbs has previously issued monthly progress reports on a limited basis to those immediately concerned, and although the various contractors and governmental laboratories associated with the program have contributed reports and other data on specific subjects, this will be the first organized attempt to disseminate timely information to a broad list of individuals and institutions interested in the rehabilitation of the amputee. This is being done in furtherance of the intent of the Congress which, in Public Law 729, authorizes the Administrator of Veterans' Affairs "to make available the results of his investigations to private or public institutions or agencies and to individuals in order that the unique investigative materials and research data in the possession of the Government may result in improved prosthetic appliances for all disabled persons."

In offering these reports to the reader who has not been in a position to follow recent progress in this field as unfolded through the Artificial Limb Program, it can be stated that the views and information to be set forth in this and subsequent issues are the result of long and objective study by specialists in the various branches of science and engineering involved. These findings, therefore, can be accepted with considerable confidence as indications not only of the present state of the art but also as to future trends. And where these findings may appear at variance with previous traditional concepts or the writings of earlier authorities, it can be said simply that the field of prosthetics is even today largely uncharted and untraversed—that it is a field where the marvels of modern science and engineering have yet to leave their mark.

The Objectives of the Upper-Extremity Prosthetics Program

Craig L. Taylor, Ph.D.[1]

JL HE upper-extremity prosthetics program, under the sponsorship of the Advisory Committee on Artificial Limbs, National Research Council, has been a growing and evolving program from its inception in 1945. Its initial objectives were limited to time and motion study of amputees and to device invention and development. But from the vantage point of 1954 we may list many additional objectives that have been assumed according to the necessities of a national program dedicated to the welfare of the amputee. As new activities have been added, none of the original have been abandoned, although certain of the original ones have been reduced in relative emphasis and expenditure.

Figure 1 illustrates in schematic form the major phases of the upper-extremity program as they have waxed and waned over the years from 1946 to 1953. The scope and magnitude of these activities represent a program with few parallels in our peacetime economy. As is evident in Figure 1, not all the activities were started (or even conceived) at the outset. But, as has been pointed out by Strong,[2] no one could predict at the outset the ramifications of a program dedicated to the tangible goal of putting new and improved prostheses on amputees. The appropriateness of this program under the auspices of the National Research Council was underscored by President Bronk, who praised the ACAL program as a fitting example of the service to the public welfare for which NRC was founded.[3]

FUNDAMENTAL STUDIES

The study of normal and amputee biomechanics underlies all improvement in prosthetic replacement. A continuous program of inquiry in this field is therefore essential. Although much of such research is undertaken without immediate practical goal, free inquiry brings to light ideas which find widespread application, as has already been demonstrated time and again. The continuous observation of arm motions and of prosthetic motions provides a nourishing bed of interest and information from which the application phases draw strength and purpose.

The program of fundamental studies has featured research on normal motions, analyzed in terms of physical mechanics and in terms of industrial time and motion concepts. These investigations have built up a body of information on the patterns of motion, speeds, forces, and skills that is invaluable in conceiving, planning, and predicting the results of new developments. A special phase of this program has had to do with cineplasty, where the direct utilization of muscle force has remarkable potentialities for prosthetic replacement but where intimate knowledge of the mechanics of the muscle is required in order to obtain successful operation of the prosthesis. Knowledge of stump shrinkage, of finger forces, of external power controls, of accessory body mechanics, of mechanical stresses in the prosthesis during use—all these are fundamental to the proper

[1] Professor of Engineering and Biophysics, University of California, Los Angeles; member, Advisory Committee on Artificial Limbs, National Research Council; chairman, Upper-Extremity Technical Committee, ACAL, NRC.

[2] Strong, F. S., Jr., *The Artificial Limb Program: Five Years of Progress.* Advisory Committee on Artificial Limbs, NRC, Washington, November 1951.

[3] Bronk, D. W., President, National Academy of Sciences. Address to the Advisory Committee on Artificial Limbs, Annual Meeting, Washington, May 1953.

assessment of normal and of amputee biomechanics.

The objectives of the program of fundamental studies in the upper extremity may be summarized as:

1. To study the performance of manipulative activities in normal individuals and to analyze the activities in terms of biomechanics and of time and motion criteria.
2. To compare the motions of amputees with prostheses with similar motions of normals in order to define the patterns of altered and substitute motions peculiar to amputees.
3. To measure the forces and displacements of muscles and muscle groups in relation to cineplasty, harness controls, and external power controls.
4. To define the alterations in general body mechanics in amputees as a result of the asymmetrical loss of body weight.

DEVELOPMENT OF PROSTHETIC DEVICES

The "bread and butter" of the ACAL program is the development of improved prosthetic devices, and a major emphasis has always been placed upon this phase of the program. Development of each device originates in the need shown by fundamental studies or by experience with amputees. Design, experimental fabrication, amputee test, and field evaluation are the successive steps through which each device must pass. The past and present development laboratories include Northrop Aircraft, Inc., the Army Prosthetics Research Laboratory, and the University of California at Los Angeles, but other agencies, such as New York University and many cooperating industry limbshops, function in the final evaluation phases.

ACAL developments in prosthetic devices include new inventions and many adaptations of mechanisms and materials from other technical fields. Engineers have delved deep into the rich heritage of American technology to find applications of plastics, lightweight metals, and mechanisms that have immensely improved the structural and functional characteristics of upper-extremity prostheses. In short, the development objectives are:

1. To invent, adapt, and apply new materials and mechanisms so as to add new functions, or to improve old functions of prostheses, seeking in the end to provide an armamentarium of devices to meet the needs of every amputee type.
2. To design and redesign prosthetic components for simplicity and ease of manufacture, and for durability, without loss of essential function.
3. To create a system of interchangeable components which may be singly prescribed for the individual amputee case, but which can be combined into a func-

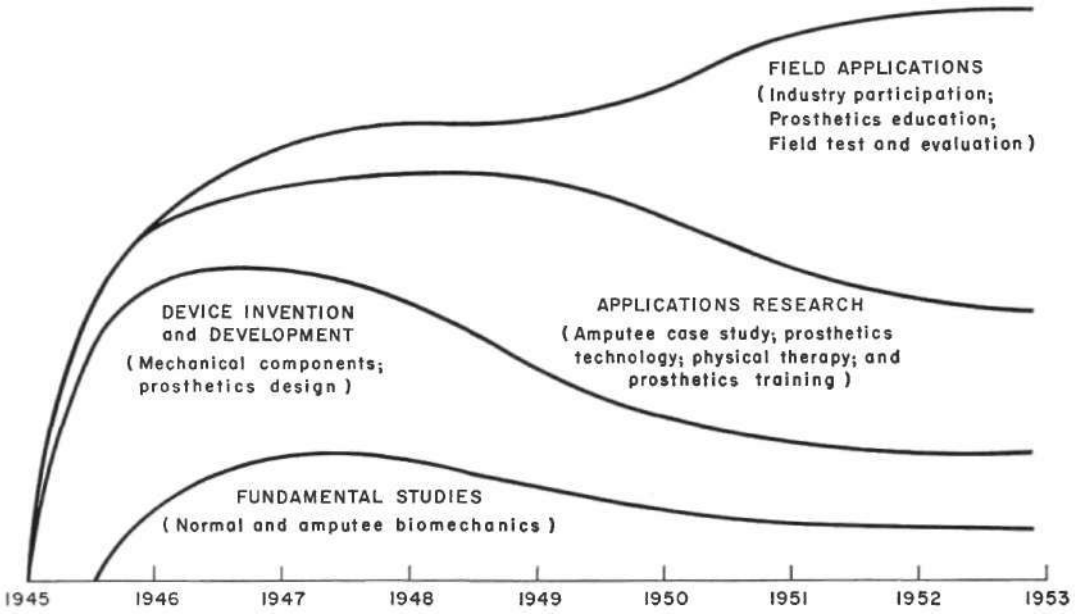

Fig. 1. Trends in the upper-extremity prosthetics program, 1945-53.

tionally integrated and an esthetically compatible prosthesis.

4. To incorporate cosmetic and anthropomorphic principles into basic design so that prostheses are not abnormally conspicuous and are pleasing from the standpoint of color, texture, and form.

INDUSTRY ADVISORY PARTICIPATION

From earliest days, ACAL has recognized the benefit that would accrue to its activities if the experienced "know-how" of the industry could be utilized in an effective way. To attain this goal, it was considered necessary to bring into the planning meetings of the ACAL group the counsel of leading prosthetists and limb manufacturers. Accordingly, three members of the limb industry were made members of the Upper-Extremity Technical Committee to serve at the national level, while in Los Angeles a local Industry Advisory Committee was set up to advise and aid the UCLA project. These cooperative ventures have proved to be of great mutual benefit, the objectives being briefly as follows:

1. To learn from the industry the needs for device development, for advancement in prosthetics technology, and for improvement of amputee services.

2. To utilize the experience and judgment of members of the limb industry in determining policy and in planning cooperative ventures involving field application studies.

CONTRIBUTIONS TO PROSTHETICS TECHNOLOGY

With the wealth of World War II technological development to draw upon, the ACAL program rapidly adopted new materials and practices, not only in the design and development of new prostheses but also in shop fitting and fabrication practices. Most outstanding of these innovations is the incorporation of plastics for prosthetic use. The principal laboratories under the program, APRL, Northrop Aircraft, Inc., and UCLA, have exemplified these uses, and their reports have been a source of information to the industry.

The objectives are:

1. To adapt new and different materials for use in fitting and fabrication.

2. To introduce into prosthetics practice methods of measurement and fabrication tending to improve quality of service and economic efficiency.

AMPUTEE CASE STUDY

In the early stages, the ACAL program emphasized research and development on devices, and amputees necessarily were fitted with experimental prostheses in order to conduct studies, trials, and tests of the equipment. It soon became apparent, however, that established practices in prescription, fitting, and training of amputees were highly variable and that, to round out consideration of all factors bearing on amputee rehabilitation, these practices themselves should become the subject of investigation. This objective was strengthened by the knowledge that no single design of prosthesis is superior for all amputees but rather that, of many types of equipment, the most suitable selection for a given amputee depends upon his individual personal, social, and occupational needs and desires. Accordingly, the Case Study Program was initiated at UCLA in 1950 and continued until 1952. The large amount of information on the 70 amputees in this study is being reduced for publication; much of it has been directly transferred into the Educational Program (see below).

The case study of cineplastic amputees at APRL has followed in its major outline the procedures at UCLA, and much valuable information is being gathered on this important class of amputee.

These programs serve an especially important role in bridging the gap between fundamental work in the laboratory and practice in the field. Prosthetics involves, in unique degree, a combination of science and technology with the practical arts. Every amputee is to some extent a special case. It has therefore been necessary to incorporate the case-study phase in order to ensure the i applicability of technical improvements.

In concise form, the objectives of the Case Study Program may be stated as follows:

1. To investigate the application of prostheses to a wide range of amputee types so that a rational procedure for prescription for the needs of the amputee can be formulated.

2. To test and develop the elements of physical and occupational therapy that apply to amputee rehabilitation and prosthetic use.

3. To discover the effect of occupation, education, recreational interest, and other personal factors of the amputee upon his prescription, fitting, and training.

4. To determine effective methods for evaluation of amputee service, not only pertaining to the quality of mechanical equipment but also to the results of training, to the end that the amputee obtains a truly functional prosthesis.

