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UPPER-LIMB PROSTHETICS

1971 Revision

(Including Prosthetists' Supplement, 1976 Revision)

Prosthetics and Orthotics
New York University
Post-Graduate Medical School

Reprinted September 1976

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TABLE OF CONTENTS

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CHAPTER 1

PROSTHETIC AND ORTHOTIC CLINIC PROCEDURES

The prosthetic-orthotic clinic may be viewed as a means of communication between interrelated medical and ancillary specialists. It is essentially a method of organizing the patient management activities of a number of people and serves to provide necessary contact between various specialists involved in prosthetic-orthotic rehabilitation--these basic teams consisting of the physician or surgeon, acting as "clinic chief;" the physical and/or occupational therapist; and the prosthetist-orthotist.

Other personnel may be required, according to the special needs of the situation. In various clinics, the additional services of the rehabilitation counselor and social service case worker have proven to be important. The rehabilitation counselor is frequently able to provide useful information concerning the patient and to relate prosthetic and orthotic matters to plans for vocational rehabilitation. The counselor can also provide the very desirable liaison between the clinic and the governmental or private agency which has referred the patient. The social service case worker can often assist in explaining the physical restoration program to the patient and his family, which is helpful in developing their cooperation. The case worker also provides the necessary liaison between any social services agency involved and the clinic. Ideally, both these individuals should have had some specialized training in prosthetics and orthotics.

Since in the overwhelming number of cases, the prosthesis or orthosis wearers will require other medical treatment, it is mandatory to have medical specialists, such as dermatologists, pediatricians, or internists available.

Goals and Purposes of the Clinic

The major purposes and goals to be achieved by the prosthetic-orthotic clinic are:

1. Coordinated Pattern of Treatment

In order to provide amputees and orthosis wearers with the best medical and prosthetic-orthotic service, the contribution of each of the specialists should be made in coordination and conjunction with that of the others. It is becoming more infrequent, but certainly not unheard of, for a prosthetist-orthotist or a physician to plan a prosthetic-orthotic management program without acting in concert with the others.

When an individual is receiving treatment from more than one specialist, and the anxieties of the situation provoke some degree of discontent, there is a noticeable tendency for some patients to distort the intentions and contributions of each profession in relation to the others. This is aggravated when the patient functions as a means of communication between the professionals concerned. Since there is always a certain degree of conscious and subconscious distortion of the patient's perceptions of the treatment processes, he should not be afforded the opportunity to complicate the process of communication among the various professionals concerned.

On another note, we may anticipate that the behavior and demeanor of the patient will differ when he is with the prosthetist or orthotist, as contrasted with the physician or therapist. These differences in overt behavior patterns may easily and logically suggest different patterns of treatment to each of the professions. It should be realized, though, that this varying behavior on the part of the patient may be transitory and that the best treatment lies in a uniform plan rather than in a number of discrete ones.

It is clear that prosthetic-orthotic clinic procedures permit a more uniform evaluation of the patient and assist in circumventing some of the problems inherent in uncoordinated care.

2. Staff and Patient Education

It is true in prosthetics and orthotics, as in other medical situations, that there are no standard procedures which apply with equal effectiveness to every patient. Moreover, prosthetics and orthotics are fields in which the contributions of each of the specialists may only be partially understood by the others. Consequently, there is an important need for an interchange of ideas and a distillation of the best thinking through group discussion. In this sense, then, an important goal of the clinic is the mutual education of the treatment team members.

One aspect of this educational process is that the clinic serves as a vehicle which permits a limited selected group of physicians and surgeons to specialize and become experts in the prosthetic and orthotic fields.

There is not, ordinarily, a sufficient caseload to keep very many physicians expertly conversant with prosthetic-orthotic matters. However, there are assuredly sufficient cases to permit a small group of physicians and surgeons in each community to see appreciable numbers of these types of patients in the clinic situation. This fact encourages the establishment of groups with sufficient experience and education to make them competent both to prescribe and checkout prosthetic-orthotic devices. Clearly this is a desirable goal since, not infrequently, physicians who lack the necessary technical information and background to come to sound professional conclusions are called upon to pass judgment concerning prostheses and orthoses.

The role that the clinic must play in the education of the patient, his family, or both is equally important. Most patients and their families, arriving for prosthetic-orthotic care, are subject to wide and varied misunderstandings and misinterpretations as to the ultimate use and value of a prosthesis or orthosis. Consequently, clinic personnel must orient the patient concerning his goals and anticipations, as well as to provide him with the best assistive device available.

Professional Status of the Prosthetist-Orthotist

It is probably true that a major factor in attaining patient satisfaction with the prosthetic-orthotic service he receives is related to the personal attitudes and evaluations of the patient regarding the prosthetist-orthotist. There are two considerations which may prompt a less-than-satisfactory attitude: the lack of status of the prosthetist-orthotist as a part of an organized professional medical service; and the lack of training and experience of prosthetists-orthotists in the proper handling of psychological, interpersonal aspects of their vocation.

In the last analysis, the patient needs to adjust himself to and accept the product fabricated by the prosthetist-orthotist, and there is substantial evidence that the patient's attitudes toward a prosthesis or orthosis is closely related to his attitudes toward the prosthetist-orthotist. It seems reasonable, therefore, that whatever can be done to improve the attitude of the patient toward the prosthetist-orthotist will have a significant, positive bearing on the results of the treatment.

Although the ultimate solution of this problem involves long-range sociological and educational considerations, the prosthetic-orthotic clinic helps on an interim basis by providing prosthetists and orthotists with the opportunity to observe and participate in the professional medical care of patients. This cannot help but provide the beginnings of professional status which is sorely required.

Prosthetic-Orthotic Clinic Procedures (See Figure 1, Page 9)

A pattern of prosthetic-orthotic clinic operation has evolved which essentially includes the following steps:

1. Pre-Prescription Examination
2. Prescription
3. Pre-Fitting Treatment
4. Prosthetic-Orthotic Fabrication
5. Initial Checkout (Evaluation)
6. Prosthetic-Orthotic Training
7. Final Checkout (Evaluation)
8. Follow-Up

1. Pre-Prescription Examination

It is recommended that the first meeting of the clinic, the so-called prescription meeting, be preceded by an appropriate physical and psychological examination of the patient so that pertinent information concerning the patient is available to the clinic members beforehand.

Forms are available to summarize the essentials of this examination for both the amputee and the orthosis wearer (See Medical Prosthetic Summary Pages 10-13). Separate forms are available for various types of prostheses and orthoses wearers. Study and analysis of this information provide a sound basis for determining the type and nature of the care required by the particular patient. The treatment may be medical, surgical, or prosthetic-orthotic in nature, or a combination thereof.

PROSTHETIC-ORTHOTIC CLINIC PROCEDURES

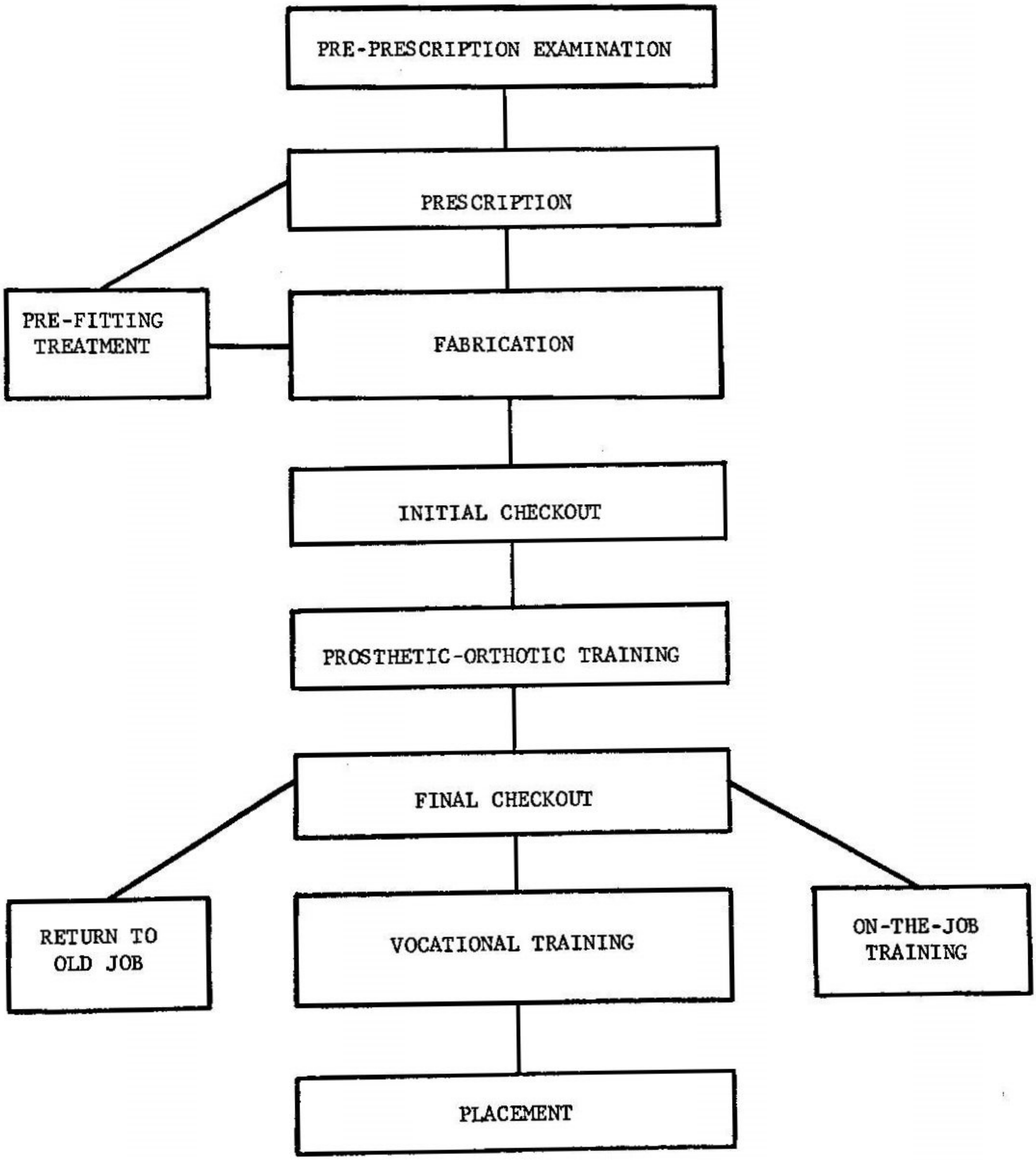

FIGURE 1

MEDICAL PROSTHETIC SUMMARY: UPPER LIMB

A. PERSONAL FACTORS

1. Name____________________ Date__________
2. Home address____________________ Phone__________
3. Business address____________________ Phone__________
4. Distance from clinic_______________ Phone contact__________
5. Age__________ Height__________ Weight__________
6. (Circle items which apply)

   Male Female Veteran Civilian Single Married
7. Education (years) and field of specialization_______________

   ____
8. Present occupation (title and description of duties)__________

   ____

   ____
9. Occupation prior to amputation____________________
10. Future occupational plans____________________
11. Hobbies and recreational interests____________________
12. Amputee referred by____________________
13. Financial arrangements____________________

B. MEDICAL FACTORS

1. Date, cause, and site of amputation and of revisions, if any:__________

   ____

   ____
2. Amputation: Right__________ Left__________
3. Before amputation, was the amputee right-handed_____; left-handed_____; ambidextrous_____?
4. Length of stump:

   For below-elbow ______inches from medial epicondyle to end of bone.

   For above-elbow ______inches from acromion to end of bone.

   ______inches from axilla to end of bone.
5. Arm length on sound side: ______inches from medial epicondyle to ulnar styloid.

   ______inches from acromion to lateral epicondyle.
6. Amputee classification: (See Page 13 for computation)__________

7. Indicate limitations of motion of the shoulder girdle. (Note elevation, depression, scapular abduction, scapular adduction, etc.)________________

____

____

8. Strength and range of motion:

	Strength	Range of Motion in Degrees
For below-elbow:		
a. Pronation	________	________
b. Supination	________	________
c. Elbow flexion	________	________
For above-elbow:		
a. Shoulder flexion	________	________
b. Shoulder extension	________	________
c. Shoulder abduction	________	________
d. Shoulder rotation	________	________

9. Condition of stump: (Check as many items as apply)

   a. Shape: Screwdriver (for below-elbow)____ Cylindrical____ Tapered______ Bulbous______

   b. Musculature: Loose and flabby_____ Firm_____ Average_______

   c. Other characteristics: Pain______ Edema_____ Bony prominences_______ Probability of shrinkage______

10. Special considerations: (scarring, neuromata, adhesions, presence of foreign bodies, dermatitis, etc.)________________________

____

____

C. PROSTHETIC FACTORS

1. Description of present prosthesis:

   For below-elbow:

   a. Terminal device (Type and control)________________________

   ____

   b. Wrist (Disconnect, flexion unit, or both)__________________

   ____

   c. Socket (Material and construction)______________________

   ____

   d. Elbow hinge (Type and material)________________________

   ____

   e. Upper-arm cuff (Type and material)______________________

   ____

   f. Harness and control system (Type and materials)______________

   ____

For above-elbow and shoulder disarticulation:

a. Terminal device (Type and control)________________

b. Wrist (Disconnect, flexion unit, or both)________________

c. Forearm (Material and construction)________________

d. Elbow (Type and control)________________

e. Socket (Material and construction)________________

f. Harness and control system (Type and materials)________________

2. Present prosthesis has been worn _____years. Previous ones were worn a total of _____years.

3. Upon objective evaluation, in what respects, if any, is the present prosthesis unsatisfactory?________________

4. Rate the amputee's control of his prosthesis as "Good", "Fair", or "Poor":

a. At mouth____________.

b. At waist____________.

c. At floor____________.

d. In general (have the amputee handle a few objects)____________.

5. How often does the amputee wear his prosthesis?

a. Hook worn_______hours a day, ______days a week.

b. Hand worn_______hours a day, ______days a week.

6. List activities in which the prosthesis is used. If the prosthesis is not generally worn, list activities in which the stump is used.

a. Dressing________________

b. Eating________________

c. Working________________

d. Recreation________________

7. What is amputee's opinion of his present prosthesis and its components? (Review function, appearance, desired improvements, etc.)________________

8. What benefits does the amputee think would result from wearing an improved prosthesis or in securing a first one?________________

9. Does the amputee have decided preferences or dislikes for particular prosthetic components? If so, explain.________________

10. Does the patient understand the approximate amount of time that will be required to provide him with prosthetic service? ______________________

____

Examined by ______________________

After performing the calculations indicated below, circle the amputee type in the following table.

CLASSIFICATION OF UPPER-EXTREMITY AMPUTEES

BELOW-ELBOW		ABOVE-ELBOW	
Per Cent of Forearm Remaining	Amputee Type	Per Cent of Humerus Remaining	Amputee Type
0 - 34	Very Short Below-Elbow	0 - 29	Shoulder-Disarticulation
35 - 54	Short Below-Elbow	30 - 49	Short Above-Elbow
55 - 99	Long Below-Elbow	50 - 89	Standard Above-Elbow
- 100	Wrist-Disarticulation	90 - 100	Elbow-Disarticulation

CALCULATION FORMULAE FOR AMPUTEE CLASSIFICATIONS

FOR BELOW-ELBOW UNILATERAL AMPUTEES:

$$\frac{\text{Stump Length} \times 100}{\text{Sound Forearm Length}} = \_\_\_\_\_\_ \text{ per cent.}$$

FOR ABOVE-ELBOW UNILATERAL AMPUTEES:

$$\frac{\text{Stump Length} \times 100}{\text{Sound Upper Arm Length}} = \_\_\_\_\_\_ \text{ per cent.}$$

FOR BELOW-ELBOW BILATERAL AMPUTEES:

a. Theoretical Length of Forearm = Height in inches x 0.14 = ________ inches.

b. For Right Stump: $\frac{\text{Stump Length} \times 100}{\text{Theoretical Forearm Length}} = \_\_\_\_\_\_$ per cent.

c. For Left Stump: $\frac{\text{Stump Length} \times 100}{\text{Theoretical Forearm Length}} = \_\_\_\_\_\_$ per cent.

FOR ABOVE-ELBOW BILATERAL AMPUTEES:

a. Theoretical Length of Upper Arm = Height in inches x 0.19 = ________ inches.

b. For Right Stump: $\frac{\text{Stump Length} \times 100}{\text{Theoretical Upper Arm Length}} = \_\_\_\_\_\_$ per cent.

c. For Left Stump: $\frac{\text{Stump Length} \times 100}{\text{Theoretical Upper Arm Length}} = \_\_\_\_\_\_$ per cent.

FOR BELOW-ELBOW/ABOVE-ELBOW BILATERAL AMPUTEES:

a. Theoretical Forearm Length = Height in inches x 0.14 = ________ inches.

b. For Below-Elbow Stump: $\frac{\text{Stump Length} \times 100}{\text{Theoretical Forearm Length}} = \_\_\_\_\_\_$ per cent.

c. For Above-Elbow Stump: $\frac{\text{Stump Length} \times 100}{\text{Sound Upper Arm Length}} = \_\_\_\_\_\_$ per cent.

2. Prescription

Ordinarily, the patient's first contact with the clinic is for the purpose of developing an appropriate medical, surgical, or prosthetic-orthotic prescription. At this point the pre-prescription examination results are evaluated, and those aspects of the patient's condition which have an immediate bearing on problems of prosthetic-orthotic restoration are rechecked. This is followed by a detailed consideration of the appropriate treatment procedures for the patient in question. If the resulting prescription calls for medical care, the physician or the therapist, as indicated, would undertake its implementation. If the prescription is for further surgery, the surgeon would obviously take the necessary action. If the prescription is a prosthetic-orthotic one, the prosthetist-orthotist assumes the responsibility. In some instances, the prescription may involve several of these considerations but, usually, prosthetic-orthotic treatment is deferred until medical and surgical care are sufficiently underway.

The prosthetic-orthotic prescription should correctly be a detailed description of the device and services which a patient is to receive and should not merely be a series of generalized instructions. This is not in any real sense a "prescription." Vague instructions result in the prosthetist-orthotist being unable to construct a definitive appliance with any assurance that his product will reflect the intent of the clinic or meet the needs of the patient. (See Prosthetic Prescription: Upper Limb, Pages 15 and 16)

The importance of a detailed prescription cannot be overemphasized. In the past, prosthetists and sometimes orthotists have been placed in the position of planning complete appliances according to their own best judgment. After delivery of such appliances, the prosthetists-orthotists have been subjected to criticism concerning their choice of various components and their utilization of certain principles of fit and alignment. By obtaining a mutually acceptable, detailed prescription at the clinic session, such difficulties are minimized.

As a matter of practical clinic operation, it has been found desirable that the prosthetist-orthotist contact the clinic chief if he wishes to recommend any significant change in the prescription during the course of fabrication. Such recommendations are often entirely legitimate, based on

PROSTHETIC PRESCRIPTION: UPPER LIMB

Patient____ Date______________

Amputation Type____________________________ Right________ Left__________

MEDICAL AND SURGICAL PRESCRIPTION

1. Is surgery indicated? Yes_____ No_____ If so, specify condition and indicate treatment____

____

____

2. Is preprosthetic therapy indicated? Yes_____ No_____ If so, give detailed prescription and intended result_________________________________

____

____

____

3. Should fitting be delayed for any reason? Yes_____ No_____ If so, why?

____

____

____

PROSTHETIC PRESCRIPTION (Consider vocation, avocation, and patient preference, as well as stump and general physical characteristics.)

Below-Elbow

Socket: Double-wall__________ Single-wall__________

Split__________ Muenster__________

Elbow hinge: Flexible__________ Single pivot__________

Polycentric__________ Step-up__________ Other__________

Cuff____

Modifications____

Above-Elbow and Shoulder Disarticulation

Socket: Double Wall ______ Single Wall ______ Shoulder Cap ______

Elbow Unit: ______

Modifications: ______

Harness

Type: ______ Material: ______

Modifications: ______

Control System

Single ______ Dual ______ Biceps Cineplasty ______ Other ______

Terminal Device

Hook: ______ Hand: ______

Wrist Component

Wrist Unit: ______ Flexion Unit: ______

Forearm Sizing

Standard Plan ______ Interchangeable Plan ______

Prosthesis to be fabricated by:

Date of Delivery:

______
Clinic Chief

new evidence which comes to the fore during the fabrication and fitting procedure. However, the important requirement is that the clinic chief concurs with the contemplated changes before they are put into effect.

In prosthetics and orthotics, many judgments are calculated risks or best guesses. Since the prescription decisions reached should reflect the best judgment of all, it does not seem reasonable that the ethical and fiscal responsibilities of these judgments should be placed on the prosthetist-orthotist alone but, rather, should be a joint responsibility of the clinic.

Experience in various clinics has shown that purchasers of prostheses and orthoses prefer to place their trust and confidence in the clinic judgment. Even in cases of failure, they are increasingly willing to tolerate the financial losses involved because they have become convinced that, through the clinic process, the best in professional judgment has been brought to bear on the problem.

3. Pre-Fitting Treatment

Where indicated, the patient is referred for appropriate physical therapy, which includes muscle strengthening and improvement of range of motion and muscular coordination, as well as procedures designed to encourage shrinkage of the stump and the relief of symptoms related to surgical trauma.

4. Prosthetic-Orthotic Fabrication

The fabrication of the prosthesis or orthosis is completed by the prosthetist-orthotist and essentially involves the implementation of the prescription written by the clinic.

5. Initial Checkout (Evaluation)

After "prescription," the second major responsibility of the clinic is "initial checkout." There is some question as to whether the somewhat colloquial term "checkout" is the best word to describe this activity. However, since it has now become fairly well ingrained, it probably must be used until a better term presents itself.

Initial checkout is essentially the first evaluation of the prosthesis-amputee or orthosis-patient complex as a biomechanical entity. It may be defined as a systematic examination of the patient with the prosthesis or orthosis. This is accomplished before training with the appliance is given and before the device is delivered to the patient. It is performed in some clinics with the appliance in the unfinished state, so that minor improvements may be introduced at a minimum cost. Initial checkout is important for two reasons: to provide assurance that the prescription developed by the clinic has been followed precisely, and to evaluate the biomechanical adequacy of the prosthetic-orthotic device against set standards of quality, efficiency, and design. (See Prosthetic Checkout Forms, Pages 98-101 and 112-115)

It is most important that this latter purpose be accomplished by successful passing of initial checkout before permitting the patient to wear the device for any extended period. In this way, corrections can be introduced before the development of undesirable physical or psychological reactions. Learning to use even the best of prostheses or orthoses is a difficult and arduous task for most patients. To ask them to attempt utilization of a device with discernible inadequacies seriously compounds the difficulties. It is, therefore, incumbent upon the clinic to assure itself that the prosthesis or orthosis is as completely satisfactory as possible prior to approving it for wear, training, and delivery.

6. Prosthetic-Orthotic Training

Upon completion of a satisfactory evaluation of the prosthesis or orthosis at initial checkout, the normal procedure calls for the referral of the patient to the therapist for appropriate prosthetic-orthotic training. It is important to emphasize that the training properly occurs after all significant shortcomings in the appliance have been remedied. This procedure permits a continuous, rational transition in the care of the patient from the prosthetist-orthotist to the therapist.

The length, type, and intensity of training depend upon the nature of the disability, the characteristics of the patient, and on other lesser considerations. The therapist may permit the patient to wear the device at home at an appropriate point in the training program. When the therapist, by means of objective evaluations and clinical judgment, feels that the patient has profitably completed the training program, arrangements are made for the "final checkout."

7. Final Checkout (Evaluation)

"Final Checkout" is perhaps best defined as a procedure to assure the prosthetic-orthotic clinic that the patient is not in immediate need of any further prosthetic-orthotic, medical, or surgical attention.

At this checkout, which is the third major responsibility of the clinic, the extent and effectiveness of the patient's use of the prosthesis or orthosis is evaluated, the biomechanical adequacy of the device is reviewed, and the physical and psychological status of the individual is confirmed. Upon ascertaining that these three factors are all satisfactory and that the patient would not profit from any further immediate prosthetic-orthotic, medical, or surgical care, the patient may be considered to have completed the necessary treatment.

8. Follow-Up

Since the prosthesis or orthosis is subject to mechanical changes and the patient is frequently subject to physical alterations, the optimal patient-prothesis (-orthosis) relationship may be thought of as transitory. Consequently, the maximum in prosthetic-orthotic function is obtainable only when the patient is called in for follow-up examinations over an indefinite period.

One suggested pattern for such follow-up visits is one visit every six months. Others have recommended a graduated schedule of visits. In either case, the purpose of these visits is to determine that no changes have taken place in the physical characteristics of the patient which adversely affect the fit and alignment of the appliance and that no mechanical deficiencies have developed which tend to make the operation of the device less efficient. Some of the changes which take place are such that the patient himself may not be aware of them, whereas the clinic, utilizing more expert observation and objective measures, is able to uncover such shortcomings.

The three fundamental steps in the prosthetic-orthotic clinic process, prescription, initial checkout, and final checkout, are viewed as a basic minimum in the care of any individual requiring a prosthesis or orthosis for the first time. In the case of a patient who is being seen solely for the replacement of his appliance, the initial and final checkouts are conveniently combined into a single step, assuming satisfactory follow-up procedures are in effect. On the other hand, when conditions are less than ideal, both the initial and final checkouts may require several repetitions before they are satisfactorily completed. In rare cases, a new prescription may be indicated.

Other Considerations

There are several additional considerations which are neither medical nor prosthetic-orthotic in the strictly technical sense and yet seriously affect clinic operations. It seems appropriate that some attention be given to these factors. They include the following:

1. Clinic Administration or Coordination

In order to keep the natural confusion which a patient experiences in appearing before a clinic at a minimum, it is important that such considerations as schedules for patients, the proper preparation of forms, the care of checkout equipment, the reduction of waiting time for patients, and the availability of a single person on whom the patient can always rely for counsel, be taken into account in the organization of a smoothly functioning clinic.

2. Physical Arrangements

It is sometimes overlooked that a quiet, large, well-lighted room for the clinic meeting, with both the waiting and dressing areas appropriately separated from the clinic operations per se, as well as a reasonable scheme for the control of visitors, are important requirements. The use of sample prostheses-orthoses, pictures, charts, and other material of an audio-visual nature are helpful in the orientation of the patients.

3. Interaction Among Clinic Members

One not-infrequent problem is the domination of the clinic activities by one of its members, usually the physician or the prosthetist-orthotist. Some clinic chiefs, perhaps because of status considerations, do not ask questions nor draw sufficiently upon the knowledge of the other clinic members. Rather, they resolve what may be to them an embarrassing situation in a manner which curtails the potential contribution of other members of the group.

On the other hand, the prosthetist-orthotist may, at times, control the clinic. In these instances, no discussions evolve concerning controversial prosthetic-orthotic issues and, in effect, the clinic becomes a stage for the prosthetist-orthotist. From time to time, this problem arises when there is a lack of interest on the part of the physician, or when he is burdened with responsibilities which do not permit sufficient time for attention to prosthetic-orthotic work.

The ideal situation exists, of course, when each member's experience is fully utilized in solving the problem at hand. It is the responsibility of the clinic chief to set the tone for this interaction and, ordinarily, the physician's experience and status are required to set a desirable pattern to these meetings. Consequently, in a very real sense, the prosthetic-orthotic clinic is an exercise in medical leadership.

4. Psychological Effects on Patients

There can be no gainsaying the importance of the psychological factors which make up good prosthetic-orthotic adjustment. This process, although complex, seems to involve at least two important considerations for clinic operation. They consist in providing the patient with a clearcut understanding of the treatment process and of the prosthetic-orthotic equipment which he is expected to wear, as well as a sense of friendly interest, psychological support, and personal concern.

In conclusion, those clinics which overlook any of the above factors, regardless of the degree of technical competence exercised by the members of the rehabilitation team, find results of their treatment are less satisfactory. The prosthetic-orthotic clinic is an integral part of the process of psychological rehabilitation and must provide a personal type of support, as well as appropriate technical service.

Summary

It has been found that clinics that assiduously but flexibly follow this procedural pattern, accompanied by competent technical knowledge on the part of its members and by an awareness of their patients' psychological needs, meet with considerable success in the rehabilitation of all types of prosthesis and brace wearers.

CHAPTER 2

PSYCHOLOGICAL ASPECTS OF AMPUTATION[1]

Introduction

Amputation is a disability that may affect the child, the adult, and the aging individual, occurring, as it does, at any time during the entire span of human life. The earliest manifestation is a child born as a congenital amputee, with an incomplete extremity or extremities; the latest occurrence, when the limb of a very elderly individual is amputated in an effort to add additional months or years to the life span. The factors which influence the care and treatment of a child born with a limb missing are considerably different than those which affect the management of an adult with a traumatic amputation suffered as a result of an automobile accident, and are again different from the problems of the elderly man who has had a limb amputation in his later years because of diabetes. It becomes clear that the problems of amputation depend to a considerable degree on the individual's chronological age and are specifically related to the psychological and physical attributes which are characteristic of his age group.

It is important to note that taking amputees as a group there is no direct relationship between the extent of the physical loss and the patient's psychological difficulties. These difficulties are more dependent upon the personality attributes of the individual than the type of amputation. Therefore, one individual with a "limited" physical loss may present far greater adjustment problems than another with a "major" loss.

In directing our attention to the behavioral reactions of the amputee, an analysis of the psychological aspects of the problem suggests that it is best explored along three channels.

The first is concerned with the experiences and reality problems which impinge on the individual as a result of amputation.

---

1. Extracted from a chapter entitled, "Amputation," by Sidney Fishman, Ph.D., in Psychological Practices with the Physically Disabled, edited by James F. Garrett and Edna S. Levine and published by the Columbia University Press, New York, 1961.

The second deals with the variety of ways in which an amputee reacts to these stimuli; the types of behavior he displays and the patient's introspections concerning his disability.

The third discussion is concerned with an identification of those psychodynamic processes which may clarify the relationships between the objective experiences associated with amputation and the resulting behavioral responses.

The Amputation Experience

In considering the stimuli that the amputee experiences, let us examine first the reality problems which are engendered by the disability. An appreciation of the nature of the problems stimulated is likely to pave the way for understanding the behavior of those experiencing them. A number of rather specific physical, psychological, and social problems of a unique nature develop because of the permanency, finality, and irrevocability of the loss associated with amputation. Furthermore, these physical and psychosocial problems must be considered in relation to one another because of their intimate and complex interactions. Lastly, the significance of the problems associated with amputation, prosthetic wear, and personal readjustment are great and deserve detailed identification.

A. Physical Capacities

1. Functional Limitations

Although the psychological satisfactions concomitant with physical activity have not been thoroughly studied, it is clear that there is an inborn drive to use one's physical resources. This is evidenced by the baby's unlearned determination to walk, crawl, and manipulate objects. The child's and adult's spontaneous participation in a variety of physical activities is a further example of this need. Although we have some difficulty in precisely defining the nature of this drive for physical activity, it is perfectly clear that there are significant psychological needs and satisfactions associated with it, and that with amputation, these gratifications become limited.

In addition to the pleasures evolving directly from the use of one's physical faculties, as in walking, dancing, or swimming, there are other satisfactions which are achieved only through the use of prehensile or ambulatory function as a necessary intervening step. In this latter instance, the pleasures do not grow as much out of the physical activity itself but from the results of its application, as in climbing to the balcony of a theatre, holding a drink, or picnicking in a desirable but somewhat inaccessible place.

In approaching physical tasks, both from the direct satisfactions involved and for the related pleasures, the alternatives open to the amputee are (a) to avoid performing the task, (b) to compensate for his loss by the greater use of the remaining extremities, or (c) to perform the function by utilizing an artificial replacement for the missing member. Depending on the task and situation with which he is confronted, an amputee is likely to utilize all three alternatives as solutions at various times. But no matter which course the amputee chooses, his need to perform a wide variety of physical acts without restriction, limitation, or special consideration can be only partially satisfied.

It is important to note that in general the lower extremity prosthesis replaces the lost extremity much more adequately than the upper extremity prosthesis. This is a consequence of the fact that ambulation is essentially a repetitive, cyclic activity taking place primarily in two planes, which can be duplicated by an artificial leg with relative effectiveness. Upper extremity function is considerably more varied and complex, and almost always involves motion in three planes, which makes the problem of duplication very much more difficult. Because of these facts, it is somewhat fortuitous that arm amputations occur most frequently in younger people who normally have the greater physical and psychological adaptability necessary to learn the use of an upper extremity prosthesis.

2. Functional Failures

Ordinarily, our society has relatively negative attitudes toward people who fail in various activities, whether these be at work, school, sports, or social affairs. Failure as a student, an error in a ball game, or failure to progress in one's job or business are all subject to society's criticism.

The use of a prosthetic appliance, however, inevitably implies a certain amount of failure in physical function as an outgrowth of three facts, which are beyond the conscious control of the amputee. Bearing in mind that the prosthesis is a simple machine, (a) any inadequacy in the design or construction of its parts and/or fitting to the amputee can cause a failure in function; (b) unless the artificial limb is perfectly controlled by the amputee, it again will fail to provide proper function; (c) the new amputee has not developed a sufficient level of neuromuscular coordination to maintain consistent control of the limb.

In view of these considerations, the amputee, especially the new wearer, must anticipate a reasonable number of instances when he will fail during ambulation by falling down, or will fail in the simple act of prehension by having something drop from his artificial hand. These failures of essentially elementary human functions are a source of concern and embarrassment for the individual because of the social and physical consequences. Even when the individual becomes expert in the use of the artificial appliance, the occasional possibility of failure exists. Depending upon the individual's need for presenting an appearance of perfection to his peers and himself, this anxiety concerning public failure tends to inhibit the person's use of the appliance.

B. Comfort

1. Pain Related to Prosthetic Wear

An additional difficulty in adjustment stems from the individual's need to be free from pain and tension so as to be as comfortable as possible. It is not ordinarily known or pointed out that prostheses are inherently uncomfortable appendages and even the most skillfully made one cannot be considered completely comfortable and therefore cannot be taken for granted by the wearer. What we have come to regard as a comfortable prosthesis is simply one that offers a minimum and tolerable degree of discomfort.

Although not widely expressed, the above point of view should not be surprising since, in fitting a prosthetic device for the lower extremity amputee, tissues and muscles are performing atypical functions, i.e., primarily weight-bearing. Until the tissues become acclimated, desensitized, and/or calloused to these new functions, considerable discomfort is the rule.

Even after prolonged periods of prosthetic usage, the desensitization is not complete and some discomfort continues. An additional physiological complication is that most areas on the stump have markedly lower pain thresholds than corresponding areas on the opposite limb.

Although the problem of weight-bearing does not exist with upper extremity amputees, the remaining musculature is still subjected to unusual stresses, and for both lower and upper extremity amputees, the body tissues are encased in relatively rigid, impermeable materials (wood or plastic) that interfere with normal ventilation and cause irritation and discomfort due to heat and perspiration.

2. Phantom Sensation and Pain

A second type of discomfort stems from the phenomena of phantom sensation and pain. Especially during the immediate post-operative period, amputees almost universally continue to sense the existence of the distal segments of the lost extremity as if it were still part of the body. In a large percentage of cases, this phantom sensation is initially a painful one, in that the body part is experienced to be in a cramped or unnatural position. With time the painful aspects of the phantom sensation tend to disappear for most amputees; however, the presence of the phantom remains indefinitely in varying stages of clarity. In some few instances, especially among older amputees, the phantom remains permanently painful and presents a considerable problem. At best, phantom sensation is a moderately distracting stimulus and, at worst, tends to be quite painful and troublesome.

3. Fatigue

Although research has not given us final, reliable data concerning the amount of energy expended in typical tasks by various types of amputees as compared to normals, preliminary studies tell us that these differences are significant. For example, an above-knee amputee performing a given ambulatory task expends considerably more energy than does his non-handicapped counterpart. Since the amputee is called upon to expend more energy, it is necessary for him to divert effort that once went to other activities and apply it toward his disability. As a result of this additional effort, he is also likely to experience fatigue more rapidly than the non-handicapped person. Both phenomena (continuous expenditure of effort and the early experience of fatigue) tend to interfere with the individual's motivation to participate in activities which are part of the rehabilitation process.

Another aspect of this problem is concerned with the fact that certain aspects of the operation of prosthetic devices are <u>not</u> automatic. In other words, the amputee needs to pay variable but continuous attention to the activation, control and use of his prosthesis. This requirement for increased attention may be viewed as making demands on the psychological resources of the patient. It serves to divert his attention from other matters and to focus attention on obtaining satisfactory ambulation or prehension. Although we cannot translate these demands into terms of physical energy and fatigue, its role as an additional and continuing drain on the amputee's resources is apparent.

C. Appearance

1. Visual Considerations

The word cosmesis, which pertains to adornment, beautification, or decoration, is widely used in the field of prosthetic restoration as a synonym for problems associated with one's visual appearance. This cosmetic problem is a greater one for upper extremity amputees of both sexes and female lower extremity amputees, since in both these instances the extremity is not normally covered by clothing. Because of our mode of dress, it is a lesser problem for the male lower extremity amputee and for very young children whose state of psycho-sexual development makes for little concern over matters of personal appearance. With the advent of adolescence this situation changes dramatically and cosmetic considerations become of urgent importance.

It is interesting to note that there is an entire group of orthopedic disabilities similar to amputation which have this "external badge" attached to them. All people afflicted with these disabilities are readily identified as being different. On the other hand, the majority of diseases are primarily internal in nature and may be completely secreted unless the individual chooses to confide concerning his illness. These "external" disabilities tend to set up a single problem related to the observation that we live in a society where great emphasis is placed on the quality, adequacy, and conformity of one's physical appearance. The problem is an outgrowth of the fact that we all tend to groom ourselves according to a pattern, place great emphasis on dress and make-up with "good looks" as an important goal.

Obviously, when one suffers an amputation, his appearance is changed, both in his own eyes and in the eyes of others. Since the values associated with appearance are important, when members of our society do not meet these standards, they suffer a loss of group acceptance. Since the need to be accepted is great, intrapersonal problems develop.

2. Auditory Considerations

Although the primary cosmetic problem for the amputee is the adequacy of his visual appearance, there are also problems connected with the noise-producing characteristics of the conventional prosthetic device. Since the prospect of being conspicuous by virtue of some inadequacy in one's make-up is a threatening one, the matter of adapting to a substitute extremity that produces noise becomes a cause for concern.

An artificial limb being a simple machine may have a variety of low-level sounds associated with its operation. Some amputees are concerned with noise caused by air escaping around the brim of the socket or in the articulation of the prosthetic knee or ankle. Others are sensitive to the atypical sound of the prosthetic foot hitting the floor in certain situations. Upper extremity amputees may react to the noise associated with the prosthetic elbow locking in position or the terminal device closing on an object. Although these noises are of a very low intensity level and go unnoticed by most people with whom the amputee associates, a significant percentage of the amputees are aware of these sounds and tend to project this awareness to others. Since cosmetic values, both visual and auditory, are threatened by amputation and attendant prosthetic restoration, another area of adjustment is disturbed.

D. Vocational and Economic Factors

Any interference in an individual's ability to earn his way in competitive society is psychologically threatening. Our understanding of this problem, as it affects amputees, may be aided by considering the "socio-economic scale", which in a general way categorizes people in terms of the social status accorded them. In general, an individual's position on the scale is intimately tied in with his occupational pursuits. The occupations that are accorded the highest status on this scale are professional, managerial, and executive in nature, while the unskilled labor categories represent the lowest. It is to be noted that the duties of the professional, managerial, and executive group are primarily dependent upon intellect and personality (ability to think, speak, write, persuade, or make decisions), while those in the unskilled group are primarily dependent on manual resources (carry, push, pull, walk, stack, or load). One can readily see that the potential re-employability of an amputee depends on the extent to which the individual is capable of intellectual or manual activities.

When people in the former group suffer an amputation, there are probably no significant threats based on economic considerations at all. With the exception of a small group in the performing and fine arts and certain professions, the ability of this group to pursue their occupations is essentially unaffected, as are their positions as wage earners. The only special economic problems faced by this group are the medical and prosthetic expenses associated with this chronic disability. On the other hand, those who earn their livelihood primarily by the performance of physical activities involving the use of arms and legs, and who do not have intellectual and personal resources for training in other fields, suffer a very severe economic handicap as a result of amputation. They are no longer competitive with their full-bodied peers.

The empirical fact is that the large majority of unemployed and marginally employable amputees come from this low socio-economic group. Unless selective placement is introduced or special arrangements are made on the job, these people remain unemployable. Hence for this significant segment of the amputee population, the social need to be economically self-sufficient is threatened.

As one might anticipate, there is a marked decrease in the numbers of amputees who are employed in agriculture, skilled and semi-skilled and unskilled occupations. In one nationwide study of 1630 upper extremity amputees, conducted by Berger in 1958, 64% of the sample were employed in these types of jobs before amputation, while only 27% were still employed in these jobs after amputation. By way of contrast, only 14% of the sample were engaged in professional, managerial, clerical, sales and service positions before amputation, but 41% were so engaged after amputation. The percentage of individuals in the study who became unemployed increased from 1% to 19%. Although the same types of shifts are to be found in employment data concerning lower extremity amputees, they are not quite so severe, since a lower extremity amputation is less limiting for most occupations than is an upper extremity one.

E. Social Considerations

Perhaps the single most important psychological prerequisite for a well-adjusted, productive life is the respect and the status that one receives from his associates and peers. Over and above the physical amenities of existence, the satisfactions received from the regard and affection of people close to one (friends, family, co-workers) are all-important. With regard to the amputee, this status is threatened and the possibility of loss of acceptance by one's peers becomes very real. The amputee is not ordinarily obliged to guess how others feel about him. He can (except in the case of the congenital amputee) simply reflect upon what he thought about other handicapped people before he himself was amputated. These attitudes, which he held toward other disabled people, are now directed toward the self.

It is likely that early in these reflections, the word "cripple" comes to the amputee's mind along with its various connotations of inadequacy, charity, shame, punishment, and guilt. Obviously, when an individual views himself or feels that he is being viewed by others in these terms, he considers himself an object for lessened respect and will react to this changed status accordingly. Since these attitudes are not at all likely to enhance the self-concept, but rather devalue it, the patient may be expected to undertake defenses against these attacks on his integrity.

Social prejudices with regard to the disabled have long been reflected in our literature with such villainous characters as Captain Hook, Captain Ahab, Long John Silver, and others, being identified as amputees. These characterizations tend to continue unsatisfactory attitudes toward the handicapped by virtue of their influence on youngsters during their formative years. It is, of course, true that very significant educational programs have been attempting to change the social attitudes toward the handicapped and teach that the loss of an extremity does not automatically devalue a person. However, attitudes toward the disabled that have been centuries in the making are not easily changed in a short period, regardless of the intensity of the effort. For the time being, we must face the reality that significant loss of social status accompanies amputation and that the human need to retain self-respect and the respect of one's associates is seriously threatened.

It would be most helpful to be able to formulate a general statement concerning which of the above problem areas are most significant. If this were possible, emphasis and attention could be paid to the more important aspects of the patient's problems, and less attention to the others. However, it is not possible to make this generalization, since different problems emerge as significant for different patients, depending upon their personal system of values. Also, the process of prosthetic rehabilitation involves a series of compromises and although the treatment serves to reduce a number of the amputee's problems, it does not completely resolve any one of them. In the reduction of certain problems, new ones are sometimes introduced or old ones aggravated. Hence, in treating the amputee, one must evaluate the interactions among all of these problems and proceed accordingly.

The reader has, of course, noted the great emphasis under the preceding headings, A, B, and C, concerning matters relating to the wear and utilization of a prosthesis. This attention is a direct consequence of the central role of the prosthesis in the personal and vocational rehabilitation of the amputee. The utilization of the prosthesis is the first evidence of the individual's capacity and desire to re-enter productive society. As such, its acceptance and use is frequently a very reliable prognostic index of the effectiveness of the entire rehabilitation effort.

Certainly many of the problems discussed would be eliminated if no attempt were made at functional restoration. Although such an approach would simplify the readjustment problems we have dealt with, it would in turn re-introduce personal, social and cultural problems of the very type we are attempting to solve through rehabilitation efforts. The humanistic values of our society suggest that the greatest effort be expended to expedite a return of independent function as the first step in the social re-integration of the individual.

Amputee Behavior

In turning to the second question of how the amputee reacts to the problems engendered by amputation two questions arise. What are the typical behavioral consequences of amputation? What are the individual's introspections, attitudes, opinions, and feelings?

A. Behavior during Hospitalization

Let us first consider the amputee's behavior during hospitalization in the relatively immediate post-operative period. During World War II, several studies were made of amputees during the period of hospitalization. One study by Wittkower in 1947, which surveyed 200 British War Service amputees by means of interviews, noted expressions of depression, resentment, anxiety, defiance, cheerfulness, resignation, and indifference as the dominant behavioral reactions. A second study by Randall, Ewalt and Blair in 1945, which evaluated one hundred hospitalized U. S. Army veteran amputees by means of the Rorschach Test and psychiatric interviews, noted shame, self-pity, worry about family, depression, anxiety, feelings of good fortune, and no significant emotional responses among the group. A third study by Hughes and White in 1946, with 350 amputee patients in a U. S. Naval Hospital, concluded that amputees retained their normal personality reactions. All three investigations found a number of patients who adjusted relatively easily to the loss of a limb while others adjusted with great difficulty. These studies, as well as more recent clinical experience in civilian hospitals, have all suggested that after the immediate trauma associated with the amputation subsides, there is an intensification of the individual's emotional reactions during the first few weeks or months post-operatively. It is at this time that overt emotional reactions to amputation are strongest.

A final study by Ladieu, Harpan, and Dembo in 1947 concerned itself with the attitudes of amputees and other orthopedically disabled towards receiving help from non-disabled individuals. Unfortunately with the conclusion of World War II, there have been no further systematic reports of the immediate post-operative behavior of any sizable groups of amputee patients.

B. Long Term Behavior

After the immediate traumatic psychological effects of amputation surgery and its realization have passed, the behavior displayed becomes more and more closely related to the pre-amputation personality of the individual.[2] After the initial emotional distress is passed, as the

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2. The reader will note the exception to this statement when considering the congenital amputee, or one who has lost a limb in the first years of life.

individual begins to make his adjustment to the experiences associated with amputation, the behavior of almost all amputees falls well within the limits of what may be called "normal". There is apparently no special, definable neurotic or psychotic process involved in the long-term adjustment to amputation. It is not surprising, therefore, that a wide variety of amputee behavior is reported by various observers, since the overt behavioral pattern of amputees reflects the complete spectrum of adjustment and may therefore occasionally reflect the predispositionsand biases of the observer.

In what way, then, does the amputee's long-term behavior differ from that of the non-disabled individual? Although there are no significant differences in the overt behavior pattern, amputees do express unique attitudes, opinions, and feelings concerning their disability and about the recurrent stresses which they are called upon to face.

In an attitude questionnaire administered to some 359 adult upper-extremity male amputees of long standing, an attempt was made to study nine personality variables; (1) acceptance of loss, (2) identification with the disabled, (3) appraisal of functional adequacy, (4) independence, (5) sensitivity, (6) appraisal of acceptance by others, (7) sociability, (8) frustration and (9) optimism. The predominant findings by Fishman and Siller in this 1958 study suggested that no matter which aspect of personality was studied the subjects tried to maintain feelings of bodily integrity and adequacy by denying many of the personal, vocational, and social consequences of amputation. They attempted to de-emphasize physical difficulties, rejected notions of abnormality,and set their cosmetic and functional desires in line with those of normal people. These findings, however, must be interpreted in the light of the amputee's strong need for unprejudiced recognition from the non-disabled. In order to gain this recognition, the amputees obviously responded in a manner which only partially represented their true feelings. Therefore, it is clear that this data more nearly reflects how the amputee feels he should be regarded rather than how he actually regards himself.

In another investigation by Fishman in 1949, utilizing the clinical interview as the major investigative tool to study 48 lower-extremity, veteran, male amputees of long standing, it was possible to establish a higher degree of rapport than through questionnaires. An analysis of the interview protocols indicated a considerably higher number of negative self-references than positive self-references, revealing a relatively non-accepting set of attitudes towards their disability The major types of overt behavior which were associated with these expressions of negative self-concept were (1) hostility, (2) dependency, (3) timidity, (4) superficial self confidence, (5) unstable motivation, (6) rationalization of situations, (7) compulsivity. The types of behavior which were associated with positive self-concept were (1) self-assured, confident behavior, (2) stable motivation, (3) gregariousness, (4) no expressed hostility, and (5) positive attitudes towards the artificial limb.

Although there were demonstrable differences in the kinds of behavior which accompanied negative and positive references towards the self, in some instances the same or a similar self-concept was the motivating factor behind markedly different reactions. In one non-accepting person, hostile, aggressive behavior may arise, while in another, non-acceptance is expressed through timid, hesitant, or depressed behavior. Rejection of amputee status may, in one instance, produce hostility towards the prosthetic device or towards rehabilitation personnel, while, in other instances, attention-getting behavior or complete withdrawal is the result of the same rejecting attitude. The evidence clearly indicates that different types of behavior may evolve from similar self-perceptions depending on other individual aspects of the personalities involved.

C. Behavior Related to Prosthetic Wear

Probably the next most significant event in an individual's life after the fact of the amputation per se is the receipt and subsequent utilization of a prosthetic device The individual's acceptance or non-acceptance, use or non-use of the device, and the associated attitudes are of pivotal influence on the nature of his later life. In view of the emphasis placed on prosthetic wear it is important to consider if there are any definable psychological consequences associated with such wear Specifically, are the attitudes or behavior of the amputee altered in any significant way by virtue of wearing a prosthetic device, or does the device simply provide increased physical function?

As a part of the study of upper-extremity amputees referred to previously, 359 were evaluated psychologically prior to being exposed to systematic prosthetic treatment and were then re-evaluated some months after the completion of such treatment. The data led to the conclusion that, with the active use of an appropriate prosthetic device, there was:

1. a decrease in expressed feelings of sensitivity and frustration.
2. an increase in feelings of social adequacy.
3. a generally greater acceptance of his disabled situation.
4. a greater feeling of effectiveness and functional independence.
5. greater self-reliance.
6. greater security and self acceptance.
7. less shyness and more adaptable behavior.

One may question whether the amputee actually fully experienced these positive changes, or whether they were, in part, expounding an expected "cultural norm" towards prosthetic restoration.

On the basis of the data available from this study, it is not possible to answer this question with any finality, although one may reason that both considerations contributed to the amputee's opinions. However, when the clinically reported attitudes and reactions of the overwhelming percentage of amputees who consistently wear prosthetic devices are considered, there is indeed strong evidence that there are meaningful psychological advantages associated with prosthetic wear.

Similar values for prosthetic wear were identified among a group of 159 juvenile amputees by Fishman and Peizer in 1958. In this group, prosthetic wear increased the scope of the children's activities and display of independent behavior. This was accompanied by an observable improvement in the emotional stability, school adjustment, social confidence, and the quality of the self references made by members of this group. Except for one survey by Chapman, Palmer, Bell, and Buckley made in 1959, describing the functional values of prostheses for older amputees, there have been no comparable studies to shed light on the psychological effects of prosthetic wear on the geriatric patient.

Although the large majority of amputees profit both functionally and psychologically from prosthetic wear, there is a significant number who apparently do not. In the study of upper extremity amputees referred to above, efforts were made to determine the reasons for unsatisfactory prosthetic adjustment and the following points evolved:

1. Normally very little information concerning prostheses is available to new amputees early in the rehabilitation program and this deficiency encourages the development of unrealistic expectations concerning prosthetic wear.
2. Overly optimistic anticipations concerning the value of prostheses were in most cases modified downward after prosthetic wear and were accompanied by considerable personal disappointment and distress.
3. No attempt is ordinarily made to alter pessimistic attitudes towards prosthetic wear prior to fitting.

These findings suggest that a considerable service could be rendered if the amputee would be made aware of the realities of prosthetic wear by appropriate counselling prior to the time of prosthetic fitting and training so as to make maximum motivation and to minimize disappointments.

In another aspect of this same study, it was substantiated that the amputee's post-fitting attitudes and use of the prosthesis are closely related to, and may be predicted on, the basis of his pre-fitting attitudes. The data indicated that opinions held by the amputee before he had been exposed to prosthetic devices exercise a controlling influence over later prosthetic acceptance, performance, and use. On the basis of these findings, one might conclude that it is not appropriate to provide a prosthetic appliance to an individual until he has developed an attitudinal predisposition to accept its purposes and functions. Should a patient display consistently negative attitudes in this regard, an educational effort would most assuredly be required in an attempt to influence and change the prefitting attitudes.

Amputee Psychodynamics

We turn now to the third area of discussion to complete the analysis of the psychological reactions to amputations. In so doing we focus our attention on the psychodynamic processes which act as a bridge between individual experiences and the resulting behavior.

A. Perception of Disability

In a number of instances, predictions of rehabilitation potential based upon physical considerations prove to be quite inaccurate, overshadowed as they are by a psychological factor, namely, the patient's unique perceptions of his disability. In many instances these perceptions have a greater influence on the rehabilitation process and its result than the physical extent of the disability. The self-concept, representing as it does the sum total of the complex interactions among these perceptions, as such, reflects the personal meaning of the loss to the individual. The nature of these perceptions is also closely dependent upon the value structure of the individual.

A rather well-known corollary concept is that of the body image, a concept which focuses on the individual's perceptions of his body and physique. Since, taken by itself, it is a less inclusive construct than the self-concept it is not as useful in dealing with the fuller relationships between an amputee's behavior and his environment.

It is most unusual to find a realistic self-concept among new amputees. In most cases, relatively inaccurate and distorted self-perceptions exist. This is not a surprising assessment, since the patient does not normally have access to any considerable experience with the disabled. He does not know what to expect in living as an amputated person, and, in view of the rather significant trauma associated with his loss, he focuses his anxieties on the amputation and considers the disability a more central factor in his future life than is realistic. It is, therefore, probably more correct to say that a person "must learn to live with his perceptions of his disability" rather than "with his disability".

Since the amputee acts in terms of his perceptions, and not necessarily reality, the consequences of a highly distorted estimate of one's disabled condition are reflected in the increased difficulty in accepting the requirements of the rehabilitation process. If steps are not taken to correct these self-perceptions prior to the prescription and fitting of an artificial limb and training in its use, it may be almost impossible to accomplish these processes at all. When rehabilitation does proceed, it does so haltingly and with great resistance and difficulty.

Therefore, we are as much concerned with trying to effect a change in the individual's perceptions as we are in trying to change the realities themselves. If this be the case, the treatment of the amputee assumes two foci: (1) a diminution of physical loss by appropriate medical care, introduction of prosthetic devices, as well as prosthetic and vocational training, and (2) a revision of unrealistic ideas and attitudes concerning disability through continuous re-education. Both these approaches are designed to increase the effectiveness of the patient's functional and psychological resources.

B. Consequences of Frustration

The manner in which people respond to disaster, the death of a loved one, the destruction of their home, or the illness of a child, varies in a myriad of ways. Similarly, the reactions to amputation tend to follow the same variable pattern. Almost any type of behavioral response can be seen following the expected frequencies of normal, neurotic, and psychotic behavior in the population as a whole.

The previous discussions have described a number of significant human needs that cannot be completely gratified as a result of the loss of an extremity. We have suggested that these circumstances tend to frustrate the individual and to generate conflict because of permanently unobtainable goals. Furthermore, it has been pointed out that the extent of conflict is dependent upon the patient's perception of his disability, as well as its real limitations. Consequently, the more inaccurate the patient's perceptions are, the greater the anticipated psychological difficulties.

Conflict and frustration are theoretical constructs which describe certain aspects of human adjustment, and their presence inevitably results in the development of tension within the individual. In order to re-establish psychological equilibrium, the energy associated with these tension states must be reduced. This reduction in tension is accomplished through overt or covert behavior, which is characterized by a variety of emotional reactions and adjustive mechanisms.

The emotions aroused may be fairly specific ones, such as anger or fear, or they may be quite diffused, such as anxiety. Furthermore, as a result of amputation the emotional reactions are almost universally of a negative quality (e.g., anxiety, fear, anger) as distinguished from positive feelings (e.g., love, affection, joy). When strong negative emotions are experienced, they tend to be expressed rather directly through overt behavior, while less strong and less specific emotions tend to be more easily inhibited and modified. In any event, it is most unlikely that the amputee's strong tensions will be relieved through the expression of any single type of emotional response.

The behavior exhibited by the individual also depends on his previously learned adjustive patterns. Hence, in many instances an unconscious defense mechanism comes into play, such as projection, displacement, rationalization, regression, somatization and denial. When these come into play the overt behavior pattern may be void of or extremely limited in any identifiable emotional reactions. The reactions of the amputee to frustration and conflict usually include both overt emotional experiences and unconscious defenses, each coming into play on the basis of how the individual perceives and interprets the specific environmental situation, as well as the intensity and variety of the emotions being experienced. This psychodynamic sequence serves as a basis for the often expressed conclusion that adjustment to disability is closely related to the individual's pre-amputation personality and behavior.

With the recognition of the wide variety of psychodynamic processes and emotions utilized in responding to stress, the need to identify, define, and measure the specific processes used by an individual has become quite important. In a current investigation, started in 1960 by Weiss, an effort is being made to study how twelve psychodynamic processes are used by amputees in their adjustment.

The measurement of each of these adjustment techniques is being accomplished through the use of appropriate psychological tests. The plan calls for the performances on this battery to be correlated with the amputees' observable behavior in the rehabilitation and vocational setting, so that the relationship of these psychodynamic processes to amputee adjustment and behavior will be clarified. The twelve variables, all of which have evolved from extensive clinical experience with amputees, follow:

1. Sociopathic Impulsivity
2. Emotional or Neurotic Impulsivity
3. Displacement and Paranoid Reactions
4. Phobic Reactions
5. Depression
6. Encapsulation or Constriction
7. Somatization or Somatic Preoccupation
8. Inadequate Control of Tension
9. Pessimism
10. Inadequate Masculine Role Identification
11. Inadequate Compensatory Ambition
12. Stress Intolerance

The psychological processes listed above generally result in a willingness to compromise with limited restorative goals through a diminution of the amputee's motivation to regain his lost functions. The consequences of poor motivation are particularly devastating in this instance, because the amputee is called upon over and over again to expend greater effort and energy than is normally demanded of a non-handicapped person for the accomplishment of the task at hand. Also the variety of "secondary gains that society provides certain groups of amputees tends to curtail further the necessary expenditure of effort.

The empirical evidence substantiates the theoretical considerations, in that the single most important problem facing the rehabilitation worker concerns the ways and means of implementing the marginal motivation of so many patients. Since the rehabilitation process is clearly re-educational in nature (and since it has been appropriately said that no one can teach, only create a situation that is conducive to learning) the question arises as to what techniques will help stimulate the patient's learning during the rehabilitation process.

Psychological Rehabilitation

Aspects of five important areas of human activity were described as being frustrated by virtue of amputation, namely, physical function, cosmesis, comfort, vocational and economic factors, and social considerations. It is clear that in order to assist the amputee, these problems, as modified by his perception of them, must be dealt with so as to diminish the frustrations and conflicts involved. These problems cannot be erased. They may be modified or compromised, but cannot be negated. The problem of the rehabilitation of the amputee becomes, therefore, one of assisting the patient to incorporate certain limitations into his pattern of life so as to assure minimal interference with the large variety of other important activities of living. Several suggestions for extending assistance follow.

First, the actual processes of physical restoration, personal and vocational counseling, as well as job placement, assist the individual in partially meeting a number of his needs. When the amputee uses a prosthesis, he does not walk as well as a non-handicapped individual, but his gait more closely approximates that of the normal than it does when crutches are used.

The prosthesis does not look exactly like the normal extremity. However, if properly fabricated, it can meet the requirements of reasonable appearance. The prosthesis will not be completely comfortable but probably can be designed to fit within the pain tolerance limits of the individual. As he learns to utilize and control his prosthesis, the frequency with which it fails him diminishes. Personal counseling assists the amputee to clarify and correct his perceptions, so that he comes to understand the goals of the rehabilitation process, what he may anticipate in the future, and what he must learn to live with. By appropriate vocational counseling and placement procedures, the insecurity associated with re-employment can be reduced, and he learns to accept himself and, thereby, the attitudes of others.

A second significant approach revolves about the ability of the rehabilitation personnel to introduce substitute values and life goals in the place of those held prior to amputation and around the patient's ability to accept these new goals. For example, if the patient's occupation prior to amputation involved considerable use of the affected extremity, one can achieve significant psychological progress by suggesting other occupations that make significantly lesser demands on the extremities and yet hold satisfactions for the patient. As a substitute value or goal is offered and accepted, an important factor developing frustration and conflict is thereby eliminated.

Thirdly, a problem frequently exists in preparing the patient to be amenable psychologically to the processes of prosthetic restoration and vocational rehabilitation. In the early post-operative stages, an amputee may be viewed as undergoing an emotional reaction not dissimilar to those of people who suffer a catastrophe, such as the death of a loved one. In both instances, the emotional reactions of the bereaved operate in a somewhat circuitous fashion that must be interrupted at some point if the individual is to recover from the loss and re-enter normal life activities. These circumstances dictate the involvement of the amputee patient in some purposeful activity at the earliest psychologically suitable moment, which will tend to divert him from a continuing preoccupation with his loss.

In this connection, the prosthetic training procedures fulfill the extremely important function of involving the patient in challenging and important activities. In addition to the obvious primary purpose of prosthetic training, which is that of teaching one to use the prosthesis, the secondary purpose of requiring physical and mental concentration is significant. It is important to note that, ordinarily, only the occupational or physical therapist spends sufficient time with the patient to provide continuous and important supervision and stimulation along these lines.

Fourth, a technique that is sometimes helpful in motivating the amputee patient involves placing him in contact with previously rehabilitated amputees. This is a particularly important procedure to be used with those amputees who find it impossible to relate to or identify with the non-amputated professional worker. In fact, he is unable to profit from instruction or reassurance as a result of his attitude that no one who has not lost an extremity can really understand his situation.

In these instances, the involvement of suitably readjusted amputees as persons with whom the new patient may identify and from whom he may learn cannot be overestimated. A word of caution must be introduced, however, concerning the qualifications of the amputee to serve as inspiration. An individual of substantial personal adjustment must be used so that the new amputee does not become an outlet for the mentor's problems and anxieties.

Fifth, the continuous expression by rehabilitation personnel of appropriate concern, attention, reassurance, and respect tends to assuage the troublesome emotions being experienced by the patient. Negative destructive emotions simply do not flourish as well in an atmosphere typified by this type of accepting professional climate.

Lastly, the thought that each patient must be treated in terms of his own value system must be emphasized again. Placing the proper emphasis on each of the amputee's problems is part of the process of diagnosis and prognosis and is a prerequisite for developing a sound management concept.

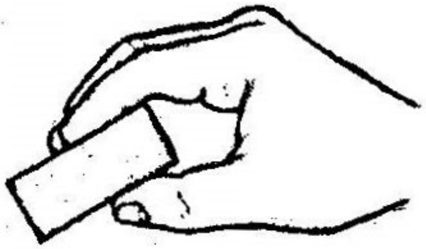
These several suggestions, though by no means exhaustive of what can be done, should tend to reduce the frustration and conflict as well as the strength of negative emotions being experienced by the patient. In turn, the individual's motivation to restore himself as a functioning member of society will tend to increase.

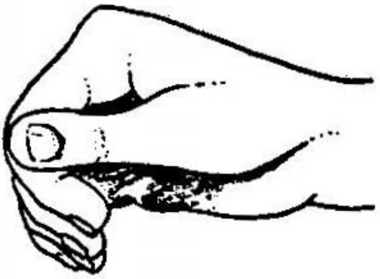
Criteria of Successful Rehabilitation

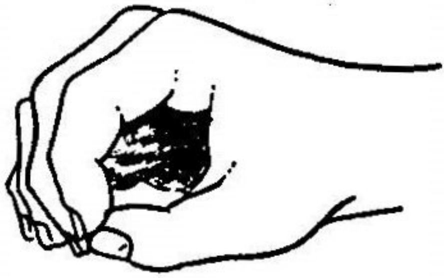
By what criteria can we gauge the success of the rehabilitation of an amputee? Does the answer lie in the apparent perfect restoration of lost function, or in the ideal cosmetic replacement, or in the most comfortable prosthesis? Partially, success lies in all of these, but it may in some cases exist with a minimum of these accomplishments.

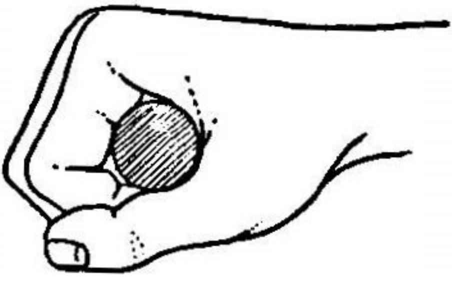
We cannot expect the same standards of performance from patients of dissimilar physical and psychological characteristics. We can accomplish only that which the individual's pre-amputation physical and psychological potentials permit It is, therefore, possible to have a more successful result in the rehabilitation effort with people who are capable of less physical function than with those who are capable of more.

In view of this fact, success in rehabilitation may be defined in terms of psychological rather than physical criteria. Rehabilitation may be said to be successful when the amputation and its related considerations are no longer the central adjustment problem for the individual. As the ability to use the prosthesis more automatically or subconsciously increases, as the client's awareness of being physically limited and different becomes less threatening, and as the amputation becomes a minimal source of interference in his familial, vocational, and social activities, the elements of successful rehabilitation have been approached.

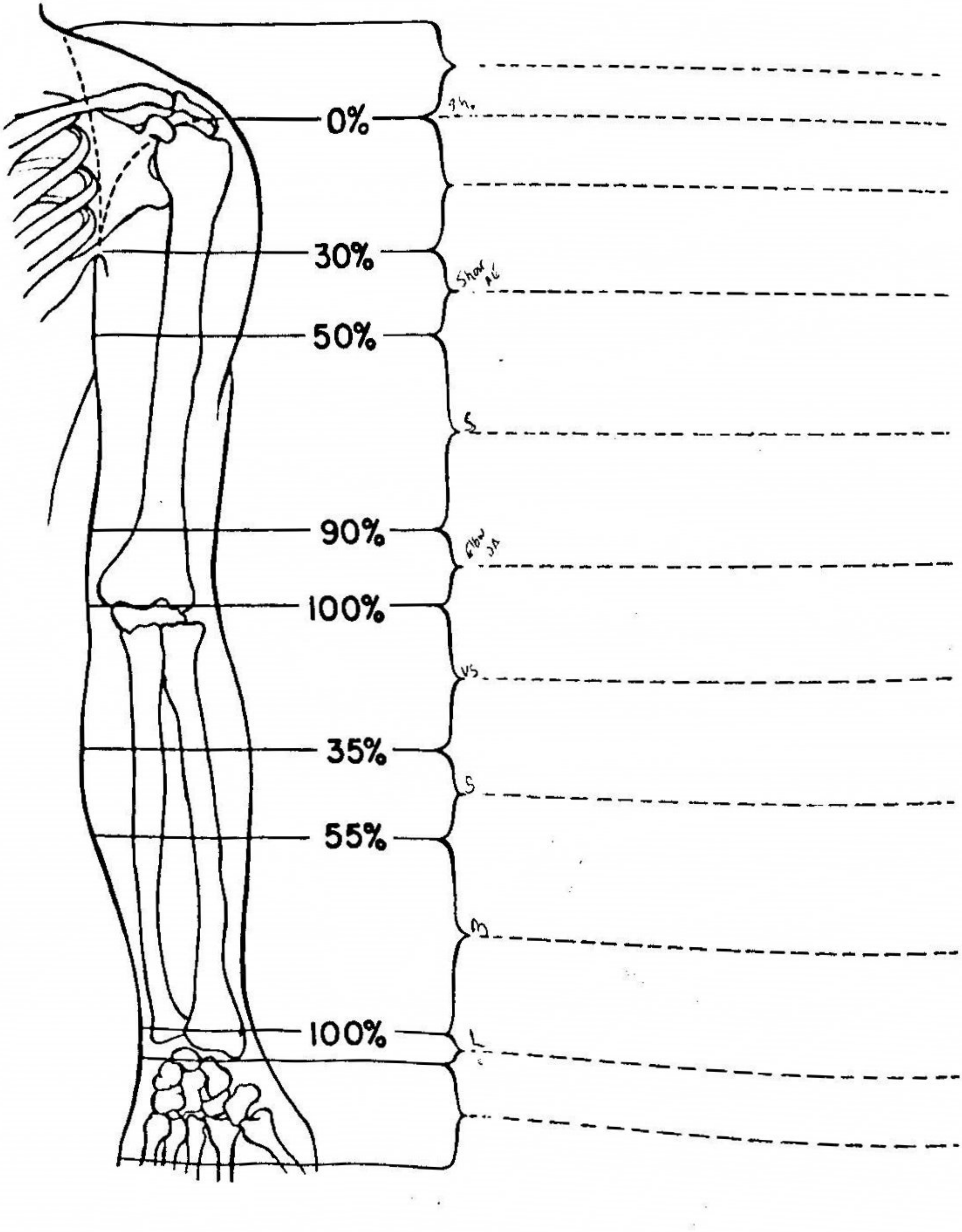








CLASSIFICATION BY LEVEL OF AMPUTATION



CHAPTER 3

COMPONENTS OF UPPER-LIMB PROSTHESES

The components common to all upper-extremity prostheses are the terminal device and the wrist unit. The characteristics and functions of these components and of the additional components of below-elbow, above-elbow, and shoulder prostheses are discussed in this chapter.

TERMINAL DEVICES

The primary purpose of the terminal device is to replace the grasp function of the hand. Since various types of grasp are available to the human hand, the prosthetic replacement must permit the most satisfactory and useful forms. Terminal devices can be divided into two categories: hooks and hands.

Hooks

By far the most commonly used terminal device is the split-hook type, first extensively developed by D. W. Dorrance nearly 40 years ago. By allowing the amputee to open and close the hook, objects can be grasped between the "fingers"; the shape of the fingers also permits some to the other usual functions of the hand, such as holding, carrying, pulling, or pushing objects.

The Dorrance series of hooks are all actuated by a control cable, and all employ the voluntary-opening (VO) mode of operation. The amputee exerts force on the control cable to open the fingers against the force of rubber bands which act as a spring to close them and to provide a prehension or pinch force. Prehension force is determined by the rubber bands used; this force is approximately 1½ lb. per rubber band. These hooks are available for right or left side and as standard utility models and heavy-duty or special-purpose models. The standard utility models are available in five sizes, ranging from infant to adult. The heavy-duty models, commonly called "farmer's" hooks, are available in one adult size and are provided with special tool-holding features which adapt the hook to manual labor. The heavy-duty models are made of stainless steel, and the standard utility models are made of either stainless steel or aluminum alloy. The aluminum hooks weigh 2 to 3 ounces; the stainless steel, 6 to 13 ounces.

Prescriptions must be written with due consideration of the vocational and avocational pursuits of the patient, and also the manner in which he undertakes such activities. Steel hooks are recommended for activities requiring a very durable terminal device; aluminum hooks are often preferred because of their lighter weight but are subject to breakage from severe use.

Far less common than the Dorrance hooks is the Sierra two-load hook. This is a voluntary-opening device which has prehension force supplied by two heavy spiral springs mounted within a small case; a selector button on the thumb permits the choice of either 3½ or 7 pounds pinch force. While change of pinch force is desirable, this type of hook is likely to have relatively more maintenance problems.

Another less-common hook is the Sierra-APRL voluntary-closing hook. Since the amputee closes the hook with his own body power by means of the control cable, he has precise control of finger pressure or prehension force, ranging from ¼ to ½ lb. up to 20 to 25 lbs. A self-locking feature automatically locks the hook in the grasp position as soon as the amputee relaxes, enabling him to hold an object firmly without exerting continued effort. The hook also has a large (3½ inches) and a small (1½ inches) prehension opening available at the choice of the amputee, controlled by means of a small switch lever on the case. In addition, the automatic locking mechanism may be disengaged (by moving the switch to the center position), allowing for "free-wheeling" with a prehension opening of 1½ inches and used for convenience in certain activities, such as the sorting of small objects without constant locking and unlocking. This hook is very suitable for fine work and for well-organized, carefully selected patients, but it does present durability and maintenance problems. In addition, since each grasp activity involves a closing, locking, unlocking, and opening cycle, the extra motions may become uneconomical in terms of energy expenditure during a day's use.

Hands

Hands are used by an increasing number of amputees, often on a interchangeable basis with a utility hook. They may be divided into three classes: passive (cosmetic), voluntary-opening, and voluntary-closing. Cosmetic gloves which closely duplicate skin shade and other features of the normal hand are used with these hands.

As the name implies, the passive hand contains no functional mechanism and is intended for cosmetic effect. However, it may also be used for certain activities, e.g., to stabilize paper for writing or clothing for ironing, or for assisting in buttoning with a sound contralateral extremity. It is available in various sizes, can be made very lifelike in appearance, and is relatively light in weight (3-4 ounces), since no mechanism is involved.

The voluntary-opening hands are available in a number of sizes, with various different features, and comprise models by Becker (Lock-Grip, Imperial, and Plylite), Dorrance, Robin-Aids, and Sierra-APRL VO. The Becker Lock-Grip and its successor, the Imperial, are strong and provide reasonable function, with all fingers and thumb working and with a locking-type mechanism, but are quite heavy (approximately one pound). The Becker Lock-Grip is available in eight sizes, and the Becker Imperial is available only in one (adult) size. The Plylite hands are relatively light (10-12 ounces) and are available in various sizes but provide only minimal function by means of a cable-controlled movable thumb. The Dorrance hands are available in four sizes (Models 1, 2, 3, 4) for ages ranging from 4 years to adult, and are probably the most satisfactory group on the basis of appearance and ease of operation. The thumb and first two fingers move and come together in a "three-jaw-chuck" pattern which permits grasp of many different types of objects. Robin-Aids hands have the distinguishing feature of adaptability to the partial-hand amputation; the moving parts are all located distally, so that the overall length of the hand can be shortened to adapt it to the transmetacarpal amputation. In addition, individual third and fourth fingers may be removed to accomodate unamputated portions of the hand. All four fingers operate, and the fingers are adjustable at two joints for selected positioning -- a help in holding various-sized objects. A two-position thumb allows extra-wide grasp. The Sierra-APRL VO hand, available in standard adult size only, incorporates a two-position thumb which provides large and small openings, permitting easy handling of objects of various sizes. A "Bac-Loc" feature operates in all finger positions and enables amputees to hold heavy objects securely.

The only voluntary-closing hand is the Sierra-APRL VC Hand, available in one standard adult size. It has a mechanism similar to that of the Sierra-APRL VC Hook, providing controllable prehension force with automatic locking in the grasp position. Like the Sierra-APRL VO Hand, its two-position thumb provides large and small openings. Its weight is 12 ounces without glove.

A comparison of hooks and hands, which must often be considered in the prescription of a prosthesis, indicates certain advantages of each. The hand is definitely superior in terms of cosmesis and for grasping a large or round object, such as the handle of a tool. The hook is superior for grasping small objects, visual cues (allowing the user to see much more of what he is doing), use in restricted area, weight, cost, and maintenance. When making this comparison, one should bear in mind the function of a prosthesis for a unilateral amputee. In most cases the prosthesis will serve as a helper and will not often be required to perform intricate, delicate movements. For instance, although the hook may be superior for handling coins, the amputee will use his intact extremity for this purpose. In the case of the bilateral amputee, however, all activities must be performed with the prosthesis. Accordingly, a bilateral amputee will very rarely be provided with two hands.

WRIST UNITS

Wrist units are used for attaching terminal devices to prostheses, as well as providing for terminal-device rotation (pronation and supination) to place the terminal device in the best position to accomplish a desired activity. Since encasing the below-elbow stump in a socket limits active pronation and supination in all but the very long stump, and since this activity is completely lost at higher levels of amputation, the wrist unit must provide this function.

The rotation function is passive; the amputee rotates the terminal device in the wrist unit with his sound hand or by his other hook (if bilaterally fitted) or by pushing against a part of the body or other surface to produce either pronation or supination. The wrist unit also permits interchange of terminal devices -- from a hook to a hand or from a heavy-duty hook to a standard utility hook, for example.

Wrist units are made either as friction wrists or locking wrists. Friction wrist units (washer or bushing types) permit pronation and supination of the terminal device and hold it in the selected position by means of friction. These wrist units are available in four sizes of round-shape units, two sizes of oval shape, and two sizes of a special thin version to be used for the wrist-disarticulation amputee. Locking-wrist units permit manual rotation and then hold the terminal device locked in a fixed position. Two locking wrists are commercially available, differing in their methods of control: the button-type unit and the ring-type unit. The former has a control button which, with light pressure, unlocks the wrist to allow rotation of the terminal device; axial pressure (pushing in) on the terminal device then causes the wrist to lock in the desired position. Firm pressure on the control button will release the terminal device for exchange with another. In the ring-type unit, operation is controlled by a movable three-position ring. Turning the ring to the right allows free rotation of the terminal device to the desired attitude, where it is locked by turning the ring to the center position. Turning the ring to the left permits disconnect of the terminal device. Two sizes of the button-type and one size (adult) of the ring-type are available.

Particularly for the bilateral amputee, who must be able to operate the terminal device close to the body, a prosthetic component to provide wrist flexion is often indicated. Two types of wrist-flexion unit are available: external and internal. The external type (Sierra), which comes in two sizes (adult and child), is worn between the wrist unit and the terminal device and allows manual positioning of the terminal device in either the straight or flexed position. The adult size allows setting and locking in one of three positions: zero, 25 degrees, or 50 degrees of flexion. The child size allows two positions: zero and 50 degrees of flexion. The internal type (Hosmer), available in three sizes (adult, medium-small, and child), combines a friction wrist and a wrist-flexion unit in one unit and provides for setting and locking in three positions: zero, 30, or 50 degrees of flexion.

BELOW-ELBOW COMPONENTS

The prosthetic forearm incorporates the wrist unit and the socket. Both the forearm shell and the socket are usually made of plastic. The socket encases the stump and extends its control function to give force and movement to the prosthesis.

A "split socket" is sometimes used with patients who have very short stumps so that special types of hinges (which are discussed in the next section) can be used to either increase available range of motion or to incorporate an elbow-lock mechanism in the prosthesis. The split socket consists of a true socket that encases the stump and a forearm shell to which the wrist unit and terminal device are attached (Fig. 1).

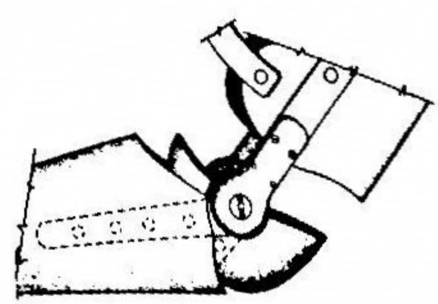


Fig. 1. Split Socket

Alternative methods to the split-socket technique for fitting amputees with very short below-elbow stumps are the preflexed socket and the Muenster or Hepp-Kuhn prosthesis (Fig. 2). The preflexed arm prosthesis has a below-elbow socket constructed so that the longitudinal axis of the forearm shell is preset in approximately 20-25 degrees of flexion to the long axis of the socket. The socket extends over the olecranon and is used with or without hinges. With this arrangement the average patient can operate his terminal device in the areas used most of the time and still retain full torque about the elbow. Although this technique yields less elbow flexion than the split socket and step-up hinge procedure, the reduction in force requirements and ease of use more than compensate for this limitation. In the Muenster prosthesis (Fig. 2) the socket and forearm are set in a position of inital flexion and the socket encloses the olecranon and the epicondyles of the humerus. The intimate stump encapsulation, flexion attitude, and high trim lines of this socket provide excellent retention and security. Therefore, in most cases, the need for suspensory apparatus to maintain the socket on the stump is obviated, and the harness need control only the terminal device. As in the case of the preflexed socket, limited range of motion is a problem but in most instances is more than compensated for by the advantages.

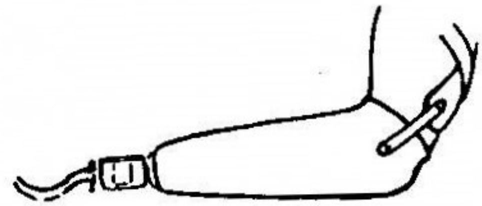


Fig. 2 Muenster Socket

Below-Elbow Hinges

Below-elbow hinges connect the socket to a cuff or pad on the upper arm and are important in terms of suspension and stability. There are three major types: flexible, rigid, and "step-up" -- the selection depends primarily upon the site of amputation and the residual function.

Flexible elbow hinges, which are flexible straps of leather, metal, or other material, serve primarily to suspend the forearm socket. They permit active pronation and supination of the forearm (as well as flexion and extension of the elbow) and are used where sufficient voluntary pronation and supination are available to make it desirable to retain these functions, e.g., in wrist-disarticulation and long below-elbow amputations.

Rigid hinges are utilized for short below-elbow cases where normal elbow flexion is present but little or no voluntary pronation-supination is available and additional stability about the elbow is needed. Pronation and supination of the terminal device are then accomplished passively by the use of the wrist unit. Two types of rigid hinges are available: single pivot and polycentric. The mating gear teeth on the polycentric hinge impart a displacing action to the socket during elbow flexion and provide clearance for bunching of flesh in the crook of the elbow, a common problem for amputees with fleshy arms.

Step-up hinges are used, together with a "split-socket" prosthesis, for very short below-elbow cases where usable elbow flexion is limited. By virtue of a gear or lever arrangement these hinges permit the stump to drive the prosthetic forearm through an increased range of motion. In the gear-type, step-up hinge the step-up ratio is 2:1, i.e. the forearm shell moves two degrees for every degree of motion of the stump. In the variable-ratio, step-up hinge the step-up ratio averages 3:2. The disadvantage of step-up hinges is that approximately twice the force is required from the stump to provide the same amount of flexion than is the case with no step-up; it is often necessary to provide an assistive lift from the shoulder harness.

Another special device is the stump-activated locking hinge which is used, together with a split-socket prosthesis and a dual-control system, for patients having very short below-elbow stumps with practically no lifting force. In this system the cable which operates the terminal device is also used to lift the forearm to the desired position, whereupon a small amount of stump motion will activate the elbow lock. With the elbow locked, a pull on the cable will then operate the terminal device.

Cuffs and Pads

Except in the Muenster prosthesis, a half cuff or a triceps pad, with the appropriate hinges, is used on the upper arm to connect the socket to the harness and help furnish socket suspension and stability. In addition, it serves as an anchor for the control-cable reaction point. The half cuff, with or without a strap or billet across the front of the arm, is used in the majority of short below-elbow fittings. The triceps pad is used with long below-elbow, wrist-disarticulation, and transmetacarpal prostheses.

Below-Elbow Harness and Controls

The functions of the below-elbow harness are: to suspend the prosthesis from the shoulders so the socket is held firmly on the stump; utilize body motions, e.g., shoulder flexion and scapular abduction, as sources of power or force; and transmit this force via a cable system to operate the terminal device. Three types of harness are used: figure-eight, chest-strap with shoulder saddle, and figure-nine.

The figure-eight harness (Fig. 3) is the most commonly used. The axilla loop acts as a reaction point for the transmission of body force to the terminal device. The front support strap and inverted-Y Suspensor carry the major portion of axial loads.

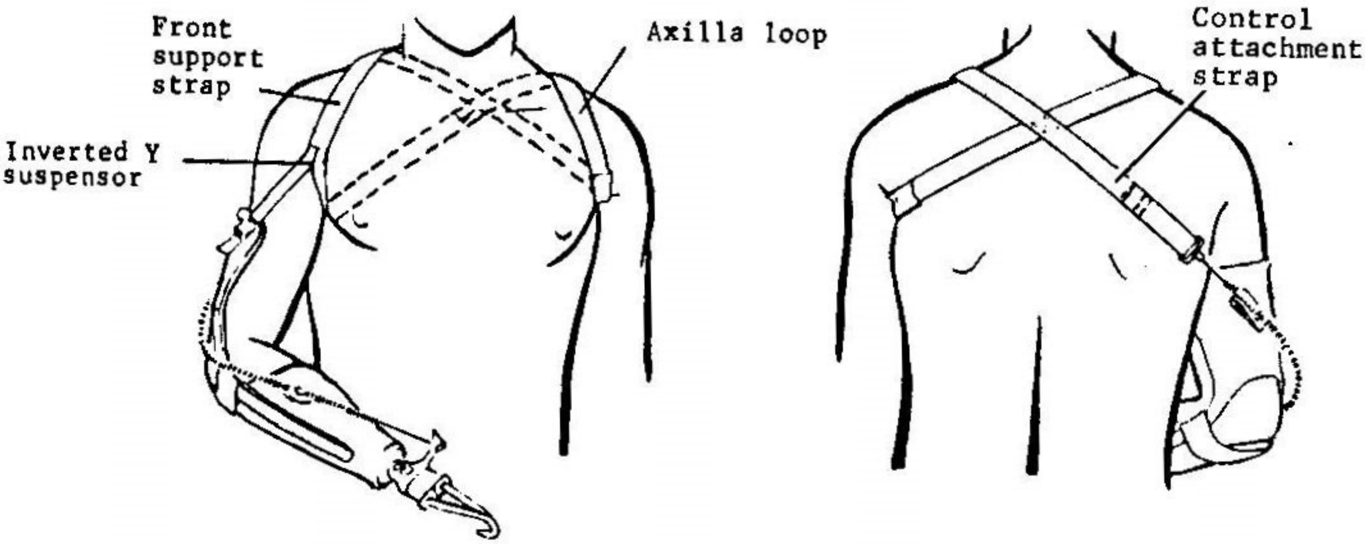


Fig. 3 Below-Elbow Prosthesis with Figure-8 Harness

The chest-strap harness with shoulder saddle (Fig. 4) is used for a patient who cannot tolerate an axilla loop and for patients who do a great deal of heavy lifting. It is not appropriate for women and it has a tendency to rotate upon the chest when excessive forces are applied to the control cable.

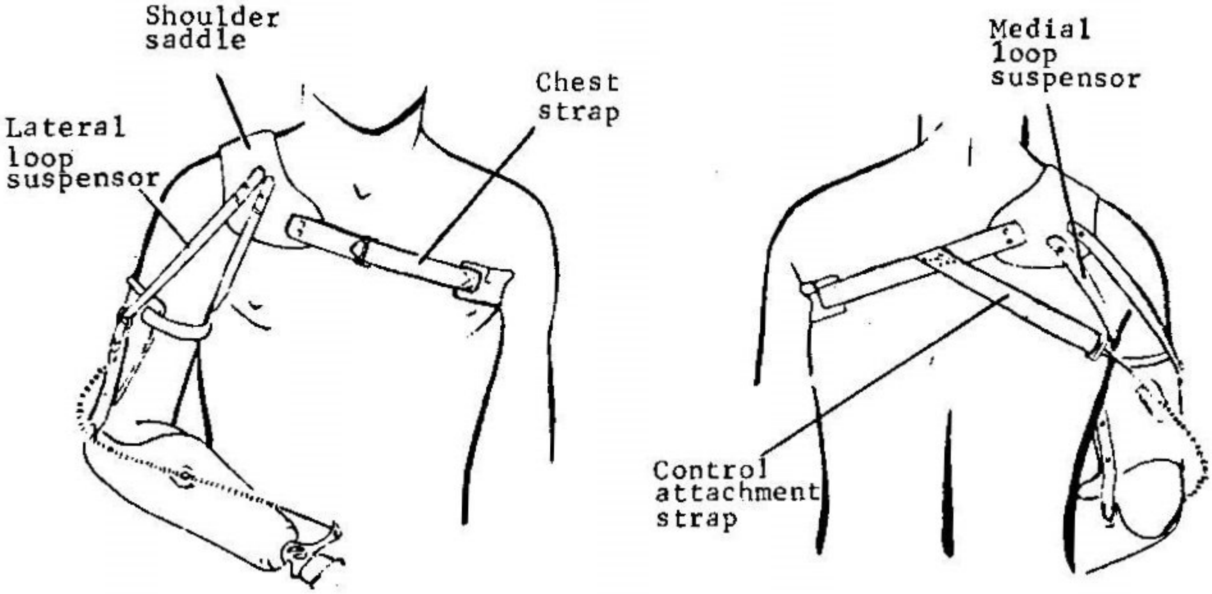


Fig. 4 Below-Elbow Prosthesis with Chest-Strap Harness and Shoulder Saddle

A simplified harness of a figure-9 configuration is most often employed with the Muenster prosthesis (Fig. 5). It consists of an axilla loop and a control attachment strap. An advantage over conventional types of harnessing is the greater freedom and comfort afforded by elimination of the usual front support strap and triceps pad or cuff.

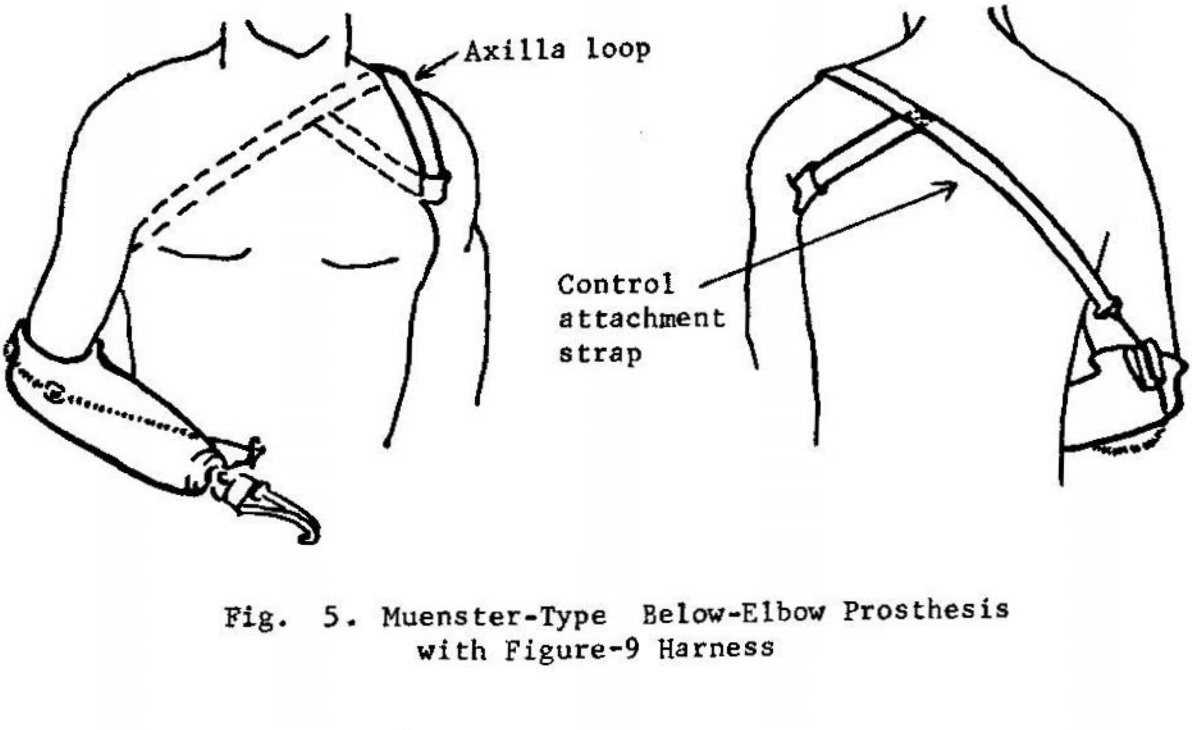


Fig. 5. Muenster-Type Below-Elbow Prosthesis with Figure-9 Harness

A bilateral amputee is ordinarily fitted with a figure-8 harness in which the axilla loop is replaced by the control attachment strap and anterior support strap to the opposite prosthesis (Fig. 6). Many amputees require an elastic cross-back strap between the control attachment straps to prevent the harness from rising when the amputee operates one or both of his terminal devices. Each prosthesis has the same single control system as used on a unilateral prosthesis.

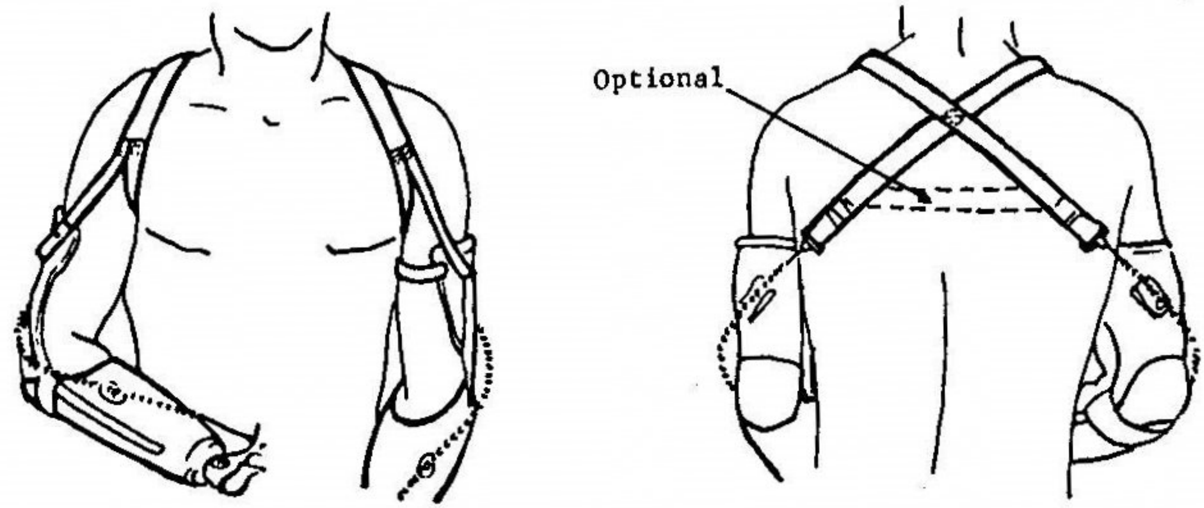


Fig. 6 Bilateral Below-Elbow Harness

The typical control system for transmission of power to the prosthesis consists of a flexible stranded stainless-steel cable with appropriate terminal fittings or coupling units and a flexible tube or housing inside which the cable slides. The terminal fittings are used to attach one end of the cable to a harnessed body control point and the other end to a point of operation or control of the prosthesis, e.g., the terminal device. The housing acts as a guide or channel for the transmission of force by the cable. Two types of control-cable systems are used: Bowden control and dual (fair-lead) control. The former is used in the below-elbow single-control system, and the latter is used in the above-elbow dual-control system and in the very short below-elbow split-socket prosthesis with stump-activated locking hinge.

The Bowden control system (Fig. 7) consists of a continuous length of flexible housing through which the cable slides. The housing is fastened by a base plate and retainer to the forearm shell and by a housing cross-bar assembly to the cuff or triceps pad; these housing retainers also serve as reaction points when force is applied to the cable. The Bowden cable system is required to transmit body power for a single purpose--to operate the terminal device.

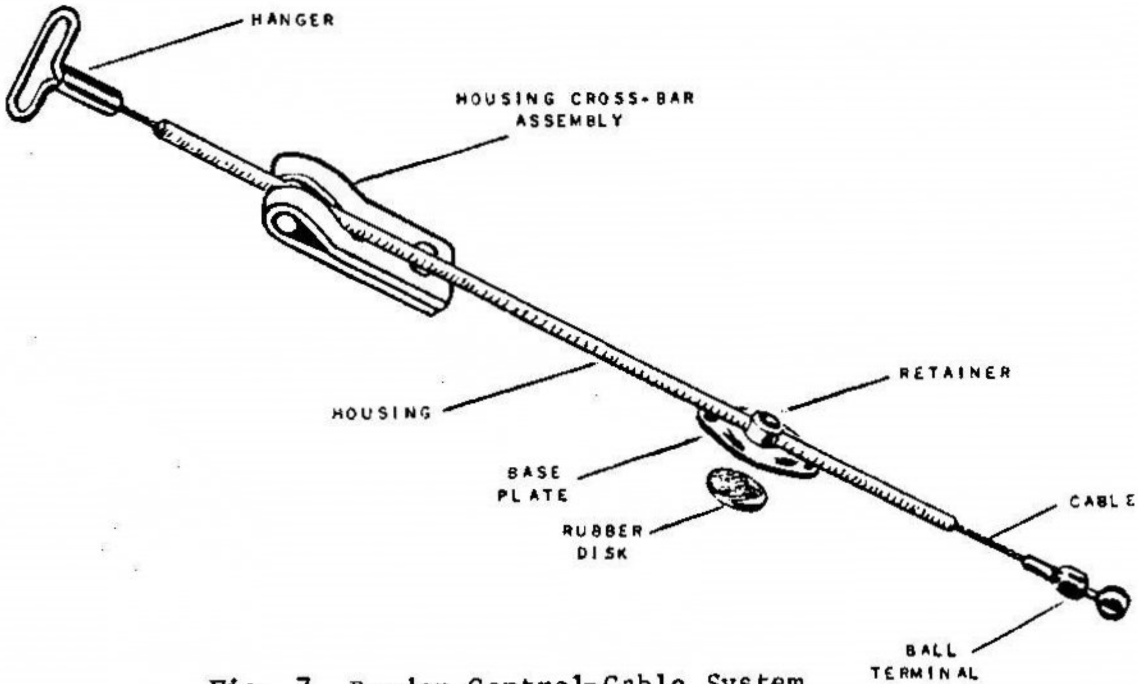


Fig. 7 Bowden Control-Cable System

The fair-lead or dual-control system (Fig. 8) consists of a cable held in place and guided by separate lengths of housing. The pieces of housing are fastened with retainers at points where the cable must be supported or operated through an angle. Since the system must provide force for two functions (elbow flexion and operation of the terminal device), two fair-lead housings are necessary: the proximal, through which the cable slides when the elbow is flexed; and the distal, through which the cable also slides when the terminal device is operated.

