Spring 1957

Artificial Limbs

A Review of Current Developments

PROSTHETICS RESEARCH BOARD

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Artificial Limbs

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While this issue of ARTIFICIAL LIMBS, unavoidably much delayed, was still in press, word was received of the death of Dr. Sterling Bunnell, of a heart attack, at his home in San Francisco, on August 20, 1957. On behalf of the Prosthetics Research Board, ARTIFICIAL LIMBS expresses deepest regret at the passing of its distinguished contributor.

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Getting Down to Cases

CHARLES O. BECHTOL, M.D.[1]

It is the common teaching of all experience that even the most carefully planned activities seldom follow the course originally laid out for them. Man tends to play himself through life by ear, as it were, in a series of false starts and fortunate recoveries. In all fields of endeavor, therefore, hindsight is more often than not the quality which, in the long run, keeps people going in the general direction of progress. That such is the way things are is perhaps nowhere more patent than in the evolution of the Artificial Limb Program.

When, for example, in 1945, the Committee on Prosthetic Devices (now the Prosthetics Research Board) set out to improve the lot of the amputee population, it chose for itself the seemingly obvious, if also apparently simple, goal—the design and development of new and improved artificial-limb components. Because of the more or less widely held misconception, even among amputees themselves, that improved devices alone might well raise the level of the art of limb prosthetics to that existing in other fields of science and invention, the Committee established, through arrangements for contract research, a far-flung program with principal emphasis on the fundamental investigation of human locomotion, on time-and-motion studies of the human arm and hand, and on what might by some be called professional gadgeteering.

After a few years of organized effort on the part of engineers and prosthetists, with the consequent development of new and supposedly improved models and techniques, and after the application of experimental prostheses to amputees for initial tests of the new equipment, it became perfectly clear that, if genuine improvement in amputee service were to be had, something more would be needed. In retrospect came realization of the circumstance that no single design of prosthesis is ever apt to be superior for all amputees of a given type and, conversely, that every amputee presents in one way or another a special problem not amenable to mass treatment. Put in engineering language, the difficulty was seen to lie in the fact that dealing with the rehabilitation of

[1] Associate Professor of Surgery and Chief of the Division of Orthopedic Surgery, Yale University; Orthopedic Consultant, Veterans Administration Hospital, West Haven, Conn.; formerly Assistant Clinical Professor of Orthopedic Surgery, University of California, and Western Area Consultant for Orthopedic and Prosthetic Appliance Clinic Teams, Veterans Administration; member, Committee on Prosthetics Research and Development, PRB, NRC.

amputees means dealing with a "nonstandard product," the human being. He comes in all sizes, shapes, and conditions. And his reaction to any given selection of equipment is almost always grossly influenced by his individual personal needs and characteristics—physical and mental—as well as by his activity requirements. Since most of the new devices and new methods were largely untried at the clinical level, there existed no valid criteria either for determining when components had been prescribed and fitted to best advantage in the individual case or for assessing the degree of utilization achieved by a given wearer. In the absence of demonstrable proof of successful application on a relatively broad scale, the limb industry was understandably reluctant to adopt the new ways and means with any ostensible enthusiasm. But at the beginning of the Artificial Limb Program in 1945 no one was in a position to predict such eventualities.

Lacking, in brief, was the experience necessary for the construction of a general set of principles of amputee management. In recognition of this state of affairs, and in view of the especially challenging problems prevailing in the upper extremity, there was established in mid-1950, in the Department of Engineering at the University of California at Los Angeles, the so-called "Case Study Program," with the purpose of investigating the application of prostheses to a wide variety of amputee types and of developing effective methods for evaluation of amputee service, not only with regard to the quality and applicability of the mechanical equipment but also with concern for the effect of training and of occupational, educational, recreational, and other personal factors on the final success of prescription and fitting. Intended to bridge the gap between fundamental work in the laboratory and practice in the field, and with excellent industry participation, the work continued until 1953. Analysis of the data thus accumulated continued until late in 1956.