PROSTHETICS EDUCATION

It has been a cardinal principle of the ACAL group that the products of its research, investigation, and development should be speedily disseminated to all technical and professional groups interested in applying such knowledge for the welfare of the amputee. The scope of these activities has steadily increased. Early discoveries were conveyed by means of technical reports which were primarily useful to the other member laboratories and to manufacturers within the industry. Later, as case study and other application phases of the program developed, the broader responsibility was assumed of supplying educational materials dealing with many aspects of technical and professional prosthetics service. Two volumes have been prepared. *Human Limbs and Their Substitutes* (McGraw-Hill, in press) supplies an authoritative reference on prosthetics, while the *Manual of Upper-Extremity Prosthetics* (University of California at Los Angeles, 1952) has been issued to serve as a shop guide for the practicing prosthetist.

Valuable as the printed material has proved to be, it was found that the needs of the prosthetist for advanced training could not be met with sufficient rapidity and thoroughness. These craftsmen, lacking formal institutional training in their specialty, and with the highly variable backgrounds of apprentice training, displayed great need for direct instruction to bring them up to the standard required by the new technology. Two other professional groups most concerned in amputee service, physical and occupational therapists and physicians and surgeons, were no less in need of learning the newer knowledge of prosthetics.

This condition made it imperative to offer an accelerated advanced training in the theory and practical arts concerned in prosthetics. Accordingly, the Prosthetics Training Program was instituted at UCLA with the following objectives:

1. To give for selected groups of prosthetists advanced training in the skills and knowledge needed to make and fit upper-extremity prostheses using many of the most recent refinements arising from research.

2. To give for selected groups of physical therapists and occupational therapists advanced training in the skills and knowledge needed to assist amputees in adjusting themselves physically, mentally, and vocationally to the use of the newer developments in upper-extremity prostheses.

3. To enable physicians and surgeons to expand their understanding of the possibilities and limitations of the more recent developments in prostheses and of some effective procedures for taking advantage of these developments.

4. To encourage the acceptance and practice of the "team approach" to the problem of prosthetic prescription, in which the physician or surgeon, as captain of the team, is assisted by professionally qualified physical therapists, occupational therapists, and prosthetists.

FIELD RESEARCH STUDIES

To test the usefulness of the knowledge gathered during the ACAL research program, a field research project was instituted in Chicago during 1952. The intent was to determine whether the local rehabilitation people concerned with the problems of prosthetics—the physician, the therapist, and the prosthetist—would benefit from the new knowledge. Accordingly, a group of Chicago physicians, therapists, and prosthetists were invited to attend a "pilot" course in upper-extremity prosthetics at UCLA, the content of the course being based almost exclusively upon the research performed under the ACAL program.

Upon completion of the training, a clinic was established in Chicago, where a group of 50 amputees was processed in accordance with the information taught at UCLA. The status of each amputee was carefully evaluated both before and after clinic treatment. Results showed a dramatic and clear-cut improvement in the functional and psychological attributes of this group of amputees. Thus, initial field evaluation clearly demonstrated the practical usefulness of the research results when applied to amputees in the local situation.

Upon completion of the Chicago study, and

in close coordination with the educational program already described, nationwide field studies were instituted under the supervision of the Prosthetic Devices Study, New York University. The purposes of these studies, which are presently going on, are as follows:

1. To ensure the proper application of the research findings to upper-extremity amputee cases throughout the country.
2. To provide the local clinics throughout the country with administrative and technical consultation so that assistance may be provided in the resolution of difficult problems.
3. To evaluate the effectiveness of these procedures when applied to amputees, in order to determine where problem areas still exist and thus to direct future research toward the resolution of these difficulties.

It is anticipated that, upon conclusion of the present field research program, studies will have been conducted in conjunction with clinics operating in some 40 of our largest communities.

CONCLUSION

As a result of the upper-extremity prosthetics program, arm amputees can now be provided with reasonably comfortable, functional prostheses. Studies indicate that between 80 and 90 percent of the arm amputees fitted during the UCLA Case Study Program and the Chicago Project continue to wear and use their prostheses. When this is compared with the 10-percent figure estimated for arm amputees throughout the country who wear prostheses, it appears that some measure of success has been achieved. But it is apparent to workers in this field that the progress made to date is merely a step in the proper direction and that we can expect continued improvement in all aspects of upper-extremity rehabilitation.

The Prosthetics Clinic Team

Charles O. Bechtol, M.D.[1]

the increasing complexity of medicine and its related sciences, the day is past when a single man can cope successfully with all the specialized problems in the treatment of injury and disease. The "horse-and-buggy" doctor did an excellent job considering the limited number of drugs and facilities available to him. His results, however, can in no way compare with those obtained at a well-conducted, modern clinic, where a team of physicians as well as representatives of all the allied medical specialties are available. A comparable situation now prevails in the field of artificial limbs.

The basic Prosthetics Clinic Team is composed of a physician, a therapist, and a prosthetist. Workers in other fields, say a psychiatrist or psychologist, a social worker, a vocational counselor, or an engineer, should be available for consultation when the basic team considers that such services are required. Each member of the team has been trained to perform one particular job well, and, despite the considerable education and experience of each of these team members, no one man could be expected to carry out the entire procedure beginning with surgery and ending with the fitting and training of the patient. Although it is not generally stated, the patient himself is also a member of the team, since during the period of fitting and training he must cooperate by carrying out the instructions of the various team members and at the same time make and convey his own observations on the good and bad qualities of the prosthesis.

THE FUNCTION OF EACH TEAM MEMBER

THE PHYSICIAN

The physician acts as the chief of the clinic team. His particular training has prepared him to coordinate various ancillary services in the solution of all types of medical and surgical problems and to follow the progress of the patient until the difficulty for which medical care was sought has been corrected. In the past, this has been known as the "end result idea," more recently as *Rehabilitation.* The physician, in addition to his specific duties, is able to act in this same supervisory capacity in the prosthetics clinic team.

First, the physician can evaluate the general medical status of the patient and either carry out any necessary surgery or, if he is not a surgeon, refer the patient to a properly qualified one. Immediate postoperative care in the hospital is under his direction. Then the prescription for physical therapy, whether preoperative or postoperative, is in his hands, and he is also the person who assumes ultimate responsibility for prescribing the prosthesis.[2] Moreover, the physician supervises evaluation of the prosthesis and renders final approval. And lastly, it is his responsibility to ensure that adequate training in use of the prosthesis is provided, to the end that the amputee may be able to gain the full functional advantages offered by a properly constructed, modern prosthesis.

THE THERAPIST

The particular field of the physical and occupational therapists lies in preoperative and postoperative training and physical conditioning. The therapist is almost solely responsible for training in use of the prosthesis and usually for details of the checkout and evaluation procedures. These functions, however, are no more important than are those of physical conditioning and training in use of

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[2] It must be emphasized that these prescriptions, even though they be signed by the physician, should correctly be the product of consultation by the entire team. It is perhaps in the preparation of these prescriptions that the knowledge of each team member is utilized to the fullest.

the prosthesis. And hence the therapist is a most necessary consultant in decisions relating to time of fitting, type of prosthesis, and type of postprosthetic training.

THE PROSTHETIST

The special problem of the prosthetist, of course, is the actual fabrication and fitting of the artificial limb. Thus he is an indispensable member of the team. His consultation is particularly valuable at the time of prescription of the prosthesis. Using the medical data supplied him by the physician and the therapist, he can give excellent advice as to the relative degree of function that can be offered by different artificial-limb components. With cooperation in this respect, later changes in the prosthesis can be held to a minimum and possibly avoided entirely.

OTHER CONSULTANTS

In complex cases, the team will often feel a need for the services of others. It may be necessary to call upon a psychiatrist or psychologist to determine whether the mental attitude of the patient is such that a prosthesis can be used. Or a design engineer may be able to devise a mechanism or component that will be useful in special cases. Finally, the services of a vocational counselor or social worker may be needed in determining some of the future requirements of the amputee.

ADMINISTRATIVE PERSONNEL

In addition to the professional services involved, it is mandatory that someone assume the usual administrative responsibilities. An orderly clinic cannot be conducted without someone to schedule the patients' visits, to maintain individual records, and to carry out other administrative functions. This is of course true of any type of clinic operation, but it is perhaps even more important here because of the many factors involved and the numerous disciplines required.

PROCEDURES IN THE CLINIC

An amputee appears before the team a minimum of three times, as shown graphically in Figure 1. The first visit is for the purpose of preparing the prosthetics prescription, the second to evaluate the amputee and his prosthesis before training, the third to evaluate the amputee and his prosthesis after training.

VISIT NO. 1

If, in the opinion of the team, the amputee is ready for fitting, a prescription is prepared. If for some reason—medical or otherwise—he is not ready, appropriate therapeutic measures are recommended.

On hand is a preprescription form (Fig. 2) on which have been recorded such data as the cause of amputation, the patient's background, his physical limitations, and his desires for the future. Before attempting to prepare a prescription, each team member should be thoroughly familiar with the information given in the preprescription form. Unless the therapist is familiar with the case, it is desirable to check any existing physical limitations.

The prescription is prepared through the cooperative effort of the team and is signed by the physician. Fitting is then carried out by the prosthetist in accordance with the prescription. A prescription form for upper-extremity amputees is shown in Figure 3.

VISIT NO. 2

Upon completion of the prosthesis, but before training, the amputee is brought before the clinic team a second time. Here emphasis is placed on "before training." Taken literally, this may mean that the amputee will have no conception of even the simpler control movements. In the final stages of fitting the upper-extremity amputee, however, it is necessary that the prosthetist instruct the amputee in basic control motions in order to ensure that the prosthesis is capable of function as fitted. Accordingly, the prosthetist must be thoroughly familiar with initial training procedures lest unnatural motions have to be unlearned.

The primary purpose of the second clinic visit is to ensure that the amputee is ready for training. Included is an evaluation of his physical and mental condition as well as of the degree of comfort and function provided by the prosthesis. A simple but comprehensive series of tests has been developed to aid in evaluating functional aspects in upper-extrem-