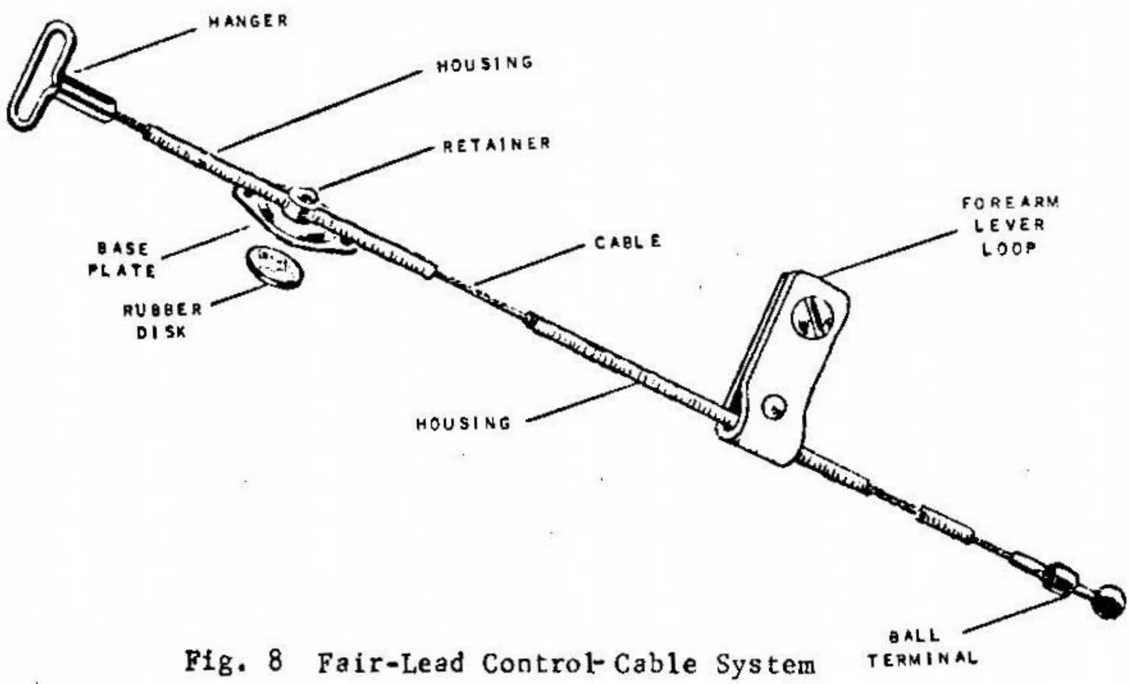


Fig. 8 Fair-Lead Control-Cable System

ABOVE-ELBOW COMPONENTS

Above-elbow prostheses consist of a terminal device, wrist unit, forearm, elbow unit, an upper arm, a socket and a harness and cable system. The terminal devices and wrist units are the same as those used for the below-elbow prostheses, while the elbow units and harnesses differ in several respects from those used in below-elbow prostheses.

<u>Elbow Units</u>

When an amputation occurs at or above the elbow joint, elbow function is supplied by the use of an elbow unit which provides for elbow flexion and for locking in various degrees of flexion. Two types are used: external elbows (outside locking) and internal elbows. The former is used with the elbow-disarticulation prosthesis and the latter with above-elbow and shoulder prostheses. Both types of elbows are flexed by means of the control cable of the dual-control system and locked at the desired flexion angle by a separate elbow-lock control cable. The elbow-lock control cable is attached at one end to the elbow mechanism and at the other end to the harness. The lock mechanism operates on the alternator principle, that is, locking and unlocking actions alternate with each control-cable cycle of tension-relaxation. For amputees who have difficulty flexing their prosthetic forearms, an accessory in the form of a spring assist for elbow flexion may be provided for use with the internal elbow.

In above-elbow and shoulder prostheses, passive humeral rotation is accomplished by means of a turntable between the elbow unit and the upper-arm shell or socket. As in the case of a wrist unit, friction between the elbow unit and the turntable permits control of the rotation to maintain the desired plane of elbow operation.

Above-Elbow Harness and Controls

In addition to suspending the prosthesis from the shoulders, the above-elbow harness must transmit power to flex the prosthetic forearm, to lock and unlock the elbow unit, and to operate the terminal device. The harness designs most frequently used for the above-elbow prosthesis are modifications of the basic figure-8 and chest-strap patterns used with the below-elbow prosthesis and are illustrated in Figs. 9 and 10.

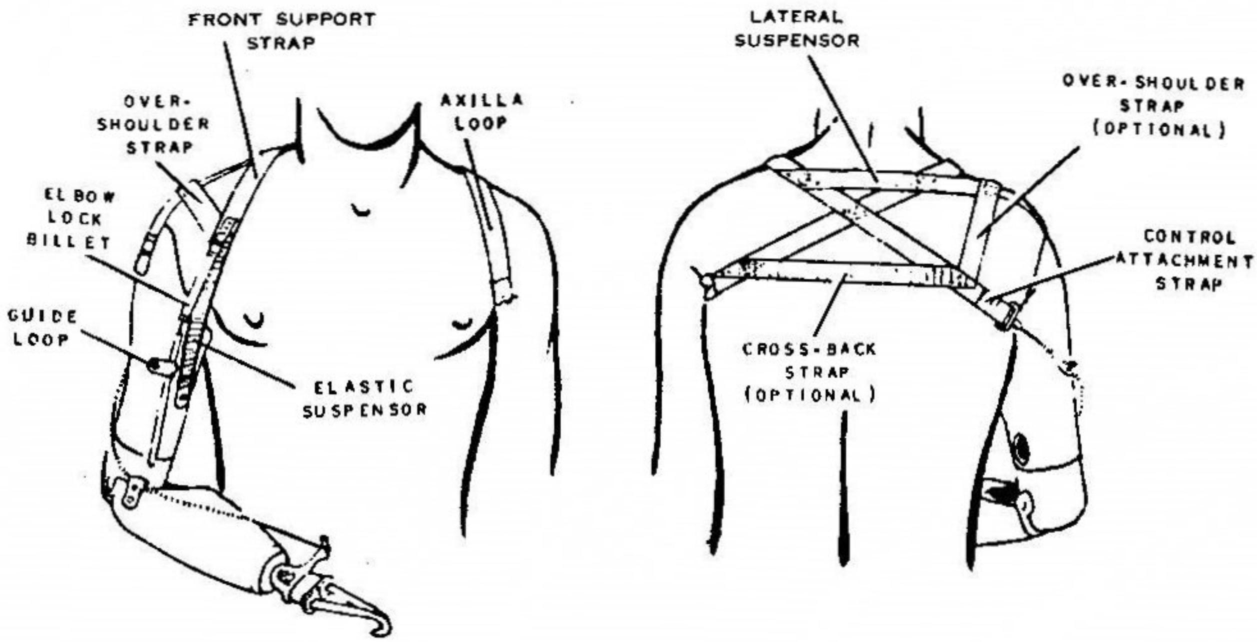


Fig. 9 Above-Elbow Prosthesis with Figure-8 Harness

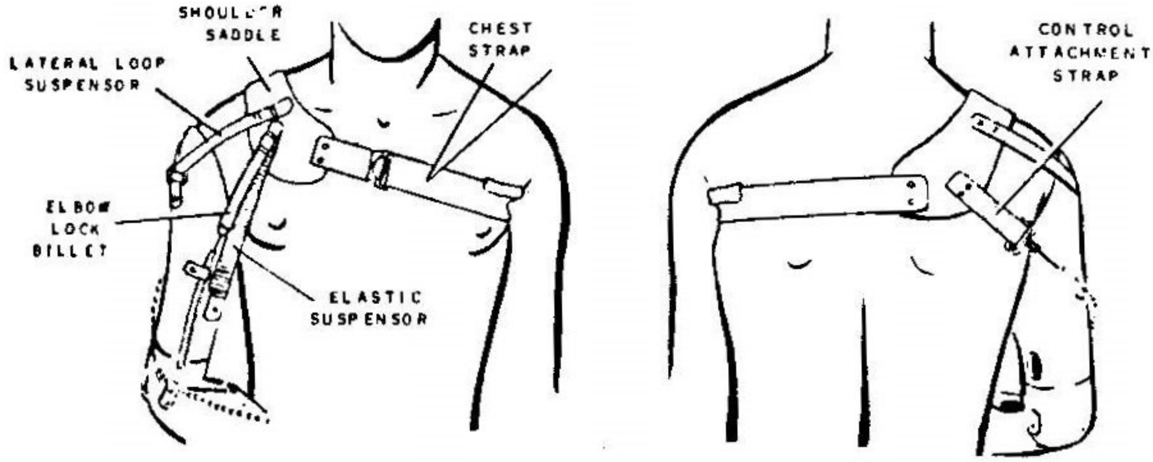


Fig.10 Above-Elbow Prosthesis with Chest-Strap Harness and Shoulder Saddle

The bilateral harness (Fig. 11) is a combination of two above-elbow figure-8 harnesses; each axilla loop is replaced by an attachment to the opposite prosthesis. A cross-back strap and two over-the-shoulder straps may be added to improve harness stability. The dual-control system used on each prosthesis is identical with that used on a unilateral above-elbow prosthesis.

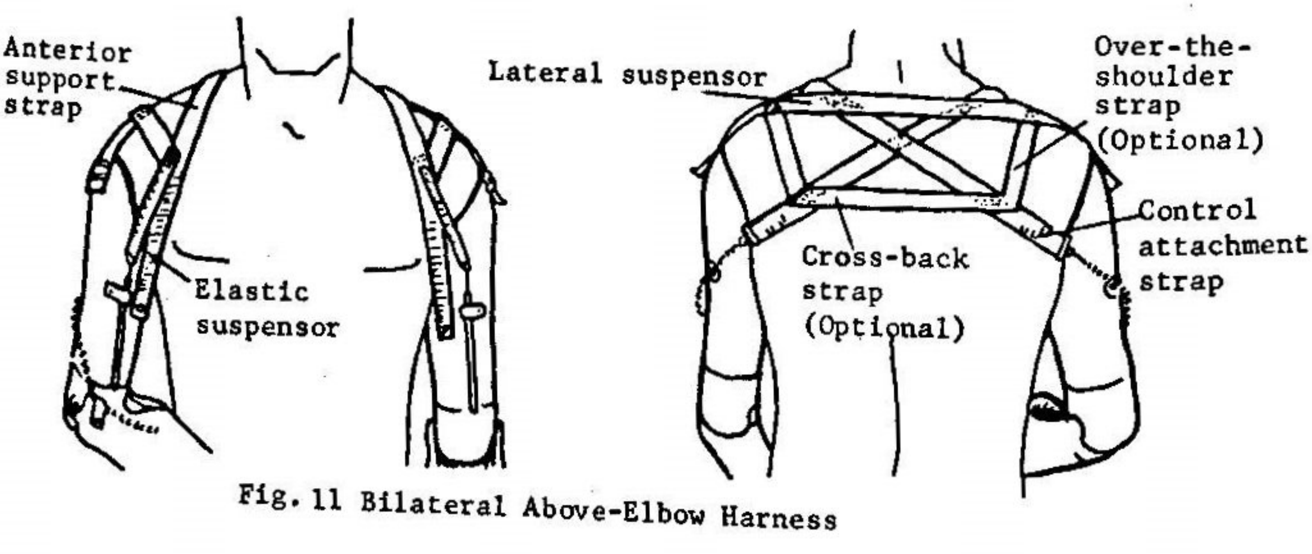


Fig. 11 Bilateral Above-Elbow Harness

As previously mentioned, the fair-lead control-cable system is used in the above-elbow prosthesis to transmit force for two functions; elbow flexion and terminal device operation. Elbow locking and unlocking are controlled by a second cable, the elbow-lock cable. When the elbow is extended and unlocked, flexing the shoulder transmits force to the forearm lever loop, raising the forearm to the desired level. If the amputee wishes to use the terminal device at this point, he locks the elbow and then operates the terminal device by continuation of the control motion, i.e. shoulder flexion.

SHOULDER PROSTHESES

All shoulder prostheses, regardless of differences in size, consist of a terminal device, wrist unit, forearm section, elbow unit, humeral and shoulder sections, and a harness and cable system. The terminal device, wrist unit, forearm section, and elbow unit are identical to those used in the above-elbow prostheses. The shoulder section includes a socket, which provides (1) comfortable, stable bearing upon the residual shoulder elements and thorax, and (2) means of utilizing whatever mobility remains in the shoulder girdle for control of the prosthesis.

Several shoulder components are available, ranging in capability from no motion whatsoever to friction-controlled passive motion in any direction. When "monolith" construction is used, the humeral section and shoulder socket are laminated together, and no relative motion between these components is possible. Use of abduction joints permits passive abduction of the humeral section. This is convenient for the wearer in dressing and in sitting in a chair with arms. Incorporation of a bulkhead in the shoulder unit makes passive flexion and extension of the humeral section available. A flexion-abduction joint may be used, which combines the features of an abduction joint and bulkhead. Occasionally a universal joint is utilized, which permits motion of the humeral section in all planes.

Shoulder Harness and Control Cables

The basic shoulder-prosthesis harness (Fig. 12) has a chest strap that is attached to the anterior and posterior aspects of the laminated shoulder section. An elastic suspensor helps to stabilize the shoulder section and yet permits movement of the shoulder girdle.

The harness and control system usually includes a waistband with a strap connected to the elbow-lock control cable. The waistband stabilizes the distal end of the elbow-lock control strap, so that shoulder elevation trips the elbow lock. The dual functions of elbow flexion and terminal-device operation are controlled by a fair-lead type control-cable system, as in the above-elbow prosthesis. The most common control motions are shoulder-girdle flexion for elbow flexion and terminal-device operation and shoulder elevation for elbow locking and unlocking. In the forequarter amputation, of course, only the opposite shoulder is available for control motions.

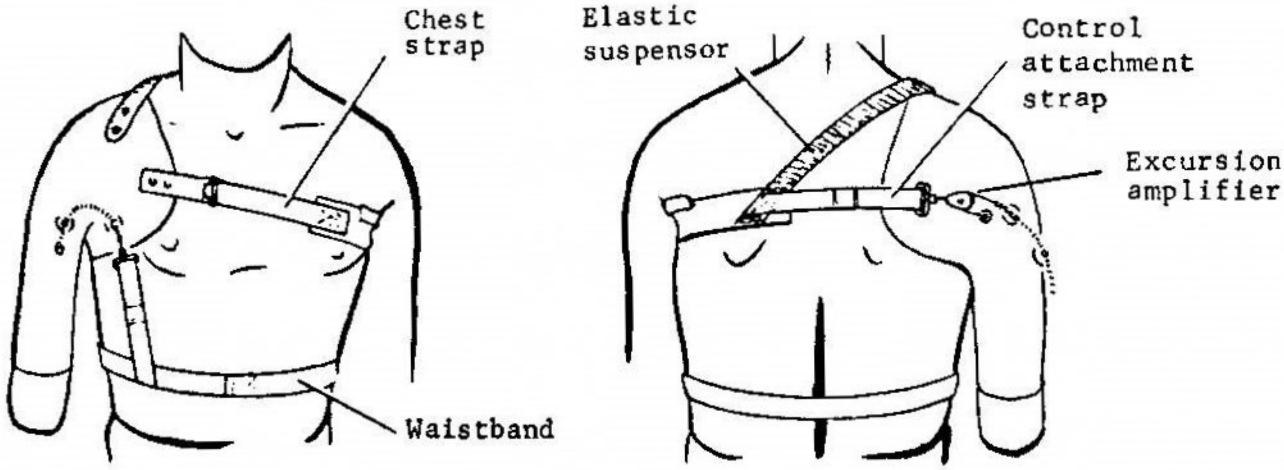


Fig. 12 Shoulder Prosthesis with Basis Shoulder Harness and External Movable Sheave-Type Excursion Amplifier

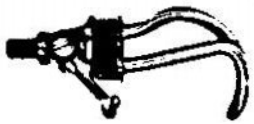
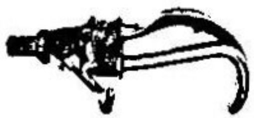
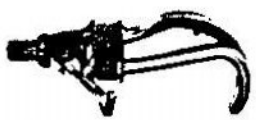
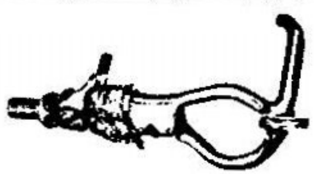
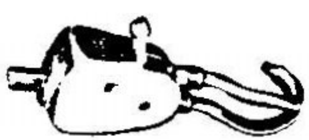
If the amputee cannot successfully operate the prosthesis with the basic harness, three additions may be helpful:

1. Excursion amplifier
2. Axilla loop
3. Shoulder sling with an axilla loop

An excursion amplifier is a device that converts a larger force with small excursion into a lesser force with increased excursion. In most cases the shoulder amputee has an abundance of strength in his shoulder girdle, but in many cases he lacks sufficient excursion for successful prosthetic operation. The excursion amplifier makes it possible to convert some of this surplus force into additional excursion. Most terminal devices require 1½ to 1 3/4 inches of cable travel for full operation, and 2 to 3 inches are needed to elevate the forearm through a range of 125 degrees. Two types of excursion amplifiers which have been used to attain the needed movement are the lever and the movable pulley or sheave (Fig. 12).

The axilla loop encircles the shoulder on the side opposite the prosthesis and transmits more shoulder-girdle movement to the cable than does the chest-strap harness. The shoulder sling harnesses most of the excursion available as a result of the wider area through which the extreme tip of the shoulder swings when the scapulae are abducted.

TERMINAL DEVICES
HOOKS

	Name	Length	Weight	Material	Method of Operation	Finger Shape	Finger Surface	Other Models
								
								
								
								
								
								
								

I. PASSIVE (COSMETIC) HAND

II. VOLUNTARY OPENING HANDS

BECKER LOCK-GRIP
BECKER IMPERIAL

BECKER PLYLITE

DORRANCE

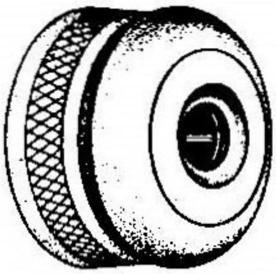
ROBIN AIDS

SIERRA-APRL VO

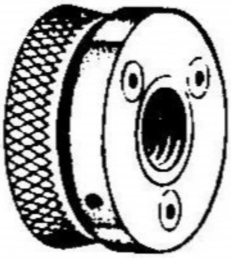
III. VOLUNTARY CLOSING HAND

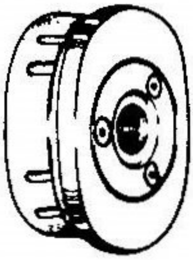
SIERRA-APRL VC

FRICTION WRISTS:
Washer Type

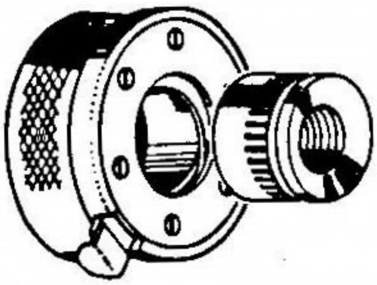


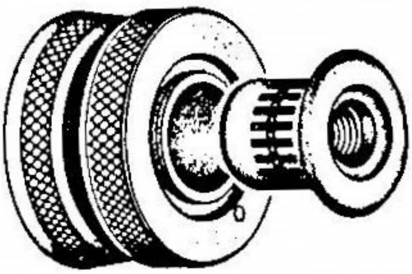
FRICTION WRISTS:
Bushing Type



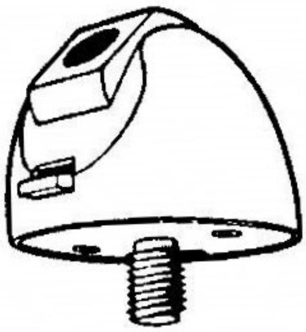


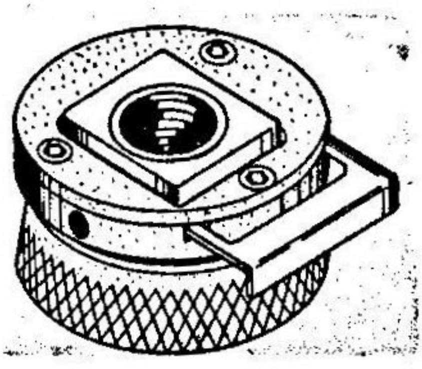
LOCKING WRISTS



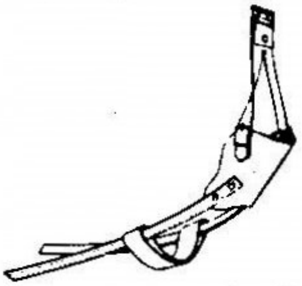
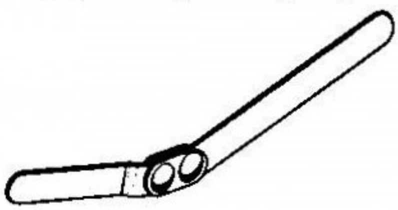
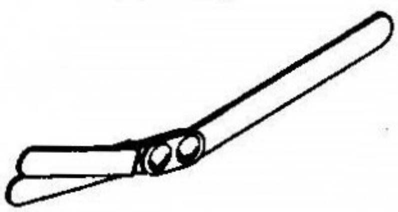
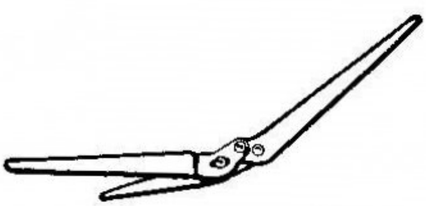
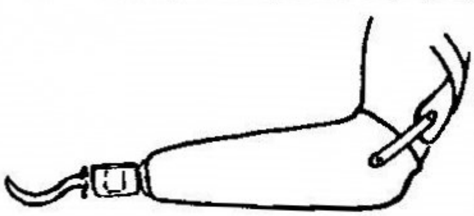
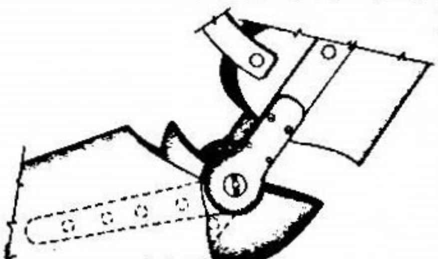


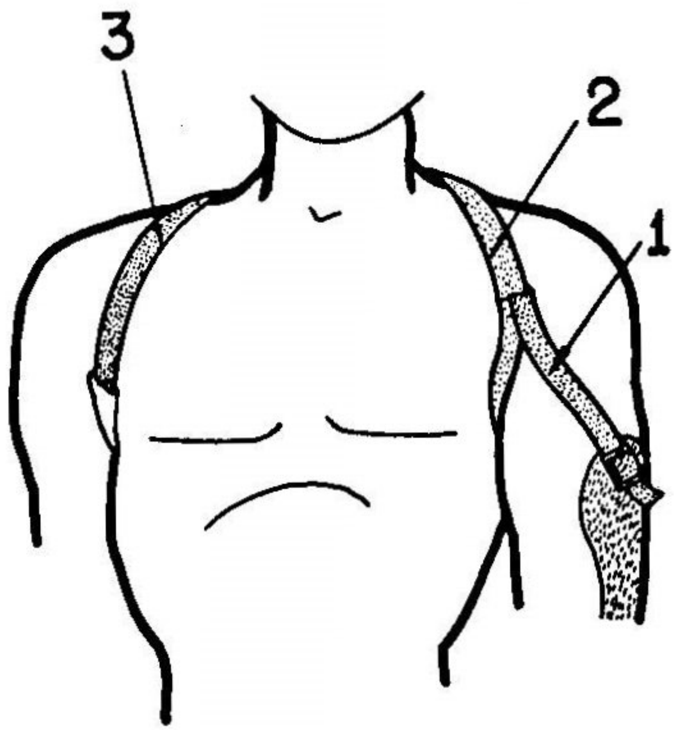
WRIST FLEXION UNITS



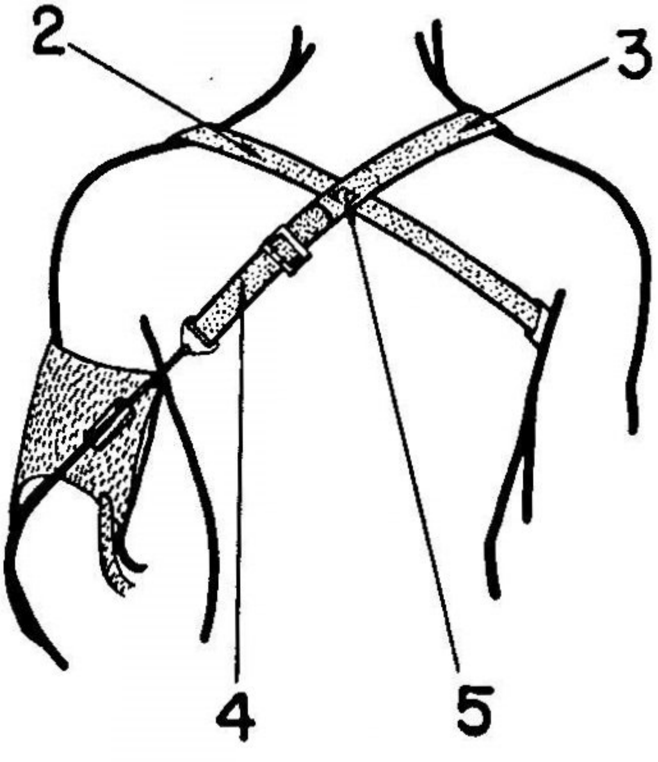


BELOW-ELBOW HINGES

	NAME	CHARACTERISTICS
		
		
		
		
		
		
		



ANTERIOR VIEW



POSTERIOR VIEW

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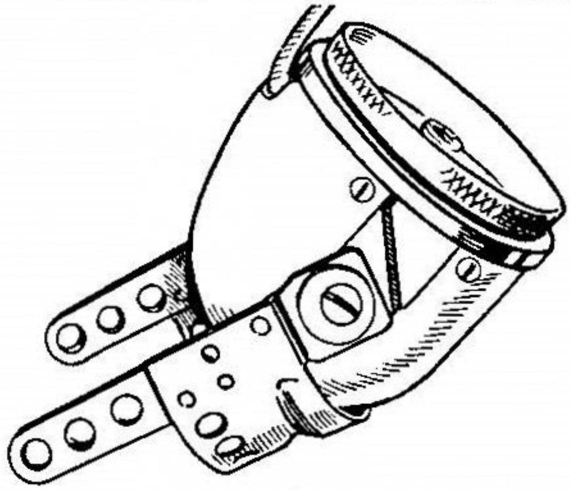
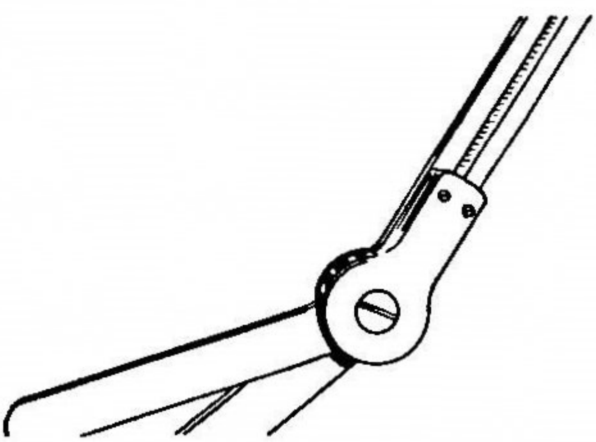
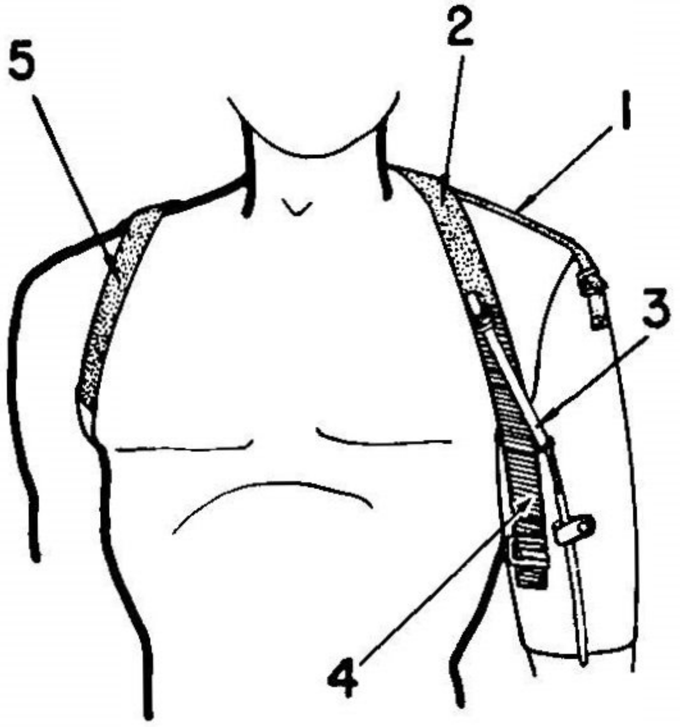
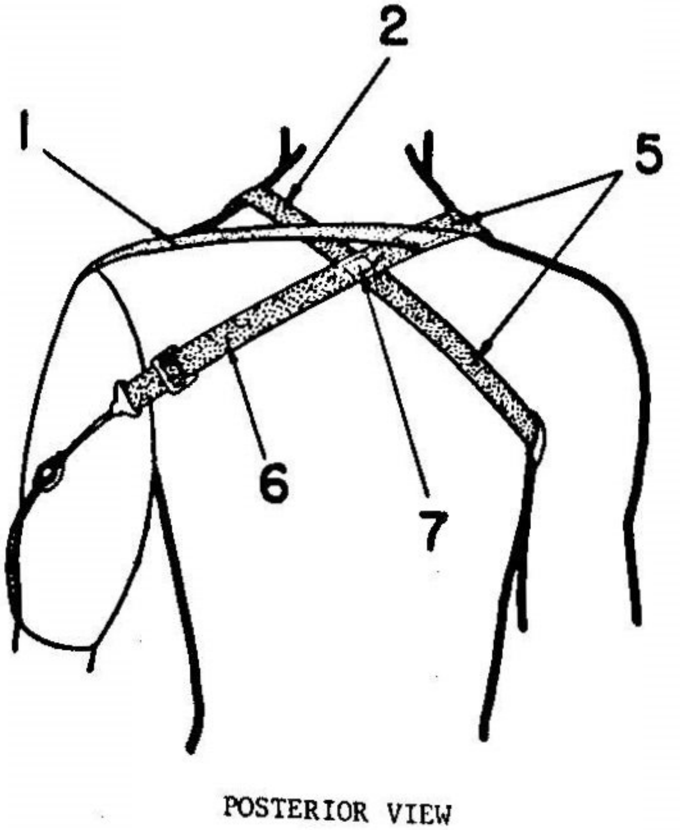
		
		
		

THE ABOVE-ELBOW FIGURE-EIGHT HARNESS



ANTERIOR VIEW



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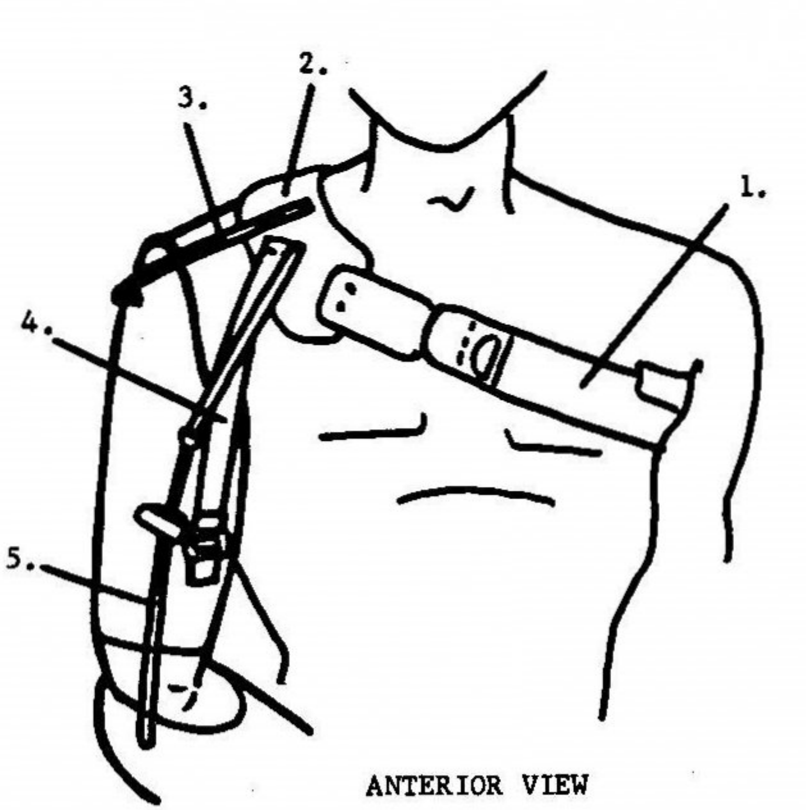

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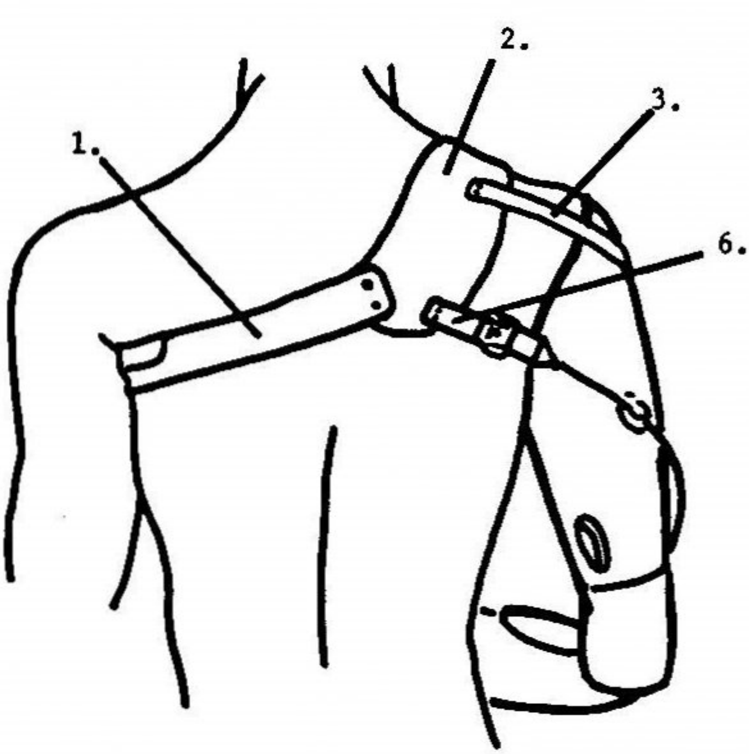

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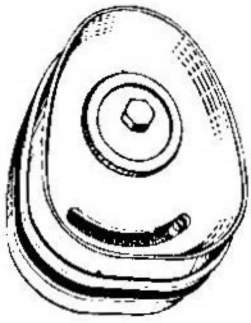

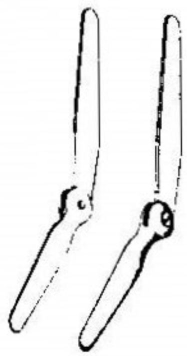

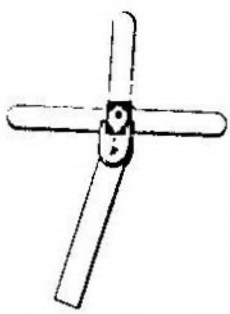

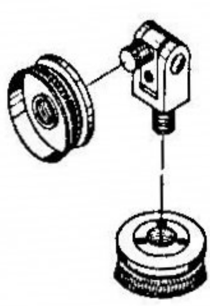

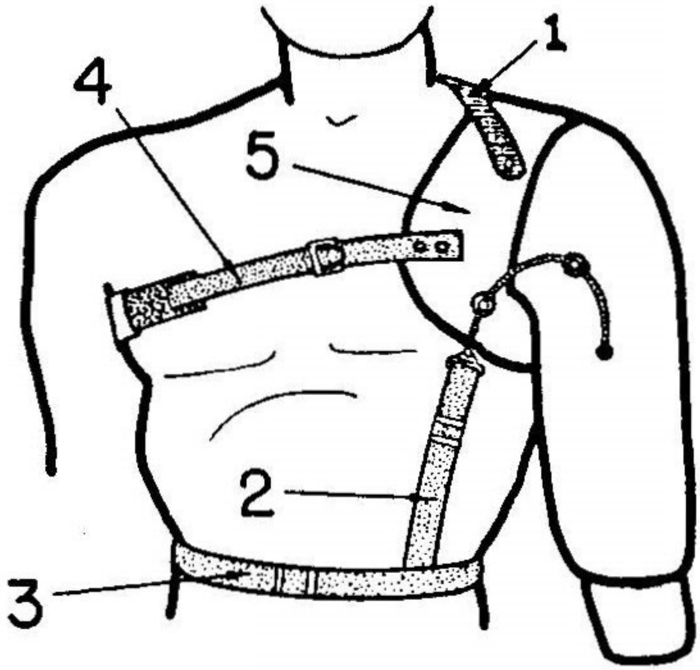

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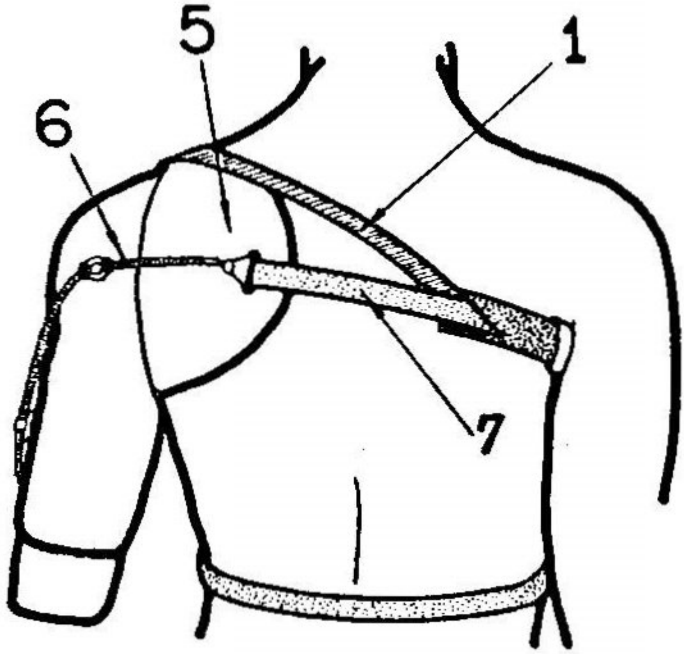

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CHAPTER 4

COMPONENTS FOR CHILD UPPER-LIMB AMPUTEES

Early Fit

Children are fitted at eight months of age with either a passive or an active prosthesis. If fitted with an active prosthesis, however, the infant cannot be expected to voluntarily control the prosthesis. The purposes of early fitting are:

1. To improve balance - sitting, standing, walking
2. To accustom the child to normal, symmetrical-length upper extremities
3. To simulate bilateral function at normal work distances
4. To incorporate a prosthesis into the child's body image
5. To help the child and his parents accept a prosthesis for function and cosmesis
6. To reduce dependence on tactile sensation on the end of the stump

Terminal Devices

All terminal devices for children are voluntary opening, except the passive mitt.

At eight months of age the child is fitted with a Dorrance 12P hook which is covered with Plastisol. The cable is usually not connected to the hook at this time. The parent opens the hook so that the child can observe its function. If incidental opening of the hook is desired for training purposes, the cable may be attached at this stage, but it is usually difficult to harness. The passive mitt is infrequently prescribed; few objects can be maintained in it and it does not prepare the child or his family for the function and appearance of a hook.

By 18 to 24 months of age a cable is connected to the 12P hook for active use. The child is now capable of operating the terminal device and thereby may perform a great many complex bimanual activities, such as bead stringing and use of construction toys.

At 3 to 5 years of age he may receive a 10P, a 10X aluminum hook, or a 10 steel hook with serrated fingers. These are similar to the 12P in function, but larger in size. "X" designates a terminal device with neoprene lining, which provides finer prehension, manipulation, and greater durability than does Plastisol. Steel hooks with serrated fingers are well suited for very active children.

From 5 to 15 years of age most children are fitted successively with 10X, 99X and, finally, 88X hooks. A 9 or 8X may be specially ordered for the very active boy; both are made of steel and, are more durable than aluminum hooks.

Hands are not as functional as hooks. All children's hands are heavier, more difficult to open, and less durable than children's hooks. However, where cosmesis is important, particularly to parents and to teenage girls, a passive or active hand with a cosmetic glove can be fitted.

Dorrance child-size hands are relatively easy to operate and are light and cosmetic. The smallest of these (Dorrance #1) is suitable for an average-size 5 year old. Its weight, however, may be excessive for a child with a short stump, particularly if fitted with a Muenster prosthesis. In addition, the 5 year old will probably not be able to take adequate care of the hand and glove.

Also relatively easy to operate and cosmetic are the Otto Bock child-size hands, the smallest of which is suitable for an average-size 8 year old. This hand is lighter in weight than the equivalent-size Dorrance hand.

The Robin-Aids hand is particularly suitable for partial-hand and transcarpal amputees. The full hand may be fitted to persons with higher amputations, but it is less functional, considerably heavier, and requires a stronger cable-pull to open, than the Dorrance or Bock hand.

Wrist Units

Small constant-friction wrist units with nylon are available. For bilateral amputees who require prosthetic simulation of wrist flexion, two components are in current usage: the wrist-flexion unit and the flexion wrist. The child wrist-flexion unit, unlike the adult unit, provides only one position of palmar flexion and cannot be locked in that position. It is more durable and easier to operate than the flexion wrist. However, since the wrist-flexion unit must be used in conjunction with a separate wrist unit, it increases the weight of the prosthesis. To compensate for the increased length of this unit, a correspondingly smaller terminal device or a shorter forearm may have to used. The flexion wrist permits the amputee to pre-position his terminal device in any degree of pronation or supination, as well as to place the device in one of several angles of palmar flexion. However, it is a more delicate unit and requires the child to be aware of two planes of movement and the interrelationship between them.

Below-Elbow Components

Most sockets are double wall. An amputee with a short or very short below-elbow stump may be fitted with a socket set in greater than usual initial flexion at the elbow. This may be a preflexed socket with triceps pad and figure-8 ring harness or a muenster socket with a figure-9 harness. For the child under 11 years of age, the Muenster prosthesis should seldom be prescribed for two reasons:

1) it is not easily modified for the rapidly growing child and
2) suspension is difficult to maintain with the poorly defined bony landmarks of the young child. Flexible hinges are most commonly used. However, if elbow mobility is limited or the stump is short, a split socket with step-up hinges or a stump-activated elbow lock, may be required.

A standard figure-8 harness with a small ring is most frequently fitted with below-elbow prostheses. Since the infant normally has "round shoulders," making it difficult to keep the harness properly positioned, the figure-8 harness may need to be modified. Specifically, an anterior strap (usually elastic) is often placed between the axilla loop and the Y-suspensor to prevent the latter from sliding off the shoulder.

Above-Elbow Components

The type of socket used for the child with an above-elbow amputation is basically the same as for the adult. Occasionally a unit arm which has no elbow but, rather, is a continuous piece, may be prescribed. Friction elbows, which are passively positioned, are usually used for the child under three years of age, since he cannot successfully operate an elbow lock before this age. For active use, there are internal and external elbow units available which are scaled-down versions of the adult units.

The figure-8 harness is again the preferred harness for most above-elbow amputees.

Shoulder-Disarticulation Components

Except for the difference in size, the sockets, the shoulder units (bulkhead, flexion, abduction, and universal), and the elbow units are essentially the same as those available for adults. However, the harness and the cable-control system often needs to be modified. The congenital shoulder-disarticulate generally has a malformed scapular and, therefore, lacks both excursion and power. Control sites for terminal-device operation must be found elsewhere in the body; attachment of the control attachment strap to a thigh corset is one solution. Since the child does not have a well-defined waist, a nudge control, rather than a waist strap, may be employed for the elbow lock.

To eliminate as much friction as possible, a single housing may be used. In this event, elbow flexion would be achieved passively.

The chart which follows summarizes child components in relation to various age levels.

	GROSS ACTIVITY	PINCH AND GRASP	LEAD HAND & SKILL DEVELOPMENT	SKILLED PERFORMANCE	INCREASED COSMETIC & VOCATIONAL NEEDS	
AGE IN YEARS	0 1	2 3 4	5 6 7 8 9 10	11 12	13 14	15 16+
<u>TERMINAL DEVICE</u>: HOOK	12P	12P 10P,10X,10	10X- - - - - - - - - - - -99X 9 (special)	88X 8X	5XA	5X APRL-VC
HAND	Passive mitt no longer used		Dorrance #1 and #2 Otto Bock Robin Aids: - soft hand - partial hand	Cosmetic Dorrance #3 & #4 Otto Bock	Same	APRL-VC
<u>WRIST UNIT</u>:	Friction	Friction	Same Some bilaterals: Friction flexion unit Flexion wrist	Same Some bilaterals: Same	Same Some bilaterals: Locking flexion unit Flexion wrist	Same
<u>BELOW ELBOW</u>: SOCKET	Double wall, preflexed	Preflexed (Modified Muenster) Standard Split	Same	Same Muenster	Same	Same
HINGES	Flexible	Flexible Step-up Stump-Activated Lock	Same	Same, but more with Muenster	Same	Same
PAD/CUFF	Triceps pad Triceps pad with anterior strap from Y-strap to socket	Triceps pad Half cuff	Same	Same	Same	Same
HARNESS	Figure-8: control attachment strap replaced by elastic strap; may need chest strap from Y-strap to axilla loop.	Small ring	Same	Same Figure-9 with Muenster	Same	Same

	GROSS ACTIVITY	PINCH AND GRASP	LEAD HAND & SKILL DEVELOPMENT	SKILLED PERFORMANCE	INCREASED COSMETIC & VOCATIONAL NEEDS	
AGE IN YEARS	0 1	2 3 4	5 6 7 8 9 10	11 12	13 14 15	16+
ABOVE ELBOW: ELBOW UNIT	Friction	Outside: E/D Inside: A/E Active use: 3-4 years	Same	Same	Same	Same
SOCKET	Unit arm (no separate elbow joint) sometimes	Single wall: E/D Double wall: A/E	Same	Same	Same	Same
CONTROL	None	Passive elbow but with standard dual set-up	Active dual control	Same	Same	Same
HARNESS	Same as B/E	A/E Figure-8	Same	Same	Same	Same
SHOULDER DISARTICULATION: ELBOW UNIT	Same as A/E	Same as A/E	Same	Same	Same	Same
SOCKET	Essentially same as for adult, with modifications for congenital deformities. Weighted shoulder cap for unilateral fitting of bilateral	Same	Same	Same	Same	Same
CONTROL	None	Same as A/E	May have continuous housing (Bowden) - passive elbow flexion	Same as A/E	Same	Same
HARNESS	Chest strap	May need thigh corset for TD and elbow controls; nudge control for elbow lock	Same	Same	Same	Same

CHAPTER 5

FABRICATION, FITTING, AND HARNESSING PRINCIPLES AND PROCEDURES

After members of the clinic team examine the amputee and formulate a prescription for a prosthesis to meet the patient's needs, the prosthetist is responsible for fabricating the appliance as prescribed. This chapter outlines the principles and procedures involved in the fabrication of below-elbow, above-elbow and shoulder prostheses.

BELOW-ELBOW PROSTHESIS

SOCKET

Fabrication begins with the socket, which must be comfortable and accurately fitted to the stump to provide stability and to distribute pressure as widely as possible. Since mechanical components are attached to the socket, it must also be structurally sound.

Marking and Measurement

The prosthetist marks standard anatomic landmarks, all bony prominences, and any tender spots with indelible pencil; then he measures the length of the stump and a series of girths. He also records the length of the sound arm of the unilateral amputee for guidance in sizing the prosthesis.

Primary Cast

Plaster-of-Paris bandage is wrapped around the stump to form the primary stump cast, or wrap (Fig. 1).

Fig. 1

Master Mold

The prosthetist forms the master mold by pouring liquid plaster of Paris into the hollow primary wrap. He compares the dimensions of the master mold with the recorded stump measurements, makes any corrections indicated, and then smooths and lubricates the exterior surface.

Check Socket

Stockinette is pulled over the corrected, smoothed master mold and is impregnated with wax. The resulting malleable wax check socket is fitted to the patient (Fig. 2), so the prosthetist can accommodate any pressure-sensitive spots. For long below-elbow and wrist disarticulation stumps, the prosthetist shapes the wax to produce an oval "screw-driver" rather than cylindrical contour, to permit the amputee to transmit most of his residual forearm pronation and supination to the socket and terminal device. The wax socket also allows the prosthetist to identify the axis of elbow motion and to ascertain the location of trim lines for maximum, comfortable forearm mobility. In general, a longer stump can control a socket with a relatively distal anterior trim line, usually in the middle third of the forearm. Short and very-short below-elbow stumps require higher anterior trim lines, sometimes located in the antecubital fossa.

Fig. 2

The check socket is perhaps the most important step in fabrication of the upper-extremity prosthesis, for it determines the amount of comfort, purchase, and mobility afforded by the socket.

Lamination Mold and First Lamination

The prosthetist pours plaster into the check socket. He applies a separating medium over the resulting mold, so that the plastic resin which will form the socket cannot penetrate the plaster. Stockinette is then pulled over the prepared mold. If metal elbow hinges are to be used, the hinge straps are aligned and secured to the mold (Fig. 3). A polyvinyl alcohol (PVA) pressure sleeve is pulled over the stockinette, and resin is poured through the mouth of the sleeve to permeate the stockinette.

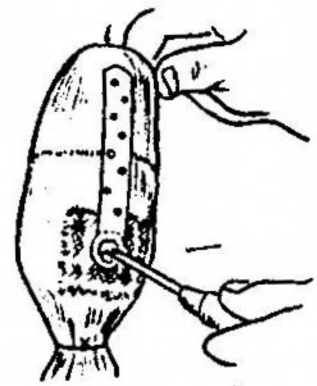


Fig. 3

Build-up, Second Lamination, and Socket Trim

After the plastic has solidified, a build-up form of appropriate length is attached temporarily to the socket. The prosthetist fits the wrist unit to the open (distal) end of the form, and pours wax into it (Fig. 4). After the wax solidifies, the

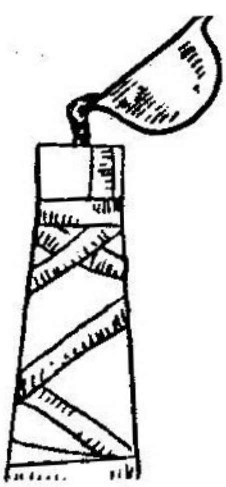


Fig. 4

form is removed, stockinette is pulled over the wax, and the outer wall of the socket is laminated. When the resin has hardened the socket is cured in the oven. The heat-curing process melts the wax which runs out of the forearm extension. The completed double-wall socket is trimmed to the margins the prosthetist determined with the check socket, to provide the amputee with optimum fit and comfort.

CUFF AND HINGES

The cuff is fabricated of leather or plastic to conform to the upper arm. If flexible hinges have been prescribed, they are secured to the triceps pad and socket; otherwise, rigid metal hinges, shaped to the contours of the amputee's arm, join a half cuff to the socket (Fig. 5). A housing cross-bar assembly is fixed on the upper-arm cuff to guide the path of the Bowden cable.

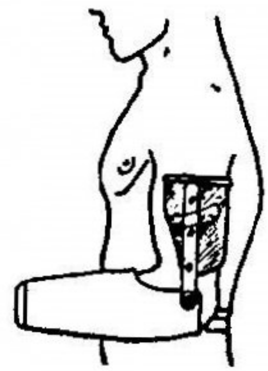


Fig. 5

HARNESS AND CONTROL SYSTEMS

Correct application and adjustment of the harness and control system are essential for proper prosthetic function. Although the prosthetist utilizes standard designs, the system is always custom fitted to the individual amputee.

Unilateral Below-Elbow Figure-8 Harness

With the socket and cuff on the amputee, the prosthetist lays the harness strap (usually made of dacron) along the deltopectoral groove, up over the shoulder, diagonally across and down the back, to form a loop around the axilla on the sound side. He then checks that the harness cross is below the seventh cervical vertebra and slightly to the sound side. In place of the cross, however, a ring may be used. The ring allows the harness to remain relatively flat on the back when the amputee performs overhead activities. In addition, since the straps can be buckled to the ring, adjustment is facilitated. Nevertheless, the ring is contraindicated for the very slender amputee who is likely to be chafed by contact of the metal with his back, and for any amputee who requires maximum harness stability.

The inverted-Y strap is attached to the arm cuff. The control attachment strap is fitted so that it passes approximately at midscapular level and is then connected to the control cable. The cable housing is joined to the housing crossbar assembly on the cuff and to the base plate retainers on the prosthetic forearm. The harness is checked for comfort and function, and the straps are sewn in place (Fig. 6).

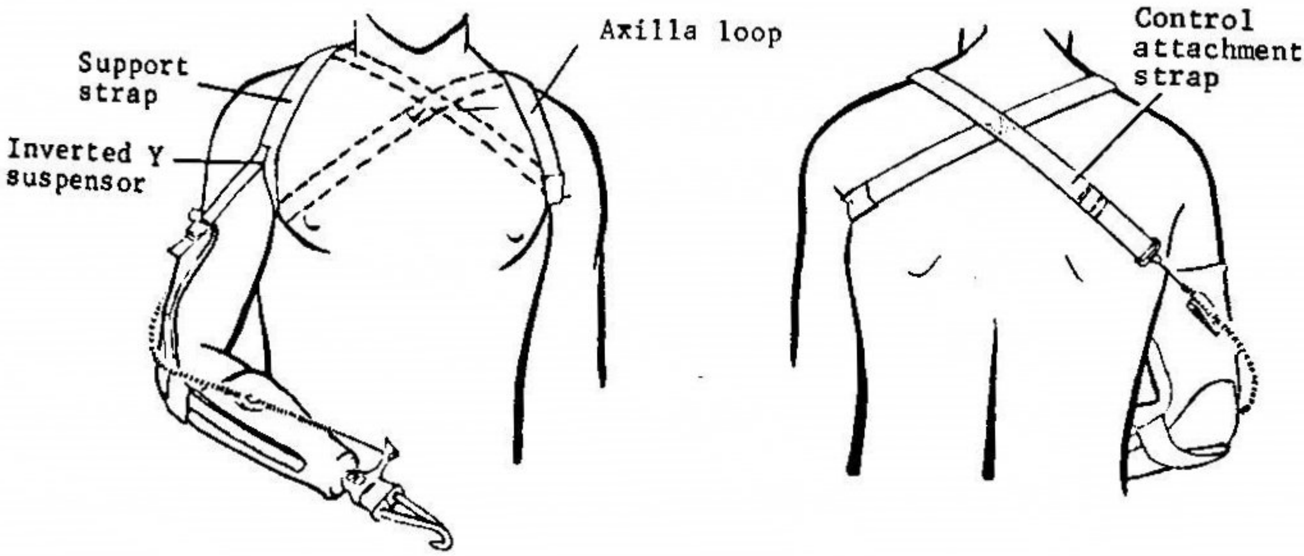


Fig. 6 Below-Elbow Prosthesis with Figure-8 Harness

Unilateral Below-Elbow Chest-Strap Harness with Shoulder Saddle

The prosthetist places the shoulder saddle (usually made of leather) on the amputee. He extends the chest strap from the anterior-medial corner of the saddle, across the chest, under the axilla and across the back to the posterior-medial corner of the saddle. Suspension loops run through D-rings on the medial and lateral portions of the cuff and attach to the anterior and posterior portions of the saddle. The control attachment strap is joined to the saddle so the line of pull of the control strap is toward the sound side. As the amputee goes through a variety of motions with his prosthesis, the saddle is observed and the attachment points of the loop suspensors are adjusted until it is stable (Fig. 7).

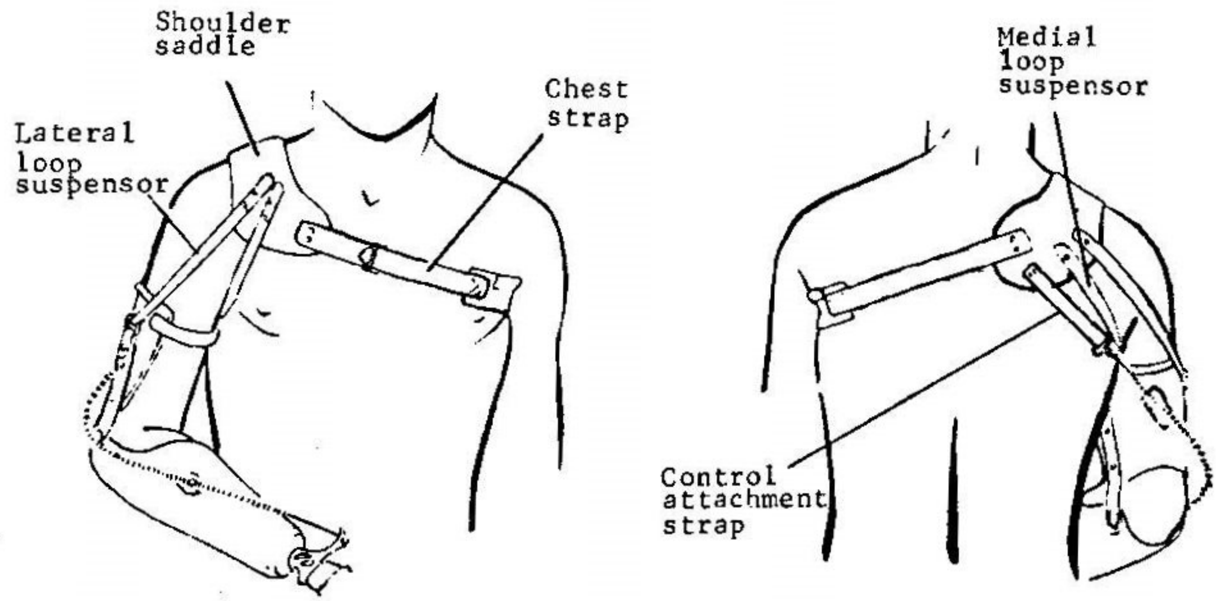


Fig. 7 Below-Elbow Prosthesis with Chest-Strap Harness with Shoulder Saddle

Muenster Below-Elbow Figure-9 Harness

The prosthetist forms an axilla loop on the sound side, continues the strap diagonally across the back and attaches it to the control cable. The proximal cable housing may be held in position by a retainer on the posterior proximal portion of the socket (Fig. 8).

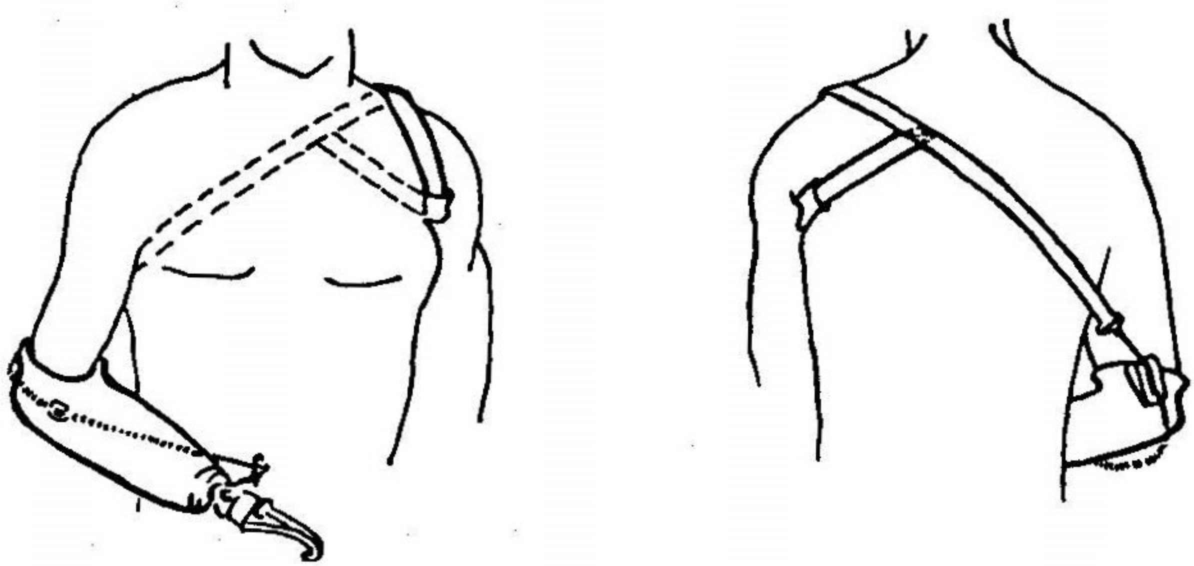


Fig. 8 Muenster Below-Elbow Prosthesis with Figure-9 Harness

Bilateral Below-Elbow Harness

To form this harness, the prosthetist passes the webbing from one inverted-Y suspensor, up over the amputee's shoulder, and diagonally down the back to the control cable of the opposite prosthesis. He repeats the procedure on the other side. The two control attachment straps cross slightly below the seventh cervical vertebra.

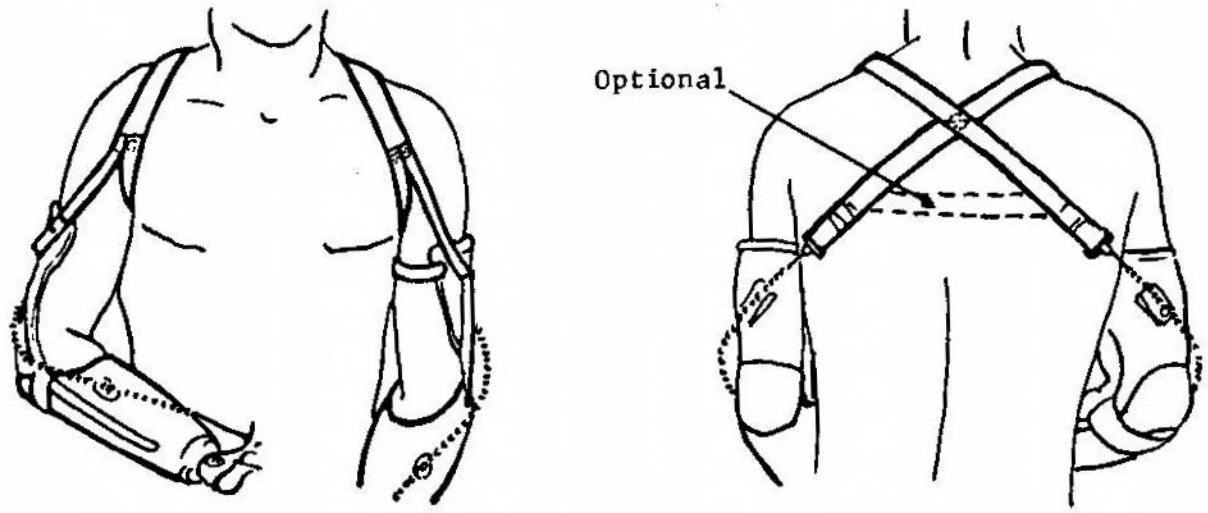


Fig. 9 Bilateral Below-Elbow Harness

ABOVE-ELBOW PROSTHESIS

The standard above-elbow prosthesis differs from a below-elbow prosthesis primarily in the type of elbow unit and the forearm shell. Both include similar wrist units, terminal devices, cable systems, and harnesses.

Measurement and Fabrication

As with below-elbow prostheses, the prosthetist measures the length and girth of the stump and the length of the sound arm of the unilateral amputee. The sequence of steps in socket fabrication is essentially the same as followed for a below-elbow prosthesis.

The wax check socket is compressed slightly to improve purchase on the arm. Trim lines are established according to the length and firmness of the stump. Ordinarily, a socket for a firm, standard above-elbow stump is trimmed so that there is no restriction of shoulder abduction, flexion, or hyperextension. A short or flabby stump gains stability with proximal extensions of the socket margins while sacrificing shoulder mobility.

After the socket is fitted to the amputee and the humeral section extended to proper length, the forearm shell, complete with wrist and elbow units, is attached. The prosthetist adjusts the turntable so that the patient can passively produce internal and external rotation without excessive effort.

HARNESS AND CONTROL SYSTEMS

The fitting and proper adjustment of the harness and control system are especially important for the above-elbow amputee, since body motions must be used not only to operate the terminal device, but also to flex the prosthetic elbow and to activate the elbow-locking mechanism. An inadequate harness and control system can have a markedly adverse effect on all of these functions.

Unilateral Above-Elbow Figure-8 Harness

The procedure followed for fitting the figure-8 harness on the above-elbow amputee is quite similar to the procedure for the below-elbow amputee. The above-elbow anterior support strap, however, has an elastic section to provide excursion for the elbow-lock control. As the amputee directs his humerus obliquely down and back to effect elbow locking, he stretches the elastic. Recoil of the anterior support strap is essential for the cycling mechanism in the elbow unit. The elastic portion of the anterior support strap is attached to the anterior-medial aspect of the arm.

The lateral support strap, made of nonelastic webbing, is the chief suspensor of the above-elbow prosthesis. The lateral support strap is connected to a point on the posterior-proximal portion of the axilla loop. It then passes horizontally to the opposite side, and is attached to the proximal edge of the socket, slightly anterior to the acromion (Fig. 10).

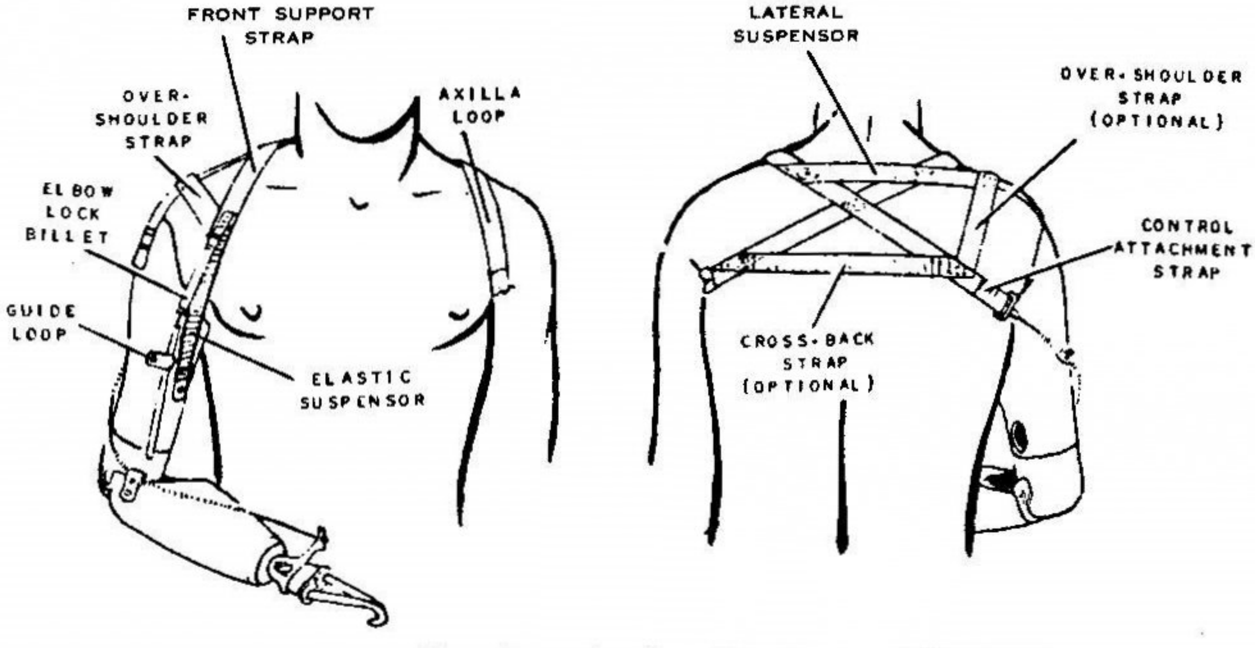


Fig. 10 Above-Elbow Prosthesis with Figure-8 Harness

The housing is mounted by means of a base plate or plates to the posterior-lateral aspect of the arm, and the leather lift loop is positioned below the elbow axis on the forearm. The position and size of the lift loop determine the relative ease of elbow flexion. The more distal or the longer the loop, the less force required for elbow flexion with, however, proportionately greater cable excursion needed. Conversely, a shorter or more proximal loop requires the amputee to provide more force, though less excursion for the same amount of forearm motion. A compromise between excursion and effort, the loop is approximately 1 inch high from its pivot to the anterior margin, and is located approximately 1 1/4 inches distal to the elbow axis. The control cable passes through the lift loop and is attached to the terminal device at one end and to the control attachment strap at the other. The elbow-lock cable is joined to its control strap.

Unilateral Above-Elbow Chest-Strap Harness with Shoulder-Saddle

The unilateral above-elbow chest-strap harness and shoulder saddle is fitted in the same way as the below-elbow harness (Fig. 11)

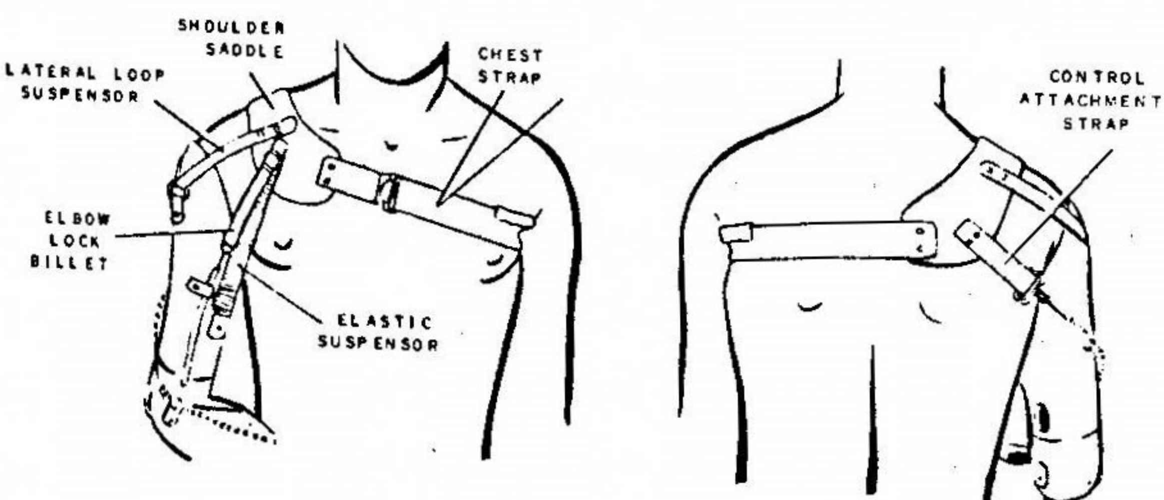


Fig. 11 Above-Elbow Prosthesis with Chest Strap Harness with Shoulder Saddle

Bilateral Above-Elbow Harness

With the bilateral harness, the control attachment strap for one prosthesis is brought up over the opposite shoulder and down anteriorly to the elastic suspensor which, in turn, is attached to the socket. This is done on both sides. The rest of the procedure is the same as for the unilateral figure-8 harness (Fig. 12).

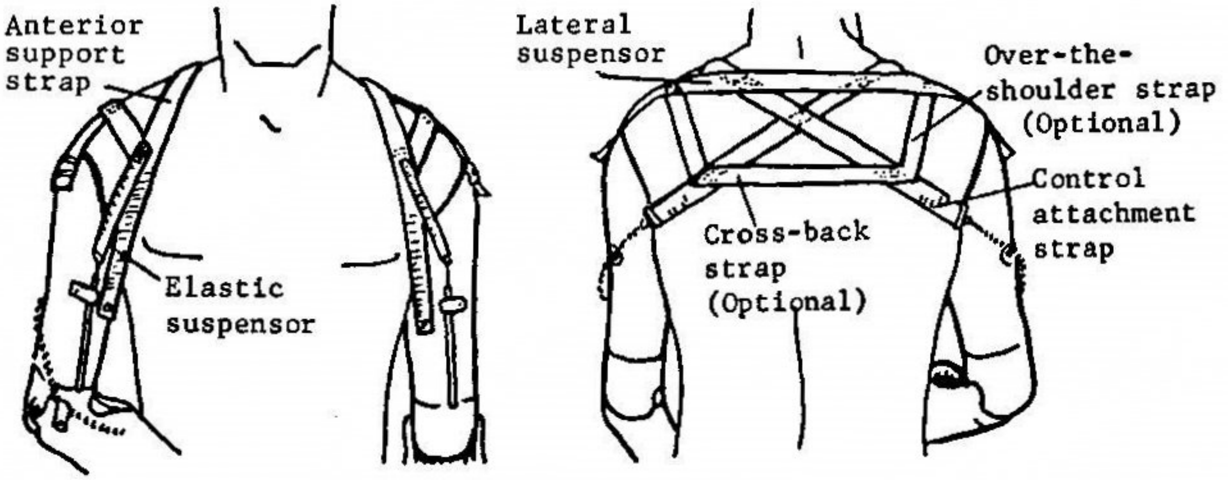


Fig. 12 Bilateral Above-Elbow Harness

SHOULDER PROSTHESIS

The prosthetist begins the fabrication of the shoulder socket by measuring the sound extremity and by marking tender areas and bony prominences on the amputated side. He measures the distance between the spinal column and the most lateral prominence of the amputated shoulder, the hemidiameter of the shoulder. The frontal silhouette of the torso, shoulder, and the sound arm to the elbow are outlined on tracing paper. The prosthetist then sketches on the tracing a symmetrically contoured prosthetic shoulder cap and arm. The socket and arm section are fabricated to the planned contour by techniques similar to those used for the below-elbow and above-elbow sockets. The prosthetist joins the socket and arm sections by bolting the sectional plates together or by assembling a shoulder joint.

An alternative method, used particularly for humeral-neck amputations, is monolith construction, in which shoulder and arm sections are completely fused. Finally, the elbow and forearm unit and terminal device are attached, and the control system and harness assembled.

The basic shoulder-prosthesis harness (Fig. 13) has a chest strap which is fitted in much the same way as the below-elbow and above-elbow chest-strap harness. The strap is attached to the front of the shoulder cap and runs across the chest, under the axilla, across the back, to end at midscapular level at the control-cable hanger. An elastic suspensor strap from the front of the cap, approximately over the deltopectoral groove, is brought up over the shoulder to the chest strap, slightly toward the sound side of the body.

A band of dacron is fitted around the waist and the elbow-lock control strap attached to it.

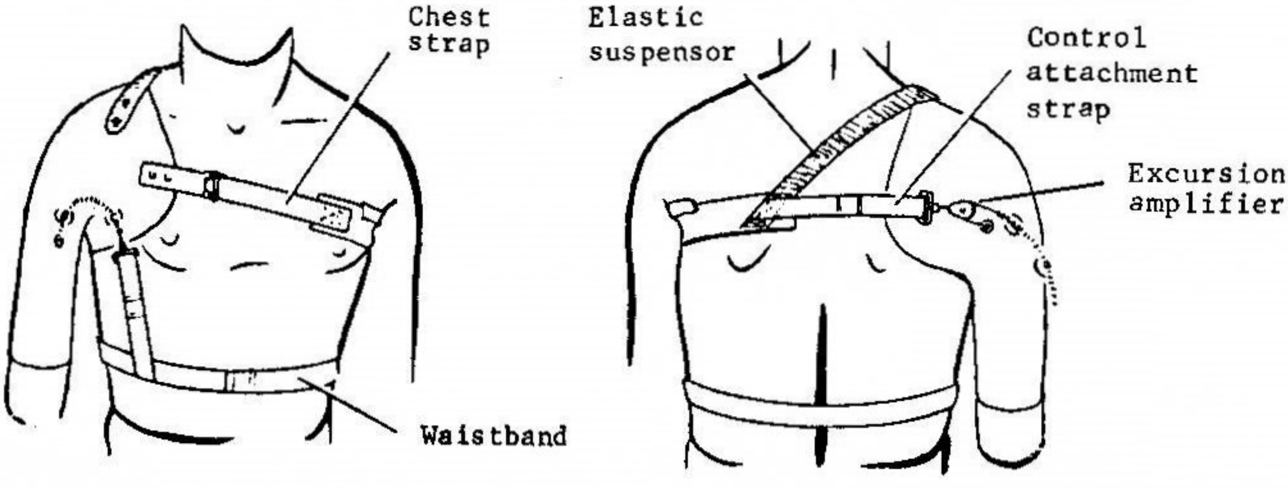


Fig. 13 Shoulder Prosthesis with Basic Shoulder Harness and Excursion Amplifier

UPPER-LIMB MEASUREMENT CHART

Prosthetist ______________________ Date ______________________

Patient's Name ______________________ Amputation Date ______________________

Amputation Type __________ Rt. _____ Left _____ Color Guide No. ______________________

Height __________ Age __________ Sex: Male __________ Female __________

Socket: Double Wall _____ Single Wall _____ Split _____

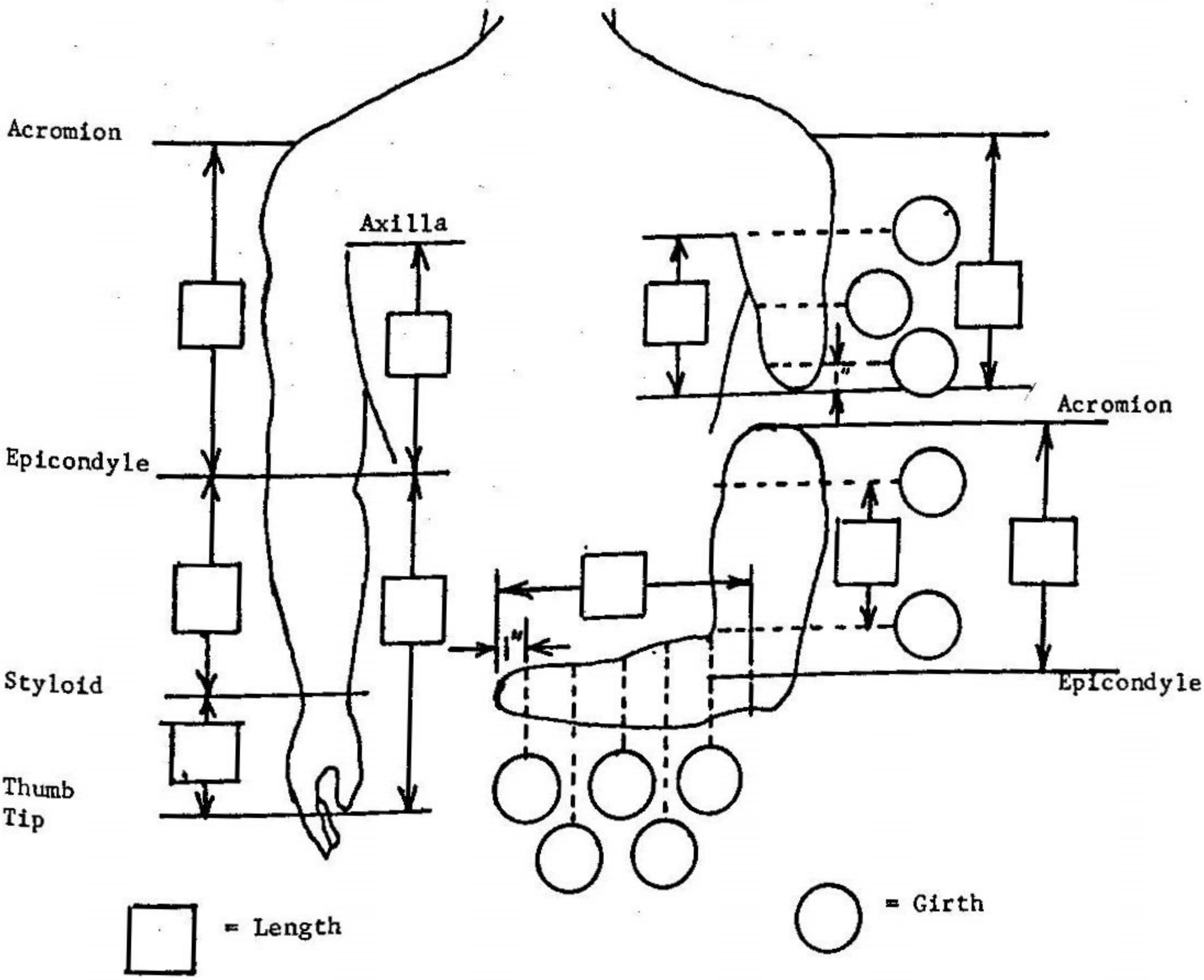
Muenster _____ Shoulder Cap _____

Hook __________ Hand __________ Wrist __________ Hinge __________ Elbow __________

Shoulder Joint __________ Cuff __________ Harness __________ Control System __________

Special Considerations ____

____



CHAPTER 6

CHECKOUT OF BELOW-ELBOW PROSTHESES

The role of the checkout procedure in the prosthetic management of amputees has been discussed previously in the chapter entitled, "Prosthetic and Orthotic Clinic Procedures." The purpose of this chapter is to provide guidance in carrying out an effective checkout for the below-elbow prosthesis.

A checkout consists of a series of tests to be performed and questions to be answered. These tests and questions help to structure the checkout process so that it will be systematic and thorough. (See Prosthetic Checkout Form: Below-Elbow, Pages 98-101)

The following pages provide explanatory material on the various tests and items and identify some of the causes of deficiencies that may be found. It is important that sound practical judgment be exercised in executing the checkout procedures. The tests and items on the form are intended as guides in evaluating the adequacy of the prosthesis. In most cases, a negative response to these items indicates a need for correction or modification. In other instances, however, valid reasons may exist for deviations from the checkout standards, and such considerations should be kept in mind.

Equipment

The following pieces of equipment are recommended for use in performing the checkout:

1. Spring scale registering up to 50 lbs. in 1-lb. increments
2. A smaller spring scale registering up to 30 lbs. in 1/2-lb. increments
3. Goniometer
4. Six-inch ruler
5. Tape measure
6. Wooden block, 1 3/4" long x 3/4" wide x 1/2" thick
7. Three adapters (Fig. 1)
   a. scale to hand
   b. scale to hook
   c. scale to hanger
8. Loop (Fig. 1)

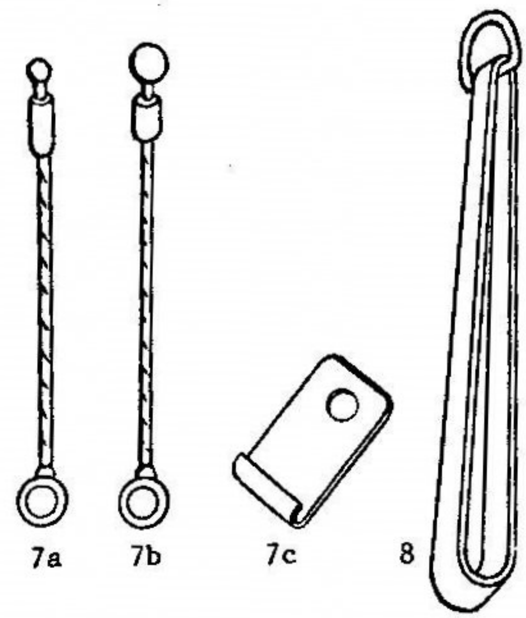


Fig. 1 Checkout Test Equipment

PROSTHETIC CHECKOUT FORM: BELOW-ELBOW

Date________________

Name of Patient____

Initial Checkout ( ) Final Checkout ( )

Pass ( ) Provisional Pass ( ) Fail ( )

If the patient needs further attention, please indicate the area in which treatment is required:

Medical-Surgical______________ ( ) Training______________________ ( )

Prosthetic___________________ ( ) Other_________________________ ( )

(Vocational, Psychological, etc.)

Comments and Recommendations:

____

____

____

____

____

Clinic Chief

Prosthetic Checkout Form: Below-Elbow

	PROSTHESIS OFF	PROSTHESIS ON	PERFORMANCE STANDARDS
RANGE OF MOTION			
1. Stump Rotation (Total Range)	____°	____°	Total rotation with prosthesis on should be half that with prosthesis off.[1] (For "Muenster-Type" prosthesis, see Footnote 2)
2. Elbow Flexion			
Maximum Extension Angle (Initial Flexion)	____°	____°	
Maximum Flexion Angle	____°	____°	Active flexion with prosthesis on should be within 10 degrees of range with prosthesis off.[2]
Range	____°	____°	
TERMINAL DEVICE OPENING AND CLOSING[3]	HOOK	HAND	
1. Mechanical Range	____in.	____in.	
2. Active Range (Forearm at 90 degrees)	____in.	____in.	Full opening and closing should be obtained in all test positions.
3. Active Range (at Waist)	____in.	____in.	
4. Active Range (at Mouth)	____in.	____in.	
CONTROL SYSTEM EFFICIENCY[3]			
1. Force Applied at Terminal Device	____lbs.	____lbs.	
2. Force Applied at Harness	____lbs.	____lbs.	
3. Efficiency = Force at Terminal Device / Force at Harness	____%	____%	Should be 80% or greater for single control cable system.
STABILITY			
1. Displacement of Socket on Stump with 50 pounds Axial Load (one-third body weight for children)		____in.	Prosthesis should not slip on stump more than 1 inch.[4] Harness should not tear.

[1] This standard applies to medium, well-formed stumps, but is often exceeded with wrist disarticulation and long below-elbow stumps. Short or fleshy stumps may not be able to attain the 50% standard.

[2] In "Muenster" sockets, forearm rotation is eliminated and maximum elbow flexion is considerably limited (average 105 to 110 degrees). Furthermore, because of decreased elbow flexion, the measurement of terminal device opening at the mouth may not apply. However, the terminal device should open fully at maximum elbow flexion.

[3] Fingers directed medially.

[4] Because of the intimate fit of the "Muenster" socket, the slippage should not be more than ½ inch.

Prosthetic Checkout Form: Below-Elbow

CONFORMANCE WITH PRESCRIPTION

_____ 1. Is the prosthesis as prescribed? If a recheck, have previous recommendations been accomplished?

DIMENSION

_____ 2. Is the prosthesis the correct length?

TERMINAL DEVICE AND WRIST UNIT

_____ 3. Do the terminal device and wrist mechanism function properly?

_____ 4. If a cosmetic glove is used, is it undamaged, properly color-matched, and pulled completely onto the fingers?

_____ 5. If a length adapter is used, is a fairing for the hand or hook installed?

ELBOW HINGE

_____ 6. Does the elbow hinge function properly without pinching flesh or otherwise causing discomfort?

CUFF

_____ 7. Does the cuff fit snugly without gapping during forearm flexion and terminal device operation?

HARNESS

_____ 8. Is the axilla loop small enough to keep the cross of the Figure 8 harness well below the seventh cervical vertebra and slightly to the unamputated side?

_____ 9. Is the axilla loop properly covered and is it comfortable?

_____ 10. Is the control attachment strap below midscapular level and does it remain low enough to give adequate cable travel?

_____ 11. If there are additional harness straps, can their use be justified?

_____ 12. Does the front support strap pass through the delto-pectoral groove?

_____ 13. If a chest strap harness is used, is the saddle of proper size and placement, and is the chest strap comfortable?

CABLE SYSTEM

_____ 14. If a hook is to be interchanged with a hand, is the hook-to-cable adapter the proper length?

_____ 15. Is the control cable free from sharp bends?

_____ 16. Is the housing on the control cable long enough to prevent contact of the cable with the patient or with the prosthetic forearm, but short enough so it does not interfere with function?

_____ 17. Is the cable housing the proper length between the housing cross bar and the retainer on the forearm, neither too loose nor too tight?

SOCKET

_____ 18. Is the socket comfortable, especially when compression force and torque are applied?

_____ 19. Is the stump free from abrasions, discolorations, and other signs of irritation immediately after the prosthesis is removed?

WORKMANSHIP

_____ 20. Is the general workmanship satisfactory?

PATIENT'S PERFORMANCE AND OPINION

_____ 21. Can the patient demonstrate effective use of the terminal device and wrist mechanism?

_____ 22. Does the patient consider the prosthesis satisfactory as to comfort, function, and appearance?

RANGE OF MOTION

A comparison should be made between the amount of motion with the prosthesis on, and with the prosthesis off. The purpose of these tests is to identify any restriction of motion due to the prosthesis, and to direct attention to possible remedial action. In order to save time, it is advisable to take all measurements with the prosthesis off before taking those with the prosthesis on.

Stump Rotation (Total Range)

In measuring rotation of the forearm (supination and pronation), the amputee's elbow should be flexed to 90^{o} (Fig. 2). As indicated on the checkout form, the total rotation with the prosthesis on should be at least half of that with the prosthesis off.

Failure to meet the standard may be due to poor fit, improper socket trimlines, or inadequate length of the flexible hinges. If flexible hinges are used with short or fleshy stumps, the standard may not be attainable in spite of good socket fit and hinge placement, but every effort should be made to obtain as much active rotation as possible.

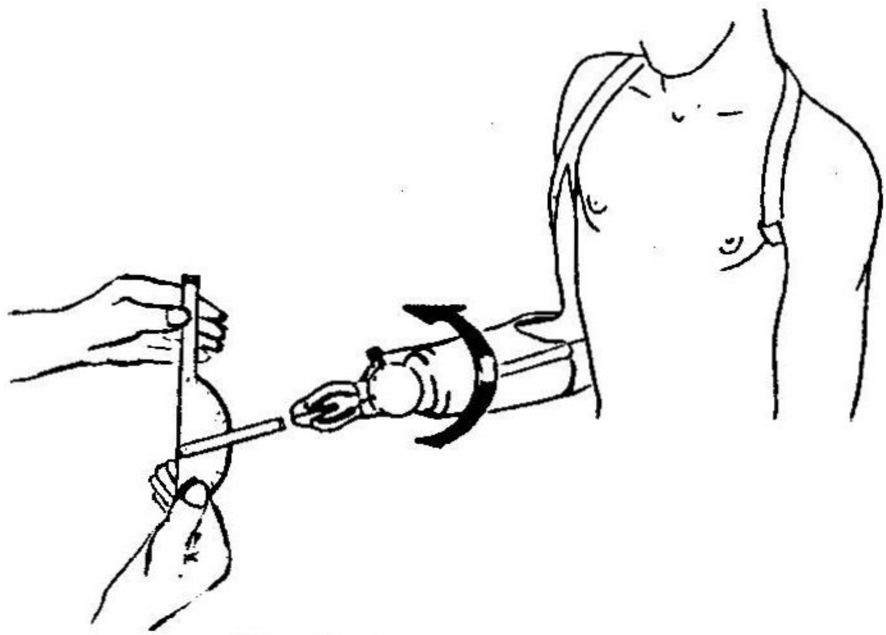


Fig. 2 Forearm Rotation Test

Elbow Flexion

The method of measuring elbow flexion is shown in figure 3. Total flexion with the prosthesis on should be within 10 degrees of the range with the prosthesis off. Improper trimlines of the socket, and poor alignment of the mechanical joint of the rigid hinge are possible causes of restricted range of elbow flexion. With the Muenster-type of socket, the amputee should be able to attain approximately 105 to 110 degrees of flexion. In addition to improper trimlines, inadequate relief for the biceps tendon may further limit flexion in the Muenster socket.

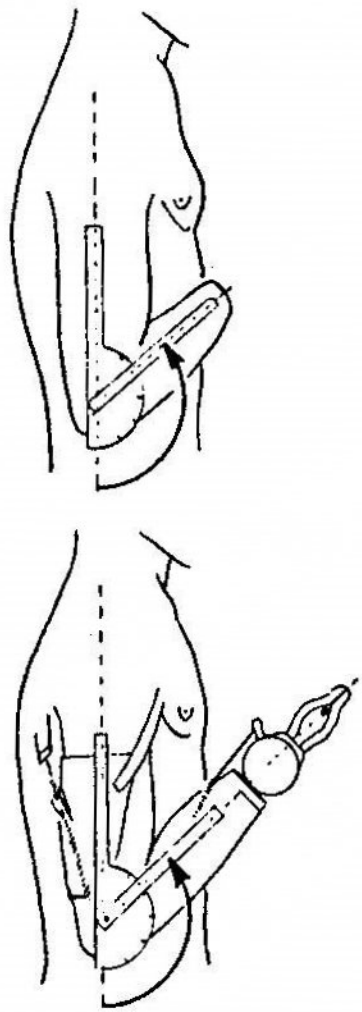


Fig. 3 Elbow Flexion Test

TERMINAL DEVICE OPENING AND CLOSING

The amputee should be able to obtain full active opening or closing (depending on the type of device) when the forearm is positioned at 90 degrees of elbow flexion and also with the terminal device at the waist and at the mouth. First, the examiner should open the terminal device and measure the amount of mechanical range available between the tips of the hook or between the tips of the thumb and index finger of the hand. Then, ask the amputee to flex his elbow to 90 degrees and actively operate the terminal device. Again measure the maximum opening available. Repeat this procedure at the waist and at the mouth (Fig. 4). Since the Muenster wearer will not be able to reach his mouth, ask him to perform at maximum range of elbow flexion. To compute the percentage of opening or closing, multiply by 100 the amount

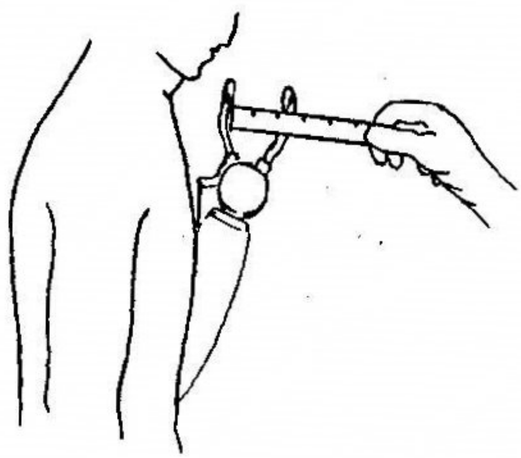


Fig. 4 Terminal Device Operation (at Mouth)

of opening or closing obtained at 90 degrees of elbow flexion at the mouth and at the waist, then divide by the maximum mechanical range.

If the amputee cannot achieve full opening or closing in the designated positions, it may be due to a cable housing which is too long, improper harness or cable adjustment, or control motion limitations.

CONTROL SYSTEM EFFICIENCY

To evaluate the control system efficiency, a comparison is made between the force required to operate the terminal device at the operating lever, and the force required at the control attachment hanger. Position the terminal device in the normal carrying angle (hook fingers pointing in the medial direction). Flex the forearm to 90 degrees and disconnect the cable from the terminal device.

Connect the scale-to-terminal-device adapter to the operating lever or cable of the terminal device, and insert a one-half inch wood block in the grasp of the terminal device. Attach the scale to the adapter and apply force in the same direction as that of the control cable before it was disconnected, as shown in figure 5.

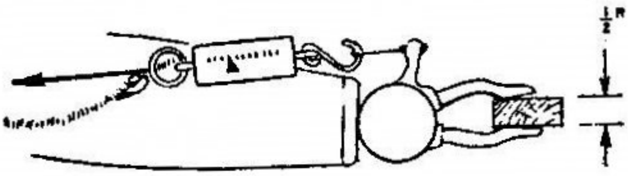


Fig. 5 Force at the Terminal Device

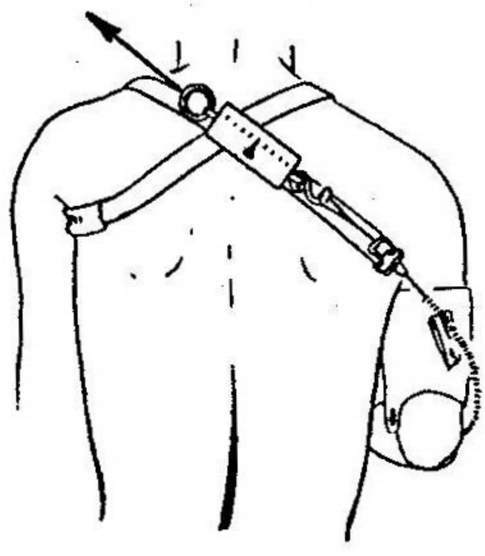


Fig. 6 Force at Hanger

With a voluntary opening device, note the force reading on the scale at the instant the fingers of the terminal device move away from the block. With a voluntary closing device, note the force reading on the scale at the instant the fingers touch the block. Two readings should be taken. If there is a difference between the two readings, a third reading should be taken, and the average of the three readings recorded as the operating force requirement at the terminal device.

Disconnect the scale and adapter from the terminal device and reattach the control cable. Connect the scale-to-hanger adapter to the hanger at the control attachment strap. Stabilize the amputee's arm vertically at the side, with the elbow flexed 90 degrees. Attach the scale to the adapter and apply force in the same direction as that of the control cable and control attachment strap, as shown in figure 6. The scale should not dig into nor pull out from the back. Readings are taken in the same manner as described above for the voluntary opening and voluntary closing devices.

The control system efficiency is computed by multiplying by 100 the force measured at the terminal device and dividing the result by the force measured at the hanger. The efficiency should be at least 80 per cent. If the standard is not met, it may be due to excessive friction because of improper location of retainers, sharp bends, or frayed cable.

STABILITY

The objective is to determine if the prosthesis maintains its position and is comfortable when a heavy axial load is applied.

Have the amputee stand with his arms at his sides. Attach the scale to the terminal device, using an adapter or strap if necessary, and apply a force of 50 pounds straight down, instructing the amputee to resist the force. Measure the vertical displacement of the prosthesis with respect to the epicondyles or acromion, as in figure 7. In applying this test to the person with an elbow flexion contracture or a Muenster prosthesis, the arm should be allowed to move backward so that the forearm will be in vertical alignment with the axial load.

A 50-pound pull should not cause discomfort, the prosthesis should not slip from the stump more than one inch (or half an inch for the Muenster) and no part of the prosthesis or harness should fail. When applying this test to children or small adults, the downward pull may be reduced to a force equal to one third of the subject's bodyweight.