So fruitful was the case-study work in upper extremities at UCLA that in the spring of 1953 there was organized at the University of California at Berkeley a similar investigation into the problems of the leg amputee, especially the above-knee case, a matter that had already been the subject of fundamental research and engineering design at that institution since the beginning of the Artificial Limb Program eight years earlier. Again with the wholehearted cooperation of the limb industry, the so-called "Clinical Study" in lower extremities has, like the UCLA Case Study, now garnered much valuable information on which to base some general principles.

Because the experience gained at UCLA and at Berkeley represents the most reliable data available on what now constitutes good practice in limb prosthetics, the bulk of this issue of ARTIFICIAL LIMBS is devoted to a presentation of selected case histories, predominantly the histories of typical problem cases as contrasted with cases that responded readily and well to routine fitting. The balance is given over to a discussion, by one of the world's best-known leaders in hand surgery, of the possibilities for surgical reconstruction of damaged hands and of the application of prostheses for the partial hand, an area which offers, if anything, even more highly specialized individual cases and which therefore has not yet been the subject of any major investigation within the Artificial Limb Program. Bunnell's contribution fills admirably what would otherwise be a noticeable gap in the coverage.

As regards the broad implications of the case material, it is worth observing how many and diverse are the ways in which the problem of amputee rehabilitation must be attacked and how wide is the variety of skills necessarily brought to bear. In pursuit of clinical work it was found essential to enlist the participation of numerous specialists, each with his own particular interests and abilities. Functioning together, these people not only aided materially several hundred cooperating amputee subjects but at the same time contributed to their own self-development and hence to the growth of techniques suitable for widespread dissemination to practicing clinic teams. Thus, in a larger sense, they laid the basis for the nationwide program of prosthetics education now so well under way. Because, in turn, the education program resulted in a vast increase in the number of available clinic teams, amputees in the United States are today reaping benefits that could scarcely have been visualized seven or eight years ago. Here then, in the results of the case studies, lies the key to continued advancement in the mastery of limb prosthetics.

Some Experience with Prosthetic Problems of Upper-Extremity Amputees

MARVIN S. GOTTLIEB, M.A.,[1]
ROBERT L. MAZET, JR., M.D.[2]
CRAIG L. TAYLOR, Ph.D.,[3] AND
MARIAN P. WINSTON, B.A.[4]

The history of the upper-extremity prosthetics program up to 1954 has been outlined in a previous article in this journal (*7*). From 1950 to the present, the upper-extremity research group established in the Department of Engineering, University of California at Los Angeles, has processed some 300 arm amputees: 72 during the Case Study Program (*3*), an overlapping 250 during the 12 schools at the Prosthetics Training Center (*1*), a small group of adult research amputees, and 104 children seen at the Child Amputee Prosthetics Project (*4*) prior to July 1, 1956. From the adult cases we have selected 23 of special interest to summarize in this article.

First presented are five cases that responded well to standard methods, the purpose being to establish a baseline for comparison with the problem cases. Cases aided by the development of special equipment and by training in its use are grouped in one section because of the interrelationship between fitting, correct equipment, and amputee training. Under the heading of special equipment come the prototypes of several devices now standard in the armamentarium and also some modifications that remain unique to the individual wearer.[5] Cases aided by medical and biomechanical treatment are grouped together, again because of the interrelationship involved.

Although some three fourths of all arm amputees encountered in the program have become consistent users of functional prostheses, we have chosen to present unsolved problems in nearly half of the case histories given here. The reason, obviously, is to draw attention to the areas of need. Apart from some unilateral wrist-disarticulation and long-below-elbow amputees who operate easily and efficiently without prostheses (whom we do not consider to be problem cases), arm amputees who have the opportunity to be fitted properly, but who fail to use their prostheses, most often fall into one of three classes:

1. Women of limited strength who object to the weight of forearm and terminal device.
2. Persons with severe biomechanical limitations, such as forequarter amputees.
3. Individuals suffering from disabling pain.