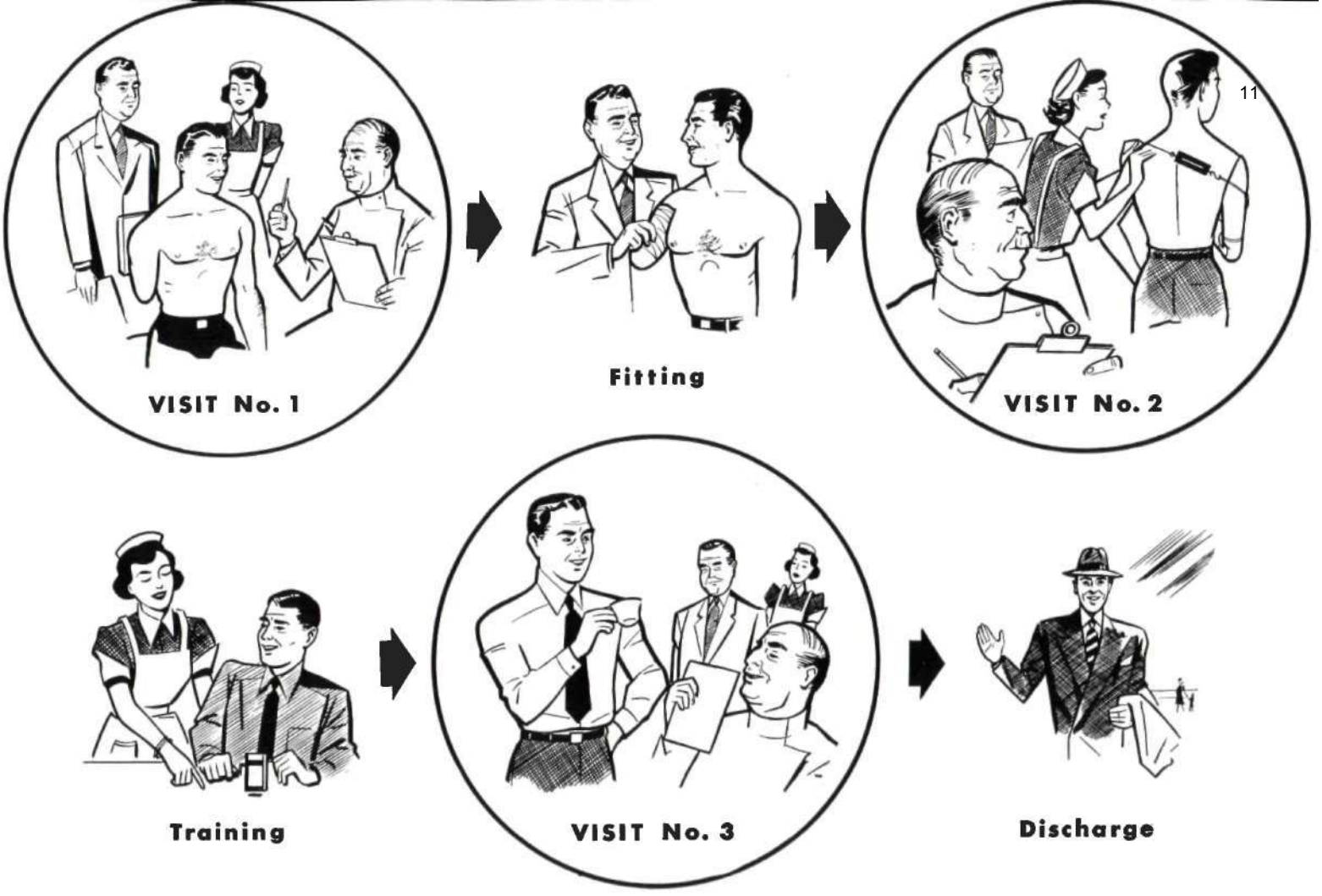

Fig. 1. Steps in the clinic—team procedure.

ity cases, and a description of these appears elsewhere in this issue (page 25).

When the team is satisfied that training is in order, the patient is referred to the therapist for this phase of the rehabilitation procedure. Although a patient and his prosthesis may meet all the criteria of the checkout procedures during the clinic session, quite often use of the prosthesis or changes of the stump during training make modifications necessary. Hence, the more familiar the therapist is with the functional aspects of the various components of the prosthesis the more quickly can he call such deficiencies to the attention of the team. Not only is time saved, but factors which tend to discourage many amputees are eliminated. The over-all result is added confidence in the prosthetics team.

VISIT NO. 3

Upon completion of training, the amputee is once more brought before the clinic team for a final evaluation of his ability to resume an active role in society. The patient should be encouraged to request the services of the team whenever required and also to report for follow-up examinations at regular intervals. The length of time between visits depends, of course, upon the peculiarities of each case, but as a rule it is best that the patient be examined at least once a year.

UPPER-EXTREMITY PREPRESCRIPTION FORM

PART I

1. Name.....Date.....
2. Home address.....Business address.....
3. City.....Phone contact.....
4. Age.....Height.....Weight.....
5. (Circle those which apply) Male Female Single Married
6. Amputee referred by.....
7. Education (in years) and field of specialization.....
8. Present occupation (title and description of duties).....
9. Occupation prior to amputation.....
10. Future occupational plans.....
11. Hobbies or recreational interests.....
12. What does the amputee think of his present prosthesis and its parts (function, appearance, desired improvements, etc.)?.....
13. In each of the following areas, list activities in which the prosthesis is used. If prosthesis is not generally worn, list activities in which the stump is used.
    a) Dressing.....
    b) Eating.....
    c) Working.....
    d) Recreation.....
14. How often does the amputee wear his prosthesis?
    a) Hook worn.....hrs. a day and.....days a week.
    b) Hand worn.....hrs. a day and.....days a week.
15. What benefits does the amputee think would result from wearing an improved (or securing a first) prosthesis?.....
16. Does the amputee have decided preferences or dislikes for particular prosthetic components? If yes, please explain.....
17. Before amputation was the amputee right-handed..... left-handed....., or ambidextrous.....?

PART II

1. Date.....

2. Date and cause of amputation .....

3. Amputation: Right.....Left.....

4. Stump length: BE.....inches medial epicondyle to end; AE.....inches acromion to end; AE.....inches axilla to end.

5. Arm length on sound side.....inches medial epicondyle to ulnar styloid.
.....inches acromion to lateral epicondyle.

6. Limitations of motion of shoulder girdle (elevation; depression; forward shrug; rearward shrug):.....

7. Indicate in degrees and by standard muscle-testing procedures the range of motion and strength of the stump in the following movements:

Pronation	(BE).....	Strength.....
Supination	(BE).....	Strength.....
Elbow flexion	(BE).....	Strength.....
Stump flexion	(AE).....	Strength.....
Stump extension	(AE).....	Strength.....
Stump abduction	(AE).....	Strength.....
Stump rotation	(AE).....	Strength.....

8. Stump characteristics (check as many of the following as apply):

Screwdriver shape (BE).....	Edematous.....
Cylindrical.....	Firm .....
Tapered.....	Loose and flabby.....
Bulbous.....	Probable shrinkage.....
Bony prominences	Pain.....

9. Special considerations (medical conditions, etc.):.....

10. Describe prosthesis now worn:
a) Terminal device(s).....
b) Wrist (disconnect, flexor, rotator).....
c) Forearm (material and construction).....
d) Elbow (hinges, BE).....
e) Upper-arm cuff (type and material, BE) .....
f) Elbow (type and control, AE) .....
g) Socket (material and construction, AE).....
h) Harness and control system (description of harness and cable as well as materials used).....

11. Present arm made by .....Worn.....Years
Previous arms worn.....Years

12. a) In what respects is the present prosthesis unsatisfactory? Explain.....
b) In what respects is the present prosthesis satisfactory? Explain.....

13. In each of the categories listed below, the amputee's control of his prosthesis is: Good; Fair; Poor (Specify)
a) At mouth .....
b) At waist.....
c) At floor .....
d) Generally (have amputee handle a few objects).....

14. Rate on a 5-point scale (5, excellent; 1, poor) amputee's physical suitability for wearing a prosthesis (consider stump length, strength, range of motion, pain, sensitivity, etc.)
Rating..... Comments.....

Fig. 2. Typical preprescription information form for upper-extremity amputation.

Patient's name ..... Date .....
Type of amputation .....
Medical and Surgical Considerations
1. a) Are there any medical or surgical conditions which should receive attention?
Yes ..... No .....
b) If yes, please specify condition and indicate treatment .....
.....
.....
2. a) Is physical therapy indicated? Yes ..... No .....
b) If yes, please specify kind, dosage, duration, reason for prescription, and intended result .....
.....
3. Should fitting be delayed until treatment indicated above is completed? Yes ..... No .....
Prescribed Equipment
4. What is the indicated type of prosthesis? .....
5. Below-elbow prosthesis:
a) Cuff: Triceps pad ..... Half ..... Full ..... Epicondyle cuff ..... Epicondyle clip ..... Epicondyle strap .....
b) Elbow hinge: Leather ..... Cable housing ..... Insert ..... Metal side strap ..... Polycentric (step-up) ..... Other .....
c) Socket: Double wall ..... Single wall ..... Rotation type ..... Split socket .....
d) Socket material .....
e) Special modifications .....
.....
6. Above-elbow and shoulder-disarticulation prosthesis:
a) Socket: Double wall ..... Single wall ..... Shoulder cap ..... Sectional plates .....
b) Socket material .....
c) Elbow unit .....
d) Special modifications .....
.....
7. Terminal device(s) and wrist device(s):
a) Hook ..... Hand .....
b) Disconnect unit .....
c) Wrist flexion unit .....
d) Wrist rotation unit .....
e) Wrist length adapters .....
8. Harness:
a) Type .....
b) Material .....
c) Special modifications .....
9. Control system: Single ..... Dual ..... Triple ..... Other .....
10. Miscellaneous instructions .....
.....
.....
.....
.....
Physician

Fig. 3. Typical prescription form for upper-extremity prostheses.

CONCLUSION

The concept of the Prosthetics Clinic Team is not a mere theory. Under the direction of Dr. Augustus Thorndike, the Prosthetic and Sensory Aids Service of the Veterans Administration has established 30 such teams since 1949. Others are in operation in private clinics and within the Armed Services. The initial success of these teams, often under very difficult operating conditions, has led the Advisory Committee on Artificial Limbs to stimulate development of evaluation techniques that can be used under clinical conditions and to encourage the use of the clinic-team approach for amputee rehabilitation generally.

The Upper-Extremity Prosthetics Armamentarium

MAURICE J. FLETCHER, Lt. Col., USA (MSC)[1]

The word "armamentarium" is defined as "the equipment, instruments, apparatus, or paraphernalia used by the practitioner of medicine." As applied to artificial limbs, it refers to the array of components necessary for the prescription fitting of prostheses in relationship to the site of amputation.

In the prosthetics armamentarium, it is desirable that a complete range of components be available in order to provide satisfactory prostheses for all sites of upper-extremity amputations. A few gaps still remain in the present armamentarium of devices, but such temporary inadequacies are in the area of special cases, such as in transcarpal and forequarter amputations and in children's prostheses.

The few remaining gaps are being rapidly filled, and supplementary components for fortifying the present armamentarium, such as additional hand sizes, are under consideration at the present time. The fact that devices now exist in each category of necessary arm components does not necessarily mean that they are the ultimate. They might even be interim devices, but they do permit prescription fitting of arm prostheses to a degree of efficiency heretofore unattainable.

As a device is made available for each category of the armamentarium, improvements are attempted in these individual devices to increase their efficiency and usefulness to the amputee. New models and methods of operation are being exploited in the hope of providing, eventually, even more efficient restorative prostheses. It is the purpose here to provide brief descriptions of the functions provided by the basic units of the present upper-extremity armamentarium. For a more detailed treatment of the devices and the philosophy underlying their design, reference may be had to *Human Limbs and Their Substitutes* (McGraw-Hill, in press) and to the *Manual of Upper-Extremity Prosthetics* (University of California at Los Angeles, 1952).

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TERMINAL DEVICES

A.PRL MODEL 4c VOLUNTARY-CLOSING HAND AND COSMETIC GLOVE

As the name implies, in the APRL voluntary-closing hand (Fig. 1) prehension force is obtained voluntarily by the amputee. Tension applied to a control cable closes the index and middle fingers against the thumb in a three-jaw-chuck pattern. These one-piece, hollow, metal fingers move through a 1 1/2-in. range, but since the thumb tip can be set in either of two positions 1 1/2 in. apart, objects up to 3 in. wide can be grasped. Finger angles are such that a grasped object is forced inward toward the palm. Security of grasp is further increased by the use of felt pads on the inner surfaces of the fingers and thumb. Any degree of prehensile force up to about 35 lb. can be obtained. The ring and little fingers are of cast latex and are attached so that they roughly conform to the shape of the object being handled.