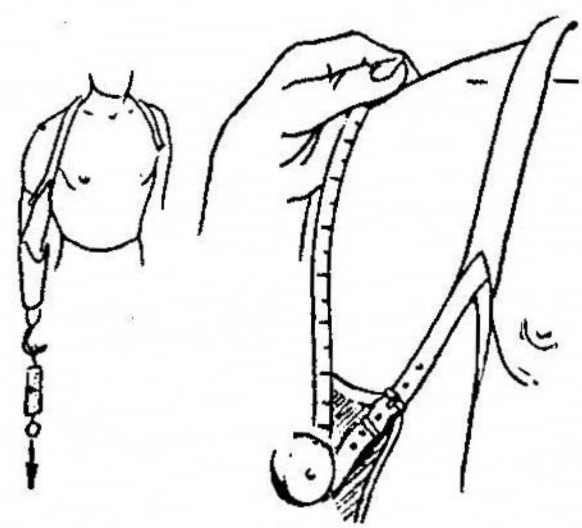


Fig. 7 Tension Stability

When the performance tests described above have been completed, attention is directed to the items that follow to obtain further information on the fit, comfort, and function of the prosthesis.

1. Is the prosthesis as prescribed? If a recheck, have previous recommendations been accomplished?

The terminal device, wrist unit, socket type, and suspension should be specified in the prescription. During the fabrication, the prosthetist may find it necessary to deviate somewhat from the original prescription. Approval should be obtained, however, from the clinic chief before any modifications are made.

2. Is the prosthesis the correct length?

The most distal portion of the closed terminal device should approximately correspond to the tip of the thumb on the sound side. The comparison of length is made when the amputee is standing with his arms extended at his sides. If there appears to be a difference between the length of the prosthesis and the intact arm, the examiner can measure from the epicondyle or acromion process to the end of the terminal device, and compare the result with the corresponding measurement on the contra-lateral side.

If there is a definite discrepancy, check to be sure that the socket is on completely, or whether the interchangeable plan has been properly employed.

3. Do the terminal device and wrist mechanism function properly?

Check the fingers of the terminal device for even contact between the surfaces, and for significant wear of the neoprene covering, if it is used. Also determine whether the selector switch on the APRL or Sierra-2-Load hook is functioning properly. Ascertain if the friction provided by the wrist unit is appropriate to the individual's needs and, if a locking wrist has been prescribed, determine that it functions properly.

4. If a cosmetic glove is used, is it undamaged, properly color-matched, and pulled completely onto the fingers?

With the commercially available cosmetic gloves, it should be possible to match the patient's own skin tones fairly closely. In evaluating the color match, it is desirable to check the hands in natural sunlight because a comparison under artificial light may be misleading. In a hand which has moving fingers the glove may interfere with function if it is not pulled completely onto the hand.

5. If a length adapter is used, is a fairing for the hand or hook installed?

Although absence of the fairing will not affect mechanical function of the prosthesis, it produces an unacceptable appearance.

6. Does the elbow hinge function properly without pinching or otherwise causing discomfort?

Have patient flex and extend his arm through the full range of motion. The hinge should fit close to the arm but should not interfere with motion or cause any undue pressure.

7. Does the cuff fit snugly without gapping during forearm flexion and terminal device operation?

If the cuff has excessive gapping, there may be a concentration of pressure in those areas where the cuff is in contact with the skin and the cuff will not provide a stable reaction point. Improper location of the rigid hinge axis is a common cause of gapping.

8. Is the axilla loop small enough to keep the cross of the Figure-8 harness well below the seventh cervical vertebra and slightly to the unamputated side?

It is important to try to avoid pressure on the prominence of the seventh cervical vertebra. If the cross is towards the unamputated side, the axilla loop is smaller and therefore becomes more stable; at the same time, the control attachment strap will be longer and allow for more freedom of motion and better alignment.

9. Is the axilla loop properly covered and is it comfortable?

In order to help keep the harness clean, the axilla loop should be covered with a pliable plastic. If the harness is not comfortable, the patient may reject the prosthesis.

10. Is the control-attachment strap below midscapular level and does it remain low enough to give adequate cable travel?

Placing the control-attachment strap as low as possible (without interfering with clothing) from the center of rotation of the shoulder joint minimizes the amount of humeral flexion required to operate the terminal device. If the control-attachment strap is located between the midscapular level and the inferior angle these requirements are usually met.

11. If there are additional harness straps, can their use be justified? On occasion it may be necessary to modify the basic harness to fit a particular patient's needs, but it is important not to exceed the patient's "gadget-tolerance" and to be able to justify the need for the additional straps.

12. Does the front support strap pass through the delto-pectoral groove? The junction between the deltoid and pectoralis major muscles provides a natural channel in which the front support strap may lie. If it is placed too far lateral to this groove the harness may slip off the shoulder. On the other hand, if it is too far medial, it will probably be uncomfortable for the patient.

13. If a chest strap harness is used, is the saddle of proper size and placement and is the chest strap comfortable?
The shoulder harness may be prescribed for individuals who will be doing heavy lifting, or who cannot tolerate a Figure-8 harness because of discomfort on the axilla. Therefore, it should be large enough to distribute the pressure evenly, but small enough to minimize bulk and to allow for good contouring.

14. If the hook is to be interchanged with a hand, is the hook-to-cable adapter the proper length?
The ball receptacle on the operating cable for a hand is necessarily placed outside the cosmetic glove. Therefore, the attachment of the ball receptacle to the control cable is more proximal than is the attachment to the operating lever of the hook. This difference in length must be made up by a hook-to-cable adapter (Fig. 8). If the length adapter is not the correct length, it results in inconvenience and need for harness adjustment when terminal devices are interchanged.

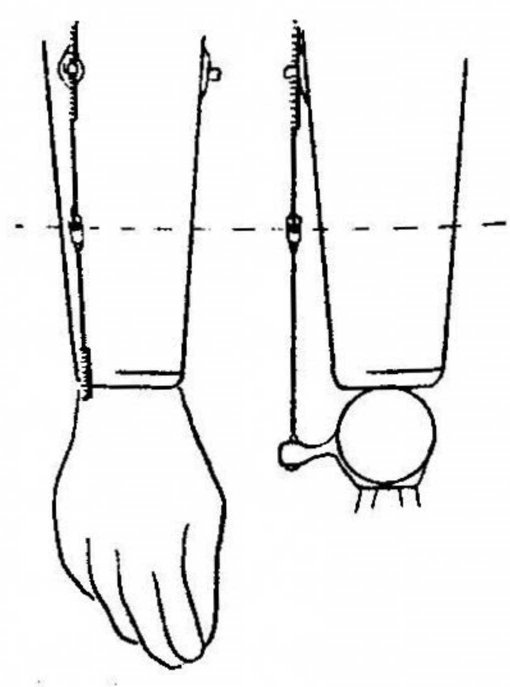


Fig. 8 Hook-to-Cable Adapter

15. Is the control cable free from sharp bends?

Check the cable throughout its visible length to be sure there are no kinks or fraying. It is particularly important that the retainers be placed so that there is not a sharp bend at the point where the cable exits from its housing or from the hand, as this will cause excessive friction.

16. Is the housing on the control cable long enough to prevent contact of the cable with the patient or with the prosthetic forearm, but short enough so it does not interfere with function?

If the cable housing is inadequate, there may be excessive friction resulting in patient discomfort, reduced control system efficiency, and damage to the prosthetic forearm. However, if it extends too far distally or proximally, it will interfere with the function of the terminal device.

17. Is the cable housing the proper length between the housing cross bar and the retainer on the forearm, neither too loose nor too tight?

Have the patient flex and extend his elbow. The cable housing should not pinch or restrict range of motion. On the other hand, if it is too loose, it will be unsightly and interfere with clothing.

18. Is the socket comfortable, especially when compression force and torque are applied?

The patient should be asked to stabilize his stump in the socket, while the examiner attempts to move the socket on the stump. Take note of any areas of discomfort that the amputee might mention so that special attention may be given to these areas when the prosthesis is removed.

19. Is the stump free from abrasions, discolorations, and other signs of irritation immediately after the prosthesis is removed?

Inspect the stump immediately for evidence of excessive pressure or abrasion. Reddening of the stump is an indication of areas of pressure. However, if the redness subsides within five minutes, and the patient does not complain of discomfort, the pressure may be within tolerable limits. If a stump sock is worn, the marks made on the skin by the weave of the sock can provide an indication of the areas to which pressure is being applied.

20. Is the general workmanship satisfactory?

The harness should be checked for fraying, incomplete stitching or malfunctioning fasteners. Look for inadequately laminated areas, protruding screws, unpeened rivets and rough surfaces in the socket.

21. Can the patient demonstrate effective use of the terminal device and wrist mechanism?

The last two items may be eliminated on the initial checkout since the patient probably will not have had any formal training. On a recheck, the patient should be asked to position his hook, interchange terminal devices and pick up objects of various shapes and weights. He should be able to utilize the selector switch on the terminal device for various size openings or prehension loads.

22. Does the patient consider the prosthesis satisfactory as to comfort, function, and appearance?

Ask the amputee for his opinion of the prosthesis. After he volunteers his overall reaction, try to obtain further information, particularly in reference to comfort, stability, effort and appearance.

CHAPTER 7

CHECKOUT OF ABOVE-ELBOW PROSTHESES

The procedures and techniques for checkout of the above-elbow and shoulder-disarticulation prostheses are, to a great extent, essentially the same as for the below-elbow prosthesis. Where there are no significant differences, an asterisk is placed adjacent to the item in the text.

For some items the performance standards for the above-elbow and shoulder-disarticulation prostheses are lower than the corresponding standards for below-elbow prostheses because of the greater complexity of the fitting and harnessing problems involved and the biomechanical limitations imposed by the higher level of amputation.

In other instances, although checkout procedures are the same as for the below-elbow prosthesis, the reasons for failure to comply with the standards may be different, or more numerous, than those listed in the below-elbow instructions. For these items additional comments are included.

The checkout form for above-elbow and shoulder-disarticulation prostheses is shown on pages 112 to 115. The discussion of procedures, standards and techniques on succeeding pages applies to both above-elbow and shoulder-disarticulation prostheses, unless a specific distinction is made.

PROSTHETIC CHECKOUT FORM: ABOVE-ELBOW AND SHOULDER-DISARTICULATION

Date____________________

Name of Patient____

Initial Checkout ( ) Final Checkout ( )

Pass ( ) Provisional Pass ( ) Fail ( )

If the patient needs further attention, please indicate the area in which treatment is required:

Medical-Surgical______________ ( ) Training________________ ( )

Prosthetic__________________ ( ) Other__________________ ( )
(Vocational, Psychological, etc.)

Comments and Recommendations:

____

____

____

____

____

Clinic Chief

Prosthetic Checkout Form: Above-Elbow and Shoulder-Disarticulation

	PROSTHESIS OFF	PROSTHESIS ON	PERFORMANCE STANDARDS
RANGE OF MOTION			
1. Shoulder Flexion	____°	____°	90 degrees
2. Shoulder Abduction	____°	____°	90 degrees
3. Shoulder Extension	____°	____°	30 degrees
4. Prosthetic Elbow: Mechanical Range		____°	135 degrees
5. Prosthetic Elbow: Active Range		____°	135 degrees
6. Humeral Flexion Required to Flex Elbow Fully		____°	Should not exceed 45 degrees.
TERMINAL DEVICE OPENING AND CLOSING[1]	HOOK	HAND	
1. Mechanical Range	____in.	____in.	
2. Active Range (Forearm at 90 degrees)	____in.	____in.	Full opening and closing should be obtained with the forearm at 90 degrees.
3. Active Range (at Waist)	____in.	____in.	50% or greater opening and closing should be obtained at waist and mouth.
4. Active Range (at Mouth)	____in.	____in.	
CONTROL SYSTEM EFFICIENCY[1]			
1. Force Applied at Terminal Device	____lbs.	____lbs.	
2. Force Applied at Harness	____lbs.	____lbs.	
3. Efficiency = $\frac{\text{Force at Terminal Device}}{\text{Force at Harness}}$	____%	____%	Should be 70% or greater.
4. Force Required to Flex Elbow from Position of 90 degrees	____lbs.	____lbs.	Should not exceed 10 pounds. Should not cause inadvertant terminal device operation.
STABILITY			
1. Displacement of Socket on Stump with 50 pounds Axial Load (one-third body weight for children)		____in.	Prosthesis should not slip on stump more than 1 inch. Harness should not tear.

[1] Fingers directed medially.

CONFORMANCE WITH PRESCRIPTION

_____ 1. Is the prosthesis as prescribed? If a recheck, have previous recommendations been accomplished?

DIMENSIONS

_____ 2. Is the prosthesis the correct length and do elbow levels coincide?

TERMINAL DEVICE AND WRIST UNIT

_____ 3. Do the terminal device and wrist mechanism function properly?

_____ 4. If a cosmetic glove is used, is it undamaged, properly color-matched, and pulled completely onto the fingers?

_____ 5. If a length adapter is used, is a fairing for the hand or hook installed?

ELBOW UNIT

_____ 6. Does the elbow function properly?

_____ 7. Is the forearm set in adequate initial flexion?

_____ 8. Can the amputee swing his arms while walking and raise his elbow 60 degrees to the side without the elbow locking involuntarily?

_____ 9. Can the patient use the turntable to position the forearm satisfactorily?

HARNESS

_____ 10. Is the axilla loop small enough to keep the cross of the Figure-8 harness well below the seventh cervical vertebra and slightly to the unamputated side?

_____ 11. Is the axilla loop properly covered and is it comfortable?

_____ 12. Is the control-attachment strap below midscapular level and does it remain low enough to give adequate cable travel?

_____ 13. Is the lateral support strap properly positioned?

_____ 14. If there are additional harness straps, can their use be justified?

_____ 15. Does the front support strap pass through the delto-pectoral groove?

_____ 16. Is the elastic front suspensor of adequate length and properly located?

_____ 17. If a chest strap harness is used, is the saddle of proper size and placement, and is the chest strap comfortable?

CABLE SYSTEM

_____ 18. If a hook is to be interchanged with a hand, is the hook-to-cable adapter the proper length?

_____ 19. Is the control cable free from sharp bends?

_____ 20. Is the housing on the control cable long enough to prevent contact of the cable with the patient or with the prosthetic forearm, but short enough so it does not interfere with function?

CABLE SYSTEM (continued)

_____ 21. Does cable housing cover the cable adequately without restricting forearm flexion?

_____ 22. Is the leather lift loop the proper length and is it positioned to allow adequate terminal device operation after full forearm flexion and heavy enough to withstand buckling during use?

_____ 23. Does the leather lift loop pivot on the screw and grip the cable housing tightly enough to prevent slipping?

_____ 24. Does the elbow lock cable lead directly from the access hole to the delto-pectoral groove?

SOCKET

_____ 25. Is the socket comfortable, especially when compression force and torque are applied?

_____ 26. Is the stump free from abrasions, discolorations, and other signs of irritation immediately after the prosthesis is removed?

WORKMANSHIP

_____ 27. Is the general workmanship satisfactory?

PATIENT'S PERFORMANCE AND OPINION

_____ 28. Can the patient demonstrate effective use of the terminal device, wrist mechanism, and elbow unit?

_____ 29. Does the patient consider the prosthesis satisfactory as to comfort, function, and appearance?

RANGE OF MOTION

With the prosthesis on, measurements are taken of the active range of motion in shoulder flexion, hyperextension, and humeral abduction. The examiner then asks the amputee to repeat the same motions with the prosthesis on and with the elbow locked in the fully extended position. The above-elbow amputee should be able to achieve at least 90 degrees of flexion and abduction, and 30 degrees of hyperextension. It is seldom necessary for the patient to perform above the shoulder level. Also, it is difficult to stabilize the socket on the stump in this position. Socket and harness fit primarily influence the range of motion available. For short stumps, the acceptable ranges may be slightly less than the usual standards.

A comparison should be made between the mechanical range and the active range of forearm flexion. With the prosthesis on, manually flex the forearm section through its full range, which should not be less than 135 degrees. If the range is restricted, it may be due to improper trim of the forearm section, or the elbow unit may be malfunctioning. Next, direct the amputee to actively flex the forearm through its maximum range. If the active range is less than the mechanical range, look for housing which is too long, poor harness adjustment, or control motion limitations.

It is important to determine whether the amount of humeral flexion necessary to flex the forearm completely is within an acceptable range. If the control motion should exceed 45 degrees, the amputee may have difficulty working close to the body in bimanual skills. The amputee should be instructed to flex the forearm through its maximum range; the amount of humeral flexion required to do this is measured by the examiner. Improper harness adjustment is usually the problem if the required motion exceeds 45 degrees. Poor cable alignment is another possible cause of difficulty.

TERMINAL DEVICE OPENING AND CLOSING

The amputee should be able to actively obtain full opening or closing with the elbow locked at 90 degrees. However, at the mouth and waist, it may not be possible to attain full opening, and 50 per cent may be acceptable as a minimal standard. The difficulty is encountered because a substantial amount of cable excursion is used to flex the prosthetic elbow and the remaining excursion is insufficient to provide full opening or closing of the terminal device. The reasons for failure to meet these standards are the same as those stated in the below-elbow instructions.

CONTROL SYSTEM EFFICIENCY

The procedure in computing the efficiency for the above-elbow and shoulder-disarticulation prosthesis is the same as for the below-elbow prosthesis. Because of the greater friction inherent in the dual control system, the acceptable minimal standard is 70 per cent as compared to 80 per cent for the below-elbow prosthesis. When an excursion amplifier is used on a shoulder-disarticulation prosthesis, it reduces the amount of motion necessary to operate the terminal device or flex the elbow by one half, but doubles the force required. It is necessary, therefore, to multiply by two the result obtained by the standard procedure, to compensate for the mechanical effect of the amplifier.

A check should also be made as to the amount of force the amputee must exert in order to flex the forearm. While the scale-to-hanger adapter and the scale are still attached (from the test above), unlock the prosthetic elbow and support the prosthetic forearm so that it is horizontal. Stabilize the socket vertically at the side and pull the scale along the normal line of the control-attachment strap. Note the force at the instant the prosthetic elbow starts to flex. The force required to flex the forearm should not exceed 10 pounds. However, in the case of the shoulder-disarticulation prosthesis, with an excursion amplifier, a force of 20 pounds is acceptable.

STABILITY

In checking this item, a fifty pound axial load is used, as was the case with the below-elbow amputee. With the shoulder-disarticulation prostheses, and with some above-elbow prostheses, the acromion process may not be accessible as a stabilization point for measurement. When this occurs, the end of the tape can be held against the seventh cervical or first thoracic vertebra to provide a fixed point for measurement of displacement.

When the performance tests described above have been completed, attention is directed to the items that follow to obtain further information on the fit, comfort and function of the prosthesis.

*1. Is the prosthesis as prescribed? If recheck, have previous recommendations been accomplished?

2. Is the prosthesis the correct length and do elbow levels coincide?

The overall length of the prosthesis and the relative length of upper arm and forearm of the prosthesis are compared to the sound side by visual inspection. If warranted, a more precise comparison may be obtained by comparing the measurement from the acromion process to the axis of the prosthetic elbow with the measurement from acromion process to the lateral epicondyle of the humerus on the contralateral side. The forearm measurements can be compared in the manner described previously for the below-elbow prosthesis.

*3. Do the terminal device and wrist mechanism function properly?

*4. If a cosmetic glove is used, is it undamaged, properly color-matched, and pulled completely onto the fingers?

*5. If a length adapter is used, is a fairing for the hand or hook installed?

6. Does the elbow function properly?

The examiner should lock and unlock the elbow in all of the locking positions to determine whether the elbow unit is functioning properly.

7. Is the forearm set in adequate initial flexion?

The prosthetic forearm is usually set in approximately 10 to 15 degrees of initial flexion. This helps reduce the amount of force necessary to flex the elbow. More than 15 degrees, however, may prove to be unsightly.

8. Can the amputee swing his arm while walking and raise his elbow 60 degrees to the side without the elbow locking involuntarily?

If the amputee cannot swing his arm while walking without the elbow automatically locking, it may be due to incorrect adjustment of the elbow-lock control cable.

9. Can the patient use the turntable to position the forearm satisfactorily?

The turntable should be loose enough so that the patient is able to position the forearm with relative ease, but not so loose that the forearm cannot resist a force of 2 to 2½ pounds at the terminal device without displacement.

*10. Is the axilla loop small enough to keep the cross of the Figure-8 harness well below the seventh cervical vertebra and slightly to the unamputated side?

*11. Is the axilla loop properly covered and is it comfortable?

*12. Is the control-attachment strap below midscapular level and does it remain low enough to give adequate cable travel?

13. Is the lateral support strap properly positioned?

The lateral support strap should pass slightly anterior to the midline of the shoulder to provide optimum function and stability of the socket on the stump.

*14. If there are additional harness straps, can their use be justified?

*15. Does the front support strap pass through the delto-pectoral groove?

16. Is the elastic front suspensor of adequate length and properly located?

The elastic from suspensor should be approximately 6 inches long so that the amputee's control motions will not be restricted.

*17. If a chest strap harness is used, is the saddle of proper size and placement, and is the chest strap comfortable?

*18. If a hook is to be interchanged with a hand, is the hook-to-cable adapter the proper length?

*19. Is the control cable free from sharp bends?

*20. Is the housing on the control cable long enough to prevent contact of the cable with the patient or with the prosthetic forearm, but short enough so it does not interfere with function?

21. Does cable housing cover the cable adequately without restricting forearm flexion?

If the ends of the proximal and distal fair lead housing at the elbow impinge when the elbow is flexed, full flexion will not be achieved because of the interference. There should be about one-fourth inch of clearance between the ends of the fair lead housing.

22. Is the leather lift loop the proper length and position to allow adequate terminal device operation after full forearm flexion and heavy enough to withstand buckling during use?

The leather loop should be sufficiently short and positioned closely enough to the elbow axis to minimize the excursion needed to operate the terminal device and flex the elbow. If the loop is placed too close to the elbow or is too short, however, the force required to operate the prosthesis may be excessive.

23. Does the leather lift loop pivot on the screw and grip the cable housing tightly enough to prevent slipping?

The lift loop should pivot so that the cable follows a smooth path as it exits from the housing throughout the full range of elbow flexion and extension.

24. Does the elbow lock cable lead directly from the access hole to the delto-pectoral groove?

If the elbow lock cable follows a fairly straight path, it will reduce the amount of friction that occurs between the housing and the cable.

*25. Is the socket comfortable, especially when compression force and torque are applied?

*26. Is the stump free from abrasions, discolorations, and other signs of irritation immediately after the prosthesis is removed?

*27. Is the general workmanship satisfactory?

*28. Can the patient demonstrate effective use of the terminal device, wrist mechanism, and elbow unit?

*29. Does the patient consider the prosthesis satisfactory as to comfort, function, and appearance?

*Questions are essentially the same as for below-elbow checkout.

Amputee Training

A prosthesis may be defined as the addition to the body of some artificial part such as a leg, eye, or tooth in substitution for the missing member. The application may be primarily cosmetic, as in the case of an eye, or functional as demonstrated by a primitive leg pylon (peg-leg). Upper-extremity prostheses are designed to provide the maximum amount of functional regain to the amputee with as little discomfort, effort, and sacrifice of cosmesis as possible. However, the attempt to restore the function of a lost member by a substitute mechanical apparatus presents complex problems in the control of the apparatus. Training is necessary to establish a satisfactory amputee-prosthesis relationship, since it is the man-machine combination which determines the performance and the ultimate amputee acceptance of the prosthesis.

This chapter presents the philosophy and approach to training the amputee, lists the requirements of a trainer, and defines some of the basic concepts regarding training. In addition, specific instructions and methods are presented to enable amputees of various types to accomplish representative activities. These step-by-step procedures should not be regarded as the only or the best way to perform an activity; they are furnished to record a method that has been used satisfactorily and has a high probability of success. This material should be used to establish a baseline of procedure from which the trainer can independently develop skills and techniques of training suited to the particular amputee.

IMPORTANCE OF RESIDUAL FUNCTION

The unilateral amputee, who retains complete function in one extremity, represents the majority of the amputee population. The unilateral group may be separated into the BE, AE, and Shoulder types. Of these types, the Wrist Disarticulation exemplifies the least complicated problem from the standpoint of replacement or residual function, since the sound side possesses normal function, while the amputation side still has the function of the shoulder girdle, arm, elbow, and forearm. The problem increases in complexity with higher levels of amputation, reaching a maximum with the unilateral Forequarter.

The six possible combinations of bilateral amputee may be grouped into three functional classes:

(1) BE with BE, AE, or Shoulder (BE-BE/AE/S)

(2) AE with AE or Shoulder (AE-AE/S)

(3) Shoulder-Shoulder (S-S)

The first class has the greatest residual function, having in common the use of the shoulder girdle, upper arm, elbow, and forearm on at least one side — a major factor from the standpoint of prosthetic replacement. Amputees in the second class retain all or partial function of the shoulder girdle and upper arm (humerus) on at least one side. Finally, the bilateral Shoulder amputee has the least amount of residual function and is the most complex problem of all the types.

It is clear that the procedure or method of training must be specifically designed to fit the amputee type. Since separation by amputee type in presenting the training procedure in this chapter would be too involved, the breakdown used is a division into BE, AE, and Shoulder for the unilateral case, and the three functional classes listed above for the bilateral.

Residual function can be enhanced by the use of physical therapy, when indicated by a physician The general physical and mental condition should be brought to the highest possible level before the training program is initiated. However, certain aspects of pre-prosthetic therapy may be carried out concurrently with the training program.

PRINCIPLES OF AMPUTEE TRAINING

The over-all aim of training is to enable the amputee to become as self-sufficient as possible in all the activities of daily living, commensurate with the amputee's needs. Although there is no clearly "best" program, there is much experience upon which to base a procedure and selection of activities.

In the "potential" approach to training, the amputee is trained in activities which he does not necessarily need to perform but which help develop complex motion patterns that increase the potential level of performance. Thus, a unilateral amputee may be trained to ladle soup by utilizing the prosthesis as the major limb. The "practical" approach states that the unilateral should be trained only to use his prosthesis as a helper in two-handed activities. In light of present information and experience, the "practical" approach is recommended.

Choosing activities suited to the amputee's needs, and allowing the amputee to indicate what additional and special training is desired, are the best guides in organizing a program. A very important aspect of the training program is the evaluation of a new amputee's capabilities with respect to his former occupation. This should be carried out in close cooperation with vocational rehabilitation personnel. The training program should serve also as a trouble-shooting phase, during which the reliability and practicability of mechanical components can be evaluated, and malfunctions or need for readjustment of harness or mechanism can be recognized and remedied. The program also enables further and more intimate evaluation of individual amputee needs and provides a means of continuous feedback to the clinic team concerning the physical and mental condition of the amputee.

If the amputee is to achieve his own rehabilitation, he must avail himself of the trainer's knowledge. In order to give him this knowledge, the amputee trainer should be aware that the key to learning is desire and interest or motivation. Motivation, as a concept applied to amputee training, signifies that the amputee must want to learn to use his prosthesis effectively in order for learning to occur. The therapist, by creating an incentive for the amputee, can indirectly motivate the subject to work efficiently. Time should be taken to explain to the amputee why training is important.

Among the goals or incentives which usually motivate amputees to use their prostheses effectively are:

1. Independence in activities of daily living.
2. Ability to return to the former work or to get a better job. This involves both financial security and social prestige.
3. Improved appearance, less awkward and conspicuous motions.
4. Ability to return to preferred hobbies and recreations, or to learn new skills.
5. Emulation of well-trained amputees. This is extremely helpful, provided the experienced amputee is not possessed of so much more residual function than the new amputee that the contrast increases the latter's feelings of helplessness. This might happen if, for instance, a bilateral Short AE-Shoulder amputee compared himself with a bilateral BE. Experienced amputees who are as similar as possible to the new amputees in age, sex, level of amputation, physical condition, etc., can be of great help.
6. Feeling that progress is being made toward the goals. As in other forms of physical and occupational therapy, one of the trainer's most important contributions is to keep up the amputee's morale by keeping the goals before him and encouraging the belief that he is progressing toward them. This is discussed further under *Sense of Accomplishment*.
7. Desire to please the trainer. The trainer's personality is important.

Some Factors Which Affect Learning

Habit Pattern Interference is one of the factors which hinder learning. A noteworthy training problem involves the congenital amputee and the unilateral amputee of long standing, who have developed motion patterns which enable them to manage most of their daily affairs with acceptable success. For them, learning to use a prosthesis effectively is made difficult by interference from existing motor habits and by lack of motivation.

Knowledge of Results The trainer must never forget that the amputee has lost much of his normal "feedback" system and often cannot tell until too late whether or not he is using a correct technique. For example, the amputee grasping a doorknob with his hook cannot tell whether or not the hook has been positioned correctly until the door opens. It is important for the trainer to let the amputee know *immediately* what is wrong with the grasp of the doorknob. Even if the amputee is doing everything right, he may feel uncertain because he cannot tell for himself, and require reassurance.

Instructions Very often in instructing the amputee, the trainer does not know how the particular amputee with his particular equipment should approach the task, perhaps because of the marginal function of the amputee, the uniqueness of the task, or the lack of experience of the trainer. In this case it is suggested that trainer and amputee work together until a successful method has been evolved, when a specific set of instructions should be detailed and followed.

Time Limits Two of the common standards employed to measure the amputee's learning are the reduction of errors and the reduction in time to do a specific activity. In training the amputee, time standards based on experience are useful, but the amputee should never be made to work against time standards set by other amputees. Rather, the amputee should strive to improve his own performance.

Age and Sex As old age approaches, ability to learn new skills decreases. This factor can be counteracted by additional teaching procedures to motivate the older amputee. Studies in the field of motor learning indicate that sex is not an important variable in determining speed of learning except insofar as it is correlated to past experience and physical power. In prosthetics it is generally true that the body power available to operate the prosthesis is greater for males than for females. This would give male amputees an advantage in the operation of terminal devices.

Sense of Accomplishment "Nothing succeeds like success." The limited data that have been gathered on this point substantiate the statement. Reward and feelings of success and accomplishment apparently do more to improve performance than a sense of failure. In training the amputee it is wise to start off with an activity that the amputee can readily master. If difficult activities are attempted unsuccessfully, reverting to a simpler activity is helpful. The trainer should always attempt to leave the amputee with a "sense of success."

Problem of Handedness

What types of training activities should the amputee trainer plan for the new amputee who has lost his preferred hand? Should writing and other activities which require a high level of manual dexterity be transferred to the remaining hand, or should the amputee be trained to accomplish these activities with his prosthesis? One of the arguments for not transferring immediately to the remaining hand is based on the opinion that left-handed children who are forced to use their right hands develop emotional instability. However, it is now believed that such emotional instability is caused by the authoritarian parental approach and not by the conversion to the nonpreferred hand *per se*. On the other hand, there is considerable evidence which shows that the human is quite capable of achieving a high level of dexterity with the nonpreferred hand.

In view of this evidence it appears reasonable to conclude that the new amputee who has lost the preferred hand will, quite likely, transfer complex activities to the remaining hand during the pre-prosthetic period in order to achieve independence in daily activities. However, if the amputation is below the elbow, the amputee trainer may attempt to teach the subject to use the prosthesis for everyday living activities, including writing. Such training, if successful, will insure excellent prosthesis use. Transfer to the nonpreferred extremity can always be made at a later time.

Methods of Determining When an Amputee is Trained

How can the trainer establish when an amputee is trained? This question leads to another, namely, what is meant by the term trained"? Does it mean that the subject has attained the best performance in all possible activities? Obviously, no matter how ambitious a training program may be, it is always possible to add one more activity or to improve the performance of a given task. Of necessity, therefore, the amputee trainer can determine the adequacy of training only within the limits set by the time available and the evaluation technique employed.

Research methods of evaluating training are based on the learning curve. The amputee is trained in an activity until the performance time remains the same on many attempts and there is no further improvement in his facility and cosmetic appearance indices. As an external check of the attained learning plateau, awkward movements and avoidable delays (errors in performance) should disappear when the highest level of learning is attained. If ten sequences or activities are employed to evaluate training, ten learning curves are necessary, and even in the case of the unilateral BE amputee, a considerable amount of time is involved. In addition, when using research techniques, it is necessary to control to the utmost any extraneous variables which may influence performance. Thus, training must be spread over many days, test props must be standardized, etc.

In contrast to research methods, certain practical techniques of evaluating training have evolved. These techniques are admittedly less accurate, but require less time. In some amputee training centers a checklist is kept, and when the amputee has performed a group of activities to the trainer's satisfaction, he is considered trained.

Requirements of the Trainer

It is nearly impossible to create a comprehensive set of requirements for an amputee trainer. It is easier to specify the requirements in terms of complete knowledge of everything in the field of prosthetics related to training. However, in attempting to specify the major factors and areas in which a trainer should be proficient, the following list has been compiled:

1. An ability to establish a good trainer-amputee rapport, to motivate the amputee to want to learn to use the prosthesis and to instill a problem-solving attitude within the amputee.
2. A commonsense approach to training, which considers the amputee's needs and which stresses practical application.
3. Knowledge of factors affecting learning.
4. Familiarity with the anatomy and kinesiology of the upper extremity.
5. Knowledge of the body control motions necessary to operate a prosthesis.
6. Extensive experience in training and realization of amputee problems or, at least, a knowledge of some special techniques employed by amputees of various types for the performance of various activities.
7. A sound liaison with the prosthetist in order to exchange information about the mechanical characteristics of the prosthesis as related to function.
8. A complete knowledge of the functional and mechanical characteristics of prosthetic components.
9. A familiarity with current developments in the field of upper-extremity prosthetics.

AMPUTEE ORIENTATION PRIOR TO CONTROLS TRAINING

General Considerations

The prosthesis will generally be used as an assist to the sound limb to enable the amputee to regain lost function. However, the role of the prosthesis must be evaluated independently for each amputee and for any given activity or task.

For the bilateral amputee, at least one functional prosthesis is essential. The longer stump is usually the dominant side. The maximum functional value of a prosthesis cannot be predicted; there may be much more regain than is anticipated. The prosthesis also has limitations; an amputee must not expect the prosthesis to duplicate the function of lost human members. In contrast to a bilateral amputee, a unilateral amputee does not "need" a prosthesis to achieve basic independence, but will learn to depend on it in varying degrees according to need, incentive, and successes in attempted performance.

Since the amputee will have learned something about prosthetic components and controls in the course of the fitting and fabrication procedure, some repetition may occur. It is important during the controls training phase to avoid establishing or reinforcing unsatisfactory control motions or bad habits.

Wearing a Stump Sock

The use of a stump sock seems to be determined by amputee preference, considering perspiration absorption, warmth, padding and other such factors. Socks of cotton or nylon stockinet are most frequently used; wool is generally utilized where warmth or additional padding is required. If socks are used, several should be kept on hand to facilitate laundering.

Care of the Prosthesis

Socket plastic (especially the interior) should be wiped with soap and water daily or as often as necessary for cleanliness. A damp cloth should be used, rather than immersing the prosthesis in water and risking getting water into mechanical components.

The amputee should never pry or hammer with the socket or terminal device, as shown in Figure XII-1.

The harness should be washed when soiled. The use of synthetic materials and the elimination of leather from harnesses allow repeated washings without greatly shortening the useful life. Two harnesses should be supplied so that one can be worn while the other is being laundered.

Selection of Terminal Device Prehension Force

Factors which influence the initial setting of prehension force (loading) for new amputees include:

a. The amount of resistive force the amputee is able to generate or tolerate in the stump, axilla, or other pressure areas.
b. The actual prehension force requirements for use by the amputee.

In most cases the force should be lower at the beginning of training to build up tolerance with minimum fatigue and discomfort.

For Voluntary-Closing Devices The spring loading against which the amputee must work to close the hook fingers cannot be adjusted. However, it is sufficiently low so that most amputees can regulate the prehension force in accordance with the VC principle.

For Voluntary-Opening Devices The spring-operated Two-Load hook should initially be set on the light load (approximately 3.5 lbs.) and changed to heavy load as needed. The rubber-band-operated hooks should have a minimum of two new bands at the start. For AE prostheses there should be sufficient rubber bands to prevent the hook opening when the forearm is being flexed.

The bands should be increased by the trainer to provide an optimum prehension force considering training requirements and amputee tolerance. A rubber band may be cut with

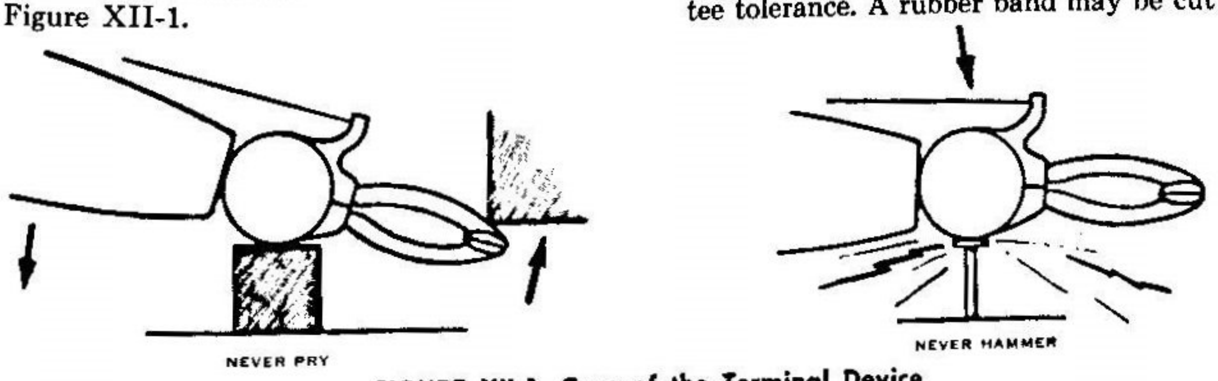


FIGURE XII-1. Care of the Terminal Device

scissors into smaller bands if necessary, to obtain the optimum loading. Actually, number of bands is not a good index of prehension force since the rubbers are not uniform even when new. Also, each model of hook (such as Dorrance 5x, 88x, 7) will have different prehension forces for the same number of bands because of mechanical advantage, neoprene prehension surfaces, and other characteristics.

Eventually the amputee will be able to decide on the hook loading to fit his individual needs. Adults may use from about 3 to 10 or 15 lbs. prehension force in their activities. The rubber bands oxidize after a time and lose their strength; they are also affected by oils, solvents, heat, etc. and should be replaced as needed.

Harness Adjustment

During the training phase, the harness may stretch or take a "set" through use. This may necessitate adjustments at all buckles. The trainer should be aware of the importance of proper adjustments and should make them as necessary, under the guidance of a prosthetist. The trainer should teach the amputee how to adjust the harness so that upon completion of training the amputee can maintain the harness in proper adjustment. Indelible index marks on the harness may aid the amputee in correctly reattaching and adjusting a harness after laundering.

Use of T-Shirt with Harness

It is recommended that the male amputee wear a T-shirt because it tends to keep the harness cleaner by absorbing perspiration, and because the cloth serves as padding under the harness, decreasing local irritation and pressure especially in the axilla area. Some female amputees prefer to wear the harness over the blouse or dress.

Prosthetics Terminology and Components

The trainer should instruct the amputee in the use of correct prosthetics terminology and in the characteristics of existing prosthetic components during the training program. In addition, any information concerning research and new developments in prosthetics should be shared with the amputee.

Visual and Auditory Cues

The amputee must rely on his vision to a great extent in the performance of activities because manual tactile sensation has been destroyed as a result of amputation. Special attention must be given to activities which necessitate operating the terminal device behind the body, under the chin, in a pocket, and other places where the amputee cannot see the terminal device. Certain components, such as elbow units, manual lock wrist units, and voluntary-closing TD's, emit audible sounds (clicks) which are used by the amputee as cues in operating the components. Auditory cues are also important in diagnosing impending breakdowns and malfunctions.

CONTROLS TRAINING

The trainer should be thoroughly familiar with the body control motions and the theory of control systems and harnessing. Table XII-1 lists the body control motions required by each of various harness and control systems to operate the prosthesis. In addition, a thorough knowledge of the functional operating characteristics of all prosthetic components is mandatory. This knowledge should be increased and kept up to date by a study of prosthetic catalogs, since it is beyond the scope of this manual to cover all available prosthetic devices.

Following is a description of specific procedures to be learned by the amputee. Controls training is presented for the unilateral amputee, starting with BE, AE, and S types, and then for the bilateral of each level.

BE Figure 8 Harness with Single Control

Putting on and Removing Prosthesis

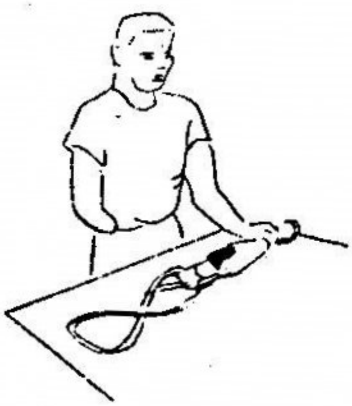
ON: Amputee places the prosthesis on a table, front side up, with the terminal device

TABLE XII-1

BODY CONTROL MOTIONS REQUIRED FOR VARIOUS HARNESS AND CONTROL SYSTEMS TO OPERATE PROSTHESIS

System	Harness	Body Control Motion	Prosthesis Operation
Below-Elbow			
Single Control	Figure 8 or Chest Strap	Arm Flexion	Prehension
	Double Axilla Loop	Scapular Abduction	Prehension
Dual Control (split socket)	Figure 8 or Chest Strap	Arm Flexion	Prehension Forearm Flexion Assist
Above-Elbow			
Dual Control	Figure 8 or Chest Strap	Arm Flexion	Prehension Forearm Flexion
		Arm Extension	Elbow Lock
Triple Control	Chest Strap	Scapular Abduction	Prehension
		Arm Flexion	Forearm Flexion
		Arm Extension	Elbow Lock
Shoulder			
Dual Control	Chest Strap	Scapular Abduction	Prehension Forearm Flexion
		Shoulder Elevation, Extension, Flexion or Manual	Elbow Lock

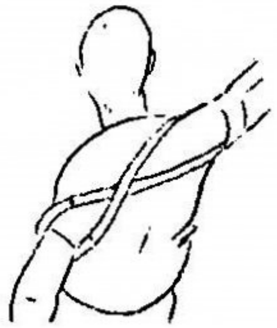
on the side of the sound arm. Amputee checks to make sure that a) the harness is not twisted; b) the distal retainer is correctly inserted into the baseplate; c) the housing cross-



bar is secure in the leather strap; and d) the cable housing is free of kinks.

Amputee grasps the socket with his hand and slips his stump under the Y-strap and into the socket. Amputee raises the stump with prosthesis above his head, allowing the harness to hang. The procedure is much the same as putting on a coat.

Amputee then reaches across his back with his hand, grasps the harness near the cross, and permits the webbing to slide through his



fingers to prevent twisting until the axilla loop is positioned. Amputee inserts his hand into the loop, allowing it to slide down the arm to its position in the axilla. Amputee then shrugs shoulders to settle the harness into place.

NOTE: As an alternate method, the amputee may place the stump in the prosthesis and the sound arm in the axilla loop, working in front of the body, then raise both arms above the head to permit the axilla loop to slide down the arm while the cross of the

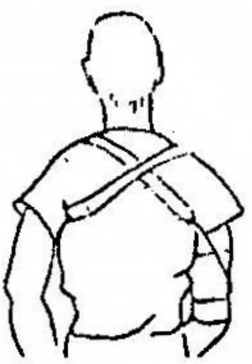


Figure 8 slides down behind the head. This method is similar to putting on a pullover sweater.

OFF: Amputee raises both arms above the head, grasps the socket and withdraws the stump while pulling off the socket, and removes the axilla loop. Care is taken not to allow the harness to become tangled, which would make it harder to put on next time.

Forearm Control

This requires no special training, since the residual forearm flexion or rotation is employed to produce the same motion of the prosthesis. However, in the VSBE (Split Socket) Prosthesis, stump motion is transmitted through a step-up hinge to the forearm shell. Since the stump moves at a different rate and is in a different position than the forearm shell, some practice is needed for forearm control. However, this control is usually acquired by the amputee after a few practice flexions.

Terminal Device Operation

The basic control motion is flexion of the arm (humerus) wearing the prosthesis. The shoulder on the BE side should not flex more than necessary to produce a normal, comfortable "reaching-out" motion. The shoulder on the opposite side does not flex, but resists the force transmitted through the harness and acts as a stabilization area. This control motion produces opening in a voluntary-opening device and closing in a voluntary-closing device. A method for teaching the control motion follows:

Direct the amputee to flex the forearm to 90 degrees with arm (humerus) vertical and to observe the slack in the control cable. (A voluntary-closing device should be in the open position.)

Stabilize the amputation-side shoulder with one hand and grasp the prosthesis at about midforearm with the other. Move the forearm forward until tension develops in the control cable. Call attention to the feel of the harness as tension increases, and to the resistance necessary by the opposite shoulder.

Continue to move the forearm until the terminal device operates.

Have the amputee repeat the control motion until control of the terminal device is mastered at various positions such as mouth, perineum, etc.

Wrist Unit Operation

Adjustment of the unilateral amputee's wrist unit is accomplished by the sound hand. For manual friction types, the terminal device is rotated in the unit to the desired position. The manual lock types are operated by the sound hand.

Interchange of Terminal Devices

The amputee should be able to change TD's without having to remove the prosthesis from the stump. The manual lock type wrist unit facilitates the operation. A hook-to-cable adapter is necessary when the interchange is between hand and hook.

VSBE Figure 8 With Dual Control

Putting On and Removing Prosthesis

The procedure is exactly the same as the BE Figure 8 with single control.

Forearm Control

Since the step-up hinge is used on the VSBE prosthesis, motion of the stump is amplified to the forearm shell. However, when a dual control assist is added, the stump flexion force imparted to the forearm shell is aided by arm (humeral) flexion acting through the control system on the lever loop. Elbow stabilization is achieved by voluntary fixation of the stump in any selected position. For the VSBE prosthesis with a stump-actuated locking hinge, control of the forearm is the same as that of the AE prosthesis with dual control.

Terminal Device Operation

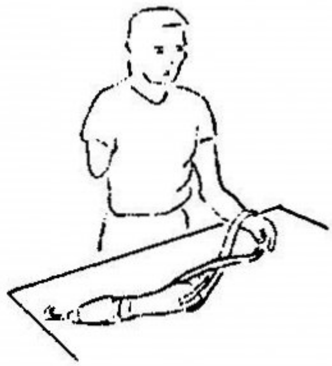
To open or close the terminal device, the stump must stabilize the forearm shell against the flexion force on the lever loop so that arm (humeral) flexion produces force which is transmitted to the terminal device. The method is the same as given for the BE Figure 8 with single control.

AE Figure 8 With Dual Control

Putting On and Removing Prosthesis

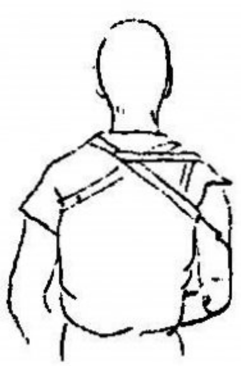
If the AE stump is long enough, the prosthesis may be put on in the same manner as for the BE. If the stump is short, the following method may be used:

ON: Amputee places prosthesis on a table, front side up, and makes certain the harness is straight, the retainers are correctly inserted in the baseplates, and the housing is free of kinks.



Amputee inserts sound arm into the axilla loop, raises the arm and slides the loop into position, allowing the prosthesis to hang in the back with the harness straight. By leaning to the amputation side, the prosthesis is

moved into position so the sound hand can reach across the front, grasp it and hold it so the stump can be inserted. Amputee shrugs shoulders to settle the harness into place.



OFF: The reverse procedure is used to remove the prosthesis.

Forearm Control

When the elbow mechanism is unlocked, the basic arm (humeral) flexion control motion produces flexion of the forearm section. The shoulder on the AE side should not flex more than necessary to produce a normal, comfortable reaching-out motion. The opposite shoulder does not flex, but resists the force transmitted through the harness and acts as a stabilization area. A method for teaching the forearm control follows:

Manually unlock the elbow. Stabilize the shoulder on the AE side with one hand, and grasp the prosthetic forearm with the other.

Flex the forearm to about 90 degrees and call attention to the slack in the cable caused by that motion.

Move the forearm section forward to produce arm (humeral) flexion, and indicate that this motion takes up the cable slack.

Ask the amputee to hold the forearm in that position. As soon as the load has been assumed, release the forearm and instruct the amputee to bring the stump slowly back to its starting position, which allows the forearm to return to its extended position.

Now ask the amputee to bring the stump forward and accomplish the same result. CAUTION: Place, or have the amputee place, one hand in a guarding position near the amputee's face to prevent the terminal device from hitting the face if a stronger than necessary arm flexion motion is made.

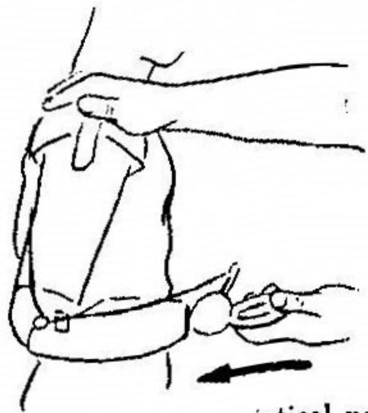
Repeat the forearm flexion operation until speed of movement and flexion angle are controlled.

Elbow Lock Control

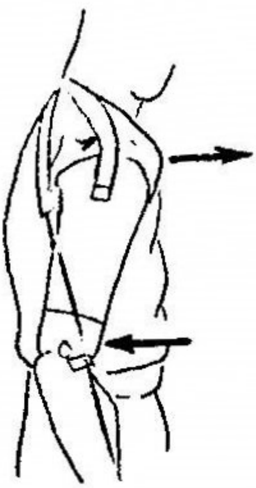
The principle of operation for this control is to increase the distance between the harness attachment point (on the deltopectoral line) and the elbow unit. The basic control motion has been considered to be arm (humeral) extension. (Since stump extension causes prosthetic forearm extension, obviously stump extension alone could not be used to lock the elbow while maintaining forearm flexion). Actually, a combination motion composed of arm extension, arm elevation (abduction), shoulder flexion (scapular abduction) and shoulder depression, is needed to refine and reduce the control motion. A method for teaching elbow lock control follows:

Manually unlock the elbow unit. Stabilize the shoulder on the AE side with one hand and grasp the terminal device with the other.

Have the amputee relax. With the forearm at 90 degrees, slowly push the prosthesis back, producing arm extension, until an audible click is heard and the unit locks. Hold the amputation-side shoulder steady during this operation.

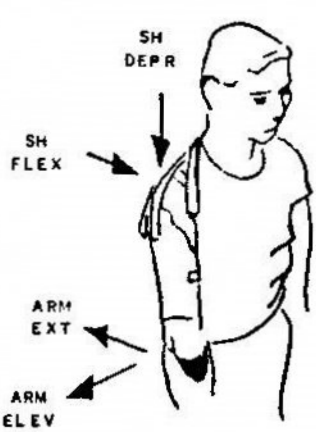


Return the arm to the vertical position to remove tension from the elbow lock cable, permitting the alternator to index for the unlocking phase. A faint click can be heard when the unit indexes.



Push the prosthesis back until a click is heard and the elbow unit unlocks.

Repeat the procedure and then ask the amputee to duplicate it with stump motion, while the forearm is in the fully extended position, making no attempt to control forearm flexion.



As soon as the elbow lock can be operated in that manner, instruct the amputee to flex the shoulder (bring the point of the shoulder forward) as the arm stump extends. The addition of shoulder flexion should decrease the angle of arm extension required to operate the elbow lock.

When the amputee has mastered this combination motion, add shoulder depression (pushing the stump further down into the socket). The combination of shoulder flexion and depression tends to reduce still further the amount of arm extension required.

Until this point, there has been no attempt to control the forearm. Now proceed to combine forearm flexion and elbow lock operation. Unlock the elbow and have the amputee flex the arm to produce about 90 degrees of forearm flexion, and use the combination motion to lock the elbow.

If the forearm falls, the stump has been moved to the rear or extended in such a way as to take tension off the forearm flexion control cable. This may be compensated for by adding arm elevation (raising the stump out from the side) to the combination motion so as to keep tension on the cable and maintain a constant angle of forearm flexion while the elbow is being locked.

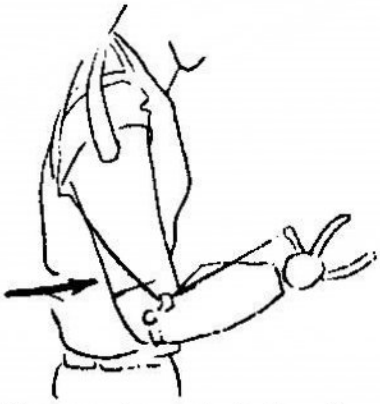
Have the amputee reverse the procedure and unlock the elbow, allowing the forearm to return smoothly to the starting position.

Repeat the procedure, guiding the amputee's stump and shoulder by hand if necessary to insure the proper control motion, until the forearm can be smoothly and efficiently locked and unlocked in any position of flexion.

Terminal Device Control

When the elbow unit is locked, further stump flexion increases tension in the dual control cable until the terminal device operates. However, much of the stump flexion is used up in flexing the forearm fully, so that less cable excursion is available to operate the TD in full flexion. A method for teaching the control follows:

Direct the amputee to unlock the elbow, flex the forearm to 90 degrees, lock the elbow, and flex the arm (bring the stump forward) in the same manner as for flexing the forearm, while resisting the tug on the harness with the opposite shoulder. The terminal device will operate.



Have the amputee unlock the elbow and repeat the procedure for various positions of forearm flexion.

When the amputee has mastered the basic terminal device control, provide verbal cues for complete operations in space, such as opening and closing the terminal device near the mouth, perineum, at the side, in front at shoulder level, etc.

Arm Rotation Control

In addition to the residual arm flexion, extension, and elevation, the AE amputee usually retains a fair amount of arm rotation. This residual rotation is used to provide control of the prosthesis in medial and lateral rotation. With the Standard and Short AE, rotation is limited but can be supplemented by manual control of the turntable on the elbow unit. The Elbow Disarticulation amputee has excellent control of this motion. This rotation of the forearm about the arm axis allows the terminal device to be operated closer to the centerline of the body. To obtain arm rotation, the amputee places the forearm at 90°, then applies force to the distal portion of forearm to produce medial or lateral rotation, as desired.

Wrist Unit Operation

The wrist unit is operated by the sound hand. Operation depends on the type of unit, which may be manual friction or manual lock.

Shoulder Prosthesis With Chest Strap

Putting On and Removing Prosthesis

ON: Amputee makes certain the retainers are straight in the baseplates and the cable housing has no kinks. Amputee places the prosthesis on the shoulder stump, then reaches behind, grasps the chest strap, straightens it and fastens it in front. If there is an additional

axilla loop, care must be taken not to catch it under the chest strap. The sound arm may be inserted into the loop before fastening the chest strap, or the loop may be put on afterward like a coat sleeve.

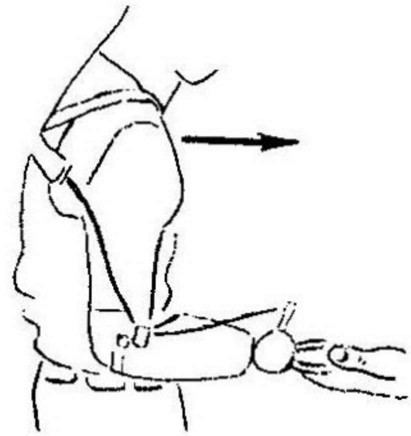
OFF: The reverse procedure is used to remove the prosthesis.

Forearm Control

For the basic shoulder harness with dual control, the body control motion for forearm flexion is scapular abduction (shoulder flexion) on the amputation side. When the harness is modified by addition of an axilla loop on the opposite side, the control motion becomes biscapular abduction (bilateral shoulder flexion). A method for teaching forearm control for either system follows:

Manually unlock the elbow. Grasp the terminal device and flex the forearm to about 90 degrees, calling attention to the cable slack produced.

Direct the amputee to flex the shoulder (bring the shoulder forward) to take up the cable slack. As soon as the load has been assumed, release the terminal device and instruct the amputee to return the shoulder to the starting position, to cause a lowering of the forearm to the extended position.

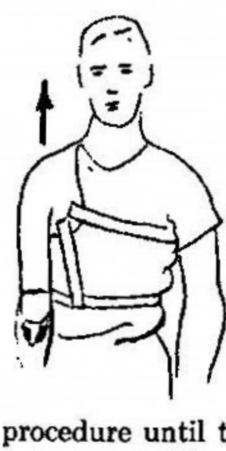


Now ask the amputee to flex the shoulder to accomplish forearm flexion. Repeat the procedure until speed of movement and flexion angle are controlled.

Elbow Lock Control

The basic shoulder harness employs shoulder elevation to control the elbow lock. However, other controls, such as opposite shoulder flexion, shoulder extension, or manual, may be encountered. The fundamental principle of operation is the same for all: to increase the distance between the harness attachment point and the elbow unit. A method for teaching elevation control of elbow lock follows:

Manually unlock the elbow unit. Have the amputee elevate the shoulder (raise the shoulder) until the lock operates, then relax to allow the mechanism to alternate.



Repeat the procedure until the unit can be locked and unlocked smoothly.

Proceed to combine forearm flexion with elbow lock operation. Unlock the elbow and have the amputee flex the shoulder to produce about 90 degrees of forearm flexion; maintain the forearm in that position and elevate the shoulder to lock the elbow.

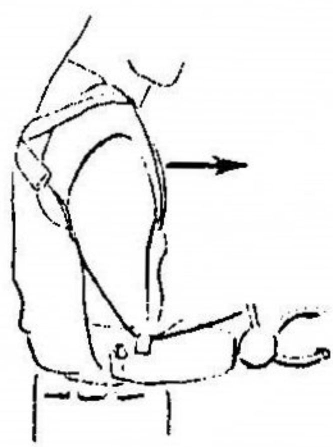
Have the amputee reverse the procedure and unlock the elbow, controlling the forearm in its return smoothly to the starting position.

Repeat the procedure until the forearm can be smoothly and efficiently locked and unlocked in any position of flexion.

Terminal Device Operation

When the elbow unit is locked, further shoulder flexion increases tension in the dual control cable until the terminal device operates. However, much of the shoulder flexion is used up in flexing the forearm, so that very little is available to operate the TD in full flexion. A method for teaching the control follows:

Direct the amputee to unlock the elbow, flex the forearm to 90 degrees, lock the elbow and then flex the shoulder in the same way as to produce forearm flexion. The terminal device will operate.



Have the amputee unlock the elbow and repeat the procedure for various angles of forearm flexion until the operation is accomplished smoothly and efficiently.

Arm Rotation Control

The shoulder amputee retains no arm function. Arm rotation is obtained by manual control of the turntable on the elbow unit to allow the terminal device to be operated closer to the centerline of the body. With the forearm at 90°, the amputee grasps the distal portion of the forearm and applies force to produce medial or lateral rotation, as desired.

CONTROLS TRAINING FOR THE BILATERAL AMPUTEE

For the bilateral amputee fitted with two prostheses, controls training may be considered as essentially the combination of two unilateral amputees, with some of the following special considerations.

Cross-Controlling

Since the control systems of both prostheses usually attach to the same harness, the force produced by the control motion to operate a prosthesis on one side may be transmitted through the harness, tending to cause a partial operation of the other prosthesis.

The position of the forearms of bilateral AE dual control prostheses changes the effective cable excursion. That is, if the forearm on one side is locked in full flexion (with the arm section hanging vertically), slack is produced in the cable and harness; consequently, more control motion is needed to obtain full forearm flexion or hook opening on the other side.

Conversely, if the forearm on one side is locked in full extension, the opposite side requires a minimum control motion.

The principle is important in activities, such as eating, which require maximum flexibility on one side without producing forces in the cable to cause loss of prehension and the dropping of objects. Setting the TD prehension force higher on one side may help to minimize the effects of cross-controlling.

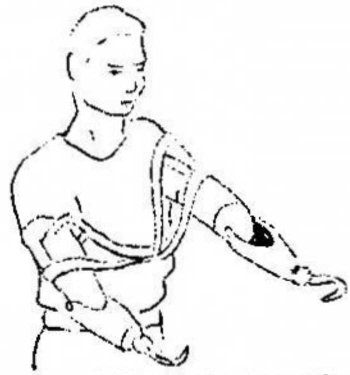
In general, the bilateral amputee will refine and revise the basic body control motions to suit the particular situation. Shifting the harness or letting the control attachment strap slide up over the deltoid are examples of the type of refinement a bilateral may use to obtain optimum control.

Putting On and Removing Prostheses

There are two major methods for putting on bilateral prostheses.

OVER THE HEAD: The prostheses are prepositioned front side up on a table with the harness straight and the cable housing free of kinks.

The shorter stump is inserted under the harness and into its prosthesis first, while the



longer stump stabilizes the prosthesis. After the longer stump is inserted, the prostheses are raised so that the harness may be flipped over the head and shrugged into place.

LIKE A COAT: In this method, the longer stump goes into its prosthesis first. The stump is then elevated, allowing the other prosthesis

to hang diagonally across the back. By leaning to one side, the short stump can be inserted into the prosthesis and the harness shrugged into place.

Wrist Unit Operation

This operation is much more difficult than for the unilateral. However, rotation of the terminal device in the manual friction wrist unit can be accomplished by any of these methods:

1. Pulling on the thumb of one hook with the other to cause pronation.
2. Holding the hook between the knees and abducting to produce supination or adducting to produce pronation.
3. Tapping the hook thumb or fingers on the knee or other surface to produce either pronation or supination.

Wrist Flexion Unit Operation

The operating characteristics of the wrist flexion units currently available are described in Chapter IV. The general procedure for operation by the bilateral amputee is as follows:

Model A

Amputee depresses the control button with the tips of pronated hook fingers, the edge of a table, the knee, etc. If the line of pull of the cable passes medial to the flexion axis of the unit, amputee applies tension to control cable of prosthesis to flex the TD into the desired position, and releases the button to lock the unit.

If the cable passes laterally, it may be necessary (depending on the level of amputation) to pull the unit into correct position with the other hook, or to push it into place with the knee, or make use of gravity to accomplish this difficult operation.

To extend the TD, the button is depressed and slack provided in the cable to allow the spring in the unit to pull it into extension.

Model B

Amputee pushes switch lever forward to disengage the unit, and flexes the unit in the same manner as the Model A.

To extend the TD, the movable hook finger of the opposite TD is used to push the lever. Then, while relaxing cable tension on the wrist flexion unit side, the unit may be extended by opening the hook of the other side. Thus, the fixed hook finger pushes the TD into the extended position, while the movable finger continues to press on the lever.

NOTE: The wrist flexion unit is usually prescribed for the "assist prosthesis," which is generally on the shorter stump. Therefore, for the bilateral with one BE prosthesis, the BE side will usually operate the flexion unit. The methods described above are difficult for bilateral AE's to accomplish. Bilateral Short AE's may find the Model B nearly impossible to operate unless modified. It is recommended that in these severe cases, extensions be added to the operating lever or buttons to enable the amputee to operate the unit.

CRITERIA FOR COMPLETION OF CONTROLS TRAINING

Controls training may be considered complete when the amputee has maximum control of the terminal device in space. He should be able to operate all components reliably with minimum error, effort, and body contortion or "body English." He should understand the purpose of each component and the function it is intended to replace.

It is difficult to use training time as a criterion since some amputees complete controls training in a few minutes, while others may require a much longer training period, because of differences in body configuration, harness design, neuromuscular coordination, and other factors.

Attempts have been made to define completion of controls training by the use of tests. At present, however, relying on the trainer's judgment seems to be most practicable.

USE TRAINING

Basic Concepts

Prepositioning: Before attempting an activity, the terminal device should be in the best position to accomplish the activity. Thus, prepositioning may involve the rotation of the TD, flexion of the forearm, locking the elbow unit, turntable rotation, etc., to properly position the TD prior to attempting a task. In its broadest meaning it may even include the proper locating of tools or utensils to be used in the activity. Figure XII-2 defines the TD prepositioning terminology.

In general, the prepositioning of the components of a prosthesis should result in an orientation of the prosthesis in space which resembles that of a normal limb engaged in the same task. *As a rule, most difficulties arise because of improper prepositioning.* The trainer may find an amputee attempting to perform some task requiring use of the hook, with the hook in the wrong position in rotation and with the amputee engaging in awkward body contortions to no avail. The importance of prepositioning cannot be overemphasized; it is the key to the successful completion of most activities.

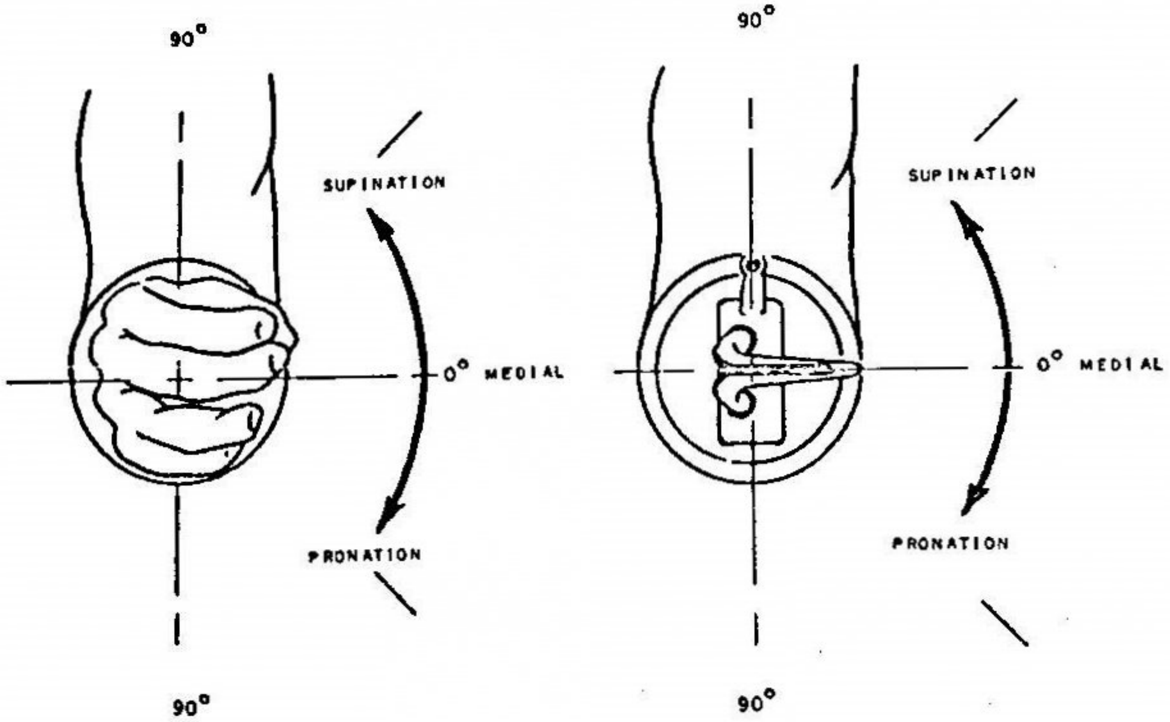


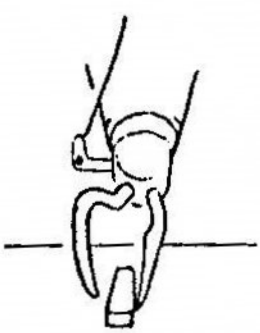
FIGURE XII-2. Terminal Device Prepositioning Terminology

Stability of Objects in the Terminal Device: For any given object such as a knife, fork, cup, etc., there is an optimum position in the grasp of a terminal device to provide the greatest stability for the activity in which it will be used. The best position will vary with each type of TD and can easily be determined by trial.

Drills in Approach, Grasp, and Release

Only one finger moves during the operation of most terminal devices. It is important to approach an object to be grasped so that the stationary finger is close to the object. The movable finger can then close upon the object without moving the object.

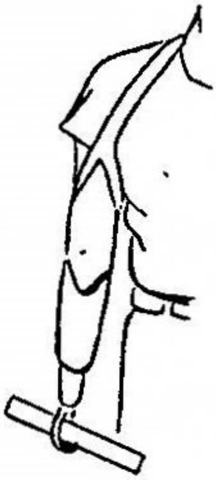
This can be demonstrated by having the amputee practice approach, grasp, and release drills (AGR) on a small wood block.



In grasping simple objects, the TD should be prepositioned (rotated) *until the prehension plane of the TD corresponds to the most stable grasp plane of the object.* As the terminal device is moved about in space, the TD prehension plane assumes various angles. It is important for the amputee to be able to predict the position of the TD so that it may be properly prepositioned, preventing undue body contortion.

A drill to point out the value of proper prepositioning consists of holding a ruler at various angles in space while the amputee prepositions the TD in rotation, approaches, grasps and releases the ruler.

The prehension force of VO devices may to some extent be regulated or selected. To accomplish this the amputee must maintain some tension on the control cable; this results in less force at the TD fingers. Thus, a fragile item such as an ice cream cone or an egg can be grasped without breaking it. Drills in this activity using a wad of paper, a paper cup, or other crushable objects will enable the amputee to perfect this technique.



The prehension force of VC devices is regulated by the amount of force applied to the operating lever; release of this force causes the TD to lock. However, unlocking requires the application of a slightly larger force Because of this principle, the amputee should use no more force than necessary to grasp securely. If excessive force is used, releasing sometimes becomes difficult.

Crushable or deformable objects may be safely grasped by the VC devices, since the proper prehension force can be selected.

Drills to develop facility in this operation consist of having the amputee practice AGR on various shapes of wood and rubber and on fragile items such as ice cream cones and paper cups.

TECHNIQUES FOR THE UNILATERAL AMPUTEE

Dressing Activities

Trousers (Hook or Hand)

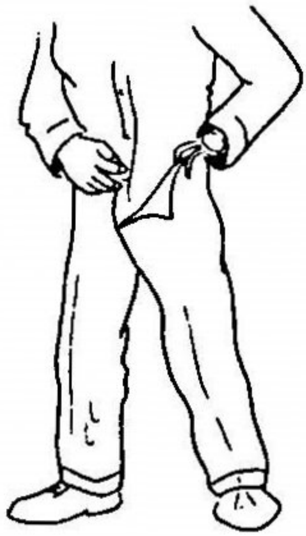
BE Procedure: Sound hand prepositions the TD (terminal device) in about 45° pronation.

TD grasps the waistband or belt loop and helps to pull the trousers up.

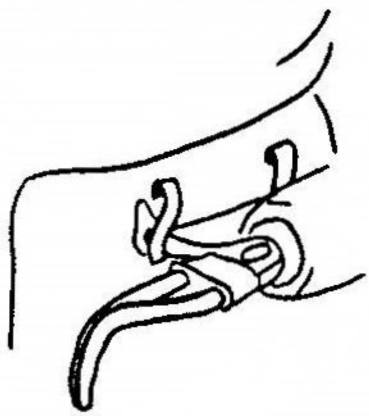
TD holds the trousers up while the sound hand tucks in the shirt and fastens the waist hook, snap, or button.

TD stabilizes the fabric at the bottom of zipper to facilitate zipping with the sound hand.

AE or S Procedure: The forearm is flexed and locked at about 90 degrees and the turntable internally rotated, as necessary. The TD



holds trousers up while the sound hand tucks in the shirt and fastens the trousers, belt, etc. The working area is generally restricted to the front of the body.



Shirt (Hook)

BE Procedure: The hook is prepositioned in the medial (0°) position.

To *unbutton* the cuff, the edge of the cuff near the button is grasped between the tips of the third and fourth fingers and the bulge below the thumb (the thenar eminence). Holding or rubbing the shirt against the body may facilitate this operation.

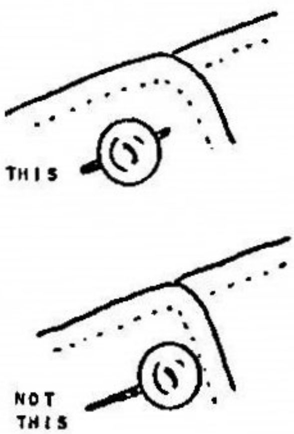
The hook finger tips grasp the overlap of the cuff near the button, opposite the long axis of the buttonhole.

Combined motions of pulling the hook toward the body and rotating and extending the sound forearm produce a "peeling" of the buttonhole over the button.

All tension must be removed from the cable to assure maximum prehension for the VO hook.

Shirt sleeves should be long enough to permit sound fingers to position cuff easily.

Cuff circumference should be great enough to encircle the carpus with enough freedom to allow unbuttoning. (A button locked in the end of a buttonhole is very difficult to unbutton).



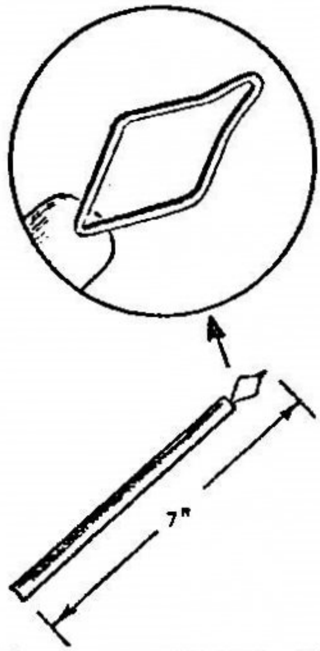
To *button* the cuff, the hook finger tips grasp the cuff near the buttonhole, opposite its long axis.

Combined motions of the sound wrist (especially dorsiflexion) and the hook, guide the button into the hole. The proximal edge of the button should enter the hole first.

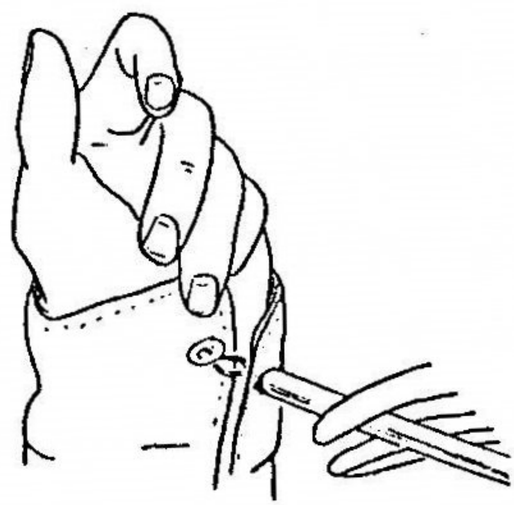
When the button is about halfway through the buttonhole, the sound-side fingers can stabilize the cuff while the hook releases.

The button is then grasped or pushed into final position by the hook tips.

NOTE: A device to assist in the buttoning operation may be used for speed. This is a variation of the buttonhook which can be made from a paper clip and dowel. With the proper prepositioning, the cuff can be buttoned rapidly and reliably. However, the buttonhook is not necessary for the unilateral BE. This amputee type should learn both techniques and be as independent of devices as possible.



AE or S Procedure: The BE method may be used successfully by Elbow Disarticulation amputees and some Standard AE's if there is sufficient stability of the prosthesis in arm rotation and flexion. Forearm is flexed 90 degrees and locked. This activity is simplified for the AE by using a buttonhook. For the Shoulder amputee, a buttonhook is highly recommended.



Necktie (Hook or Hand)

BE Procedure: Sound hand prepositions TD in rotation to achieve a comfortable and practical holding position high on the chest.

The tie is placed around the neck, under the collar, with the small end of the tie on the amputation side of the body.

The small end is grasped with the TD and all cable tension is released.

During the conventional tying operation the prosthesis extremity usually tends to drop gradually, thus making the small end too long in the final knot. Therefore, the amputee should start with an extra-short small end.

AE Procedure: The forearm is flexed fully and the elbow locked. In order to operate the TD near the body's midline, arm abduction is used. If necessary, the turntable is internally rotated to augment arm rotation.

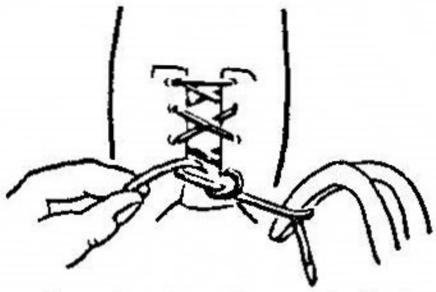
S Procedure: A wrist flexion unit is of decided advantage in operating next to the body in this midline position. The forearm should be flexed accordingly, and internally rotated.

Shoelaces (Hook or Hand)

BE Procedure: The foot is raised near the arm to reduce the undesired tension on the cable which develops from reaching toward the floor. A stool, chair, step or a semi-kneeling position may be used.

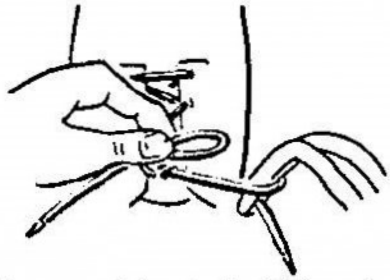
The TD is prepositioned in rotation so the hook fingers are pointing toward the knot. They should be angled medially to achieve a maximum visibility of the TD tips.

For the first knot, the sound hand crosses the lace from its side into the grasp of the TD. The TD holds the lace tightly while the sound

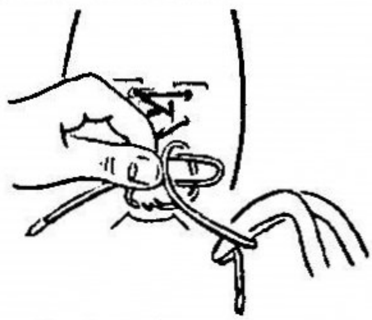


hand makes the first knot. Both laces are pulled to tighten the knot.

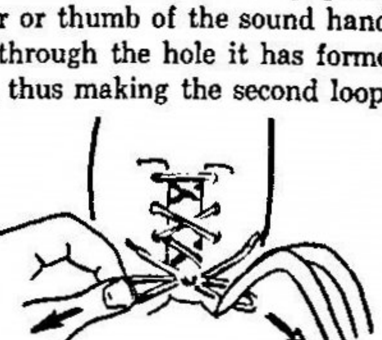
NOTE: The lace is likely to pull out of the grasp of the TD. Taking a hitch around the hook fingers after the initial grasp should prevent this.



For the second knot, the TD maintains its hold on the lace (following first knot) while the sound hand makes a loop. The loop should be small (about 1½ inches), and is pinched in place next to the first knot.



The prosthesis guides its lace around the loop (over from front to back or under from back to front) and releases its grip as the index finger or thumb of the sound hand forces the lace through the hole it has formed with the loop, thus making the second loop.



The TD grasps the first loop and the sound hand takes the new loop. Both loops are drawn firmly to form the bow.

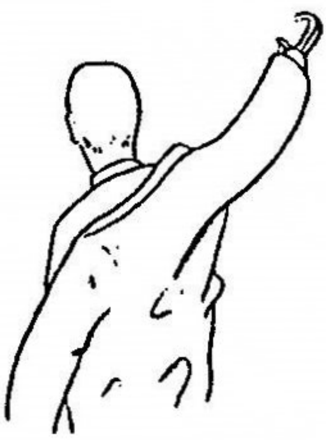
AE Procedure: The forearm is flexed to a comfortable working position and the elbow locked; turntable is positioned accordingly. The procedure is essentially the same as for the BE.

S Procedure: Because of limitations of motion and function, it is usually recommended that the sound hand tie shoelaces.

If the amputee cannot do this, then a special lacing method may be used, or loafer type shoes may be worn.

Coat, Sweater, Shirt (Hook or Hand)

BE Procedure: In order to help protect the sleeve of the garment, the center of a handkerchief may be grasped and allowed to drape over the hook before starting into the sleeve. This procedure will also facilitate the sliding of a hand with plastic glove into a sleeve by decreasing friction.



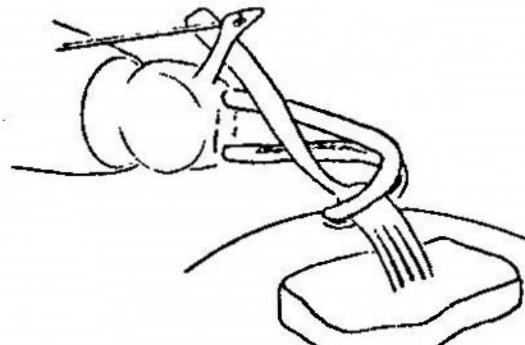
When putting on clothing, the prosthesis is inserted into the sleeve until the TD is exposed. Then the sound extremity may manipulate its way into the other sleeve, and the garment may be shrugged into place.

AE or S Procedure: Note BE instructions. The coat sleeve is drawn over the prosthesis with the forearm extended. When the TD protrudes from the sleeve, the forearm should be flexed to slightly more than 90 degrees and locked. This prevents the sleeve from slipping off while it is being raised over the shoulder. The AE amputee may be able to use upper-arm flexion to advantage.

Eating Activities

Cutting Food (Hook or Hand)

BE Procedure: Hook fingers grasp flat surface of fork handle. Tines point away from thumb of hook.



Fork handle rests on dorsal surface of thumb of hook.

Wrist unit is rotated until fork tips rest easily and evenly on plate surface (hook fingers approximately horizontal with tips pointing toward the body.)

Knife is held by sound hand.

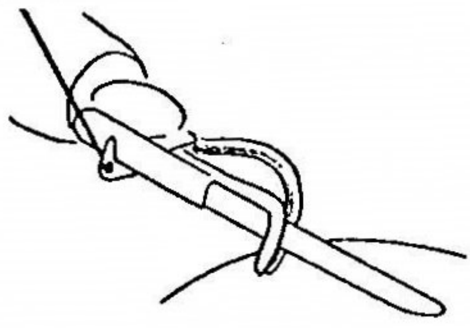
Forces on the fork to stabilize food are exerted downward and backward (i.e., dragging back motion).

Knife motion is sawing, rather than extreme pressure downward or tearing of food.

Plasticine clay may be used to simulate food during training, but real food is preferable. Plasticine adheres to the plate, causing it to slip on the table surface, whereas most food will slip on the plate.

Easily cut food, such as a baked potato, should be attempted initially.

As an alternate method, the knife blade may be held in the hook with the handle resting against the dorsal area of the hook thumb. Pointing the hook fingers downward (90-degree pronation) results in the proper angle of the knife blade.

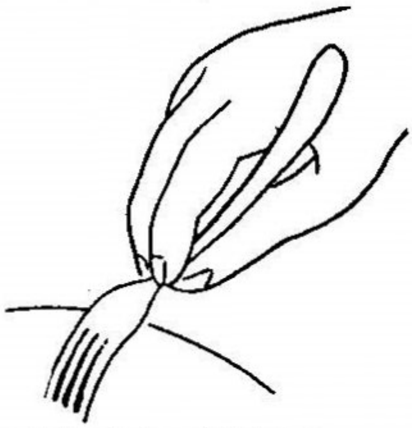


The fork is held in the sound hand, making transfer of cutlery for transporting of food to the mouth unnecessary.

Unless the hook prehension force is high, the knife tends to slide in the hook grasp.

If a *hand* is used instead of a hook, the prepositioning is as follows:

The base of the fork handle is rested on the radial border of the tip of the middle finger.



Tines of the fork point down.

Handle of the fork rests flat on the hand between the thumb and index finger.

Hand is closed, thus grasping the base of the fork handle in 3-jaw-chuck prehension.

Knife is held by the sound hand.

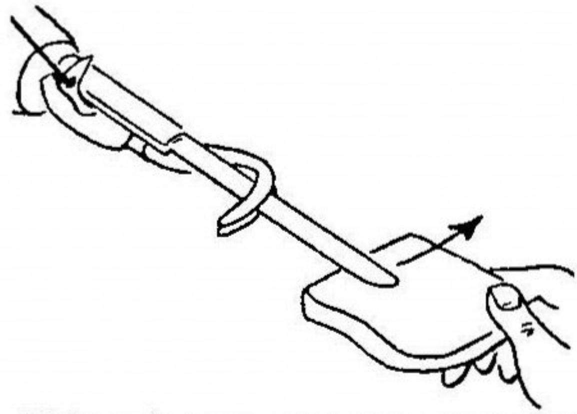
AE Procedure: Note BE instructions for prepositioning of TD and utensils. Arm abduction is to be stressed. Turntable may be used if internal rotation is necessary. Forearm is locked in the angle of forearm flexion which appears most natural and produces the best performance.

S Procedure: Note BE instructions for prepositioning TD and fork. If possible, the table should be slightly lower than the elbow level. The position of the turntable, the angle of forearm flexion, and the position of the fork in the TD should be altered until the performance is deemed as effective and natural as possible. It is unlikely that the knife will be held in the TD by this type of amputee.

Buttering Bread (Hook or Hand)

BE Procedure: Knife blade is placed in the hook fingers with blade edge pointing toward hook finger tips.

Handle of knife rests against dorsal surface of hook thumb.



Wrist unit is pronated approximately 45 degrees.

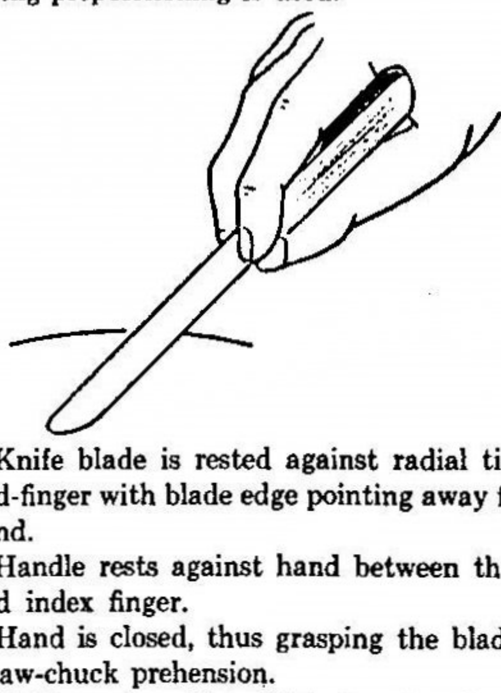
Bread is held by sound hand.

Butter is cut and placed on the bread. It is spread by a motion away from the body by the lower surface of the blade.

Great assistance in spreading comes from motion of the bread by the sound hand.

Direction of loads on the knife is critical, as the knife may tend to dislodge.

If *hand* is used instead of a hook, the following prepositioning is used:



Knife blade is rested against radial tip of mid-finger with blade edge pointing away from hand.

Handle rests against hand between thumb and index finger.

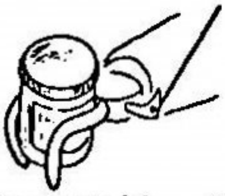
Hand is closed, thus grasping the blade in 3-jaw-chuck prehension.

AE Procedure: Note BE instructions for prepositioning TD and knife. The forearm is locked in a degree of flexion which imitates the "normal" for cutting and spreading. The spreading motion is a combination of arm abduction by the prosthesis and moving the bread against the knife.

S Procedure: The effectiveness of the prosthesis for this activity is questionable. It is probably most efficient for the sound hand to position the bread on the plate and apply the butter while the TD stabilizes the bread, if possible.

Opening Jar or Bottle (Hook or Hand)

BE Procedure: The middle of the bottle is grasped in the TD. The wrist unit is rotated until a convenient angle is achieved.



All tension is removed from the cable to assure maximum grasp, and the lid is unscrewed.

AE or S Procedure: Note BE procedure. The forearm is flexed to about 90 degrees and locked and the turntable internally rotated as necessary to obtain a practical and comfortable position.

Carrying Tray (Hook or Hand)

BE Procedure: The hook fingers are prepositioned so they are in line with the tray at waist or other preferred carrying level, approximately in the medial position.

The TD and the sound hand grasp the lateral edges of the tray.

Security is gained by allowing the tray edge to insert as far as possible into the TD opening.

Tray balance should be stressed. Balance may be improved by placing the TD farther away from the body than the sound hand.

AE or S Procedure: Note BE instructions. The forearm is flexed to about 90 degrees and locked to conform to the pattern set by the sound extremity; the turntable is internally rotated if necessary.

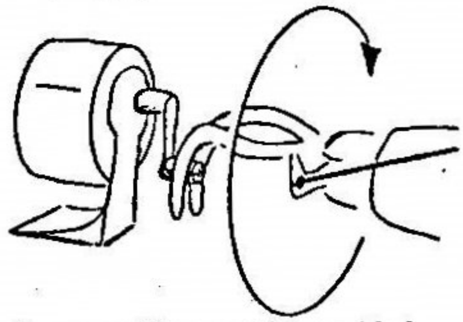
If grasping the tray in the TD does not provide enough stability, the tray may be rested on the forearm section, with grasp and balancing action performed by the sound hand.

Clerical Activities

Sharpening Pencil (Hook or Hand)

BE Procedure: For a *right amputee* the handle of the sharpener is grasped with hook or hand, preferably with arm abducted and flexed and forearm flexed. Pencil is held by sound hand.

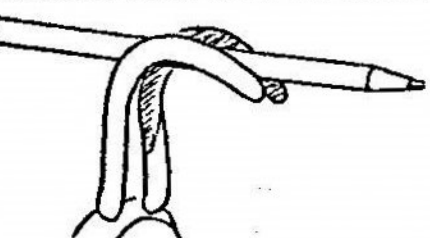
Forearm performs the circular motion to turn the handle.



Tension on cable must be avoided.

Difficulty is encountered if the pencil is forced too hard into the sharpener.

If TD grip is inadequate, the arms may be crossed. The pencil may be held by the hook while the sound hand turns the handle.

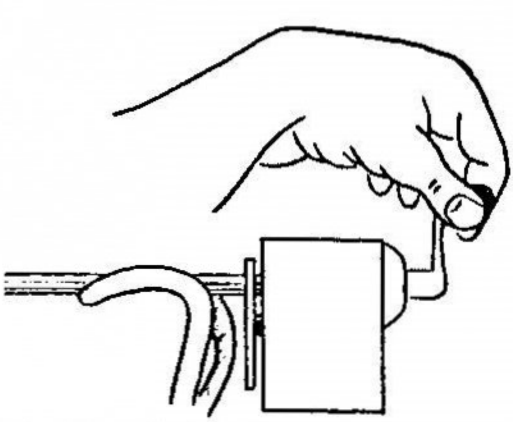


For a *left amputee*, the pencil is grasped with TD. Two-point contact of hook fingers or 3-jaw-chuck hand prehension furnishes greater stability.

Tension on cable should be avoided.

Pencil should be held in line with the hole to avoid jamming, breaking and uneven sharpening. Sound hand turns the handle.

AE Procedure: For a *right AE*, the TD may either turn the handle or cross over to hold the pencil. The forearm is flexed and locked and the turntable adjusted in the most comfortable and practical angle, according to the position of the sharpener. To turn the handle, a



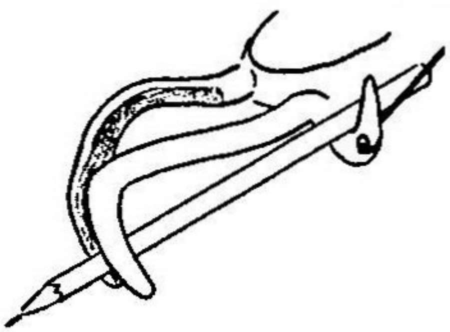
combination of shoulder and stump motion may be used effectively to produce a circumduction of the forearm section. Arm abduction may be almost 90 degrees.

If the cross-over technique is chosen, the amputee should position the body so that TD can hold the pencil in the proper alignment in the sharpener. The *left amputee* should hold the pencil in the TD and turn the handle with the sound hand.

S Procedure: The TD will hold the pencil in the sharpener if possible. Since there is very little motion of the arm section, success in this activity will depend a great deal on the height of the sharpener.

Writing (Hook)

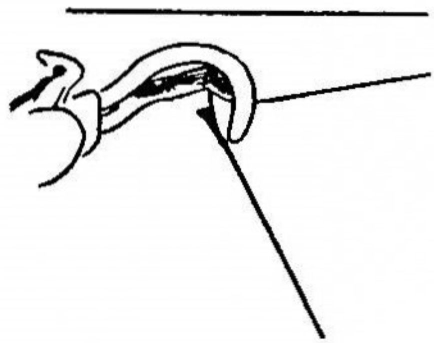
BE Procedure: The pencil is grasped by the hook fingers, with the proximal portion resting on the thumb. The hook is rotated to the medial (0 degrees) position. If prehension



force is high enough, the pencil may be held by the hook fingers in a semi-vertical position.

To hold the paper while the sound hand writes, the TD is pronated about 45 degrees or to a comfortable holding position.

A corner of the paper is pinched in the hook, or stabilized by resting the tip of the hook and/or forearm socket on the paper.



NOTE: Slickness of the bare socket and hook limits the degree of stability. A rubber "secretary's thumb" may be pinched by the hook and its friction quality used as a holding assist; or rubber surgical tubing may be slipped onto the stationary hook finger.

AE or S Procedure: Writing will usually be done by the sound hand. The prosthesis may assist by stabilizing the paper.

Telephone (Hook or Hand)

BE Procedure: For the desk phone, positioning of the TD will vary with different receiver models; the prepositioning should be left until later in the activity.

The receiver is grasped with the sound hand.

If writing is to be performed with the sound hand, the receiver is transferred to the prosthesis.

The mouthpiece is grasped to aid in balancing the receiver and in reaching the ear level.

If this is not practical, the handle next to the mouthpiece is grasped.

After the receiver has been lifted to the head, the rotation unit may then be used to position the receiver to the ear.

If lifting the receiver is difficult because of weight, it may be transferred to the TD after the forearm is flexed.

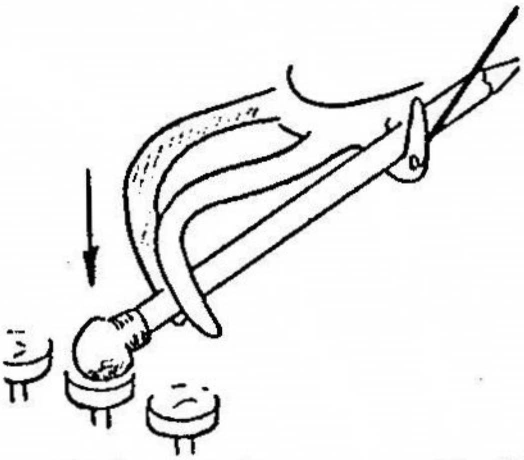
The pay phone activity is basically the same as the desk phone. The terminal device holds the receiver while the sound hand inserts coins, dials, writes, etc.

AE or S Procedure: Note procedure for the BE. It will usually be necessary to furnish external assistance or manually flex the forearm against the weight of a telephone receiver. The amputee will probably place the receiver in the TD when the forearm is locked at the waist level, then unlock the elbow and assist the lift with the sound extremity or the table edge. The wrist unit may then be used to position the receiver to the ear.

As an alternative, the amputee may fully flex the forearm, lock it and then insert the receiver in the TD, if sufficient TD opening is possible at that degree of forearm flexion.

Typing (Hook or Hand)

BE Procedure: The hook fingers are pronated 90 degrees, or the 3-jaw-chuck hold is used by the hand, to grasp an eraser or a pencil, with the eraser downward. Or the hook finger tips may be used alone.



The TD depresses the keys on its side of the keyboard. A rounded-off supplementary pencil eraser will furnish a wider contact base and decrease the chance of the pencil catching between the keys.

AE or S Procedure: This activity can be done by some AE's, but it is not efficient. It is recommended that the sound hand do the typing.

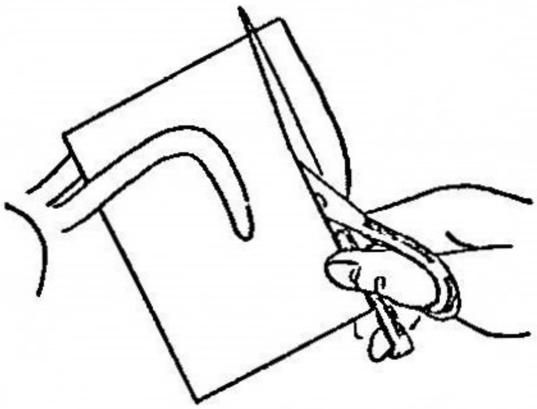
The prosthesis is not used for this activity by a Shoulder amputee.

Scissors (Hook or Hand)

BE Procedure: Material to be cut is placed in the TD. Scissors are grasped by the sound hand.

The TD is slightly supinated until the portion to be cut is easily reached by the scissors.

The area to be cut should be as close to the area grasped as practical. This avoids "flopping" of the material.



The material should be repositioned as cutting angles are changed.

AE or S Procedure: Note BE procedure. The forearm is internally rotated, flexed, and locked to provide the most effective working position.

Other Clerical Activities: Newspaper Reading, Use of Ruler, Stapling, Clipping, Gluing, Opening Envelopes

These and other clerical activities may be suggested and introduced by the trainer.

Although not essential to accomplishing the activity, the prosthesis may improve performance by serving as a prehension holder or stabilizer.

Household Activities

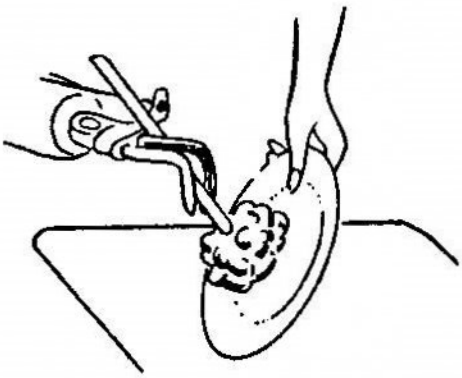
NOTE: In the following activities, no techniques are given for the Shoulder amputee. The functional limitations are so great and Shoulder amputees differ so much in function that specific techniques cannot easily be given.

The trainer should familiarize himself with the procedures for unilateral BE and AE, and then work with the Shoulder amputee to develop techniques that fit the needs of the particular case.

Dishes (Hook)

In order to achieve the greatest security of grasp while washing dishes, the dishes should be held in the sound extremity whenever practical.

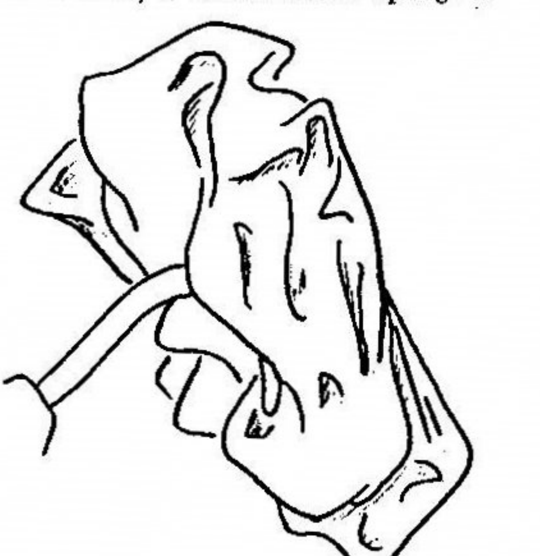
Depending on the individual's preference, a dish mop, a home-made mitten, a cellulose sponge, etc., is held and manipulated by the TD.