[1] Formerly Junior Research Engineer, Engineering Artificial Limbs Project, Department of Engineering, University of California (Los Angeles).

[2] Clinical Professor of Orthopedic Surgery, University of California Medical School (Los Angeles); Chief of the Orthopedic Service, Wadsworth Veterans Hospital; member, Committee on Prosthetics Research and Development, PRB, NRC; Past-President, American Board for Certification of the Prosthetic and Orthopedic Appliance Industry, Inc.

[3] Professor of Engineering and Physiology, University of California (Los Angeles); Project Leader, Engineering Artificial Limbs Project, Department of Engineering, University of California (Los Angeles); member, Committee on Prosthetics Research and Development, PRB, NRC.

[4] Editor, Engineering Artificial Limbs Project, Department of Engineering, University of California (Los Angeles); formerly Editor, Prosthetics Education Project, UCLA Medical Center.

[5] Since these case histories are drawn from the UCLA experience, the devices presented as solving problems are those designed by this particular project. We

Just to show that arm amputees are no exception to the general orneriness of mankind, the closing section covers cases presenting unsolved psychosocial problems.

It will be clear that several of the case histories might have been classified under some of the other headings. For example, in view of the drastic effects that the patient's postamputation decrease in earnings had on his family life, Case 9, discussed from the viewpoint of special equipment, could as reasonably have been classified under psychosocial problems. Case 13, discussed under biomechanical treatment, represents also an achievement in equipment modification. And so forth.

The expression "man-machine combination" is a well-worn phrase in contemporary biotechnical research. In limb prosthetics, one might say, there is a "man-equipment-training combination" in which the man may be modified by medicine, by surgery, by physical or occupational therapy, by developments in the psychosocial realm, or by training in control and use of the prosthesis. The equipment must be compatible with all these and may have to be modified by redesign or special fitting to overcome the man's biomechanical limitations. Training may be either of negligible importance, as in Case 12, or crucial, as in Cases 7 and 11. Its usual importance tends to be somewhere between the two extremes.

Finally, it may be noted that the standards, procedures, and techniques employed in fitting, fabrication, and training are all described in detail in the *Manual of Upper Extremity Prosthetics*, 2nd Edition (*8*). Similarly, all materials and most of the components mentioned are listed in the *Manual*, together with sources and characteristics. Of the components not otherwise referenced directly, all have already been described in previous issues of ARTIFICIAL LIMBS, in the collaboration by Klopsteg, Wilson, *et al.* (*5*), in manufacturers' catalogs, or in the general literature of the field. A number of the special components are described in recent reports of the Engineering Artificial Limbs Project at UCLA.

were in no position to present the stories behind valuable components which emerged from other laboratories and limbshops.

CASES RESPONDING WELL TO STANDARD METHODS

CASE 1, FOREQUARTER

History

Case 1, male, a 30-year-old medical photographer, was first seen in the Case Study in February 1951, eight years postoperative. His left forequarter amputation, in which the left scapula and two thirds of the clavicle had been removed, followed injury in wartime Naval service. The Navy had provided him with a Navy-Fitch (*2*) arm (double-coupled-flexion type with wooden forearm, leather socket, catgut cords, and double chest-strap harness) but had not trained him to use it. Because of socket discomfort, he had worn no prosthesis for the preceding five years and was unable to operate his Navy-Fitch arm at all for testing purposes. He was able to fulfill all his functional needs satisfactorily with one hand, did not believe that any functional prosthesis for his level of amputation was available, and sought only a cosmetic replacement.

Examination and Evaluation

The patient was 6 ft. 4 in. tall, weighed 195 lb., was well muscled, and had good posture considering the extent of his loss (Fig. 1). The operative scar on the left shoulder girdle was well healed and not tender, but the area of the axilla was hypersensitive to touch. The subject was able to move the end of the remaining third of the clavicle only very slightly in flexion-extension but was judged to have a good range of motion in elevation-depression.