The actuating mechanism, shown in Figure 1, consists of a cam-quadrant type of clutch which automatically locks the index finger and middle finger in place when tension in the control cable is released. Reapplication of tension automatically unlocks the mechanism, and a spring forces the fingers to the fully open position, at which point the mechanism is recocked and ready for another cycle. Backlash is eliminated in the lever system by incorporation of an auxiliary spring-and-lever

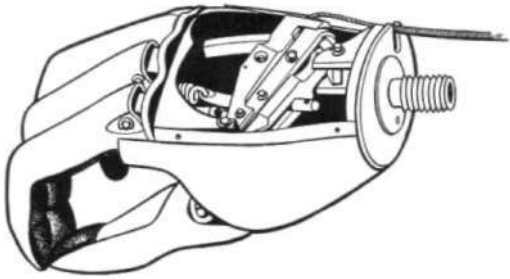

Fig. 1. APRL model 4C voluntary-closing hand.

system. In fact a certain amount of frontlash may be introduced into the system. The voluntary-closing type of mechanism permits fuller utilization of the potentialities of a cineplasty tunnel than any device heretofore available.

The APRL hand is covered by a cast polyvinyl chloride glove of extremely natural appearance (Fig. 2). Developed especially for the APRL hand, it has been designed with particular regard to eliminating as much as possible the resistance to operation of the fingers. In order to reduce the necessarily high cost of coloring each glove on a custom basis, after careful experimentation six Caucasian and six Negroid shades have been provided. They satisfy the majority of amputees.

APRL VOLUNTARY-CLOSING HOOK

The APRL voluntary-closing hook (Fig. 3) contains essentially the same mechanism employed in the APRL hand. One hook finger is closed against a stationary hook finger, the two designed to accommodate objects up to 3 in. in size. A control button permits the engagement of a stop to limit hook opening to 1 1/2 in. so that the hook finger does not have to move through its full range before recocking of the locking mechanism takes place. Moreover, locking action in the 1 1/2-in. open position can be eliminated at the will of the amputee when this is desired for repetitive tasks. The rubber-lined, lyre-shaped, aluminum hook fingers are specially designed to provide maximum function. The smooth exterior surfaces present the least amount of friction to aid in entering pockets, while the rubber linings provide friction to aid in handling objects. Duckbill finger tips lend facility in handling small objects. By removing the fingers and reinstalling them 180 deg. from the original position, a right hook can quickly be converted to a left, or vice versa.

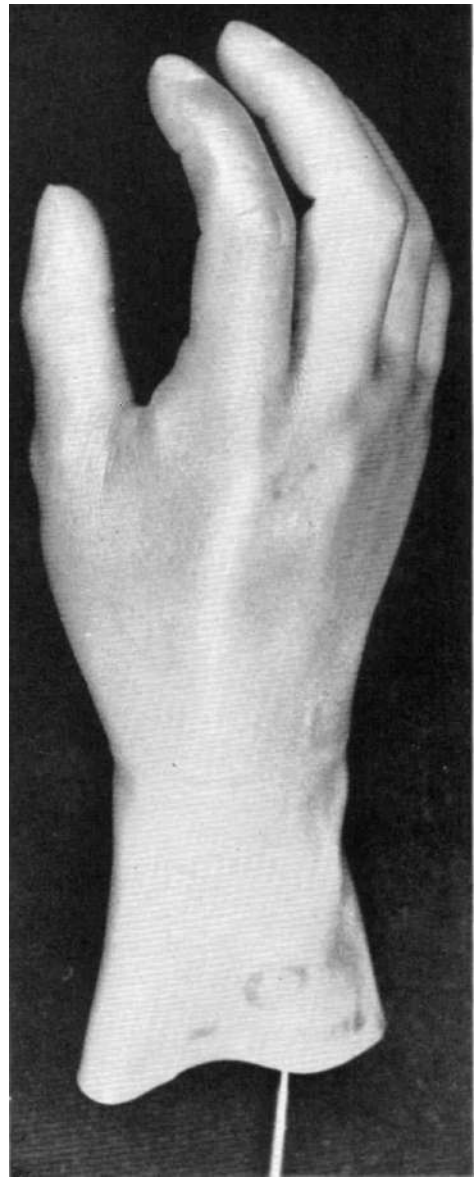

Fig. 2. APRL model 4C voluntary-closing hand covered with APRL cosmetic glove.

NORTHROP-SIERRA VOLUNTARY-OPENING TWO-LOAD HOOK

In the Northrop-Sierra voluntary-opening two-load hook (Fig. 4), designed primarily for

bilateral amputees, tension on the control cable causes one hook finger to open against a spring force, which in turn provides prehensile force between the hook fingers when there is no tension on the control cable. The spring force is provided by two identical coil-type springs. When both are engaged, a prehensile force of approximately 7 lb. is available at the finger tips. When only one spring is engaged, 3 1/2-lb. of force are available.

The lyre-shaped fingers are the same as those used in the APRL hook.

DORRANCE VOLUNTARY-OPENING HOOK

Prehension in the Dorrance hooks is provided by rubber bands which force the hook fingers together. Adjustment of the prehension force is accomplished by adding or removing bands. Hook fingers are available in many different sizes and shapes of both steel and aluminum. Dorrance hooks offer the extreme in ruggedness and simplicity. The model known as Utility # 5, shown in Figure 5, is very popular.

LENGTH ADAPTERS AND FAIRINGS

To provide a constant effective prosthetic length when terminal devices of different lengths are interchanged, as in the case of the APRL hook and hand, length adapters and fairings (Fig. 6) have been made available. The length adapter is simply a stud with male threads at one end and female threads at the other so that it may be inserted between terminal device and wrist unit. Also available is a plastic fairing which covers the length adapter and provides a smooth transition between the oval end section of the APRL hand' and the circular section of the wrist unit. .

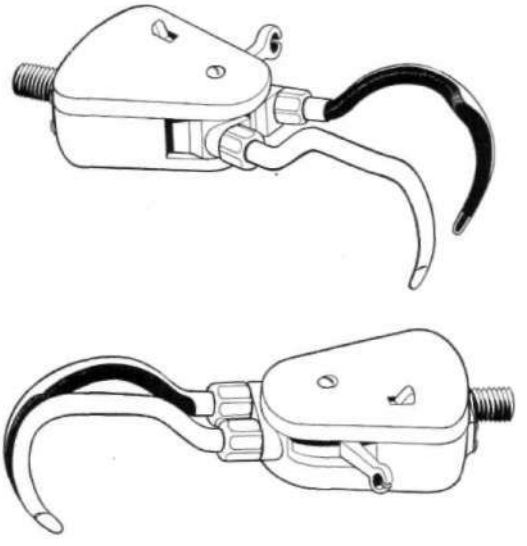

Fig. 3. APRL voluntary-closing hook in open and closed positions.

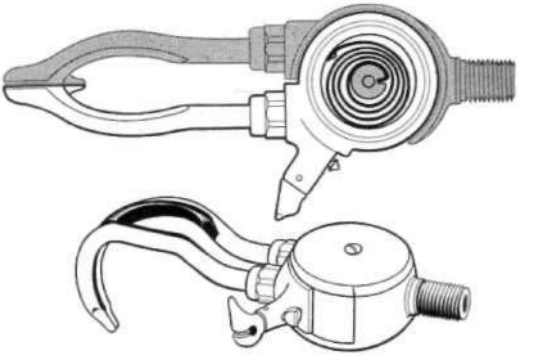

Fig. 4. Northrop-Sierra voluntary-opening two-load hook. Schematic diagram (above) shows arrangement of hook thumb and enclosed coil springs.

WRIST UNITS

MANUAL FRICTION-TYPE WRIST UNITS

Female threads receive the stud of the terminal device, the wrist-flexion unit, or the*

Fig. 5. Dorrance #5 utility hook.

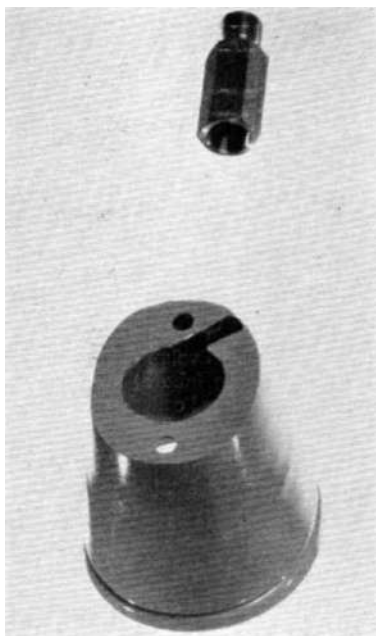

Fig. 6. Wrist fairing and length adapter for APRL model 4C hand.

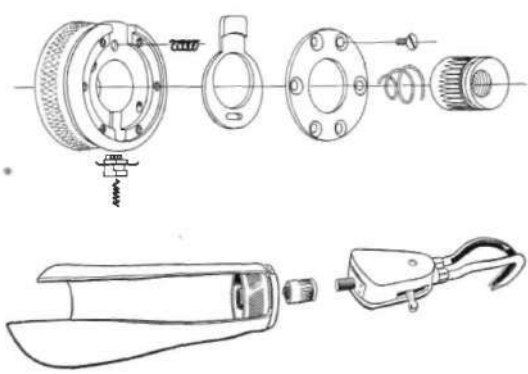

Fig. 7. Hosmer F-M wrist unit, with exploded view showing arrangement of parts.

length adapter to permit attachment of these units to the arm. Compression of a rubber washer between the terminal device and the wrist unit provides sufficient friction to permit a certain amount of adjustment in the rotation of the terminal device without slippage under average operating conditions. SierraEngineering Company supplies the friction-type wrist unit in one size, 2 in. in diameter, suitable for the average adult male, while Hosmer supplies essentially the same unit in three sizes—2 in. in diameter for the average male, 1 3/4 in. in diameter for women and large children, and 1 3/8 in. in diameter for small children. All these units are designed to facilitate incorporation into plastic-laminate arms.

MANUAL LOCK-TYPE WRIST UNITS

Hosmer F-M Wrist Unit

Rapid interchange of terminal devices and positive locking of the terminal device in the pronation-supination plane are afforded by the Hosmer F-M (Fletcher-Motis) unit (Fig. 7). A serrated steel adapter with an annular groove is attached to the stud of the terminal device by threads. To connect the terminal device to the arm, the stud is forced into the wrist unit until a locking yoke and gear segment are engaged. To adjust the amount of rotation of the terminal device, the control button is depressed to the first detent, which releases the gear lock and permits rotation since the terminal device is retained by engagement of the locking yoke in the annular groove on the adapter. Further depression of the control button disengages the locking yoke and permits removal of the terminal device. A coiled compression spring attached to the end of the adapter facilitates operation of the F-M unit.

Hosmer Quick-Change Wrist Unit

The Hosmer quick-change wrist unit provides essentially the same function as the F-M unit but is not quite as rugged and is more difficult to operate in some instances. The adapter and terminal device are released by rotating the forward portion of the wrist section, which disengages a detent-type lock. The quick-change unit is lighter in weight than the F-M unit and is used when weight is an important factor.

NORTHROP-SIERRA WRIST-FLEXION DEVICE

The Northrop-Sierra Model B wrist-flexion device (Fig. 8), when used, is installed between the terminal device and the wrist unit. Consisting of a simple detent-type lock with three positions, it permits manual positioning and locking of the terminal device at 0, 25, and 50 deg. of flexion. Depression of a control button at the base of the unit disengages the lock to permit a change in the amount of wrist flexion.

Fig. 8. Northrop-Sierra model B wrist-flexion device.