Detergents should be avoided, since they tend to dissolve the lubricating oils in the hook and wrist unit mechanism.

The amputee who engages in frequent dishwashing should continually clean and oil the stud threads and bearing of the hook.

The AE may prefer to hold the dish in the TD while the sound hand washes it. If this method is used, a hook mitt or sponge hook finger covers may be constructed and used to advantage.

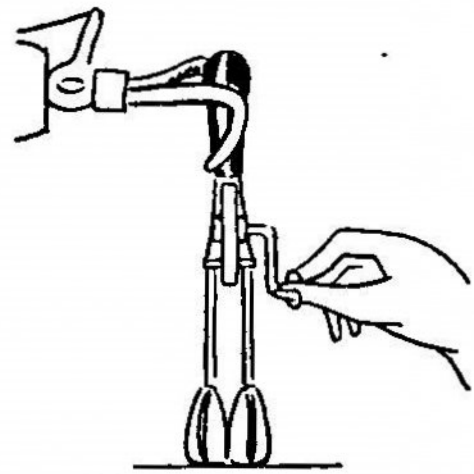


When drying dishes, the sound hand holds the dish while the TD grasps the towel.

The towel is gathered or bunched in the hook to pad the mechanism and furnish an absorbent drying area. Terry-cloth ("Turkish toweling") dish towels are helpful.

Egg Beater (Hook)

The TD holds the beater in position while the sound hand turns the mechanism.



Ironing (Hook)

The sound hand manipulates the iron. The TD is used to stabilize and position the material.

Rubber surgical tubing may be pulled over the stationary hook finger to increase the friction for smoothing out the fabric.

Can Opener, Wall Type (Hook)

Sound hand positions the can in the opener mechanism.

The TD moves the lever or handle to lock the opener. Sound hand then turns the handle to open the can. Then the hand holds the can while the TD unlocks the opener.

Sweeping (Hook or Hand)

The TD is generally used as the assist, chiefly as a pivot and supporting point. The major force comes from the sound extremity.

The broom handle is grasped by the TD approximately 18 inches from the top. It rests in the open area between the hook fingers. The sound hand grasps the top of the handle.

Experimentation in the degree of hook positioning is necessary. Some amputees prefer

the hook fingers pointing upward, others downward. Generally, they point in line with the broom handle. For the AE, the elbow may be locked or unlocked, according to individual preference.

Other Household Activities: Preparing Vegetables, Padlock and Key, Sewing

These activities and others which are related to household activities may be suggested and introduced by the trainer.

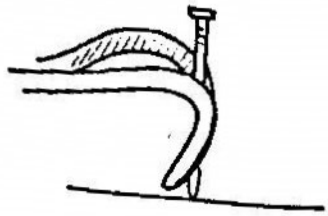
The prosthesis is generally employed as the holder or stabilizing assist. Individually preferred patterns may be worked out by the amputee and trainer, utilizing prepositioning to orient the prosthesis and TD for performing each task.

Workshop Activities

NOTE: In the following activities, no specific techniques are given for the Shoulder amputee. The trainer should familiarize himself with the BE and AE material and work out activities in which the prosthesis can definitely be used to advantage.

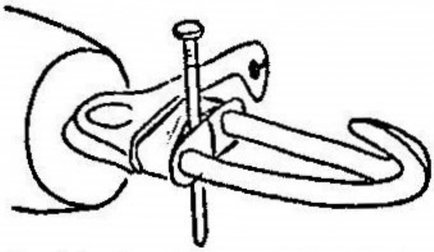
Hammering Nails (Hook)

Long nails may be held in the hook fingers or rubber band guard. Hook is pronated 90 degrees so the nail is perpendicular to the wood. For short nails, the hook is supinated 90 degrees and the nail inserted between the fingers.

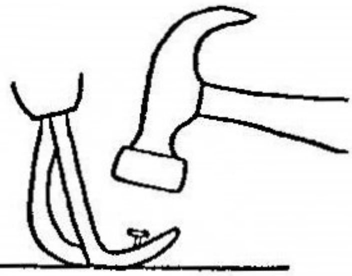


LONG NAIL

The hook should rest on the surface of the wood. Some positioning may well be accomplished by body compensation, but for ease



and skill, this should be minimal, thus allowing concentration on the hammering activity.

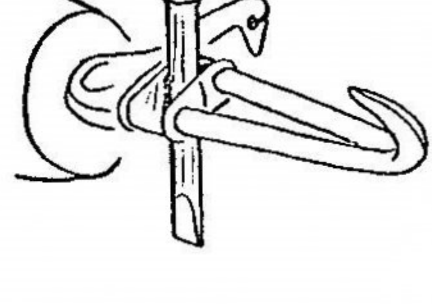


When correctly positioned, the tip of the nail should just contact the wood. Care and accuracy during the initial stroke result in a greater degree of success.

Mallet and Chisel (Hook)

The chisel is handled with greater skill if it is not held in a rigid position in the TD. Care must be taken, however, to assure a safe hold.

If a manual lock wrist unit is used, it may be unlocked to allow facility in changing cutting direction. With a TD having a rubber



band guard, the chisel is inserted behind the guard; the rubber bands help to prevent its slipping, act as shock absorbers, and at the same time allow freedom of motion. The usual safety precautions should be observed.

Brace and Bit (Hook)

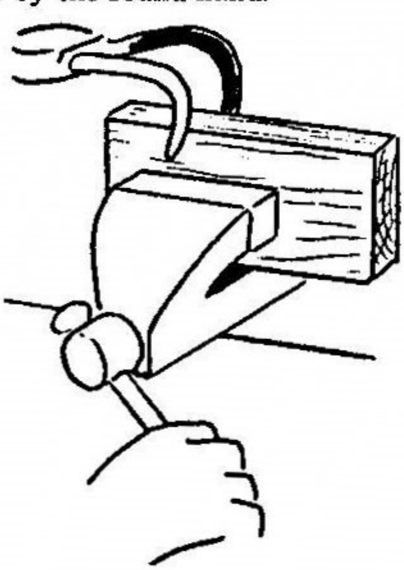
The prosthesis supports the brace in a vertical position while the sound hand inserts or extracts the bit and operates the 3-jaw-chuck of the brace. When drilling on a vertical surface, the amputee generally operates the brace with the sound hand and supports the brace by resting the end against the body. However, the TD may grasp the brace and assist in support or may even turn the bit. If desired, the brace handle may be modified for additional stability of grasp by flattening or notching the handle to fit the TD.

When drilling on a horizontal surface at a level where the chest cannot be used for support, the prosthesis is best used to turn the brace while the sound hand stabilizes it. This technique requires a high degree of skill to be effective.

Vise (Hook)

Either the sound hand or the TD may be used to stabilize the wood in the vise while it is clamped into place. For the BE, either may actually screw or unscrew the vise. The sound hand does the final tightening and initial loosening.

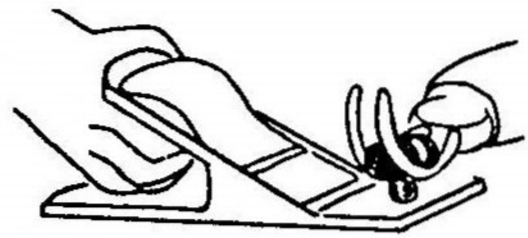
For the AE, the tightening will probably be done by the sound hand.



Plane (Hook)

Small (box) planes may be operated with skill without the assistance of a prosthesis.

For larger (jack) planes it is advisable to employ both extremities for greater skill as well as safety. The contoured handle is held by the sound extremity. The knob is held by the prosthesis, which assists in directing the tool, as well as provides force assistance.

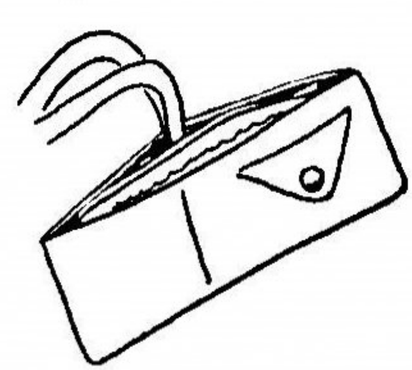


The AE amputee may unlock the elbow to allow a long, smooth planing motion, or leave it locked in order to get more force.

Miscellaneous Activities

Wallet (Hook or Hand)

TD holds the wallet, preferably gripping it in the middle for balance and at the top edge to prevent "pinching" the currency in the grip.



The sound hand can then remove the currency or coins.

The AE and S amputees should flex and lock the forearm at about 90 degrees.

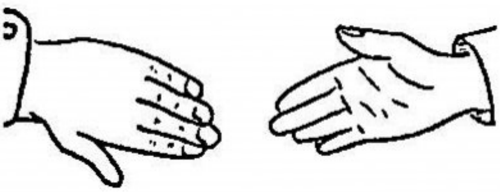
Lighting Match (Hook or Hand)

The book matches are held in the TD by pinching a corner of the "strike area." The flap is opened and the match struck by the sound hand.

The AE or S amputee should preposition the TD and lock the forearm in the most desirable angle of flexion.

Shaking Hands

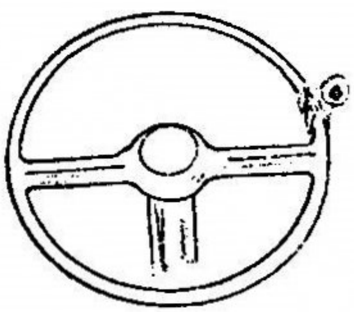
The right amputee may shake hands in a natural manner by extending his sound arm and inverting his hand. The left amputee is not concerned with this.



Driving a Car

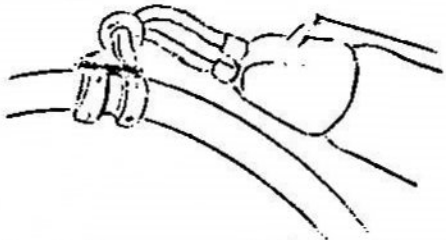
The actual turning of the steering wheel while driving will usually be done by the sound extremity.

However, if the prosthesis has sufficient function, performance can be considerably improved by using the prosthesis to assist the sound arm in turning the wheel or stabilizing it while the sound arm momentarily performs some other activity.



One item of special equipment engineered in the interest of safety and comfort is the Northrop-Sierra Driving Ring. It is commercially available from most prosthetic suppliers.

In use, the ring is first attached to the steering wheel in either the 9 o'clock position (for the left amputee) or the 3 o'clock position (for the right amputee). The ring can later be moved to satisfy the amputee's preference after trying it.



The hook fingers are rotated so they can be inserted into the driving ring. The fingers are secure in the ring for turning forces but can be easily slipped out of the ring when desired or in emergencies. Neither the ring nor the wheel should be grasped by the hook fingers; it is easy to get the fingers locked or bound up when the wheel is turned.

The motion required for steering with the TD in the driving ring is essentially the same as the motion of a sound arm turning a steering wheel equipped with a "spinner" knob.

The unilateral AE should have the elbow unlocked if the prosthesis is used to assist in driving.

It is doubtful if a Shoulder prosthesis will be of any value to assist in driving.

The left knee or top thigh surface can be used to assist the sound extremity in stabilizing the wheel.

TECHNIQUES FOR THE BILATERAL: BE-BE/AE/S

The trainer should review the techniques employed by the unilateral amputee before initiating bilateral training, and should be familiar with the prepositioning terminology shown in Figure XII-2 and the amputee type notation at the beginning of this chapter.

This section of the chapter presents activities suitable for use in a training program and techniques to be used as a guide. Each activity must be worked out and evaluated for the individual amputee.

All complex manipulation techniques presented here assume use of a hook with rubber or neoprene-lined fingers.

Dressing Activities

T-Shirt

Putting on a T-shirt is made easier by first straightening the shirt out on a flat surface.

The BE stump is inserted first into its sleeve, up to the fold of the elbow. The shirt is raised above the head and the head inserted. Then the arm is lowered, the shirt drawn over the head and shrugged into place.

Brassiere

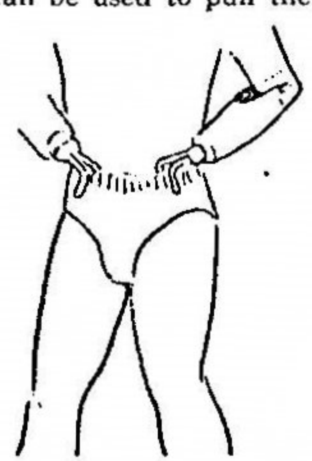
A strapless bra or one that fastens in front is recommended. Strapless bras may be fastened in front and then turned around, or in some cases, fastened first, then put on over the head.

Stump Socks

The prosthesis now may be put on after the T-shirt is on. If stump socks are desired by the amputee, they should be placed on a flat surface in position for being pulled on. One stump is inserted into a sock while the other stump assists by holding and rubbing the sock into position. The teeth are then used to pull the socks tight and hold each in position if necessary while the prostheses are put on.

Undershorts or Underpants

The shorts or panties should be positioned properly before being grasped with the terminal device. The TD need only hold the garment while the legs are inserted. Then the BE prosthesis can be used to pull the shorts up.



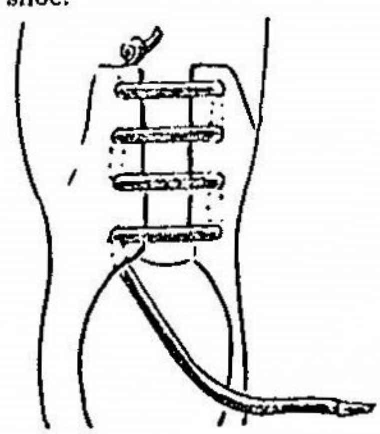
Shorts with an elastic waistband instead of buttons or snaps should be used to make the task simpler. (Stumps alone may be used to perform this activity, in lieu of prosthesis.)

Socks

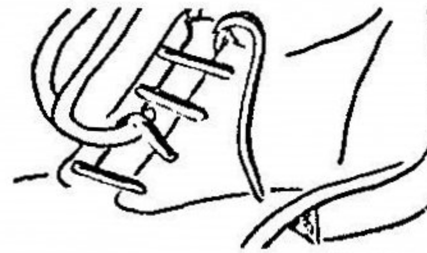
The sock should be held in position by the BE side TD while the foot is inserted part-way into the sock. At this point, a new grip should be taken to twist the sock over the tip of the TD in order to prevent the sock from slipping out when force is applied to pull the sock into position. Care should be taken to avoid poking a hole in nylon or silk socks.

Shoes

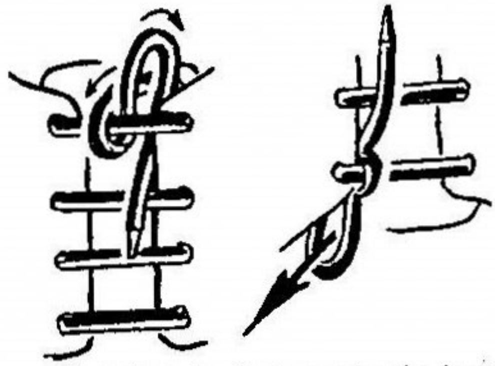
Although some bilateral BE amputees can lace and tie shoes in the conventional manner, most bilaterals should wear shoes of the loafer or zipper type. If shoes with laces are desired they should be laced in a special manner to simplify the tying operation. The accompanying illustration shows a common method for lacing a shoe.



After the foot is inserted into the shoe, the lace is tightened, working progressively from the bottom to the top. This can be accomplished by inserting the hook tips in between the lace and the shoe tongue and pulling.



To tie the knot, the free end of the lace is grasped about two inches from the eyelet so it forms a loop. Then the loop is pushed under



the crossing lace to form a simple knot as shown. The loop is released, a new grip taken, and the knot tightened by pulling toward the eyelet.

Shirt

The cuffs are buttoned before the shirt is put on. The assist TD holds each cuff down on a flat surface while the dominant TD works the hole over the button. The cuffs need not be unbuttoned again since they will slip over the TD's.

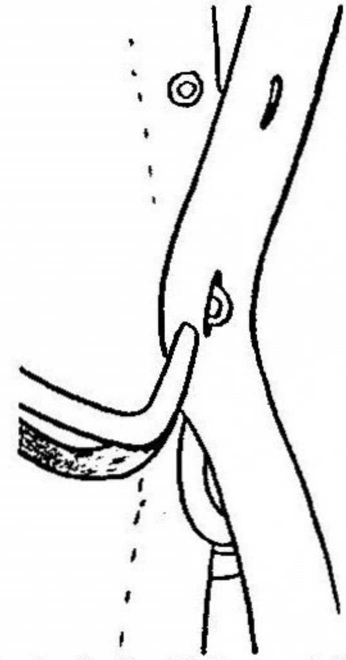
The assist prosthesis is inserted into its sleeve first until the TD protrudes. The forearm is flexed 90° (and locked if on AE or S)

to hold the shirt while the dominant TD works the shirt up over the shoulder. Then by leaning to the dominant side, the amputee can reach behind, insert the prosthesis in the sleeve and shrug the shirt into place.

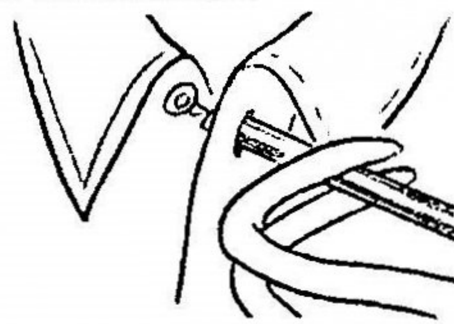
The shirt can be buttoned by most BE-BE's and some BE-AE's in the following manner:

The button side of the shirt is stretched tight, either by pulling down with the assist TD or by leaning against the edge of a table.

The dominant TD grasps the shirt near the bottom buttonhole and works the buttonhole over the button. The operation progresses from the bottom button to the top.



A buttonhook should be used for the top button. A mirror is also required to enable the amputee to see the collar button area. A wrist flexion unit can be used to advantage when working in this area. The buttonhook is grasped in the TD and pushed through the buttonhole. The button is then hooked and pulled through the hole.



If desired, the buttonhook may be used for the whole buttoning sequence.

NOTE: Many bilateral amputees wear shirts with sleeve length short enough to keep cuffs out of the way of the thumb path when the TD is operated.

Trousers or Skirt

The belt is threaded through the belt loops. The dominant side TD grasps the belt loop and holds the trousers or skirt in position. The amputee inserts the legs into the trousers or skirt; either the sitting or the standing position may be used. The garment is pulled up to the waist.

The assist prosthesis is flexed to 90° (and locked if an AE or S). The hook grasping a belt loop, holds the trousers or skirt up while the dominant side stuffs the shirt inside the waistband.

The waistband should have a hooking clasp fastener rather than a button or hooks and eyes, and should be loose enough around the waist to make the fastening easier. The dominant TD can do the fastening while the assist holds.

Once the waistband is fastened, the fly or placket can be held taut by the assist TD if possible, or by the edge of a table, while the other hook grasps the zipper tab and zips up the fly. A small keychain or an inconspicuous loop of leather, ribbon, or chain may be attached to the tab for easier grasp.

The dominant hook then buckles the belt.

Necktie

A wrist flexion unit on either side is of considerable help in accomplishing this activity.

The tie is placed under the collar so the small end is on the dominant side. The assist limb is prepositioned to bring the TD to the front and center of the chest so the small end of the tie can be grasped.

The assist TD grasps the small end and brings it across the chest to form a cross with the long end overlying.

While the assist TD holds the short end, the dominant TD fashions the desired knot.

Once the knot is made, the tie may be kept tied and slipped on and off as desired.

Some amputees may prefer the "already-tied" type.

Sweater

A cardigan type sweater is recommended rather than a pullover type. However, a BE-BE can don a pullover without much difficulty. The technique for donning the cardigan type is similar to that for a coat.

Coat

The dominant side holds the coat so that the assist prosthesis can be inserted into its sleeve. As soon as the TD protrudes from the sleeve the forearm is flexed to 90° (and locked if an AE or S) to hold the coat while the dominant side pulls the coat up over the shoulder and is inserted into its sleeve.

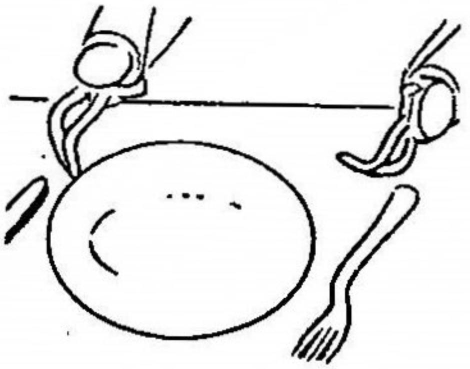
The coat is then shrugged into place and the large buttons fastened without a buttonhook in a manner similar to the shirt.

NOTE: The flexion of prosthetic forearms (especially AE and S) may be difficult because of the additional weight and restriction of the coat sleeves.

Eating Activities

Cutting Meat

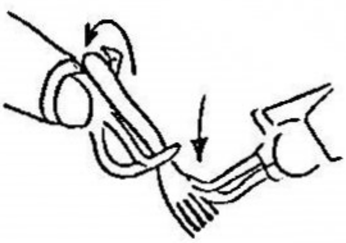
The dominant hook is prepositioned at about 90° pronation. Assist hook is in the medial (0°) rotation position. If the assist arm is an AE, the forearm should be flexed (about 90°) to allow the TD to rest on the table top near the plate.



The dominant TD grasps the fork and turns it over.

The assist TD then grasps the fork near the tines.

Dominant TD positions the fork in the hook finger-thumb hold. This can be accomplished by pulling the fork handle in place with the hook or by pressing down on the end of the fork to pivot it into place. The friction surface of hook rubber bands may be used to advantage in this positioning.



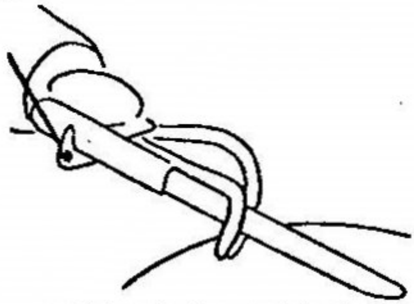
The dominant TD then grasps the knife blade near the handle. The knife is positioned by the assist TD into the hook finger-thumb hold in the same manner as the fork.

The fork is pressed into the food to stabilize it with a downward and backward force.

The knife cuts the food with a sawing motion and medium force. A serrated blade will require minimum force to cut.

NOTE: The BE/S amputee may have considerable difficulty with this activity because of the immobility of the S prosthesis. Also, the amputee should avoid cross-controlling or inadvertently applying tension in the control cable, causing the utensils to drop.

After cutting is complete, the knife is pivoted out of its finger-thumb position, then positioned over the plate edge and gently released.



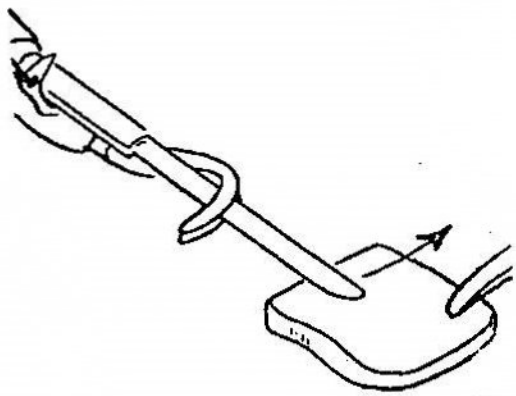
The same thing is done with the fork. It is then turned over by the dominant side, and positioned for carrying the food to the mouth.

Buttering Bread

Dominant TD is pronated about 45°. A slice of bread is grasped and positioned on the plate or table. Maintaining tension on the control cable will prevent the hook fingers from pinching through the bread.

The assist prosthesis is positioned to stabilize the bread; the TD is pronated about 90° and the forearm flexed (and locked if AE) as necessary to obtain the proper position.

The knife blade is grasped by the dominant TD near the handle and pivoted into the same finger-thumb hold as for cutting.

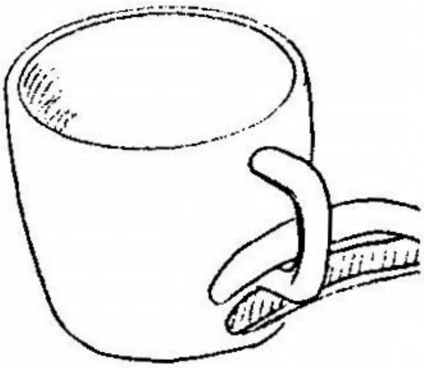


Soft butter is cut in such a manner that it can be transported to the bread on the lower side of the blade and spread.

Drinking

Glass: The dominant TD is prepositioned in 90° pronation. The glass may be picked up either with the hook fingers encircling it or grasping the rim on the distal side.

Cup: The cup may be held in the same manner as the glass. As another method, the bottom of the cup handle can be grasped with the TD in the medial (0°) rotation position. In this hold, the handle will be stable in the hook fingers.



NOTE: Stable grasp is a function of cup handle design and prehension force. If the cup extends below the handle, the cup will rest against the stationary hook finger and be stabilized against a downward force. If the prehension force is sufficient, stability will be afforded in the medial-lateral direction.

Opening Jar or Bottle

The assist TD is prepositioned in 90° pronation and the jar grasped in the middle. The prosthesis is prepositioned in such a manner as to hold the jar firmly against some surface.

The dominant TD is rotated to 90° supination and the lid or cap is grasped.

A small amount of dominant arm flexion and abduction is used to start to unscrew the lid. Then the hook is opened and the rubber

prehension surface of the stationary finger utilized to work the lid the rest of the way off.

The reverse procedure is used to close the jar.

Carrying a Tray

Both TD's are prepositioned in the medial (0°)position.

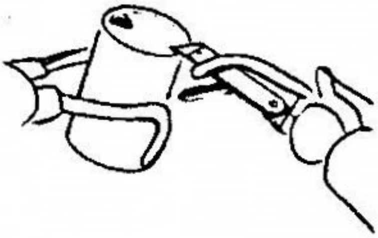
The tray may be grasped by both TD's. The

dominant TD should grasp the tray farther out from the body for stability.

If the assist side is an AE or S, the forearm should be locked at 90°. If desired, the tray may be rested on the forearm section instead of being grasped.

Opening Beverage Can

The assist TD is rotated to 90° pronation and the can is grasped and stabilized against a surface.

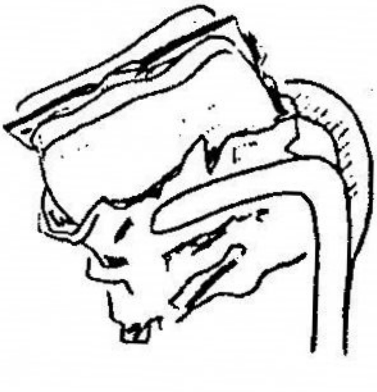


The dominant TD is placed in the medial (0°) position. The can opener is then grasped, positioned on the can and gentle pressure applied by elevating the arm.

Handling Sandwiches

A sandwich is best held in the dominant TD, with tension maintained in the control cable to keep the hook fingers from cutting or crushing.

Waxed paper or a sandwich bag should cover the half of the sandwich under the hook fingers.



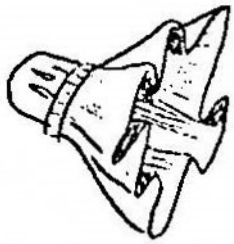
Personal Hygiene

NOTE: Prior to dressing or putting on the prosthesis, the stumps may be used to advantage in some of the following activities.

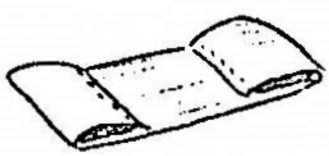
Bathing

The water faucets can be operated by the BE stump.

The washcloth (and towel) may be wrapped around the end of the stump or held in the fold of the elbow and stabilized by the opposite stump if of sufficient length.



Special modifications to the cloth may be made, such as sewing on a strip of elastic into which the stump can slip. Each end of the towel can be folded over and sewed to form pockets into which the stumps can be slipped.



Rinse water may be scooped up to the face by the fold of the elbow.

Brushing Teeth

Toothpaste is more convenient to use than powder. The cap may be removed by using the teeth and lips while holding the tube between the stumps or in the elbow fold.

The toothbrush likewise may be held in the elbow fold with the bristle end positioned both medially and laterally for brushing.

This activity may be performed with the prostheses. The toothbrush is held in the dominant TD, which is supinated about 45°. The brush is first positioned with the bristles

up and toward the medial side—then changed, bristles downward, in order to reach both sides of the teeth.

Head motion may be necessary to facilitate proper brushing.

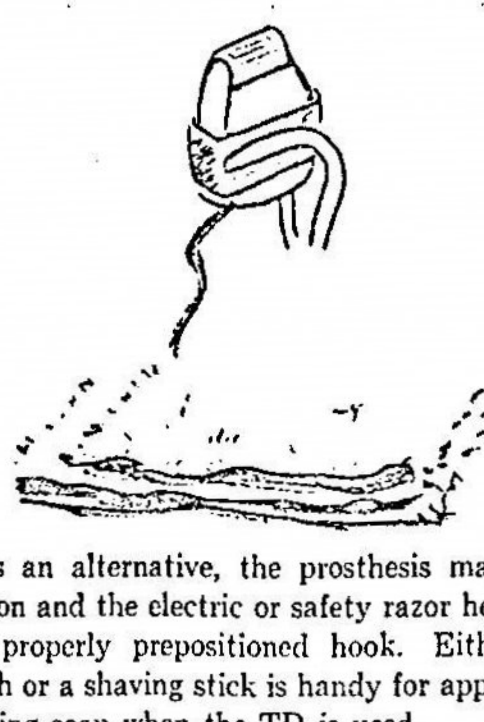
Shaving

The operations of applying shaving cream, changing the razor blade and drawing the safety razor across the face to remove the beard, may be accomplished with the stumps after practice; however, the stumps must be long enough to hold the razor in the proper position. Head motion is used while holding the razor steady.

Certain types of razors with blade dispensers lend themselves rather well to blade changing.

However, by far the simpler method for shaving is to use an electric razor; shaving may be accomplished by holding the razor between the stumps if they are of sufficient length.

It is desirable to have a very wide rubber band around the body of the razor to prevent it from slipping from the grasp. Also, it is wise to cover the washbowl (or any hard surface over which the shaving operation is performed) with a folded towel to minimize damage to the electric razor, if is accidentally dropped.



As an alternative, the prosthesis may be put on and the electric or safety razor held in the properly prepositioned hook. Either a brush or a shaving stick is handy for applying shaving soap when the TD is used.

Combing Hair

The dominant TD should be correctly prepositioned so the comb can be grasped and drawn through the hair. Usually 45° to 90° of TD supination is necessary.

Care of the hair for a woman is largely dependent on the hair style. Loose, casual hairdos are recommended. Considerable experimentation must be done to find the best method.

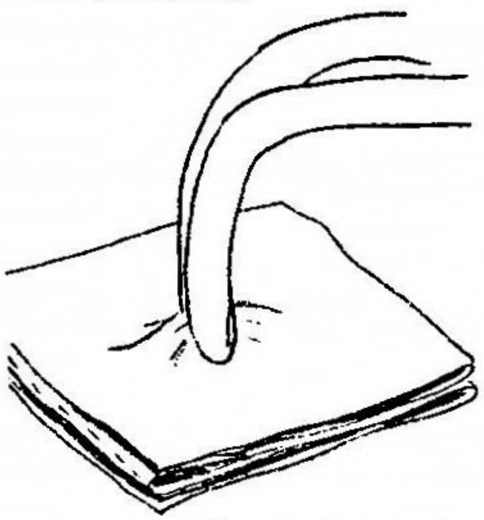
Cosmetics

Cosmetics can be applied with the dominant TD; some women amputees prefer to use the stumps alone. Lipstick cases that are opened by sliding a button, rather than by unscrewing, are recommended. A square case can be held easily in the TD. Sliding the button to open the case and bring up the lipstick can be done with the mouth or the assist TD.

Toileting

Urination and defecation can be accomplished independently if the amputee can handle the clothing. The amputee's ability to operate belts, zippers and fasteners will determine how easily this can be done. These problems are discussed in dressing techniques.

The process of wiping after defecation can usually be executed without too much difficulty since the dominant (BE) side has sufficient mobility to position the TD in the proper area to perform the activity.



The dominant TD unrolls enough toilet tissue to fold into a square pad about six layers thick. The tissue can be held on the surface of the thighs during the folding operation.

The TD grasps the pad of tissue by pinching it in the center. Then the TD is rotated to about 45° to 90° supination. The amputee can reach behind the body and place the TD and tissue in position for wiping.

The front approach may be used if desired, but there is more tendency to apply force to the control cable and open the hook inadvertently.

General

Driving a Car

The BE-BE/AE/S class of amputees can drive a car with conventional steering and shift and with no special equipment or modification; however, automatic transmission and power steering greatly simplify this activity.

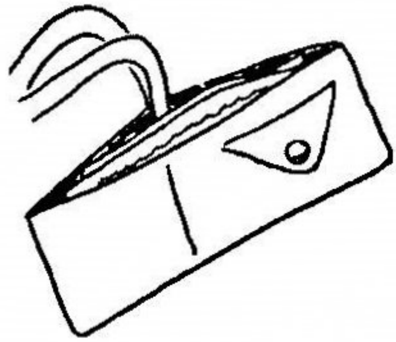
One driving ring (as discussed in the unilateral techniques section) is required. If both extremities have enough function to perform the activity, two rings may be installed so they can be used alternately. Otherwise, the dominant BE side can manage.

However, in this case, modifications to the controls are usually desirable. The turn signal control can be located and modified so it can be knee-operated, and the shift lever can be lengthened if necessary. Ignition, light, starter and other switches may need to be relocated to make the task easier for the "one-TD" operation.

Friction in the wrist unit should be great enough to prevent the hook from rotating while turning the wheel.

Wallet — Bills and Coins

The dominant TD is prepositioned so the hook fingers can reach into the pocket and withdraw the wallet. It is opened (using the

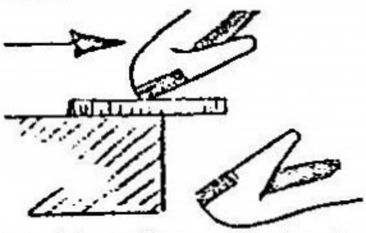


thigh for a table if necessary) and placed in the assist TD so the currency can be removed.

With practice, the TD can reach into a pocket and remove coins. Shaking the TD in the pocket helps to orient the coins in the grasp of the TD.

However, a small coin purse, preferably the compartmented type, is recommended. The purse is easier to withdraw from the pocket.

In picking a coin from a table, the hook can be opened and the movable finger prehension surface used to slide the coin to the table edge. Then with a quick coordinated motion of pulling the coin off the table and snapping the hook shut, the coin can be grasped. The coin may be picked up with the hook tips if finger shape permits.

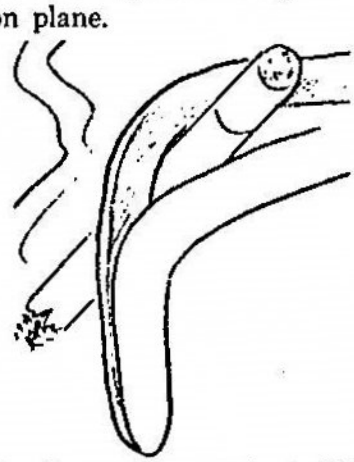


When receiving change, it is often helpful to have it stacked and placed in the TD's grasp or picked up from the edge of the counter.

Smoking a Cigarette

Prepositioning must be worked out depending on the type of cigarette pack and in which pocket it is carried.

In many hooks, the cigarette may be held without crushing between the fingers in the area where the fingers converge to form the prehension plane.



Paper book matches can be held in the assist hook while the dominant hook removes and strikes a match.

Telephone

The desk phone can either be held by the dominant TD or positioned in the assist TD. The receiver may be removed from its cradle and placed on the table to obtain the desired grasp position. The technique is discussed in the unilateral section.

The wall-type pay phone presents a much more difficult activity. Holding the receiver or dialing can be accomplished by the BE-side TD. The problem is inserting the coin into the coin slot.

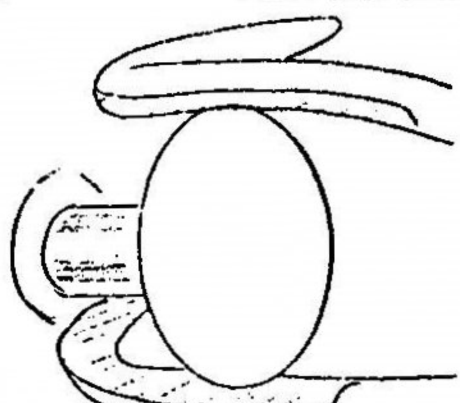
If the amputee has sufficient residual function to operate both TD's at the coin slot, the coin can be held flat in front of the slot in one TD while the other TD taps or pushes it into the slot. To position both TD's in front of the body without having tension in the control cables to cause inadvertent hook opening, the amputee can shift the harness up in back so the control attachment straps ride up over the deltoid muscles. This will allow more freedom of movement.

The pay phone task is one which requires much work and practice in prepositioning.

Unlocking and Opening Doors

The dominant TD can turn the key to unlock a door by the use of arm abduction or adduction.

The same applies to turning a doorknob. It is important to have a secure grip; prehension



force should be sufficient. Neoprene or rubber hook finger lining greatly improves performance in this activity.

Operating Faucet Handle

The hook fingers are prepositioned so the hook grasps the faucet handle. Then by abducting the arm, the hook fingers will apply force to open the faucet. Or, the TD may be used to tap the handle into open or closed position.

Handling Liquids

Flexible plastic bottles are very useful for holding and dispensing liquids. The flexible surface provides greater security of grasp. Various types are available from housewares and cosmetic departments and chemical supply houses.

Note

Additional specialized activities, both vocational and avocational, should be introduced by the trainer. The trainer and amputee should work together to develop successful techniques for performing the activities, utilizing and adapting techniques found in the unilateral section. The concept of prepositioning the TD's and prostheses for optimum performance and the attitude of inventing and developing step-by-step procedures for the solution of the problems should be basic factors in the amputee-trainer relationship.

The following is a list of suggested activities:

Clerical

- Pencil Sharpener
- Writing
- Handling Newspaper, Books
- Opening Envelopes

Household

- Padlock and key
- Washing Dishes
- Sweeping
- Can Opener
- Peeling Vegetables
- Ironing
- Plugging in Electric Cord
- Operating Electric Switches
- Pouring from Cartons or Bottles
- Picking up Objects from Floor
- Opening-Closing Window
- Sewing

TECHNIQUES FOR THE BILATERAL: AE-AE/S

Amputees in this class will have varying degrees of success in performing activities, depending on the level of amputation. The bilateral Elbow Disarticulation should experience the least difficulty. With the bilateral Short AE-S type, more reliability and function may be obtained by fitting the amputee unilaterally, with a prosthesis on the dominant side only.

At best these amputees will have difficulty, since the lack of a forearm stump will reduce the ability to position and control the terminal device in space. Special devices should be considered.

The trainer should know the BE-BE/AE/S techniques before proceeding.

Dressing Activities

T-Shirt

If the stumps are long enough, they may be inserted into the T-shirt, which may then be worked over the head and shrugged into place. Otherwise, the shirt may be positioned on the bed or the back of a chair, and the amputee may then be able to work into it.

This is a most difficult if not impossible task for the shorter stumps and help may be necessary.

Stump Socks

The lips and teeth should be used to help pull the stump socks on.

Brassiere

If possible, a strapless bra may be fastened in front, then turned around.

Undershorts or Underpants

If the amputee has sufficient residual function, shorts or panties with an elastic waistband may be pulled up by the dominant AE prosthesis, locking the elbow in smaller angles of forearm flexion as required. Otherwise, a boxer style with hooking clasp fastener may be used, or this step may be omitted entirely.

Socks

Stretchable nylon socks are recommended.

The dominant TD can hold the sock while the foot is inserted. The socks can then be pulled over the heel, providing they are not too tight. One foot can assist the other in putting the socks on.

Shoes

This class of amputee should wear only loafer-type shoes or shoes which do not require lacing.

Shirt

A buttonhook must be used to button the shirt, providing the prostheses have sufficient function. Flexion units are highly desirable to enable the TD's to work close to the front of the body.

Trousers or Skirt

Trousers or skirt can be pulled up by the dominant TD and held by the assist if there is enough function.

Necktie

Since tying the tie is extremely difficult, this activity is not recommended.

Coat

It may be possible to put on a coat, depending on the level of amputation. However, considerable body contortion or "body English" must be used.

Eating

Cutting Meat

This activity should be omitted for Short AE's and above. Prepositioning sequence is essentially the same as that for the BE-BE/AE/S class.

In using the fork or spoon to transport food from plate to mouth, the forearm is usually locked at about 90°. Arm elevation and flexion is used to raise the utensil to the mouth.

If this is not feasible, the elbow may be kept unlocked. Forearm flexion resulting from pressing the forearm on the table edge is used to bring the utensil to the mouth.

Drinking

The elbow must be kept locked, and arm elevation and flexion must be used to raise the glass or cup to the mouth. "Live-lift" usually cannot be used, especially with the dual control system. However, forced lift (using table edge or thigh) may be used to position the glass to the mouth.

Personal Hygiene

Bathing

The dominant stump can hold a wash cloth or sponge modified with elastic to wash some areas of the body. Special devices will have to be developed for positioning the sponge or cloth.

Brushing Teeth

The toothbrush can be held between the stumps if they are long enough; otherwise, the brush can be grasped by the TD. Then the forearm can be flexed fully and locked and the teeth brushed by using head motion.

Shaving

The shaving stick and razor can be held in the TD with fully-flexed forearm locked and resting on a surface.

Head motion is used to accomplish the shaving.

Combing Hair

This activity may be done in the same manner as the shaving activity.

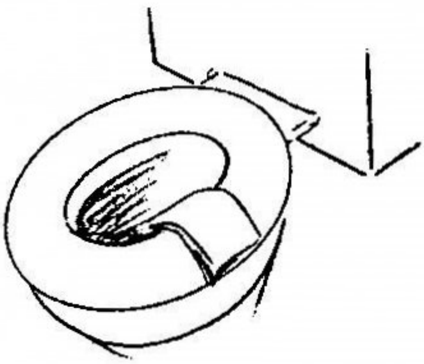
Toileting

Urination and defecation can be accomplished independently if the amputee can handle the clothing and fasteners.

Wiping after defecation in the AE case cannot usually be effected in the same manner as the BE, since the AE does not possess enough mobility and stability behind the body. However, the front or back approach technique can be used satisfactorily by some AE's.

There are several methods which can be used successfully.

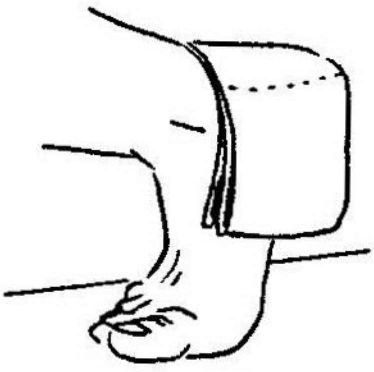
Seat Method: Several layers of toilet tissue are spread across the toilet seat or the edge of a bathtub or chair. Moistening the end of the tissue will aid in forming the layers and help stabilize the pad.



The amputee then sits so the buttocks straddle the seat or edge of the chair. By shifting the pelvis from side to side, the wiping action may be completed. Several applications may be necessary. This is a difficult activity. Considerable practice is required to develop skill and gain confidence in the method.

Heel Method: The foot is slipped out of its shoe and rested on the toilet seat. A length of toilet tissue is draped over the heel to form three or more layers, using the same technique as for the seat method above.

By squatting on the heel, the tissue is placed in apposition to the anus.



Fore and aft motion of the pelvis will bring about a satisfactory wiping action.

The tissue can then be grasped by the hook and disposed of. Repeated application will result in successful cleaning.

General

Driving a Car

This activity is discussed in the Unilateral and Bilateral BE-BE/AE/S sections.

The car should have power steering; the turntable and wrist unit of the prosthesis should be sufficiently tight to prevent their turning when steering. With this feature, and modification of gear lever, turn indicator handle, etc., it should be possible for a Short AE-Shoulder amputee to drive a car.

NOTE: The additional activities are similar to those for the BE-BE/AE/S class of amputees. They will be more difficult, so more time and energy will be required to work them out for the individual amputee.

TECHNIQUES FOR THE S-S AMPUTEE

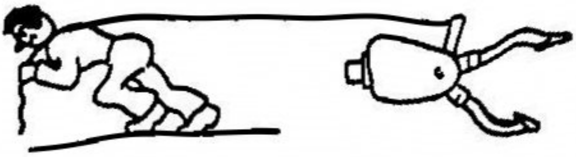
The use of a prosthesis by an amputee of this class to perform even a simple activity is marginal. Experience with S-S amputees has been limited since the number of cases in the total amputee population is very small, but it has shown that fitting the amputee either bilaterally or unilaterally with conventional Shoulder prostheses has been unsatisfactory in general.

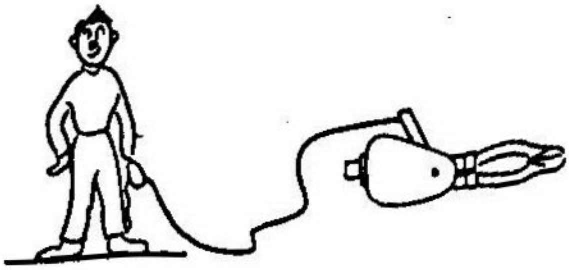
The best approach a trainer can have is to be familiar with the techniques of the lower level bilateral types and apply them with imagination and inventiveness insofar as possible to the S-S amputee. Design and experimentation with special assisting devices is recommended. Encouraging the amputee to learn to perform some activities with the feet should be considered.

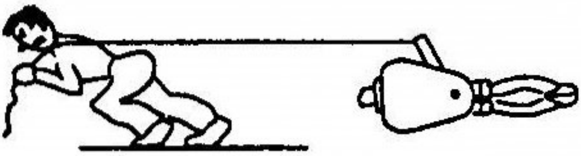
The trainer should read the section on *Unilateral Equipment for Bilateral Shoulder Amputees* in Chapter XIV for some recent developments on this problem.

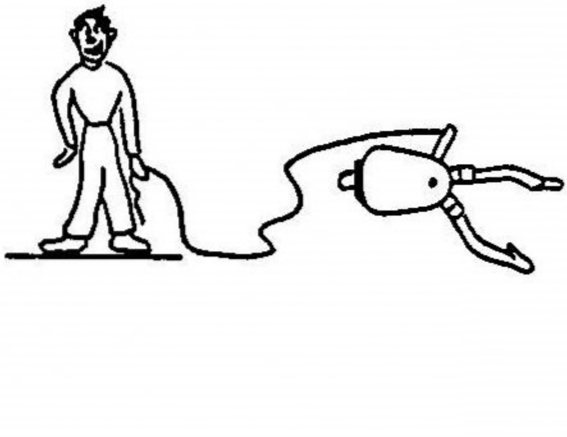
UPPER-EXTREMITY PROSTHETIC CONTROL MOTIONS

	WRIST DISARTICULATION AND LONG BELOW-ELBOW	SHORT BELOW-ELBOW	ELBOW DISARTICULATION	ABOVE-ELBOW	SHOULDER DISARTICULATION	BILATERAL
TERMINAL DEVICE OPERATION	Shoulder (glenohumeral) flexion, shoulder girdle flexion on amputated side	→	→	→	Bilateral shoulder girdle flexion	
WRIST FLEXION	Substitute with humeral internal rotation and abduction on amputated side, or by use of sound extremity	→	→	→	→	Wrist flexion unit adjusted by opposite hook, thigh, table
PRONATION AND SUPINATION	Active: fitted with flexible hinges	Wrist unit adjusted by sound hand	→	→	→	Wrist unit adjusted by opposite hook, thigh, table
ELBOW FLEXION	Active	→	Shoulder flexion, shoulder girdle flexion on amputated side	→	Bilateral shoulder girdle flexion	
ELBOW LOCK OPERATION	Active	→	Shoulder girdle depression and shoulder hyper-extension and abduction	→	Cable: shoulder girdle elevation or pull by sound hand Button: chin nudge	
HUMERAL ROTATION	Active	→	→	Turntable adjusted by sound hand	→	Turntable adjusted by opposite hook
HUMERAL ABDUCTION	Active	→	→	→	Abduction unit: leans to amputated side	









EVALUATION OF TRAINING FOR UPPER-EXTREMITY AMPUTEE

Name_______________ Age_____ Date__________

Terminal Device_______________ Amputee Type__________

KEY
- [X] - Should be able to do it.
- (X) - Can do it.
- [ ] - Does with sound side.
- [NA] - Not applicable.
- [CP] - Cannot be expected to perform.

Date Completed	Suggested Activities	Without Prosthesis	Unilateral B/E with hook	Unilateral A/E with hook	Unilateral S/D with hook	Bilateral with hooks B/E, A/E	Comments
A. CONTROLS							
	1. Open TD		X	X	X	X	
	2. Close TD		X	X	X	X	
	3. Preposition TD		X	X	X	X	
	4. Wrist flexion		NA	NA		X	
	5. Lock and unlock elbow		NA	X	X	X	
	6. Rotate turntable		NA	X	X	X	
B. EATING							
	1. Spoon					X	
	2. Fork					X	
	3. Cut with knife and fork		X	X	X	X	
	4. Drink from cup, glass					X	
	5. Hold glass and fill from faucet		X	X	CP	CP	
	6. Open milk container		X	X	CP	X	
	7. Remove straw from paper		X	X	X	X	
	8. Eat sandwich					X	
	9. Butter bread		X	X	X	X	
	10. Carry tray		X	X	X	X	

EVALUATION OF TRAINING FOR UPPER-EXTREMITY AMPUTEE (Continued)

Date Completed	Suggested Activities	Without Prosthesis	Unilateral B/E with hook	Unilateral A/E with hook	Unilateral S/D with hook	Bilateral with hooks B/E, A/E	Comments
C. DRESSING							
	1. Doff and don prosthesis		X	X	X	X	
	2. Doff and don shirt, blouse		X	X	X	X	
	3. Socks: doff, don		X	X		X	
	4. Shoes: doff and don					X	
	5. Shoes: lace and tie		X	X		CP	
	6. Trousers and skirt: up and down		X	X		X	
	7. Use zipper: side, front, jacket		X	X	CP	X	
	8. Buckle belt		X	X		X	
	9. Buttons: front, side		X	X		X	
	10. Button cuffs		X	X	X	X	
	11. Tuck in shirt, blouse		X	X	X	X	
	12. Coat off and on hanger		X	X	X	X	
	13. Rubbers		X	X		X	
	14. Glove		X	X	X	NA	
	15. Tie necktie		X	X	X	X	
	16. Glasses: clean, take off, put on		X	X	X	X	
	17. Garter belt		X	X		X	
	18. Brassiere		X	X	CP	X	
	19. Safety pin: open and close		X	X		CP	
	20. Stockings, panty hose					X	

EVALUATION OF TRAINING FOR UPPER-EXTREMITY AMPUTEE (Continued)

Date Completed	Suggested Activities	Without Prosthesis	Unilateral B/E with hook	Unilateral A/E with hook	Unilateral S/D with hook	Bilateral with hooks B/E, A/E	Comments
D. PERSONAL HYGIENE							
	1. Grasp washcloth					X	
	2. Comb hair					X	
	3. Set hair		X			CP	
	4. Grasp toothbrush and apply paste		X	X	X	X	
	5. File nails		X	X	X	NA	
	6. Wipe self					X	
	7. Put on sanitary belt, napkin, tampon		X	X		X	
	8. Shave					X	
E. SCHOOL							
	1. Turn single page					X	
	2. Hold book open		X	X	X	X	
	3. Drop coin in slot					X	
	4. Hold paper and cut		X	X	X	CP	
	5. Weight paper and write		X	X	X	X	
	6. Ruler		X	X	X	X	
	7. Paper clip		X	X	X	CP	
	8. Hold jar and open		X	X	X	CP	
	9. Sharpen pencil		X	X	X	X	
	10. Open envelope		X	X	X	X	
	11. Carry lunch box		X	X	X	X	
	12. Carry school books in bag		X	X	X	X	

EVALUATION OF TRAINING FOR UPPER-EXTREMITY AMPUTEE (Continued)

Date Completed	Suggested Activities	Without Prosthesis	Unilateral B/E with hook	Unilateral A/E with hook	Unilateral S/D with hook	Bilateral with hooks B/E, A/E	Comments
F. OTHER							
	1. Rolling pin		X	X		X	
	2. Open door					X	
	3. Open two-knob drawer		X	X	X	X	
	4. Light switch					X	
	5. Plug into electric wall socket					X	
	6. Can openers: soft drink, wall-gear type		X	X	X	X	
	7. Padlock and key		X	X	X	X	
	8. Thread needle		X	X	X	X	
	9. Telephone		X	X	X	X	
	10. Dry dish		X	X	X	X	
	11. Support mixing bowl and stir		X	X	CP	X	
	12. Sweep with straw broom		X	X	CP	X	
	13. Dust pan and brush		X	X	X	X	
	14. Remove wallet from pocket					X	
	15. Take bill from wallet		X	X	X	X	

EVALUATION OF TRAINING FOR UPPER-EXTREMITY AMPUTEE (Continued)

Date Completed	Suggested Activities	Without Prosthesis	Unilateral B/E with hook	Unilateral A/E with hook	Unilateral S/D with hook	Bilateral with hooks B/E, A/E	Comments
G. PLAY							
	1. Pull toys		X	X	X	X	
	2. Push toys		X	X	X	X	
	3. Place peg in hole					X	
	4. String beads		X	X	X	X	
	5. Place 2 and 3 dimensional shapes					X	
	6. Catch ball (12")		X	X	CP	X	
	7. Doll carriage		X	X	X	X	
	8. Bicycle		X	X	X	X	
	9. Wheelbarrow		X	X	X	X	
	10. Irish mail		X	X		X	
	11. Swing		X	X	CP	X	
	12. Jump rope		X	X	CP	X	
	13. Fishing rod		X	X	X	X	
	14. Bow and arrow		X	X	CP	CP	
	15. Baseball bat		X			CP	
	16. Grasp playing cards		X	X	X	X	
	17. Hand sewing and embroidery		X	X	X	X	
	18. Knit and crochet		X	X	X	X	
	19. Assemble model kits		X	X	X	X	
	20. Woodworking: file, plane, vise; hammer (toy)		X	X		X	

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UPPER-LIMB PROSTHETICS

1971 Revision

(Including Prosthetists' Supplement, 1976 Revision)

Prosthetics and Orthotics
New York University
Post-Graduate Medical School

Reprinted September 1976

Chapters 8, 11, and 12 on Amputee Training, Medical Considerations, and Prosthetic Prescription have been reprinted from the "Manual of Upper Extremity Prosthetics," edited by William R. Santschi, published by the University of California in 1958, which is out of print. Where reflected by the changed type face, these chapters have been edited and revised, in selected instances, by New York University.

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CHAPTER 9

CONTROLS AND USE TRAINING FOR CHILD AMPUTEES

When the child receives his first functional prosthesis, it is sometimes necessary to admit him as an inpatient for intensive training. Usually, however, weekly outpatient training sessions will suffice. This will be decreased in intensity as progress is made. If poor habits should develop, or if more advanced functional needs (such as in ADL) should arise the frequency of the training sessions may be temporarily increased. He returns to the clinic at least every three months for reevaluation of prosthetic fit and operation, and determination of new functional needs. A variety of bimanual toys and activities of daily living appropriate to the child's intellectual age level are employed to train the amputee in the use of his prosthesis as an assistive extremity. The ultimate goal is full-time wear of the prosthesis as an integral part of the child's self-image and function. The therapist works very closely with the parents, instructing them in hygiene, prosthetic maintenance, and obtaining similar toys and activities for home follow-up.

Below is a brief outline of a typical training program:

I. Sequence of <u>passive</u> hook function
   - A. Teach holding function of hook <u>to parent</u>
   - B. Child pulls object out of hook
   - C. Child places object into hook as <u>parent opens hook</u>
   - D. Child opens hook by pulling on thumb

II. Sequence of <u>active</u> hook control (Starts at about 18 months)
   - A. Begin with half rubber band to allow inadvertent, unplanned opening; child actively keeps hook open.
   - B. Therapist passively flexes child's shoulder, child observes opening of hook and then repeats actively; places object into hook with his sound hand
   - C. Later allows hook to close over object by relaxing shoulder on amputated side
   - D. Finally, active release (first does this by pulling object out with sound hand or by banging). Child is unaware the motion is the same as for grasp.

E. Selective hook opening to accommodate objects of various sizes and shapes and proper timing of release. At first, opens hook too much (young normal child also lacks spatial discrimination).

F. Moves prosthetic arm, yet maintains grasp on object (by relaxing sound shoulder so it no longer serves as reaction point for control).

G. Learns that in prehension the stationary finger should be next to object.

H. Since child depends on sight, not tactile sensation, all objects should be placed within view.

III. Until child is 3-4 years old, parent or therapist prepositions TD.

IV. Until A/E is 3 or 4, parent or therapist continues elbow-lock operation while child operates only TD with cable.

V. Until A/E is 5, parent or therapist adjust turntable.

VI. Dressing

A. Doff prosthesis

1. Unilateral B/E: 3-4 years, A/E 4-5 years
2. Bilateral B/E: 3-4 years, A/E 5-6 years

B. Don prosthesis

1. Unilateral B/E: 4-5 year, A/E 4-5 years
2. Bilateral B/E: 5-6 years, A/E 6-7 years

C. Clothes off, prosthesis last; clothes on, prosthesis first.

D. Bilateral amputees

1. Self-dressing techniques depend on motivation and agility; no universal rules.
2. Encourage independence
3. Use of teeth
4. Shrug- or shawl-like stump socks
5. Sleeveless dresses, open in back, split to below waistline
6. Zipper loop for pants
7. Buttonhook
8. Velcro

TRAINING AIDS FOR THE CHILD UPPER-EXTREMITY AMPUTEE

AGE	TERMINAL DEVICE	AIDS AND ACTIVITIES
7 to 8 months: when child sits	Passive	Noisy, colorful, large toys that attract attention to the prosthesis or make the child move it; large soft ball; series of large blocks; cuddle toys
12 months	Passive	Plastic milk bottle, top, roly-poly to hit or knock, large doll, large ball, pull and push toys, cymbals, two sticks with xylophone, large dowel and disks
2 years	Active	Tricycle, Irish mail with help, doll carriage, pop beads, 1-inch beads, nesting barrels, rolling pin and Play Doh, hammer and pegs, pail and shovel
		Bilateral: feeding--swivel spoon, rubber band at hook tips, elbow unlocked
3 years	Active; prepositioning, selective opening. Also active elbow control	Put-together toys, Looney Links, nuts and bolts, medium-size beads Dressing: prosthesis off when child begins taking clothes off, unbuttoning
		Bilateral: feeding--swivel spoon, pusher, plate guard, wet sponge or paper under plate, flat-handled cup
4 years		Scissors (move along paper), coloring, gross and finer-construction toys Dressing: don prosthesis when child begins to dress himself, shrug garment
		Bilateral: feeding--swivel spoon, try regular bent spoon, pusher, wet sponge or paper under plate
5 to 9 years		Construction toys refined, models, crafts, fishing rod and reel, pencil sharpener, writing, sewing, jump rope, ball games
		Unilateral: feeding--knife and fork by age 6 or 7; carry tray Dressing--garment fastenings (lace, knot, tie bow; zip jacket, pants) Unilateral should be independent by age 8 years
		Bilateral: feeding--cup held from above
9 to 15 years		Knitting, woodworking, leather lacing, loopers, bead work, card games requiring player to hold many cards with controlled cable tension
		Unilateral: grooming--brush, comb, set hair, toothpaste and brush, lipstick
		Bilateral: dressing--clothing adaptations Toilet--with or without devices, such as reacher, split pants, sanitary panties

CHAPTER 10

CARE OF UPPER-LIMB PROSTHESES

HOOK AND WRIST UNIT

1. Use just enough motion to open or close the hook.

2. Do not use the hook as a hammer.

3. If your hook operates with rubber bands, be sure to replace weakened ones. When you are learning to use your hook, one or two bands are sufficient. When you start using it regularly, three are suggested. Should you do heavy work and need more force, add more bands.

4. Strong acids, lacquer, and paints will weaken the neoprene rubber lining of your hook. Avoid contact with these. Rough usage will also damage this part of the hook. The hook should be retreaded when the lining is worn.

5. Keep the hook clean and free from dirt.

6. Never oil the hook yourself. If it does not function properly, take it to your prosthetist for repair.

7. Keep the wrist unit clean and avoid getting dirt in it. Otherwise, you will have difficulty turning the hook and changing terminal devices.

CABLE

1. Should the cable break, return the prosthesis to the prosthetist for repair.

2. When using cable adapters, be sure to keep them with the hook or the hand so they will be available when you change your terminal device.

3. If the cable housing starts to spread, check with the prosthetic facility. Excessive spreading of the housing will cause the cable to wear.

4. If there is excessive friction in the control system between cable and housing, check for a kink in the cable.

HINGES AND ELBOW UNIT

1. Never oil the hinges on the below-elbow prosthesis. If you cannot bend your elbow easily, consult the prosthetist.

2. Never oil the elbow unit with internal mechanism; if it does not function well, take it to the prosthetist for inspection.

SOCKET

1. Wipe the socket daily, using a wash cloth with soap and water. Dry the socket thoroughly before wearing it. Do this more often if you have been perspiring.

2. Wash the socket every other week with a dilute solution (1 per cent) of formalin or rubbing alcohol.

   Directions for washing the socket:

   A. Wipe solution inside the socket with a cotton swab.
   B. Leave it on one to two hours.
   C. Rinse the socket with alcohol.

3. Keep the outside of the socket clean with soap and water.

4. The metal fixtures on the socket do not require oiling.

LEATHER

1. Clean the inside of the leather cuff (the portion in contact with the arm) daily with a damp cloth and allow it to dry thoroughly before wearing it.

2. If the leather does not have a protective coating, clean the outside of the cuff with saddle soap every week.

HARNESS

1. Remove the harness from the socket at the buckles and wash it with soap and water. This should be done weekly. Be sure to clean under the plastic covering.

2. If the tips of the harness straps become worn or ravel, singe them with a match flame to seal the edges.

APRL HAND

1. Never try to remove the glove from the hand yourself. Have the prosthetist change the glove.

2. Wash the hand at least three times daily with a wash cloth, soap, and lukewarm water. Do not let water get inside the mechanism of the hand. If there is a tear or crack in the glove, avoid wetting this area.

3. When not wearing the hand, keep it stored in its plastic bag in a box in a dark place. The glove will darken slightly with age and with exposure to light.

4. The following are some of the substances which should be washed off the glove immediately with soap and water (not cleaners or solvents):

   Grease, fountain pen ink, food (except mustard and egg yolk), and alcoholic beverages, such as beer and whiskey.

5. The following substances will weaken the glove if kept on the glove more than one hour:

   Gasoline, benzine, kerosene, turpentine, and carbon tetrachloride.

6. The following materials will stain the glove permanently. Efforts should be made to keep the hand away from these. If the glove becomes stained, wash it immediately.

   Fresh newsprint, carbon paper, lipstick, brightly dyed fabric, tobacco stain in large quantities, mustard, and egg yolk.

7. Since ball point pen ink dries on contact, it will stain the glove permanently and should therefore be avoided.

8. Lacquer and shellac weaken the glove, so do not rest your hand on these surfaces for prolonged periods. Do not leave the hand on a painted or varnished table without first placing it in its plastic bag.

9. Never oil or grease any part of the hand.

10. Remember use just enough force to lock your hand in the desired position. Excessive force will make it difficult or impossible to unlock it.

11. If your hand mechanism sticks, return it to the prosthetic facility to be repaired.

Medical Considerations

Although parts of this chapter are directed primarily to the surgeon, the content is pertinent for all who participate in amputee management. A summary of the medical causes of amputation is followed by a discussion of preparing the patient for amputation medically and psychologically. Sites of amputation, amputation surgical technique, post-operative care, physical therapy, stump hygiene and stump pathology are then reviewed and concluded with the role of the surgeon in the prosthetic clinic team.

The causes of amputation are summarized in tabular form as Table II-1.

PREPARATION OF THE PATIENT FOR AMPUTATION

When amputation has been decided upon, it is the physician's duty to make sure that the patient really understands the necessity for the procedure, what will be done, and the conditions that will face him afterward. Laymen usually do not have a clear picture of amputation or of rehabilitation, and may have many erroneous conceptions. It is best to explain to the patient the level of amputation selected and the reasons for it; then describe the step-by-step plan for post-operative conditioning of the stump, the pre-fitting exercise program, what can be expected of a prosthesis, and how the patient will be helped to readjust socially and economically to his amputation. It is also advisable to inform the patient that he will probably experience some phantom sensations, a usual sequel to amputation, and that the phantom limb will probably grow fainter with time, and perhaps disappear entirely.

It is important to avoid needless anxiety. Any person faced with amputation will have

TABLE II-1. CAUSES OF AMPUTATION

A. Congenital
   1. Agenesis (failure to develop)
   2. Malformation
B. Trauma and its sequelae
   1. Traumatic amputation
   2. Compound fracture with nonunion or malunion
   3. Penetrating wounds with blood vessel damage; thrombosis, embolism, and traumatic aneurysm
   4. Burns and frostbite
C. Peripheral vascular disease
   1. Arteriosclerosis
   2. Arteriosclerosis with diabetes
   3. Buerger's disease (thromboangitis obliterans) and Reynaud's disease
D. Thromboses and embolisms
E. Malignant growths
F. Infections
   1. Pyogenic osteomyelitis or arthritis
   2. Granulomatous osteomyelitis or arthritis
   3. Infection superimposed on arterial insufficiency
G. Trophic changes
   1. Spina bifida
   2. Charcot joint
   3. Leprosy
   4. Cord injuries and neoplasia
H. An insensitive, cold, or painful extremity which is functionless and a burden to the patient's hand

many questions and many worries: How will amputation affect his job, his social life, his hobbies? How will he look? What attitude will people take toward him? How good is an artificial arm — if, indeed, the patient knows that a functional prosthesis can be obtained. It is highly advisable to take the time to elicit his questions and answer them fully. The help of a psychologist, social worker, therapist, or prosthetist can be enlisted for alleviating and solving these problems.

Physical preparation of the patient will obviously include local and general treatment as necessary to put him in the best possible condition to undergo surgery. Pre-operative exercises to increase general muscle tone are advantageous. The part to be operated upon should be freed of infection if this is feasible. If the extremity is cold and clammy, with poor circulation, as in Buerger's disease, more prompt healing may often be assured by a prior sympathetic ganglionectomy. Diabetes, if present, must be brought under control. Protein balance and an adequate red cell count should be obtained by replacement therapy, if necessary.

SITES OF AMPUTATION

Improved surgical techniques, the discovery of antibiotics, and the development of new prosthetic materials and devices, have all contributed to the trend toward more conservative amputations. Newer techniques make possible the preservation of length previously sacrificed. Except for certain points in the hand (specified below), every bit of length remaining in the upper extremity can now serve a purpose, provided the amputee is fitted with a prosthesis and components wisely selected in accordance with the principles laid down in Chapter III.

The changing attitude toward "sites of election" in the upper extremity is illustrated in Figure II-1, where the previous contraindications against amputation at certain levels are shown to be eliminated by the development of prosthetic equipment suited to these amputation levels. It should be noted that, prior to World War II, many surgeons were in favor of leaving the humeral head in place when performing a shoulder amputation, for cosmetic reasons. New developments have added prosthetic reasons.

The Hand

The desirability of preserving all possible length in the fingers and hand is universally acknowledged. The only exceptions to this are:

1. In the phalanges, it is better to shorten the finger slightly than to leave the bulbous and relatively tender distal expansion of these bones.
2. In most instances, the distal two-thirds of the second and fifth metacarpals should be excised when the corresponding finger must be sacrificed. The presence of a knuckle in the absence of the finger is unsightly, frequently sensitive, and often traumatized. However, the patient may be unwilling to give up a quarter of the breadth of his palm.
3. The distal two-thirds of the third and fourth metacarpals may be removed for cosmetic reasons under similar circumstances. The tough palmar skin should cover the stump end.

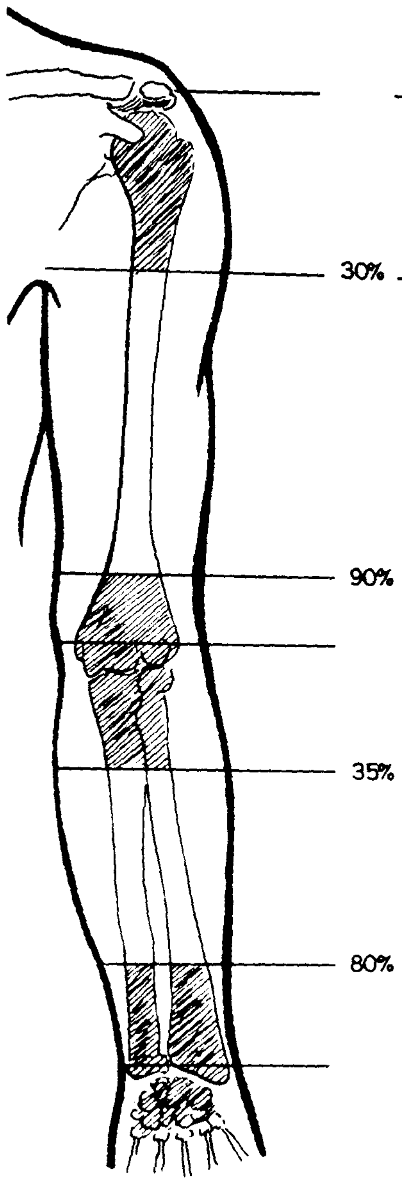
Wrist and Forearm

Amputations through the wrist area were universally condemned for prosthetic reasons until recently. However, the development of the present Wrist Disarticulation prosthesis has made it possible to preserve the dorsal and volar flexion and full rotation, while providing a functional prehension device, without extreme length of prosthesis. In the wrist disarticulation operation, resection of the radial and ulnar styloids obviates unsightly and easily traumatized prominences.

The Krukenberg amputation, in which fingerlike appendages are fashioned by separating the two forearm bones for prehension, presents no prosthetic problem, since no prosthesis is indicated. It is rarely used in the United States; however, it has one great advantage for blind patients — sensation is preserved.

Amputations At and Above the Elbow

The proximal portion of the ulna and the distal end of the humerus have similarly been



TYPE	PREVIOUS REASON FOR REJECTION	NEW DEVICE	ADVANTAGE OVER NEXT HIGHER AMPUTATION
Shoulder: Humeral Neck	Too short for AE socket	Improved Shoulder socket and harness	Increased control of prosthesis
OBSOLETE SITES OF ELECTION			
Elbow Disarticulation	No room for Elbow Unit	Outside Locking Elbow Hinge	Better control of humeral rotation
Very Short BE	Too short for socket	1. Step-up Hinge 2. Stump-Actuated Locking Hinge	1. Retains position sense of elbow 2. Better control of elbow lock than AE
OBSOLETE SITES OF ELECTION			
Wrist Disarticulation	Prosthesis forearm too long	Special wrist components	Better control of pronation-supination
Transcarpal	Prosthesis forearm too long	Special wrist components	Better control of pro-nation-supination and wrist flexion

Unshaded: Obsolete sites of election   Shaded: Sites discussed above

FIGURE II-1. Amputation Levels Now Useful for Prosth ill-regarded in the past as amputation sites, principally because of the difficulty of prosthetic fitting. Newer devices, such as the step-up elbow hinge and the outside locking elbow joint, have overcome these difficulties. Even a very short residual ulna, too short to be useful in flexing the prosthetic forearm, can be used to operate the prosthetic elbow. And the Elbow Disarticulation amputee can now be fitted with a prosthesis of normal length, with the elbow in normal position.

Above the elbow, all possible length should be preserved. Even though a humeral stump above the deltoid and pectoral insertions lacks motion, every inch of length is functional in that it increases the stability and thus improves the function of the prosthesis.

Shoulder Disarticulation and Scapulothoracic (Forequarter) amputations are occasionally necessary. The surgeon can do little to aid the prosthetist in these cases, other than provide a pad of muscle beneath the skin, and good skin without scars.

Summary

There are today no sites of election in upper extremity amputation. With certain exceptions in the hand noted above, all possible length should be retained.

AMPUTATION SURGERY

The aim of the amputation surgeon is to produce a firm tapered or cylindrical stump, free of sensitive scars, with bone well padded along its length and covered at its tip by healthy, nonadherent fascia and skin. The suture line should be located as far as possible from the prosthesis pressure areas on the anterior surface. Healthy skin is essential if the stump is to withstand use; split skin grafts will not accomplish this purpose.

Of the two general types of amputation—the open and the closed—the closed, flap, or plastic amputation is performed whenever possible. Open or circular amputation is an emergency operation only, performed when the extremity is grossly infected or in traumatic cases where such infection is probable. It is performed at the lowest possible level and is followed after three to eight weeks by a secondary closure.

The Closed, Flap, or Plastic Amputation

Details of the technique of the closed amputation are well covered in numerous texts and will not be reviewed here. The important consideration is the construction of adequate skin flaps which cover the stump without tension. A fishmouth incision is universally used and, as mentioned above, it should be planned so that the suture line falls in an area that will not be subject to pressure from the prosthesis. Deep fascia is incised at skin level. The muscle mass is cut back far enough so that, after the bone is divided, the retracted ends of the muscle will be the same length as the bone. The bone therefore is sawed off an inch or more proximal to the level of the skin incision, depending on the size of the muscle mass.

Most surgeons believe that the periosteum should be stripped from the bone for about a half-inch above the line of the saw cut, in order to prevent the formation of spurs by periosteal proliferation. In the forearm, both bones are cut at the same level.

Blood vessels are pulled down gently, ligated, and cut so that they will retract well above the bone end. Nerves are likewise pulled down gently and cut proximal to the bone end, so that the inevitable proliferation of nerve fibers in this area will be well protected by the muscle mass and will not be pinched between the prosthesis and the bone end. Some surgeons inject the nerves with a sclerosing solution; others bury the main nerve trunks in the bone. The majority of surgeons feel that these procedures are unnecessary.

Careful hemostatis is secured. Deep fascia is sutured over the bone end. Drains are inserted at the ends of the suture line, and the skin is closed. If there is any tension on the skin, traction should be instituted. The stump is bandaged for shrinkage with elastic bandage on the operating table; compression should be maintained post-operatively until a prosthesis is worn. The drains are removed in 48 to 72 hours.

Technique of the Open or Circular Amputation

As the name suggests, this is a procedure in which the wound is left open. It is done at the lowest possible level, regardless of prosthetic considerations, and usually by the modified guillotine procedure. The extremity is removed as quickly as possible, with minimal operative trauma.

A circular incision is made through skin, subcutaneous tissue, and deep fascia. The skin is permitted to retract. The soft tissues are divided, permitted to retract, and the bone or bones sawed off squarely. No sutures are inserted. The application of immediate skin traction, and its maintenance until the wound is fairly healed, is mandatory. Failure to keep traction on this type of wound invariably results in retraction of the skin and soft tissues with protrusion of a raw bony surface, extensive scarring, and perhaps infection with much pain. Sequestration of the bone end may occur. Continuous traction, on the other hand, maintains a protective pad of muscle tissue on all sides of the bone. Further, it pulls the skin edges down over the muscle mass, promoting much more rapid healing and a properly shaped stump.

In the secondary operation after three to eight weeks, the surgeon plans to achieve a stump that is well shaped, covered by good skin, and meets the other requirements mentioned above.

POST-OPERATIVE CARE OF THE STUMP

Traction must be maintained after open amputation, and in closed amputation if the skin is under tension. To prevent hemorrhage, edema, and swelling, and to promote shrinkage, compression bandaging must be maintained until the fitting of the prosthesis. The stump should be freshly bandaged at least once a day with elastic bandage, applied tightly at the distal end and snugly at the proximal end. *It is important to avoid loose bandaging at the tip, and tightness at the proximal end of the stump.*

Prevention of joint contractures is a cardinal requirement. A splint in position of function may be used if desired, but is not usually necessary. The important considerations are not to position the stump so that joint contractures develop, and to mobilize it as soon as possible.

POST-OPERATIVE PHYSICAL THERAPY

All joints proximal to the site of amputation should be moved through their full range of motion at least three times daily as soon after amputation as possible. These motions should be performed by the patient if possible, or by the physical therapist when the patient cannot voluntarily perform the motions.

After healing, the patient should be encouraged to exercise the residual muscles of the stump. These exercises are performed simply by having the patient contract his muscles against no resistance, in the manner of quadriceps setting. This has the effect of assisting the circulation, preventing adherence of scar tissue, and reducing edema.

Massage of the stump can be started after healing is complete. The principal value of this technique is to overcome fear of having the stump handled. It also may act to prevent adhesions and assist the venous flow.

Mobilization of the Shoulder and Arm Stump

It is imperative that an upper-extremity amputee have a mobile shoulder girdle, as the limitation of motion of any segment will result in a corresponding limitation of other segments. For example, limitation of scapular motion on the thorax will restrict the range of humeral motion and thus impair prosthetic function. Exercises designed to maintain a freely mobile shoulder girdle are necessary. These must be done bilaterally, as the amputee uses both shoulders for prosthesis operation, either for actual motive power or for "body English." The exercises involve elevation of the shoulders and abduction-adduction of the scapulae, both free and against resistance.

Flexion of the Above-Elbow amputee's humerus is the source of power for both forearm flexion and prehension in the commonly used dual control system. This motion must be developed to provide the amputee with a strong "motor" through a full range of movement. Extension of the humerus is used as the control motion for the elbow lock, and must also be well developed. Both free and resistive exercises should be used routinely at least twice daily.

When the Above-Elbow amputee flexes or abducts his stump, or a combination of the two, there is a tendency for the stump and prosthesis to rotate internally. The amputee can control this, as in a normal arm, by using the rotator muscles of the upper arm. The development of these muscles can be carried out by having the patient rotate the stump through the full range and contract firmly at the end of the range. Unilateral amputees of long standing may have lost the ability to control these muscles; consequently, the techniques of muscle re-education may be necessary.

Mobilization of the Forearm Stump

For the Below-Elbow amputee, the movements of forearm flexion-extension and pronation-supination must be developed through the maximum range. Limitation of forearm flexion prevents use of the prosthesis in the most vital action spheres, such as the mouth and chest. Many amputees discard the prosthesis because they are unable to perform tasks requiring full flexion. Simple forearm flexion exercises, both free and against resistance, should be performed twice daily in order to develop a full range of motion and normal strength through the range.

The harnessing of pronation-supination is difficult at best, and practically insurmountable if further complicated by a limitation of stump rotation. If the amputee of more than two-thirds forearm length has a limited range of pronation-supination, passive stretching should be undertaken. This should be done by the physical therapist twice daily, and continued by the amputee at home or in the ward. When some degree of mobility has been achieved, active pronation-supination should be practiced. The patient should pronate through his complete range and then contract hard. This has the effect of stretching the various limiting tissues, as well as developing the strength of the muscles. This procedure should be repeated in supination.

Development of the Residual Biceps

Apart from harnessing, the Above-Elbow amputee has an additional source of socket stability. Contraction of the biceps bulges it against the socket, improving the stability both by increasing the pressure on the socket and by firming the stump. Exercises to develop the biceps can be carried out simply by having the amputee contract his muscle strongly. This technique is in keeping with the principles of progressive resistance exercises, except that the amount of resistance is unknown. While no forearm flexion is possible, the tight investing tissue provides resistance enough to encourage biceps development. The amputee should contract his biceps through its full range and then attempt to contract even harder. This stretches the surrounding tissue, increases the contractile range and strength of the muscle, and aids in decreasing the excess tissue of the flabby stump on which the prosthesis tends to rotate.

Correction of General Body Mechanics

In the Short Above-Elbow or Shoulder amputation, various deviations from normal posture may be caused by the loss of the weight of the member. The resultant shift in the center of gravity, and the atrophy of the musculature on the side of the amputation, may cause scoliosis with or without compensatory curves. Cases have been seen with a difference of 1.5 inches between the acromial heights measured from the floor. Scoliosis exercises should be performed to correct these deviations, improve the appearance, avoid postural back strain, and place the muscles in the proper anatomical positions for use. In addition, passive stretching of the elevator muscles of the shoulder complex should be carried out to assist in maintaining the shoulder level and in freeing the shoulder movement.

Stump Shrinkage—Plaster Bandage Technique

The importance of proper bandaging to support the soft tissues and promote stump shrinkage has been discussed. Despite proper bandaging, further shrinkage always occurs when a prosthesis is worn. Shrinkage ranks as a problem in the Above-Elbow stump that has not been fitted with a prosthesis, because usually the amputee uses his AE stump very little and leaves it hanging at his side, two factors which act to induce a flabby and sometimes edematous stump. By contrast, the Below-Elbow amputee usually makes much use of his stump for holding, lifting, and carrying objects.

For "problem stumps" which are fat or edematous, the writer* has had uniformly good results in about 30 cases with an unyielding plaster of Paris bandage. The plaster bandage is applied over a thin cotton stump sock, as described for the wrap in the fabrication chapter, but slightly tighter. The amputee should feel slight pressure, which should disappear within 24 hours. The plaster bandage is suspended by a regular Figure 8 harness, thus accustoming the amputee to the harness before prosthetic fitting. The plaster bandage should be replaced as soon as it starts to slip, which may be as often as every three days. Girth measurements should be taken whenever the plaster bandage is removed. When the measurement remains the same for a period of one week, the shrinkage attainable by this technique is considered to have been accomplished, and the stump is considered ready for fitting.

*H. Jampol

STUMP HYGIENE

The stump should be washed nightly with a good quality of soap, and dried thoroughly. For normal stumps, the application of alcohol or any other astringent is not advocated, nor is the application of any solution to toughen the stump. Gentle massage with olive oil or liquid petrolatum, and light powdering, may be used if desired.

Common problems in amputation stumps, and recommended treatment, are summarized in Table II-2.

STUMP PATHOLOGY

In some cases, there may be limitations of joint function due to trauma or infection. In other conditions, not all the pathology is removed by the surgery; this is true of some neurotrophic conditions, certain infections, and peripheral vascular disease. (Loss of more than the fingers from peripheral vascular disease is extremely unusual, and no particular prosthetic difficulty is presented thereby—unlike the situation in lower extremities.) Severe burns, followed by extensive split skin grafting of the stump, may leave much of the skin

TABLE II-2. COMMON PROBLEMS OF STUMP HYGIENE

Problem	Recommended Treatment
Ingrown hairs	Plucking
Infection of hair follicles	Wash nightly with pHisoderm
Excessive perspiration	Drill ventilating holes in prosthesis Wear thin cotton stump sock, fresh daily Apply Aluminum Chloride twice weekly; 20% solution if tolerated, otherwise 10%
Cannot tolerate AlCl	Rub with alcohol instead
Fungus infection (red-brown encrustation, weeping)	Wash socket with alcohol Stop wearing prosthesis until cleared up Apply 5% formalin nightly, washing it off afterward with alcohol
Blackheads	Apply moist heat, followed by squeezing
Infected sebaceous cyst (small tender inflamed tumor)	Apply moist heat If fluctuating, incision and drainage
Recurrent infected sebaceous cyst	Excision Packing cyst with silver nitrate crystals has been done, but is extremely painful for a day or so
Chafed areas	Ultraviolet radiation often helpful

hypertensive to any pressure. Marked congenital defects in form and function may also be found.

Conditions That May Preclude Immediate Fitting

Certain definite physical signs in stumps indicate the necessity for medical consultation prior to fitting. These include any evidence of chronic skin irritation such as eczema, excoriation of skin with weeping lesions, tiny hemorrhages, or hot, tender, red areas indicating the presence of inflammation. Palpable tender masses are sometimes indicative of neuromata or bony spurs, which may or may not need excision. Bony overgrowths are usually of minor significance unless painful. Relief of the socket over them ordinarily suffices to permit comfortable use of a prosthesis.

Relief of the socket may be all that is necessary for a neuroma. Painful neuromata are often successfully treated by injection or ethyl chloride spray. Excision is not always followed by relief of pain; occasionally, section of the pain tract in the spinal cord is necessary before relief is secured. Psychotherapy is often beneficial.

Extensive sensitive scars for which relief of the socket is not practicable can often be surgically resected to make a better stump. Areas of thin skin over bony prominences, which break down under mechanical influences, should be replaced by healthy, full-thickness skin.

Conditions Arising After Fitting

All the conditions just noted may develop after the amputee begins using a prosthesis. Treatment is the same as before fitting. Irritation, excoriation, or ulceration of the skin may occasionally result from local pressure of the prosthesis over a particular area, or as the result of an imperfect fit. The remedy is the correction of the causative condition. Edema of the stump sometimes results from choking by too tight a fit at the top or the end of the stump; enlargement of the socket in the constricting area is indicated. Flaws in construction, wrinkles, creases, and cracks in the socket material are technical errors and will be avoided by following the directions given in the chapters on fabrication.

Phantom sensations are experienced by the vast majority of amputees and are usually not painful. True phantom pain is a serious, often baffling complication for which medical treatment is indicated, but is not within the scope of this discourse.

ROLE OF THE SURGEON IN THE PROSTHETIC CLINIC TEAM

The surgeon is dependent on the therapist for conditioning the stump, and on the prosthetist for the artificial limb. They, in turn, anticipate that the surgeon will present them with the best stump which surgical skill will permit in the given instance. They expect a firm, rather tapered stump in which the bone is covered on all sides by good padding and at the tip by healthy nonadherent fascia and skin. They expect the stump to be free of contractures and sensitive scars, and without infection.

The surgeon's responsibility does not end when the operative wound is healed. It continues throughout conditioning of the stump, restoration of function in the remaining muscles and joints, psychological acceptance by the patient of his handicap, prescription of a suitable prosthesis, and training in its use. These obligations necessitate the cooperative action of the prosthetic team: patient, doctor, physical therapist, psychologist, amputee trainer, and job counselor. Each has an important and interdependent role in the rehabilitation of the amputee. The prescription of the prosthesis, however, is the duty of the physician. It cannot be delegated to the prosthetist. A knowledge of the various types of prostheses, their performance and limitations, and their adaptability to the type of amputation and type of amputee is essential.

Prosthetic Prescription

The prescription of equipment and other services, such as medical treatment, physical therapy, and psychological treatment, is the focal point of the amputee prosthetics program. It is during prescription that the clinic team members combine their knowledge to provide the specific plan for each amputee's rehabilitation program.

With the information on such personal factors as medical history, vocation, avocation, fitting history, preferences, gathered in the initial interview, the clinic team is enabled to carry out its decision-making function efficiently and completely. As clinic team procedures may vary considerably according to local conditions, it will be most useful here to state the principles basic to a proper prescription, leaving to the individual group the question of detailed application.

As a matter of interest and for lack of other data concerning the particular categories discussed in this chapter, examples and statistics are included which are drawn from the UCLA experience, an exhaustive study of 240 arm amputees, including 22 bilateral cases, between 1950 and 1954. In this chapter, the term "cases" refers to individual amputees, while the term "stumps" includes both stumps of bilaterals.

The prescription form shown on pages 15 and 16 not only contains the specifications of the prosthesis and its component parts, but also contains the recommendations for other services such as medical, surgical, and therapeutic. The form is arranged in two parts, the first part is concerned with primary factors to be considered in the prescription, and the second part is concerned with the specification of the prosthesis.

Pre-Prescription Information

Background information is required if an effective prescription is to be made, but much of this information should be gathered before the prosthetic clinic meeting and recorded on a Medical-Prosthetic Summary Form, such as that shown on pages 10-13.

Experience has shown that the amputee is often ill at ease if questioned in front of the group and may not express himself freely. When the case history is unusual, members of the clinic team need to study this information prior to the meeting. A recommended procedure is to have a qualified member of the clinic team administer the pre-prescription interview in private and present the information to the clinic prior to the arrival of the amputee. This enables the members to discuss the case freely. Upon admittance of the amputee, the clinic team can utilize its time most effectively by adding to their prior knowledge. Amputee A. serves as an example of why pre-prescription information is extremely valuable in many cases.

A. is a female shoulder disarticulation amputee, aged 68. During the pre-prescription inter view it was ascertained that she had undergone several operations in the previous ten years. The names of the hospital and physician were obtained, and at the time of the prescription meeting a full medical report was available. The report indicated that the operations and the amputation were necessitated by a malignancy and that the prognosis in the case was unfavorable. Because of this information, and also in consideration of her advanced age, the clinic team agreed that a functional prosthesis was contraindicated. However, a shoulder cap was prescribed for cosmetic purposes, since A. expressed concern with her appearance.

Medical and Social Factors

In this category are three important areas of clinic decision: determination of the amputee type, evaluation of general health, and diagnosis of specific stump conditions. The first of these is dealt with at length under *Prosthesis Specification.*

General health. From the sample, there is no reason to believe that the general health of the amputee population varies significantly from the general health of the total population. Perhaps the only exception is the presence of malignancies, which were found to exist in only four of the amputees seen. All four were shoulder disarticulation cases, and all four died soon after fitting. However, the importance of obtaining a medical record from the amputee cannot be overemphasized, despite the low incidence of general health disorders in the amputee population. It is necessary to find out whether or not the amputee has been treated for his amputation by any previous physician or rehabilitation agency. If he has, then it is required under the code of professional ethics to get clearance from that physician or agency and to find out what was done for the amputee's welfare. The amputee may be afflicted with some physical condition which can be aggravated by participation in a rigorous rehabilitation program. Finally, it is necessary to discover any conditions which should be treated before fitting is attempted. Of cases seen at UCLA, 11 percent presented various medical problems, but of these, only half were considered serious enough to warrant attention before a prosthesis could be prescribed.

Stump conditions. Insofar as the stump itself is concerned, it appears that abnormalities, such as bone spurs, tender scars, skin rashes, neuromas, and other stump conditions, are of low statistical importance. When present, many of these can be dealt with by suitable fitting modifications. For example, 23 percent of stumps examined at UCLA had hypersensitive areas which were painful to the touch. Only one amputee, however, had to undergo surgery for removal of a painful neuroma. The others were fitted satisfactorily by marking the location of the neuroma and relieving the socket over this area. Bone abnormalities were present in 13 percent of the stumps, but in only one case was surgery required.

Physical Therapy

Fifty percent of the UCLA amputees were believed to be in need of physical therapy. The prescription for such therapy was based, in many cases, on the body mechanics examination, conducted before the prescription meeting. In prescribing physical therapy the clinic must consider several factors, all of which play an important role in fitting the amputee with a prosthesis and teaching the amputee how to use the prosthesis. These factors, which will be discussed briefly, are stump shrinkage, stump strength and range of motion, and postural problems.

Stump shrinkage. There is agreement that shrinkage is a bothersome problem, but lack of agreement as to how it should be handled. Investigations of shrinkage are complicated by the fact that often the need for new sockets, which may be attributed to stump shrinkage, is actually due to poor initial fitting. Fourteen percent of the sample were judged by the clinic teams to have stumps sufficiently flabby or edematous to present shrinkage problems; half of these were amputees of less than a year's standing.

Stump strengths and ranges of motion. These are easily determined by examination during the pre-prescription contact and, at the clinic meeting, exercises should be prescribed to remedy any deficiencies. The data indicate that forearm and humeral rotation are the motions most seriously affected. Approximately 80 percent of the Above-Elbow amputees had limitations of humeral rotation, and 80 percent of the Below-Elbow amputees had limitations of forearm rotation. The clinic prescribed therapy, not only on the basis of the magnitude of the limitation, but also on the basis of the increase that could be expected. Thus, certain cases that are considered absolutely limited in range of motion by bone malformations did not get physical therapy. In none of the cases was a delay in fitting considered necessary, since it was believed that the use of the prosthesis itself would serve to increase the strength and range of the stump's motion.

Posture. Marked postural deformities have been infrequent among the sample. Studies have shown that Above-Elbow amputees tend to carry the shoulder on the amputated side slightly higher. In only one case was a marked scoliosis present.

Vocational and Avocational Considerations

Perhaps some of the most significant criteria for prescription of a prosthesis can be obtained from vocational and avocational data. In fact, a distinction has been made between "heavy duty" and conventional prostheses, the former being prescribed for amputees engaged in heavy work, and the latter for amputees engaged in all other jobs. However, in the cases tabulated, only three heavy duty prostheses were prescribed. Yet the prescription of heavy steel hooks was frequent on the ground of occupational requirement.

The terminal device is extremely important to the amputee's vocational success. Unfortunately, present-day terminal devices do not approach the natural genius of the hand, and in many cases amputees are forced to change their vocations following amputation. The data indicate that by far the greatest occupational effect of amputation is on skilled and semi-skilled laborers who are unable to continue their original occupations. This is not only potentially a source of emotional maladjustment but also one of reduction in earning power. The clinic can render a valuable service to the amputee by attempting to reduce any arbitrary change in occupation. Very often, large industrial firms shift the amputee because of mistaken notions about the utility of a prosthesis. Ideally, the clinic, which has the total rehabilitation of the amputee to consider, should serve in an advisory capacity on any contemplated change in occupation.

Amputee B. is a case in point. He lost his arm while working as an installer of elevator and electrical equipment. The large firm by which B. was employed sent him to their own physician and decided to employ him in the office at approximately half his former salary. This reduction in income caused the man and his family severe dislocation. Ideally, this case should have been handled by a clinic who could at least have tried to return him to his pre-amputation job by the simple expedient of prescribing the best prosthesis and training. As it turned out, B. left his office job and went to work elsewhere as an elevator repairman. He is gradually working his way back to the position he was so arbitrarily removed from ten years ago.

The prescription of terminal devices may be influenced by the diversity of the amputee's vocation and avocation. The criteria must be based on logical considerations until thoroughly validated by experience.

Amputee C. was employed as a salesman and enjoyed fishing, model construction, and collecting stamps. An APRL hand was prescribed to meet his vocational requirements as a salesman and an APRL hook was prescribed for his avocational pursuits.

Another amputee, D. worked as an assembler of outdoor furniture and as a punch press operator. A steel hook was prescribed, as it was felt that an aluminum hook would not stand the heavy usage.

Psychological Factors

Although there is no evidence to indicate that the amputee population varies significantly from the non-amputee population with regard to emotional stability and other such factors, the clinic should be attentive to any psychological problems which may exist. A negative attitude toward the amputation and prosthesis can act as a deterrent to rehabilitation. Naturally, the clinic should note any gross deviations from "normal" behavior. It is a waste of time and money to fit any amputee with an expensive prosthesis, and then to accept failure because the amputee does not cooperate fully. It is generally accepted that the individual must be motivated toward his own rehabilitation, if it is to be successful.

Quantative data do not permit any generalizations about the effect of prosthetic application on personality disturbances. However, it is important to differentiate between the new amputee and the amputee of long standing. As more and more clinics come into operation, a greater percentage of patients will be new amputees. Such patients are greatly aided in their personal adjustment by directing their attention to functional replacement. The clinic should be careful to supply any necessary psychological counseling which may promote a positive attitude toward the utilization of a prosthesis.

Personal Factors

Included under personal factors which the clinic team should consider are the amputee's age, sex, educational history, prosthetics history, and personal preferences. The age and sex factors require no explanation, but one may question the importance of educational history.

Educational background. In many cases, this has helped to complete the picture of the amputee, and thus provide a better prescription. The following case is illustrative:

Amputee E., a Short Above-Elbow case, aged 20, had a history which indicated lack of specific educational training. This information led to the prescription for educational and vocational guidance, and he was referred to the State Department of Vocational Rehabilitation. Here, the promotion of occupational adjustment aided the prosthetic adjustment of the amputee.

Another case further illustrates the importance of educational history. Amputee F. presented a complicated picture, and the clinic team considered the prescription of a "trial and error" program in which several prostheses would be tried and subjected to his criticism. If F.'s educational history had not revealed that he was qualified for participation in such a program, it would not have been attempted. As it turned out, this amputee was extremely cooperative and even contributed a design for his own harness.

Prosthetics history. This is a complete record of the amputee's previous experience with artificial limbs. The amputee who has had extensive experience is in the best position to evaluate his previous prostheses. This information can prevent the repetition of previous errors in prescription.

Amputee preferences. These should be considered even if they are to be dismissed as irrelevant by the clinic team. Actually, experience has shown that the large majority of amputees do not express a specific preference. However, where specific preferences do exist, they should be noted, and if the prescription is in violation of these preferences, the reasons should be explained to the amputee. The manner of handling these situations may make the difference between a cooperative and noncooperative subject.

PROSTHESIS SPECIFICATION

The obvious anatomical basis for the general form and composition of the prosthesis is the level of amputation. This determines, to a very large extent, the residual function and therefore the functional regain which is possible in the prosthesis. There are two major elements in prosthesis design: the socket form, which determines the purchase upon the stump and the fixation of the mechanical components; and the harness, which is contrived to utilize substitute body motions in the operation of the prosthesis.

Level of Amputation

Level of amputation is the first consideration in the selection of a prosthesis and its components: as shown in the accompanying charts, "Amputee Type" and "Prosthesis Type" are the same except in atypical cases. The levels are chiefly described as percentages of the segment length, i.e., acromion-to-epicondyle for AE's, epicondyle-to-styloid for BE's, with additional criteria applied in the cases of the shoulder and partial hand amputations (see page 46). It should be emphasized that while these levels are arbitrary in detail, they demarcate functional zones which call for special types of equipment. Special cases may call for the prescription of a prosthesis of an adjacent level.

As a result of advances in equipment design, the older concept of favored sites of amputation has been abandoned and the surgeon now strives to preserve all possible functional length. It is essential that in the prescription, intelligent selection of equipment be made to attain the functional potential thus made available.