Treatment

The patient's unusually good conformation enabled him to be fitted with a modified shoulder-disarticulation prosthesis rather than with the usual forequarter type. Accordingly, a sectional type of shoulder prosthesis was prescribed, with emphasis on the cosmetic shaping of the shoulder cap. It included (Fig. 2) a chest-strap harness with four attachment points on the shoulder cap, an opposite-shoulder loop for dual control of terminal-device operation and forearm flexion, and nudge control of the elbow lock since the patient had no desire for an actively operated

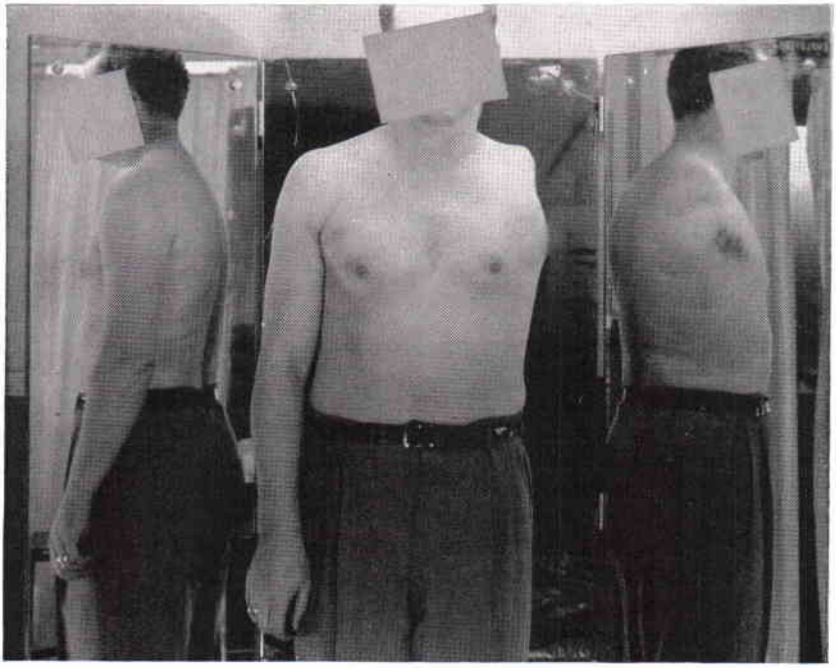

Fig. 1. Case 1. Patient as seen on referral.