Bilateral amputees find this device especially useful for working in areas close to the face and body, and some unilateral amputees have found it helpful in certain tasks necessary to their particular occupation.

APRL-SIERRA WRIST-ROTATION STEP-UP UNIT

The APRL-Sierra below-elbow wrist-rotation unit (Fig. 9) has been developed to step up or multiply the residual pronation-supination of below-elbow amputees. A given rotation of the inner socket by the stump produces, through a planetary gear system, 2.3 times that amount of rotation in the terminal device. A locking mechanism, actuated by relative motion between the forearm and upper arm, and by which the unit is unlocked upon full extension of the forearm and locked upon flexion, is provided when desired.

Below-elbow amputees with little or no pronation-supination and nearly conical stumps have been fitted successfully with this unit, since rotation of the inner socket can be produced by rotating the humerus. In this case the lock must be provided so the stump may rotate relative to the socket upon flexion.

BELOW-ELBOW HINGES

ROBIN-AIDS FLEXIBLE HINGES

Where no wrist-rotation step-up unit is used, the Robin-Aids flexible hinge (Fig. 10, bottom) is employed between the socket and arm cuff or triceps pad to impart axial stability to the entire prosthesis and yet to permit maximum use of the residual pronation-supination. The Robin-Aids hinge consists of a metal cable covered with a wrapped-wire housing and having flat terminal plates designed for firm anchoring in the plastic-laminate forearm and for fastening to the upper-arm cuff.

LEATHER-STRAP HINGES

Nylon-coated leather straps may be fabricated in the shop and used in lieu of the Robin-Aids flexible hinge.

SINGLE-AXIS HINGES

Metal single-axis hinges specially designed for plastic fabrication are available from several manufacturers. This type of hinge is used where maximum stability is required, such as in short below-elbow cases and in heavy-duty arms.

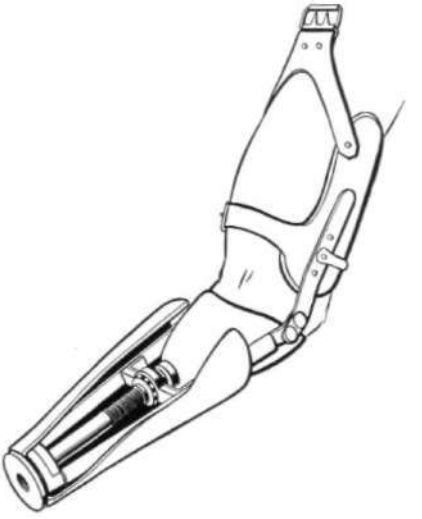

Fig. 9. APRL-Sierra wrist-rotation step-up unit.

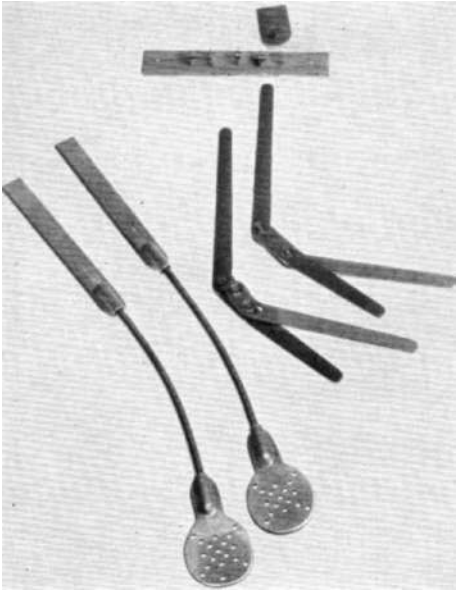

Fig. 10. Below-elbow hinges. Top, Sierra insert hinge; center, Hosmer variable-ratio step-up hinge; bottom, Robin-Aids flexible hinge.

POLYCENTRIC HINGES

Polycentric hinges may be substituted for the single-axis hinges. They are preferred by many prosthetists because less care is required in location to give the same amount of comfort to the patient. Instead of a single axis, two hinge points are provided in this unit, thereby exerting less pressure on the stump through the socket when the forearm is flexed and when some slight misalignment exists.

NORTHROP-SIERRA INSERT HINGES

Insert-type hinges might be classified as semiflexible hinges, since they provide a degree of stability somewhere between that offered by the flexible Robin-Aids hinge or the leather strap and the solid steel hinges. They are generally used on medium below-elbow prostheses where sufficient stability cannot be obtained with the flexible hinge but where the stump is long enough to provide sufficient stability so that the metal-strap hinges are unnecessary. Insert hinges are installed in "ears" on the distal end of a leather arm cuff so that the cuff may be hinged about the proximal end of the forearm socket. The method of assembly is illustrated in Figure 10, top.

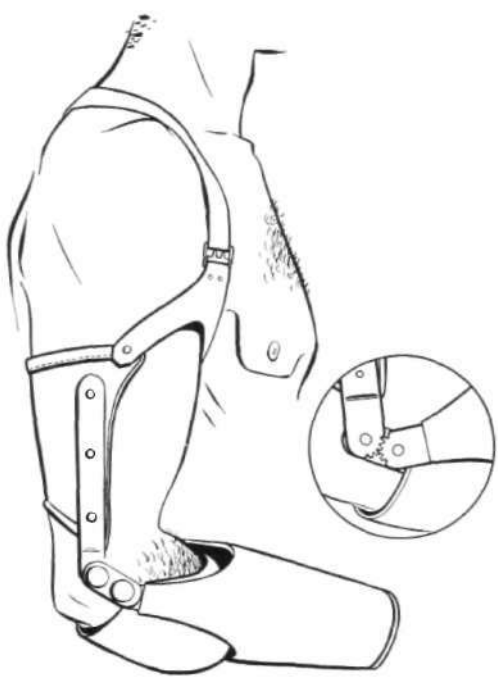

Fig. 11. Hosmer MA-100 step-up hinge.

STEP-UP HINGES

Hosmer MA-100 Hinges

The Hosmer MA-100 step-up hinge (Fig. 11) was developed to permit full flexion of the prosthetic forearm when flexion of the stump is limited to 90 deg. or more. Step-up action is provided through two gears so that flexion of the stump 90 deg. results in 135 deg. of forearm flexion. The multiplication in motion results in a corresponding decrease in torque about the prosthetic forearm, and often an assistive lift is required for forearm flexion. This is accomplished by employing one of the above-elbow harnessing systems.

Hosmer Variable-Ratio Step-Up Hinge

The Hosmer variable-ratio hinge (Fig. 10, center) provides approximately the same function as the MA-100 hinge but is usually preferred because the changing ratio of stump action to forearm action provided by the sliding lever system results in easier operation. This ratio in the fully extended position is 1:1.8, increases to 1:1.3 when the forearm is flexed 90 deg., and decreases to 1:1.8 at the 135-deg. position. Furthermore, because of the sliding action of the hinge, the stump does not extend as far below the forearm in flexion as in the case of the MA-100 hinge, a fact which in many instances eliminates the necessity for enlarging the sleeve of the garment covering the artificial limb.

ROBIN-AIDS STUMP-ACTUATED ELBOW LOCK

The Robin-Aids elbow (Fig. 12) was designed for short below-elbow cases where flexion of the forearm is limited to less than 90 deg. or for those cases where the torque about the elbow is too weak to offer sufficient stability. Full extension of the stump forces a lever into a detent on a segment about the elbow axis, locking the forearm in flexion.

Fig. 12. Robin-Aids stump-actuated elbow lock.

ELBOW UNITS FOR ABOVE-ELBOW CASES

NORTHROP MODEL C ELBOW

An alternating-type control for the locking mechanism is the prominent feature of the Northrop Model C elbow (Fig. 13). The first pull on the control cable drops a lever into a detent on a sector, resulting in a positive locking action about the elbow axis. The next pull on the control cable removes the locking lever from the detent, thereby making the forearm free to rotate about the elbow axis. Eleven locking positions are available.

In the average above-elbow case, the control cable is generally actuated by humeral extension, leaving the other hand or prosthesis, as the case may be, free. The excursion required, about 3/8 in., is so slight that after some practice most amputees are able to operate the locking unit with a motion that goes unnoticed.

Attachment to the upper arm is afforded by a single bolt in a turntable arrangement which permits the amputee to select at will the plane of forearm flexion and extension. A specially designed saddle for lamination into plastic is used for attaching the unit to the forearm.

The Northrop elbow is presently available in one size only, 3 in. in diameter.

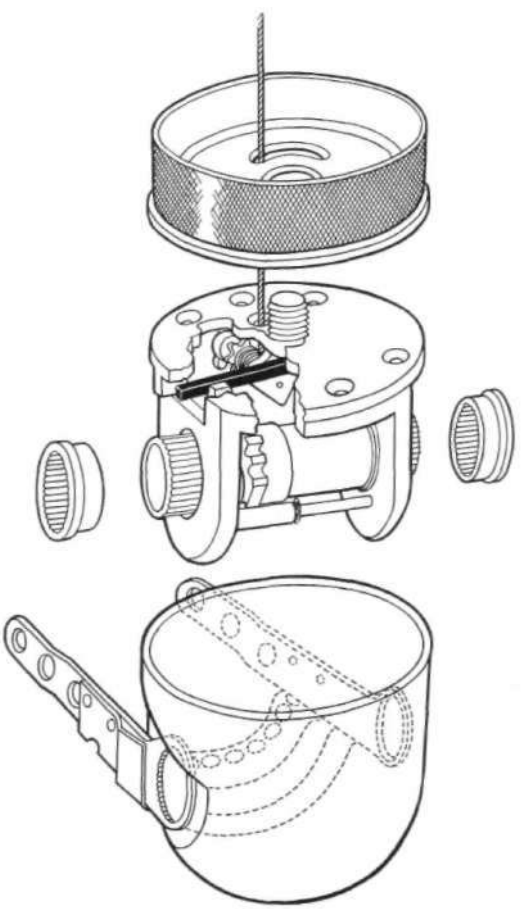

Fig. 13. Northrop model C elbow unit.

HOSMER ELBOW UNIT

Locking action of the Hosmer elbow unit (Fig. 14) is accomplished by permitting two tightly wound coil springs to wrap themselves around a shaft. Such an arrangement permits an infinite number of locking positions. Attachment to the arm and forearm and operation by the amputee follows the same pattern as in the case of the Northrop Model C.

The Hosmer unit is available in two sizes, approximately 2 and 3 in. in diameter. Recently Hosmer has added to its line a smaller elbow designed for children.

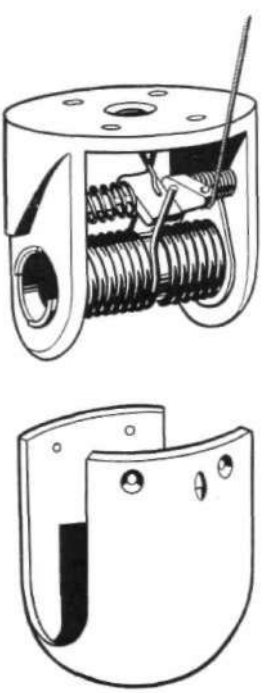

Fig. 14. Hosmer elbow unit, without turntable or forearm saddle attachments.

ELBOW-DISARTICULATION PROSTHESES

The APRL-Sierra side-locking elbow hinge (Fig. 15) was developed expressly for elbow disarticulation and for very long above-elbow cases where insufficient room exists for the fully enclosed type of elbow unit. An alternating-type locking unit on the outside of the inner hinges permits locking and unlocking of the elbow by humeral extension, as in the case of the standard above-elbow amputee. This unit may also be used on short below-elbow cases where use of the Robin-Aids forearm-actuated lock is not feasible.