Socket Type

For each stump length, as determined by amputation level, there is a characteristic socket form. The general features are emphasized in this section.

First, the socket must have sufficient axial length to gain stable purchase upon the stump. At the same time, limits must be placed upon this length to prevent it from impeding the full use of a residual function. For example, the Humeral Neck socket is limited to the scapular area posteriorly, and to the deltopectoral line anteriorly, in order to utilize the remaining mobility of the shoulder girdle. Similarly, in Long Below-Elbow stumps the proximal lip of the socket may be placed at two-thirds forearm length in order to avoid undue restriction of remaining pronation-supination.

Second, close fit of the socket to the form of the stump is essential. This is best achieved by the double wall construction which combines a form-fitted inner wall, and a cosmetic and structural shape for the outer wall. As shown in Figure III-3, only the Standard AE, Elbow Disarticulation, and Long BE types give a choice of single wall construction. Moreover, the single wall type appears to be dying out; New York University field investigators report (1956) that over 90 percent of sockets are double wall.

Harness and Control System

The amount of functional loss associated with amputation level determines the requirement for regain, but this is very much limited by the practical possibilities of harnessing substitute motion. There are only three major control sites on shoulders and arms, and several minor ones for elbow lock operation; it is evident that these must be fully utilized. The standard harness and control patterns, outlined in Figure III-3, embody the results of long research and experience. Still, each amputee differs to some extent from the average, and the fitter must apply ingenuity to obtain the full potential of control. While AE and BE types involve little departure from standard patterns, the shoulder cases nearly always require experimentation to obtain a satisfactory result. For this reason, a basic harness is specified, which is to be supplemented by various modifications until successful operation is obtained. The material on harnesses should be studied by all members of the clinic team, since the harness and control apparatus is the vital link in the amputee-prosthesis combination.

PRESCRIPTION OF MECHANICAL COMPONENTS

In prescribing the mechanical components of the prosthesis, it is important for the clinic to keep in mind the pre-prescription information and the primary factors we have discussed. A useful technique is to assign a reason for the prescription of each component, rather than to list them without considering their particular advantages in contrast to other available devices.

There may be many instances where the clinic cannot decide between two or more devices, or where none of the available devices appear suitable. The concept of the "trial prescription" has evolved to handle these cases. The "trial prescription" is particularly advantageous where the clinic handles many amputees. In such cases, it is financially expedient to have on hand a complete prosthetic armamentarium. If an amputee tries a device which does not prove satisfactory, it can be exchanged for another device without incurring undue expense.

Choosing Components in Relation to Functional Need

It is important to emphasize that most decisions have to do with functional details, such as the pattern and selection of the socket, sus-

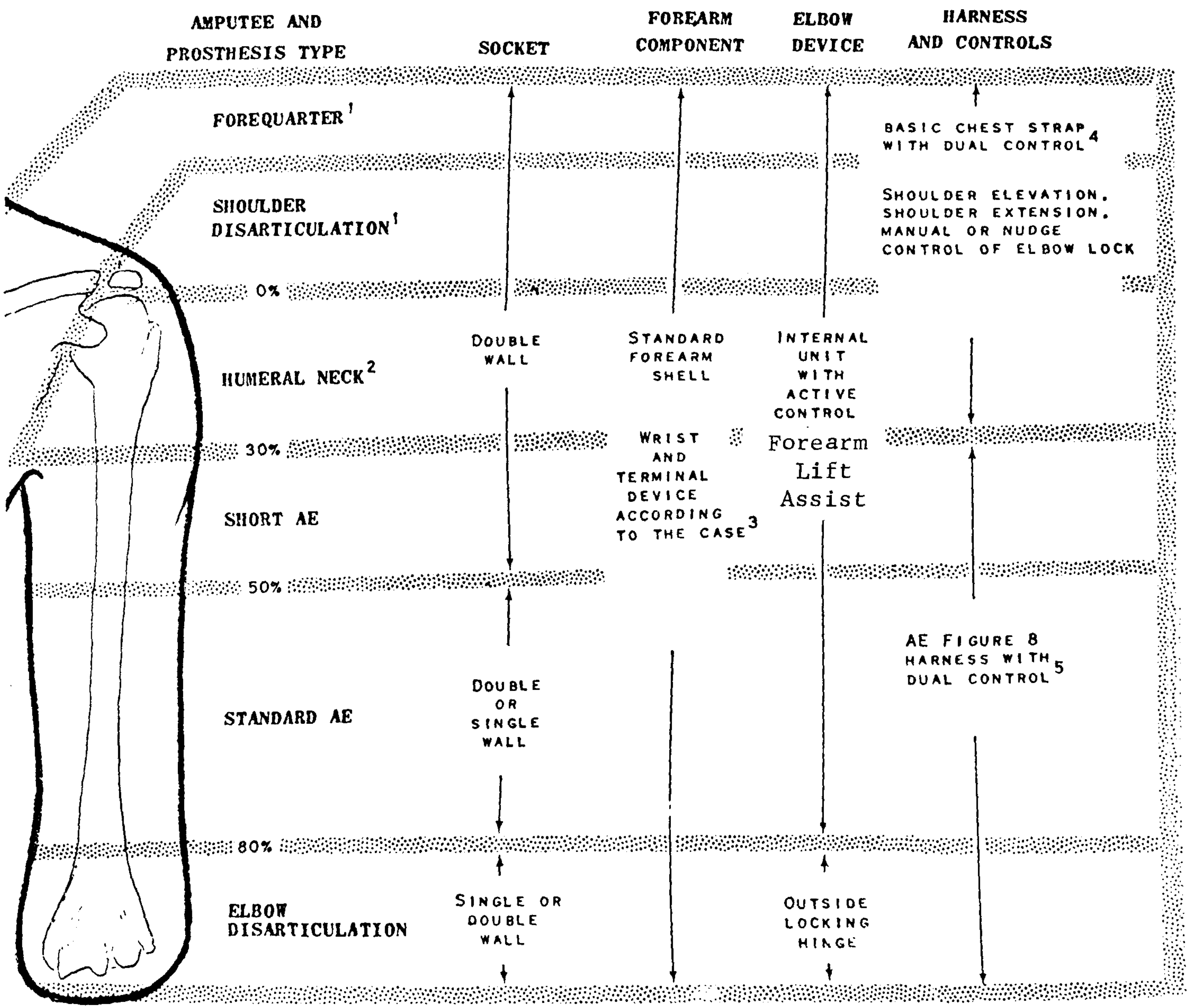


FIGURE III-3a. Shoulder and Above-Elbow Prostheses

NOTES

1. Sectional plates are commonly used.
2. Functionally a shoulder case but sectional plates cannot be used.
3. Wrist and terminal device selections may be limited in Short AE and higher levels because of reduced flexor power, unless a forearm lift assist is used.
4. Final modifications of basic harness, such as a shoulder sling or axilla loop, may be necessary for effective use of the dual control.
5. Shoulder saddle and chest strap harness may be used for heavy duty.

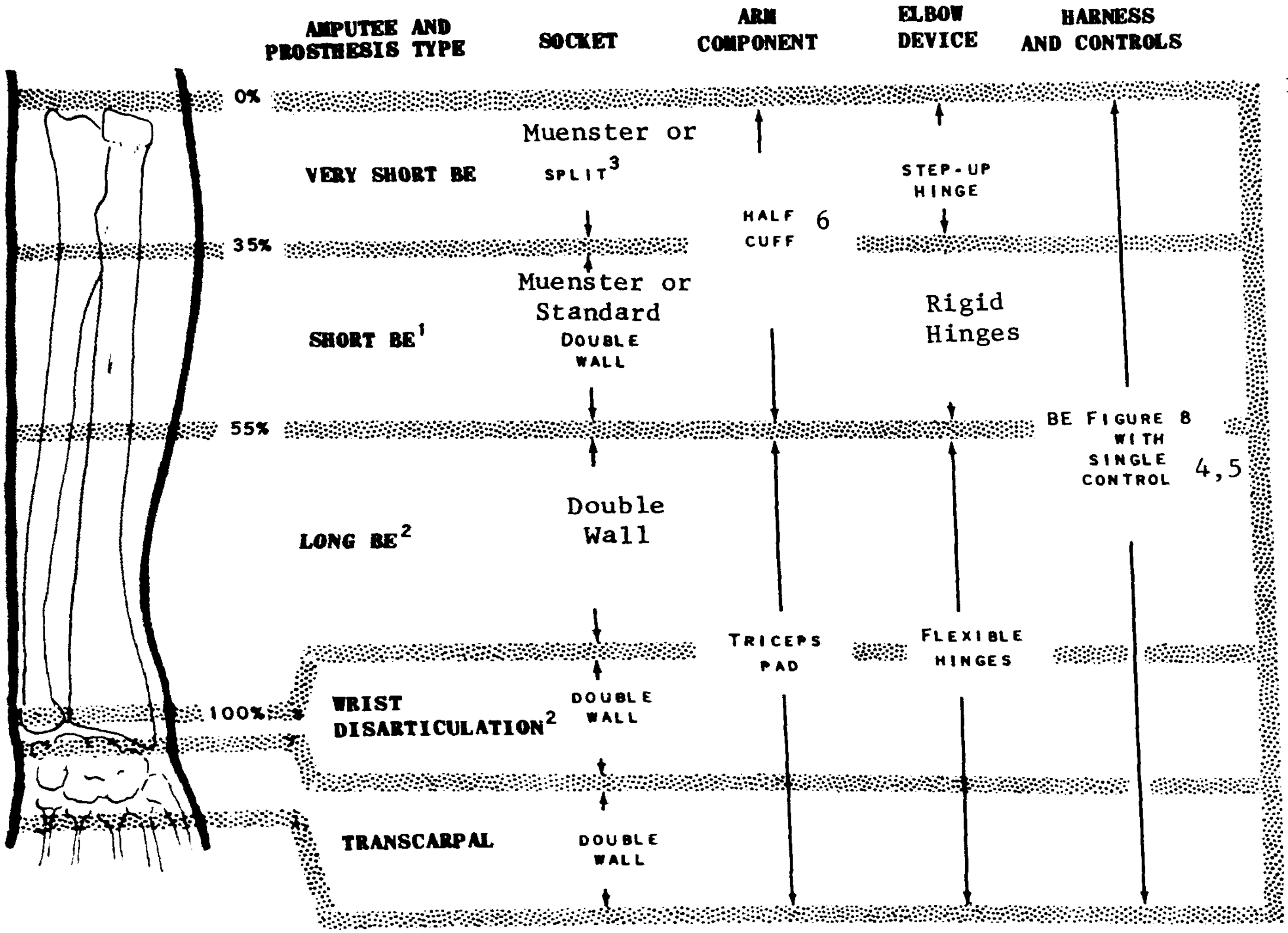


FIGURE III-3b. Below-Elbow and Hand Prostheses

NOTES

1. Short BE requires torsion stability at the elbow as given by the rigid hinge. The same type may be extended to the Long BE if pronation-supination is weak, or for very heavy duty.

2. If the stump is greater than 80% of epicondyle-to-styloid length, interchangeable plan for wrist and terminal device components not desirable because of length considerations.

3. For heavy duty applications a modified Short BE socket may be used with socket set in initial flexion.

4. AE dual control assist may be required for VSBE's if prosthetic flexion power is inadequate.

5. Shoulder saddle and chest strap may be used for very heavy duty.

6. Billet may be added if necessary.

pension and control systems. These are often more critical in assuring a good result for the amputee than many of the details of mechanical devices, such as elbow units and terminal devices. However, mechanical devices must be selected at the time of prescription, and a policy for their specification should be agreed upon.

This class of equipment is closely tied in with the commercial interests of the wholesale limb industry. It is considered to be in the best interests of professional ethics and practice to specify the mechanical devices in terms of their functional characteristics. For example, the prescription should call for a positive locking elbow unit, rather than specifying a device by its manufacturer's trade name. It is proper, for the sake of simplicity, however, to prescribe a specific manufactured product by a trade name, followed by the phrase, "or its functional equivalent." This indicates what is wanted, but does not rigidly tie the specification to a single product. Above all, every effort should be made to abolish the outmoded practice of uncritically specifying a "Dash-Arm" without regard for whether its particular features suit the needs of the specific amputee case.

Terminal Devices

In some respects the prescription of terminal devices is the most difficult. Partly this is due to the fact that there are many terminal devices to choose from, while there are relatively few of the other components.

Initial choice. The first problem is the extent to which the clinic is able to make an initial judgment concerning the best selection for the amputee. A study of 153 cases prescribed for by more than 50 clinics participating in the PTC shows that 84 percent of the times when a hook was prescribed, the prescription called for a specific hook, and 95 percent of the times that a hand was prescribed, the prescription specified a particular hand. (The greater specificity of the hand prescription was presumably due to the clinics' philosophy of functional restitution and the fact that only one commercially available hand was approved under the Artificial Limbs Program—the APRL hand.) Evidently, the clinics felt that in the great majority of the cases a specific prescription could be made, and used several principles based on general experience as follows:

(a) If the amputee has a socially-oriented vocation or avocation, he has need for a functional cosmetic hand.

(b) If the amputee's vocation or avocation involves the performance of bilateral activities requiring manual dexterity, a hook is indicated.

(c) If the amputee's vocation or avocation involves close contact between the terminal device and highly abrasive or corrosive materials, a steel hook is indicated.

These three principles are of the most general validity; many others bear only upon the prescription of a limited number of cases. Thus, they vary with level of amputation, multiple amputation, amputee preference, and other factors too numerous to formulate.

Evaluation and change. The second problem in prescribing terminal devices involves measuring the effectiveness of the initial choice and making indicated changes. This problem is the more difficult, and applies not only to the terminal device but to the complete prescription. Actually, clinics have worked more or less on the trial-and-error basis. If, after initial prescription, the amputee states that he is satisfied, the case is closed. If not, he is given another type of device for trial. There is, of course, a great necessity for principles of prescription to be based on studies that have established their validity beyond question.

Wrist Units and Combinations

The prescription of wrist devices is related to sizing and interchangeability. The selection of standard or interchangeable plan depends upon several factors. First, it is believed that the interchangeable plan is not desirable for BE's with more than 80 percent of forearm length remaining. Also, amputees who wear only hooks of conventional type may use the standard plan. Here, it should be pointed out that ready interchange of hand and hook is facilitated with the standard plan if a manual lock type of wrist unit is provided. The full interchangeable plan is designed for the additional inclusion of a flexion unit, or fairing sections, or the longer APRL voluntary closing hook.

In the past, wrist flexion devices have been prescribed for bilaterals, but other applications are uncertain. Our data indicate that if the unilateral amputee is fitted with a wrist flexion device, he tends to use it. However, this conclusion is based on subjective reports, and it must be realized that there are no objective criteria for the prescription of wrist flexion units except in the case of the bilateral amputee.

In the shoulder case, where lack of forearm flexion power requires that the effect of weight at the distal end of the arm be minimized, a forearm lift assist is indicated if a flexion unit is prescribed.

Elbow Units

For the Below-Elbow amputee the prescription of elbow hinges largely depends on the prosthesis type. The Long Below-Elbow prosthesis is usually fabricated with flexible hinges. Rigid hinges are used with short Below-Elbow amputations in those cases in which a Muenster socket is not prescribed.

With regard to the step-up hinge for the Very Short Below-Elbow amputee, questions have been raised whether certain amputees can develop sufficient torque to utilize the split-socket prosthesis. However, if the amputee has sufficient stump on which to fit the prosthesis, he will usually have sufficient torque to flex the prosthesis completely, especially if equipped with an AE dual assist.

The prescription of elbow units for the Above-Elbow amputee is straight-forward, since all shoulder-operated units are functionally similar. The Elbow Disarticulation amputee is fitted with the outside locking elbow hinge, and all others with a positive locking alternating elbow unit.

RESPONSIBILITIES OF THE MEMBERS OF THE PRESCRIPTION TEAM

Essential to the process of prescription is the bringing together of the specialized knowledge and services of each member of the prosthetic team. The physician must make all final decisions, but he should rely heavily upon the advice of his team. It is incumbent upon him to recognize and demand a high quality of performance from each member. For these reasons it is desirable to emphasize the responsibilities of physician, prosthetist, and therapist, as follows:

Function and Responsibility of the Physician

The physician should:

Understand the technical features of prostheses and the potential amputee performance.

Consult with all members of the prosthetic team and with the amputee, so that the prescription represents the combined judgment of the group.

Prescribe and demand a high quality of practice in physical therapy, fitting, and training.

Make all final decisions, execute and sign the prescription.

Make final evaluation of the results of physical therapy, fitting, and training; determine that the prescription has been satisfactorily filled.

Function and Responsibility of the Prosthetist

Advise the physician on possible prosthetic solutions for the case at hand.

Make measurements necessary for prosthesis fitting.

Fabricate (or order fabrication of) the prosthesis.

Fabricate (or order) and fit harness and control system.

Evaluate by careful test the functional results of prosthesis fitting.

Function and Responsibility of the Physical Therapist, Occupational Therapist and Amputee Trainer

Execute pre-prosthetic physical therapy of the stump and body as prescribed by the physician.

Advise the physician on the prescription of prosthetic components to facilitate the solution of anticipated training problems.

Administer the prosthesis checkout tests.

Train the amputee in prosthetic control motions, and in the use of the prosthesis in the activities of everyday living, occupation, and recreation.

Utilization of Outside Agencies and Personnel

The physician, therapist, prosthetist, and trainer are considered the necessary and permanent members of the clinic. They can, perhaps, satisfactorily handle the large majority of cases. However, the cases which are particularly resistant to rehabilitation can often be facilitated by employment of outside agencies and personnel. The amputee who needs vocational guidance should be referred to the State Department of Vocational Rehabilitation. Those requiring psychological aid should be referred to the proper agency. Infrequently, the clinic may feel that the amputee requires a prosthetic modification which has not yet been developed. In this instance, an engineer may be called into consultation.

In the ideal arrangement, the clinic will form working arrangements with these outside agencies. Rather than simply referring the amputee to the outside agency, the agency can be asked, in a sense, to join the clinic until the amputee's problem is solved. In this manner not only does the amputee benefit maximally, but the knowledge of rehabilitation will be enhanced.

UPPER-LIMB PROSTHETICS

SUPPLEMENT FOR PROSTHETISTS

Details of Measurement, Fabrication and Harnessing Procedures

TABLE OF CONTENTS

Anatomical position	Reference position of the body permitting description of location and movements. The individual is standing erect. Head . . . . . .Facing forward Arms . . . . . .Parallel to the trunk, straight at the sides. Hands . . . . .Positioned so the palms face forward. Legs . . . . . .Straight Feet . . . . . .Parallel to each other.
Anterior	Toward the front.
Posterior	Toward the back.
Superior	Toward the head.
Inferior	Away from the head.
Medial	Toward the midline of the trunk.
Lateral	Away from the midline of the trunk.
Proximal	Toward the trunk. Refers to the limbs.
Distal	Away from the trunk. Refers to the limbs.
Palmar (volar) surface	Anterior portion of the forearm and hand.
Dorsal surface. (Dorsum)	Superior portion of the foot; posterior surface of the trunk and upper limb.
Plantar surface	Inferior portion of the foot.

Sagittal plane — Any plane which divides the body into right and left portions. All sagittal planes extend vertically from the anterior to the posterior part of the body.

Midsagittal (median) plane — Plane which divides the body into equal right and left portions.

Frontal (coronal) plane — Any plane which divides the body into anterior and posterior portions. All frontal planes extend vertically from one side of the body to the other.

Transverse plane — Any plane which divides the body into superior and inferior portions. All transverse planes extend horizontally from one side of the body to the other.

Flex — To bend the limb in a sagittal plane.

Flexor — Any muscle which bends the limb in a sagittal plane.

Flexion — Bending the limb in a sagittal plane.

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Palmar (volar) flexion — Bending the wrist so the palmar surface of the hand points toward the forearm.

Dorsiflexion — Bending the wrist so the dorsal surface of the hand points toward the forearm. Bending the ankle so the foot points upward.

Plantar flexion — Bending the ankle so the foot points downward.

Extension — Straightening the limb in a sagittal plane.

Hyperextension — Extending the limb beyond anatomical position.

Abduction — Moving the limb away from the body in a frontal plane.

Adduction — Drawing the limb toward the body in a frontal plane.

Internal (medial) rotation	Twisting the limb inward along its long axis in a transverse plane.
External (lateral) rotation	Twisting the limb outward along its long axis in a transverse plane.

Pronation of the forearm	Turning the forearm so the palm faces backward.
Pronation of the forefoot (Pronation twist)	Depressing the first and second metatarsals and elevating the fourth and fifth metatarsals.
Pronation of the entire foot	Turning the medial border of the foot downward so the sole faces outward. Motion occurs around a theoretical horizontal axis, perpendicular to the frontal plane.

Supination of the forearm	Turning the forearm so the palm faces forward.
Supination of the forefoot (Supination twist)	Elevating the first and second metatarsals and depressing the fourth and fifth metatarsals.
Supination of the entire foot	Turning the medial border of the foot upward so the sole faces inward. Motion occurs around a theoretical horizontal axis, perpendicular to the frontal plane.

Inversion	Movement, primarily of the foot, combining plantar flexion, supination, and adduction. The term varus applies to the resulting deformity of the foot.
Eversion	Movement, primarily of the foot, combining dorsiflexion, pronation, and abduction. The term valgus applies to the resulting deformity of the foot.

Circumduction	Circular movement combining flexion, abduction, extension, and adduction.

The upper limb, like the lower, is connected by a girdle to the trunk, and presents three segments; the arm, forearm, and hand. The skeletal, articular and muscular arrangements of the upper extremity are similar to those of the lower one. The upper limb, however, is characterized by considerable mobility while the lower extremity's main function is stability. This distinction greatly affects the type of support or replacement that is needed by the disabled individual.

This chapter divides upper extremity anatomy regionally: the shoulder and arm, the elbow and forearm, and the wrist and hand.

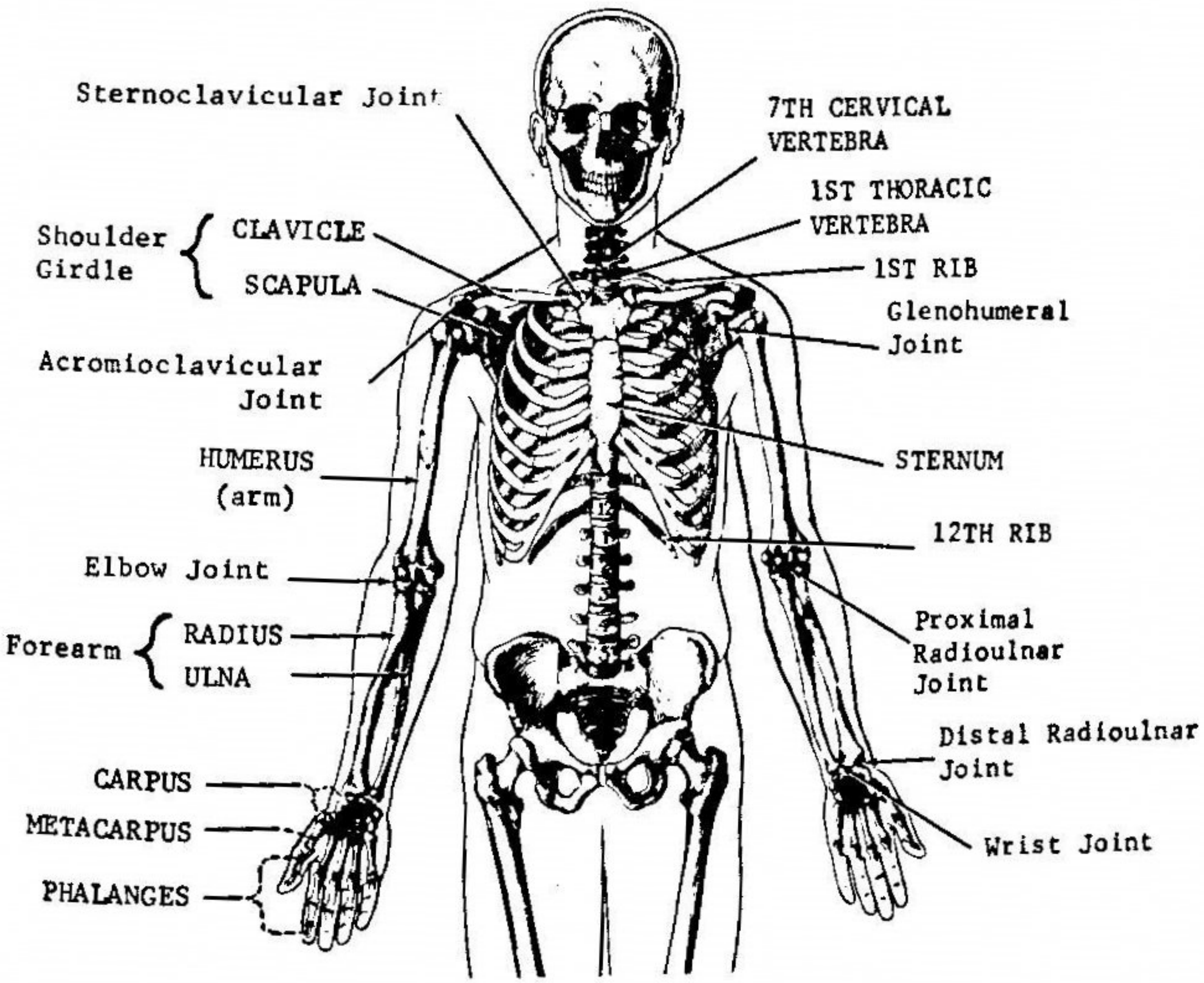


Figure 1

Nowhere in the body is there such anatomic cooperation as in the movements of the arm on the trunk. The arm travels through a wide range of motion because of close relationship between the arm and the shoulder bones. Many movements depend upon the support and stability provided by muscles that have extensive origin from the ribs and vertebrae.

Shoulder Girdle

Two bones are primarily involved in the movements of the shoulder; the scapula (shoulder blade) and the clavicle (collar bone) (Figure 1).

The scapula is a triangular bone with its base upward and apex or inferior angle, downward (Figure 2). On its lateral aspect is an oval, shallow surface, the glenoid cavity (shoulder socket) which receives the head of the humerus (arm bone). The tip of the shoulder is formed by the broad acromion process which extends like a shelf over the shoulder joint, and can be palpated easily. The anterior end of the acromion joins the clavicle, while the posterior portion is continuous with the spine of the scapula. The spine is a subcutaneous ridge of the bone, extending obliquely across the upper portion of the posterior surface of the scapula to its medial border. A bent finger-like process, the coracoid process, is the anterior projection of the scapula; it lies below the lateral portion of the clavicle.

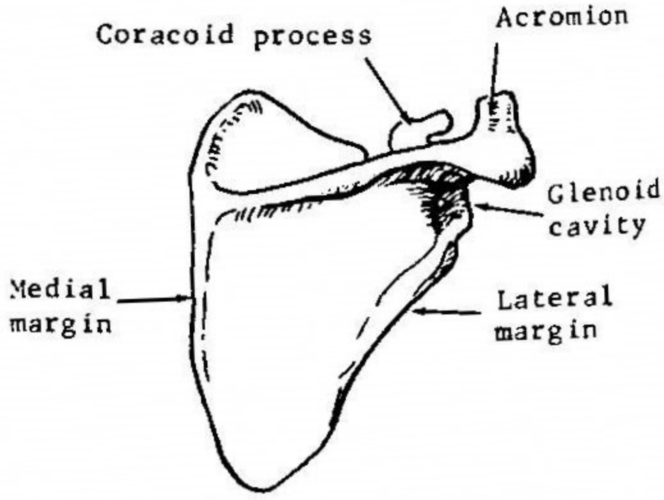


Figure 2

The clavicle is a slender S-shaped bone that lies horizontally in the upper part of the chest. The medial end articulates with the sternum (breast bone) and the lateral end with the acromion.

Seventh Cervical Vertebra

All the vertebrae in the cervical region (there are seven) have short spinous processes; C-7, which has an unusually long one, can be felt as a prominence posteriorly at the base of the neck (Figure 1). Since it is easy to palpate, it is an important landmark.

Humerus

The humerus (arm bone) consists of a shaft and two enlarged ends (Figure 3). The shaft is covered with muscles but both ends can be felt. The proximal end is formed by the smooth, rounded head that fits into the gelnoid cavity of the scapula. The distal end has two articulating surfaces, the medial and lateral condyles. Just above the condyles the bone flares into two prominences called the medial and lateral epicondyles.

Figure 3

Joints of the Shoulder Girdle

The bones of the shoulder region are joined together at three principal articulations: the sternoclavicular; acromioclavicular; and glenohumeral joints (Figure 1).

The sternoclavicular and acromioclavicular joints contribute to the movement of the shoulder girdle. These joints are freely moveable, gliding type, which allow some motion in all directions. Movements are defined as: elevation (raising shoulders toward the ears); depression (the reverse of elevation, lowering the shoulders); adduction or retraction (pulling the shoulders back); abduction or protraction (moving them forward) (Figures 4 and 5). Rotation, in which the shoulder socket tilts upwards or downwards, also occurs.

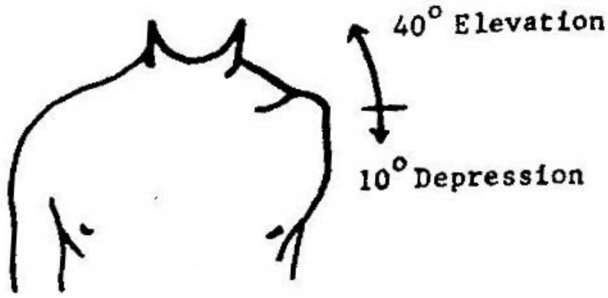


Figure 4

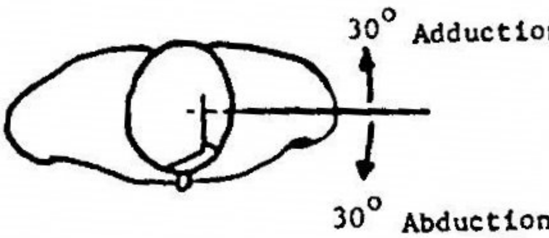


Figure 5

Shoulder Joint

The glenohumeral (shoulder) joint is a ball-and-socket type which is the most freely moveable in the body. It allows flexion, extension, abduction, adduction, and internal and external rotation. (Figures 6, 7, 8)

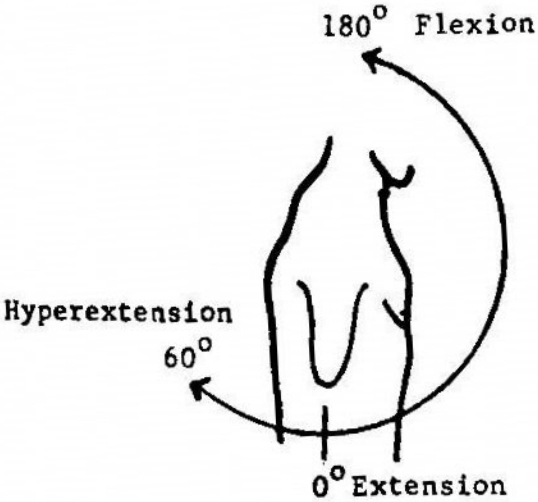


Figure 6

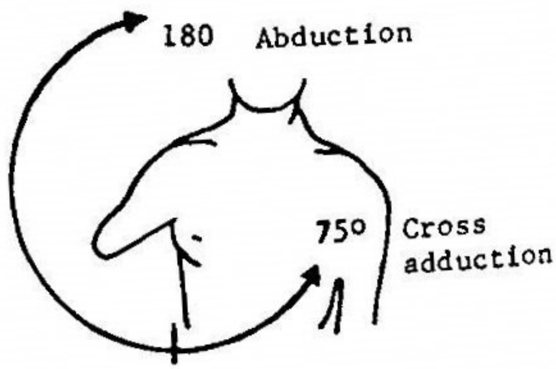


Figure 7

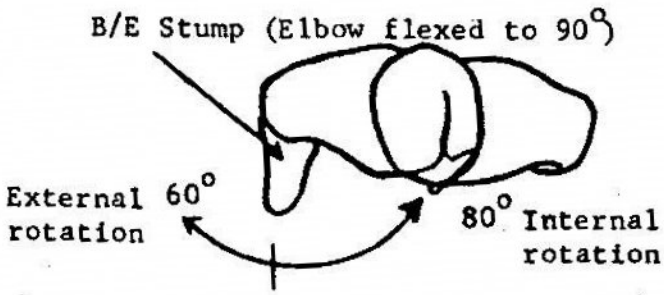


Figure 8

Scapular Muscles

The muscles of the shoulder region fix the shoulder girdle to the trunk and control the movements and positions of the arm at the shoulder.

The right and left trapezius muscles radiate like a kite from the back of the head, the scapulae, the outer borders of the clavicle, and all the thoracic vertebrae (Figures 9 a,b and 10). Its numerous functions depend on which of its fibers are acting. The upper fibers are primary elevators of the shoulder girdle.

The middle fibers of the trapezius lie between the spinal column and the medial border of the scapulae; when they contract, they tend to adduct the scapulae.

The lower trapezius' line of pull is downward; they are the major scapular depressors.

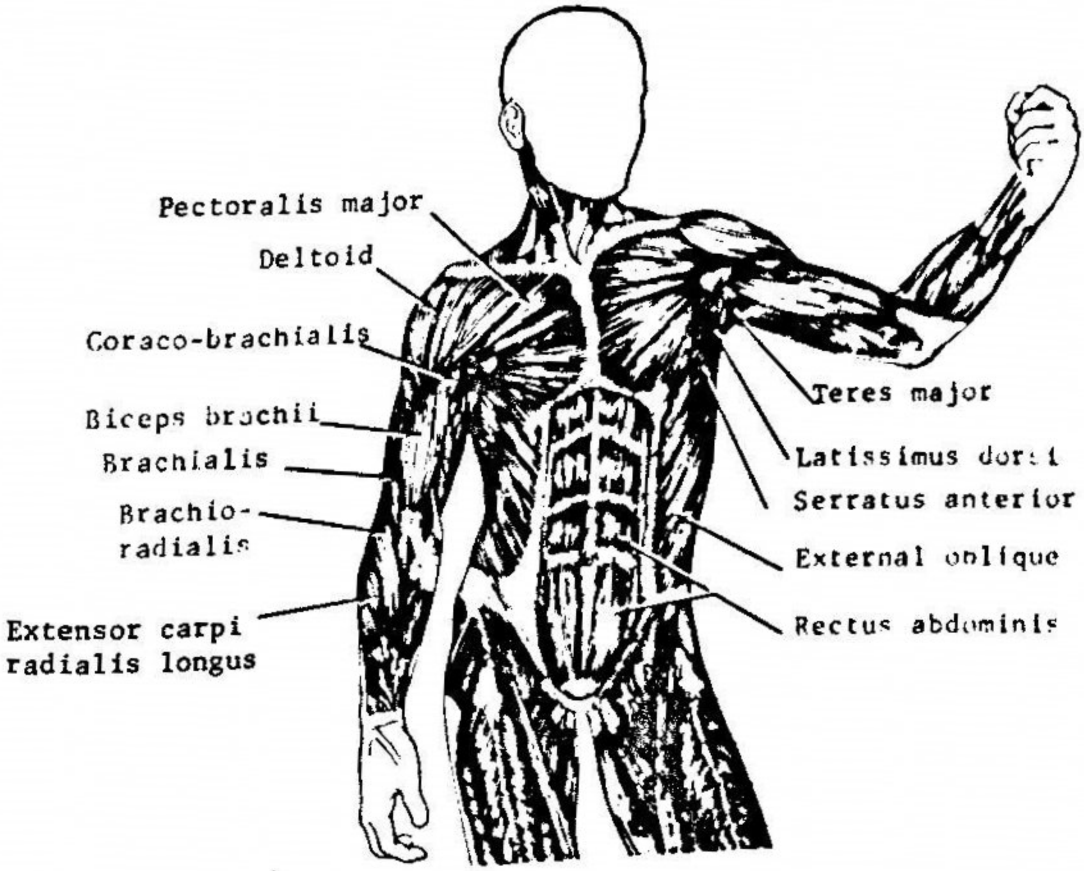


Figure 9 a

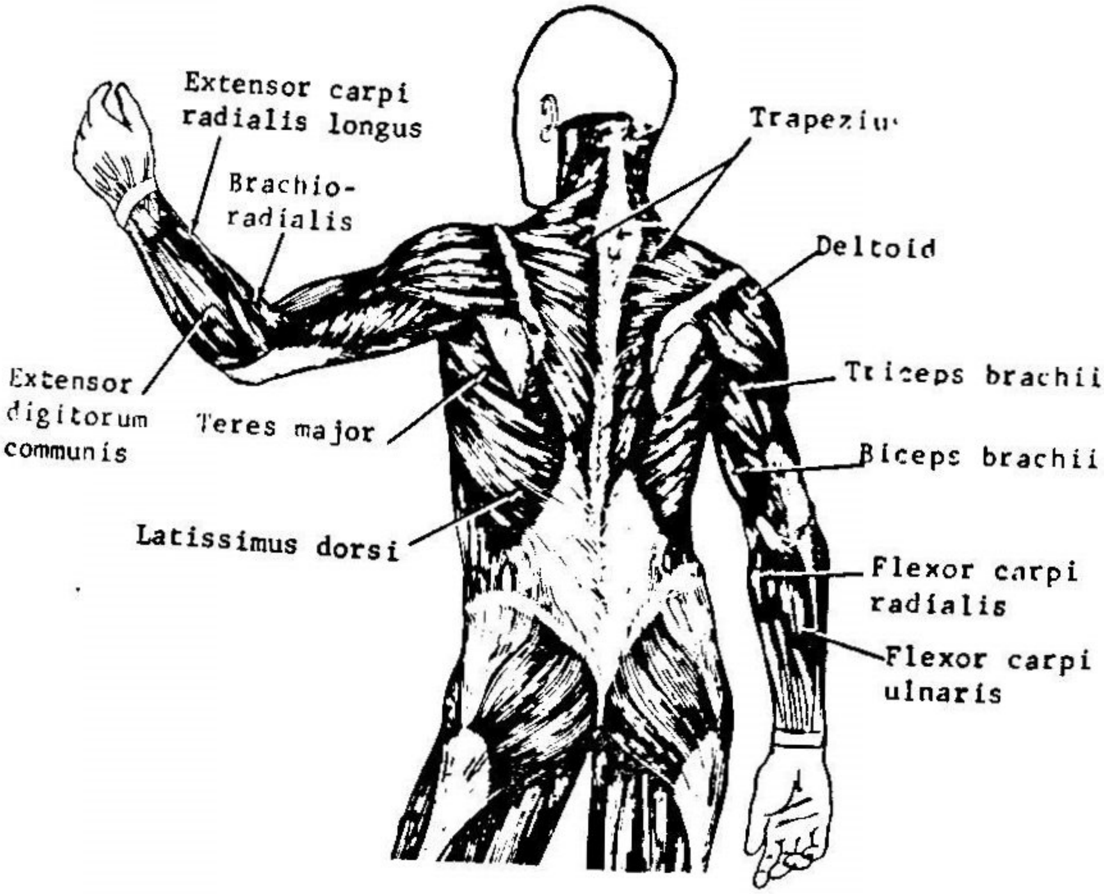


Figure 9 b

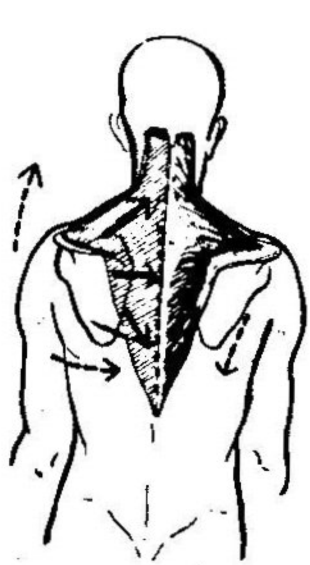


Figure 10

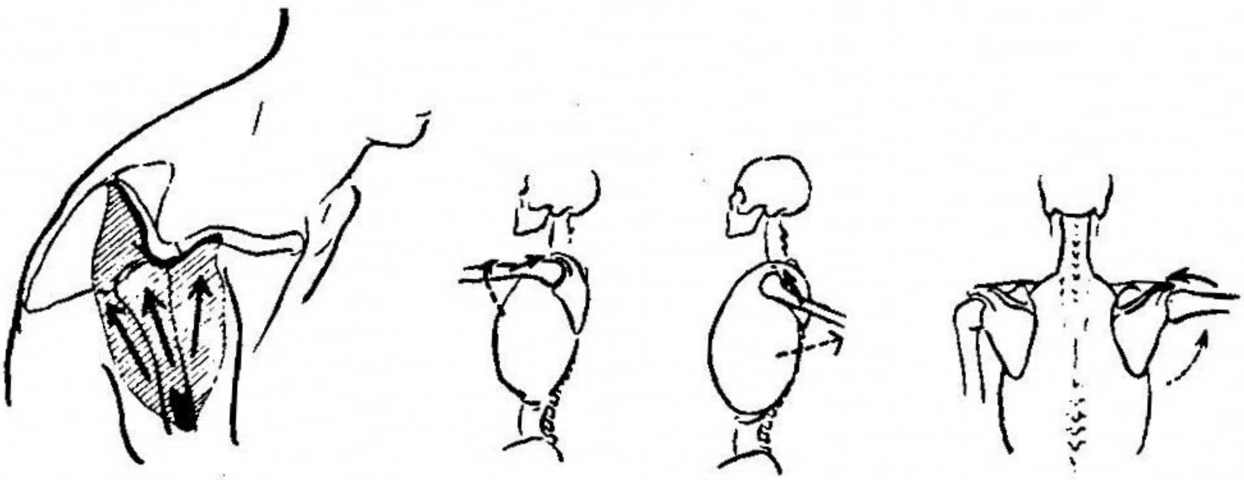
The serratus anterior attaches to the lateral sides of the ribs, passes under the scapula to the insert on its anteromedial border; its contraction produces abduction of the scapula (Figure 11).

Serratus Anterior, front view

Figure 11

Humeral Muscles

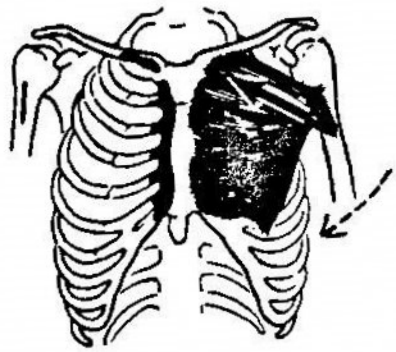
The shoulder joint has three principal axes of movement. The deltoid muscle forms a cap over this joint, passing anterior, lateral and posterior to it, to contribute to all of these motions (Figures 9 and 12).



Deltoid muscle Flexion Extension Abduction

Figure 12

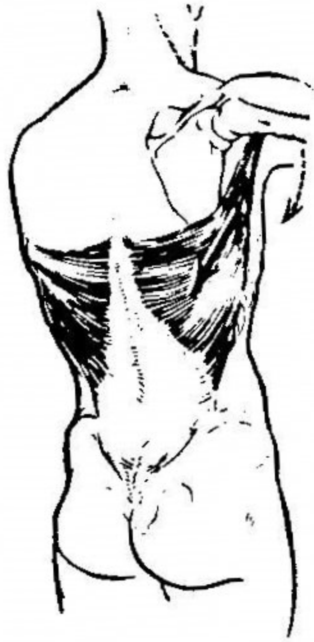
The anterior portion from the clavicle to the humerus is the primary shoulder flexor since it is in front of the joint. The pectoralis major also arises from the clavicle medially and inserts into the upper humerus, and thus is another shoulder flexor (Figure 13).



Pectoralis major

Figure 13

The posterior fibers of the deltoid originate from the spine of the scapula and join the other fibers of the deltoid in a common insertion on the humerus. Since the posterior fibers lie behind the joint axis, they act as extensors. Also crossing the shoulder posteriorly is the latissimus dorsi, a broad, flat muscle which attaches to the spine, ilium and lower ribs, and the humerus (Figure 14)



Latissimus dorsi

Figure 14

When the entire deltoid muscle contracts, it functions as the principal abductor of the shoulder since it spans the joint laterally. The supraspinatus contributes to this motion because of its position over the shoulder joint (Figure 15).

Supraspinatus

Figure 15

The latissimus dorsi in back and the pectoralis major in front course medial to the joint, and are the important shoulder adductors. The pectoralis major forms the fleshy portion of the upper chest.

Numerous obliquely placed muscles act to rotate the arm internally and externally. Others close to the joint function as stabilizers of the shoulder joint. Some of the muscles already mentioned have, with their other actions, the ability to act as rotators depending on their angle of pull. The Latissimus dorsi is a strong internal rotator. The posterior fibers of the deltoid are powerful external rotators.

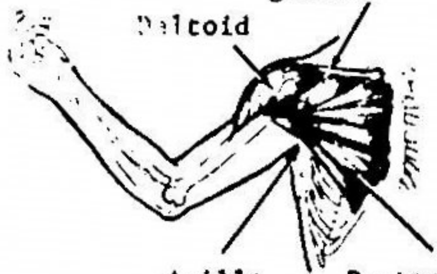


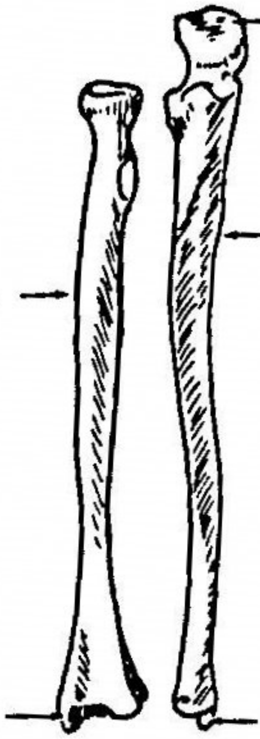
Figure 16

Deltopectoral Groove

A significant location in the upper extremity is the cleft between the deltoid and pectoralis major muscles, named the deltopectoral groove or triangle (Figure 16). It is quite easily palpated.

Axilla

The axilla (armpit) is a pyramid-shaped space between the arm and the chest (Figure 16). It is bordered by the pectoralis major anteriorly and the latissimus dorsi posteriorly. Through it pass the axillary vessels and nerves from the neck to the arm.



Right radius and ulna, anterior view

Figure 17

ELBOW AND FOREARM

The upper limb has unique functions. The ultimate purpose of all shoulder motion is to increase the area through which the hand may move. The elbow lengthens and shortens the extremity while the forearm positions the hand for more accurate placement.

The Radius and Ulna

The radius is the lateral bone of the forearm (Figure 17). It is covered by muscles proximally; distally it broadens for articulation with the bones of the wrist and has a pointed styloid process on the lateral aspect.

The ulna is the longer, more medial bone of the forearm (Figure 17). The proximal end is enlarged by a projection on the back of the elbow, the olecranon process (particularly prominent when the elbow is flexed). The distal end has a sharp medial styloid process.

Elbow Joint

This hinge type of freely movable joint is formed by the humerus and the ulna (Figure 18). It has a single axis to permit flexion and extension only (Figure 19).

Radio-ulnar Joints

The connections between the radius and the ulna allow the radius to rotate around the ulna. In anatomic position the bones lie parallel (supination); when the radius crosses the ulna the forearm is pronated (Figure 20). These motions are made possible by two separate, freely movable articulations which are pivot joints: The proximal radioulnar joint and the distal radioulnar joint (Figure 18).

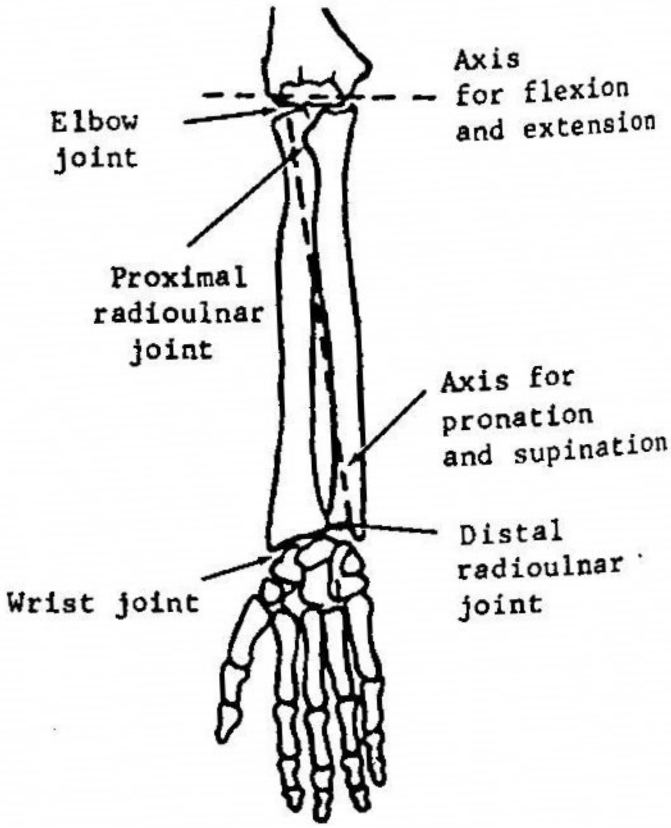


Figure 18

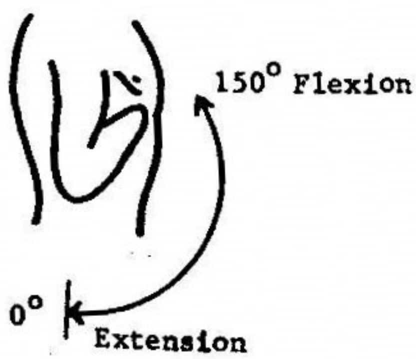


Figure 19

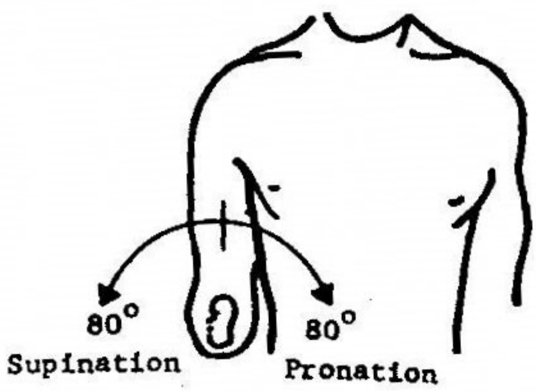


Figure 20

Elbow Muscles

Flexion of the elbow is accomplished by three muscles: biceps, brachialis, and brachioradialis. The biceps is the prominent muscle on the front of the upper arm, and is so named because it has two heads arising from the scapula (Figure 21 a,b). Both proximal tendons run in front of the shoulder joint to function as shoulder flexors. The sections of the biceps unite, and cross anterior to the elbow joint to insert into the forearm. The brachialis and brachioradialis have attachments on the humerus and the forearm, lie anterior to the elbow joint, and aid in flexion of the elbow(Figures 22 and 23).

Biceps brachii muscle

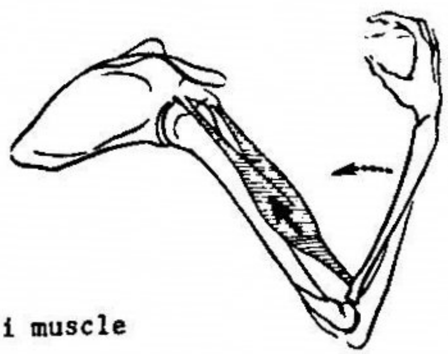
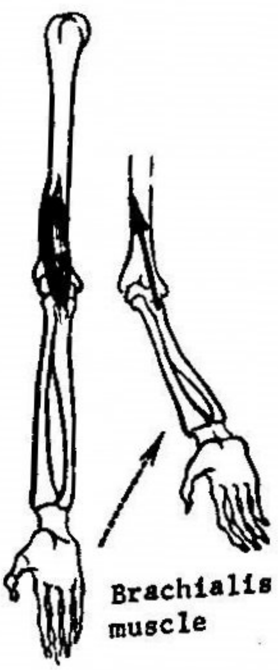


Figure 21 a

Figure 21 b



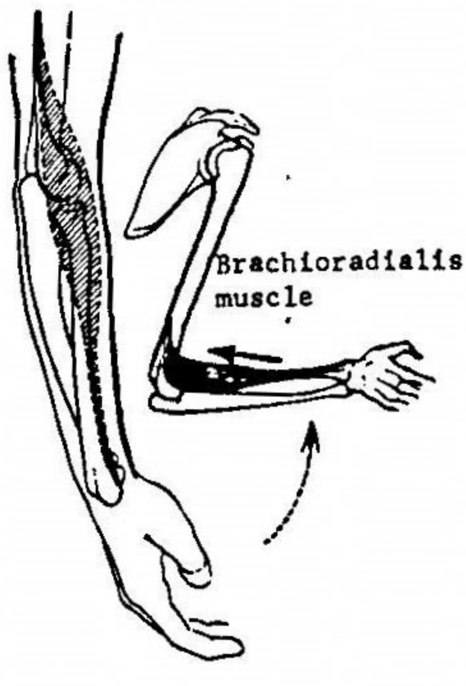


Figure 22

Figure 23

The triceps is the large muscle on the posterior aspect of the arm. It has three heads, as the name implies; one attaches to the scapula to contribute to extension of the shoulder. The other two originate from the humerus. All three parts join to insert into the olecranon process of the ulna. Since the triceps passes behind the elbow joint, it is the important extensor of the elbow (Figure 24).

Forearm Muscles

Muscles capable of supination arise from the lateral epicondyle of the humerus and insert on the radius. The biceps and supinator are the most important supinators of the forearm (Figure 25 a).

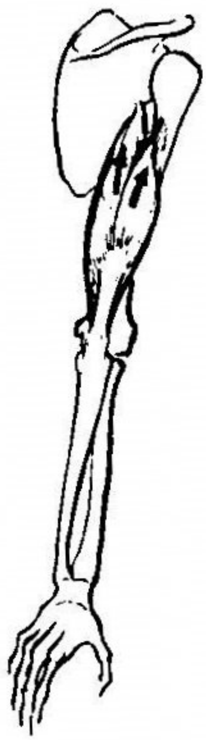


Figure 24

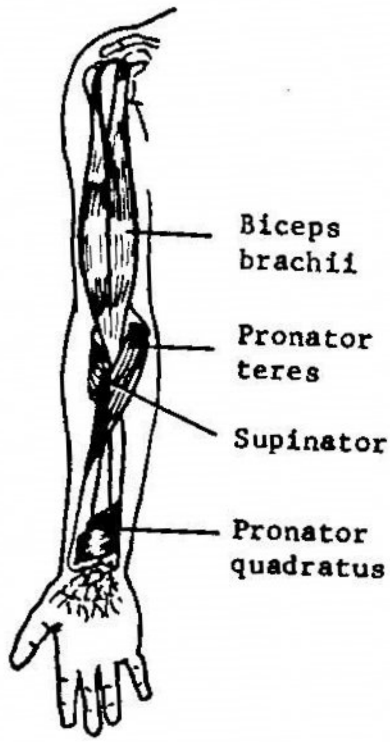


Figure 25 a

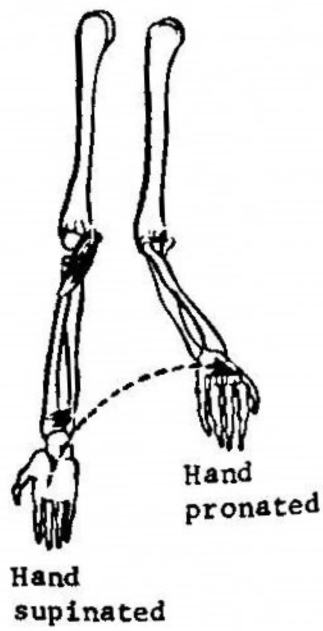


Figure 25 b

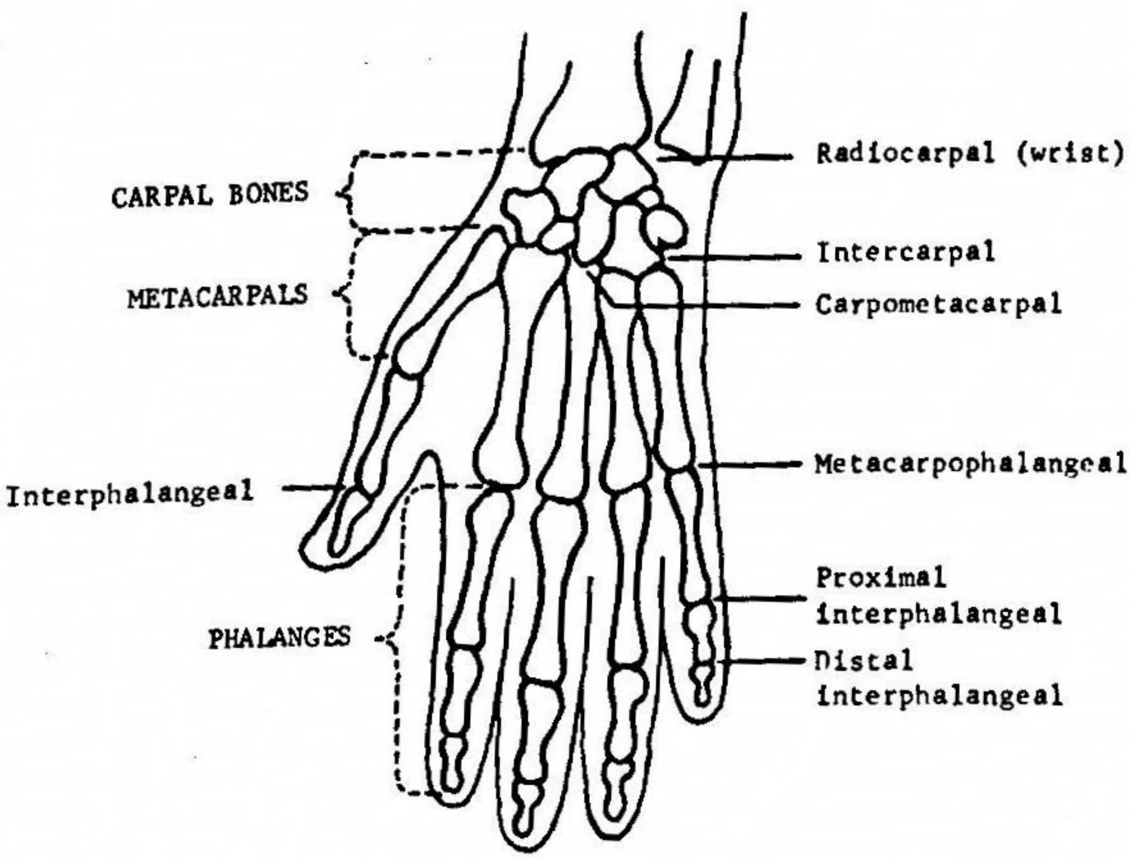
The pronator teres originates from the region of the medial epicondyle and inserts into the ulna. The pronator quadratus runs transversely between the distal parts of the radius and ulna (Figure 25 a,b).

WRIST AND HAND

Anatomically the hand of man is a highly developed, complicated mechanism capable of many different movements. The arrangement and interrelationship of 29 bones, more than 25 joints, and over 30 muscles complicates the task of rehabilitating the disabled hand.

Bones of the Hand

Below the radius are the eight carpal (wrist) bones arranged in two rows of four bones each. Beyond these small bones are the five metacarpal bones which form the framework of the hand. Joining each metacarpal are phalanges (finger bones). The thumb has two phalanges, each of the medial four fingers has three phalanges (Figure 26).



Bones and joints of the hand and wrist

Figure 26

Wrist Joint

The joint is a freely movable condyloid joint which permits motion in two planes, the sagittal and frontal (Figure 27). It allows palmar flexion (hand towards front of forearm), dorsiflexion (hyperextension or hand towards back of forearm), abduction or radial deviation (hand towards thumb side), adduction or ulnar deviation (hand towards fifth finger side) and circumduction (the combination of all these motions) (figure 28 and 29).

Joints of the Hand

The joints between the first and second row of carpal bones, the intercarpal joints, are freely movable, gliding joints allowing slight motion in all directions. They augment wrist motion (Figure 26).

The carpometacarpal joints are gliding joints with very limited motion (Figure 26).

The metacarpophalangeal junctions are condyloid joints which allow one to abduct and adduct as well as flex and extend the fingers. The interphalangeal joints are hinged permitting only flexion and extension (Figure 26).

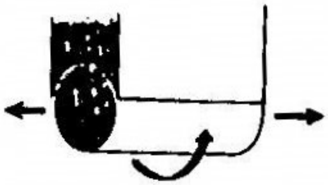


Figure 27

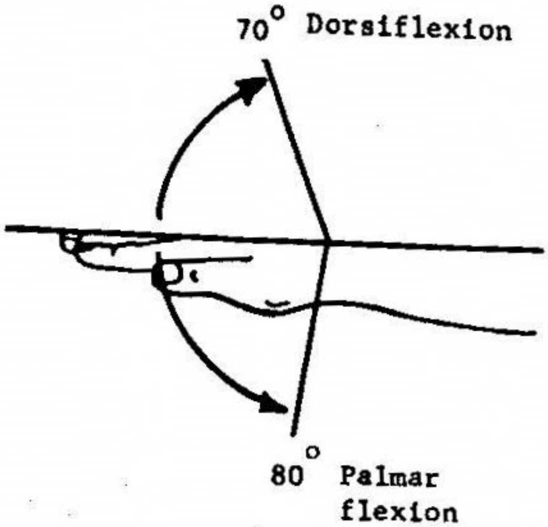


Figure 28

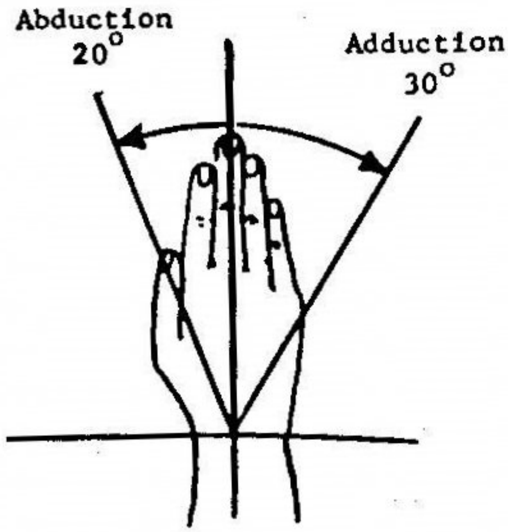
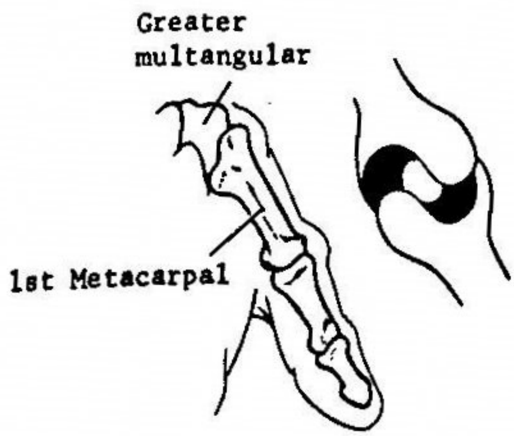


Figure 29

The carpometacarpal joint of the thumb is unique among the joints of hand. It is a saddle joint at which great amounts of flexion, extension, adduction, and abduction occur. In addition, its special construction allows the thumb to rotate into opposition so that the thumb may face other fingers (Figure 30). This variety and freedom of motion is largely responsible for the dexterity of the human hand.



Carpometacarpal joint of thumb

Figure 30

Muscles of the Wrist and Hand

The function of the hand depends on the teamwork of many muscles. Most of them move the wrist as well as the fingers. They will be discussed here in terms of group actions (see Figure 9 for general location).

The majority of muscles located in the anterior portion of the forearm cross in front of the wrist and are capable of flexing that joint. If they bridge the anterior side of the finger joints, they become finger flexors also.

Conversely, muscles on the posterior surface of the forearm which cross behind the wrist joint and/or finger joints are extensors.

Many small muscles which originate and insert in the hand aid in finger motions, and are referred to as the intrinsic muscles. Their names usually indicate their function as well as their location: thus, the opponens pollicis opposes the pollex (thumb), while the interossei lie between the bones.

FUNCTIONAL SUMMARY OF MAJOR UPPER EXTREMITY MUSCLES

SCAPULAR MUSCLES

Elevators

Levator scapulae
Upper trapezius

Depressor

Lower trapezius

Abductor

Serratus anterior

Adductors

Middle trapezius
Rhomboids

HUMERAL MUSCLES

Flexors

Anterior deltoid
Pectoralis major

Extensors

Posterior deltoid
Latissimus dorsi

Abductors

Deltoid
Supraspinatus

Adductors

Pectoralis major
Latissimus dorsi

ELBOW MUSCLES

Flexors

Biceps
Brachialis
Brachioradialis

Extensors

Triceps

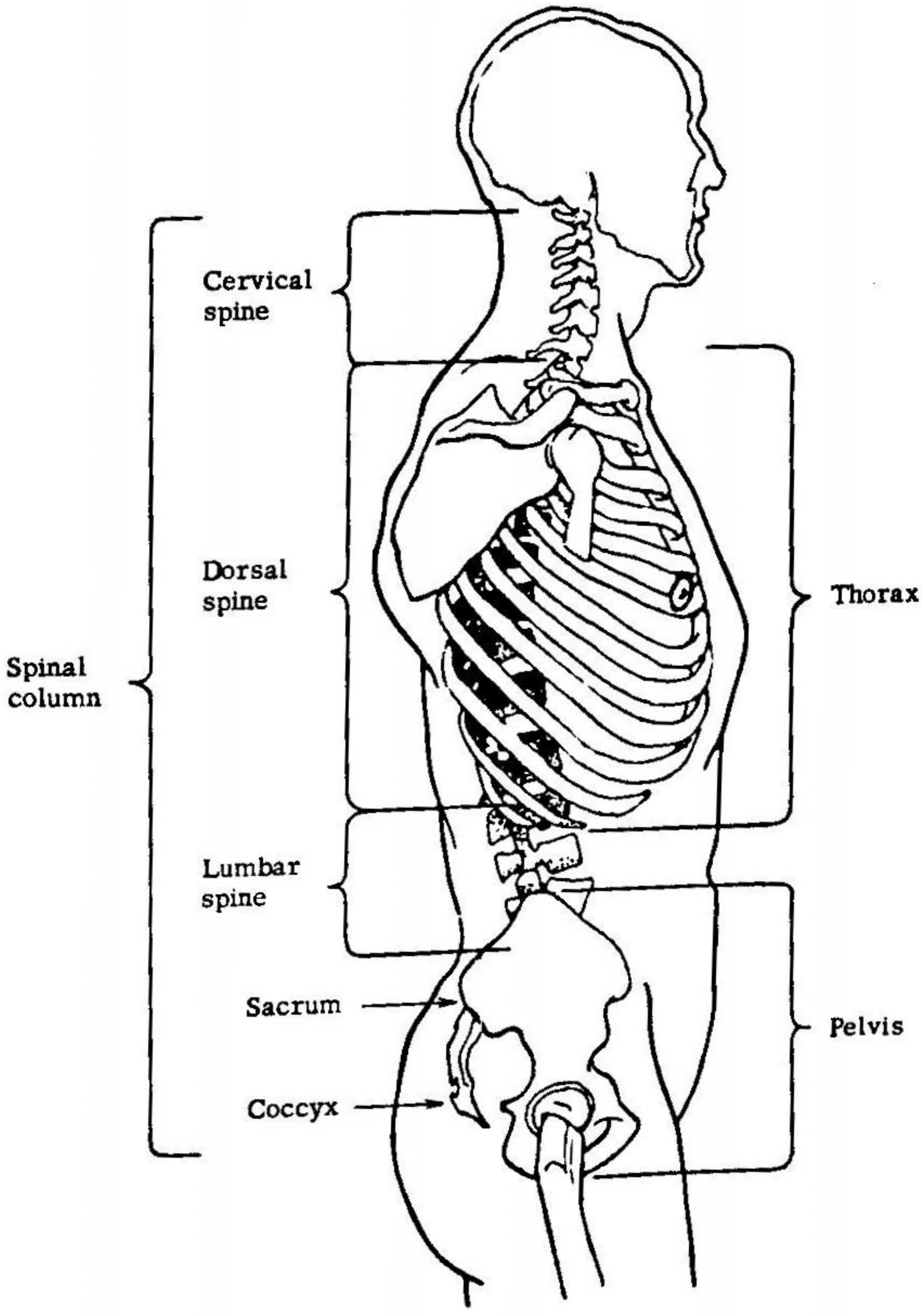
FOREARM MUSCLES

Pronators

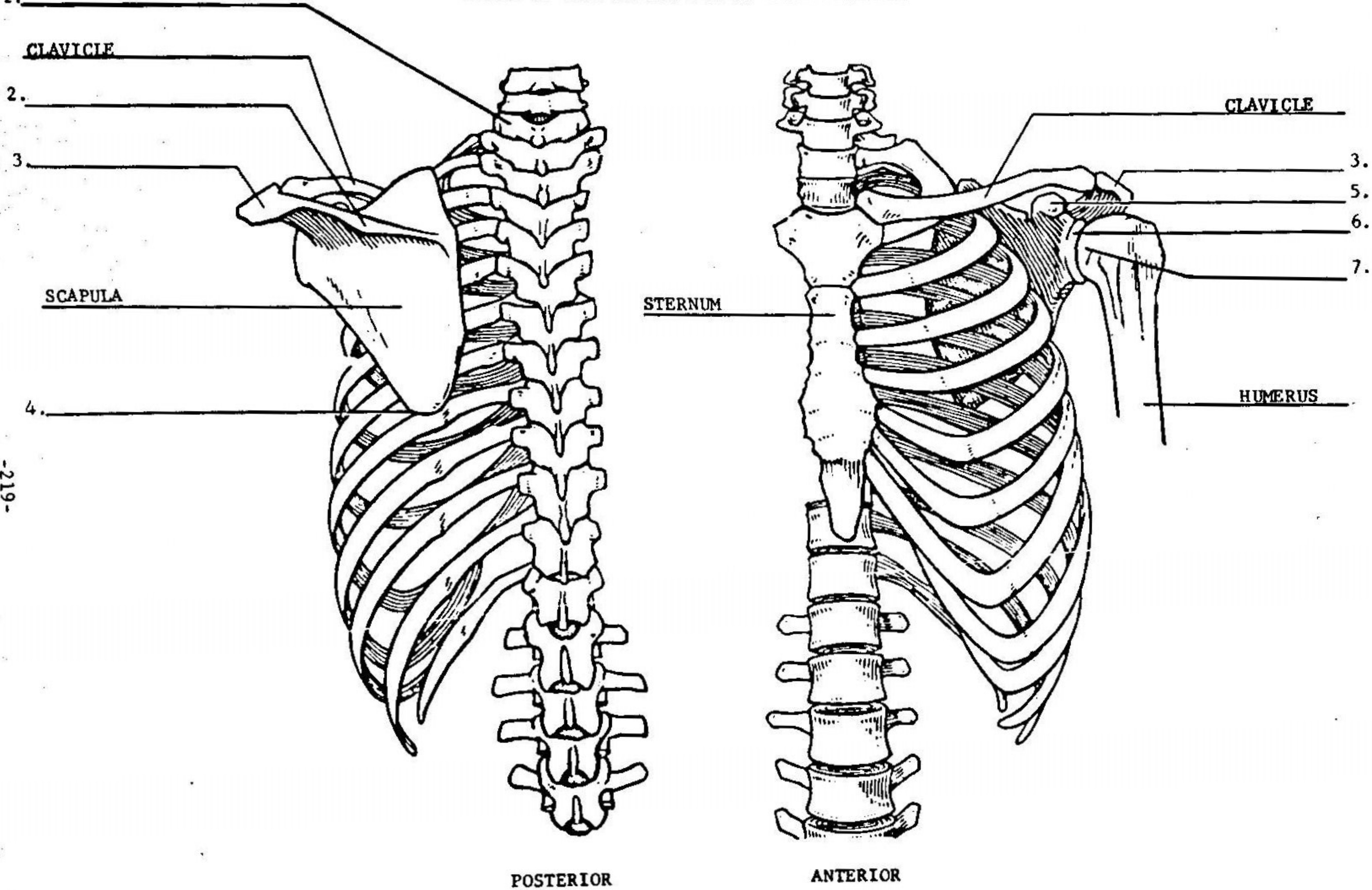
Pronator quadratus
Pronator teres

Supinators

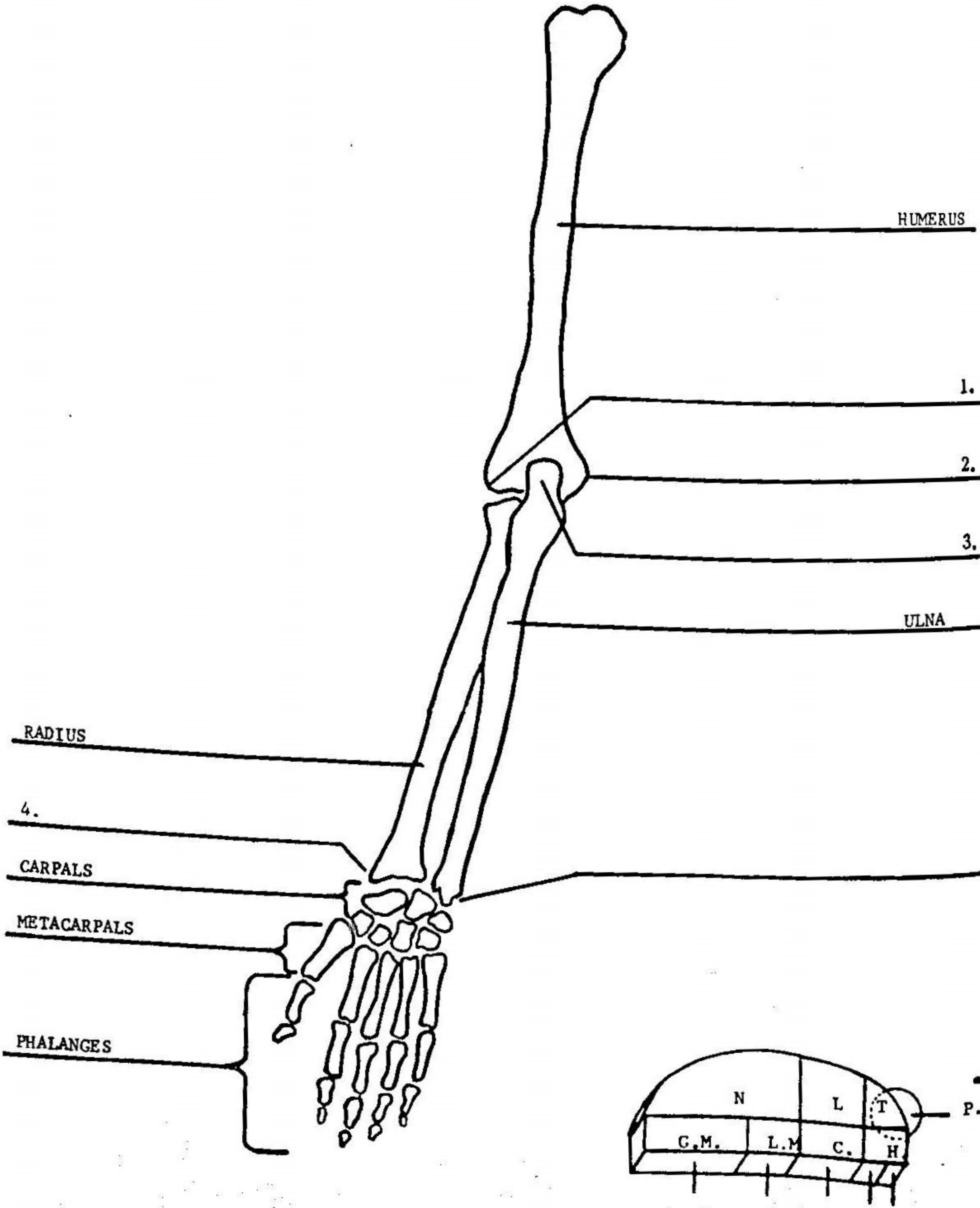
Biceps
Supinator


Cervical spine
Dorsal spine
Spinal column
Lumbar spine
Sacrum
Coccyx
Thorax
Pelvis

BONES OF THE THORAX AND SHOULDER GIRDLE

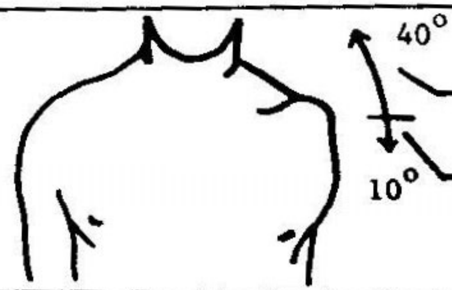
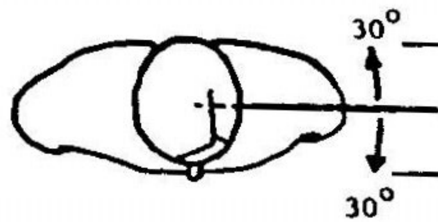


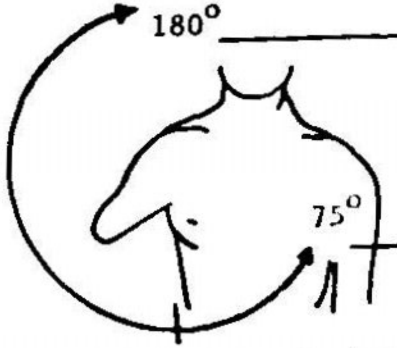
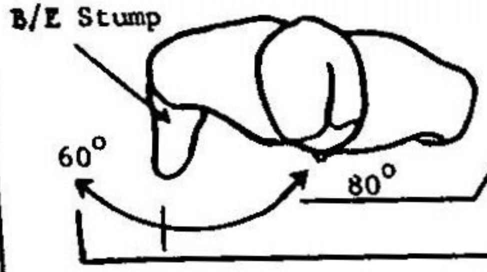
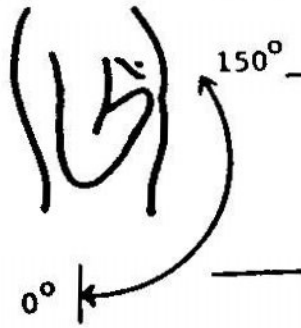
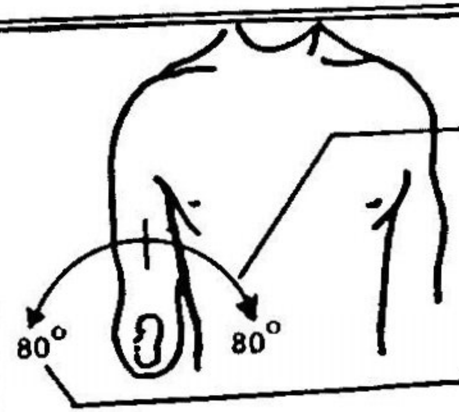
BONES OF THE LEFT UPPER EXTREMITY

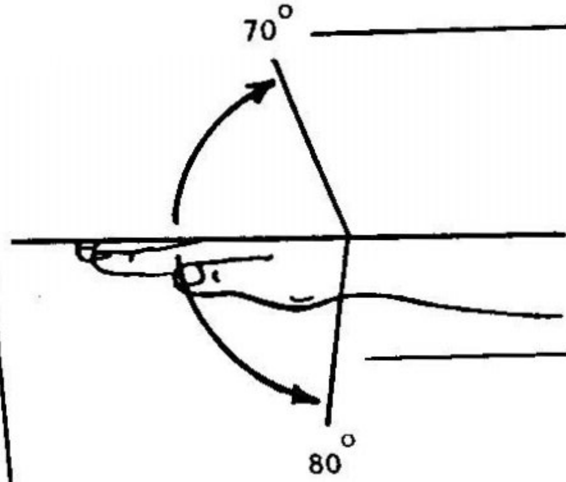
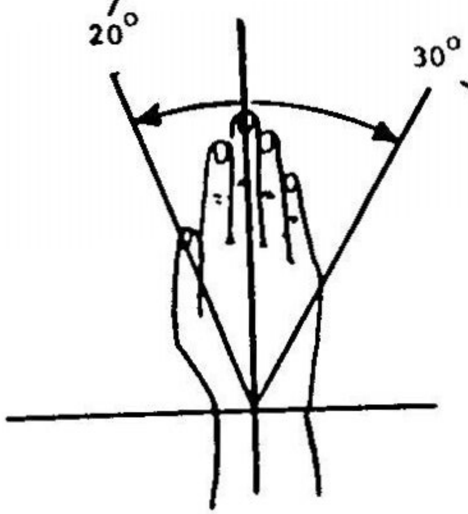


Posterior View

JOINTS OF THE UPPER EXTREMITY

JOINT OR		NAME OF MOVEMENT	
SHOULDER GIRDLE (SCAPULA)		1. ______ 2. ______	
		3. ______ 4. ______	
SHOULDER JOINT COMPONENTS: ______ ______ TYPE OF JOINT: ______ ______		1. ______ 2. ______ 3. ______	

JOINT OR MOVING PART		NAME OF MOVEMENT	REMARKS
SHOULDER JOINT (Contd.)		4. ______ 5. ______	
		6. ______ 7. ______	
ELBOW JOINT COMPONENTS: TYPE OF JOINT:		1. ______ 2. ______	
FOREARM PROXIMAL RADIO-ULNAR: DISTAL RADIO-ULNAR: TYPE OF JOINT:		1. ______ 2. ______	

JOINT OR MOVING PART		NAME OF MOVEMENT	REMARKS
WRIST COMPONENTS: __________ __________ TYPE OF JOINT: __________ __________		1. __________ 2. __________	
		3. __________ 4. __________	

Measurement

The sizing and fitting of an upper-extremity prosthesis requires a knowledge of the bones, joints, and muscles of the arm. Selection of the type of prosthesis and sizing it for length and girth are absolutely dependent upon accurate measurements, as is the mechanical functioning of the prosthesis. The measurements must be the same, whoever makes them — which means they must be taken at standard locations by standard techniques. In the past, prosthetists often took measurements in a different manner, with the result that misfits appeared between wrap and checkout. Also, misunderstandings occurred with medical doctors and therapists because they were using different measurements and different terminology.

Bones and Body Landmarks

The bones which are of most concern in upper-extremity prosthetics are the clavicle (collarbone), the scapula (shoulder blade), humerus (upper arm bone), ulna (one of the two bones in the forearm), and the seventh cervical vertebra. These are all shown in Figure I-1. Following is a description of each of these landmarks, and a method of locating them.

Thorax The chest.

Clavicle This slightly S-shaped bone runs from the upper chest center to the shoulder. It can usually be clearly seen and is easily palpated from end to end.

Acromion The acromion process is the lateral extension of the spine of the scapula. It can be identified by running the finger along the clavical laterally until it passes over a joint. which can be felt as a depression. Immediately lateral to the joint is the acromion process itself. The top surface of the bone just at the end of the acromion is the point used in prosthetic measurements. The arm should be slightly abducted and supported at the elbow to relax the shoulder muscles and make palpation of the acromion easier.

Deltopectoral Line This is the line of shoulder flexion. To locate it, place the fingertips lightly on the front of the shoulder just inside the bulge of the shoulder. As the subject flexes the shoulder back and forth, gently slide the fingertips in toward the chest—just far enough to touch flesh that is not moving. This locates the line of shoulder flexion when the outside of the finger touches moving flesh, while the inside edge of the finger rests on flesh that is not moving.

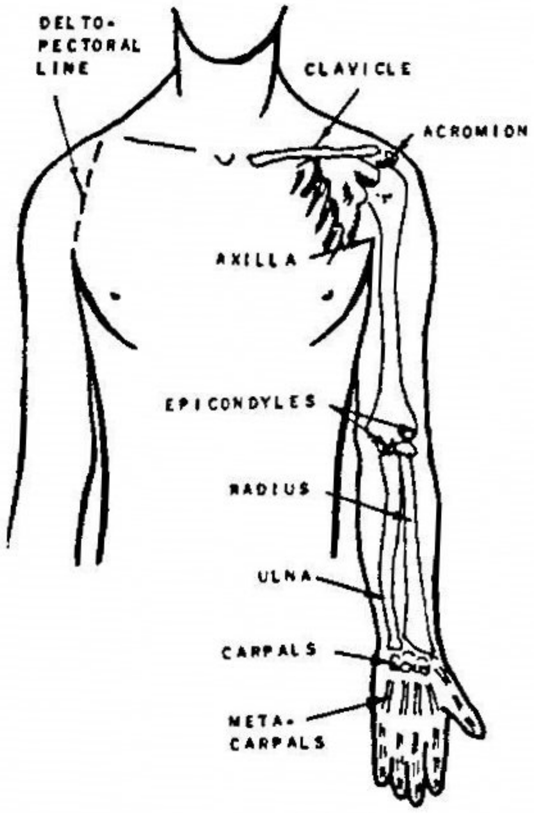


FIGURE I-1A. Bones and Body Landmarks (Front View)

Axilla This is otherwise known as the armpit. While not as precise as a bony point, it is important in prosthetic measurement. To locate it, have the amputee sit or stand with arm hanging at side. Slide a flat hand, index finger side up, into the armpit using gentle pressure upward. The upper edge of the index finger defines the axilla.

Epicondyles These are the flared ends of the humerus at the elbow, and are best located by palpation as follows. Encircle the upper arm with thumb and forefinger. Holding a rather firm grip, slide the hand down the arm until the flares of the bone are felt. The widest part of these flared ends, the epicondyles, represents the axis of elbow bending. Pinch the epicondyles between the thumb and forefinger tips and move the forearm through its range of flexion. If the fingers are not displaced, the location is verified.

Radius and Ulna The bones of the forearm. In forearm rotation, the radius rotates around the fixed ulna.

Carpals The small bones of the wrist and proximal part of the hand.

Metacarpals Bones of the hand between the carpals and the fingers.

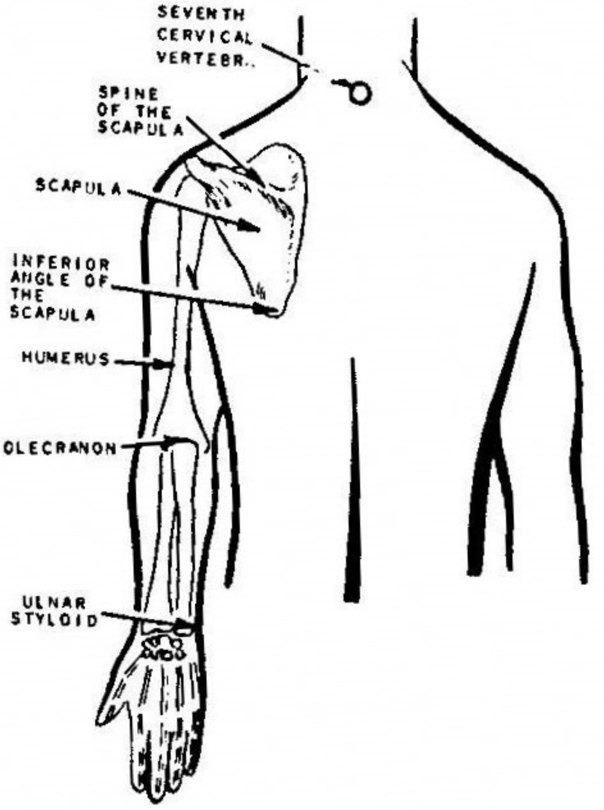


FIGURE I-1B. Bones and Body Landmarks (Rear View)

Seventh Cervical Vertebra This vertebra at the shoulder level is identified by its posterior projection. Have the subject bend his head forward. Looking across the spine at shoulder level, the bulge of the seventh cervical becomes apparent. This should be checked by palpation to verify the prominent point.

Scapula The shoulder blade.

Spine of the Scapula This large transverse ridge on the scapula can usually be seen, except in very fleshy or muscular people. To palpate, start with the acromion process and trace the ridge toward the center of the back.

Inferior Angle of the Scapula The inferior angle of the scapula is the lowest medial tip of the bone. It is found by placing a finger on the border of the scapula closest to the spine and tracing downward to the lower end of this border. The inferior angle is the point at which the border turns outward and upward.

Humerus The upper arm bone.

Olecranon Process This part of the ulna is the prominent bony projection at the posterior angle of the elbow. To identify this point, have the subject flex the forearm to 90 degrees. The lower back portion of the elbow, which is easily seen and felt, is the olecranon.

Ulnar Styloid The styloid is easily seen as a projection on the back of the wrist. The forearm should be flexed to 90 degrees, and fully pronated. The prominence on the lateral (little finger) side of the wrist is the styloid process.

STUMP MEASUREMENTS FOR FITTING AND SIZING

Girths Measurements of the stump are taken at regular two-inch intervals, measuring from the lateral epicondyle in the BE, and from the acromion in the AE, as shown in Figure I-3. Two-inch intervals are laid off on the stump with a body marking pencil, but the last mark is always placed one inch from the stump end. The tape should be drawn firmly around the stump without deforming the tissue, but no slack should be permitted. Girths are recorded to the nearest ⅛ inch. The technique of measurement is illustrated in Figure I-4.

Lengths Required length measurements are also shown. Two length measurements are required for the Above-Elbow stump: from the acromion to the end of the stump; and from the axilla to the end of the stump. The Below-Elbow stump is measured from the lateral epicondyle to the end of the stump. Firm pressure must be applied to the stump end to locate the bone end and to avoid uncertainty due to flabby flesh.

UPPER-LIMB MEASUREMENT CHART

Prosthetist ______________________ Date ______________________

Patient's Name ______________________ Amputation Date ______________________

Amputation Type ________ Rt. ____ Left ____ Color Guide No. ______________

Height ________ Age __________ Sex: Male ________ Female ________

Socket: Double Wall ____ Single Wall ____ Split ____

Muenster ____ Shoulder Cap ____

Hook ________ Hand ________ Wrist ________ Hinge ________ Elbow ________

Shoulder Joint ________ Cuff________ Harness ________ Control System ________

Special Considerations ____

____

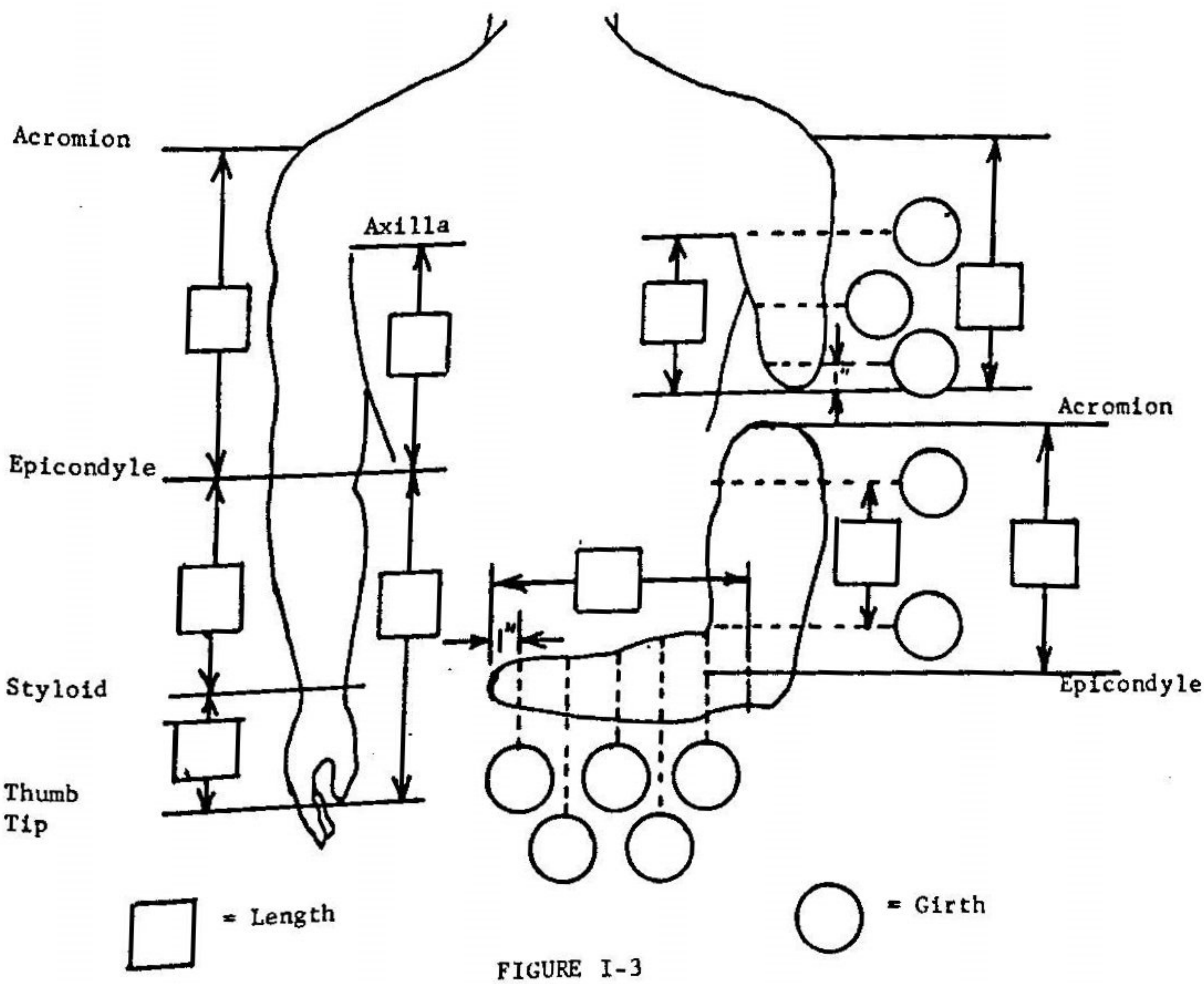


FIGURE I-3

In addition, measurements are made of the sound arm of the unilateral: acromion to lateral epicondyle (Dimension A); and lateral epicondyle to thumb tip (Dimension B). Note that both are straight line dimensions, and for this reason measurements by calipers are most accurate. If a tape measure is used, the projected or straight line distance should be taken. Figure I-4 shows a length measurement being made with caliper. For bilaterals, on whom these measurements cannot be obtained, ratios can be applied as explained at the end of this chapter.

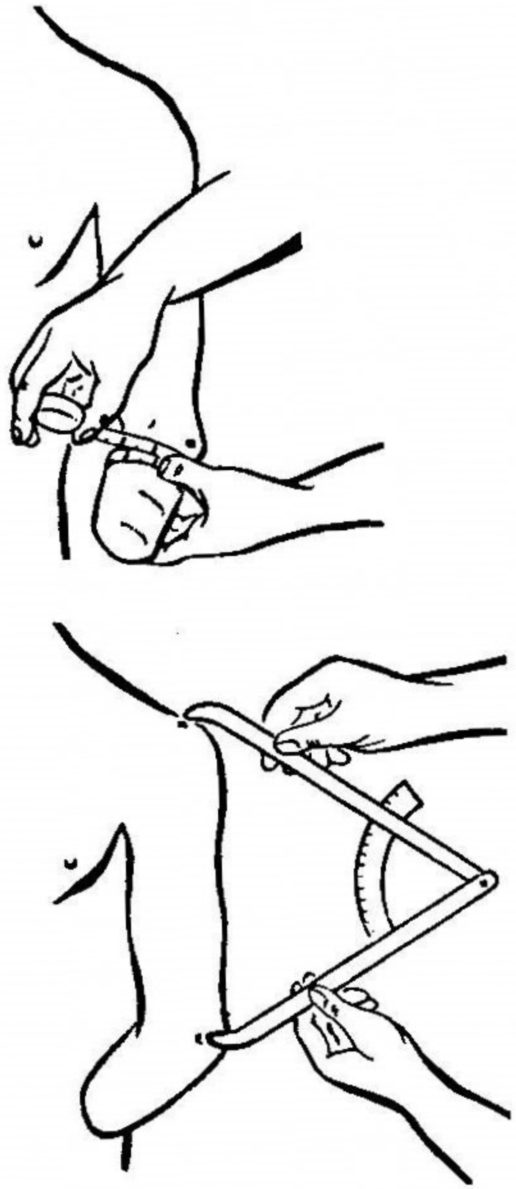


FIGURE I-4. Technique of Girth and Length Measurement

DETERMINING AMPUTEE TYPE

The first consideration in selecting the equipment for an amputee is the amputation level.

Figure I-5 shows the levels demarcating the various amputee types. The three categories of shoulder amputation are designated only by characteristic level, i.e., total removal of the clavicle and scapula, disarticulation at the glenohumeral joint, and amputation through the humeral neck. Above-Elbow levels are defined in terms of percentage of the acromion-to-epicondyle length.

Below-Elbow types are classified in accordance with the epicondyle-to-styloid length, while the transcarpal category includes losses at any level below the wrist continuing down to about mid-metacarpal level. More distal losses are so variable and so questionable as to prosthetic replacement that further classification is not practical.

The formulas for calculating percentage lengths are presented below:

Unilateral AE:

$$\% = \frac{\text{Stump Length} \times 100}{\text{Sound Arm Length}}$$

Unilateral BE:

$$\% = \frac{\text{Stump Length} \times 100}{\text{Sound Forearm Length}}$$

Since sound side dimensions will not always be available for bilaterals, indexes must be used in computing the percentage length. These Carlyle indexes are based on the ratio of average arm and forearm length to total height.