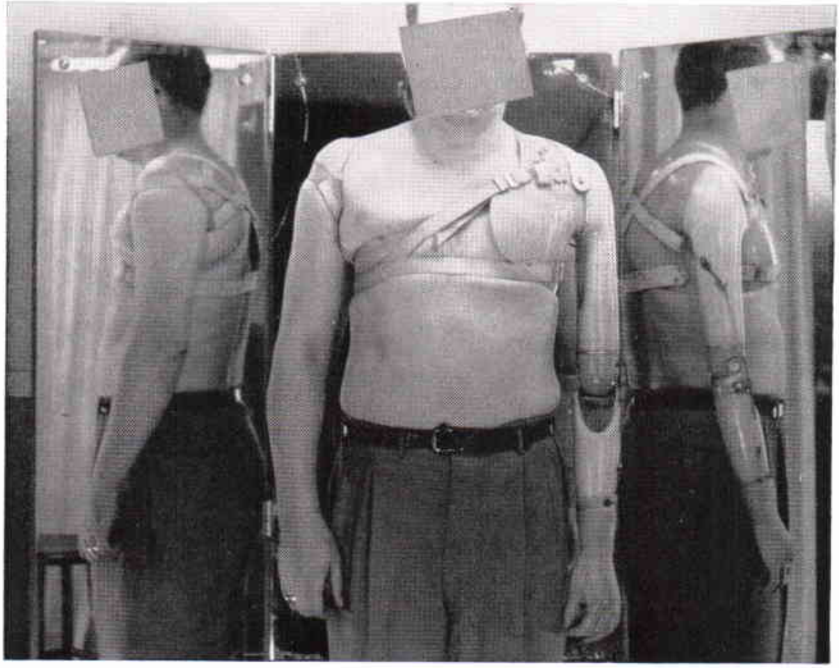

Fig. 2. Case 1. Prosthesis provided at UCLA. The unusually good physical conformation and range of motion of this forequarter amputee enabled him to be fitted successfully with a modified shoulder-disarticulation type of prosthesis rather than with the full forequarter socket. There was more functional regain than usual considering the patient's level of amputation. Compare with Cases 15 and 16.

elbow. The nudge control failed mechanically several times, a circumstance which led to a satisfactory redesign. Originally provided with a Dorrance hook, the patient later requested and received an APRL hand and hook. The pressure-control feature of the APRL hook proved "invaluable" in his darkroom work.

Training in use of the prosthesis was aided by the patient's wife, who was an occupational therapist. After training, the amputee passed nine out of ten activity tests and was judged to perform with extreme smoothness and remarkable ease and dexterity considering his level of amputation. When followed up a year later, the subject reported that he wore his prosthesis during most of his waking hours, sometimes as much as 120 hours a week, using the hand for most of his picture-taking and public-contact work and the hook in developing negatives and making prints.

Summary

In this case, better results were obtained than might reasonably have been expected. A unilateral forequarter amputee, the patient was interested only in a cosmetic replacement, did not seek functional regain, and did not believe that it was possible. Yet by proper fitting, followed by good training, he became an excellent prosthesis user.

CASE 2, WRIST DISARTICULATION

History

Case 2, male, a 38-year-old machine operator and assembler of tools and outdoor furniture, was first seen by the Case Study in June 1952, seven years after amputation. His left hand had been lost by a shrapnel injury to the wrist while he was serving in a Polish-French tank combat crew in Berlin. He had been fitted with a plastic socket with interchangeable Dorrance No. 8 hook and Becker wooden hand but had not worn the prosthesis for the preceding five months because the socket was broken. Prior to the breakdown, the patient had used the wooden hand 10 hours a day.

Examination and Evaluation

Examination showed a screwdriver-shaped stump with the styloids intact (Fig. 3). Physical condition was good, although forearm rotation was somewhat limited. The amputee had never received any physical therapy or prosthetic training.

Treatment

There is available no wrist cap that matches the elliptical cross-section of the human wrist, and the wrist-disarticulation socket must therefore be faired out to meet the round wrist caps used. In this case, an attempt was made to develop a manually operated wrist unit of elliptical cross-section using rubber O-rings to supply the friction necessary for resistance to rotation. But the resulting appearance was not satisfactory, the added length (1.3 in.) was too great, and frictional characteristics were not as desired. Rather than devote the time and effort necessary to redesigning the unit, the practical solution was adopted of using a Sierra Model C wrist cap instead and fairing out the socket accordingly (Fig. 4). Use of the Model C wrist cap decreased the length by half an inch and improved the functional characteristics.

In accordance with the patient's desire, he was supplied with an APRL hook. He preferred it because of the selective prehension and "better mechanism" and because he felt that exposed rubber bands, as in the Dorrance models, would accumulate grease in his work. But the hook required weekly servicing because of dirt accumulation, and when the patient ripped the stud off he requested a Dorrance No. 5 hook instead. After experience with the Dorrance hook, however, he reported that it tended to scratch the furniture he polished on the job. At the patient's insistence, an auxiliary prosthesis was constructed for use with the old Becker hand, which he considered ideal for the polishing operation. The patient's one remaining objection to his prosthetic equipment was that, with his limited pronation-supination, the hook could not be positioned fast enough, but the length of his stump contraindicated use of a step-up rotation prosthesis. At last report, the patient was wearing a prosthesis 10 hours a day, 70 hours a week.