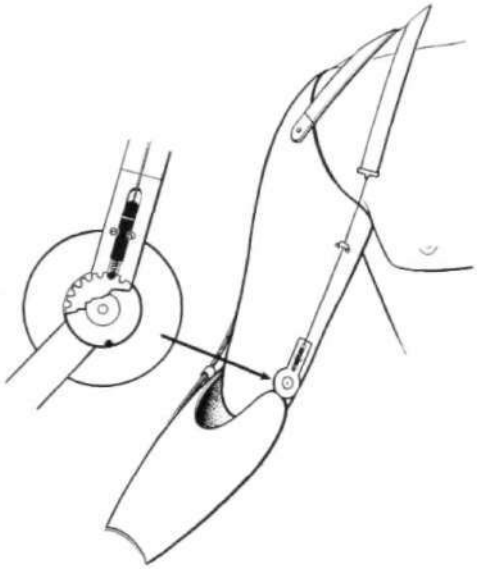

Fig. 15. APRL-Sierra outside-locking elbow hinge.

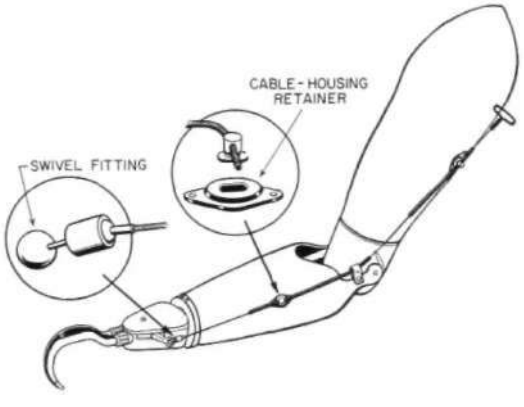

Fig. 16. Bowden-type control cable and attachments.

CONTROL SYSTEMS

For terminal-device operation and forearm control, Bowden-type controls, along with such parts as retainer and terminal fittings specially designed for use on artificial arms, are available from a number of sources for both the harness and cineplasty applications. This type of control system (Fig. 16), consisting of high-strength woven wire cable enclosed in a wrapped-wire housing, has proven infinitely more satisfactory than anything else used to date, mainly because of its resistance to stretching and its relatively high power-transmission efficiency.

BELOW-ELBOW BICEPS CINEPLASTY CONTROL SYSTEMS

Special control-system kits are available for below-elbow amputees with biceps cineplasty tunnels. The twin-cable system (Fig. 17), often

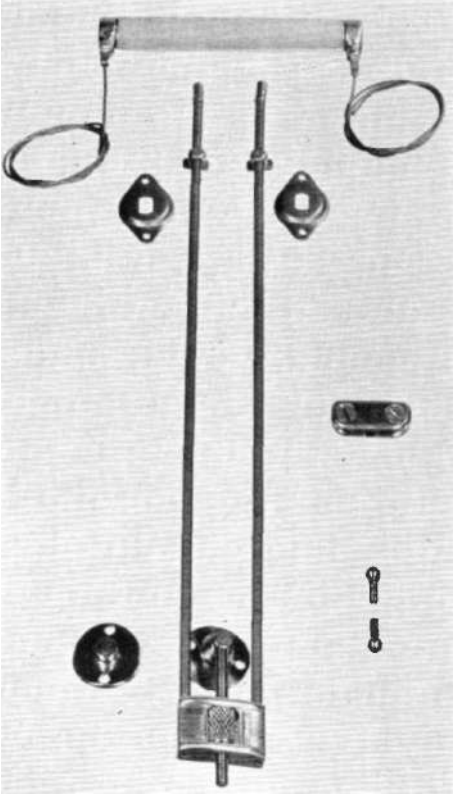

Fig. 17. Twin-cable control system for below-elbow biceps cineplasty.

referred to as the UCLA system, is available with either straight or ox-bow acrylic tunnel pins reinforced with a copper core. Provisions have been made for quickly attaching or removing the control cables with respect to the pin. Rapid selection of the initial tension on the muscle tunnel is made possible by the incorporation of a turnbuckle type of unit which controls the effective cable length.

A single-cable system using a sheave-type equalizer and known as the APRL system is also available (Fig. 18). Cable-tension adjustment is provided by a single cable-length adjuster installed between the sheave and the terminal device. Each of these systems is considered merely as a replacement for the shoulder-operated control system, since all other portions of the prosthesis are the same whether operated from the shoulder or from the muscle tunnel.

NUDGE CONTROL

For the shoulder-disarticulation case, in which it is impossible to provide from shoulder movement force and excursion necessary to operate the Northrop Model C or Hosmer elbow, there is available the Nudge Control, which permits the elbow lock to be controlled by chin movement. The nudge control (Fig. 19) is especially useful for bilateral shoulder-disarticulation cases.

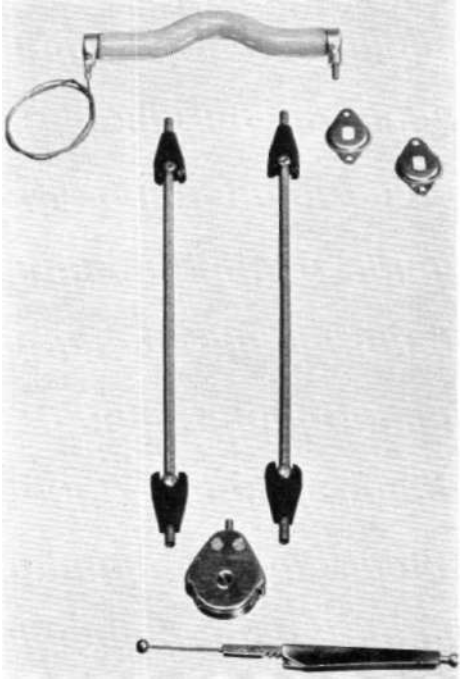

Fig. 18. APRL single-cable control system for below-elbow biceps cineplasty

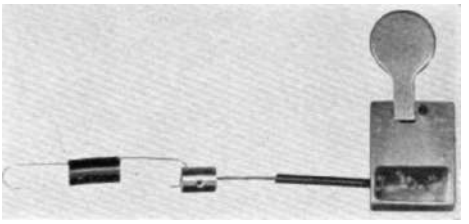

Fig. 19. Nudge control for operation of elbow lock in shoulder-disarticulation case.

CONCLUSION

This, briefly, completes the basic items of the armamentarium of devices available for prescription fitting relative to sites of amputation. There are, however, many supplementary devices, available in the field and well known to the industry, which are used with the devices described.

With the existence of the many devices now on the market, it is possible to custom-build prostheses to rare or irregular cases, and to increase the number of items in the armamentarium makes such custom-building more feasible. A number of improvements are constantly being made in the research establishments on existing devices, and these, of course, will be fed into the industry as they are developed to the point where they are considered commercially marketable and necessary items of the armamentarium.

Needless to say, each existing armamentarium item is being accorded careful study by the various research groups in an effort to increase efficiency and utility. Many new devices are now in the research stage; some are approaching the transitional period; others are known to be necessary and steps have been taken to prove such devices and to production-engineer them to the point where they will be marketable from the standpoint of increased efficiency, decreased maintenance, and economics. To mention a

few items, the goals sought include improved terminal devices, both hand and hook; the cosmetic glove; improved elbow-lock mechanisms and elbow mechanisms themselves; the cosmetic approach to the entire prosthesis, up to and including the shoulder; and improvement of the over-all control systems to make them more efficient and more durable than are those now available. Already existent items of the armamentarium, such as harnesses, harness materials, and fittings, have been passed by purposely in this discussion, since they are well known to the industry. The use of some of the new synthetic materials, such as nylon, orlon, and dacron webbing, is standard practice in most limbshops. These new webbings are perspiration-resistant and possess adequate strength to meet the requirements of modern prosthetic devices. New webbings of various types and structures are constantly under study and test. Steady improvement has been made in the process of weaving these materials to prevent stretching.

It is hoped that, through the gradual improvement of all items of the armamentarium, the comfort and utility of upper-extremity prostheses will be increased to the point where an amputee will continuously wear and use a prosthetic device and will no longer be considered by society as a handicapped person. It may then be realized that the amputee can perform his job as well as can the normal person. The prescription fitting of each individual case may become so precise and so efficient that there will no longer be a question as to the value of the prosthesis to the amputee in returning to his place in society. The continuous development of new items for the armamentarium, and improvement in items existing in the present armamentarium, will make available to the prosthetist a variety of components permitting the satisfactory fitting of each amputee in conformance to his own individual pattern of life and will permit the new amputee to resume many jobs without loss in efficiency.

Artificial Arm Checkout Procedures

Lester Carlyle, M.E.[1]

The story of civilization's slow but steady march of progress from the days of the Roman Empire, through the Industrial Age, and into the present Technological Age is the story of measurements. The standardization of such common units as the inch and the foot required thousands of years, but once that was accomplished, it paved the way for an almost unbelievably rapid technological advance. One need only compare the developments that have occurred since the metric system was devised in 1793 with those of all the preceding centuries. Replacement of the craftsman's personal art with clearly understood, standard methods has enhanced the lives of all of us by making simple necessities, as well as more luxurious items, available in more adequate quantities and at more reasonable prices.

Just as mankind in general profited from measurement standardization, so can those who have lost a limb or limbs and those who devote themselves to replacing lost members. Every person concerned with the manufacture and fitting of a prosthesis—whether he be a prosthetist, amputee, trainer, or representative of the paying agency—has felt the need for some set of standards to determine the worth of the prosthesis. Development of such a "yardstick of performance" was just as necessary to the advancement of the prosthetics industry as was the standardization of the inch to the Industrial Age. The so-called "checkout procedures" provide the prosthetist and other members of the clinic team with an invaluable tool for measuring the biomechanical effectiveness of all upper-extremity prostheses.

Such questions as "Does this prosthesis fit as well as your last one?" or "Can you work it?" receive only a vague, often uncertain, answer, but such criteria are too often accepted as a measure of performance. One of the first steps in establishing a set of standards is to determine which variable factors can be measured accurately. In upper-extremity prosthetics, some of the measurable factors are ranges of motion with and without the prosthesis, control-system efficiencies, forces necessary to flex the forearm, live-lift of the forearm, socket stability, movement of the terminal device when locking the elbow, plus several others. Once the factors are determined, a test program must be set up and carried out. The results of such a test must first be analyzed, then a trial set of standards must be established, and finally the standards must be laboratory-tested on as great a number of amputee subjects as possible.

To this end, a test station was established, and 29 amputees, selected at random from a mailing list, were tested. Approximately 30 tests were applied to these amputees and their prostheses. By combining the test data with research and practical experience, a preliminary set of liberal standards was drawn up. The standards were then applied to more than 70 amputees during the two-year existence of the Case Study Program at the University of California at Los Angeles. Certain modifications and refinements in the tests were made until the procedure attained present form.

One of the prime requirements in establishing the tests was that their application be kept simple, with respect both to the equipment and to the procedures to be followed. Sufficient accuracy of measurement can be obtained with a ruler and a spring scale, and the test standards are liberal enough to allow minor inaccuracies without rejecting the prosthesis. The most important concern is, first, that all tests be applied in a similar manner and, second, that the results be compared to a universally acceptable standard.