Bilateral AE:

$$\% = \frac{\text{Stump Length} \times 100}{\text{Height (inches)} \times 0.19}$$

Bilateral BE:

$$\% = \frac{\text{Stump Length} \times 100}{\text{Height (inches)} \times 0.14}$$

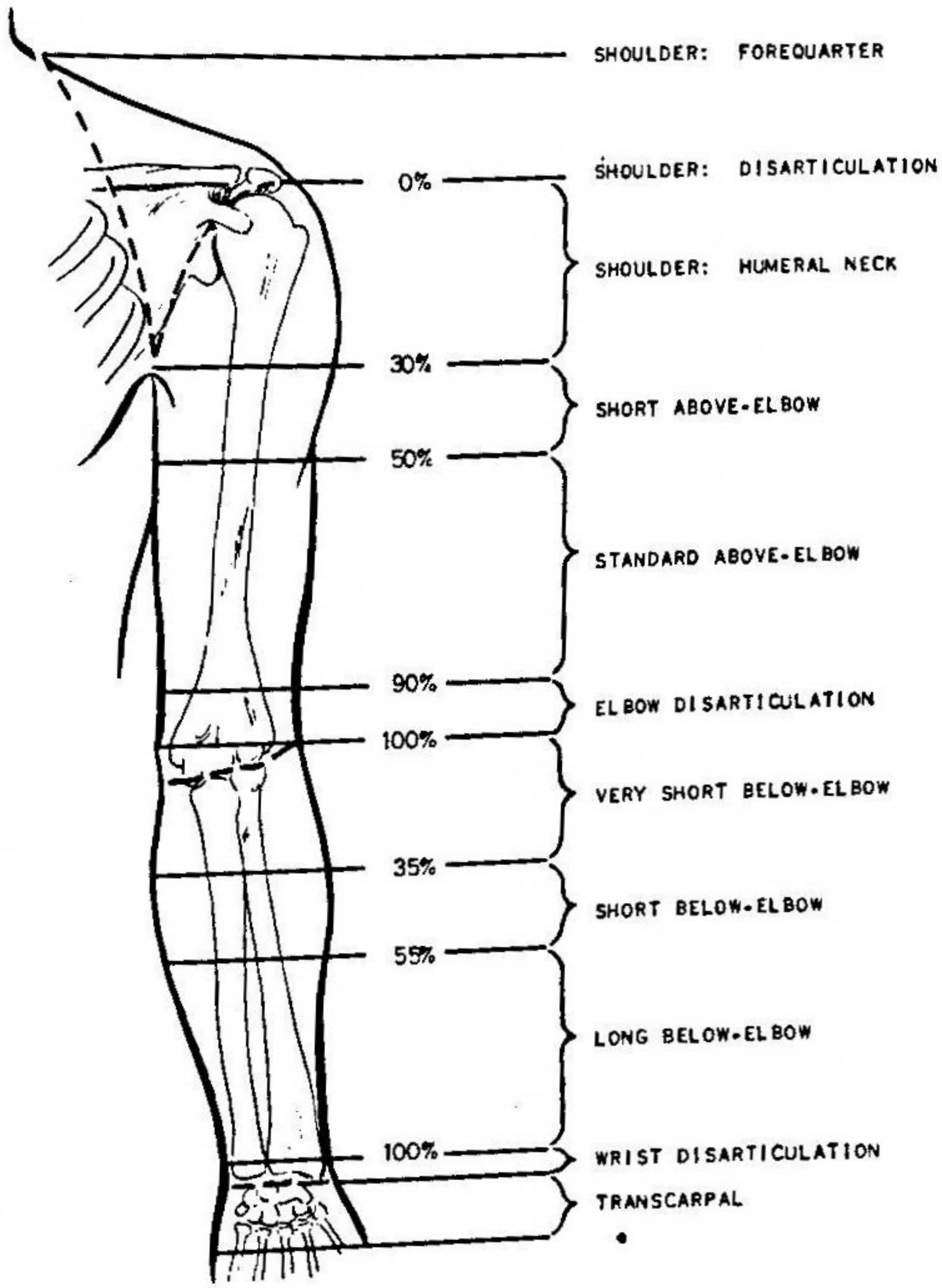


FIGURE 1-5. Amputee Type Based on Amputation Level

LENGTH SIZING OF THE PROSTHESIS

The objective here is to match prosthesis length to the critical dimensions of the normal arm. The two basic types of prosthesis are shown in comparison to a normal arm in Figure I-6. Four important dimensions are the basis for prosthetic sizing, Dimensions A, B, C, and D.

Dimension A This measurement extends from the acromion to the lateral epicondyle in the natural arm, and from the acromion to the elbow hinge center of the Above-Elbow and Shoulder types of prothesis. It therefore determines the lengths of the arm portions of these prostheses so that the elbow placement will be proper. For the unilateral, Dimension A will be obtained from the measurement of the sound side, as shown. For the bilateral, Dimension A can be obtained as explained at the end of this chapter. The forearm sections of Above-Elbow prostheses are sized in accordance with the Below-Elbow dimensions given below.

Dimension B This measurement extends from lateral epicondyle to the natural thumb end. The thumb should be drawn in against the index finger when the dimension is taken. In unilaterals it is, obviously, measured on the sound arm; in bilaterals, the procedures are explained at the end of this chapter. The selection of the thumb tip as the appropriate terminal point for a prosthesis with a hook is based upon prosthetic experience rather than any particular theory.

The Sizing Plans

Standard Plan

This plan permits only limited interchangeability, no wrist unit, and limited accommodation for the artificial hand. It can be used for either AE or BE amputees. For BE amputees of longer than 80 percent of the epicondyle-to-styloid length it is the only feasible plan.

The BE prosthesis shown in Figure I-6 is sized to the Standard Plan. The prosthetic forearm length (Dimension C) is planned to correspond to the epicondyle-to-styloid length minus ⅝ inches. Then, a terminal device such as the APRL hand will match the sound arm in length to the thumb tip. The possible terminal device combinations with the standard plan are shown in Figure I-7.

Forearm length for the AE and BE

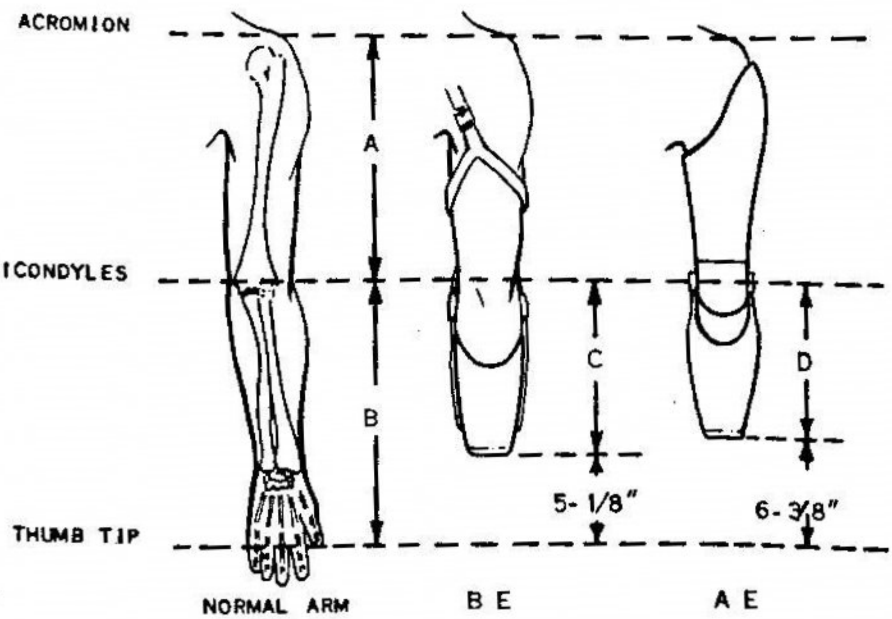


FIGURE I-6. Prosthesis Length Dimensions for Sizing
Dimension C demonstrated on Below-Elbow Prosthesis
Dimension D demonstrated on Above-Elbow Prosthesis

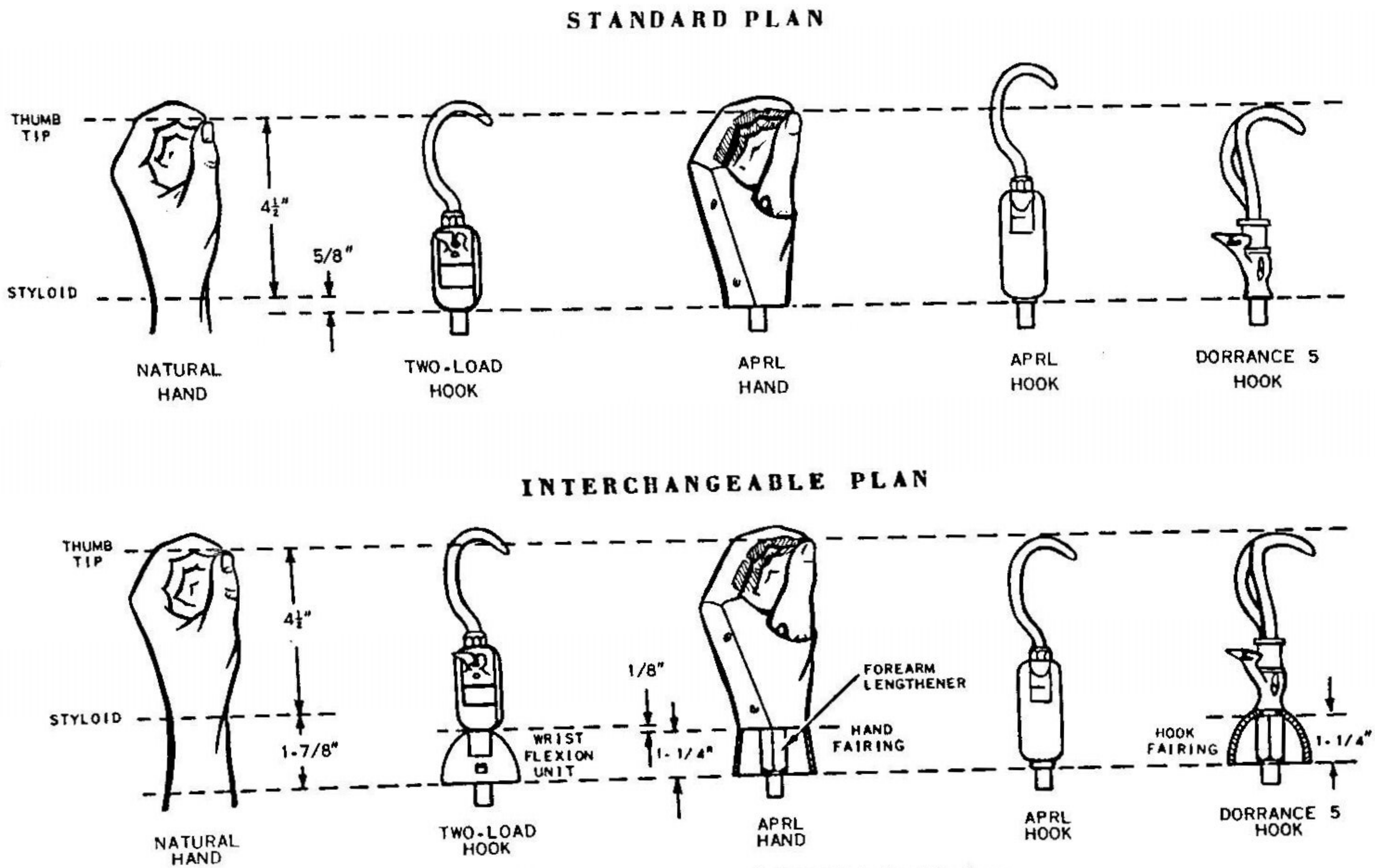


FIGURE I-7. Terminal Device and Wrist Unit Combinations for Standard and Interchangeable Plans prostheses, except for Wrist Disarticulation and Transcarpal types, will then be found by subtracting 5⅛ inches from the epicondyle to thumb tip length.

Dimension C = Dimension B — 5⅛ in.

Dimension B is shown for a range of amputee sizes in Table I-1.

Interchangeable Plan

This plan (Figure I-6) is designed to accommodate all terminal devices and wrist units. The forearm lengthener with hand fairing provides a more satisfactory fitting of a prosthetic hand. It also permits interchange with a short hook. In this plan the forearm is made 1¼ in. shorter than that used for the Standard Plan. The prosthetic forearm length is obtained by subtracting 6⅜ in. from the epicondyle to thumb tip length.

Dimension D = Dimension B — 6⅜ in.

These arrangements for various types of terminal devices and wrist unit combinations are shown in Figure I-7. Dimension D, the reduced forearm length, is shown for a range of amputee sizes in Table I-1.

Table I-1 below can be used to determine the maximum forearm stump length which can be accommodated within the sizing schedules for the Standard and Interchangeable plans. Since the wrist units (caps) are approximately ¾ inch in length and socket lamination takes up another ¼ inch, an allowance of one inch should be made. For the Standard Plan, Dimension C minus 1 inch gives the maximum stump length. For the Interchangeable Plan, Dimension D minus 1 inch gives the maximum stump length. Longer stumps than these will not fit within the sizing plans, and the hook or hand may protrude beyond the natural thumb length.

Sizing the Bilateral Prosthesis

Without the presence of a normal arm as a sizing reference, guidance must be obtained

TABLE I-1. ARM AND FOREARM LENGTH SIZING

1	2	3	4	5	6	7
			Standard Plan		Interchangeable Plan	
Amputee Height (in.)	Dimension A (in.)	Dimension B (in.)	Dimension C (in.)	AE Forearm Size (in.)	Dimension D (in.)	AE Forearm Size (in.)
60	11.4	12.6	7.5	7.5	6.2	6.0
61	11.6	12.8	7.7	7.5	6.4	6.5
62	11.8	13.0	7.9	8.0	6.6	6.5
63	12.0	13.2	8.1	8.0	6.8	7.0
64	12.1	13.4	8.3	8.5	7.0	7.0
65	12.4	13.6	8.5	8.5	7.2	7.0
66	12.5	13.9	8.8	9.0	7.5	7.5
67	12.7	14.1	9.0	9.0	7.7	7.5
68	12.9	14.3	9.2	9.0	7.9	8.0
69	13.1	14.5	9.4	9.5	8.1	8.0
70	13.3	14.7	9.6	9.5	8.3	8.5
71	13.5	14.9	9.8	10.0	8.5	8.5
72	13.7	15.1	10.0	10.0	8.7	8.5
73	13.9	15.3	10.2	10.0	8.9	9.0
74	14.1	15.5	10.4	10.5	9.1	9.0
75	14.2	15.8	10.7	10.5	9.4	9.5
76	14.4	16.0	10.9	11.0	9.6	9.5
77	14.6	16.1	11.1	11.0	9.8	10.0
78	14.8	16.4	11.3	11.5	10.0	10.0

Code:

Dimension A—Acromion to lateral epicondyle (elbow hinge center)
Dimension B—Lateral epicondyle to thumb tip
Dimension C—Lateral epicondyle (elbow hinge center) to face of wrist unit
Dimension D—Lateral epicondyle (elbow hinge center) to face of wrist unit

from average human measurements. For Dimension A, the Carlyle index is the ratio of acromion-to-epicondyle length to height.

Dimension A = height in inches x 0.19

The index used to compute Dimension B is the ratio of epicondyle-to-thumb-tip length to height.

Dimension B = height in inches x 0.21

Table I-1 provides these dimensions for a range of body heights (Columns 2 and 3) so that calculation is not necessary. The ratios for women are close enough to those for men so that the table may be used for both.

Selecting the Commercial Forearm For a Unilateral AE

Table I-1 can also be used in selecting the length of the commercial forearm for a given AE case. As these are available in half-inch steps, the commercial size nearest to Dimension C is shown in Column 5 for the Standard Plan. That nearest to Dimension D is given in Column 7 for the Interchangeable Plan.

GIRTH SIZING OF THE PROSTHESIS

So far, our discussion of sizing has been confined to prosthesis length. Single wall sockets formed to the stump, and double wall sockets formed according to the instructions in this manual, will be of suitable girth for the amputee's general build. However, in selecting elbow units and forearms for the AE case, attention should be given to small size or slenderness of the amputee. Medium sized elbows with matching forearm sections are now commercially available for women and thin men; they should be used when a midarm girth under 8 inches is needed.

Fabrication of Below-Elbow Prostheses

THE FUNCTIONAL ROLE OF SOCKETS

The principal components of a Below-Elbow prosthesis are the socket, wrist unit, elbow hinge, and arm cuff. The socket is the foundation of the prosthesis. It must have purchase upon the stump and should be stable, though comfortable, in its fit with the stump. The socket must bear weight both axially and in all lateral directions. The mechanical components, control guides, and retainers are attached to it. So it must be structurally sound as well as being custom fitted. Finally, the socket extends the control function of the stump to which it is fitted, giving movement range and direction to the prosthesis.

Sizing has now been reduced to standard practice as previously described. The requirement of formability and strength in socket materials has been satisfactorily met by the introduction of plastic laminates. These materials permit close fitting to the stump impression, by procedures in which negative and then positive molds are made. Variations in strength can be introduced by variations in formula, reinforcing material, and number of laminate layers. A final feature of great importance is that the texture and coloring of the plastic laminate can be controlled to achieve satisfactory cosmetic results.

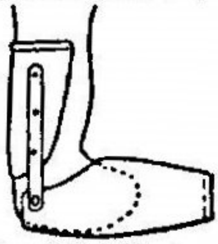
Forearm Rotation (Pronation-Supination)

Unfortunately, the socket stability needed for flexion interferes with rotation. Stumps that are 50 percent or less of normal forearm length have no residual rotation. With longer BE stumps, the proximal part of the socket can be cut down to give freedom for rotation, while the distal part provides stability by its grip on the stump. About half of normal forearm rotation is available to the wearer of a Wrist Disarticulation socket.

Short BE

A double-wall socket increases axial stability (reducing piston action of the stump in the socket).

It is impractical to preserve the residual rotation (usually less than 60°), so rigid or semi-rigid hinges are used to prevent slippage

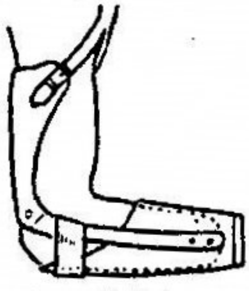


while permitting full 135 degrees of flexion. Manual rotation is provided by the wrist unit.

The half cuff with or without billet adds to stability of the prosthesis on the arm and serves as an anchor for the control cable reaction point.

Long BE or Wrist Disarticulation

Proper forming of the distal portion of the socket into a "screwdriver" shape provides enough purchase to transmit at least half the residual rotation to the prosthesis. Additional manual rotation is provided by the wrist unit.



A double wall socket increases axial stability; single wall construction may be used where stump shape permits. The anterior proximal portion of the socket is shaped to allow a full 135 degrees of flexion and to minimize the restriction in rotation, while the posterior part distributes flexion loads along the total stump length.

Flexible hinges with cross-hanger prevent slippage without inhibiting rotation.

A triceps pad usually provides enough stability on the arm and reaction point anchorage.

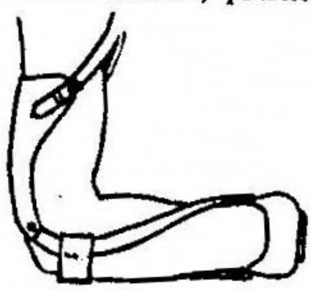
Transcarpal

In addition to allowing full forearm flexion and nearly full rotation, the socket permits some regain of residual flexion at the wrist. Manual rotation is also provided by the wrist unit.

Flexible hinges and cross-hanger yield axial stability without sacrificing rotation or wrist flexion.

The triceps pad supplies stabilization, as for the Long BE.

Because of the great variation in stump length and configuration, a more specialized type of prosthesis may be desired. Successful prostheses have been fabricated which use foam-rubber-lined sockets, plastic or leather



forearm cuffs, and other modifications to improve the stability and comfort on the stump.

DESCRIPTION OF FABRICATION OPERATIONS

Review of Prescription

The prescription is the basis for all prosthetic work. It is the result of a careful study by the prescription team of the desires and needs of the amputee, and it must be followed to the letter. The prosthetist should contribute ideas concerning the case during the prescription meeting and should thereafter work in accordance with the form, unless some obvious discrepancy becomes apparent. In the latter case, he should get in touch with the physician and state the problem to him.

Reviewing the prescription will not only recall the particulars of the case, but it will also insure preparation of supplies and components so that work can begin without delay when the amputee arrives.

Measurements

Accurate measurements of the stump and sound arm are necessary for successful fitting. The cast is often slightly different in size and shape because of difficulties in taking the mold, so accurate stump measurements are required to check subsequent shaping of the cast.

The Mold or Wrap

The first reproduction of the stump is a negative plaster mold, often called the wrap, since it is made by wrapping the stump with plaster of Paris bandages. While other methods may be used, the plaster wrap seems to be the most practical method of obtaining a satisfactory impression.

The Cast or Model

The second reproduction is a positive plaster of Paris cast made from the mold. It is shaped to include all necessary reliefs and changes to insure a proper and comfortable fit of the socket.

The Check Socket

The third impression, often called the check or test socket, is formed of stockinet and wax and is a negative reproduction made from the model. It includes the changes to the model, such as relief areas. Since it is easily re-formable after trial on the stump, it enables the prosthetist to make necessary revisions in fitting and prevents or minimizes changes to the plastic socket.

The Lamination Cast or Model

The fourth and final reproduction of the stump is a positive cast, either solid or hollow, over which the plastic socket will be laminated. Since the model is made from the check socket, it incorporates all fitting changes, and the surface has the exact form of the interior of the plastic socket.

Socket Layup and Lamination

This step consists of covering the lamination model with reinforcing materials such as dacron felt and nylon stockinette, preparing the pressure sleeve and resin, and impregnating the reinforcing materials with resin.

The Extension

This process consists of applying wax or foam to the socket and shaping it to form a model for the forearm. The extension thus determines proper forearm sizing and wrist-unit alignment.

Forearm Layup and Lamination

Reinforcing materials are drawn over the socket and extension, tied into the wrist unit, and rigid hinges (if used) are properly positioned. The layup is then laminated.

Trim and Assembly

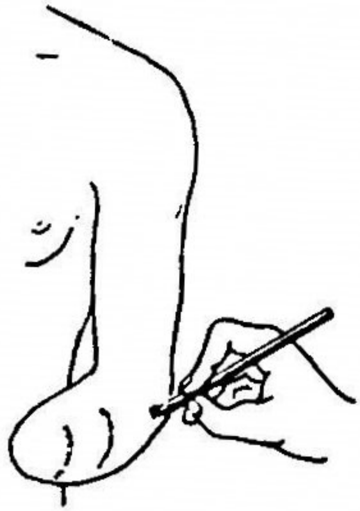
This step comprises shaping the proximal end of the socket to conform to the stump, in order to provide maximum socket stability consistent with motion of the stump. It also includes the assembly of components, such as forearm lengtheners, flexion units, hinges, cuffs, control systems, and harness, to complete the fabrication of the prosthesis.

MOLDING FOR ALL BE PROSTHESES

Measurement and Marking

1. Location of Measurement Marks

Use an indelible pencil to mark the elbow axis (epicondyles) and the stump, as previously described. When fabricating a Transcarpal type prosthesis, mark the wrist axis (styloids) instead of the elbow axis. The indelible marks will transfer to the wrap in the next operation.



2. Record of Measurements

Measure and record the girths and lengths according to the technique given previously.

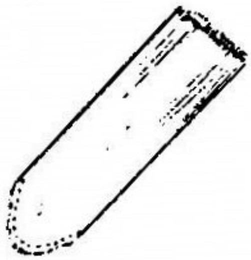
3. Location of Relief Areas

Mark all bony prominences, tender spots due to scars or underlying neuromas, etc. These marks will also transfer to the wrap and will indicate areas where relief of socket pressure on the stump may be necessary.

The Mold or Wrap

1. Preparation of Cast Sock

Sew a length of stockinet sufficient to extend at least 2 inches beyond the epicondyles (styloids in the case of a Transcarpal) in a curve to match the end of the stump. The stockinet should be of appropriate width to fit snugly to the stump.



Cut the excess off below the seam. Draw the cast sock over the stump with the seam on the outside and clamp in place to an elastic

strap running in a Figure 8 pattern across the back and around the opposite shoulder.

2. Preparation of Plaster Bandages

Cover the clothing of the amputee with a sheet or gown to protect it from plaster.

Soak a plaster bandage in water until air bubbles cease. Use a three-inch bandage; the large width will distribute pressure more evenly over the stump, giving a smoother contour to the inner surface of the wrap. Remove the bandage from the water and squeeze gently to remove excess water, taking care not to squeeze out the plaster.

3. Application of Plaster Bandages

The mold is taken with the patient's elbow flexed at least 80 deg. and the forearm positioned midway between pronation and supination.

Start the wrap near the midpoint of the stump and roll the bandage in a spiral downward, overlapping each previous turn by about half the bandage width. Continue to the end of the stump. Lap several layers over the end and spiral back up past the midpoint to just proximal to the epicondyles and olecranon (or styloids if Transcarpal type), then back to the

starting point. Do not wrap too tightly over the epicondyles or styloids. Repeat the procedure until about three separate layers cover the entire stump. If the prescription calls for flexible hinges, flatten the medial and lateral aspects of the distal third of the wrap to obtain a "screwdriver" contour.

4. Completion of Mold

Remove the elastic strap and carefully pull the mold (including the cast sock) from the stump. For some Wrist Disarticulation or Transcarpal types, it may be necessary to cut the wrap in order to remove it from the stump.

The indelible marks previously made on the stump will have transferred to the cast

sock. Go over and strengthen these marks on the inner surface of the wrap so they will transfer in the succeeding operation.

The Cast or Model

1. Preparation

For measuring convenience, fill the wrap with water, then pour the water into a rubber mixing bowl. (Rubber facilitates the removal of the set plaster.) Sprinkle plaster evenly into the water until additional plaster no longer dissolves. Mix the plaster and water carefully by hand to work out all lumps and air bubbles.

Obtain a pipe approximately ½ inch in diameter and 12 inches long, and dent the end

third so that it will anchor firmly in the plaster and serve as a holding rod.

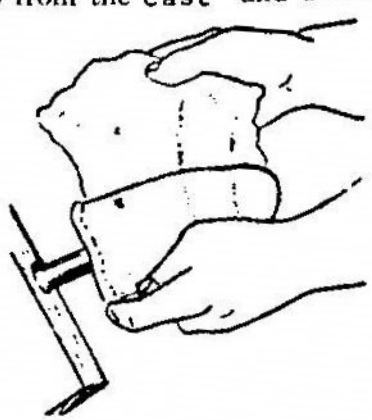
2. Application of Plaster

Pour the wrap about a third full of the plaster mixture and shake it gently to remove any entrapped air. Fill the rest of the wrap and prop it up to harden.

When the plaster has set sufficiently to support the weight of the rod, insert the dented end into the plaster. Allow the plaster to harden.

3. Removal of Wrap

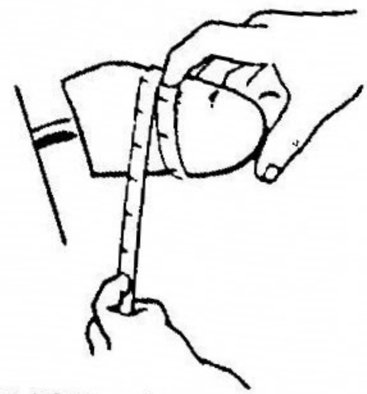
Cut the wrap down the side with a knife, taking care not to damage the cast. Strip the wrap from the cast and discard it.



With indelible pencil, re-mark the landmarks that have transferred from the wrap to the cast.

4. Completion of Model

Measure girths on the model and compare them with the recorded stump measurements. Use a knife, scraper, or wire screen to shape and smooth the model to proper size. Be careful not to reduce the areas where relief is needed. In cases where a heavy stump sock



will be worn, shape the model slightly larger to allow for this. If measurements of stump and model differ widely, measurements and/or wrap technique may be in error. Recheck!

The Check Socket

1. Preparation of Wax

Heat the beeswax on an electric plate (not open flame, for the fumes are flammable) to a temperature of about 275° F. or until bubbles just begin to form when a test piece of stockinet is dipped into the wax.

2. Layup

Cover the model with a thin film of parting compound such as petrolatum, to prevent adherence of the wax to the plaster.

Cut two lengths of cotton stockinet of appropriate width, each twice as long as the model, plus eight inches. Pull one length inside the other and then place half of the stockinet gently over the model so that petrolatum does not saturate the fabric. With heavy cotton cord, loosely tie off the stockinet at the distal end of the model. Reflect the remaining length over the model, pull down tightly, and tie off around the mandrel.

3. Application of Wax

With a ladle or cup, dip out the hot wax and pour it over the stockinet. Use enough wax to impregnate the stockinet completely and place in cool water to harden. Be careful never to allow water to be introduced into the basin of hot wax.

While the wax is cooling, press and massage it to be sure that all contours have been faithfully reproduced.

4. Removal of Check Socket

While still warm, cut the proximal edge of the check socket to conservatively approximate trim lines and slide or pull it off the model. For the short BE, initial anterior trim should be close to the biceps tendon, while for the long BE, initial anterior trim should be about two inches distal to the biceps tendon. Posteriorly, the trim line should be just proximal to the olecranon for both short and long stumps.

If it is difficult to remove the check socket, use an air hose to blow around the proximal edges to force separation. For some types such as the Transcarpal, it may be necessary to slit the cast to remove it from the master.

5. Check-Socket Fitting

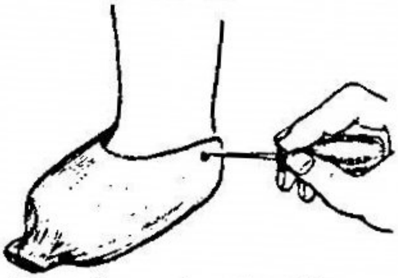
Place cotton stockinet over the stump and apply the check socket by pushing it onto the stump while pulling on the stockinet which extends through the hole in the end of the wax socket. Liberal use of talcum powder facilitates this process.

Fitting the check socket includes the following: a. overall fit, that is, is socket too loose or too tight? b. trim lines--for the short BE, the anterior trim remains as close as possible to the biceps tendon consistent with full range of flexion (135°) or, if this is not practical, consistent with a functional range of motion. If necessary, sacrifice flexion range to maintain sufficient socket-stump contact anteriorly. For the long BE, the anterior trim may be lowered as needed to allow full range of motion in both flexion and rotation. Be sure to avoid contact with the epicondyles at the extremes of pronation and supination. c. comfort--have the patient exert force in all directions against resistance and note the location of any pain or discomfort. d. total contact--cut inspection holes to check for total contact.

Since the wax check socket is malleable, its shape and volume can be readily altered to correct any problems that are uncovered.

6. Location of Elbow Axis

Use an awl to make a small hole in the check socket exactly at the center of each



epicondyle to determine the elbow axis (styloids in the case of a Transcarpal).

7. Location of Hinge Spacer— Rigid Hinges Only

If a rigid hinge has been prescribed, an adjustable hinge spacer must be aligned in the lamination mold.

The spacer enables the hinges to be maintained in parallel alignment during layup and lamination so that the hinges will operate without any binding.

Holes are punched in the check socket with a leather or cork punch of diameter to match the spacer. The holes are located with reference to the elbow axis in accordance with the particular hinge used. The spacer is inserted and adjusted to the proper width and remains in place while the lamination mold is constructed. Care should be taken not to deform the check socket when punching the holes.

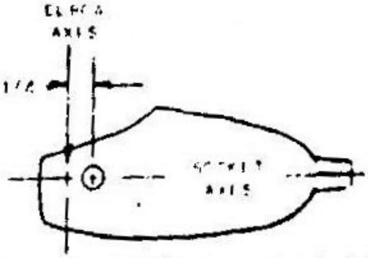
a. *Single Pivot Hinge*

Punch two holes with the centers coinciding with each epicondyle center. Insert the spacer and adjust the width to extend about

3/16 inch from the most medial trim edge of the check socket and about ⅛ inch laterally.

b. *Polycentric Hinge*

Punch two holes ¼ inch distal from the epicondyle centers with the centers lying on the socket axis. The spacer axis should be parallel to the elbow axis. Insert the spacer



and adjust the width to extend 3/16 inch from the most medial trim edge of the socket and ⅛ inch laterally.

Lamination Model: Plaster Method

1. Application of Plaster

Mix enough plaster and water to fill the socket about half full. Pour the plaster into the socket and slowly rotate the socket while pouring the plaster back into the mixing bowl. A thin film of plaster will build up inside the socket each time. Repeat this operation until the plaster wall is about ¼ inch thick all around the inside of the socket. Allow the plaster to dry for about a half-hour.

2. Removal of Check Socket

Carefully slit the wax socket with a knife and peel it from the breakout. Do not deform the socket more than necessary, since it may

be needed again if the breakout is cracked or otherwise damaged.

Hold the breakout up to the light and look inside for thin areas. If such areas exist, mix more plaster, and slush it inside the breakout until the wall is built up sufficiently.

3. Location of Hinge Spacer

If the hinge spacer was not located in the check socket, locate it now in the breakout.

Drill holes in the breakout to accommodate the spacer. Adjust for width and seal around the spacer with plaster or clay.

4. Completion of Breakout

Smooth the breakout with sandpaper or wire screen to remove irregularities. Close the proximal end with plaster that has thickened to the consistency of whipped cream. Be careful to preserve the proximal trim line on the mold. Insert a small diameter tube into the breakout to serve as a vent and holding rod. Be sure this tube is not clogged. Dry the breakout in an oven at 140° F. for at least three hours.

When fabricating a double wall prosthesis, paint or dip the breakout in parting lacquer to cover it with a thick even coat. Be careful to avoid bumps in the surface of the lacquer, for they will transfer to the plastic socket.

SHORT BE PROSTHESIS (DOUBLE WALL)

First Layup

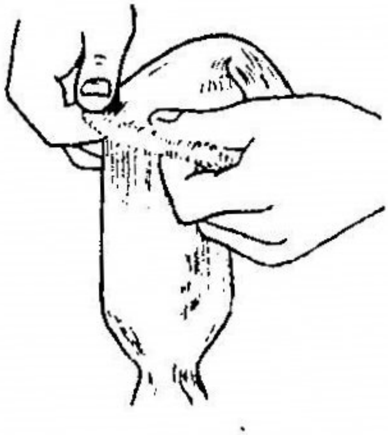
1. Preparation

Cut three lengths of stockinet, each about 3 inches longer than the lamination mold, and another about half the mold length.

Sew the end of each piece in a curve to match the distal end of the mold, and cut to form a ⅛-inch seam allowance.

2. Application of Stockinet

Pull two of the long pieces tightly down over the mold; keep the seam allowance on the outside and the ribs straight, to provide



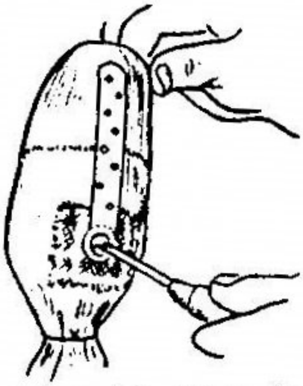
a smooth interior surface of the socket. Tie the open ends to the holding rod with string.

Cut a tiny slit in the stockinet over each of the spacer ends and force it down over each end so it fits snugly around the spacer. Pull the short piece of stockinet over the layup and trim it where the second lamination will fair in.

3. Attachment of Hinge Socket Straps

Disassemble the hinges and drill five to eight ⅛-inch holes in each socket strap to allow resin to form columns through the metal and create a secure bond. Remove the burrs from the holes with a countersink.

Using bending irons, shape the straps to the contour of the mold.



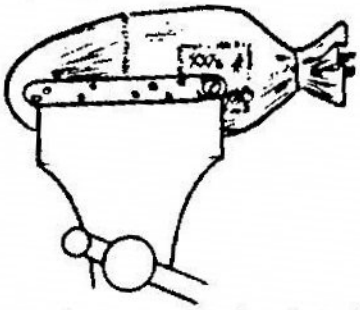
When a polycentric hinge is prescribed, install clearance spacers between the forearm straps and hinge spacer. This will facilitate assembly of the hinge in a later operation by preventing resin from curing under the mechanism or pivot part of the forearm straps.

Coat the threads of the hinge screws with silicone grease and attach the straps to the spacer. Do not tighten the screws yet.

4. Alignment of Hinge Socket Straps

Remove the layup from the vise and adjust the vise jaws to an opening about the same as the spacer width.

Place the layup in the vise with the edge of each forearm strap resting on the top edge of the vise jaws. Pivot the layup until the straps are aligned along the axis of the layup. Tighten the hinge screws to hold the straps securely to the spacer. The forearm straps will be aligned parallel.



Reposition the layup in the vise, distal end up, and pack any gaps between the straps and the layup with scraps of stockinet.

5. Completion of Layup

Turn the remaining stockinet inside out (seam allowance on the inside) and pull it over the layup.

Pull the stockinet down tight, smooth the layup, and tie the open ends tightly to the holding rod.

Lamination

Details of the procedure are not described in this manual.

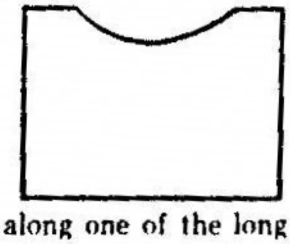
Buildup

1. Preparation

Remove the pressure sleeve from the cured socket. If a manual lock wrist unit is prescribed, disassemble the mechanism to keep it free of wax and resin. Drill several 1/8-inch holes in the face of the wrist unit where necessary to expedite wax removal.

Cover the knurled portion of the wrist unit with masking tape to keep it clean for subsequent laminating.

Obtain a 9 x 12-inch piece of Manila paper or other resin impregnated paper (half of a Manila folder is usually satisfactory) to use in making the buildup form.



Halfway along one of the long sides, make a pencil mark about ¼ inch from the edge. Draw a curve about 3 inches on each side of the mark and cut along the line. This cut side will allow the wrist unit to fit squarely to the paper when it is formed into a cone.

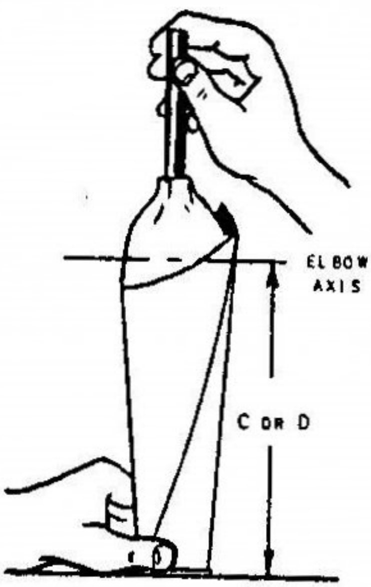
2. Alignment of Wrist Unit, Form, and Socket

Wrap the curved side of the Manila paper around the taped skirt of the wrist unit so a conical form is fashioned.

Determine the required forearm length (Dimension C or D) in accordance with the sizing plans and formulas at the end of the Measurements chapter.

With one hand, hold the cone and wrist unit with the face of the unit flat on a table.

With the other hand, position the socket in the cone so the distance between the elbow axis and the table surface corresponds to the required forearm length (Dimension C or D). A height gage is useful for setting the distance.

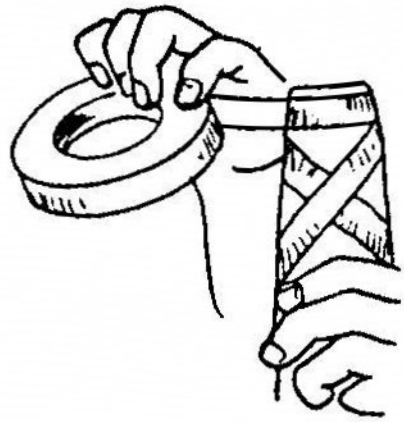


With the socket held in the proper position, adjust the cone so the proximal end fairs to the socket.

As soon as the correct conical shape is obtained, remove the socket from the form and apply one piece of masking tape at the middle of the form to hold the cone shape.

Trim the proximal end of the form if it is too long.

Align the form and socket so the cone axis is the same as the socket axis, and is at right angles to the elbow axis. Check the forearm length again to see that it is correct. Tape the proximal end of the form securely to the socket.



Square off the wrist unit so it is perpendicular to the form axis, and tape around the unit to attach it to the form. (When initial flexion is desired in the prosthesis, the forearm may be aligned in up to 30° flexion and the wrist unit may be canted 5° anteromedially.)

Mask all the seams to prevent wax leakage, then spiral-wrap tape around the form to strengthen it.

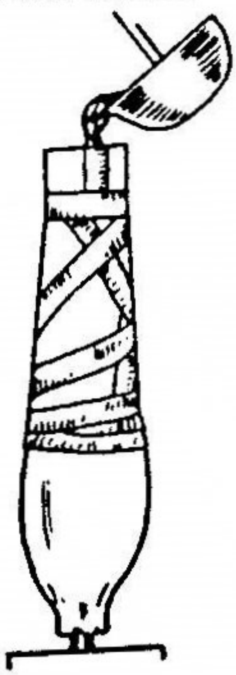
3. Attachment of Form Extension

Fashion a 3-inch-wide strip of Manila paper into a cylinder to fit around the distal end of the form so as to extend the form about 2 inches beyond the wrist unit.

Tape the extension securely to the form and tape the seam.

4. Application of Wax

Heat the wax until it is at the lowest possible pouring temperature. *Do not get the wax too hot.*



Pour a small amount of wax into the form to check for leaks. If all seams are sealed properly, pour the wax slowly to fill the form to within one inch of the top of the extension. Continue to add wax as the wax cools and shrinks.

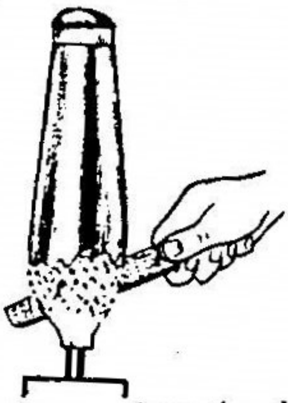
When the wax has hardened, remove the form and extension.

5. Completion of Buildup

Shape the cylinder of wax on the wrist unit into a dome so the pressure sleeve will not tear during lamination.

Smooth out any irregularities in the buildup surface to provide a smooth contour.

To insure a suitable bond between the inner and outer wall, a minimum of 1 inch of socket should remain between the anticipated trim line and the wax buildup.



Scrape excess wax from the plastic socket and clean it with benzine.

Rough up the exposed outer surface of the plastic socket with a coarse file to effect a secure mechanical bond between the inner and outer wall.

Second Layup

1. Preparation

Remove the masking tape from the wrist unit and clean the knurled surface to provide a good bonding area for the resin.

Cut one piece of stockinet about twice the length of the layup, and another 6 inches longer than the first piece.

2. Application of Stockinet

Pull one end of the short piece of stockinet

down over the forearm until the edge is about ½ inch proximal to where the buildup joins the socket.

Tie the stockinet tightly to the wrist unit with 4-cord linen thread, encircling the unit twice and making sure the thread lies completely in the groove.

Pull the free end of the piece down, keeping the ribs straight, and trim it so the edge is about ¾ inch distal to the first edge.

Pull half of the remaining piece of stockinet over the forearm and tie it to the wrist unit in the manner just described. Make sure the thread is in the groove and distal to the previous thread.

Pull the free end of the stockinet tightly down over the forearm, keeping the ribs straight, and tie the two layers securely to the holding rod.

Lamination

Mold Removal: Plaster Method

1. Preparation

While the plastic is still warm, cut off the end of the layup about 1 inch proximal to the hinges. Leave the pressure sleeve on to protect the finish of the plastic during subsequent operations.

2. Removal of Plaster

Strike the plastic socket with a rubber mallet just hard enough to crack the plaster. It

may be necessary to use a chisel to dig out plaster in the distal end of the socket. Do not strike too hard near the metal parts or delamination may occur.

3. Removal of Spacer

Cut away the plastic from the hinge screws and remove the screws. Narrow the width of the spacer and remove it from the socket.

4. Cleaning the Socket

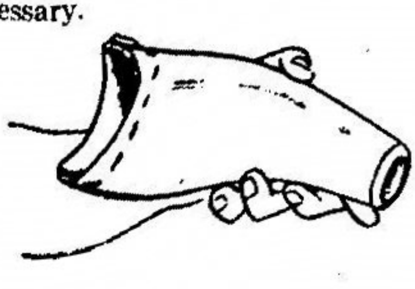
Remove the film of dried lacquer from the socket; a blast from an air hose will speed this operation. If particles of plaster and lacquer cling to the socket wall, remove them by wiping with a wet cloth.

Remove all wax or foreign material from the wrist unit.

Trim and Assembly

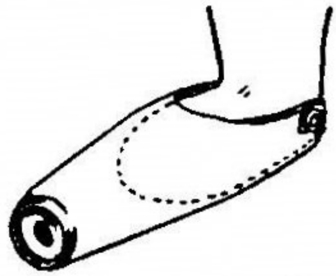
1. Determination of Socket Trim

Trim the socket to the rough trim established by the check socket. Hold the prosthesis firmly on the amputee's stump and check to determine if any alterations in trim are necessary.



The socket trim should permit flexion without the olecranon displacing the socket, and should enable the amputee to flex fully with comfort.

Cut away the plastic distal to the hinge center just enough to allow full flexion of the hinge.

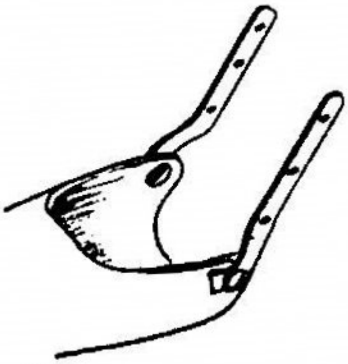


Sand all cut edges round and smooth, and seal the edges with plastic or lacquer.

2. Assembly of Hinge

Clean the hinge mechanism and assemble it onto the socket.

Hold the socket firmly on the stump and note the relationship of the arm straps to the curvature of the epicondyles and arm.



Remove the socket and bend the arm straps in a contour to within ¼ inch of the curve of the arm. Do not shape the straps tight against the arm.

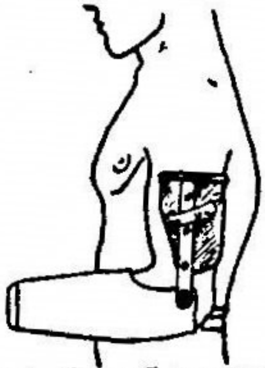
3. Fabrication of Cuff

Follow the procedure at the end of this chapter for the particular cuff prescribed (usually a half cuff).

4. Installation of Cuff

Hold the cuff and socket on the arm, with the stump flexed to 90°.

Align the straps parallel to the axis of the arm and temporarily clamp or tape the cuff to the straps. Test the alignment by flexing and extending the stump. When the alignment is correct, mark the location of the hinge strap rivet holes on the cuff. If the strap has no rivet holes, drill or punch three holes in each strap to take the rivets.



Punch holes in the cuff to correspond to the strap rivet holes.

Rivet the cuff to the straps, preferably with stainless steel, chrome, or nickel-plated rivets.

5. Installation of Terminal Device

Assemble the wrist unit and attach the prescribed terminal device and sizing accessories, in accordance with the manufacturer's instructions and the sizing plan.

6. Assembly of Control System and Harness

WRIST DISARTICULATION AND LONG BE PROSTHESIS (DOUBLE WALL)

First Layup

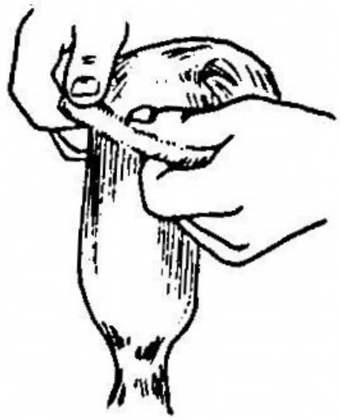
1. Preparation

Cut three lengths of stockinet, each 3 inches longer than the lamination mold, and another about half the mold length.

Sew the end of each piece in a curve to match the distal end of the breakout. Cut to provide a ⅛-inch seam allowance.

2. Application of Stockinet

Pull two of the long pieces tightly down over the mold, keeping the seam allowance on the outside and the ribs straight to provide a smooth interior surface of the socket. Tie the open ends to the holding rod with string.



Pull the short piece of stockinet over the layup and trim to where the second lamination will fair in.

3. Completion of Layup

Turn the remaining piece of stockinet inside out and pull it over the layup. Smooth the entire layup, pull the stockinet down tight, and tie the open ends of the stockinet to the rod.

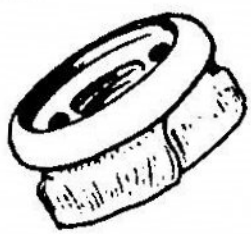
Lamination

Buildup

1. Preparation

Remove the pressure sleeve from the cured socket.

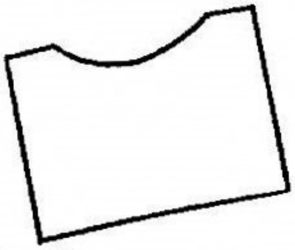
When a manual lock wrist unit is used, disassemble the mechanism to keep it free of wax and resin. Drill several ⅛-inch holes in the face of the wrist unit base where necessary to expedite wax removal. Cover the knurled section of the wrist unit with masking tape to keep it free of wax.



Obtain a 9 x 12-inch piece of Manila paper or other resin impregnated paper (half of a

Manila folder is usually satisfactory) to use in making the buildup form.

Halfway along one of the long sides, make a pencil mark about ¼ inch from the edge. Draw a curve about 3 inches on each side of the mark and cut along the line. This cut



side will allow the wrist unit to fit squarely to the paper when it is formed into a cone.

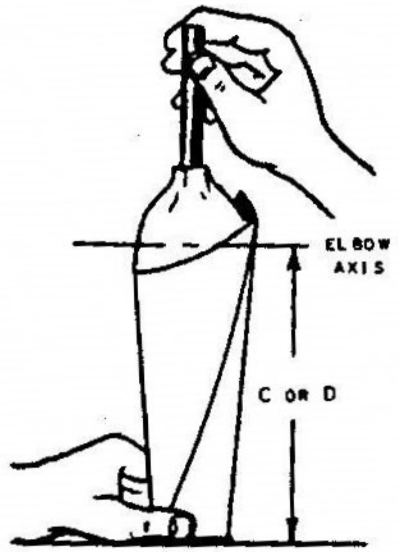
2. Alignment of Wrist Unit, Form, and Socket

Wrap the curved side of the Manila paper around the taped skirt of the wrist unit so a conical form is fashioned.

Determine the required forearm length (Dimension C or D) in accordance with the sizing plan.

With one hand hold the cone and wrist unit with the face of the unit flat on a table.

With the other hand position the socket in the cone so the distance between the elbow axis and the table surface corresponds to the required forearm length (Dimension C or D). A height gage is useful for setting the distance.

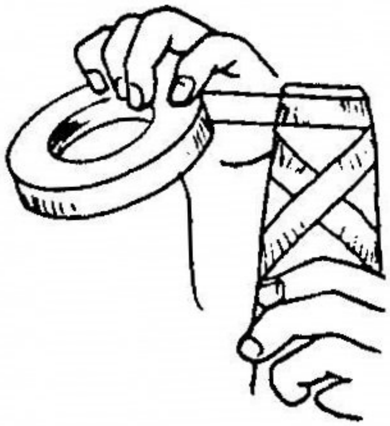


With the socket held in the proper position, adjust the cone so the proximal end fairs to the socket.

As soon as the correct conical shape is obtained, remove the socket from the form and apply one piece of masking tape at the middle of the form to hold the cone shape.

Trim the proximal end of the form if it is too long.

Align the form and socket so the cone axis is the same as the socket axis and is at right angles to the elbow axis. Check the forearm



length again to see that it is correct. Tape the proximal end of the form securely to the socket.

Square off the wrist unit so it is perpendicular to the form axis, and tape around the unit to attach it to the form.

Mask all the seams to prevent wax leakage, and spiral-wrap tape around the form to strengthen it.

3. Attachment of Form Extension

Fashion a 3-inch-wide strip of Manila paper into a cylinder to fit around the distal end of the form so as to extend the form about 2 inches beyond the wrist unit.

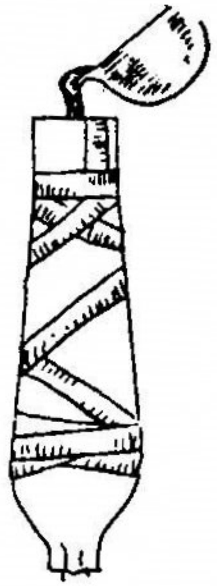
Tape the extension securely to the form and tape the seam.

4. Application of Wax

Heat the beeswax until it is at its lowest possible pouring temperature. *Do not get the wax too hot.*

Pour a small amount of wax into the form to check for leaks. If all seams are sealed properly, pour the wax slowly to fill the form to within one inch of the top of the extension. Continue to add wax as the wax cools and contracts.

When the wax has hardened, remove the form and extension.



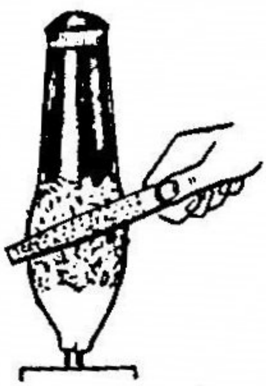
5. Completion of Buildup

Shape the cylinder of wax on the wrist unit into a dome so the pressure sleeve will not tear during lamination.

Smooth out any irregularities in the buildup surface to provide a smooth contour.

To insure a suitable bond between the inner and outer wall, a minimum of 1 inch of socket should remain between the anticipated trim line and the wax buildup.

Scrape excess wax from the plastic socket and clean it with benzine.



Rough up the exposed outer surface of the plastic socket with a coarse file to effect a secure mechanical bond between the inner and outer wall.

Second Layup

1. Preparation

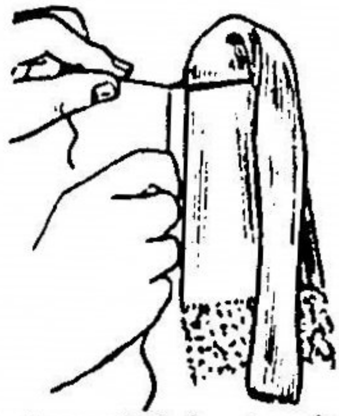
Remove the masking tape from the wrist unit and clean the knurled or grooved surface to provide a good bonding area for the resin.

Cut one piece of stockinet about twice the length of the layup and another about six inches longer than the first piece.

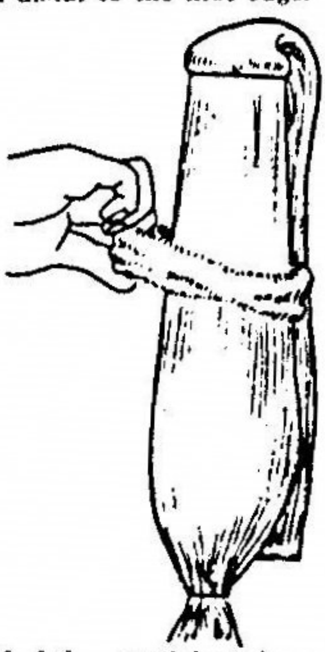
2. Application of Stockinet

Pull one end of the short piece of stockinet over the buildup until the edge is about ½ inch proximal to where the buildup joins the socket.

Tie the stockinet tightly to the wrist unit after encircling the unit twice with 4-cord linen thread, making sure the thread lies completely in the groove.



Pull the free end of the piece down, keeping the ribs straight, and trim it so the edge is ¾ inch distal to the first edge.



Pull half of the remaining piece of stockinet over the forearm and tie it to the wrist unit in the manner just described. Make sure the thread is in the groove and distal to the previous thread. (If flexible cable hinges are used, install at this stage on the layup in accordance with the manufacturer's instructions.)

Pull the free end of the stockinet tightly down over the layup, keeping the ribs straight, and tie the two layers securely to the holding rod.

Lamination

Mold Removal: Plaster Method

1. Preparation

While the plastic is still warm, cut off the end of the layup about ¼ inch proximal to the epicondyles. Leave the pressure sleeve on to protect the finish of the plastic during subsequent operations.

2. Removal of Plaster

Strike the plastic socket with a rubber mallet just hard enough to crack the plaster. It may be necessary to use a chisel to dig out

plaster in the distal end of the socket. Do not strike too hard near the metal parts or delamination may occur.

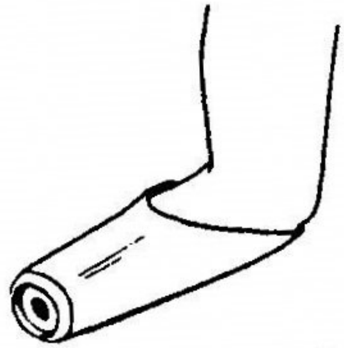
3. Cleaning the Socket

Remove the film of dried lacquer from the socket; a blast from an air hose will speed this operation. If any particles of plaster and lacquer cling to the socket wall, remove them by wiping with a wet cloth.

Trim and Assembly

1. Determination of Socket Trim

Trim the socket to the rough trim line established by the check socket. The socket trim should allow full flexion and rotation.



With the forearm at 90° and fully pronated, check to see that the trim edge on the lateral side does not cut into the stump and limit rotation.

Supinate the forearm and check the medial edge in the same manner.

Sand all cut edges round and smooth, and seal the edges with plastic or lacquer.

2. Fabrication of Cuff and Flexible Hinges

Follow the procedure at the end of this chapter for the particular cuff prescribed (usually a triceps pad).

3. Installation of Cuff, Hinges, and Cross Hanger

Use masking tape where necessary to hold the socket, cuff and hinges on the arm, with the stump flexed to 90°.

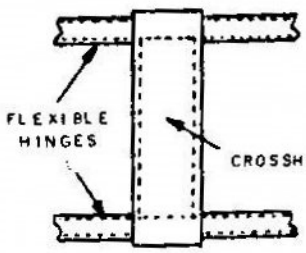
Pull the two straps from the triceps pad down snug and extend them along each side of the socket. Mark the socket on the medial

and lateral sides at about the distal fourth where the straps will be attached.

Put the ends of the straps through the cross hanger and slide it up until its proximal edge rests over the posterior proximal edge of the socket; tape it in place to the lateral strap. Secure the straps to the socket at the marks with masking tape to check the fitting.

Flex and rotate the amputee's stump. Adjust the cross hanger position and length of the straps to provide proper and comfortable fit. There should be no rubbing of the straps on the epicondyles.

When the correct alignment is obtained, sew the cross hanger to the hinge straps and cut



the straps to the correct length. Round the ends of the straps and sew.

Fasten the straps securely to the socket with cadmium plated No. 6 binding head sheet metal screws, using two in each strap. Grind off the screws so they do not penetrate the inner socket.

4. Installation of Terminal Device

Assemble the wrist unit and attach the prescribed terminal device and sizing accessories in accordance with the manufacturer's instructions and the sizing plan.

5. Assembly of Control System and Harness

CUFF FABRICATION

The procedures given are for making the cuffs, billets and straps from leather. However, the leather may be replaced by moisture-proof or washable plastic cuffs and synthetic tapes such as nylon, dacron, etc.

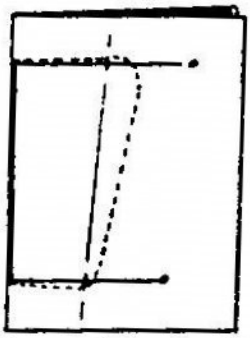
The Half Cuff

1. Preparation of Pattern

Select a piece of paper large enough to encircle the arm about 1½ times, and fold it in half.

Obtain the measurements (girths just above and below the biceps and the length between them), as shown in Figure I-3.

Lay off the length along the fold. Lay off half the girths at right angles to and at each end of the length line. Mark the center of each



of the girth lines and draw a line to connect the centers. This line will be approximately where the hinges will attach.

Curve the lines as shown and cut out the pattern so the side edges are about one inch anterior to the hinge line.

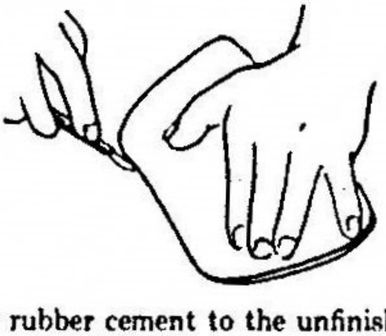
Put the prosthesis on the amputee, position the pattern, and note any corrections to be made.

Trim the pattern where necessary to allow unrestricted flexion.

2. Construction of Cuff

Cut some 6- to 8-ounce strap leather to match the pattern. Also cut a piece of heavy horsehide to match the pattern.

Place the finished surfaces of the leather together and sew together about 3/16 inch below the top edge to form a rolled edge.



Apply rubber cement to the unfinished surfaces and allow to almost dry.

Press the two cement-coated surfaces together, stretching the horsehide in all directions as much as possible.

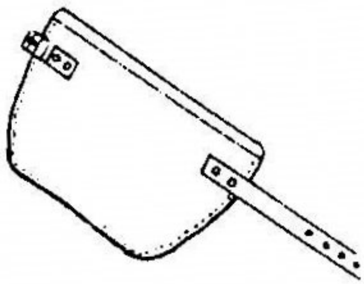
Stitch the two pieces together about ⅛ inch from the edge of the bottom and sides and trim off the excess horsehide.

Trim and burnish the edges of the cuff.

3. Construction of Billets

If a billet is prescribed, cut it ⅝ inch wide from strap leather, burnish the edges and punch the necessary holes.

Cut it to proper length and rivet it to the medial side of the cuff approximately as shown in the figure with chrome or nickel-plated rivets.



Form a strap around ⅝-inch buckles, burnish where necessary and rivet it to the lateral side of the cuff.

4. Application of Sealer

Apply two or three separate coats of sealer, such as nylon coating to all leather surfaces to prevent absorption of perspiration and provide scuff resistant surfaces.

The Full Cuff

The pattern for this cuff is made to encircle the arm completely. Either snaps or a billet may be used on the cuff.

The fabrication procedure is exactly the same as for the half cuff.

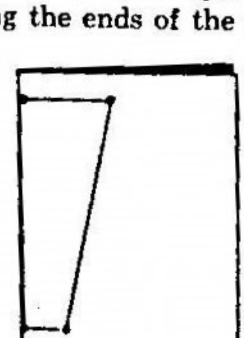
The Triceps Pad

1. Preparation of Pattern

Select a piece of paper large enough to encircle the arm, and fold it in half.

Obtain the measurements (girths just above and below the biceps and the length between them) previously made as shown in Figure I-3.

Lay off the length along the fold. Lay off one-quarter of the girths at right angles to and at each end of the length line. Draw a line connecting the ends of the girth lines.

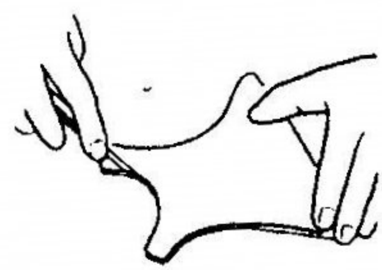


Cut out the pattern and hold it on the arm of the amputee. Mark where the flexible hinges will attach.

Trim the pattern to final shape so the straps will fair into the pad as shown in the figure.

2. Construction of Pad

Cut some 5- to 8-ounce strap leather to match the pattern. Cut a piece of 2- to 3-ounce tooling calf about ¼ inch larger than the pattern.



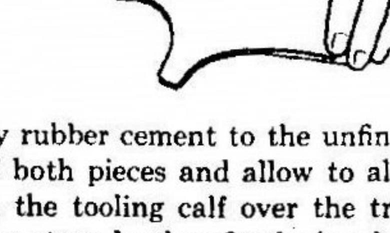
Apply rubber cement to the unfinished surfaces of both pieces and allow to almost dry.

Form the tooling calf over the triceps and press the strap leather firmly in place so the two pieces will cement together and remain curved when removed from the arm.

Stitch the pieces together about ⅛ inch from the edge.

3. Construction of Flexible Hinges

Cut two ½-inch straps, each about the length from epicondyles to wrist unit, from approximately 4-ounce elk. When fabricating a Transcarpal prosthesis, cut each strap about 3 inches longer.



Apply cement to the unfinished side of the straps and to one side of equal lengths of ½-inch dacron tape.

Cement the tape to the leather and sew together 1/16 inch from the edges.

4. Construction of Cross Hanger

Measure the circumference on the posterior portion of the stump from lateral to medial epicondyle. Approximately twice this distance will be the length of the webbing used to make the cross hanger.

Cut the cross hanger from inch-wide dacron tape.

Stitch and form the cross hanger to the shape shown.

5. Assembly of Pad and Hinge Straps

Round and stitch the proximal ends of the straps.

Tape the cuff on the amputee, with prosthesis on. Tape the straps to the cuff and adjust the location until the line of action of the straps is through the epicondyles.

Punch the necessary holes and rivet the straps to the pad with stainless or plated rivets, two in each strap about ½ inch apart. (There are other methods of attaching the straps to the cuff, such as skiving the straps and cuff and inserting the straps between the strap leather and tooling calf before stitching the pad, then riveting through the pad.)

6. Application of Sealer

Seal all leather surfaces with two or three coats of sealer such as nylon coating.

FABRICATION OF

THE "MUENSTER-TYPE" BELOW-ELBOW PROSTHESIS

I. INTRODUCTION

Short below-elbow stumps have always presented fitting problems for the obvious reasons of small attachment area, poor leverage, and decreased range of motion. Split sockets and step-up hinges have commonly been used to provide very short below-elbow amputees with a full range of elbow flexion (135°). However, this system is characterized by several features which mitigate against its overall acceptability. Step-up hinges decrease the lifting power available to the amputee, increase the bulk of the prosthesis at the elbow and proximal forearm, and historically have lacked durability.

In the mid 1950's, Drs. Hepp and Kuhn of Muenster, Germany, formulated a new approach to the prosthetic management of short upper extremity stumps. They developed a technique of fabricating sockets for below-elbow and above-elbow amputations which provided a more intimate encapsulation of short stumps.[1]

Evaluation of "Muenster" Fabrication Technique

New York University Adult Prosthetic Studies became interested in the "Muenster" technique for short and very short below-elbow amputees, following the favorable experiences reported by amputee clinics in fitting pre-flexed arms to children.[2] Consequently, this laboratory conducted an evaluation of what was considered to be the "Muenster" technique in applications to adult amputees.[3] The general characteristics of the below-elbow sockets fabricated in this study were:

1. The forearm was set in a position of initial flexion (average 35°) in relation to the humerus.
2. The anterior trim line extended to the level of the ante-cubital fold with a channel provided for the biceps tendon.

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[1] Hepp, O., and Kuhn, G. G., "Upper Extremity Prostheses," Prosthetics International, Proceedings of the Second International Prosthetics Course, Copenhagen, Denmark, July 30 to August 8, 1959. Copenhagen: Committee on Prostheses, Braces and Technical Aids, International Society for the Welfare of Cripples, 1960, pp. 133-181.

[2] Final Report, Preflexed Arm Study, Child Prosthetic Studies, Research Division, College of Engineering, New York University, New York, New York, November 1960.

[3] The "Muenster-Type" Fabrication Technique for Below-Elbow Prostheses, Adult Prosthetic Studies, Research Division, College of Engineering, New York University, New York, New York, June 1964.

3. The posterior aspect of the socket enclosed the olecranon, the trim line being just above the level of the epicondyles.

4. Because of the high anterior and posterior walls of the sockets, the range of motion for the average amputee was limited to approximately 70° (from 35° to 105° flexion) (Figures 1 and 2).

The limited range of motion characteristic of sockets fabricated in the described manner bears emphasis. In current practice, the acceptable "checkout" standard for maximum elbow flexion with the prosthesis is that it should be within 10° of stump flexion without the prosthesis. This standard is not applicable in the present circumstances. Nevertheless, the decreased range of motion available has been found acceptable by unilateral amputees who typically use their prostheses as assistive devices and perform very few activities at the extreme ends of the flexion-extension range.

The results of the New York University study of the "Muenster" type fittings cited earlier indicated that:

1. Amputees reacted positively to the comfort and security of the socket.
2. The decrease in flexion range had no appreciable effect on the prosthetic functions of unilateral amputees. However, for bilateral subjects, modification of the anterior trim line and the provision of a wrist flexion device were necessary for performance of tasks close to the body.
3. Lifting and holding forces available to the amputee were generally superior (Figures 3 and 4).

Following the favorable results obtained in fitting patients, New York University Child Prosthetic Studies initiated a study of the applicability of these procedures to children with very short, short, and long below-elbow deficiencies. As of March 1965, ten successfully fitted children ranging in age from 20 months to 10 years have worn their limbs for periods ranging from 4 to 14 months.

Although the study of the children's fittings had not been completed at this writing, the indications are that fabrication procedures for adults, as described in this manual, would be equally applicable to children.

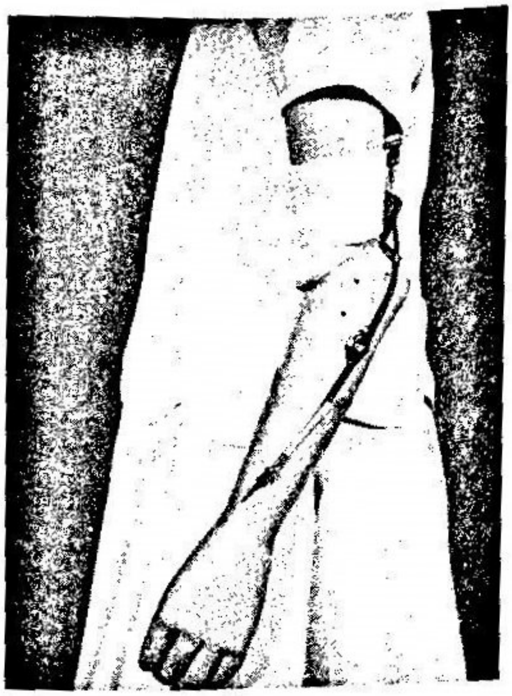


Figure 1
Maximum Extension

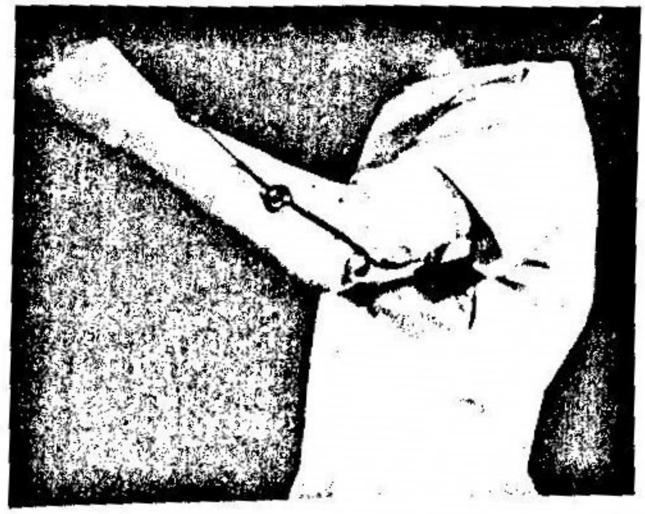


Figure 2
Maximum Flexion

Figure 3
Resisting Torque About the Elbow
(Live Lift)

Figure 4
Resisting Vertical Tension
(Axial Load)

II. PRESCRIPTION CONSIDERATIONS

A priori, this method of socket fabrication would appear to be of greatest potential benefit to amputees with stumps of the short and very short types. These are patients who, under current practice, would typically be fitted with metal elbow hinges—step-up, polycentric or, at the longer limits of the range, single pivot or flexible hinges. Prime beneficiaries might be amputees who normally would be fitted with split sockets and step-up hinges because of the inherent disadvantages in this type of fitting.

In general, this hypothesis has been verified by fitting experience to date. In the NYU evaluations approximately 90% of the stumps fitted fell into the short and very short below-elbow categories. Specifically, nine adults (including one bilateral) with stump lengths ranging from 1-1/2" to 5-1/2" (18-52%) and eight children with stumps 2" to 3" long (25-40%) were successfully fitted with "Muenster" type prostheses.

The precise limits of applicability of the "Muenster" prosthesis (minimum and maximum stump lengths) must be determined individually for each patient. However, based on a somewhat limited investigation of these considerations, the following guidelines are offered:

Minimum Length: Very short stumps virtually disappear at 90° of elbow flexion. Hence, the maximum prosthetic flexion angle obtainable with stumps in this category is limited accordingly. The shortest stump fitted at this laboratory was 1-1/2" (18%) in length. The maximum flexion angle obtained (with prosthesis) was 80°.

Thus, fitting of "Muenster" sockets to stumps as short as 1-1/2" depends upon the acceptability of a very limited amount of elbow flexion (usually less than 90°).

Maximum Length: With regard to maximum stump length, two limiting factors must be considered:

1. Depending on the extent of the anatomical deficiency, stumps of mid-length and longer usually have some degree of residual pronation-supination which may be harnessed in a conventional below-elbow socket with flexible hinges. This active pronation-supination of the prosthesis is eliminated with the

"Muenster" type fitting. The question to be decided is whether other advantages of this type of prostheses adequately compensate for the loss of rotation in a given case.

2. The configuration of the "Muenster" socket (proximal opening at an angle to the socket) presents progressively increasing difficulty to donning and doffing the prosthesis as stump length increases. Absolute stump length rather than proportion of sound side remaining appears to be the prime determinant. These difficulties can be reduced by socket modifications, such as a looser fit or lowered trim line. Such modifications, however, progressively reduce control and retention of the prosthesis.

New York University has fitted several adult and juvenile amputees whose stumps fell into the "long" classification, i.e., 55% of sound side or longer. One adult at the borderline of the "long" stump classification (5-1/2" - 56%) and a child well within this category (4" - 66%) were not affected by the considerations mentioned above. In both cases residual pronation and supination were minimal, and no difficulty was experienced in putting on and taking off the prosthesis.

On the other hand, an adult with a 7" stump (66%) required considerable modifications to the proximal brim before the prosthesis could be delivered successfully. The anterior trim line was reduced approximately 1/2" below the cubital fold to facilitate passage of the stump. The subject had about 55% of residual stump rotation but, since this rotation had not been utilized in the previous prosthesis, no deprivation was imposed by the "Muenster" type arm.

One child with a 6" stump (92%) was also successfully fitted with two different modifications of the "Muenster" type prosthesis. In the initial prosthesis, the posterior trim line was reduced to just above the olecranon for manageable donning and doffing. In a second fitting, the standard trim lines were maintained, but the socket was made somewhat looser than usual. Both modifications produced sockets with slightly reduced, but still very acceptable retention.

Thus, the "Muenster" prostheses can apparently be fitted without difficulty to stumps up to the limit of the short below-elbow classification (55%). The fitting of longer stumps involves consideration of the factors discussed, on an individual basis.

Bilateral Fittings

The question of fitting "Muenster" type prostheses bilaterally is not fully resolved. Two problems are inherent in such fittings:

1. The difficulty in donning two closely fitting prostheses without assistance.
2. The limitation imposed by restricted forearm flexion, particularly on the dominant side.

New York University has had no experience in fitting children bilaterally, but has successfully fitted one bilateral adult amputee (4" and 5-1/2" stumps). The inherent problems were resolved by:

1. Fitting the sockets less snugly than usual to facilitate donning.
2. Lowering the anterior trim line and providing a wrist flexion unit on the dominant side for activities close to the body.

It is probable that selected juvenile bilateral amputees might be successfully fitted with similar modifications.

III. PROCEDURES

A. Stump Examination and Measurements

1. Materials Required

a. Measuring Tape
b. Ruler
c. Goniometer
d. Measurement Form (Figure 5)

2. Stump Examination

A thorough stump examination is an important prerequisite to any prosthetic fitting procedure. In the "Muenster" type fitting, stump examination is even more critical than usual because of the intimate socket encapsulation of the stump. Skin irritations, painful scars, abrasions and sensitive areas must be identified so that necessary socket reliefs may be anticipated and provided.

3. Measurements

Consistent with sound prosthetic practice, it is advisable to follow the conventional measurement procedures described in the chapter entitled "Measurement" (p. 211) so that a comprehensive record will be available for future reference. The appropriate below-elbow measurements are recorded on the modified Upper Extremity Measurement Chart shown as Figure 1. However, it should be noted that since the plaster wrap casts are used as check sockets in this technique and stump molds made from the wrap casts are not corrected to measurements, the only measure essential for fabrication is the length of the normal forearm to wrist and thumb tip.

It should also be noted that stump and sound forearm lengths are measured from the olecranon rather than from the epicondyles, since the olecranon is more convenient to use as a reference point on the cast and socket. These measurements are described below.

UPPER-LIMB MEASUREMENT CHART - MUENSTER PROSTHESIS

PATIENT____________________ PROSTHETIST'S NAME____________________

AMPUTATION DATE____________________ TODAY'S DATE____________________

AMPUTATION TYPE____________________ RIGHT__________ LEFT__________

RACE: CAUCASIAN__________ NEGRO__________ OTHER__________

HEIGHT__________ AGE________ MALE__________ FEMALE__________

SOCKET: DOUBLE WALL____________________ SINGLE WALL____________________

STANDARD PLAN____________________ INTERCHANGEABLE PLAN____________________

TYPE HOOK__________ WRIST__________ HAND__________ SKIN COLOR__________

TYPE HARNESS____________________ CONTROL SYSTEM____________________

WITHOUT PROSTHESIS WITH PROSTHESIS

ELBOW FLEXION____

ELBOW EXTENSION____

Condition of Stump (irritation, abrasion, etc.)____________________

____

Special Considerations:______________________________

____

____

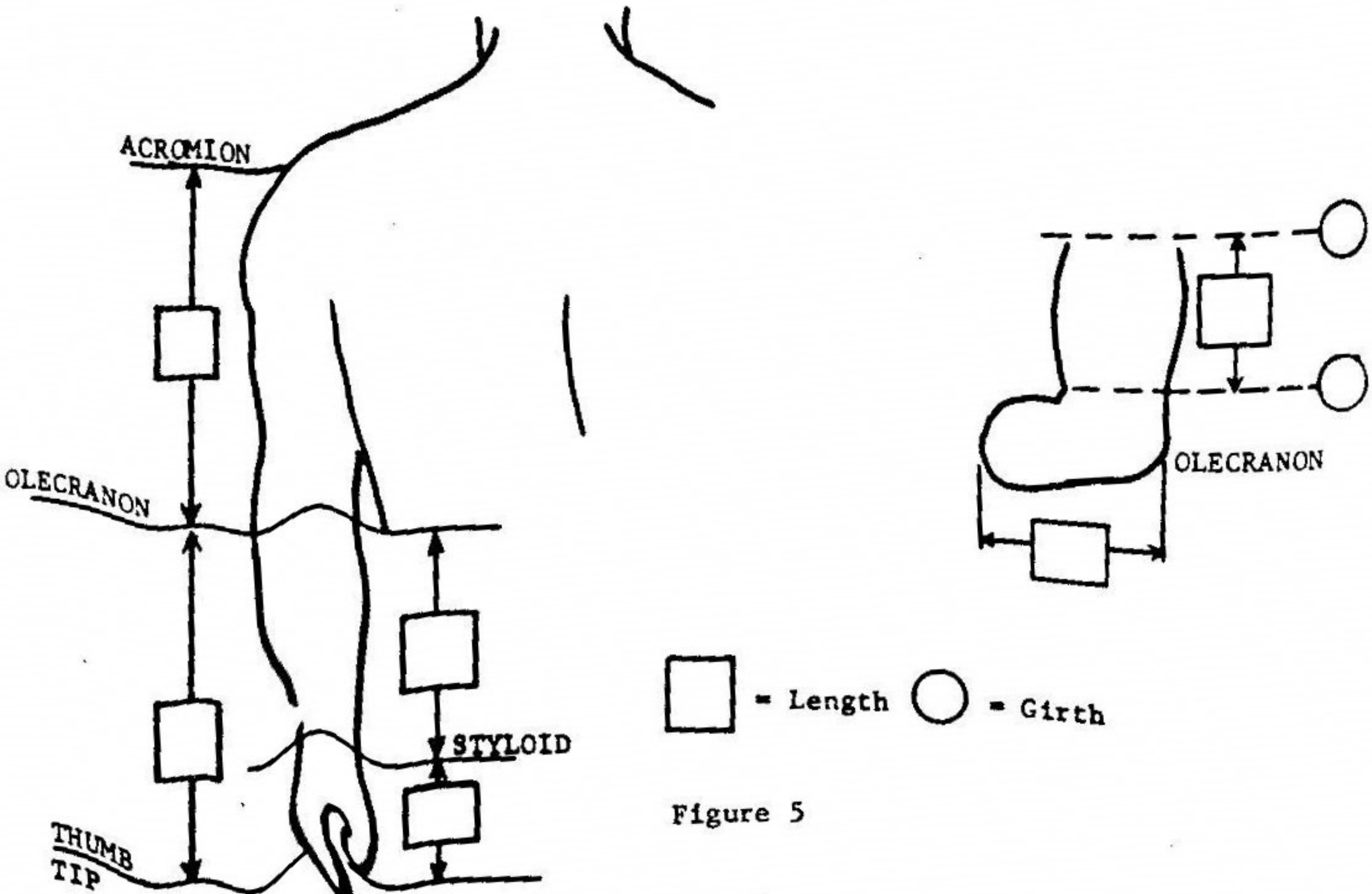
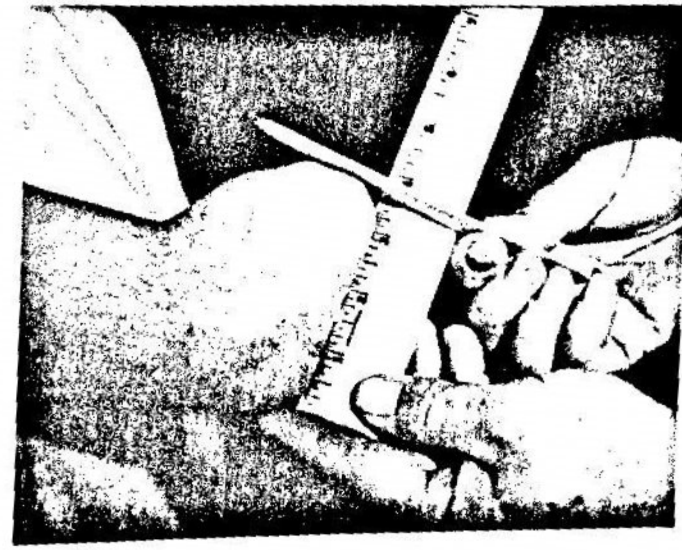
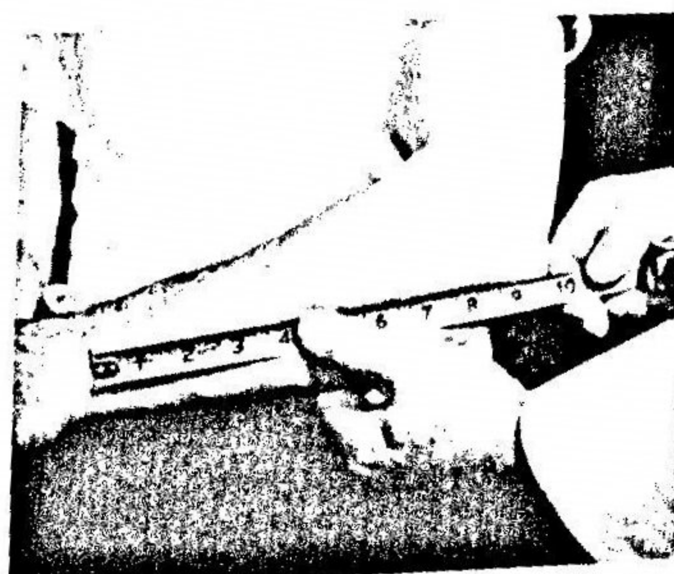


Figure 5

a. Stump Length

Measure stump length from the posterior aspect of the olecranon. If distal redundant tissue is present, the measurement should include the redundancy.





b. Forearm Length

With the forearm flexed at approximately 90°, and held mid-way between pronation and supination, record the measurements from the proximal aspect of the olecranon to the distal aspect of the ulnar styloid; and from the olecranon to a point on the ulnar border of the hand which corresponds to the thumb tip.

B. The Wrap Cast

1. Materials Required

a. Cotton stockinette (appropriate size for stump)
b. Dacron tape for temporary harness
c. Yates clamps
d. Indelible marking pencil
e. Three rolls of plaster of Paris bandage (6 or 8 cm. elastic type preferred)
f. Pail of water

2. Application of the Cast Sock

Place a snug, form-fitting cotton stockinette over the stump to insulate the skin and hair from plaster. Use the assistance of the amputee, or a temporary Figure 8 harness, to keep the stockinette free of wrinkles. The harness method is generally preferable for children.

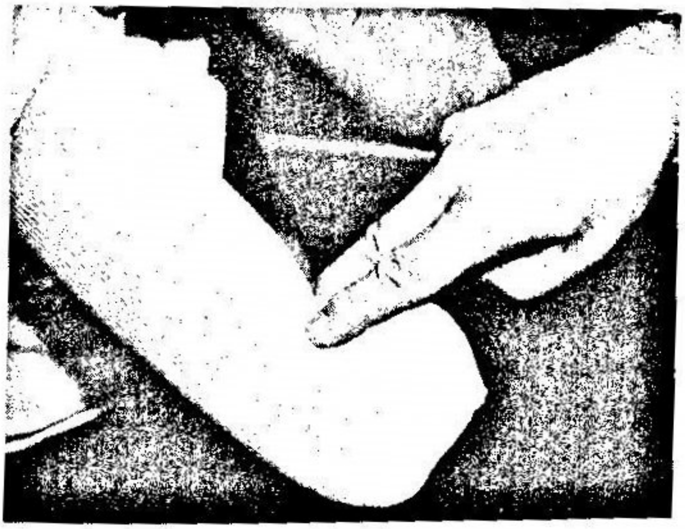
3. Practice Molding Grip

Application of the proper molding grip is essential to the success of the wrap cast and hence to the final outcome of the fitting. It is important therefore that the prosthetist practice this procedure on each amputee prior to the application of the cast. He will thus become familiar with the individual characteristics of each amputee's stump and the possibility of erroneous molding once the stump is wrapped will consequently be reduced. Furthermore, the amputee will know what to expect during the casting procedure and be in a better position to cooperate.

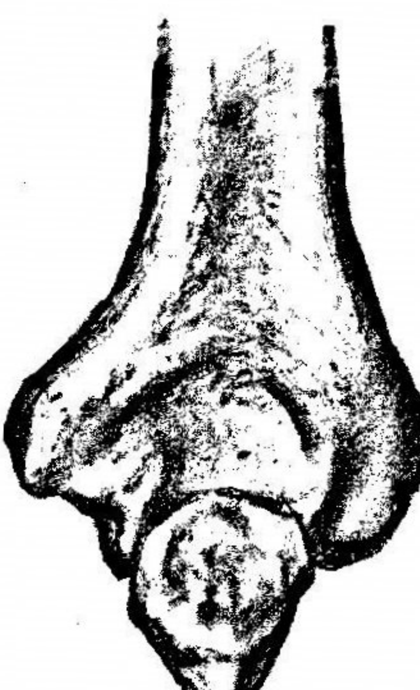
It is important to note that the prosthetist will be able to apply the molding grip more conveniently when his arms and those of the amputee are at the same level. It is suggested, therefore, that children sit on a table or stand on a raised platform.

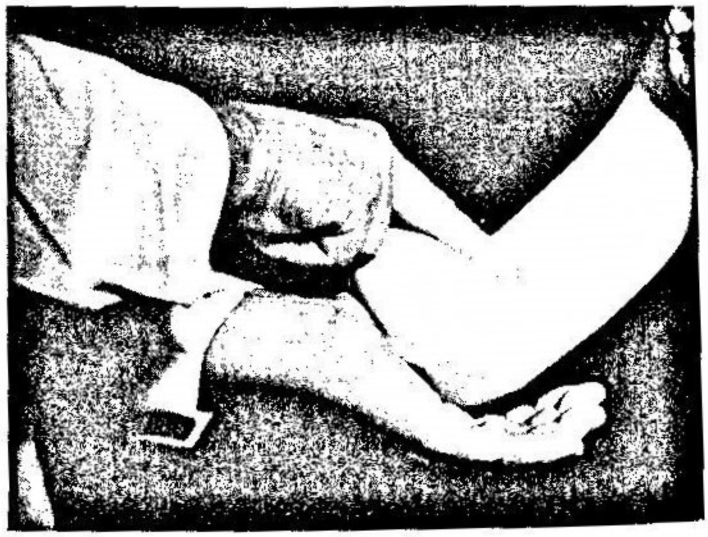
The specific steps to be followed are described for a right below-elbow amputee (the hand positions are reversed for a left amputee). Because of the fundamental importance of correct cast shaping, this aspect of the fabrication procedure is illustrated with both line drawings and photographs.

a. With the amputee's stump flexed to 90° place the extended index and middle fingers of the right hand on the anterior surface of the stump. The prosthetist's wrist should be in a neutral or slightly extended position. The two fingers should rest on either side of the biceps tendon and along the anterior surface of the stump. Exert moderate pressure (to the point of firm resistance) simultaneously into the cubital fold and downward on the anterior surface of the stump, but being sure to avoid any concentration of pressure distally.

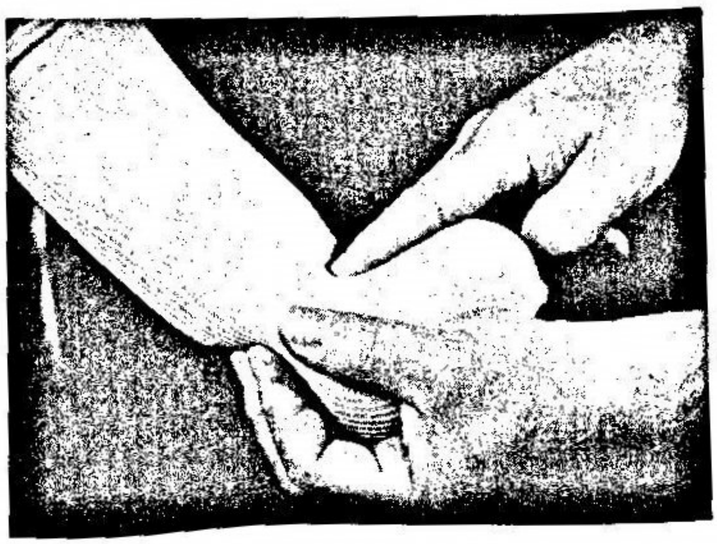


b. The dorsal aspect of the proximal ulna is distinctly wedge-shaped. Shape the left hand so that the thenar and hypothenar eminences form a channel into which this wedge will fit.

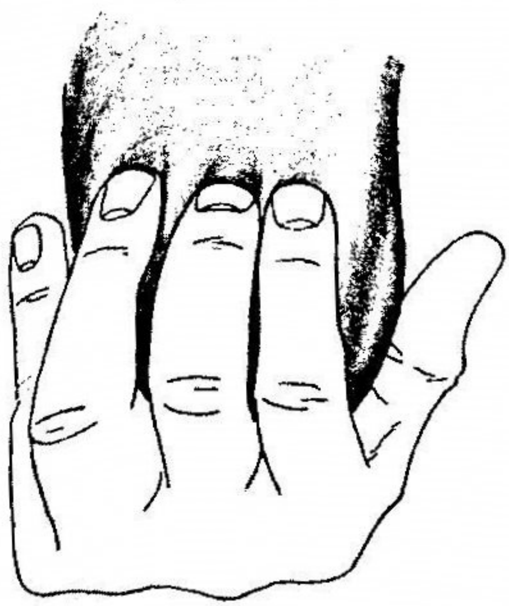




c. Position the grooved hand against the underside of the stump to provide support and stability without distortion. The metacarpal joints are located just below the amputee's olecranon.



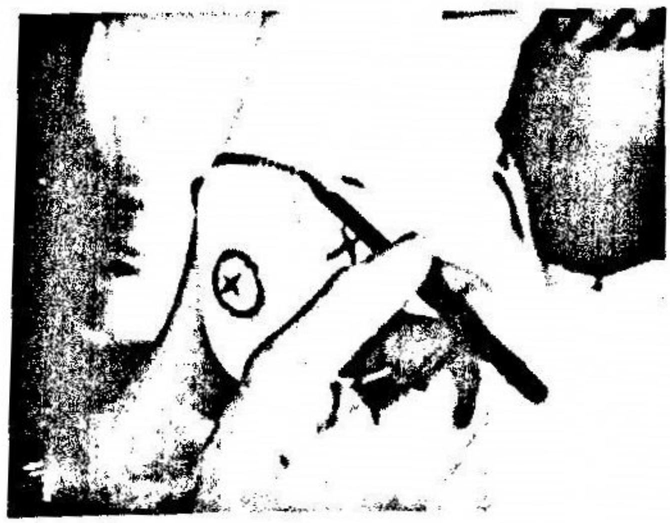
d. Cup the index, middle and ring fingers of the left hand and position them on the distal posterior surface of the humerus just above the level of the epicondyles. Apply gentle downward pressure with the pads of the fingers, being sure that there is no pressure between the palm of the hand and the olecranon. In this manner a relief is automatically provided for the olecranon. The little finger and the thumb may be curled to make contact with the medial and lateral epicondyles, respectively. However, these digits should <u>not</u> exert any pressure.



4. Reference Marks

a. Bony Landmarks

In view of the intimate fit which characterizes the "Muenster" socket, tender areas and bony prominences such as the olecranon and epicondyles must be clearly defined for the provision of necessary reliefs. With the stump flexed at 90°, mark these areas with an indelible pencil so they may be easily identified on the wrap cast.



b. Trim Lines

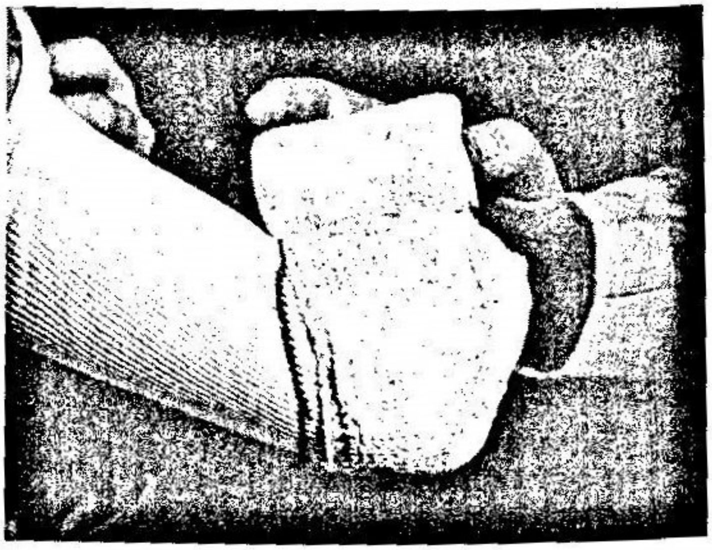
Mark a preliminary trim line on the cast sock in the following manner:

Draw a line posteriorly connecting two points one inch superior to the medial and lateral epicondyles, respectively. Continue this line anteriorly so that it passes through a point 1/2" above the mid-cubital space.

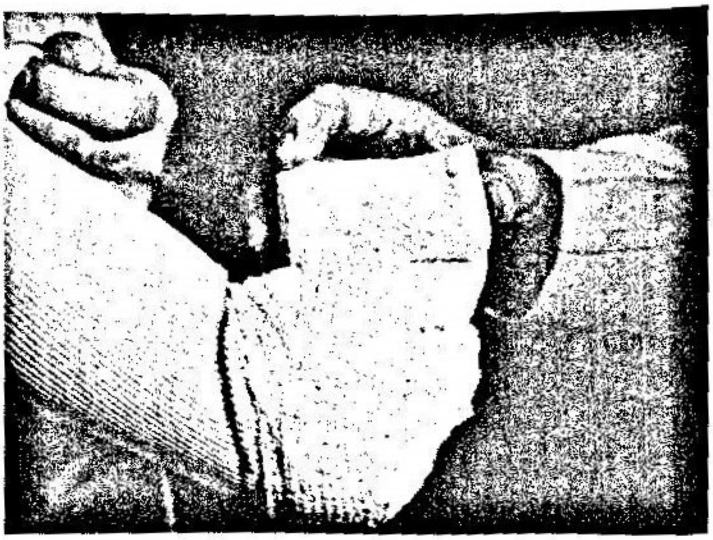
5. Wrapping the Stump

The critical relationship between the stump and socket in the "Muenster" technique cannot be over-emphasized. Every effort should be made therefore to secure a properly fitting cast. To this end, it is recommended that at least two, and preferably three, casts be taken so that the prosthetist and patient may together choose the best of the series. Elastic, or non-elastic plaster of Paris bandages may be used, but the elastic is preferred since it results in a more accurate configuration.

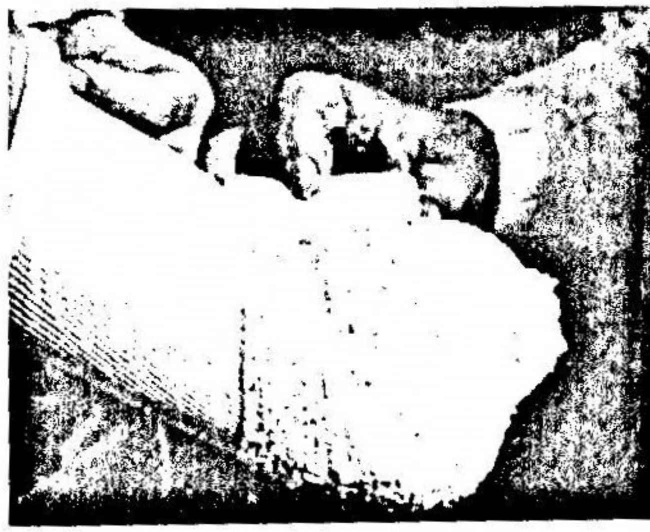
a. With the stump flexed at 90° and the humerus held mid-way between internal and external rotation, begin the wrap with two circular turns around the elbow joint (over the olecranon and cubital fold). Maintain slight tension on the plaster bandage (either elastic or non-elastic) in the process.



b. Proceed to the distal end of the stump in a Figure 8 or spiral pattern.



c. Continue the wrap at least 1/4" above the reference marks made earlier.