Summary

Case 2 was a relatively uncomplicated case that responded well to standard methods of

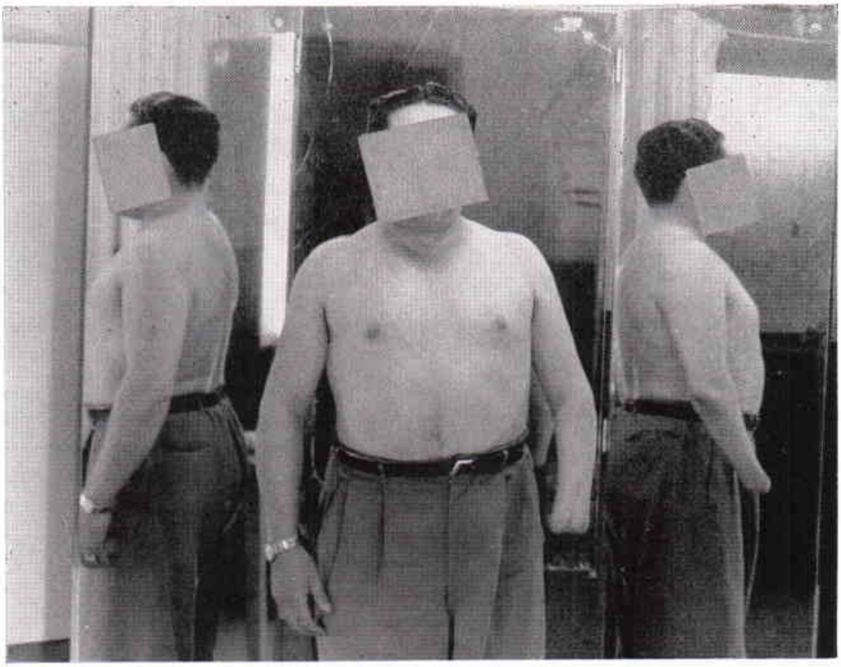

Fig. 3. Case 2. Patient as seen on referral.

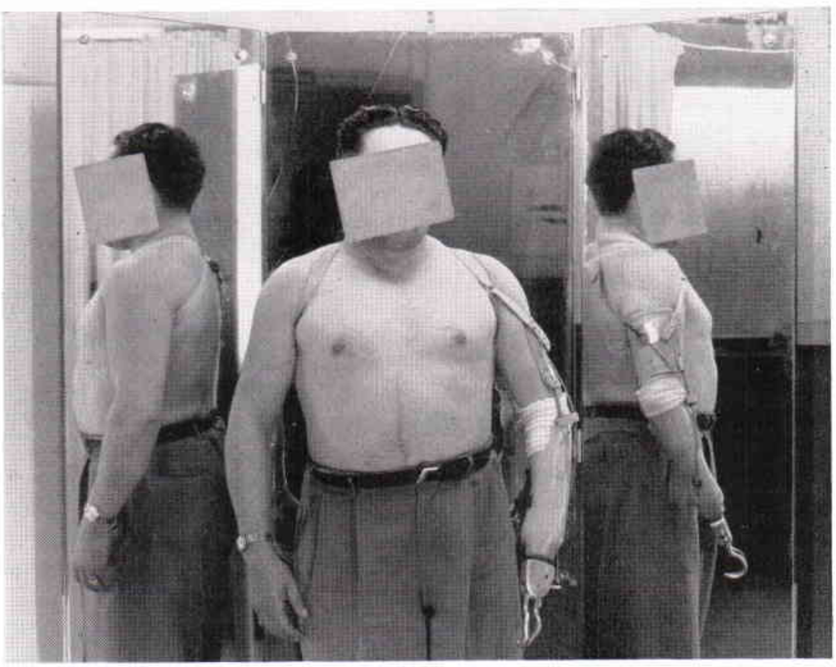

Fig. 4. Case 2. Prosthesis provided at UCLA. Because of required weekly cleaning and relative breakability in heavy work, the APRL hook shown here was later given up in favor of a Dorrance No. 5.