[1] Engineer, Artificial Limbs Project, University of California, Los Angeles.

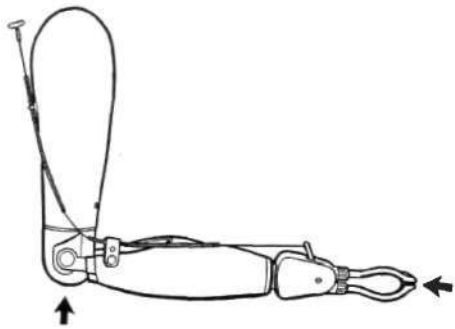

Fig. 1. Test for compression fit and comfort.

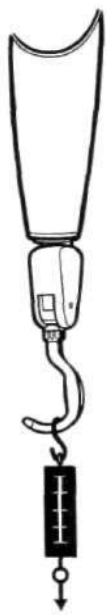

Fig. 2. Test for tension stability.

The tests and standards may be conveniently listed in three groups: general tests, applicable to all types of prostheses; tests for below-elbow prostheses; and tests for above-elbow prostheses.[2]

All tests should be performed with the amputee wearing his prosthesis. In the case of a bilateral amputee, each side should be tested separately, but the amputee should have almost complete independence of action on each side while wearing both prostheses.

GENERAL TESTS

TEST NO. 1—COMPRESSION FIT AND COMFORT

Test: Flex the forearm to 90 deg. (lock if AE). Push the prosthesis onto the stump while the wearer resists the push (Fig. 1).

Standard: The amputee should feel no undue discomfort or pain when the prosthesis is forced onto the stump.

TEST NO. 2—TENSION STABILITY

Test: Straighten the prosthesis at the side (Fig. 2). Hook the scale over the terminal device and apply a force of 50 lb. straight down. (A force of 30 lb. is sufficient for children.)

Standard: The prosthesis should not slip more than 1 in. in relation to the stump, and no part of the prosthesis or harness should fail when a 50-lb. distal load is applied.

TEST NO. 3—HOOK-OPENING FACILITY (NORMAL USE)

Test: Flex the forearm to 90 deg. (lock if AE). Have the wearer actively operate the terminal device.

Standard: The wearer should be able to obtain full range of terminal-device operation actively with the forearm flexed to 90 deg.

TEST NO. 4—HOOK-OPENING FACILITY (AT MOUTH AND PERINEUM)

Test: Flex the forearm so the terminal device is near the mouth (lock if AE). Have the wearer actively operate the terminal device. Repeat this procedure with the terminal device near the perineum.

Standard: The wearer should be able to obtain at least 70 percent of full range of terminal-device operation actively at the mouth and perineum.

TEST NO. 5—CONTROL-SYSTEM EFFICIENCY

Test: a) Disconnect the control cable from the terminal device, and attach the scale to hook-operating lever or hand-operating cable (Fig. 3a). Place a 3/4-in. block between the fingers and pull until the block slips out of a voluntary-opening hook or until the fingers of a voluntary-closing hook or hand just close on the block. Note the force at this instant.

b) Reconnect the control cable to the terminal device, and apply the scale to the T-bar, or terminal, at the other end of the control cable. Pull along the line of the harness until the block slips or the fingers touch, as before (Fig. 3b). Note the force at the instant this occurs.

c) Multiply the force measured at the terminal device by 100. Then divide by the force measured at the cable terminal as in the following formula:

$$\text{Efficiency} = \frac{(\text{Force measured at terminal devices}) \times 100}{(\text{Force measured at cable terminal})}$$

[2] These tests and standards may not apply in cases where atrophy, bone blocks, loss of muscles, and the like are in evidence.

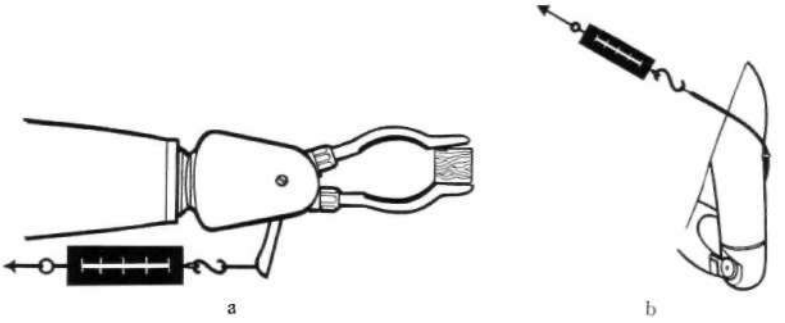

Fig. 3. Test for control-system efficiency.

Standard: The control-system efficiency should be at least 70 percent.

BELOW-ELBOW AND BELOW-ELBOW BICEPS-CINEPLASTY TESTS

All of the following tests apply to the conventional below-elbow prosthesis and to the below-elbow biceps-cineplasty prosthesis.

TEST NO. 1—FOREARM FLEXION

Test: Compare the amputee's maximum range of forearm flexion with and without the prosthesis.

Standard: Active flexion with the prosthesis on should be as great as active flexion without the prosthesis.

TEST NO. 2—FOREARM ROTATION[3]

Test: Compare the amputee's maximum range of forearm rotation (extreme pronation to extreme supination) with and without the prosthesis (Fig. 4).

Standard: Active rotation with the prosthesis on should be at least half that obtained without the prosthesis.

ABOVE-ELBOW AND SHOULDER-DISARTICULATION TESTS

All of the following tests apply to the above-elbow prosthesis, and most of them apply to the shoulder-disarticulation prosthesis. Those which do *not* apply to the shoulder-disarticulation case are marked with an asterisk.

TEST NO. 1—RANGES OF STUMP MOTION*

Test: Have the amputee straighten the prosthesis and lock the elbow. Then move his stump and prosthesis through the maximum ranges of flexion, extension, elevation, and rotation.

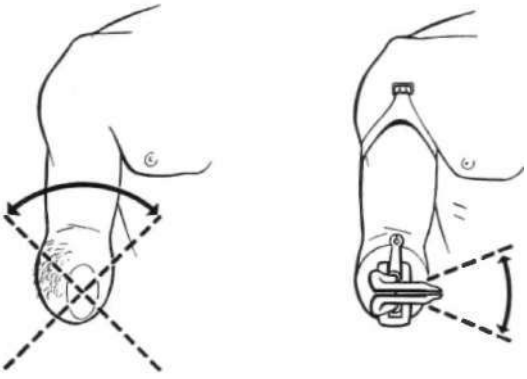

Fig. 4. Test for forearm rotation.

Standard: The amputee should be able to satisfy the following minimum requirements while wearing the prosthesis: flexion, 90 deg.; extension, 30 deg.; elevation, 90 deg.; rotation, 45 deg.

TEST NO. 2—RANGE OF FOREARM FLEXION

Test: Compare the amputee's maximum active range of prosthetic forearm flexion with the maximum manual range. Note the amount of initial forearm flexion built into the prosthesis.

Standard: The amputee should be able to flex actively to 135 deg. of forearm flexion, no more than 10 deg. of which should be due to initial flexion.

TEST NO. 3—HUMERAL FLEXION REQUIRED TO FLEX FOREARM*

Test: Have the amputee flex the prosthetic forearm actively through its entire range using humeral flexion, and note the degrees of flexion of the humerus required to do so.

[3] This test need not be applied when the stump is only half the normal forearm length or less.

Standard: Humeral flexion required to flex the prosthetic forearm fully should not exceed 45 deg.

TEST NO. 4—FORCE REQUIRED TO FLEX FOREARM

Test: Tape the fingers of the terminal device closed and unlock the elbow. Insert Ilie spring scale through the cable attachment, and flex the forearm to 90 deg. while holding the socket stationary. Pull along the normal line of the cable until further flexion of the forearm just starts, and note the force.

Standard: The force required to start flexion of the forearm from 90 deg. should not exceed 10 lb.

TEST NO. 5—LIVE-LIFT

Test: Tape the fingers of the terminal device closed and unlock the elbow. Hook the spring scale over the prosthesis at a distance of 12 in. from the elbow pivot using a leather strap if necessary (Fig. 5). Flex the forearm to 90 deg., and have the amputee actively resist while applying a straight-down pull on the scale. Note the scale reading when the amputee can no longer completely resist the pull and the forearm slips below 90 deg.

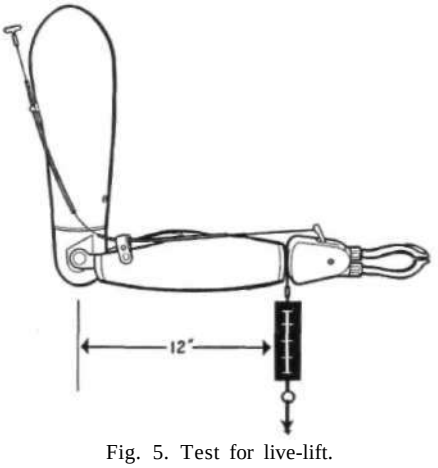

Fig. 5. Test for live-lift.

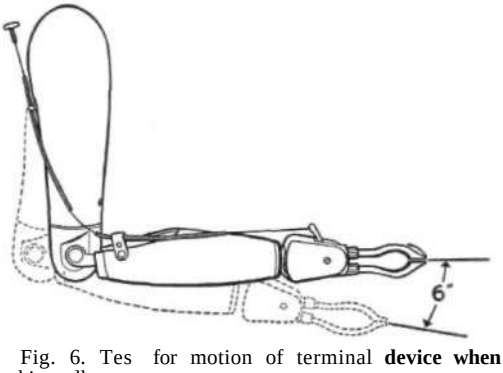

Fig. 6. Tes for motion of terminal **device when** locking elbow.

Standard: The amputee should be able to resist actively a downward force of at least 3 lb. located 12 in. from the elbow center when the forearm is flexed to 90 deg.

TEST NO. 6—INVOLUNTARY OPERATION OF THE ELBOW LOCK*

Test: Face the amputee and have him abduct the prosthesis 60 deg. Note whether or not the elbow lock operates. Then have him walk a short distance swinging the prosthesis in a normal manner, and note whether the elbow lock operates involuntarily or not.

Standard: The elbow lock should not operate involuntarily when the prosthesis is abducted 60 deg. nor during normal walking. In addition, a natural-appearing arm swing should be exhibited while walking.

TEST NO. 7—MOVEMENT OF TERMINAL DEVICE WHEN LOCKING ELBOW*

Test: Have the amputee actively flex the forearm to 90 deg. Then have him actively lock the elbow. Note the movement of the* terminal device as the elbow is locked.

Standard: The terminal device should not move more than 6 in. during active operation of the elbow lock when the forearm is flexed to 90 deg. (Fig. 6).

TEST NO. 8—SOCKET STABILITY DURING ARM ROTATION*

Test: Flex the forearm to 90 deg. and lock the elbow. Have the amputee abduct the prosthesis 60 deg. and rotate his stump and prosthesis. Note any slippage of the socket about the stump.

Standard: The amputee should be able to control the prosthesis during arm rotation, and there should be no slippage of the socket about the stump (Fig. 7).

Fig. 7. Test for socket stability during arm rotation.

TEST NO. 9—STABILITY OF SOCKET AGAINST TORQUE*

Test: Flex the forearm to 90 deg. and lock the elbow. Hook the scale over the prosthesis at a distance of 12 in. from the elbow center, using a leather strap if necessary. Have the amputee resist while pull is applied, first laterally, then medially, on the socket with a force of 2 lb. Note any slippage of the socket about the stump, or of the turntable, which may occur.