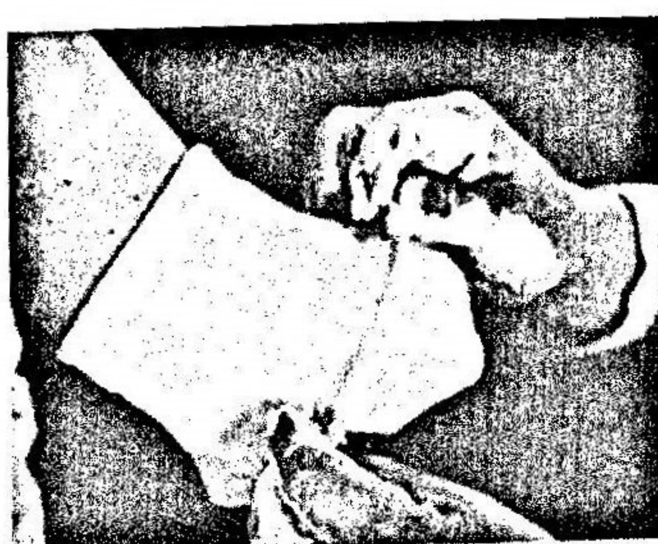
6. <u>Molding Grip</u>

Apply the molding grip practiced earlier to the plaster wrap. Finger pressure should be sufficient to displace all loose tissue (to the point where firm resistance is reached) Maintain pressure until the plaster has set.

7. <u>Removal of Wrap</u>

After the plaster has hardened, observe the following steps in removing the wrap cast:

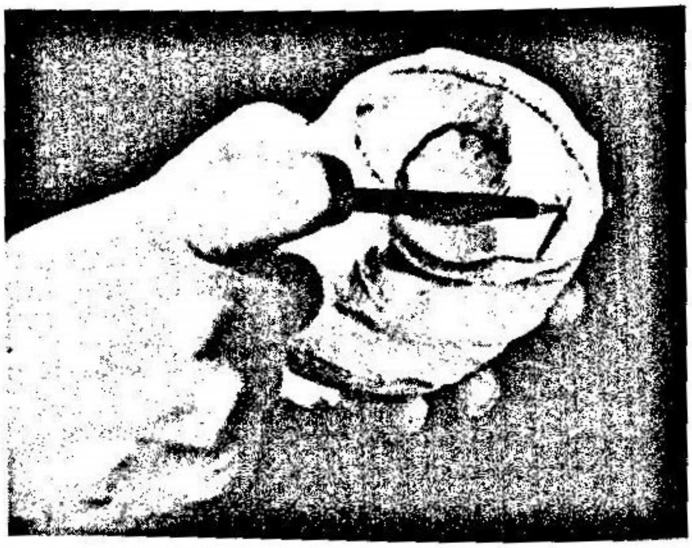
a. Reinforce the proximal end of the wrap with several turns of non-elastic plaster bandage in order to minimize distortion. Then pull the stockinette down over the cast.



b. Apply upward pressure on the arm to increase skin tension at the proximal end of the cast in order to break the vacuum seal. Gently work the cast off the stump.

8. Re-Mark Cast

Remove the stockinette from the cast and accentuate the indelible marks which have been transferred from the stockinette to the inner wall of the cast.



REPEAT PROCEDURES UNTIL A MINIMUM OF TWO, AND PREFERABLY THREE, CASTS HAVE BEEN TAKEN

C. Preparation of Check Socket

1. Materials Required

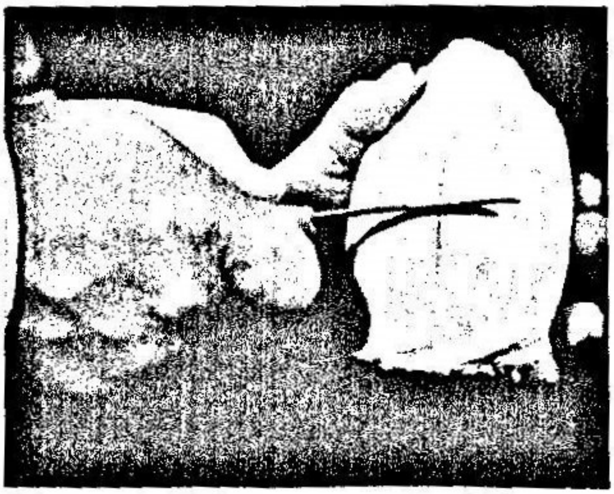
a. Knife
b. Scissors
c. Fresh Plaster
d. Water

2. Procedures

All of the wrap casts taken are prepared according to the procedures described below and are used as check sockets. The one agreed upon by both prosthetist and patient as providing the most comfortable fit, the greatest range of motion and maximum security is selected for use in preparation of the male mold.

a. Trim Distal End

Cut a hole in the wrap cast, just large enough to allow the passage of a stump pulling sock and as close to the distal end as possible so that shortening of the cast is minimized.

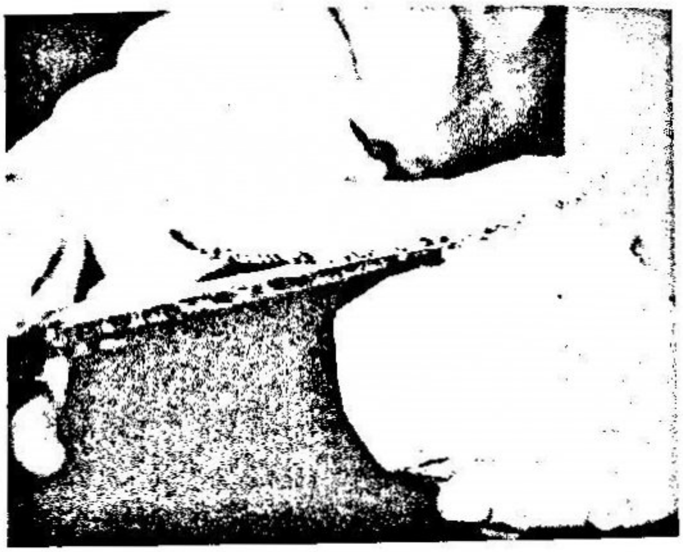


b. Provide for Inspection of Olecranon Relief

Make a cross incision (X) in the olecranon bulge of the plaster wrap for inspection of this area during fitting.

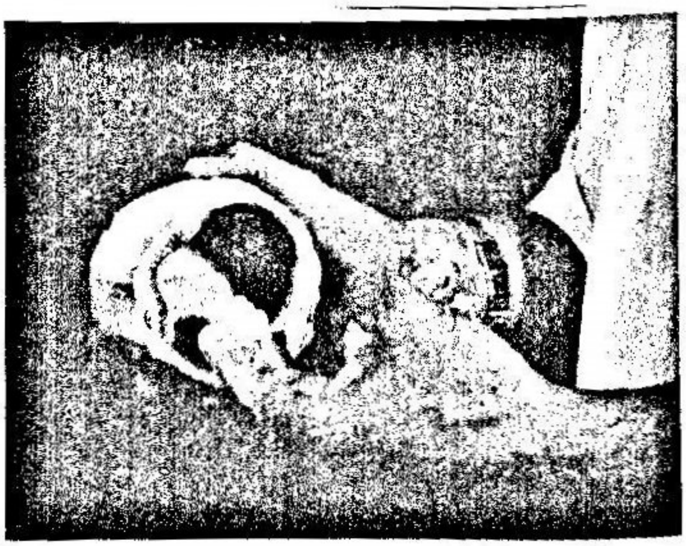
c. Trim Proximal End

The final trim lines for every socket are determined individually for each amputee. However, as an initial step, trim the cast proximally to the level of the reference line made earlier.



d. Smooth Inside of Cast

Wet the cast with water and smooth the inside with fresh plaster to remove all gauze marks, except in the areas of the epicondyles and olecranon. No plaster should be added in these critical areas.



D. <u>Fitting of Check Socket</u>

1. <u>Materials Required</u>

   a. Cotton Stockinette (stump pulling sock)
   b. Indelible Marking Pencil

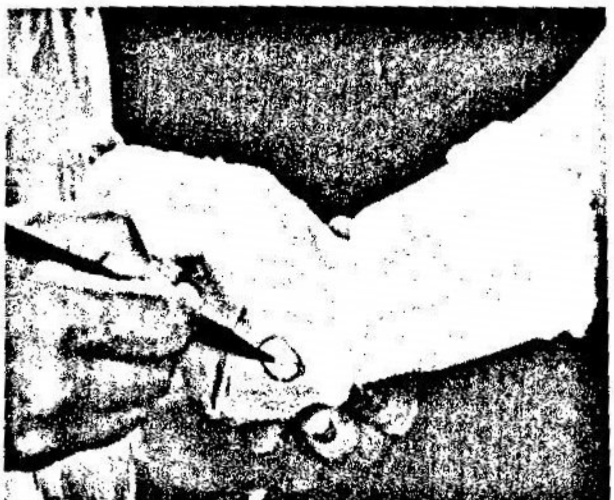
2. <u>Procedures</u>

   a. <u>Insert Stump</u>

Place a length of cotton stockinette on the amputee's stump and insert its distal end through the hole in the check socket. Pull the stump into the socket making sure that all flesh is drawn inside the cast.

   b. <u>Determine Adequacy of Fit</u>

With the check socket on the amputee, make the usual tests for adequacy of fit, comfort and range of motion by having the amputee exert a force against resistance in elbow flexion, extension and rotation. (Although the stump cannot rotate the socket, there may be some undesirable rotation of the stump within the socket.) If the fit of the check socket is not satisfactory, it should be rejected.



   c. <u>Check for Stump Irritations</u>

If the check socket causes any pain or discomfort, mark the appropriate area on the outside of the socket and provide the necessary relief.

Examine the olecranon (through the cross incision) to be assured that there is sufficient relief during maximum flexion. If not, the incision may be opened and reset with plaster of Paris to provide additional freedom.

<u>REPEAT THE SAME PROCEDURES WITH THE OTHER CHECK SOCKETS AND SELECT THE BEST ONE FOR USE IN COMPLETION OF THE PROSTHESIS</u>

E. Establish Range of Motion in Check Sockets

The maximum forearm flexion and extension positions attainable with the "Muenster" technique will be significantly less than those achieved in conventional prostheses. Experience has shown that the maximum flexion range for the typical short below-elbow amputee fitted with a "Muenster" socket is approximately 70° (from 35° initial flexion to 105° maximum flexion).[4] A range of motion of this magnitude is not always achievable but should be the initial goal of the fitting.

The principal factors limiting the range of motion are:

1. Restriction in the maximum flexion angle obtained will usually be attributable to one or more of the following conditions:

   a. insufficient relief for the olecranon
   b. too small a channel for the biceps tendon
   c. too high an anterior wall

2. Restriction in extension will usually be attributable to too high a posterior trim line

However, it must be stressed that lowered trim lines or loose fit will adversely effect retention of the socket on the stump. Hence, the initial trim lines need to be closely maintained in order to provide maximum socket retention. They should be reduced only when absolutely necessary to provide greater comfort and/or increased range of motion.

3. Materials Required

   a. Indelible Pencil
   b. Scissors or Knife
   c. Goniometer
   d. Ruler

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4 The "Muenster" Type Fabrication Technique for Below-Elbow Prostheses, Op. cit., p. 11.

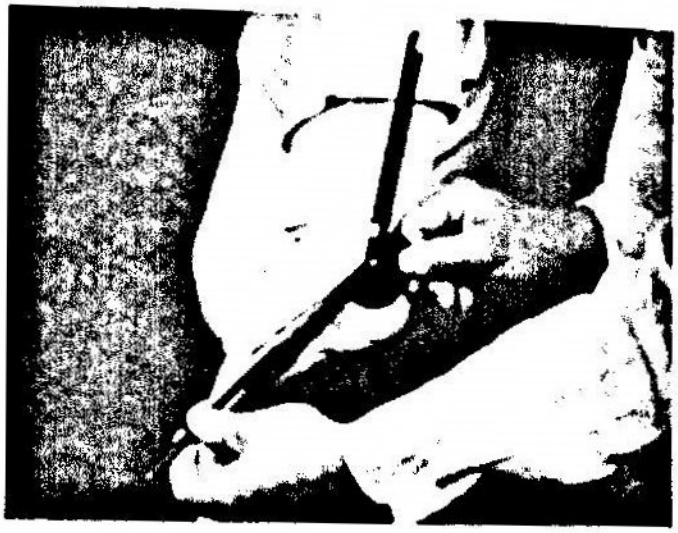
4. Procedures

a. Draw a line on the lateral side of the check socket coincident with its long axis (from lateral epicondyle to mid-distal end) to serve as a guide in measuring flexion and extension.

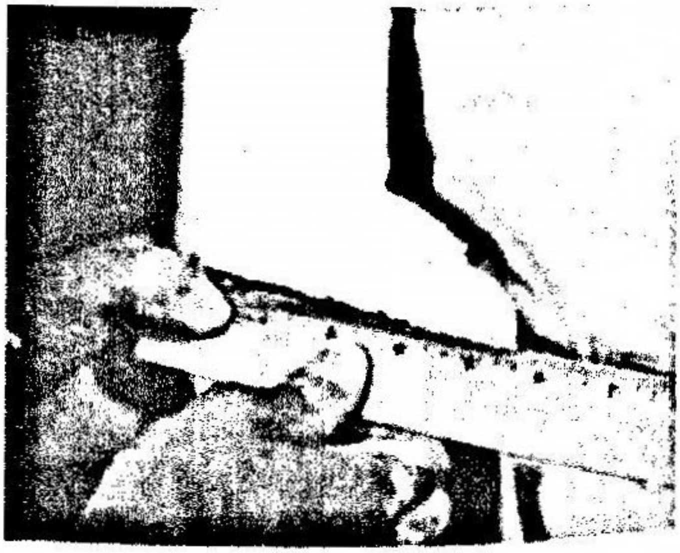
b. Place center of the goniometer on the lateral epicondyle with its lower arm on the long axis line and its upper arm lined up with the acromion. Measure maximum flexion and extension angles from these points of reference.

c. If motion is restricted, determine the specific cause of this restriction as indicated on the previous page (too high trim lines, insufficient reliefs for biceps tendon or olecranon) and take the necessary corrective action.

d. If the amputee cannot achieve the proposed 35° of initial flexion in the check socket, the discrepancy is compensated for in the alignment of the forearm shell. With the stump maintained in an actively extended position therefore, draw a second line on the check socket at a 35° angle between the humerus and stump. This line will serve as a guide in aligning the forearm shell.

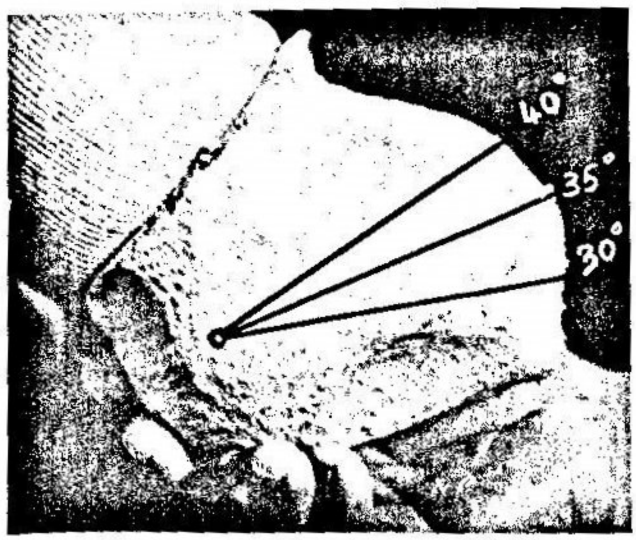


e. To test the adequacy of the proposed initial flexion angle, place a ruler along the 35° line drawn on the check socket. The length of the ruler should correspond to the intended length of the finished prosthesis (i.e., the olecranon to thumb tip measurement recorded on the Upper Extremity Measurement Form).



f. Have the amputee flex and extend this improvised forearm (check socket and ruler). Maximum flexion should be approximately 105°, except for very short stumps, where it probably would not exceed 90°. It should be noted that because of the inherent limitation of motion associated with the "Muenster" technique, the usual test of having the amputee bring his terminal device to his mouth is not applicable. The goal is to provide the maximum flexion angle possible compatible with a cosmetically acceptable initial flexion position and socket retention.

g. If the maximum flexion angle obtained with 35° of initial flexion is not acceptable, the angle of the ruler is adjusted to provide greater initial flexion. Initial flexion angles to a maximum of 45° have been used, but at the expense of decreased cosmesis. If less than 35° of initial flexion is desired for cosmetic or other reasons, the angle is decreased accordingly. Such reduction also decreases the maximum flexion angle obtainable. The selected angle of initial flexion is indicated on the check socket.



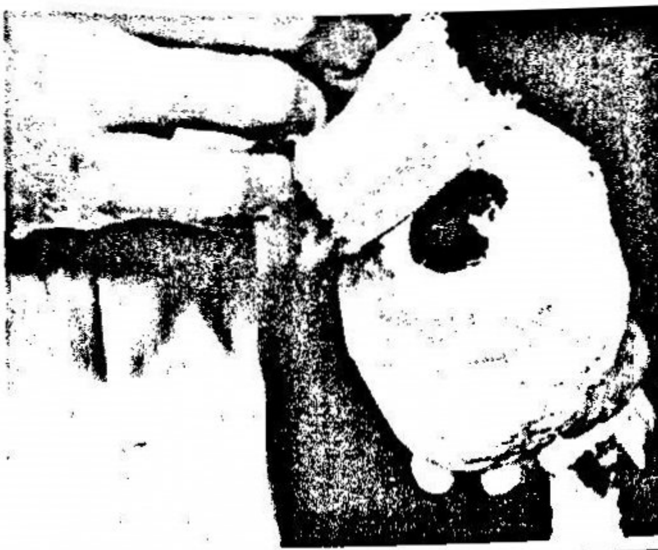
30°	Increased extension, decreased flexion.
40°	Increased flexion, decreased extension.

F. Preparation of Male Mold

1. Materials Required

a. Plaster of Paris Bandage
b. Talcum Powder
c. Hollow Pipe (approximately 12" long, 1/2" diameter)
d. Awl
e. Two Round Head Screws
f. Fresh Plaster
g. Water
h. Sanding Screen
i. Indelible Marking Pencil
j. Vaseline or Other Parting Agent

2. Procedures



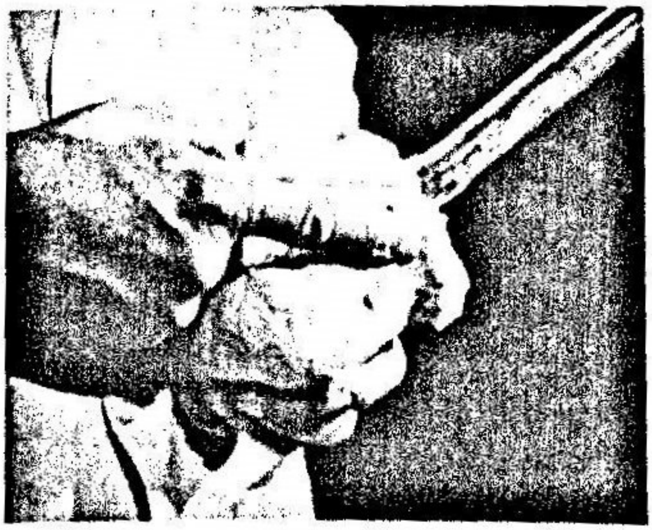
a. Close the distal end of the check socket with either plaster of Paris bandage or masking tape and make a small extension (approximately one inch) at the proximal end, again with either plaster of Paris bandage or masking tape. This extension will provide the prosthetist with a margin of safety in smoothing the stump model without disturbing the desired trim line.

b. Sprinkle the inner surface of the check socket with talcum powder and fill with liquid plaster of Paris. Before the plaster hardens, insert a hollow pipe into the plaster. Make a recess in the plaster around the pipe at the proximal end of the mold approximately 1" - 1-1/2" in diameter and 1-1/2" deep. A small hole (approximately 1/4" diameter) should be drilled in the pipe towards the bottom of the recess to facilitate vacuum lamination.

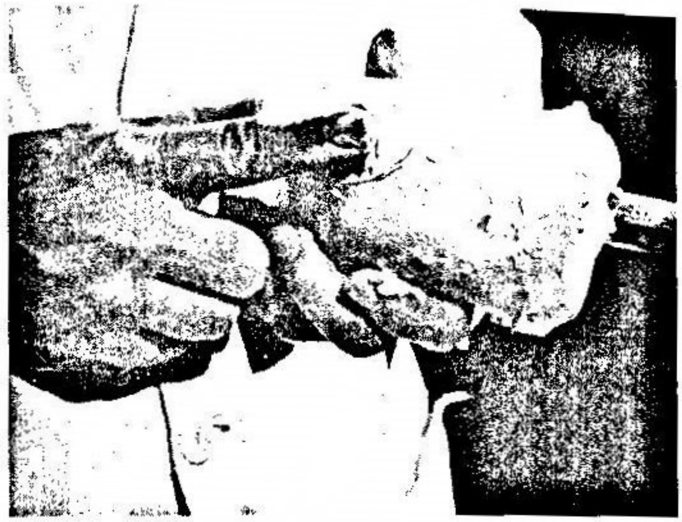
c. After the mold has hardened, puncture the plaster wrap with an awl at the proximal and distal ends of the forearm extension reference line. The punctures should penetrate into the male mold. Insert an indelible pencil into the holes and mark the male mold.

d. Remove the plaster wrap and trim major irregularities, e.g., superfluous plaster. Accentuate all reference marks on the mold.

e. Fair the junction between the stump model and the mold extension with liquid plaster of Paris to provide a smoothly curved radius.



f. Build up the olecranon area on the male mold approximately 1/16" with liquid plaster of Paris. This build up will provide additional relief for the bony prominence.



g. Build up the distal end of the mold with liquid plaster of Paris (approximately 1/2"). This build up will increase the length of the socket slightly and provide space for the cut-out hold through which the stump sock is pulled.

h. Sand the mold smooth and insert a round head screw into the two reference holes made on the lateral side of the mold. These screws will produce projections on the laminated socket through which a line will be drawn to align the forearm extension cone.

G. Lamination

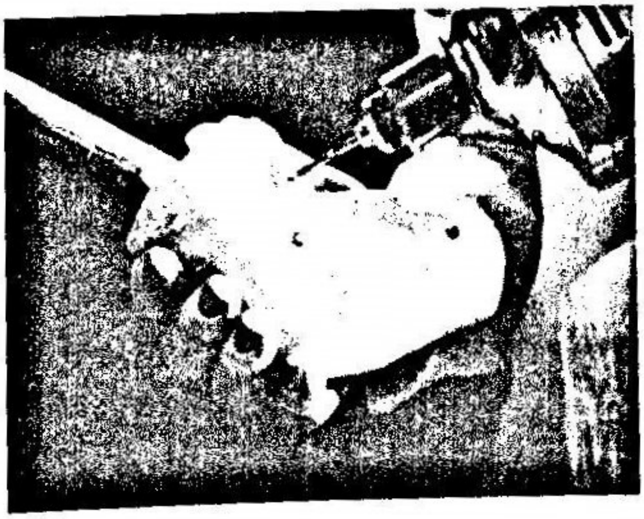
1. Materials Required

   a. 1/4" Hand Drill with 1/8" Bit
   b. PVA Sheets
   c. Dacron Blanketing
   d. Nylon Stockinette
   e. Polyester Resin
   f. Promoter
   g. Masking Tape
   h. Vacuum Pump
   i. Wrist Unit
   j. Manilla Paper

2. Procedures

The socket and forearm shell are laminated according to standard procedures. To provide a truer reproduction of the mold, vacuum lamination[5] is recommended. The sequence of steps followed are:

a. Drill 1/8" holes through the undercut areas at the proximal end of the mold in order to draw the PVA bag into those areas during lamination. The holes should exit in the vicinity of the previously mentioned hole in the pipe.



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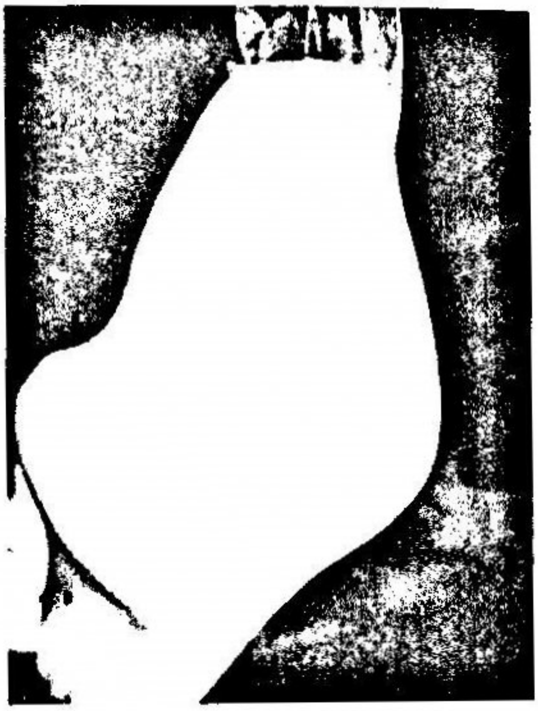
[5] Different variations of the vacuum lamination technique have been described in the following published material:

A) Hepp, O., and Kuhn, G. G., op. cit., pp. 157-167.

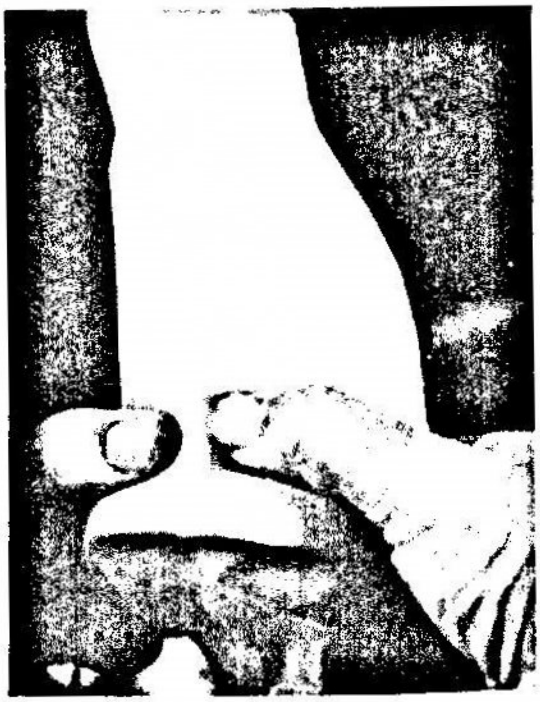
B) Above-Knee Prosthetics: Stump Casting and Socket Construction, Veterans Administration Prosthetics Center, New York, New York, May 1962, pp. 14-16, 26-30.

C) How to Use Vacuum Technique in Plastic Lamination Over Models of Irregular Shapes, University of California at Los Angeles, Prosthetics Education Program, January 1962.

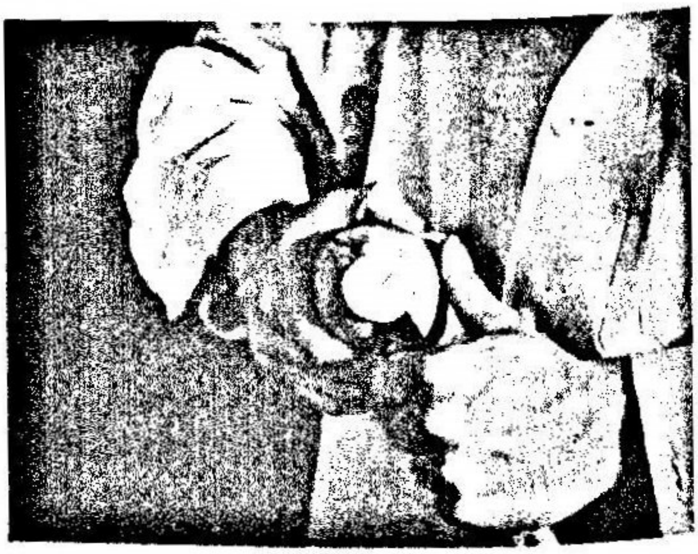
b. Lubricate mold and apply inner PVA bag, dacron blanketing (for smoother inner surface), nylon stockinette and outer PVA bag in the usual manner, under a vacuum pressure of 12 inches of mercury. (This is equivalent to 5.9 psi.)



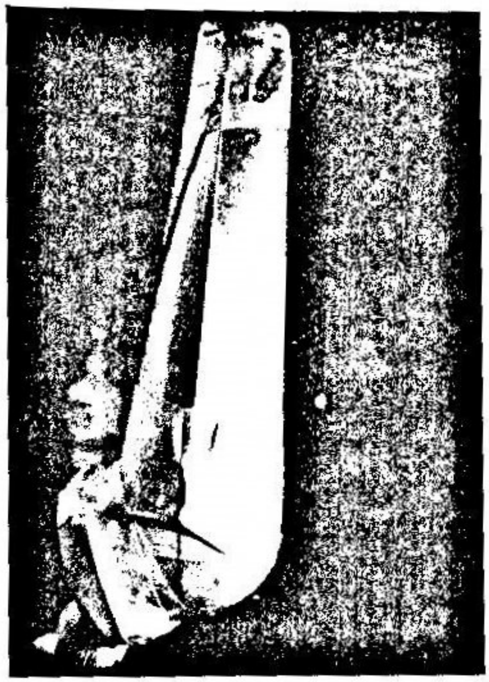
c. Apply polyester resin in the standard manner. Special attention should be paid to working the resin into the undercut areas. Oven cure as usual.



d. After the socket has cured, cut an opening in the extreme distal end of the socket. The hole should be of sufficient diameter to allow the passage of the stump pulling sock.

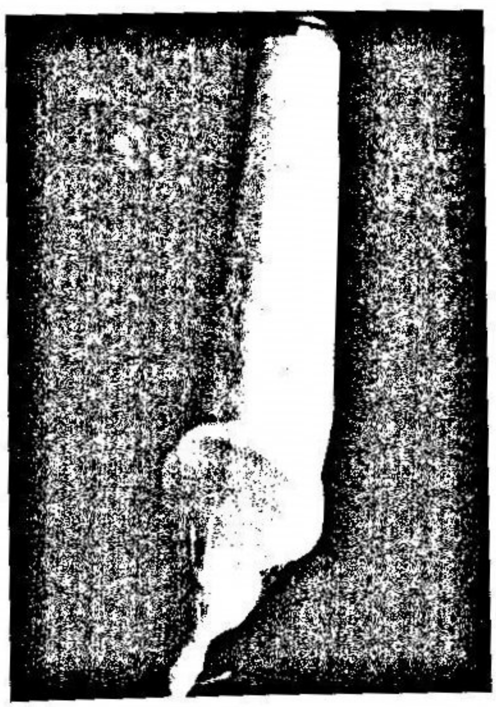


e. Draw a reference line on the outer wall of the socket by connecting the screwhead projections. Apply a forearm extension cone in the usual manner, with the long axis line of the cone coincident with the reference line.



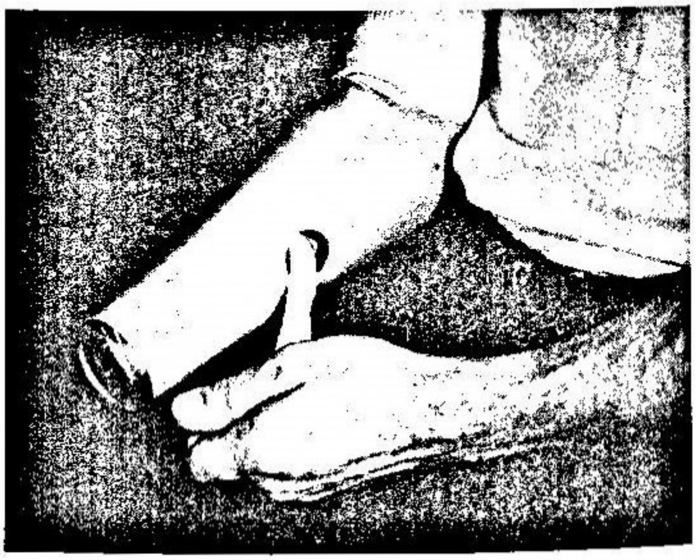
f. The lamination procedure for the forearm is the same as for the socket, except that dacron blanketing is not used. The forearm extension may be laminated as a separate section or directly over the socket using a wax melt-out. Both procedures work satisfactorily.

After the forearm laminate has been oven cured, cut the prosthesis along the proximal socket brim and break out the mold.



H. Fitting of the Prosthesis

Drill a 1" diameter hole through the medial wall of the forearm shell close to the distal end of the inner socket to permit passage of the stump pulling sock. Polish the edges of the hole with a grinding cone.



Wearing a length of cotton stockinette (approximately 8"-10") as a stump sock, the amputee inserts his stump into the socket and pulls the distal end of the sock through the hole. The application of tension on the stump sock facilitates the complete insertion of the stump into the socket. The sock is left on the stump and the end is tucked back into the forearm shell.

Check the adequacy of socket fit. Provide reliefs and modify trim lines where indicated for comfort and range of motion.

I. Harnessing

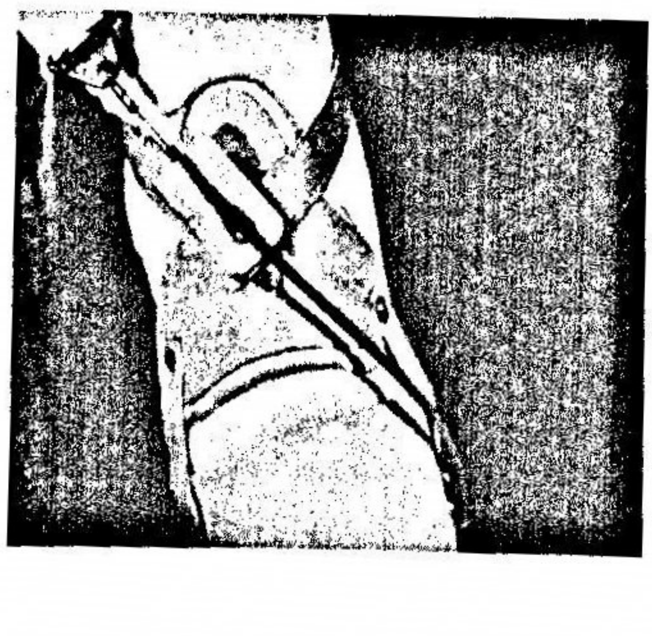
Three different harness arrangements have been used successfully at New York University with the "Muenster" type sockets.

The initial arms were fitted with a conventional Figure 8 harness with triceps pad, flexible hinges, and inverted Y strap. However, the intimate stump encapsulation, flexion attitude, and high trim lines of the "Muenster" sockets provide excellent retention and security, and in most cases obviate the need for suspensory apparatus to maintain the socket on the stump. Without harness, the majority of subjects in the New York University evaluation study with adult amputees were able to resist high axial loads (in the order of 50 pounds) with negligible socket displacement. In the fitting of child amputees the same results obtained with axial loads up to one-third of body weight. Hence, the two simplified harness systems described have proved adequate for most patients.

1. Conventional Harness

The conventional harness is fabricated according to standard prosthetic practice.[6] However, because of the integral security of the socket, the size of the triceps pad may be reduced.

In the New York University fittings a triangular shaped triceps pad constructed of light gauge aluminum covered with leather was used exclusively. The general pattern of the templates used as a guide in shaping this triceps pad is shown on the following page (Figure 6). The exact size of these templates is determined individually for each subject according to the following formula:



a. The width is equal to one-half the circumference of the arm measured just above the epicondyles.

b. The length is three-quarters of the width.

6 See chapter entitled "Harness and Control Systems"

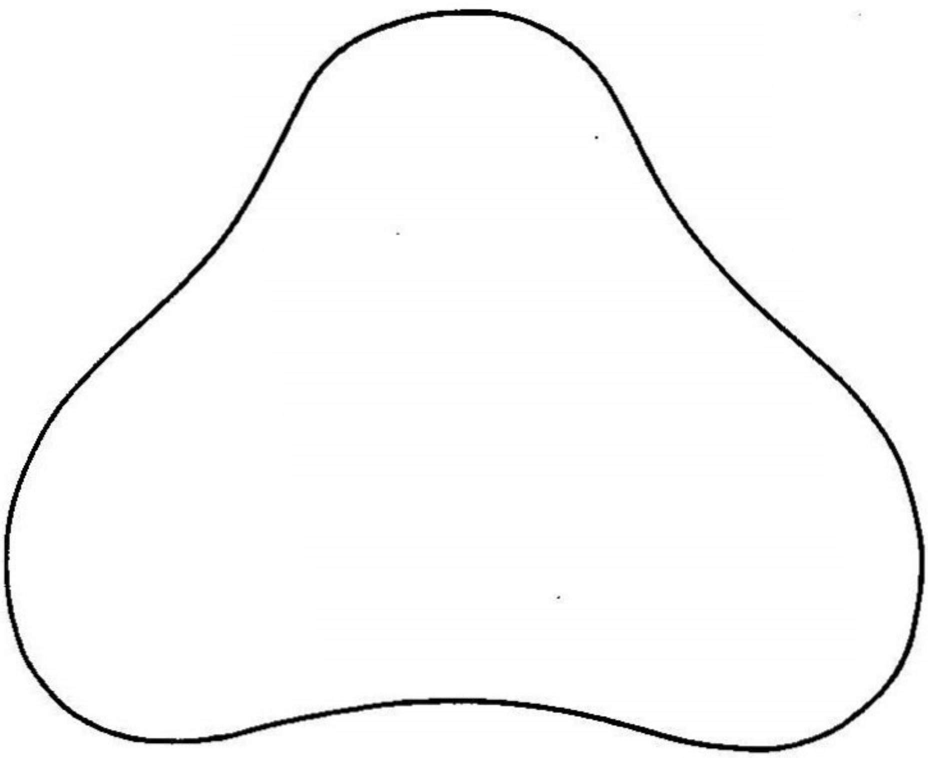


Figure 6

Template for Triceps Pad

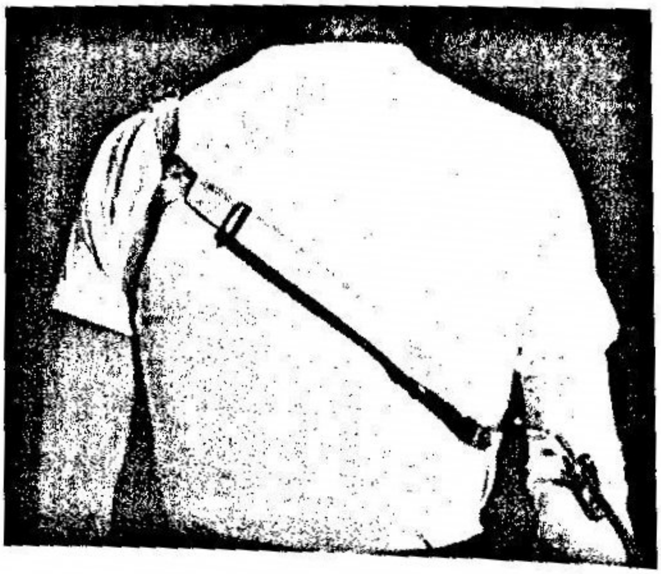
2. Simplified Harness Systems

Procedures for fabricating the two simplified axilla loop harness systems are described below. In one system the reaction point is located at the proximal socket while in the other it is located over the triceps. There is no significant functional difference between the two systems. The choice between the two systems depends on the amputees' preference regarding the location of their control cable, particularly in relation to different types of clothing; e.g., an amputee who regularly wears short sleeve shirts may prefer the triceps reaction point system, while one who regularly wears long sleeve shirts may prefer the proximal socket reaction point system.

a. Proximal Socket Reaction Point System

(1) Rivet a standard housing cross bar assembly to the mid-line of the posterior wall of the socket approximately 1/2-3/4" distal to the proximal brim. The cross bar portion of the loop is directed upward.

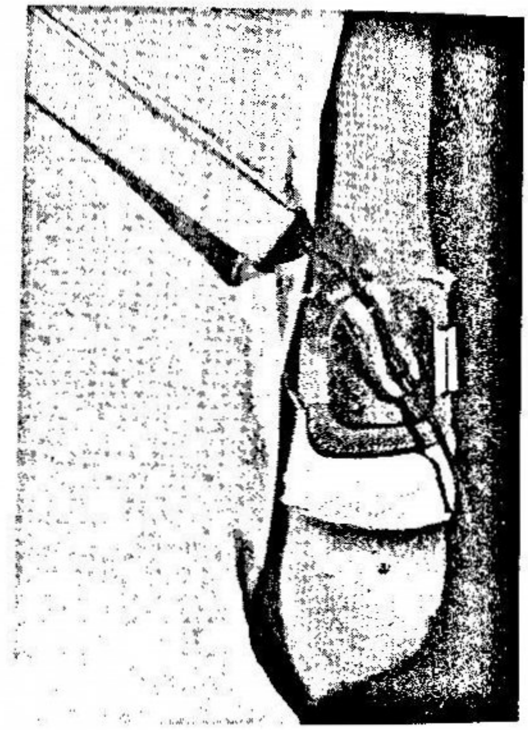
(2) Locate the distal retainer base plate on the lateral side of the forearm in the usual manner so that it produces as direct a line of pull as possible between the cross bar and the terminal device.



(3) Attach the cable housing assembly in the usual manner. Maintain the cable as short as possible without interfering with function in order to reduce the incidence of cable rubbing on the flesh or clothing.

(4) Complete the harness with an axilla loop arrangement. Flexible hinges or an additional suspensory strap (i.e., front support strap) are not needed.

b. Triceps Reaction Point System



(1) Fabricate a small leather triceps pad (3" x 3") and sew a strap (Velcro is recommended) across the middle of its posterior surface to provide a means of securing the pad on the arm.

(2) Attach a standard housing cross bar assembly over the strap and centered on the pad.

(3) Place the distal retainer base plate on the forearm in the same manner as described in the previous system.

(4) Attach the cable housing assembly in the usual manner.

Complete the harness with an axilla loop arrangement.

Fabrication of Above-Elbow Prostheses

The description of fabrication procedures for Above-Elbow prostheses is organized in the same manner as in the Below-Elbow chapter. The prosthetist should be thoroughly familiar with Below-Elbow fabrication operations and terminology before attempting an AE prosthesis.

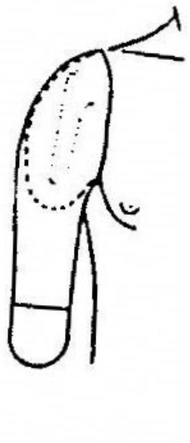
The casting and molding section furnishes techniques for all AE prostheses, with variations for specific types noted. The Standard and Short AE (double wall) fabrication methods are described next, followed by the Elbow Disarticulation type (both single and double wall).

The principal components of an Above-Elbow prosthesis are the socket, elbow unit, forearm, and wrist unit; the relationships of these components are discussed below.

THE FUNCTIONAL REQUIREMENTS OF THE SOCKET-ELBOW UNIT-FOREARM SYSTEM

Short AE

To obtain maximum stability on the short stump, a double wall socket is used, with the proximal edge encasing the acromion.



A full 135 degrees of forearm flexion, with stability in flexion, is provided by an internal locking elbow unit.

Manual arm rotation is supplied by the turntable of the elbow unit, while the wrist unit allows manual wrist rotation.

Standard AE

A double wall socket increases axial stability; single wall construction may be used where stump shape permits and where a double wall socket would make installation of the elbow unit difficult.

A full 135 degrees of forearm flexion, with stability in flexion, is provided by the internal locking elbow unit.

Residual arm stump rotation is supplemented by the elbow unit turntable. The wrist unit permits manual wrist rotation.

Elbow Disarticulation

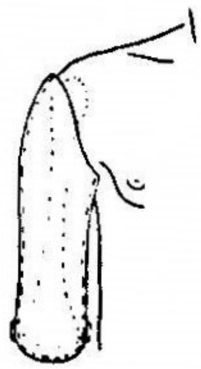
For a stump between 90 and 95 percent of arm length, a double wall socket must be used to provide the proper sizing.

For 95 to 100 percent of arm length, a single wall socket is used.

Forming the socket to fit the elliptical cross-section of the humerus at the epicondyles permits transmission of arm rotation to the prosthesis.

A full 135 degrees of forearm flexion, with stability in flexion, is provided by the outside locking elbow hinge.

Manual wrist rotation is afforded by the wrist unit.



Some Variances in Practice

The Standard AE amputee type normally includes stumps of about 50 to 90 percent of acromion-to-epicondyle length. However, the 50 percent point is not the only criterion for determining the prosthesis type. An empirical index relating humeral length (from axilla to end of humerus) to anterior-posterior stump diameter (at axilla level) is of some value in predicting the function of the stump.

$$\text{Campbell Index} = \frac{\text{Humeral Length (axilla to end)}}{\text{Stump Diameter (anterior-posterior at axilla)}}$$

The measurements should be made with firm pressure and the results interpreted as follows:

Index greater than 1.33 or $1\frac{1}{3}$:

The stump should be capable of operating a Standard AE prosthesis.

Index less than 1.33 or $1\frac{1}{3}$:

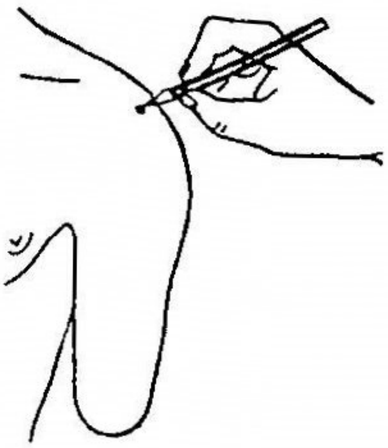
The stump is satisfactory only for the limited function of the Short AE or possibly a Shoulder prosthesis.

MOLDING FOR ALL AE PROSTHESES

Measurement and Marking

1. Location of Measurement Marks

Use an indelible pencil to mark the acromion and measurement marks on the stump. When fabricating an Elbow Disarticulation prosthesis, also mark the elbow axis if the epicondyles remain. The indelible marks will transfer to the wrap in the succeeding operation.



2. Record of Measurements

Measure and record the girths and lengths.

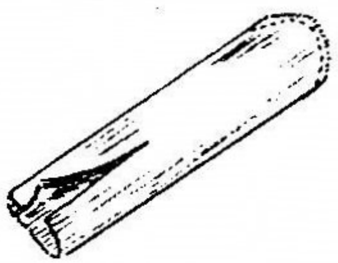
3. Location of Relief Areas

Mark all bony prominences, tender spots due to scars or underlying neuromas, etc. with indelible pencil. These marks will also transfer to the wrap and will indicate areas where relief of socket pressure on the stump may be necessary.

The Mold or Wrap

1. Preparation of Cast Sock

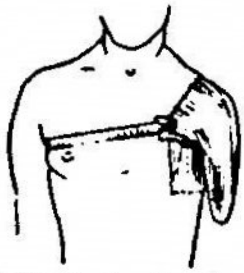
Sew a length of stockinet (sufficient to extend at least 2 inches proximal to the acromion) in a curve to match the end of the stump. The stockinet should be of appropriate



width (usually 3 inches) to fit snugly to the stump. Cut to form a $\frac{1}{8}$-inch seam allowance.

Slit one side of the proximal end slightly so it will fit well up into the axilla and over the top of the shoulder.

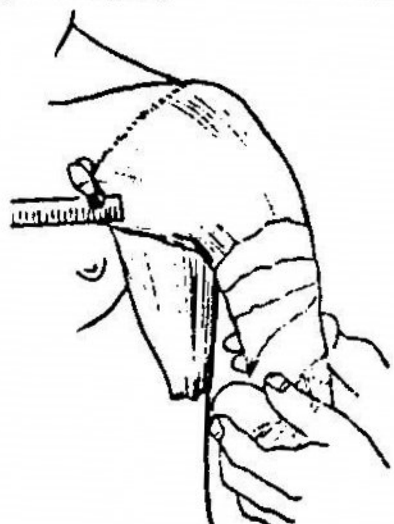
Draw the cast sock over the stump with the seam allowance on the outside. Place a piece of stockinet under the axilla to cover the hair. Clamp the sock and axilla cover in place to an elastic chest strap.



2. Application of Plaster Bandages

Cover the clothing of the amputee to protect it from plaster.

Prepare the plaster bandages and start the wrap near the midpoint of the stump. Roll the bandage in a spiral downward, overlapping each previous turn by about half the bandage width. Continue to the end of the stump. Lap several layers over the end and spiral back up past the midpoint to about 2 inches above the acromion, then back to the starting point. Do not wrap too tightly over the stump end!



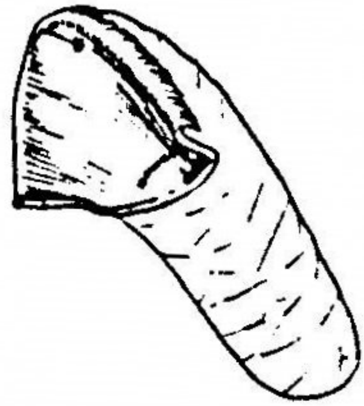
Repeat the procedure until about three layers cover the stump. As the plaster starts to set, lightly shape the wrap around any bony spurs or protrusions. Make sure the medial surface of the wrap is flat and not curved.

Allow the wrap to harden with the stump in the normal hanging position.

3. Completion of Mold

Remove the elastic strap and pull the wrap (including the cast sock) from the stump. For some Elbow Disarticulation types, it may be necessary to cut the wrap in order to remove it.

The indelible pencil marks previously made on the stump will have transferred to the cast sock. These marks on the inner surface of the wrap should be re-marked.



The Cast or Model

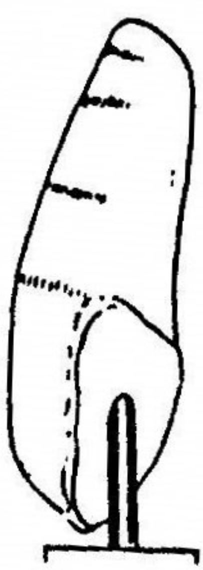
1. Application of Plaster

Prepare the plaster of Paris mixture and pour the mold full, agitating gently to remove entrapped air.

Prop the mold on its lateral side to harden. When it has hardened sufficiently, insert the dented-end third of a foot-long, half-inch pipe to serve as a holding rod.

2. Removal of Wrap

Cut the wrap down the side with a knife, taking care not to damage the cast. Strip the wrap from the cast and discard it.



Re-mark the indelible pencil landmarks that have transferred from the wrap to the cast.

3. Completion of the Model

Measure girths on the cast and compare them with the recorded stump measurements. Use a knife, scraper, or wire screen to shape and smooth the model to proper size. Be careful not to reduce the areas where relief is needed for scars, etc. In cases where a heavy stump sock will be worn, shape the model slightly larger to allow for this.

The Check Socket

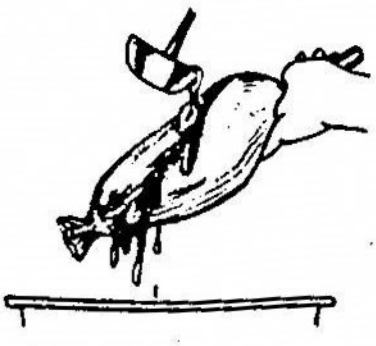
1. Preparation of Wax

Heat the beeswax on an electric plate (not an open flame, for the fumes are flammable) to a temperature of about 275° F. or until bubbles just begin to form when a test piece of stockinet is dipped into the wax.

2. Layup

Cover the master model with a thin film of parting compound, such as petrolatum, to prevent adherence of wax to plaster.

Cut two lengths of cotton stockinet of appropriate width, each twice as long as the model, plus eight inches. Pull one length inside the other and then place half of the stockinet gently over the model so that petrolatum does not saturate the fabric. With heavy cotton cord, loosely tie off the stockinet at the distal end of the model. Reflect the remaining length over the model, pull down tightly, and tie off around the mandrel.



3. Application of Wax

With a ladle or cup, dip out the hot wax and pour it over the stockinet. Use enough wax to impregnate the stockinet completely and place in cool water to harden. Be careful never to allow water to be introduced into the basin of hot wax.

While the wax is cooling, press and massage it to be sure that all contours have been faithfully reproduced.

4. Removal of Check Socket

Trim the wax around the proximal edge of the model. While still warm, slide the socket from the model, using

an air hose to blow around the proximal edge to force separation if necessary.

For some Elbow Disarticulation types it may be necessary to slit the cast to remove it from the model.

5. Check-Socket Fitting

Place cotton stockinet over the stump and apply the check socket by pushing it onto the stump while pulling on the stockinet which extends through the hole in the end of the wax socket. Liberal use of talcum powder facilitates this process.

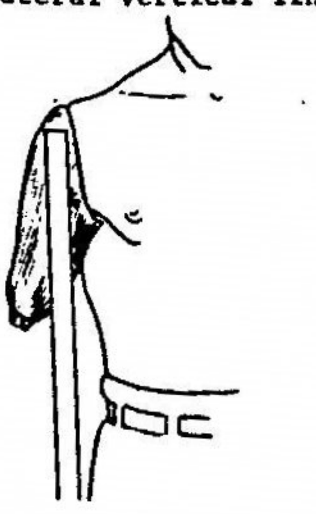
Fitting the check socket includes the following: a. overall fit, that is, is socket too loose or too tight? b. trim lines--for the standard AE and elbow disarticulation, the lateral edge of the socket extends to the acromion. For the short AE the lateral edge extends over the acromion and no less than two inches proximal to it. The anterior and posterior socket margins depend primarily on stump length and tissue consistency, but should not extend past the delto-pectoral line anteriorly, nor approximately two inches medial to the axilla posteriorly. These margins may be considerably reduced in the case of long, firm stumps. Be sure the socket fits snugly into the axilla and is flat, rather than curved, in that area. c. comfort--have the patient exert force in all directions against resistance and note the location of any pain or discomfort. d. total contact--cut inspection holes to check for total contact.

Since the wax check socket is malleable, its shape and volume can be readily altered to correct any problems that are uncovered.

6. Location of Plumb Lines (For Carrying Angle)

Place the check socket on the stump, with the stump in a natural hanging position. Be sure the patient is standing comfortably erect, in good alignment, and with weight evenly distributed on both feet. Place a plumb line along the anterior aspect of the socket so that it falls apprixmately 1/2 inch lateral to the pelvis. This plumb line will be used to establish the location and angle of the elbow unit to prevent the prosthesis from striking the body when hanging or swinging at the side.

Then place the plumb line on the lateral aspect of the socket and locate a lateral vertical line.



Remove the socket from the stump and punch two small holes near each end of the plumb lines. The holes will allow tiny protrusions to form on the lamination mold to identify the plumb lines.

Also mark the acromion location on the check socket with an awl or punch. This landmark will be used in later operations as a reference for sizing.

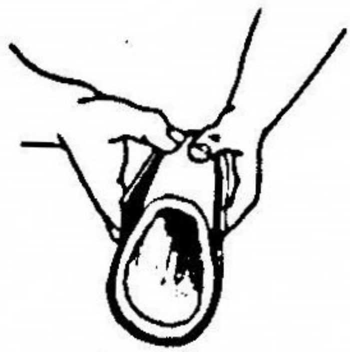
Lamination Model: Plaster Method

1. Application of Plaster

Mix enough plaster and water to fill the socket about half full. Pour the plaster into the socket and slowly rotate the socket while pouring the plaster back into the mixing bowl. Repeat this operation until the plaster wall is about ¼-inch thick all around the inside of the socket. Allow the plaster to harden for about ½ hour.

2. Removal of Check Socket

Slit the wax socket with a knife and peel it from the breakout. Do not deform the socket more than necessary, since it may be needed again if the breakout is damaged.

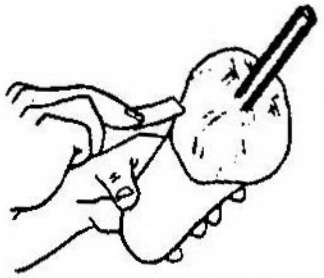


Hold the breakout up to the light and look inside for thin areas. If such areas exist, mix more plaster and slush it inside the breakout until the wall is built up sufficiently.

3. Completion of Breakout

Smooth the breakout with sandpaper or wire screen to remove irregulatities. Place roundhead wood screws in the four protrusions which define the plumb lines. These will serve to identify the vertical reference lines on the laminated socket.

Close the proximal end with plaster that has thickened to the consistency of whipped cream. Insert a small diameter tube into the



breakout to serve as a vent and holding rod. Be sure this tube is not clogged. Dry the breakout in an oven at 140° F. for at least three hours.

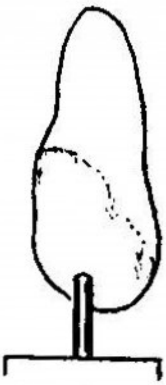
When fabricating an Elbow Disarticulation type or a double wall Short or Standard AE prosthesis, paint or dip the breakout in parting lacquer to cover it with a thick, even coat. Three or four separate coats of lacquer should be applied and allowed to dry.

STANDARD AND SHORT AE PROSTHESES (DOUBLE WALL)

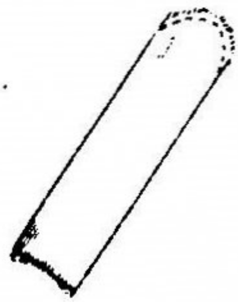
First Layup

1. Preparation

Cut three lengths of stockinet, each about 4 inches longer than the mold, and another about half the mold length.



Sew the end of each piece in a curve to match the distal end of the mold, and cut off the excess to form a ⅛-inch seam allowance.



2. Application of Stockinet

Pull two of the long pieces down tightly over the mold, keeping the seam allowance on the outside and the ribs straight to provide a smooth interior socket surface. Tie the open ends to the holding rod with string.

Pull the short piece of stockinet over the layup and trim it to where the second lamination will fair in.

3. Completion of Layup

Turn the remaining piece of stockinet inside out and pull it over the layup. Smooth

the layup and tie the open ends of the stockinet tightly around the rod.

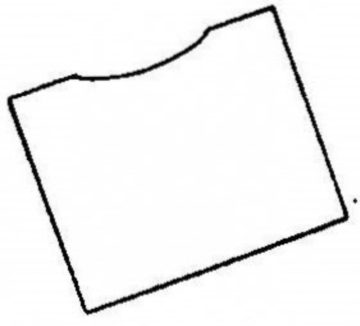
Buildup

1. Preparation

Remove the pressure sleeve from the cured socket. If the plumb lines are not visible, locate the small protrusions and draw the lines on the socket.

Remove the turntable from the elbow unit and cover the knurled skirt with masking tape to keep it free of wax. If the turntable does not have sufficient hole area to permit the bees wax to melt out readily, drill several ¼-inch holes in the face of the turntable.

Obtain a 9 x 12-inch piece of Manila paper or other resin impregnated paper (half of a Manila folder is usually satisfactory) to use in making the buildup form. Halfway along

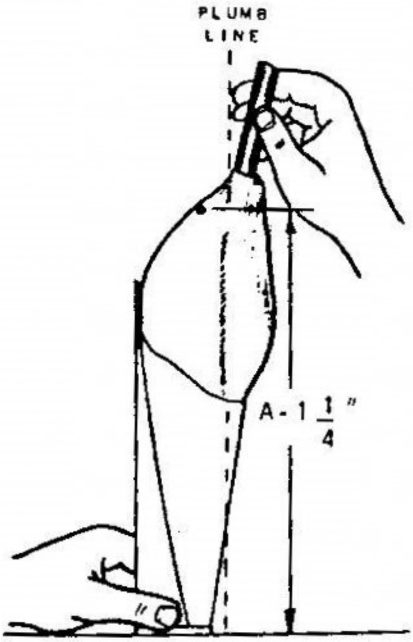


one of the long sides, make a pencil mark about ¼ inch from the edge. Draw a curve about 3 inches on each side of the mark and cut along the line. This cut side will allow the turntable to fit squarely to the paper when it is formed into a cone.

2. Alignment of Turntable, Form, and Socket

Wrap the curved side of the Manila paper around the taped skirt of the turntable so a conical form is fashioned.

With one hand hold the cone and turntable, with the turntable face flat on a table.



With the other hand position the socket in the cone so the distance between the acromion and the table surface corresponds to the required arm length (Dimension A) minus the distance between the elbow axis and the turntable face (1¼ inches for most elbow units) A height gauge is useful for setting the distance.

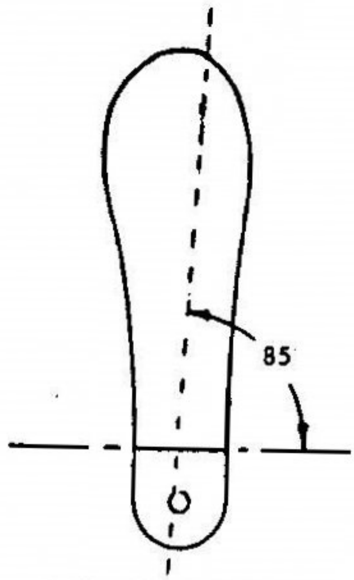
With the socket held in the proper position, adjust the cone so the proximal end fairs to the socket.

As soon as the correct conical shape is obtained, remove the socket from the form and apply one piece of masking tape at the middle of the form to hold the conical shape.

Trim the proximal end of the form if it is too long.

Align the form and socket with the edge of the turntable just lateral to the projected anterior plumb line and exactly on the socket axis in the side view. Check the arm length again to see that it is correct. Tape the proximal end of the form securely to the socket.

Square off the turntable so it is perpendicular to the anterior plumb line, and makes an angle of about 85° with the lateral plumb line.



Tape around the turntable to attach it to the form. Mask all seams to prevent wax leakage. Spiral-wrap tape around the form to strengthen it.

If an internal cable exit elbow unit is used, be sure that the elbow unit will be in the correct anterior-posterior orientation and will allow maximum medial rotation.

3. Attachment of Form Extension

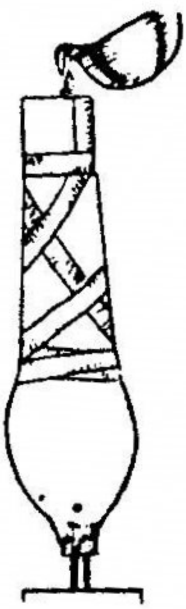
Fashion a 3-inch-wide strip of Manila paper into a cylinder to fit around the distal end of the form so as to extend the form about 2 inches beyond the turntable.

Tape the extension to the form and tape the seam.

4. Application of Wax

Heat the beeswax until it is at its lowest possible pouring temperature. Do not get the wax too hot!

Pour a small amount of wax into the form to check for leaks. If all seams are sealed



properly, pour the wax slowly to fill the form to within one inch of the top of the extension. Continue to add wax as the wax cools and shrinks.

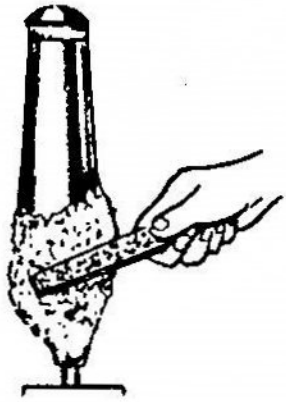
When the wax has hardened, remove the form and extension.

5. Completion of Buildup

Shape the projecting cylinder of wax on the turntable into a dome so the pressure sleeve will not tear during lamination.

Smooth out any irregularities in the buildup surface to provide a smooth contour.

Coat the buildup with a thin film of parting lacquer.



Scrape excess wax from the plastic socket and clean it with benzine.

Rough-up the exposed outer surface of the plastic socket with a coarse file to effect a secure mechanical bond between the inner and outer wall. One inch of socket between trim line and wax is needed.

Second Layup

1. Preparation

Remove the masking tape from the turntable and clean the knurled skirt.

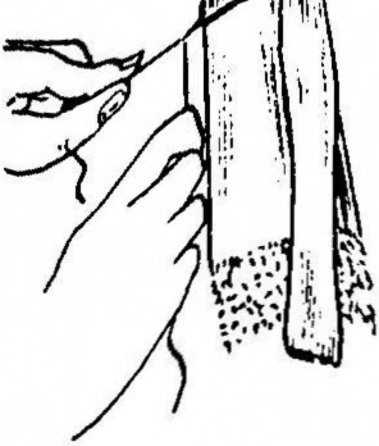
Cut one piece of stockinet 2 inches longer than twice the length of the buildup, and another piece 6 inches longer than the first.

2. Application of Stockinet

Pull one end of the shortest piece of stockinet over the buildup until the edge is about ¼ inch proximal to where the buildup joins the socket.

Tie the stockinet tightly to the turntable, encircling it twice with 4-cord linen thread and making sure the thread lies completely in the groove.

Pull the free end of the piece down, keeping the ribs straight, and trim it so the edge is about ¾ inch distal to the first edge.



Pull half of the remaining piece of stockinet over the layup and tie it to the turntable in the manner just described. Make sure the thread is in the groove and distal to the previous thread.

Pull both ends of the stockinet tightly down over the layup with the ribs straight and tie the two layers securely to the rod.

Mold Removal: Plaster Method

1. Preparation

While the plastic is still warm, cut off the end of the layup at the acromion for a Standard AE, or about 2 inches proximal to the acromion for a Short AE. Leave the pressure sleeve on to protect the finish of the plastic during subsequent operations.

2. Removal of Plaster

Strike the plastic socket with a rubber mallet just hard enough to crack the plaster. It may be necessary to use a chisel to dig out plaster in the distal end of the socket. Do not strike too hard near the turntable or delamination may occur.

3. Cleaning the Socket

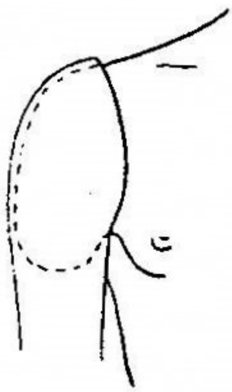
Remove the film of dried lacquer from the socket. If any particles of the plaster and lacquer cling to the socket wall, remove them by wiping with a wet cloth. Remove all wax and foreign material from the turntable.

Trim and Assembly

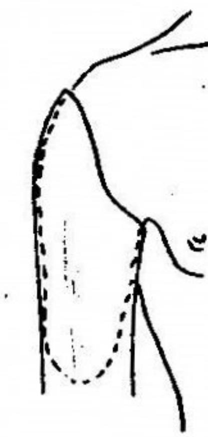
1. Determination of Socket Trim

Trim the socket to the rough trim line established on the check socket. Place the socket firmly on the amputee's stump and check the trim line for necessary alterations.

For Short AE: The lateral edge should extend about two inches proximal to the acromion, so as to provide suspension on the shoulder without restricting elevation. The anterior and axillary edges should be as high as possible without causing limitation of motion or discomfort.



For Standard AE: The lateral edge should be at the acromion, but without the edge digging in and displacing the socket when the arm is abducted.



The anterior edge should not be displaced when the arm is flexed and depressed across the body.

The axillary lip should be as high as permitted by the amputee's comfort.

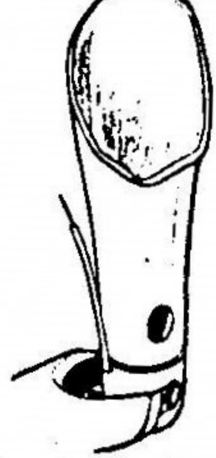
After trimming, sand all cut edges round and smooth and seal the edges.

2. Assembly of Socket, Elbow Unit, and Forearm Shell

The forearm shell, complete with wrist unit and elbow unit, can be obtained from a prosthetics supply house assembled as an AE set-up.

Cut a 1¼-inch hole in the medial distal portion of the socket (about 2 inches above the turntable skirt) to permit attaching the elbow unit to the turntable. If clearance is not sufficient, cut a hole in the distal end of the inner wall.

When an internal cable exit unit is used, drill a 1/16-inch hole about halfway up the socket (or as high as the inner wall permits) and about ¾ inch medial to the anterior-posterior mid-line. Drill the hole at an angle to prevent kinking of the cable. Smooth and seal the edges of the hole and feed the cable through it.



Assemble the elbow unit and adjust the turntable friction to withstand a torque of five ft.-lbs.

Test the elbow unit to make certain it locks and unlocks properly and allows a full 135 degrees of forearm flexion.

3. Installation of Terminal Device

Assemble the wrist and attach the prescribed terminal device and sizing accessories in accordance with the manufacturer's instructions and the sizing plans.

4. Assembly of Control System and Harness

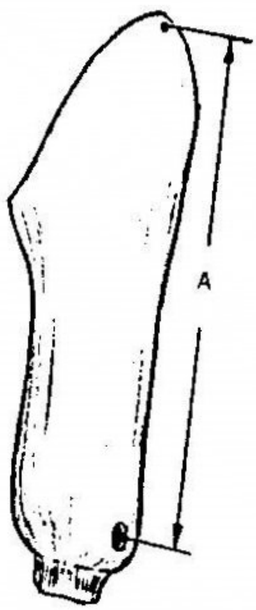
ELBOW DISCARTICULATION PROSTHESIS (SINGLE WALL)

Single wall construction is used when the stump is about 95 - 100 percent of arm length (the epicondyles remain).

Location of Outside Locking Hinge Spacer (Elbow Disarticulation Only)

Single Wall Socket

If the epicondyles remain, use an awl to make a small hole in the check cast exactly at the center of each epicondyle indicated to determine the elbow axis. Punch two holes with a leather or cork punch of appropriate diameter to match the special adjustable spacer, with the centers exactly on each epicondyle center.



Insert the spacer and adjust the width to extend about ⅛ inch from the check socket. (An alternate method is to locate the spacer later in the lamination mold.)

If no epicondyles remain, lay off Dimension A on the check socket from the acromion to locate the elbow axis. Tape the hinge on to determine the proper alignment, then punch holes and insert the spacer.

If the elbow axis lies proximal to the end of the check socket, punch holes and install the spacer as above, providing there is sufficient clearance between the spacer axis and the end of the check socket. Do not deform the check socket during this operation.

If the elbow axis lies distal to the end of the socket, the hinge spacer must be located later in the buildup operation.

Layup: Socket

1. Preparation

Cut four lengths of stockinet, each about 3 inches longer than the mold.

Sew the end of each piece in a curve to match the distal end of the mold and cut to provide a ⅛-inch seam allowance.

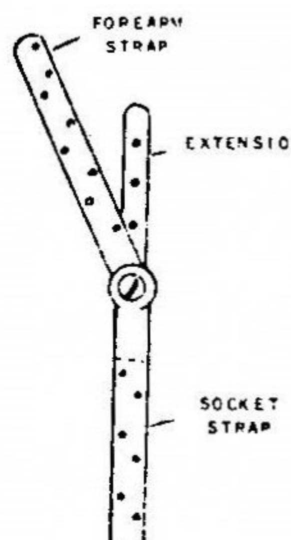
2. Application of Stockinet

Pull two of the pieces down tightly over the mold, keeping the seam allowance on the outside and the ribs straight to provide a smooth interior surface of the socket. Tie the open ends to the holding rod with string.

Cut a slit in the stockinet over each of the spacer ends and force it down over each end so it fits snugly around the protruding spacer.

3. Attachment of Hinge Socket Straps

Disassemble the hinge and drill five to eight ⅛-inch holes in each socket strap and forearm strap. Remove the burrs from the holes with a countersink.



Using bending irons, shape the straps to the contour of the layup, but do not bend the mechanism part of the strap.

If the hinge has extensions on the socket straps, bend the extensions over the distal end to conform to the shape of the layup.

They may be soldered together for greater strength if desired.

Coat the threads with silicone grease and attach the straps to the spacer, aligning them along the axis of the layup with the mechanism strap usually on the medial side.

Pack any gaps between the hinge strap and the layup with scraps of stockinet.

4. Completion of Layup

Turn the two remaining pieces of stockinet inside out (seam allowance on the inside).

Apply the last pieces, pull down tight and tie the open ends to the holding rod.

Lamination: Socket

Buildup: Forearm

NOTE: Forearm assemblies may be purchased from a prosthetics supplier.

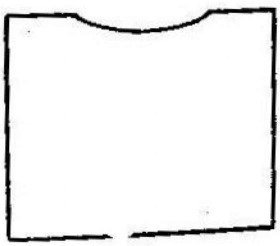
1. Preparation

Do not remove the pressure sleeve, as it will serve as a parting film during the subsequent lamination.

If a manual lock wrist unit is prescribed, disassemble the mechanism to keep it free of wax. Drill several ⅛-inch holes in the face of the wrist unit to expedite wax removal.

Cover the knurled portion of the wrist unit with masking tape.

Obtain a 9 x 12-inch piece of Manila paper or other resin impregnated paper (half of a Manila folder is usually satisfactory) to use in making the buildup form.



Halfway along one of the long sides, make a pencil mark about ¼ inch from the edge. Draw a curve about 3 inches on each side of the mark and cut along the line. This cut side will allow the wrist unit to fit squarely to the paper when it is formed into a cone.

2. Attachment of Hinge Straps

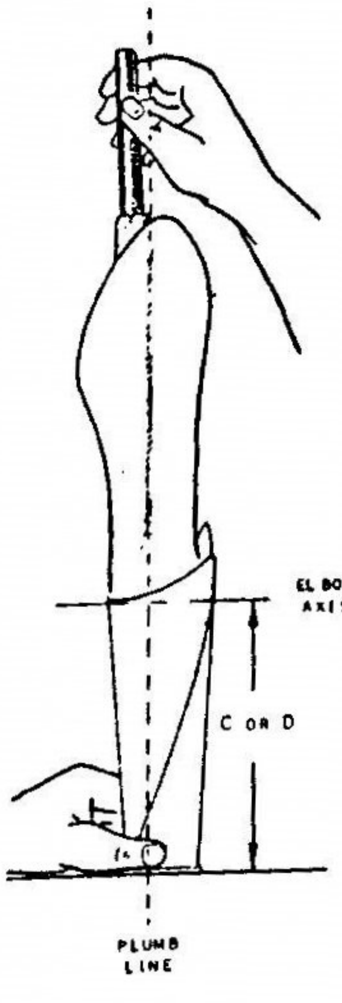
Cover the forearm straps with masking tape to prevent wax from adhering to the metal during the buildup operation.

Cut away laminate where necessary to allow assembly of the forearm straps on the socket.

3. Alignment of Wrist Unit, Form, and Socket

Wrap the curved side of the Manila paper around the taped skirt of the wrist unit so a conical form is fashioned.

Determine required forearm length in accordance with the sizing plans and formulas.



With one hand, hold the cone and wrist unit with the face of the unit flat on a table.

With the other hand, position the socket in the cone so the distance between the elbow axis and the table surface corresponds to the required forearm length (Dimension C or D). A height gage is useful for setting the distance.

With the socket held in the proper position, adjust the cone so the proximal end fairs to the socket.

As soon as the correct conical shape is obtained, remove the socket from the form and apply one piece of masking tape at the middle of the form to hold the cone shape.

Trim the proximal end of the form if it is too long.

Align the form and socket so the cone axis is parallel to the plumb line and set in about 15° initial flexion. Check the forearm length again to see that it is correct. Tape the proximal end of the form securely to the socket.

Square off the wrist unit so it is perpendicular to the form axis, and tape around the unit to attach it to the form.

Mask all the seams to prevent wax leakage, and spiral-wrap tape around the form to strengthen it.

Make sure the proximal posterior opening of the form is large enough to permit the forearm section to ride over the distal end of the socket during full forearm flexion.

4. Attachment of Form Extension

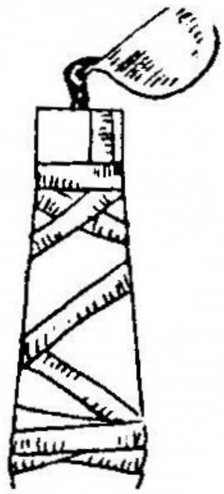
Fashion a 3-inch-wide strip of Manila paper into a cylinder to fit around the distal end of the form so as to extend the form about 2 inches beyond the wrist unit.

Tape the extension securely to the form and tape the seam.

5. Application of Wax

Heat the beeswax until it is at its lowest possible pouring temperature.

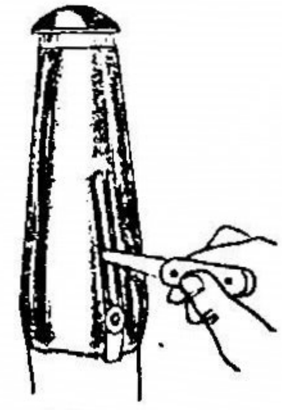
Pour a small amount of wax into the form to check for leaks. If all seams are sealed properly, pour the wax slowly to fill the form to within one inch of the top of the extension. Continue to add wax as the wax cools and contracts.



When the wax has hardened, remove the form and extension.

6. Enlargement of Hinge Grooves

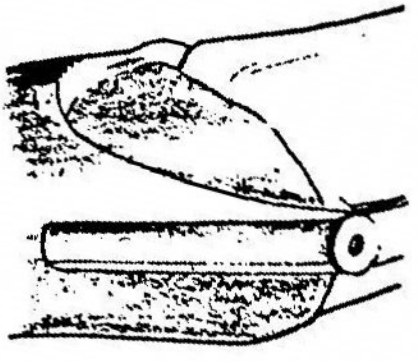
Remove the hinge straps and widen and deepen the grooves in the wax, to allow layers of stockinet to lie under the straps without pushing them above the surface of the wax.



7. Completion of Buildup

Shape the cylinder of wax on the wrist unit into a dome so the pressure sleeve will not tear during lamination.

If a rolled edge forearm cutout is desired, fashion a U-shaped depression in the anterior



proximal surface of the buildup, extending about 3 to 4 inches from the hinge axis. Make the depression about ¾ inch deep and round the edges.

Smooth the wax and coat it with a thin film of parting lacquer.

Layup: Forearm

1. Preparation

Make sure the lock mechanism has been removed from the hinge.

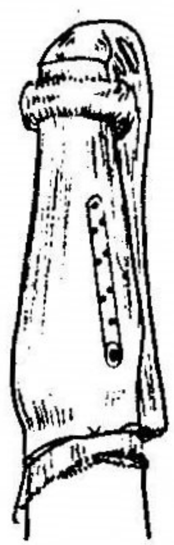
Remove the masking tape from the wrist unit and clean the skirt.

Cut two lengths of stockinet about 6 inches longer than twice the length of the forearm.

2. Application of Stockinet

Pull half of one piece of stockinet over the buildup. Tie it securely to the wrist unit with linen thread.

Turn the other half inside out and pull it over the layup. Tie the two layers to the socket about 2 inches proximal to the elbow axis.



Pull the remaining piece of stockinet over the forearm and tie it to the wrist unit in the manner just described, making certain the thread is in the groove and distal to the previous thread.

Roll the stockinet back up to the wrist unit.

3. Attachment of Hinges

Remove the masking tape from the hinge straps.

Cut away the stockinet just enough to permit assembly of the hinges.

Coat the threads with silicone grease and install the forearm straps.

Pack any gaps between the straps and the groove with stockinet scraps.

4. Completion of Layup

Roll the layer of stockinet down over the layup.

Pull the other half of the stockinet down tight, keeping the ribs straight, and tie the open ends to the socket.

Lamination: Forearm

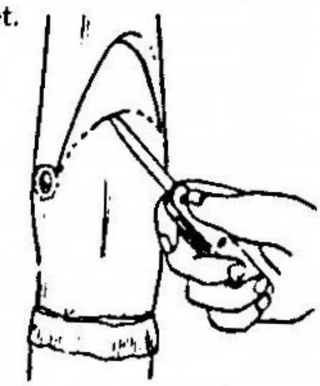
Mold Removal: Plaster Method

1. Preparation

While the plastic is still warm, cut around the screws or bolts which hold the hinge together and remove them.

2. Separation of Forearm Shell

Cut through the outer lamination as close to the socket as possible. Cut around the shell, through the peak of any bulges or high spots, so the forearm shell can be pulled away from the socket.



Separate the socket and forearm shell. Do not remove the pressure sleeve from the shell.

3. Removal of the Plaster

Cut off the socket and holding rod about one-quarter inch proximal to the acromion.

Peel off the portion of the second lamination from the socket.

Strike the socket with a rubber mallet just hard enough to crack the plaster. Do not strike too hard near the hinges or delamination might occur. It may be necessary to use a chisel to dig out plaster in the distal end of the socket.

Narrow the width of the spacer and remove it from the socket.

4. Cleaning the Socket

Remove the film of dried lacquer from the socket; if any particles of plaster and lacquer cling to the socket wall, remove them by wiping with a wet cloth.

Clean all resin and wax from the pivot or mechanism part of the hinge.

Trim and Assembly

1. Determination of Socket Trim

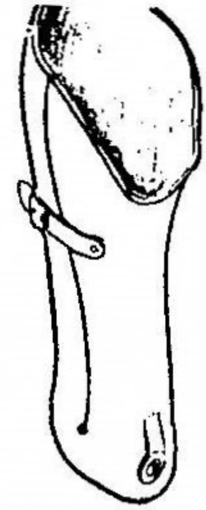
Trim the socket to the approximate trim line established on the check socket.

Check the trim with the socket on the stump.

Trim the lateral edge as high on the deltoid as possible without digging in and displacing

the socket when the arm is elevated. Trim the anterior edge so it does not displace when the humerus is flexed and adducted across the body. Trim the axillary lip as high as the amputee's comfort will permit.

For some special cases it may be necessary to trim a spiral opening in the anterior portion of the socket so the epicondyles may be "screwed" into the socket. It is also possible to slit the anterior portion along the socket axis to permit entry of epicondyles into the socket, using a billet and buckle to close the slit.

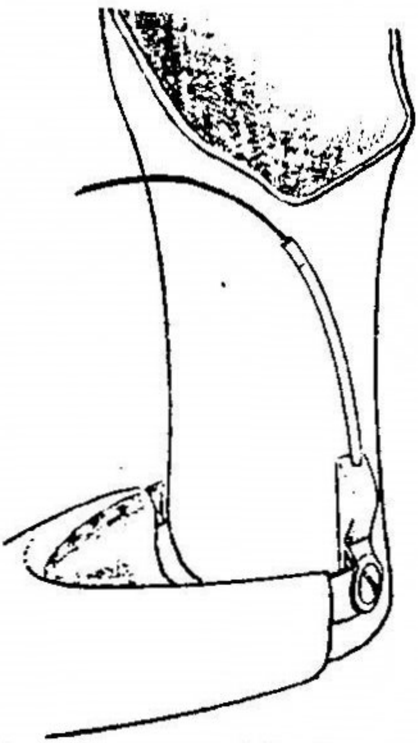


2. Determination of Forearm Shell Trim

Make certain the hinge is free of foreign material. Assemble the hinge and locking mechanism.

Trim the forearm shell to allow maximum 135 degrees of flexion.

Test the elbow lock mechanism to make certain that it locks and unlocks properly in every locking position.



3. Installation of Terminal Device

Clean any wax or foreign material from the wrist unit housing.

Assemble the wrist unit and attach the prescribed terminal device and sizing accessories in accordance with the manufacturer's instructions and the sizing plan.

ELBOW DISARTICULATION PROSTHESIS (DOUBLE WALL)

Double wall construction is used to provide proper length sizing when the stump is about 90-95 percent of arm length.

First Layup: Socket

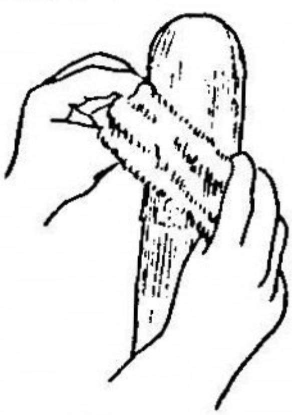
1. Preparation

Cut two lengths of stockinet, each about three inches longer than the mold, and two pieces about ⅓ the mold length.

Sew the end of each piece to match the distal end of the mold and cut it to provide a ⅛-inch seam allowance.

2. Application of Stockinet

Pull one of the long pieces over the mold, with the seam allowance on the outside and the ribs straight. Apply the two small pieces and trim the proximal edges to where the buildup will fair in.



Turn the remaining long piece inside out (seam allowance on the inside) and pull it over the layup. Tie the open ends securely to the holding rod.

Lamination: Socket

Buildup: Socket

1. Preparation

Remove the pressure sleeve from the cured socket.

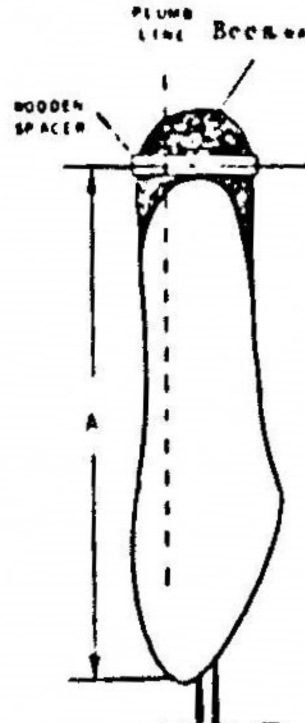
Construct a special hinge spacer from a half-inch hardwood dowel. The spacer width should be equal to the mediolateral width at the distal end of the layup. Sand the spacer so the ends are flat and parallel. Drill and tap to receive the hinge screws.

2. Application of Wax

Construct the buildup from soft beeswax to hold the hinge spacer and to provide a smooth contour for the distal end.

3. Location of Hinge Spacer

Position the spacer while fashioning the buildup so the distance from the acromion to



The spacer axis corresponds to Dimension A. In some instances, the length may be slightly longer than Dimension A, due to the inner socket length.

Align the spacer so it is at right angles to the plumb line and in the normal elbow axis plane.

The spacer will remain permanently in the socket.

4. Completion of Buildup

Smooth out any irregularities in the wax to provide smooth contours.

Scrape excess wax from the plastic socket and clean it with benzine. Rough-up the exposed outer surface of the plastic with a coarse file.

Second Layup: Socket

1. Preparation

Cut two lengths of stockinet, each about 3 inches longer than the layup, and two pieces about 1 inch longer than the buildup.

Sew the end of each piece to match the end of the buildup, and cut to provide a ⅛-inch seam allowance.

2. Application of Stockinet

Pull a short piece of stockinet over the

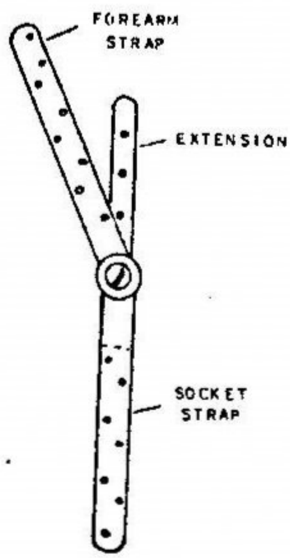
buildup until the edge is about ½ inch proximal to where the buildup joins the socket.

Pull another short piece down, and trim it so the edge is about ¾ inch distal to the first edge.

Cut a slit in the stockinet over the spacer ends and force it around the spacer so the flat spacer ends protrude.

3. Attachment of Hinge Socket Straps

Disassemble the hinge and drill five to eight ⅛-inch holes in each hinge socket and forearm strap. Remove the burrs with a countersink.

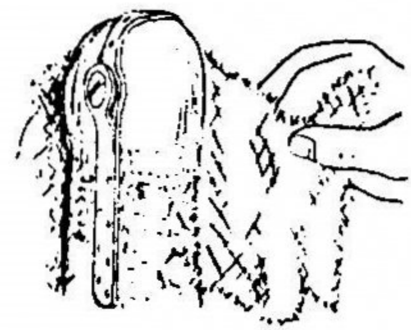


Using bending irons, shape the straps to the contour of the socket.

If the hinge has extensions on the socket straps, bend the extensions over the distal end to conform to the shape of the layup.

Apply silicone grease to the screw threads. Attach the straps to the spacer, aligning them along the axis of the layup, with the mechanism strap usually on the medial side.

Pack the gaps between the straps and socket with stockinet scraps.



4. Completion of Layup

Turn the remaining pieces of stockinet inside out.

Apply the last pieces, pull down tight, and tie the stockinet to the holding rod.

Lamination: Socket

The procedure for FOREARM BUILDUP, FOREARM LAYUP, FOREARM LAMINATION, MOLD REMOVAL, and TRIM AND ASSEMBLY is identical to that for the single wall Elbow Disarticulation.

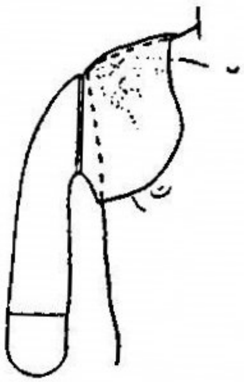
Fabrication of Shoulder Prostheses

Shoulder prostheses have a basic similarity regardless of large differences in size. They consist of a shoulder section, arm section, elbow unit, forearm section and wrist unit. However, there are some component differences, and considerable differences in the socket construction, so that the characteristics of each type must be described. The chief factor in socket construction is to obtain good bearing upon the residual shoulder elements or thorax, for stability, yet capture any remaining mobility in the shoulder girdle.

TYPES AND FUNCTIONS OF SHOULDER SOCKETS

Disarticulation

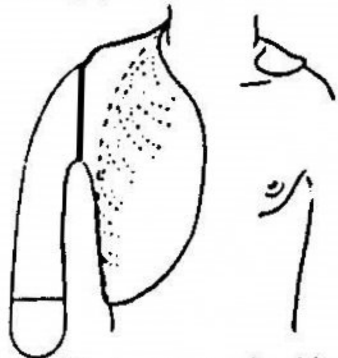
Shoulder mobility should usually be good in this type; the socket is designed to permit full scapular abduction and adduction for control system operation and for a moderate



amount of active arm positioning. There is space for sectional plates, as shown in the illustration. This permits the prosthesis to be constructed in separate shoulder and arm sections, reducing the difficulties of fabrication. Also, some passive functions can be added to the shoulder through sectional plate modification.

Forequarter

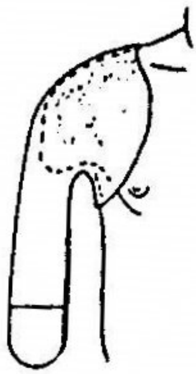
This is also two-piece, having the same components as the SD, but the thorax-bearing shoulder piece is much larger and requires an extensive fitting procedure to form the skirts



to the thorax. Obviously, no shoulder elements remain to give mobility on this side.

Humeral Neck

Unlike the first two types, there is no space for shoulder plates, and the shoulder and arm



sections are completely fused. With intact shoulder girdle, there is more residual mobility and the skirts of the socket are limited so as to retain some of this mobility in the prosthesis.

OUTLINE OF FABRICATION STEPS

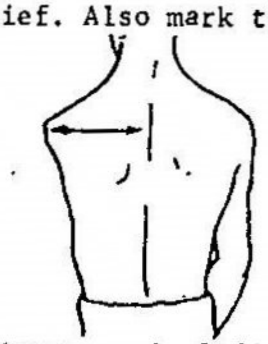
The section on casts and molding is written for the Disarticulation and Humeral Neck prostheses. Since the Shoulder Disarticulation is the most frequent of these amputee types, its corresponding prosthesis will be described first in full detail. Next, the Forequarter prosthesis will be considered as essentially a variation of this type, having similar components but special casts, molding and fitting techniques. Intermediate forms for partial scapular and clavicular losses are rare, and may be devised by the skilled prosthetist without decription here. Finally, the Humeral Neck prosthesis will be outlined with emphasis on fitting procedures special to it. For comfort, stability and appearance, all shoulder prostheses must be double wall; hence, only double wall fabrication will be presented.

Shoulder prosthesis is by far the most difficult job that the prosthetist can perform, and only a highly skilled technician should attempt it. This means that he should first be master of all the techniques of fitting and particularly the methods of plastic fabrication. Consequently, much of this detail can be omitted in this chapter, and only the major steps and unique features need be set down.

Molding; Shoulder Disarticulation and Humeral Neck Prostheses

Measurement and Marking

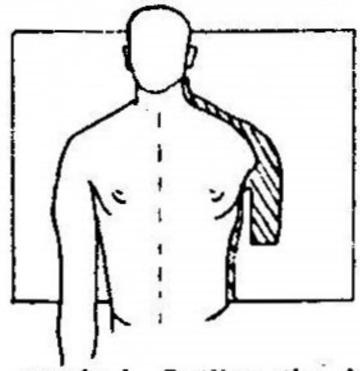
Record the sound side measurements called for by the Measurement Form. Mark tender spots with indelible pencil, for later relief. Also mark the existing



bony prominences, including the acromion, spine of the scapula, clavicle, and the end of the humerus, if present. In the case of a Shoulder Disarticulation, with no humerus remaining, the underlying coracoid process will be revealed as a lateral projection and will be important to mark for proper fitting. In addition, measure the distance between the spinal line and the most lateral prominence of the amputated shoulder—in effect, the hemi-diameter of the shoulder.

Silhouette Diagram

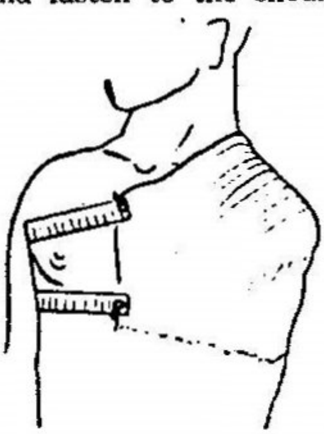
Stand the amputee in normal posture, with his back to a wall on which wrapping paper



has been attached. Outline the frontal silhouette of the torso, shoulders, and sound arm down to the elbow. Add a spinal (center) plumb line bisecting the neck and continuing to the waist. Sketch in the desired plan of the symmetrical contour of the prosthesis shoulder and arm on the chart.

The Mold or Wrap

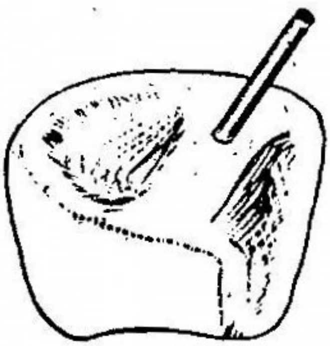
Slit 6-inch stockinet to form a rectangle of stockinet and fasten to the shoulder by an



elastic strap. Wrap plaster bandages (4-6 inches) over the shoulder to about 3 layers of thickness. The covered area is bounded by the neck, the nipple in front, the medial boundary of the scapula and 4-6 inches below the axilla. Remove the wrap when the plaster has set. Re-mark the indelible pencil relief marks on the inner surface of the mold.

The Cast or Model

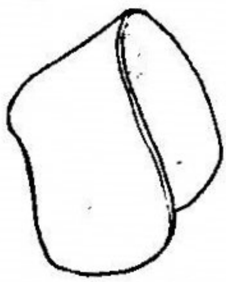
Apply parting agent to the mold and prepare plaster. Build the cast in a 1-inch thickness over the concave surface of the wrap.



Anchor a holding rod to the plaster and build a supporting bridge to stabilize the holder. Allow to harden, then strip off the wrap. Smooth and shape the model to final contour, including the indicated reliefs.

The Check Socket

Prepare 4 pieces of stockinet long enough to cover the model with generous extra length. Pull on the stockinet layer by layer, oriented in the medial-lateral direction. Ladle on the beeswax in the usual manner, harden in cool water, and seal the lateral end by pressing.

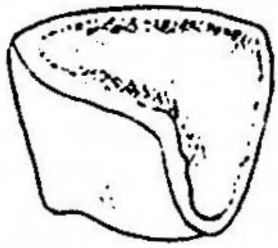


Try the check socket on the amputee's stump, working out the reliefs until a satisfactory fit is achieved. Special attention should be given to the fit around the coracoid process. Be sure to check the fit and trim while the amputee makes shoulder motions. The superior-medial socket edge should be as close as possible to the neck without impingement as the patient moves. The anterior trimline should always remain lateral to the nipple and should not restrict scapula abduction. Inferiorly, the socket margin should be low enough for socket stability, usually 3-4 inches below the axilla. Posteriorly, the socket should extend to the medial border of the scapula.

After a satisfactory fit is obtained, secure the check socket to the shoulder with elastic webbing and mark anterior and lateral plumb lines.

Lamination Model: Plaster Method

Place the check socket with the open end up, and slush in plaster to build a one-inch cast thickness. Hand forming of the skirt boundary, using nearly congealed plaster, will be necessary. Fasten in the holding rod with a mound of plaster. Fill the space with balled-up newspaper and finally cover with a thin



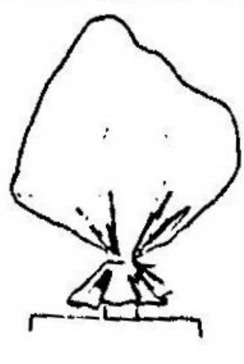
layer of plaster to complete an enclosure of the mold space.

Remove the check socket, sandpaper the lamination model smooth, and coat it with parting lacquer. It is now ready for the lamination procedure.

SHOULDER DISARTICULATION PROSTHESIS

First Layup: Shoulder Section

Fashion 3 pieces of stockinet into "socks" by cutting curved ends and sewing with a 1/8-inch seam allowance. Pull the first stockinet with



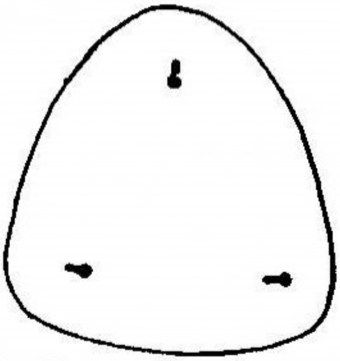
seam allowance out, then the second, and finally the third with seam allowance inward. Pull the three layers tight and gather in by tying around holding rod with string.

Lamination: Shoulder Section

The amount of resin required is 250 to 300 gm. Be sure to fill the stockinet layup with resin completely, so that when the pressure sleeve is firmly tied on, and the resin "stringed," no starved areas will result.

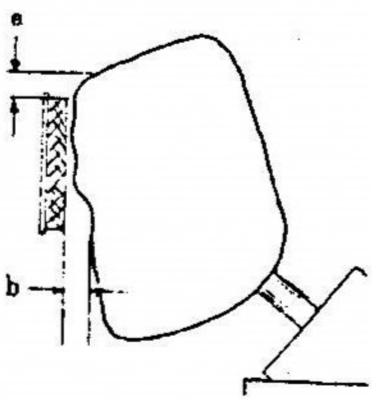
Buildup: Shoulder Section

Remove the pressure sleeve, and jig the inner wall piece for wax buildup. Note: Later assembly of the sectional plates can be facilitated by slotting and drilling the untapped holes of the inner plate to the shape of keyholes. The screws may then be pre-installed, the screwheads inserted into the holes, the plates twisted into position, and the screws tightened through the access holes in the inner socket.