Standard: The amputee should be able to resist both lateral and medial pulls of 2 lb. located 12 in. from the elbow center, and the turntable should not turn with this force.

CONCLUSION

That the test procedure has reached a sufficient degree of refinement to be used successfully in the field is evidenced by its widespread adoption. Such agencies as the United States Veterans Administration, the State Departments of Vocational Rehabilitation of California and Illinois, and others include fulfillment of the standards as a contract stipulation. It must, however, be borne in mind that these test procedures are not to be considered as the final answer. Additions, revisions, and general improvements constitute a never-ending project in the field of prosthetics evaluation.

Digest of Major Activities of the Artificial Limb Program

Lower-Extremity Clinical Study

On July 1 arrangements were completed between the Veterans Administration, the University of California, and the U.S. Navy for establishment of a Lower-Extremity Clinical Study with the primary objective of determining the most effective methods of replacing functions lost by the leg amputee. Initial studies will be confined to the above-knee amputation, but later all types of lower-extremity amputations will be included.

Under the direction of Professor Howard D. Eberhart, the Study is located on the second floor of the Oakland Naval Hospital Limb Shop. During the first three months, the necessary equipment and facilities were installed, and one patient was processed to evaluate and revise the procedures to be used.

Above-Knee Suction-Socket School

In cooperation with the Veterans Administration, the Society of Orthotists and Prosthetists of Los Angeles, the Orthopedic Appliance and Limb Manufacturers' Association, and the University of California at Los Angeles, the Prosthetic Devices Research Project of the University of California held a five-day (August 24-28) Above-Knee Suction-Socket School in Los Angeles for prosthetists from that area. The course consisted of 40 hours of lectures, demonstrations, and shop work designed to provide the prosthetist-student with the knowledge necessary for fitting and aligning the above-knee suction socket. Lectures on locomotion, alignment, and use of the adjustable knee and transfer jig were included.

The prosthetists who successfully completed their work were Robert Angelich, Western Wholesale Parts Co.; Jasper Bohannon, N. H. Nanney Co.; John J. Bray, Lanham Orthopedic Appliances; Harry E. Campbell, Prosthetics Training Center; Lloyd B. Everett, Long Beach Artificial Limb & Appliance Co.; W. H. Hoskinson, Carl Woodall Co.; William M. Jones, Long Beach Artificial Limb & Appliance Co.; Ferdinand Karg, Peerless Artificial Limb Co.; Fred C. Lucas and Charles D. Neal, Adroit Artificial Limb Co.; William Peralta, Peerless Artificial Limb Co.; and A. J. Scruggs, Lanham Orthopedic Appliances.

The Upper-Extremity Prosthetics Training Course and Field Study

The fourth session of the Upper-Extremity Prosthetics Training Course given by the Departments of Medicine and Engineering, UCLA, was completed July 17. Attendance at the first four sessions is shown in the accompanying table.

ATTENDANCE AT UPPER-EXTREMITY TRAINING COURSES

Session	Area	Number of students in attendance				Number of clinic teams in attendance		
		Prosthetists	Therapists	Physicians and Surgeons	Total	VA	Other	Total
1	New York, Boston	9	10	9	28	3	4	7
2	Dallas, San Antonio, Houston, New Orleans, Newark	8	10	11	29	4	2	6
3	Pittsburgh, Philadelphia, Washington	9	8	10	27	3	4	7
4	Buffalo, Detroit, Cleveland, Columbus	9	16	17	42	2	9	11
	Totals	35	44	47	126	12	19[a]	31

[a] Private, 15; Armed Services, 4.

The fifth session is currently in progress, and more applications in each category were received for admission to the sixth session than could be accepted.

The Field Study being conducted by the Prosthetic Devices Study of New York University is progressing on schedule. A summary of activities to date is given below.

STATUS OF UPPER-EXTREMITY FIELD STUDIES AS OF SEPTEMBER 30, 1953

Area	Clinic	Initial evaluations			Prescriptions			Initial checkouts			In training		Final checkouts		Final evaluations
		BE	AE	SD	BE	AE	SD	BE	AE	SD	BE	AE	BE	AE	
I	Boston—VARO[a]	6	6		6	6		6			2		4		
	Boston—Bay State	3	2	1	3	2	1	3	2		2	1	1	1	
	Boston—New England			1			1			1					
	New York—VARO	2			2										
	New York—I.C.D.[b]	1	2		1	2		1	2				1	2	
	New York—NYU-Bellevue	3			3			1							
	New York—VAH[C]														
	Newark—VARO	2	2		2		1	2			1		1		
II	New Orleans—VARO	3	2		3	2		1			1				
	Houston—•														
	Methodist Hospital	2	2		2	2		1	1			1	1		
	San Antonio—VARO	3	2		2	2		1	1		1	1			
	Dallas—VARO	4	2		3	2									
III	District of Columbia—VARO	1	1		1	1									
	Philadelphia—VARO	2			2										
	Pittsburgh—VARO	2			1										
	Pittsburgh—Dr. Ferdeber's Clinic	2	1	1		1									
	Totals	36	22	3	31	20	3	16	6	1	7	3	8	3	

[a] Veterans Administration Regional Office.
[b] Institute for the Crippled and Disabled.
[c] Veterans Administration Hospital, Brooklyn, N. Y.

Conference on Problems of Upper-Extremity Prosthetics

In order to coordinate as completely as possible the developmental, instructional, and field follow-up phases of the Upper-Extremity Program, a conference of staff members of the Artificial Limbs Project, UCLA, the Prosthetic Devices Study, NYU, the Prosthetic Testing and Development Laboratory, VA, and the Army Prosthetics Research Laboratory was held in New York City August 17-21.

The prescription, fitting, and training techniques for each level of upper-extremity amputation and the function and design of each armamentarium item were discussed at length. As a result, areas in which work is needed were emphasized, and many recommendations were made.

Comprehensive minutes were prepared and distributed to the conferees and members of the Upper-Extremity Technical Committee.

Lower-Extremity Technical Committee

A meeting of the Lower-Extremity Technical Committee was held at the Drake Hotel, Chicago, on October 1-2, 1953.

The addition of Col. E. A. Brav, Dr. M. H. Anderson, Dr. C. O. Bechtol, Dr. Clinton Compere, and Mr. Hans Mauch brought the Committee membership to 21 as follows:

Chairman, Howard D. Eberhart, M.S., Professor of Civil Engineering, Univ. of California, Berkeley, Calif.

Miles H. Anderson, Ph.D., Educational Director, Artificial Limbs Project, University of California, Los Angeles, Calif.

Charles O. Bechtol, M.D., Asst. Clin. Prof. of Orthopedic Surgery, Univ. of California Medical School, San Francisco, Calif.

E. A. Brav, Col., MC, USA, Chief, Orthopedic Section, Walter Reed Army Medical Center, Washington, D. C.

Thomas J. Canty, Capt., MC, USN, Chief, Amputee Service, U. S. Naval Hospital, Oakland, Calif.

John G. Catranis, Catranis, Inc., Syracuse, N. Y.

Clinton Compere, M.D., Orthopedic Consultant, Veterans Administration Regional Office, Chicago, Ill.

Renato Contini, Project Director, Prosthetic Devices Study, NYU College of Engineering, New York City

Herbert Elftman, Ph.D., Assoc. Prof. of Anatomy, College of Physicians and Surgeons, Columbia University, New York City

Sidney Fishman, Ph.D., Asst. Project Director, Prosthetic Devices Study, NYU College of Engineering, New York City

C. C. Haddan, Gaines Orthopedic Appliances, Inc., Denver, Colorado

Verne T. Inman, Ph.D., M.D., Prof. of Orthopedic Surgery, Univ. of California Medical School, San Francisco, Calif.

Fred Leonard, Ph.D., Chief, Plastics Development Branch, Army Prosthetics Research Laboratory, Walter Reed Army Medical Center, Washington, D. C.

Hans Mauch, Research & Development Laboratory, Dayton, Ohio

E. F. Murphy, Ph.D., Asst. Dir. for Research, Prosthetic and Sensory Aids Service, Veterans Administration, New York City

Charles W. Radcliffe, M.S., Lecturer in Engineering Design, Univ. of California, Berkeley, Calif.

Atha Thomas, M.D., Assoc. Prof. of Orthopedic Surgery, Univ. of Colorado School of Medicine, Denver, Colorado

Howard R. Thranhardt, J. E. Hanger Co., Atlanta, Georgia

Lucius Trautman, Minneapolis Artificial Limb Co., Minneapolis, Minn.

Edmond M. Wagner, M.E., Consulting Engineer, San Marino, Calif.

Secretary, Tonnes Dennison, Field Engineer, Advisory Committee on Artificial Limbs

To handle technical problems as they arise between Committee meetings, a Lower-Extremity Research and Development Panel was appointed as follows:

Chairman, Prof. H. D. Eberhart; C. O. Bechtol, T. J. Canty, Sidney Fishman, C. C. Haddan, V. T. Inman, Fred Leonard, Hans Mauch, and C. W. Radcliffe. *Secretary,* Tonnes Dennison; *Consultant,* E. F. Murphy; *Consulting Engineer,* E. M. Wagner.

This smaller group will be concerned with the more detailed aspects of the Program, attempt to point out areas in which investigation is required, and guide various devices through the initial phases of research and development.

A revised Transition Procedure was adopted by the Committee to aid the Research and Development Panel and others concerned in systematically developing a device through the various stages from inception to production.

Minutes of the meeting have been distributed to those concerned.

The first meeting of the Research and Development Panel was held in Berkeley, Calif., December 5 and 7, and the next meeting of LETC is scheduled to be held in Washington October 1, 1954.

Upper-Extremity Technical Committee

A meeting of the Upper-Extremity Technical Committee was held at the Drake Hotel, Chicago, on October 2-3, 1953.

The addition of Col. E. A. Brav and Dr. Miles H. Anderson brought the Committee membership to 17 as follows:

Chairman, Craig L. Taylor, Ph.D., Prof, of Engineering and Biophysics, University of California, Los Angeles, Calif.

Samuel W. Alderson, Alderson Research Laboratories, Inc., New York City

Miles H. Anderson

Charles O. Bechtol

E. A. Brav

T. J. Canty

Clinton Compere

Renato Contini

Sidney Fishman

M. J. Fletcher, Lt. Col., MSC, USA, Director, Army Prosthetics Research Laboratory,

Walter Reed Army Medical Center, Washington, D. C.
C. C. Haddan
Fred Leonard
E. F. Murphy
August W. Spittler, Col., MC, USA, Chief, Orthopedic Section, Brooke General Hospital, Fort Sam Houston, Texas
H. R. Thranhardt
Lucius Trautman
Secretary, Tonnes Dennison

To handle technical problems as they arise between Committee meetings, the Upper-Extremity Technical Committee also appointed a Research and Development Panel. It consists of:

Chairman, Dr. Craig L. Taylor; C. O. Bechtol, T. J. Canty, Sidney Fishman, M. J. Fletcher, C. C. Haddan, and Fred Leonard. *Secretary*, Tonnes Dennison; *Consultant*, E. F. Murphy; *Consulting Engineer*, E. M. Wagner.

A revised Transition Procedure identical to that adopted by the Lower-Extremity Committee was also adopted by the Upper-Extremity Committee.

Minutes of the meeting have been distributed to those concerned.

The first meeting of the Research and Development Panel was held in Washington December 10,11, and 12, and the next meeting of UETC is scheduled to be held in Washington October 2. 1954.