Plan the alignment of the inner sectional plate (the inner plate has the untapped holes for bolting to the outer plate). Use the amputee's silhouette drawing as a guide, as follows:

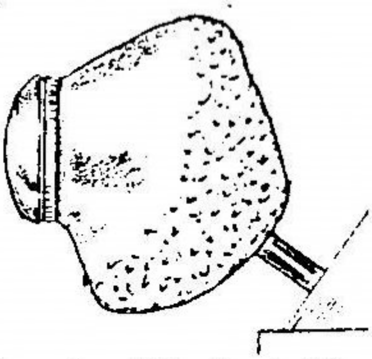
As nearly as possible, the plate should be vertical and in a sagittal plane.



The upper edge of the plate should be lower than the acromion by ¼ to ⅜ inch to give more normal shape to the shoulder. This is shown as *a* in the illustration.

The lower edge should offset from the adjacent wall by ⅝ to ¾ inch (shown as *b*).

Apply beeswax to completely fill the space between plate and laminate wall and to contour smoothly from the lamination flange of the plate to the skirt of the inner wall. The tapering off of wax should be done with due regard for appearance, but at least 1½ to 2 inches of the inner wall skirt must be left uncovered for bonding of the resin of the outer wall.

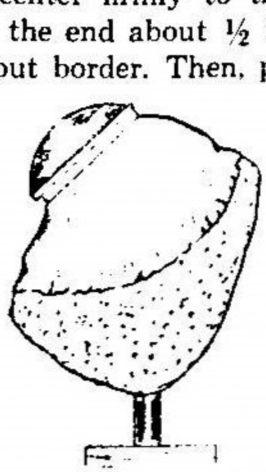


Smooth and polish the buildup surface. Rough up the exposed inner wall skirt with a rasp.

Build a dome of wax over the sectional plate in preparation for lamination procedures.

Second Layup: Shoulder Section

Clean the plate lamination flange with benzine. Prepare two pieces of 6-inch stockinet. The first is about twice the mold length; the second about a foot longer than the first. Pull half of the shorter (first) piece over the mold and tie its center firmly to the lamination flange. Trim the end about ½ inch proximal to the buildout border. Then, pull the other



end back over it and trim about ¾ inch proximal to the first. Finally, pull the long piece over the mold and tie its center firmly into the flange groove. Pull both halves strongly over the mold, gather about the holding rod and tie securely.

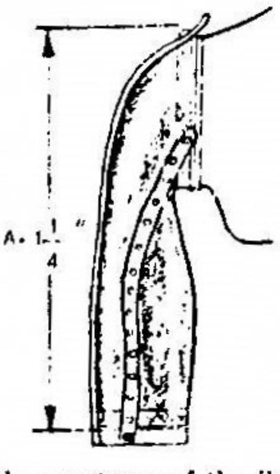
Lamination: Shoulder Section

The method of resin impregnation differs depending upon the general shape of the mold. If it is somewhat conical and elongated, the conventional pressure sleeve with pressure impregnation is employed. If it is flatter in contour, the spatula method of adding resin is used.

About 300 grams of resin is required for this lamination. When laminate has cured, make an approximate trim cut along the skirt of the socket, remove mold, strip off sleeve and clean up the socket piece. Final trim can be left until prosthesis is complete.

Alignment: Arm Section

Bolt the arm alignment jig to the outer sectional plate; take special care to make the form of the lateral strap of the jig similar to the frontal contour established in the silhouette.



The front and rear straps of the jig are bowed slightly outward to leave working room for the wax buildup of the arm section. Alignment is often made with the amputee present so that final appearance can be visualized, although if the silhouette chart is carefully made, this is not necessary. Also, bolt the elbow unit with forearm attached. Position the elbow unit in accordance with manufacturer's instructions so that 30 to 40 degrees of medial and lateral rotation is provided. Obtain types which have holes or removable plates for beeswax escape during resin curing.

The alignment principles are:

1. Acromion-to-turntable dimension must correspond to the Dimension A (acromion to epicondyles sound side), minus the turntable to elbow axis distance for the elbow unit being applied (usually 1¼ in.).

2. In side view, with amputee standing in normal posture, the elbow should hang with a slight arm flexion position.

3. In frontal view the elbow should hang free from the side the same offset distance which the normal elbow maintains. Be sure the forearm swings clear of the hip. For bilaterals this clearance should be about 1 to 2 inches.

Buildup: Arm Section

Build up the arm section by heaping and modeling the buildup wax to the desired shape. Special attention should be given to the axillary region, which must have open space for clothing. Depending upon the climate, allowance must be made according to the weight of clothing habitually worn. This clearance (*a* in the illustration) will range from 1 to 2 inches. When fully formed, remove the arm alignment jig and finish the forming and smoothing. Fashion a wax dome over the turntable and sectional plate.

Layup: Arm Section

Cut two pieces of 3-inch stockinet twice the length of the arm section. Pull the first halfway on and tie its center to the turntable flange. Stretch its inner layer over the sectional plate and tie securely to the flange. Turn the edge back and trim about ¼ inch from the flange. Repeat with the other end lapping back ½ inch. Stretching of the stockinet should insure that the axillary area is not wrinkled or bunched.

Now the second piece is treated in the same manner, with its inner end reflected and cut off ¾ inch from the plate, but the outer end is stretched tightly over the plate, gathered and tied beyond the plate.

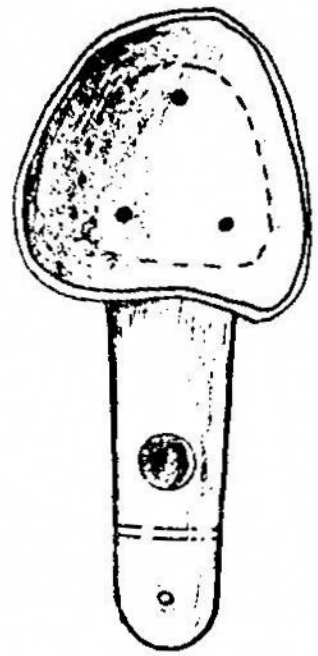
Lamination: Arm Section

Trim and Assembly

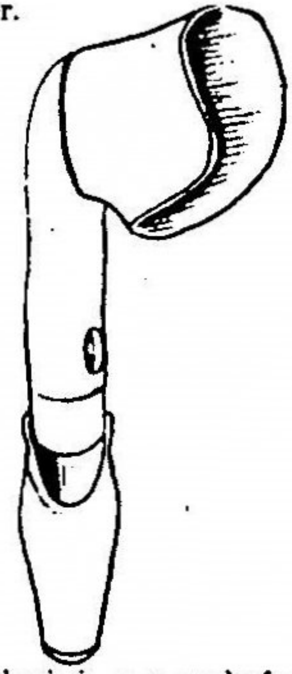
The laminate covering over the edge of the plate of the arm section is now cut off flush with the surface of the plate. This edge can be finished by light sanding.

Drill three holes about 5/16 inch diameter through the inner wall of the shoulder section in line with the plate mounting bolts. Bolt the plates, joining the arm and shoulder sections firmly.

Cut a 1¼-inch access hole through the medial surface of the arm, about 2 inches above the turntable. Bolt on the elbow and forearm unit. Adjust turntable rotation for forearm alignment, about 30° of medial arm rotation.



Trim and round the edges of the socket skirt maintaining the coverage essentially as planned for the various prostheses, but adjusting for amputee comfort and fit. Additional work on the reliefs may be required. Finally, sand smooth all edges and reliefs and finish with lacquer.



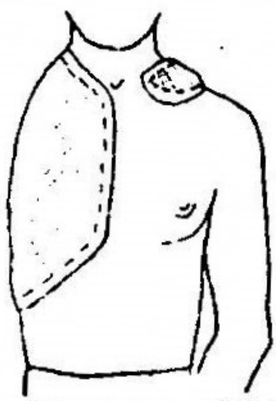
The prosthesis is now ready for harness and control installation.

FOREQUARTER PROSTHESIS

This prosthesis is characterized by a very large buildout and skirt of the shoulder section to restore the normal contour of the shoulder and give firm lodgment on the thoracic wall. Consequently, the shoulder section presents a very large job, and special comment is necessary on the casting, fitting, and fabrication detail. Otherwise, the arm and forearm sections will be identical with that for the Shoulder Disarticulation, presented in the foregoing section. As will be seen, the harness and control systems will have unique features.

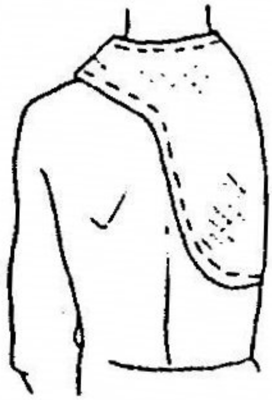
The Mold or Wrap

The illustrations show wrap area (solid lines) and final trim lines (dotted lines) for the male Forequarter amputee. In general,



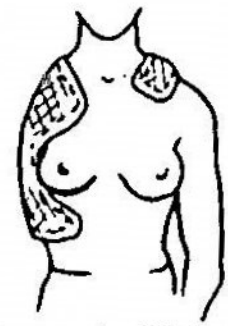
the wrap should cover an area greater than final trim by about an inch. The wrap covers the thorax area on the amputated side, from neckline to the lower margin of the ribs. To the rear the border extends diagonally upward, reaching the midline, then laps over the opposite shoulder with a hooked flap. The neck border is about at the level of the seventh cervical vertebra.

To the front the wrap is brought to within 2 or 3 inches of the midline, as shown. The



hooked opposite shoulder flap reaches over to about the clavicle level and comes within 3 or 4 inches of touching the opposite skirt.

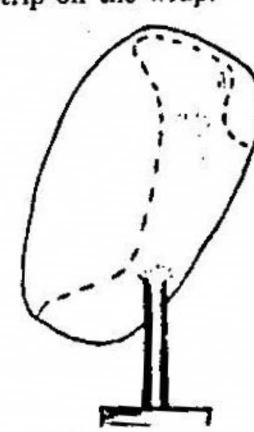
The Forequarter socket for women is similar in respect to all features except for the anterior side, where a cutout is made for the breast. A substantial lobe is provided below the breast for stabilization with a low chest strap.



Since the Forequarter fabrication procedure is long and difficult, a labor-saving deviation in procedure can be introduced by using the primary wrap as the check socket. Reliefs and revisions are made in it by cutting or building up the inner surface after trial on the amputee. The cast is prepared for the lamination mold by coating with a parting agent.

The Model: Shoulder-Thorax Section

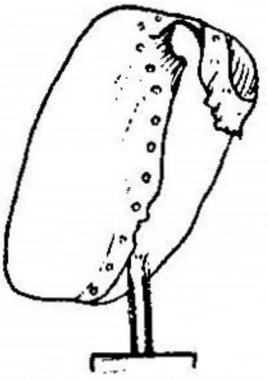
The mold is now suitably mounted with concave side up. The neck hole is dammed with a light layer of plaster bandage. Now slush plaster in and hand spread it over the concave surface to a depth of about one inch. After hardening, strip off the wrap.



Fit the mold with a holding rod and stuff its cavity with paper. Now apply plaster to round out the mold, as shown. Finish by scraping and sanding.

Layup: Shoulder-Thorax Section

Prepare four extensive pieces of stockinet by cutting open 6-inch stockinet. Draw each layer

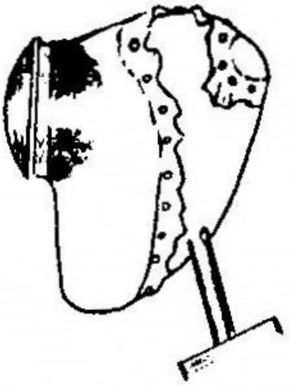


tight and tack over the edge of the mold. Be sure to remove all wrinkles and cover the entire area indicated for the wrap.

Lamination: Shoulder-Thorax Section

Buildup, Second Layup, Second Lamination: Shoulder-Thorax Section

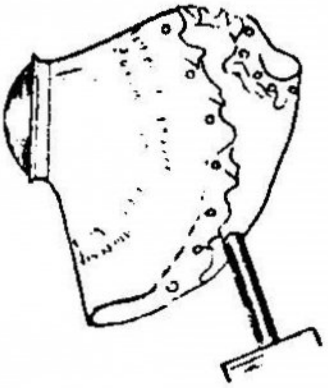
The buildup operation is similar to the Shoulder Disarticulation, including alignment, sectional plate installation, and wax buildup and dome.



Make first two layers of the layup with a piece of 6- or 8-inch stockinet, pulled on halfway and tied to the sectional plate. Stretch the lower layer proximally and trim it ½ inch beyond the margin of the wax buildup. The next layer is pulled over this and trimmed ¾ inch proximally.

Now work with two flat sheets of stockinet large enough to cover the mold area. Stretch the first one tightly over the mold, tacking it beyond the final trim edge. Tie around the plate flange, then cut a hole in the plate area, so that ¼ inch of lap can be folded back over the mold proximally.

Pull over and tack the final layer of stockinet as before. Gather and tie stockinet beyond the plate.



Fabrication of Arm Section

Follow the procedures for the Shoulder Disarticulation. Alignment, sizing, and fabrication steps are identical.

Trim and Assembly

Final trim is made along the lines shown in previous illustrations, but also as determined by final fit on the amputee. As in the case of the SD, these final checks should be performed with arm, elbow, and forearm sections assembled, so that any problems of fit, concerned with over-all weight distribution, can be corrected.

Assembly of the arm, elbow and forearm components is carried out as described for the SD case, and the prosthesis is ready for harness and control system installation.

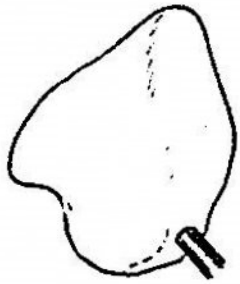
HUMERAL NECK PROSTHESIS

Of all Shoulder prostheses, the Humeral Neck type is the most difficult to fabricate, and demands the highest skill of the prosthetist. The Humeral Neck amputee has an intact shoulder girdle, and hence, the socket will be confined to the immediate shoulder area. Since the humeral head and joint capsule are present, there is no room for sectional plates, so the arm and shoulder sections are joined in a single piece.

Fabrication of the Humeral Neck socket will follow that of the Shoulder Disarticulation, except for the steps dealing with installation of shoulder plates.

First Layup

Follow the procedures for the Shoulder Disarticulation. The projecting capsule of the shoulder, will, of course, be encased in this inner socket.

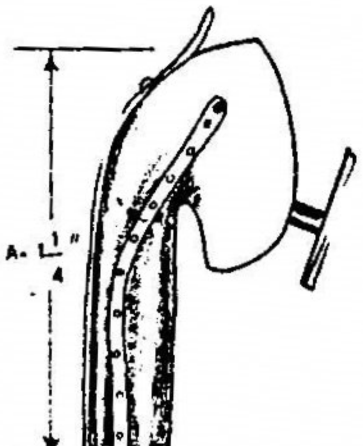


Lamination

Buildup of Arm and Shoulder

Remove the pressure sleeve from the inner wall laminate and fasten on the arm alignment jig. The silhouette chart and arm measurements are used to determine this alignment, which is just the same as for the SD buildup.

The difference is that the alignment jig straps are fastened directly to the inner wall laminate. As before, the lateral strap should be bent to form the desired arm contour. Adjust the alignment jig plate to hang to the length of acromion to epicondyle on the sound side (Dimension A) minus the distance from elbow axis to turntable, which is usually 1¼ inches.

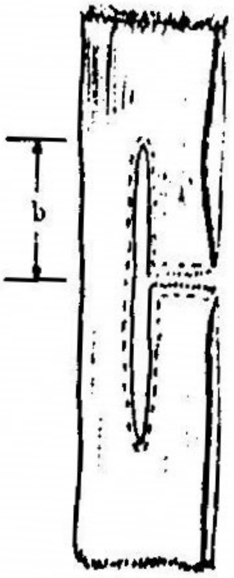


Build up soft wax inside the alignment jig and up over the distal portion of the shoulder piece. Actually, the buildup procedure here combines the shoulder section and arm section buildups described for the SD sectional socket. Remove the jig, finish, and polish. Rough up the remaining proximal skirt of the laminate piece.

Second Layup

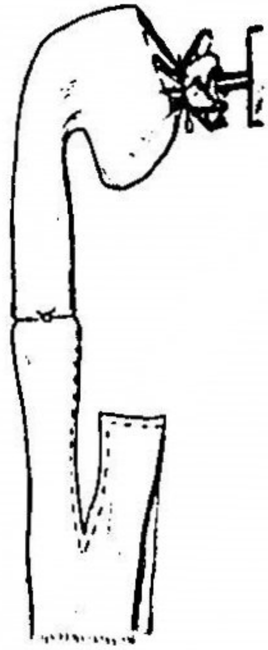
Prepare one piece of 3-inch stockinet twice the length of turntable to acromion.

Prepare another piece of 6-inch stockinet twice the length from turntable to proximal edge of laminate. Lay out pattern and cut the 6-inch stockinet as shown. Dimension *b* is the length from turntable to axilla. Stitch seams as shown by dotted lines, and cut the tube open along the borders. Pull on the 3-inch stockinet and tie the center at the turntable. Trim it so the edge is about ½ inch proximal to the bees wax border. Pull over the other half and trim about ¾ inch proximal to the first.



The patterned stockinet will now be suitable for the outer two layers when pulled on and tied at the center. Pull on the first layer, working the bend into the axilla. Tie at the turntable and fold the second layer over the layup. Stretch tightly back over arm and shoulder sections.

Pull the proximal ends over the socket, gather and tie in one or two ties, whichever is necessary to remove wrinkles from the layup.



Lamination

Warning should be given that this step in the Humeral Neck prosthesis fabrication is very difficult, and should be thoroughly studied before attempting. The pressure sleeve must be prepared in a complicated pattern for close fit with no leaks. Resin impregnation must be carried out swiftly and skillfully because of the large area to be filled and "strung" out within the curing time allotted.

Trim and Finish

As in the SD, the socket, elbow, and forearm should be assembled for final fitting. This requires that the access hole be cut on the medial surface of the arm (see SD procedure). A properly fitted Humeral Neck socket should give some mobility to arm and elbow. This is achieved by confining the posterior skirt to the scapular area, minimizing the side wall and chest bearing areas. Considerable judgment must be used to preserve a compromise with stability while achieving this mobility.

Harness and Control Systems

One of the most important factors in the proper functioning of a prosthesis is the correct application and adjustment of the harness and control system. This is because each harness, although patterned after one of several basic designs, must be adapted to the amputee's physical characteristics. No two amputees are exactly alike, so it is necessary to custom fit the harness for each individual.

The successful use of the prosthesis by the amputee is governed by the effectiveness of the harness in capturing substitute motions, and by the skill and judgment of the prosthetist in fitting the harness.

In this chapter the basic principles of harness application and judgment are presented, with suggestions for materials and patterns that have been found useful, and detailed fabrication procedures for several of the more commonly used harness designs.

GENERAL PRINCIPLES

Basic Functions of Harness and Control Systems

1. The harness must suspend the prosthesis securely from the shoulders so the socket is held firmly on the stump. In fulfilling this function it should:

a. Distribute the load as much as possible.

b. Be well suited to the body build of the amputee.

c. Be stable in all normal positions of use.

2. The harness must utilize body motions as sources of power, and then transmit this power to the prosthesis. In fulfilling this function it should:

a. Transmit power with minimum interference caused by movements of parts of the prosthesis.

b. Harness power sources capable of independent voluntary movement.

c. Be operable by relatively inconspicuous body motions.

3. The harness must be easy for the amputee to put on and take off, must be comfortable to wear, and must be strong and durable. Because it must be easy to launder, leather parts should be reduced to a minimum. Two harnesses for each prosthesis are desirable.

Effect of Amputee Build

Amputees vary in physique in the same way as does the population in general. The same is true of weight, strength, and other physical characteristics. Because of these variations, it has been found impractical to attempt to make prosthetic harnesses by any other than custom-fitting methods. If millions of harnesses were needed by that many amputees, they could be mass produced and sized in the same way as suits, dresses, and shoes. Since the amputee population is so small, such an approach is not economically sound; therefore, the prosthetist must adapt the basic harness patterns to the physique of each individual amputee. The variation that most affects harness fitting is the *width-depth ratio in the shoulders and chest* of the subject. The variations in this factor may best be illustrated by the description of the two extremes in Figure IX-1.

Most amputee builds will fall between the two extremes illustrated, and the skill and judgment of the prosthetist must be exercised to modify basic harness patterns to achieve maximum function.

Type. Shoulders broad and well muscled, deep chest. *Harnessing indications:* All types of harness easy to fit. AE triple control feasible. Basic Shoulder harness satisfactory.

Type: Narrow shoulders, poor musculature, rounded chest, fat.
Harnessing indications: Only the basic harness pattern will usually work. Special modifications often necessary in Shoulder cases.

FIGURE IX-1. Effect of Amputee Build on Harnessing

CONTROL SYSTEM PRINCIPLES

Elements of Typical Control System

The basic sources of power for prosthesis operation are located away from the prosthesis and at various points on the amputee's body, thus making it necessary to provide some means for transmitting this power from source to point of use. The control system provides this means.

The typical control system consists of a cable with appropriate terminal fittings and a flexible tube, or housing, inside which the cable slides. The terminal fittings are used to attach one end of the cable to a harnessed body control point, and the other end to the point of operation or control of the prosthesis. The housing through which the cable slides acts as a guide or channel for the transmission of force by the cable. The housing is provided with retainers that fasten it to the prosthesis, and which serve as reaction points in the transmission of force by the cable.

Magnitude of Forces Transmitted

The average amputee has sources of force and excursion of fairly high magnitude.

The forces and displacements required to operate a typical prosthesis are approximately as stated in this table:

Operation	Force	Displacement
Forearm flexion (no load on hook)	9 lbs.	2 inches
Prehension, voluntary-closing hook	9 to 35 lbs.	1.5 inches
Prehension, voluntary-opening hook	10 to 20 lbs.	1.5 inches
Elbow lock	2 to 4 lbs.	0.6 inches

From the data it may seem the amputee has ample force and excursion to handle any prosthetic operation, and that the efficiency of the control system is not a critical factor. This is not the case, as fatigue is greatly increased when the amputee has to exert his maximum effort to operate the prosthesis. The control system must transmit power as efficiently as possible to enable the amputee to obtain a maximum of prosthetic function with a minimum expenditure of energy.

CONTROL CABLE SYSTEMS

Older Types of Control Systems

In past years, control systems were devised using catgut, thongs, and various kinds of cord as a means of transmitting force to operate the prosthesis. The usual method was to thread the cord through guide loops of leather or metal. Frictional losses were very great, requiring the amputee to expend an excessive amount of energy to operate his prosthesis. This was found to be an important factor in amputees' refusal to wear a prosthesis. Older type control systems transmitted force with an efficiency as low as 10 or 15 percent; the average was about 25 percent. The control systems described in the following section are required to operate with 70 percent or greater efficiency.

Housing Fair-Lead

The housing fair-lead control cable system consists of a cable held in place and guided by separate lengths of housing. The pieces of housing are fastened with retainers at points where the cable must be supported or operated through an angle.

This control cable set-up is used in the AE dual control system, a typical example of which is illustrated in Figure IX-2.

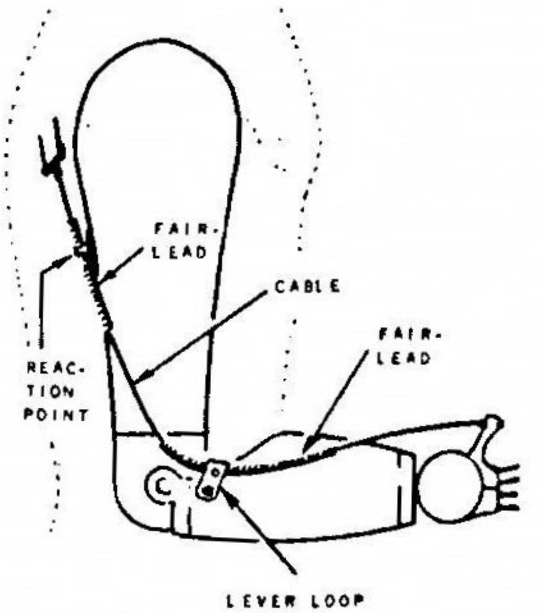


FIGURE IX-2. Fair-Lead Control System

When force is transmitted through the housing fair-lead type control cable, side forces are exerted on the fair-leads where the cable bends through an angle.

The fact that these forces are exerted where the cable operates through an angle is used to advantage in the AE dual control system. The forearm is adjusted in 10 degrees of initial flexion (so that its maximum extension is 10 degrees short of full extension). With the elbow unlocked, this slight angle through which the control cable operates causes a force to be exerted on the lever loop when the arm is flexed, which in turn flexes the forearm. The maximum force obtained would not be enough to enable the amputee to handle many objects on the basis of "live-lift." In most cases the amputee flexes the forearm to the position desired, locks the elbow, then grasps the object to be lifted.

In addition to the AE dual control system, the housing fair-lead control cable may be used for elbow lock controls on AE and shoulder prostheses.

The Bowden Control

The Bowden control consists of a continuous length of stainless steel flexible housing, with a retainer at each end, through which the control cable slides. The retainers on the housing fasten it to the prosthesis and serve as reaction points when force is applied to the cable. The Bowden cable control can be shaped to follow a straight or curved path without intermediate retainers, and can be moved through various angles and curves while being operated, without these movements affecting the over-all length relationship between the operating ends of the cable. A typical Bowden cable control is shown in Figure IX-3 with a BE single control system.

The Bowden cable is also used on the AE Triple Control.

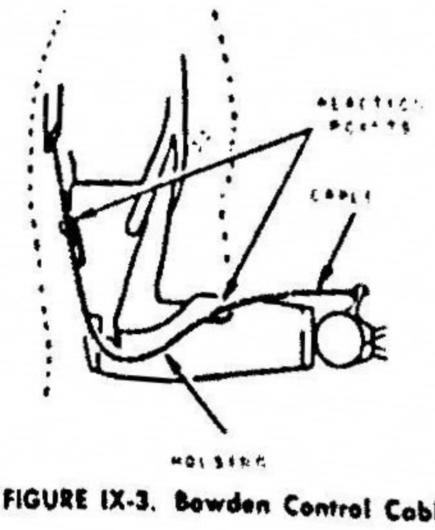
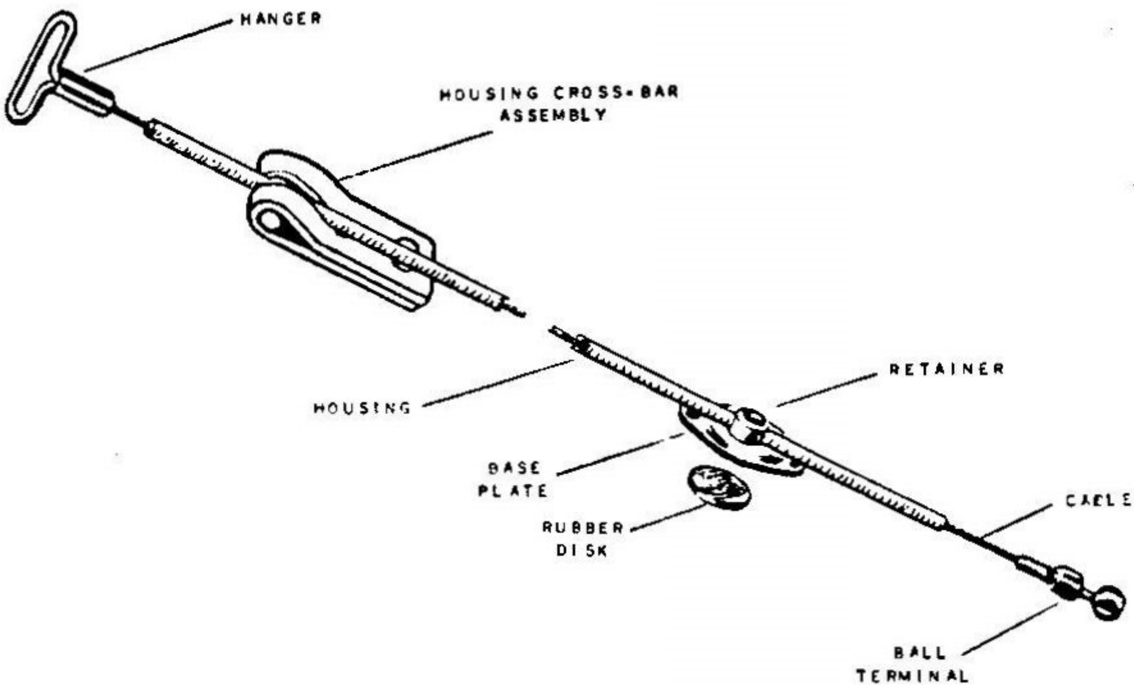
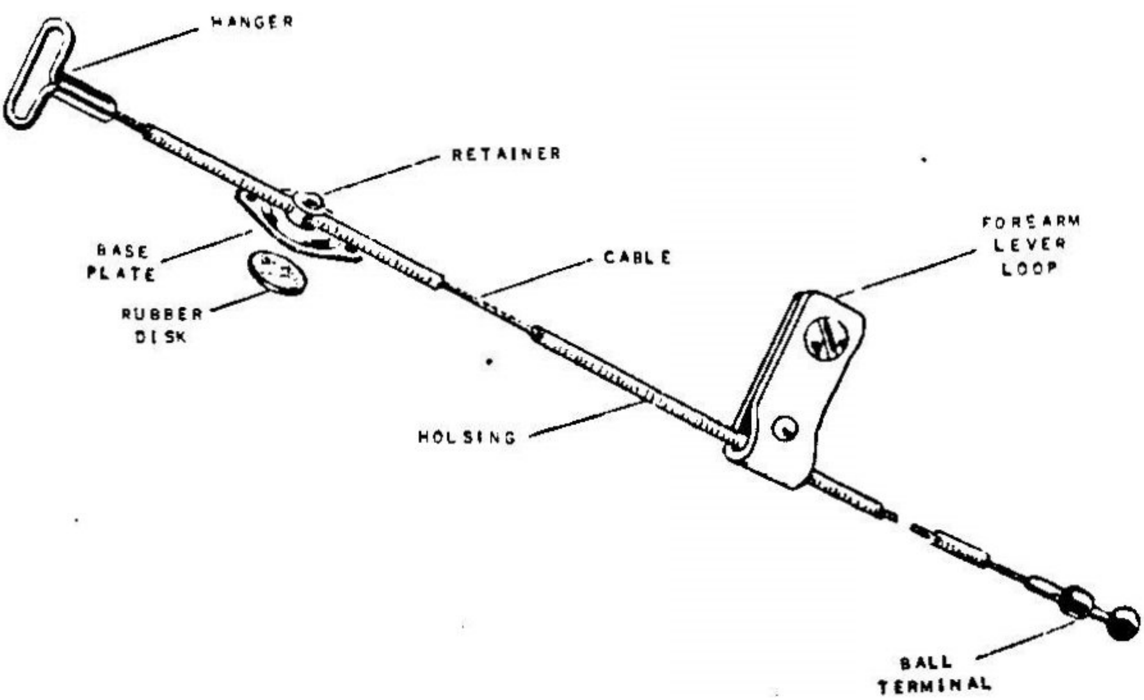


FIGURE IX-3. Bowden Control Cable



BOWDEN ASSEMBLY USED ON BELOW-ELBOW PROSTHESES



HOUSING FAIR-LEAD ASSEMBLY USED ON ABOVE-ELBOW PROSTHESES

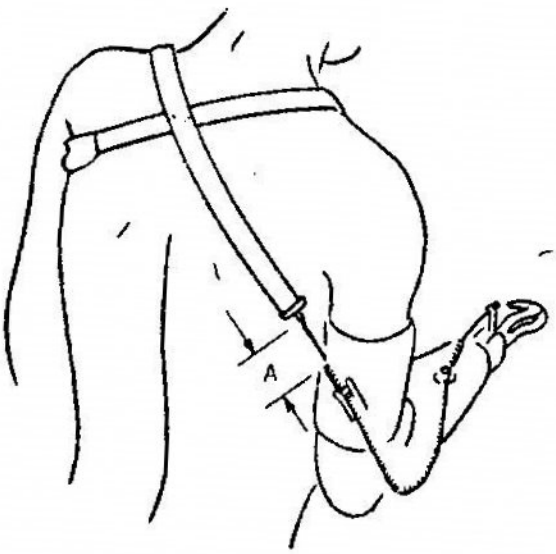
FIGURE IX-4. Typical Control Cable Assemblies

Figure IX-4 illustrates the most commonly used assemblies employing the housing fair-lead and Bowden cable principles.

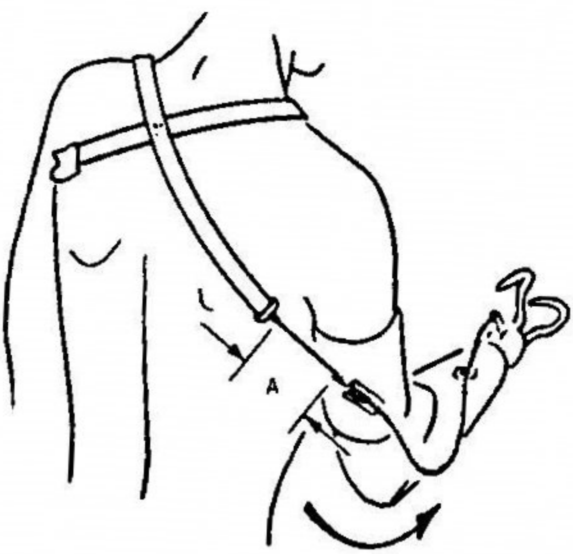
BELOW-ELBOW HARNESSING

Control Motions

In a Below-Elbow amputation the functions of the hand and wrist are absent, but those of the elbow, arm and shoulder remain. The Below-Elbow prosthesis provides substitutes for the functions of hand prehension, wrist rotation, and flexion. The harness for the prosthesis, however, is required to transmit power for one purpose only: to operate the terminal device which serves as a substitute for normal hand prehension.



Arm flexion is the major source of power used by the Below-Elbow amputee to operate the terminal device. The flexion of the arm gives relative displacement between the proximal retainer on the cuff and the attachment strap of the harness. Depression of the shoulder on the amputated side is often added to humeral flexion, either to refine control of the terminal device, or to increase cable excursion without moving the terminal device from the selected sphere of activity. Scapular abduction on the *amputation side* may occasionally be used for the same purpose. Occasionally an amputee will be seen who uses scapular abduction on the sound side to add a small but perhaps important increment to the sum of the other control motions.



INSTALLATION OF BE SINGLE CONTROL SYSTEM

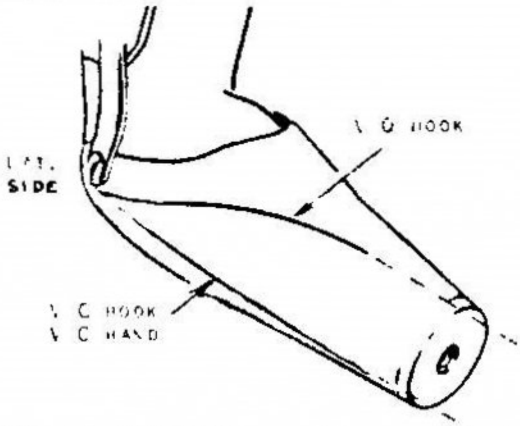
The BE single control system consists of a Bowden cable control attached by a base plate and retainer to the distal end of the socket and by a housing crossbar assembly to the triceps pad or cuff, whichever is used.

The control system is attached to and is a part of the prosthesis, but it is fitted while the prosthesis is on the amputee, and its installation is usually followed immediately by fitting of the harness; therefore installing it will be considered as part of the work of harnessing.

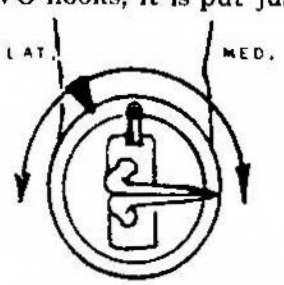
The procedure involves retainer placement, housing installation, and cable assembly, as follows:

Retainer Placement

1. Mount the distal retainer base plate on the forearm with sheet metal screws. The plate may be placed as far as the proximal third of the forearm, to minimize angulation between retainer and hook or hand mounting. This will also give adequate clearance for hand or hook connections.

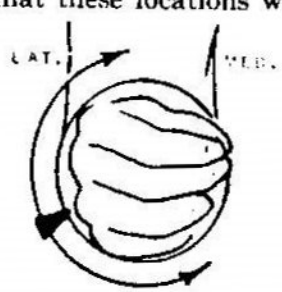


Because of the oblique path across the forearm, placement must take account of the terminal device, thickness of forearm, etc. Placement with respect to the aspect of the forearm depends upon the type of terminal device: For VO hooks, it is put just lateral to

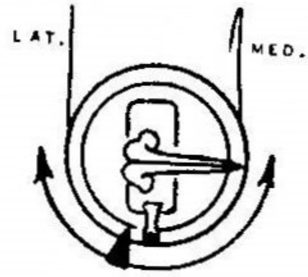


V O HOOKS

the top. For the VC hook it is located just lateral to the bottom. For the APRL hand it is put on the lateral-ulnar aspect. The illustrations show that these locations will place the



V C HAND

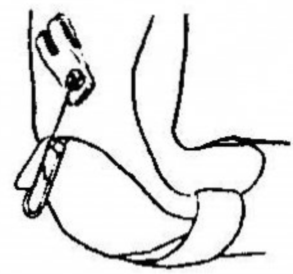


V C HOOK

retainer relative to the midpoint of 180° of rotation adjustment of the wrist unit.

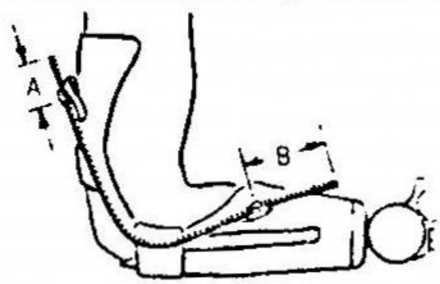
Note that two retainer plates should be provided when a VC hand is to be used interchangeably with a VO hook.

2. Temporarily mount the crossbar assembly by clamping it in the center of the cuff or triceps pad.



Housing Installation

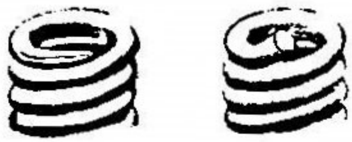
1. With the prosthesis on the stump, forearm flexed to 90°, measure the housing length between retainers and make allowances for the ends as follows: proximal end (A), about ½ inch; distal end (B), long enough to prevent the cable from rubbing on the socket in



any position of the terminal device, but not to interfere with the operating stroke of the device.

2. Screw on retainers and mount in the base plates. Adjust length so that the housing will be neither stretched nor unduly slack at any forearm position.

3. File or grind the housing ends to remove projecting end of cut wire.



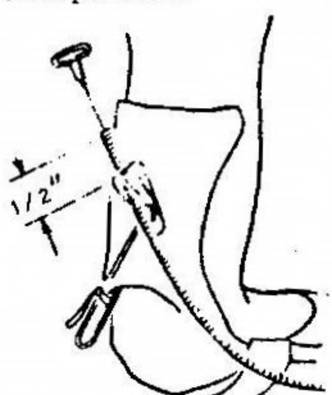
WRONG

RIGHT

Cable Assembly

1. With the prosthesis on the stump, and housing affixed, snap the ball terminal of the cable in the terminal device slot, and thread the cable through the housing.

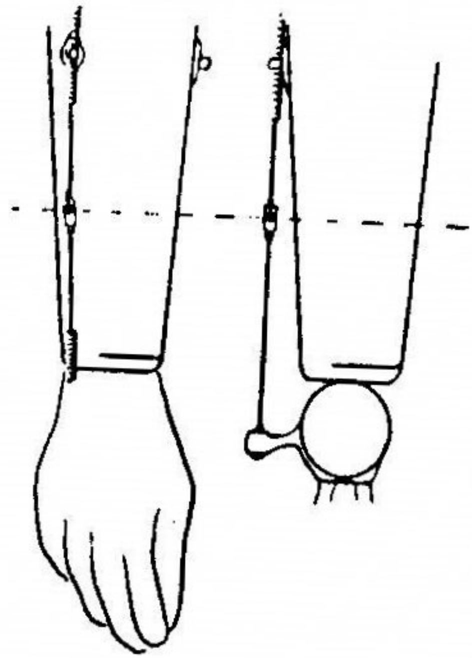
2. Take up slack in the cable through the housing and mark it for hanger installation about 1¼ inch proximal to end of the housing.



Note that this measurement is taken with terminal device in place, and closed if VO; open if VC. Also, the terminal device should be at the midpoint of its wrist rotation range. Check to make sure the mark allows enough clearance between the housing and the hanger during operation and rotation of the terminal device. Slip the adjustable hanger onto the cable and lock it in place at the marked location.

Hook-to-Cable Adapter

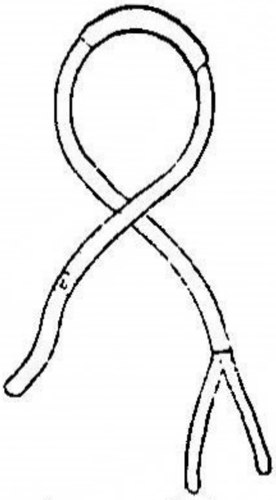
For interchangeability between the APRL hand and various hooks, a cable length adapter must be used. The hand is provided with a 5-inch cable and a small female coupling. A control cable, sized for hand coupling,



will therefore need the hook-to-cable adapter to reach the hook. The distal fitting is a large terminal ball suitable for hook connection. The adapter may either be fabricated or purchased as a unit.

UNILATERAL BELOW-ELBOW FIGURE 8 HARNESS

This harness consists of a webbing strap which has a Figure 8 pattern with an open end. It begins with an inverted Y suspensor and ends in the control attachment point.



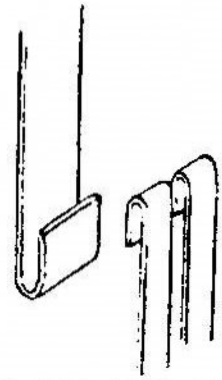
Thus, it serves to suspend the prosthesis and to provide the reaction point for control operation of the prosthesis.

Fabrication Procedure

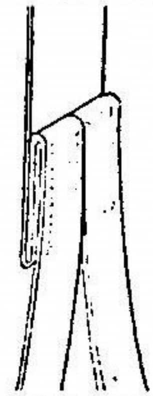
Inverted Y Suspensor

1. Place the socket and cuff (or triceps pad) assembly on the amputee's stump, and direct him to stand with his stump and prosthesis hanging in a relaxed position. A well-fitted socket will stay on the stump without support, but it may be necessary to tape or tie the triceps pad to the arm to keep it from falling out of position.

2. Prepare two 8-inch pieces of ½-inch webbing with ends lapped back one inch. Similarly lap back the end of the one-inch webbing.



3. Lay the lapped back ends together to join the 3 pieces, and sew a box and cross pattern of stitches through each ½-inch webbing joint.



4. Spread the webbing suspensors into a Y pattern.

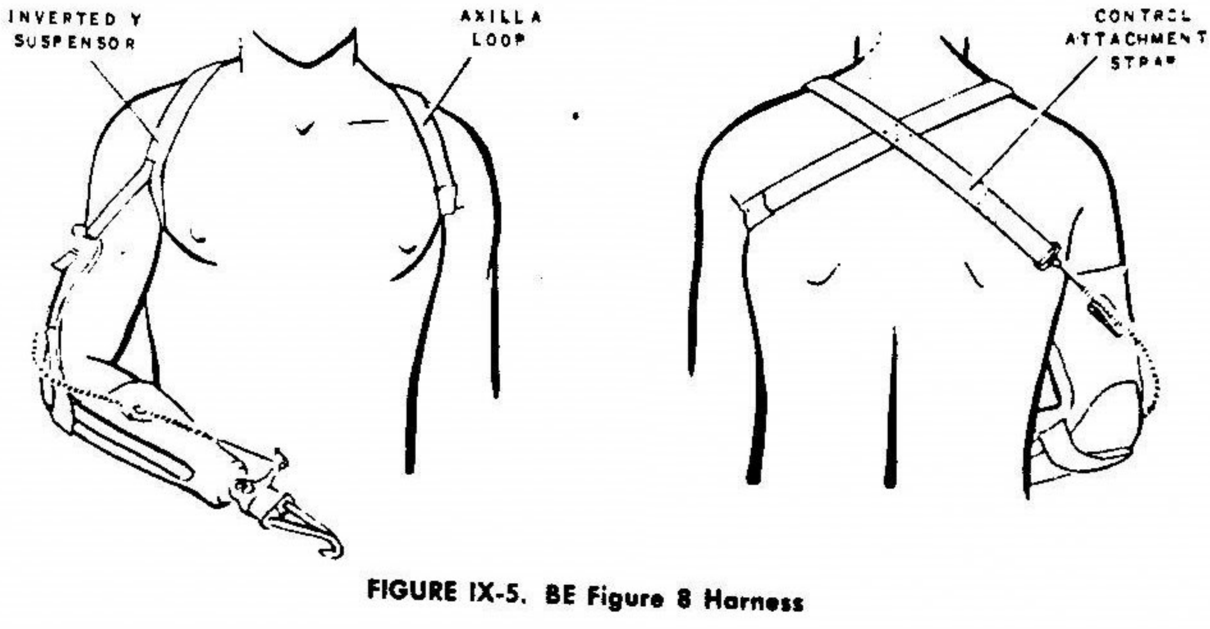
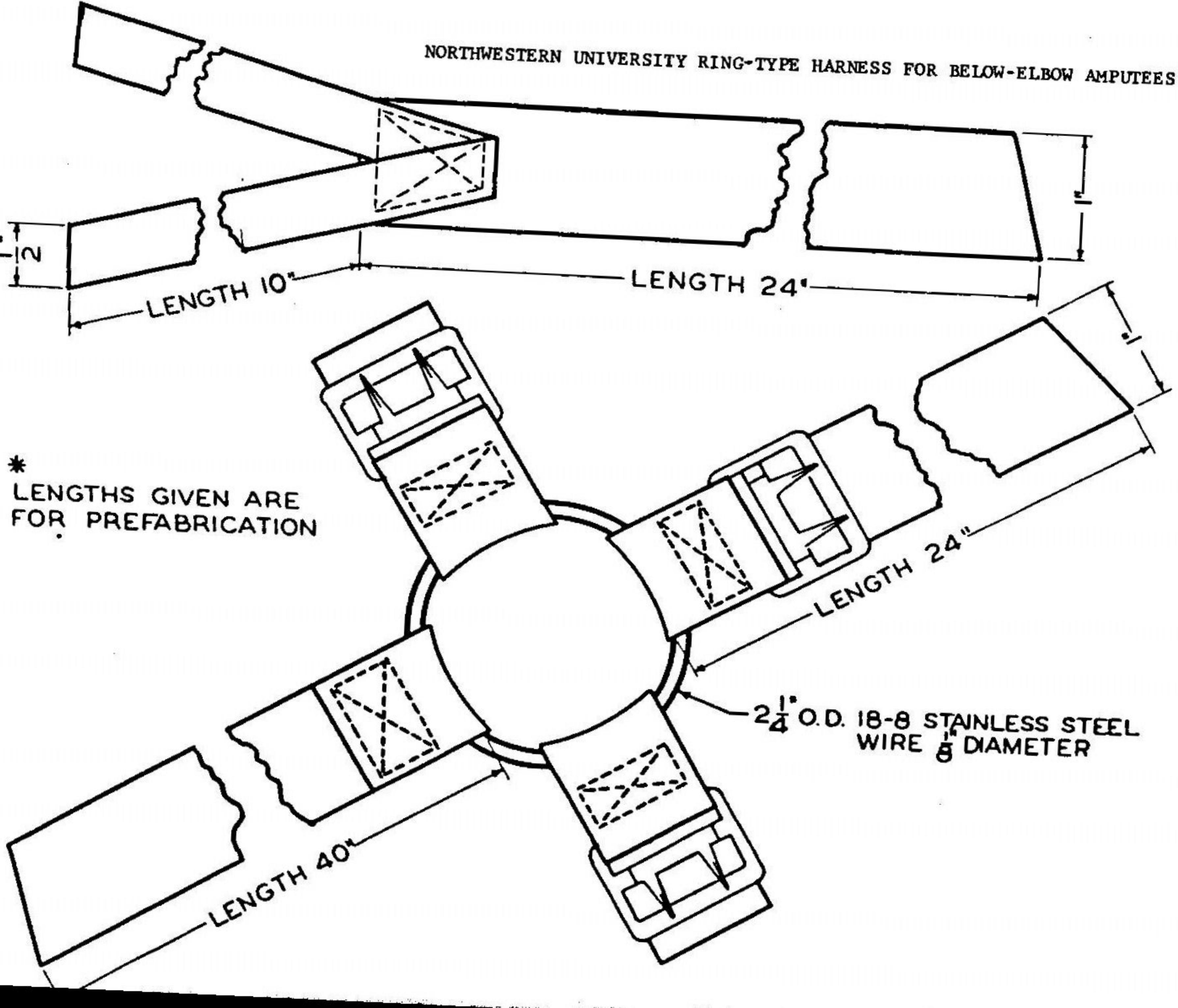
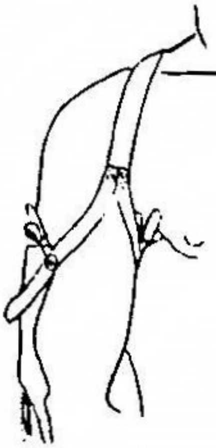


FIGURE IX-5. BE Figure 8 Harness

NORTHWESTERN UNIVERSITY RING-TYPE HARNESS FOR BELOW-ELBOW AMPUTEES



5. With Yates clamps attach the ends of the suspensors to the upper corners of arm cuff or triceps pad. Adjust so that tension on cuff

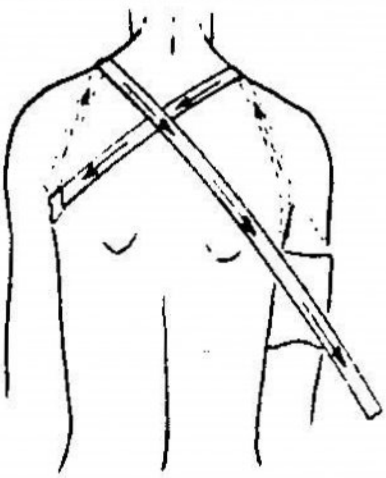


maintains alignment when the main webbing is aligned through the deltopectoral interval.

Webbing Layup

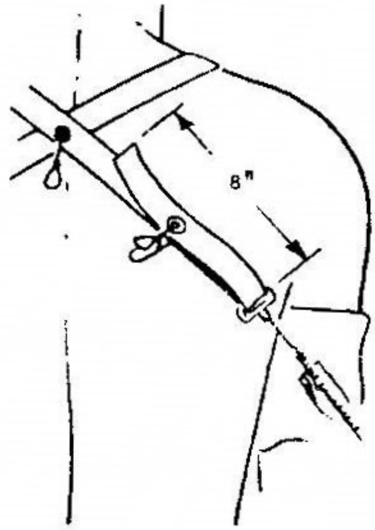
1. Cut a piece of vinyl plastic tubing so it will extend under the axilla from front to back, plus four inches, and thread it onto the 1-inch webbing to serve as a pad under the axilla.

2. Lay the 1-inch webbing along the deltopectoral line, up over the shoulder, and diagonally down across the back to the axilla on the sound side.



3. Position the vinyl plastic tubing on the webbing so it will protrude about two inches front and back, then bring the webbing up along the deltopectoral interval on the sound side and up over the shoulder.

4. Bring the webbing diagonally down across the amputee's back and thread it into the hanger so the loose end is away from the amputee's body, and fasten it with a clamp. Cut off the webbing with an 8-inch excess for



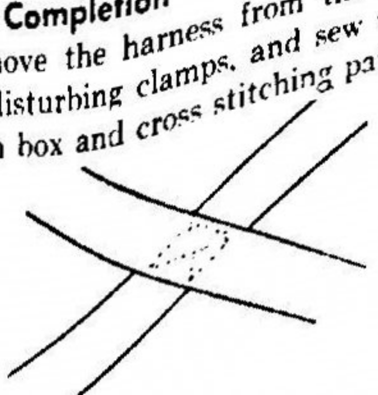
adjustment. This end becomes the control attachment strap. Be sure neither cable nor webbing is twisted or kinked. Check to make sure all straps lie snugly and are comfortably taut.

5. Check to see that the point where the harness straps cross on the amputee's back is 2 to 3 inches below the seventh cervical vertebra. The cross should be slightly to the sound side of the spinal column, so that after the harness has "set" to the wearer and stretched under load, the cross will not move to the amputation side of the spine. The control attachment strap, which runs from the crossing point to the control cable hanger, should pass over the scapula at approximately midscapular level. Clamp the crossing point securely.

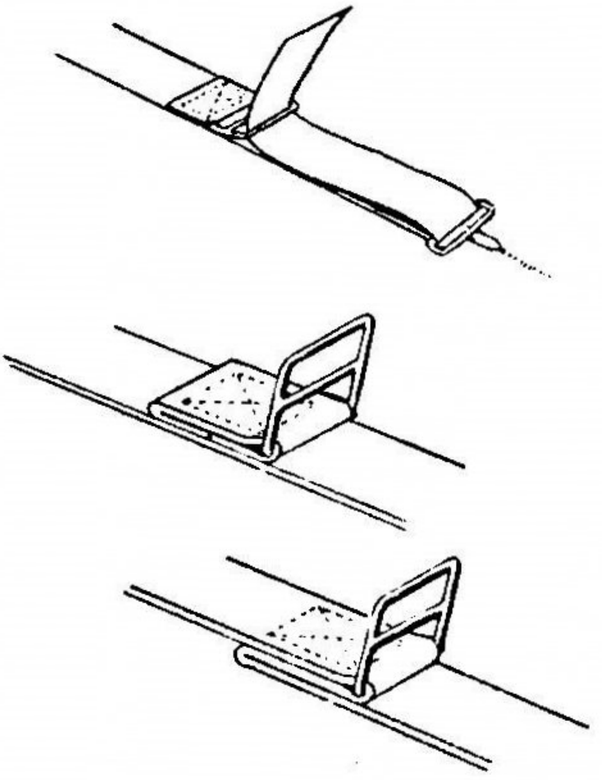
6. Check the harness for comfort and function. Have the amputee perform various control motions in many positions. If he complains of tightness or restriction of movement, readjust the straps as necessary to correct the trouble. Point out that in most cases a new harness feels tight until it is "broken in" from use.

Harness Completion

1. Remove the harness from the amputee without disturbing clamps, and sew the back cross with box and cross stitching pattern.



2. Fashion a buckle mount on the control attachment strap.



3. Sew or rivet buckle mounts to the arm cuff or triceps pad at positions which maintain the alignment established in the layup.

4. Rivet the metal mounting plate and the housing crossbar assembly to the cuff in the proper position.

5. Heat seal the cut webbing ends with a hot iron or flame; avoid charring.

6. Put the harness back on the amputee and adjust buckle fastenings at the cuff and control hanger so that harness fits snugly and with comfort.

Go through the complete checkout procedure to evaluate the prosthesis; correct any deficiencies revealed by the checkout.

UNILATERAL BE CHEST STRAP HARNESS

The unilateral Below-Elbow chest strap harness differs from the BE Figure 8 in two respects: its use of a shoulder saddle instead of a front support strap to bear the bulk of axial load; and its use of a strap across the chest, under the axilla, and across the back, instead of an axilla loop, as a means of providing some measure of stability.

It may be misleading to refer to this harness as a "heavy duty" type, as it is doubtful that its parts are any stronger than those used in the Figure 8 harness. The real difference lies in the fact that the wearer can probably carry heavier loads without suffering discomfort caused by excessive concentrations of pressure. The shoulder saddle distributes pressures over a wider area of the body than does the front support strap; the chest strap distributes pressures over a wider area than does the axilla loop.

COMMON FAULTS IN HARNESSING AND THEIR CAUSES

Fault	Cause
Harness pinches sound axilla.	Crossing point of the Fig. 8 too far to sound side.
Harness comfortable but does not give sufficient force or excursion.	Crossing point of the Fig. 8 too far to the amputation side.
Inverted Y suspensor cuts into the shoulder.	Either the two straps of the inverted Y are too tight, or the crossing point of the Fig. 8 is too high on the back.
Inverted Y suspensor tends to slip backward off the shoulder.	Attachments to the cuff are located slightly too laterally.

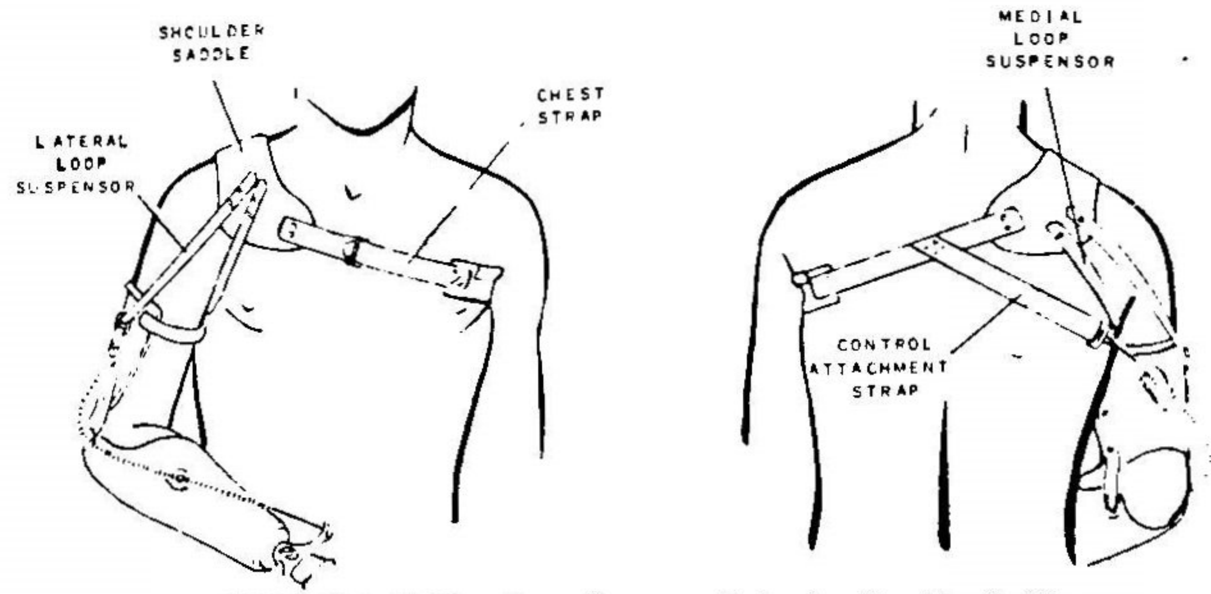


FIGURE IX-6. BE Chest Strap Harness with Leather Shoulder Saddle

However, many women dislike the chest strap harness, although in shoulder cases it often cannot be avoided.

Fabrication Procedure

1. Fabricate the shoulder saddle of 6 or 8 ounce strap leather, lined with horsehide. The one-fourth scale pattern is illustrated below. As an alternative, a webbing shoulder saddle may be fabricated according to the design in Figure IX-12 for the AE chest strap harness.

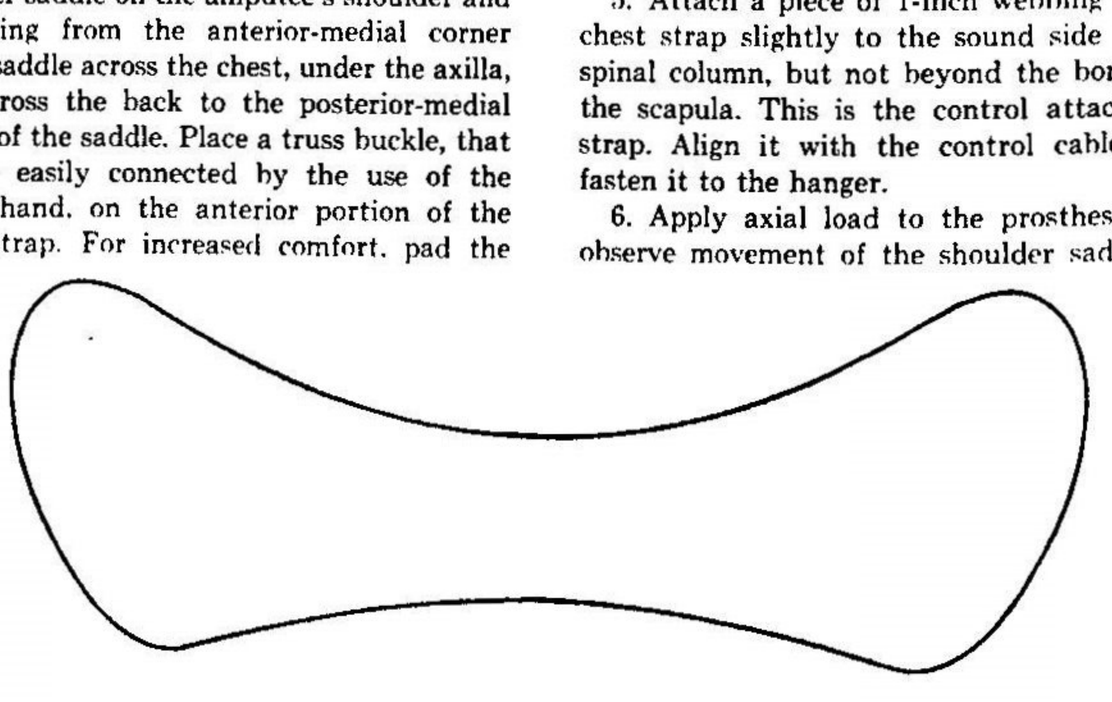
2. Cut the chest strap from 1½ inch webbing. Determine the length by placing the shoulder saddle on the amputee's shoulder and measuring from the anterior-medial corner or the saddle across the chest, under the axilla, and across the back to the posterior-medial corner of the saddle. Place a truss buckle, that can be easily connected by the use of the sound hand, on the anterior portion of the chest strap. For increased comfort, pad the strap where it passes under the axilla, using a piece of 1-inch webbing folded over the proximal edge and stitched.

3. Place the shoulder saddle on the amputee, clamp the chest strap to it, and adjust it for comfort and stability. Attach D-rings to the lateral and medial aspects of the upper portion of the cuff, at mid-humerus level.

4. Attach the medial suspensors to buckles placed on the anterior portion of the saddle and sew or rivet them to the posterior portion. Use ½-inch webbing or leather for the suspensors.

5. Attach a piece of 1-inch webbing to the chest strap slightly to the sound side of the spinal column, but not beyond the border of the scapula. This is the control attachment strap. Align it with the control cable, and fasten it to the hanger.

6. Apply axial load to the prosthesis and observe movement of the shoulder saddle. If



it buckles above the acromion, the lateral suspensor attachment points should be moved higher on the saddle. If it buckles medially, the attachment points of the medial suspensor should be moved down on the saddle. As the amputee goes through a variety of motions with his prosthesis, observe the saddle, and continue adjusting until it is stable.

7. When all adjustments for function and comfort have been completed, remove the harness and assemble all parts with permanent attachments. Have the amputee don the finished prosthesis; evaluate it by applying the checkout procedures. Correct any deficiencies revealed by the checkout.

BILATERAL BELOW-ELBOW HARNESS

The bilateral Below-Elbow harness is sometimes described as two Below-Elbow Figure 8 harnesses combined, but with the modification that the axilla loops are replaced by attachments to the opposite prosthesis. The single control systems used on each arm are each identical with that used on the unilateral prosthesis.

The bilateral Below-Elbow harness provides reaction points by bringing the strap from the inverted Y suspensor of one prosthesis over the amputee's shoulder, across and down the back to the control cable of the other prosthesis. The two straps cross slightly below the seventh cervical vertebra. In some cases it may be necessary to insert a cross-back strap between the two control attachment straps. This strap helps prevent the harness from riding up on the amputee's back, a difficulty that may occur, particularly when the amputee raises one or both of his prostheses to the level of his head.

The inverted Y suspensor used with the Below-Elbow Figure 8 harness was described in an earlier section as being made with webbing, although leather may be used with equal effectiveness, and is so used by many prosthetists. The advantage of the webbing is the ease with which it can be laundered. When used with a bilateral Below-Elbow harness, the webbing suspensors have the disadvantage of not holding their shape, thus making it difficult for the amputee to don the harness and prostheses. The use of leather for the inverted Y suspensors is recommended where this difficulty is encountered.

The procedure for making and fitting the straps and suspensors and assembling the harness can readily be conceived by any prosthetist who has successfully made the unilateral BE Figure 8 harness.

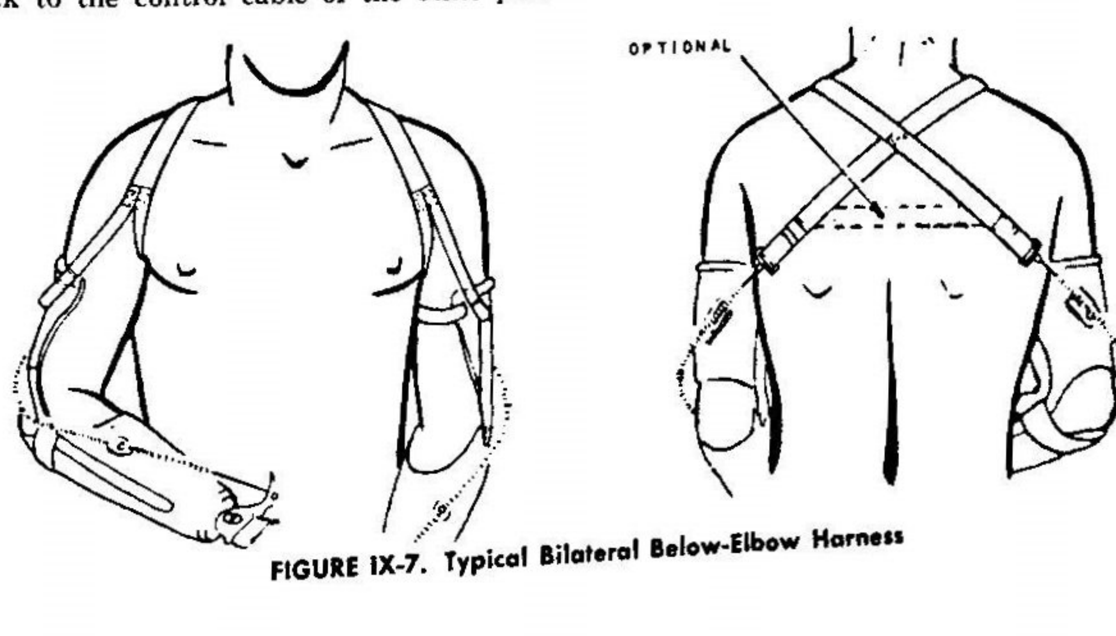


FIGURE IX-7. Typical Bilateral Below-Elbow Harness

ABOVE-ELBOW HARNESSING

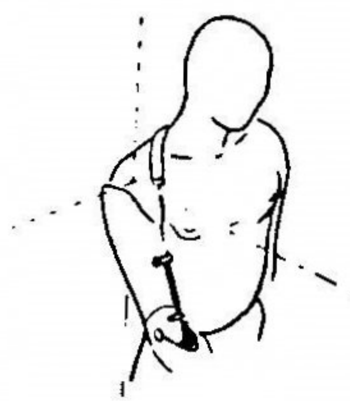
Control Motions

In an Above-Elbow amputation the functions of the hand, wrist, and elbow are absent, but those of the shoulder and arm stump remain. The Above-Elbow prosthesis must provide substitutes for these missing functions, and to accomplish this, the Above-Elbow harness must transmit power to flex the prosthetic forearm, to lock and unlock the elbow unit, and to operate the terminal device.

The Above-Elbow amputee uses the following sources of power to control his prosthesis: arm flexion, arm extension, scapular abduction, and to some extent, shoulder depression and arm abduction.

When the AE dual control system is used, the control cable is of the fair-lead type, and is so arranged that arm flexion can be used to control two functions: forearm flexion and terminal device operation. When the forearm is extended and the elbow unlocked, flexing the arm transmits force to the lever loop, flexing the forearm. The force is also transmitted to the terminal device operating lever, but the latter does not function, since the amount of force required to operate the terminal device is greater than that needed to flex the forearm.

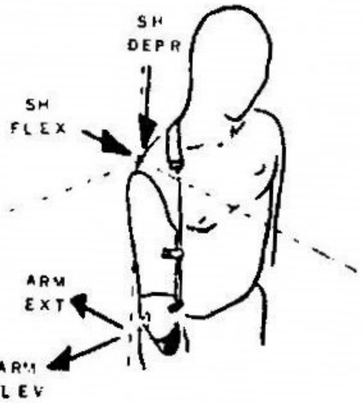
When the amputee flexes the forearm to the level at which he wants to use the terminal device, he locks the elbow by simultaneously extending and elevating the arm so that it moves obliquely to the side. The point of the shoulder must be stabilized or perhaps moved forward slightly, and the trapezius muscle is bulged by downward rotation of the scapula.



This small but complex movement increases the distance between the elbow locking lever and the point at which its cable is anchored at the superior end of the deltopectoral interval. The relative motion thus produced between the locking lever and its control cable anchor point trips the lock. This elbow lock control movement is scarcely perceptible when performed by a well-trained amputee. However, it is probably the most difficult control for most AE amputees to master.

Full scapular abduction is used by the amputee equipped with the dual control system to obtain the additional excursion required when operating the terminal device in the vicinity of the mouth.

Scapular abduction is used by the AE amputee, equipped with triple control system, to operate the terminal device through a Bowden cable control. Arm flexion is used only to flex the forearm. Each function is separately harnessed, and considerable skill is required to manage the operations independently. The separation is accomplished by splitting the harness in back, attaching the cable to one side of it, and the cable housing to the other. When the amputee abducts his scapulae, the two halves of the harness are pulled apart at the break, thus pulling on the cable and operating the terminal device.

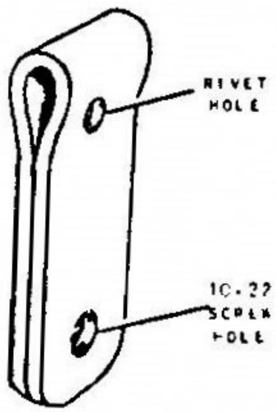


INSTALLATION OF AE DUAL CONTROL SYSTEM

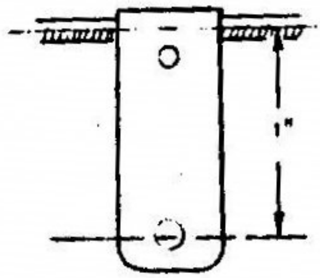
The dual control system cannot employ the Bowden control principle of transmitting force to operate the terminal device. Since the system must also provide force for forearm flexion, two fair-leads are necessary: the proximal with its retainer, through which the cable slides when the forearm is flexed, and the distal with its lever loop, through which the cable slides when the terminal device is operated. Figure IX-9 shows the components of the control system.

Lever Loop and Fair-Lead

1. Cut the distal fair-lead housing so it is about two-thirds the length of the forearm shell or short enough to permit proper terminal device operation if a hook-to-cable adapter (see BE Cable Assembly) is used. File the cut ends of the housing smooth. Install the nylon liner, and if desired, apply a piece of plastic tubing to the outside of the housing.



2. Fashion the lever loop of leather in the form of a ⅝-inch strap, folded together and punched for a rivet and 10-32 screw.



3. Insert the fair-lead into the lever loop so that it extends about ½ to 1 inch proximal to the lever loop. Rivet the loop close to the fair-lead to grip the latter tightly.

4. Drill and tap a hole in the forearm section for a 10-32 screw. The hole should be located in the axis of the forearm 1¼ inches from the elbow center. Install the lever loop with a 10-32 screw and washer. In the case of an amputee with a short stump, it may be

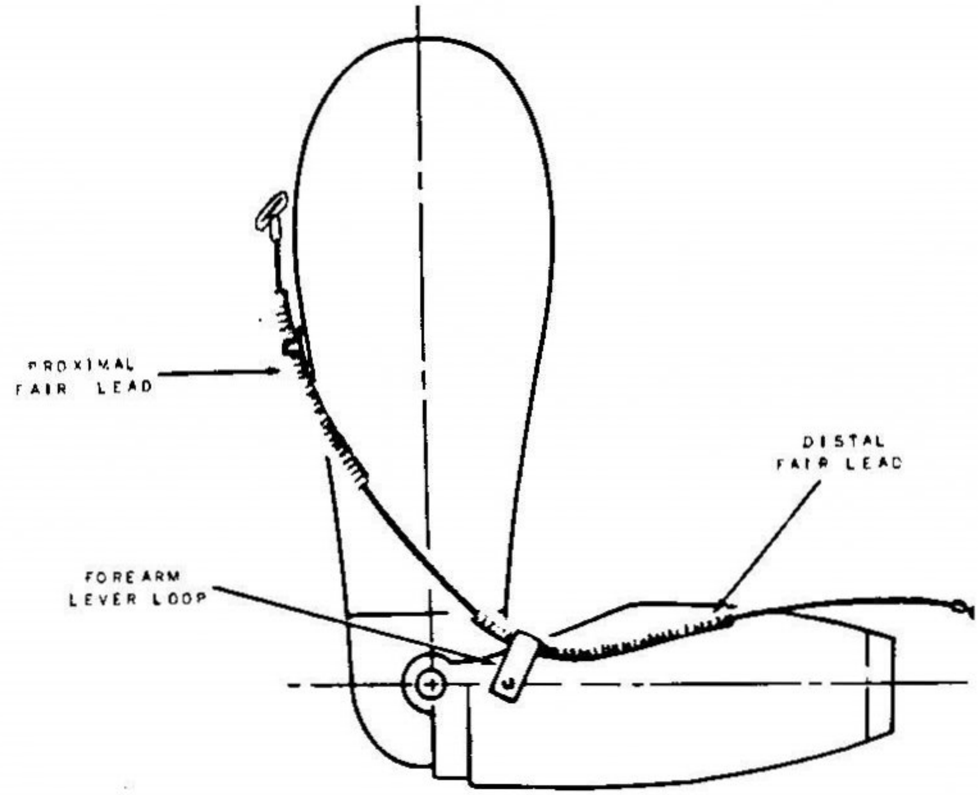
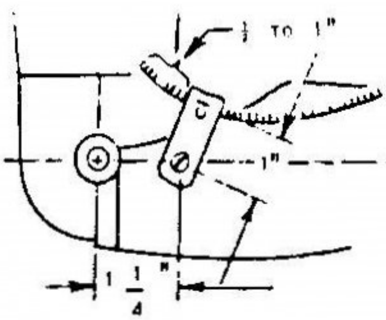


FIGURE IX-9. AE Dual Control



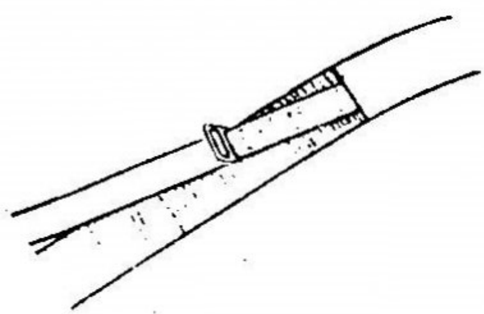
necessary to make the loop ⅛ to ¼ inch shorter to enable him to flex the forearm fully.

Fabrication Procedure for Above-Elbow Figure-8 Harness

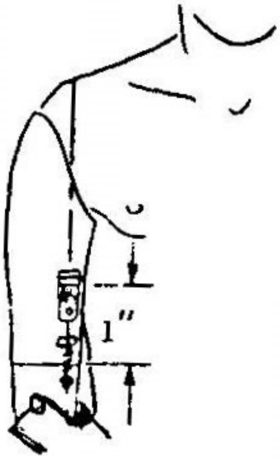
1. Prepare a 72-in. length of 1-in. dacron webbing, a 14-in. length of ½-in. dacron webbing for the elbow-lock control strap, and a 10-in. length of 1-in. elastic strap for the elastic suspensor.

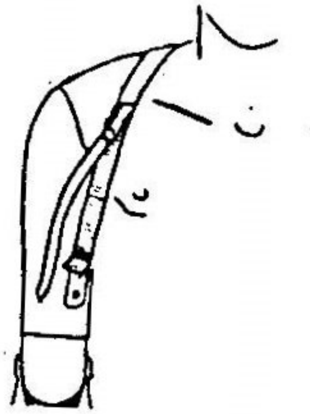
2. Stitch the elastic strap to one end of the 1-in. dacron webbing with an overlap of about 1 in. On the overlap, install a ½-in. buckle and attach the ½-in. webbing.

Slip a 12-in. piece of plastic tubing over the 1-in dacron webbing for protection of the axilla area. ..



3. With the prosthesis on the patient, position the turntable so that elbow flexion brings the terminal device towards the mouth. Remove the prosthesis and draw a vertical line on the anterior aspect of the socket directly above the point at which the control cable exits from the elbow. Rivet or screw a buckle for the elastic suspensor to the socket on the vertical line about 1-in. above the turntable.





4. As guides to location of base plates, draw two additional vertical reference lines. The first is along the lateral aspect of the socket through the center of the elbow axis and the second is along the midline of the posterior aspect of the socket.

5. With the arm on the patient, thread the elastic suspensor through the buckle just above the turntable so that the ½-in. buckle for the elbow-lock control strap lies just inferior to the clavicle in the deltopectoral groove. Continue the dacron webbing over the shoulder and across the back to the opposite axilla. Slide the plastic tubing into position to protect the axilla and continue layup of the harness, going anteriorly under the axilla, superiorly through the deltopectoral groove, over the shoulder and across the back to the prosthesis. Make sure the webbing crosses the distal third of the scapula on the amputated side and clamp it to the socket.

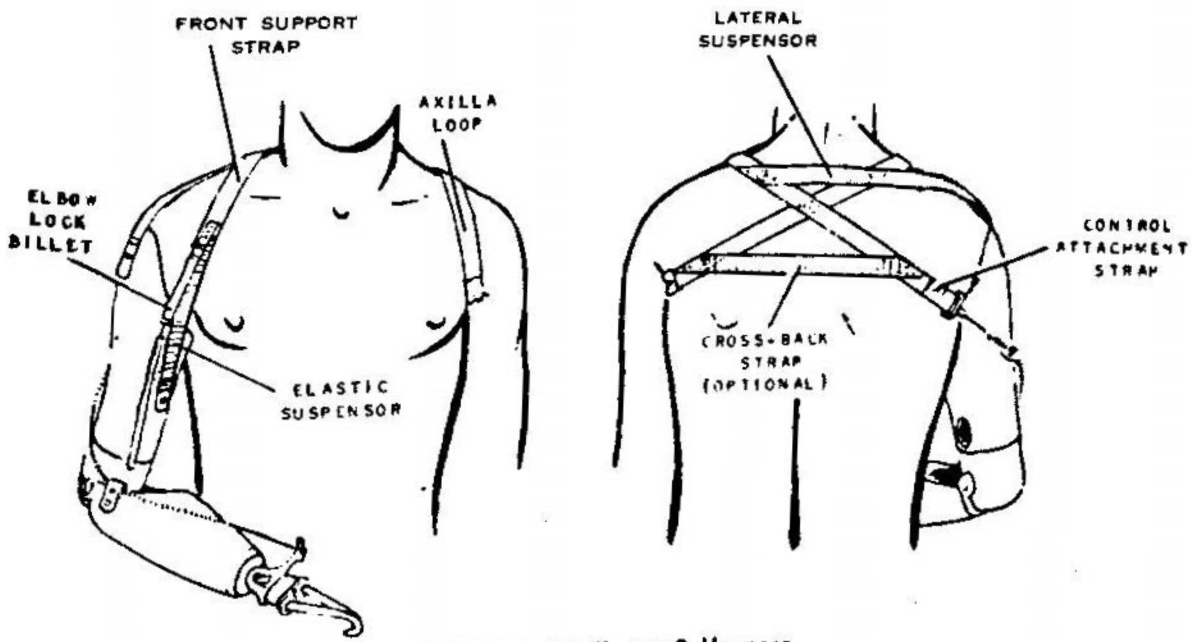
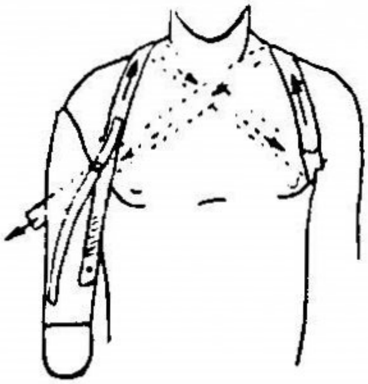
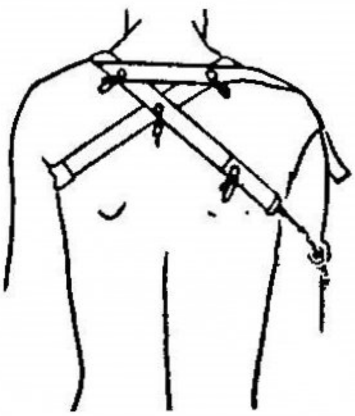


FIGURE IX-10. AE Figure 8 Harness



6. Determine the location of the lateral support strap by palpating the acromion on the amputated side and, on the sound side, the soft tissue (primarily trapezius musculature) which lies between the clavicle and the scapular spine. Place a length of webbing across the shoulders, snugly against the flesh, and clamp one end to the axilla loop where it crosses the soft tissue (trapezius) on the sound side. Extend the webbing directly over and about 3-in. past the acromion on the



amputated side. Clamp the webbing to the front support strap at a location which will keep the anterior edge of the lateral suspensor against the clavicle as it passes over the acromion.

7. Clamp a 1-in. buckle mount to the socket near the proximal edge, ½-in. anterior to the acromion, and attach the lateral suspensor to it.

8. Though a single base plate and retainer can be used to attach the housing to the socket, it is generally easier to use two retainers which provide direct control of the cable in relation to elbow center and of the control attachment strap in relation to the scapula.

With the elbow extended, pull the cable on a straight line proximally from the forearm lift loop, keeping it approximately 1-in. anterior to the elbow axis. Mark the intersection of the cable with the previously drawn lateral reference line. This is the initial location of the distal retainer. At this point temporarily mount a base plate, retainer, and short length of housing (about 4 in.). Pull the cable to check that the forearm flexes smoothly.

To find the initial location of the proximal retainer, extend the control attachment strap in a straight line and mark the point at which it intersects the previously drawn posterior reference line. At this point temporarily mount a base plate and connect the retainer and housing.

In most cases these retainer locations will result in excellent cable function. Occasionally, however, slight adjustments may have to be made to alleviate sharp bends in the cable. All such curves should be as smooth and gradual as possible, thus reducing friction.

When satisfactory locations are determined, secure the base plates to the socket, cut the cable to proper length, and attach a hanger. Keep in mind that cable length must be sufficient so as not to interfere with full extension of the elbow nor full rotation of the terminal device.

9. Review the harness carefully and readjust as necessary:

a) Check the socket suspension so that it fits snugly on the stump and is held comfortably but firmly up into the axilla. Buckle adjustments of the lateral suspensor and elastic suspensor are made here.

b) The back crossing point should lie just 1-2 in. below the seventh cervical vertebra.

c) The juncture of webbing and elastic suspensor should be over the deltopectoral interval.

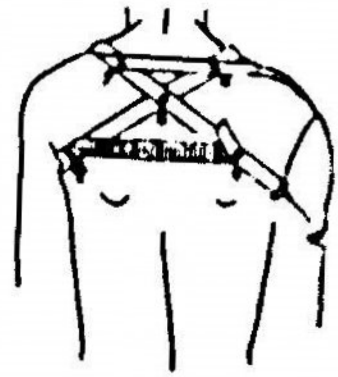
d) The lateral suspensor crosses the upper back and passes just anterior to the point of the shoulder to its buckle mount.

When satisfactory the harness should be sewn.

10. Apply the cross-back strap, if it is to be used. This elastic or webbing strap is an optional feature, but may be used to overcome the following conditions:

a) uneven distribution of forces on axilla loop, particularly the tendency of the loop to cut vertically into the axilla. The cross-back strap offsets some of this vertical force.

b) Inability of amputee to achieve full forearm flexion and terminal-device operation which can usually be alleviated with an elastic cross-back strap.



c) Tendency of the harness to slide up on the amputee's back so that the crossing point is above the seventh cervical vertebra. This usually requires a nonelastic cross-back strap.

The cross-back strap is horizontal slightly above the inferior angles of the scapulae, and is clamped to both straps of the Figure-8 where it crosses them.

11. When all connections have been made, have the amputee put on the prosthesis and harness. Make final adjustments, after which the prosthesis should be evaluated by means of the checkout procedure.

UNILATERAL ABOVE-ELBOW CHEST STRAP HARNESS

The Above-Elbow Figure 8 harness is the harness of choice for the Above-Elbow amputee, and in most cases functions with efficiency and comfort. Occasionally, however, an amputee's job requirements are such that he must lift heavy axial loads. While the parts of the Above-Elbow Figure 8 harness should always be strong enough to lift any load the amputee may be required to handle, the design of the harness is such that painful pressure concentrations on certain parts of the amputee's body may occur under such conditions. The Above-Elbow chest strap harness distributes heavy loads over a greater area of the body, thus avoiding these painful concentrations of pressure. For amputees who must lift such heavy loads, the chest strap harness is a useful design, but in actual practice it is found that comparatively few amputees are required to do heavy work, therefore this type harness is used much less than the Figure 8. Its greatest disadvantages are difficulty in applying and removing, and a tendency to rotate about the chest because of lack of a stable anchoring point. In addition, many amputees, particularly women, cannot tolerate the chest strap.

In general, the use of the chest strap harness is confined to those amputees who must lift heavy axial loads, or who cannot tolerate the axilla loop, even with a pad, or who have habitually worn the chest strap harness and do not wish to change.

The control motions used to operate the Above-Elbow chest strap harness are identical to those for the Above-Elbow Figure 8 pattern.

There are two types of Above-Elbow chest strap harnesses: the type using the leather shoulder saddle, and that using a webbing shoulder saddle.

The AE chest strap harness using the leather shoulder saddle is shown in Figure IX-11. The shoulder saddle is identical in design to that used in the BE chest strap harness, as is the chest strap. It will be noted that one lateral suspensor loop is used, connected to the socket by a D-ring, through which it is free to slide. The control attachment strap is usually connected to the lateral corner of the posterior portion of the shoulder saddle. This strap, the anterior elastic suspensor strap, and the lateral suspensor serve to stabilize the socket on the stump.

The Above-Elbow chest strap harness, webbing shoulder saddle, is shown in Figure IX-12. In this design, an improvement in resistance to socket rotation and a wider distribution of loads is achieved by using two lateral suspensors instead of one. The stabilizing effect is furthered by the use of a Y-type construction to attach the control attachment strap and the elastic suspensor strap to the chest strap.

As to strength, there is probably little to choose between the two types of chest strap harness. The webbing shoulder saddle harness has the advantage of being easy to launder, and so should be recommended for the amputee who perspires freely.

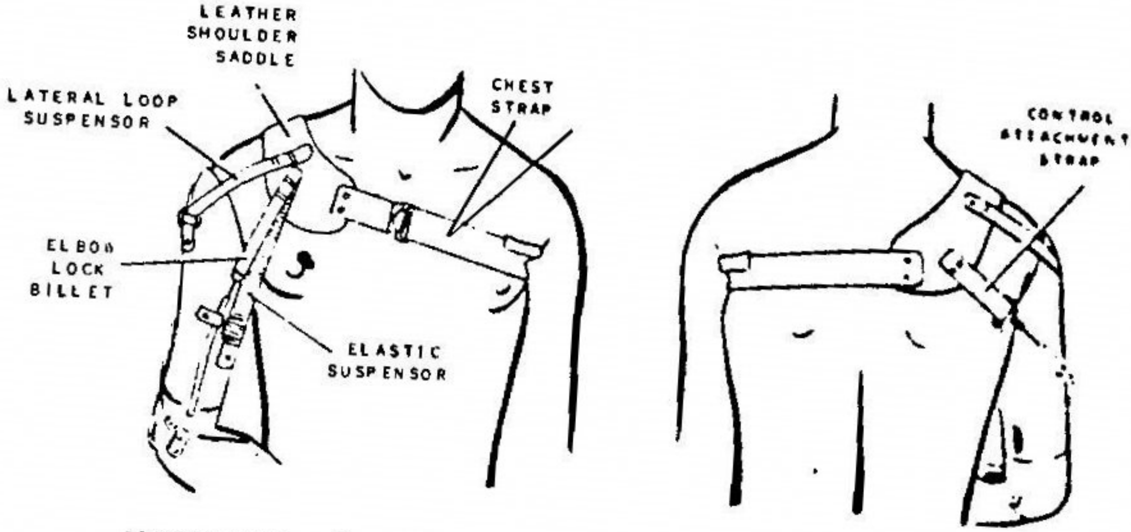


FIGURE IX-11. Above-Elbow Chest Strap Harness with Leather Shoulder Saddle

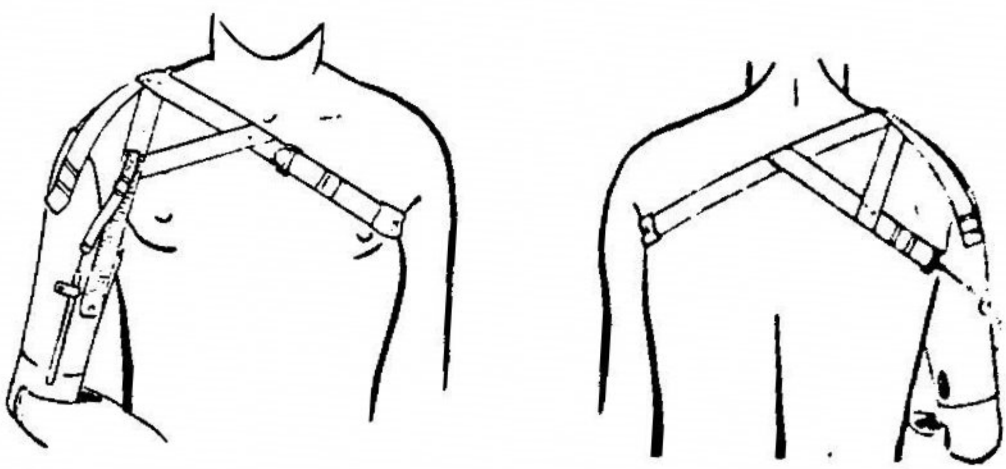


FIGURE IX-12. Above-Elbow Chest Strap Harness with Webbing Shoulder Saddle

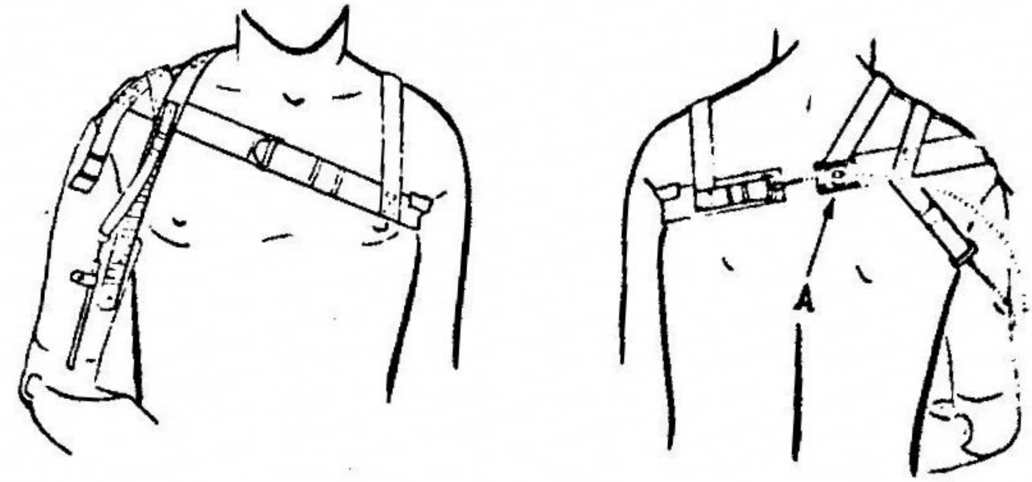
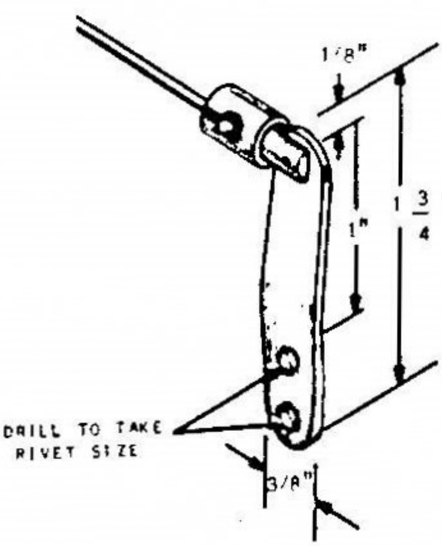


FIGURE IX-13. Above-Elbow Triple Control Harness

UNILATERAL ABOVE-ELBOW TRIPLE CONTROL SYSTEM

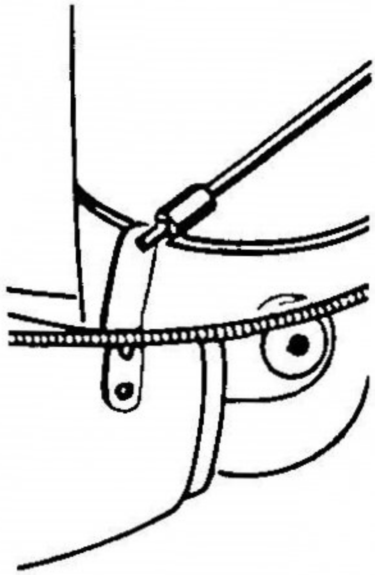
In the sections on control motions and control cable systems, it was pointed out that the Bowden cable could be used to transmit the force of scapular abduction by splitting the AE chest strap harness in the back and mounting the cable so that the housing is anchored to one side of the harness (reaction point A), and the cable to the other. When scapular abduction is used to separate the two parts of the harness at the split, the cable is pulled through the housing, and this control force can be used to operate the terminal device.

A typical triple control harness is shown in Figure IX-13. Note that the Bowden cable proximal retainer is mounted at point A on the harness to serve as a reaction point. The triple control system thus uses three control elements: scapular abduction to operate the terminal device; arm flexion to flex the forearm; and arm extension to lock and unlock the elbow unit. One can see that the Bowden cable



prehension control is similar to the BE single control; the forearm flexion control is similar to the AE dual control in respect to the proximal retainer and fair-lead. However, instead of the lever loop, this cable is attached to a special lever, mounted on the forearm as shown.

The triple control harness can be operated



successfully only by an amputee with wide, mobile shoulders; it requires three separate cable systems; and many amputees find it difficult to achieve proper separation of the controls in operating the harness system.

BILATERAL ABOVE-ELBOW FIGURE 8 HARNESS

The Figure 8 harness for the bilateral amputee is shown in Figure IX-14. Study of this harness pattern will quickly demonstrate that the principles of the unilateral AE Figure 8 harness are applied to the bilateral AE amputee in the same way the unilateral BE Figure 8 harness is applied to the bilateral BE amputee. The control attachment strap for one prosthesis is brought over the opposite shoulder and down anteriorly to the elastic suspensor, which in turn is attached to the socket. The same is done for the other prosthesis. The lateral suspensor is attached to the upper lateral aspect of one socket, carried across the back, and attached to the upper lateral aspect of the other socket. The cross-back strap, two over-the-shoulder straps, and the two elbow lock billets are applied, and the harness is complete.

As with the bilateral BE harness, the chief problem with this harness pattern is the difficulty many amputees experience in achieving proper separation of controls.

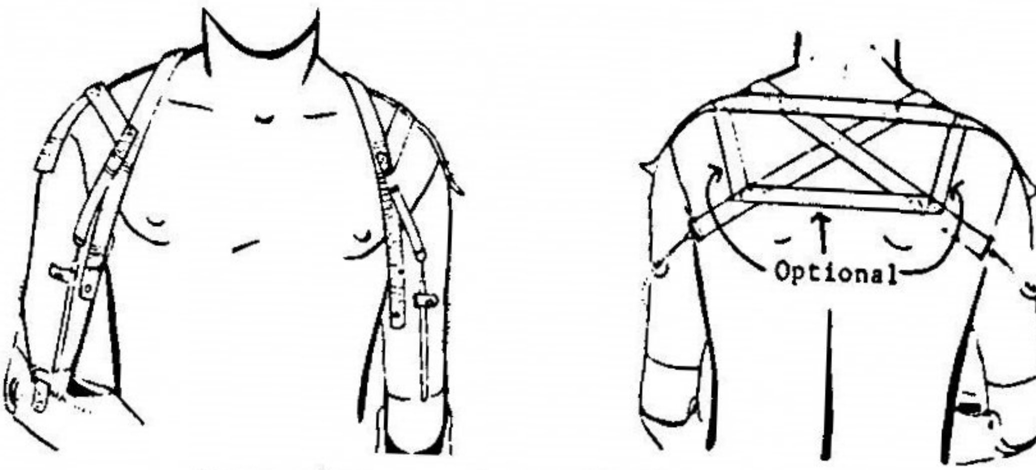


FIGURE IX-14. Bilateral Above-Elbow Figure 8 Harness

HARNESS MODIFICATIONS FOR THE SHORT AE

When the AE stump length is 30 to 50 percent of acromion-to-epicondyle length, the arm flexion control cannot be applied in the standard manner, because the humeral lever is too short. The key point is the location of the proximal retainer of the dual control system. It is typically placed at the level of the stump end, in order to insure control of the arm flexion motion. The use of two proximal retainers to conduct the control path around and down the arm (Figure IX-15) is very effective. These placements of the proximal retainer, or retainers, mean that with progressively shorter stumps the control attachment strap crosses the scapula at successively higher

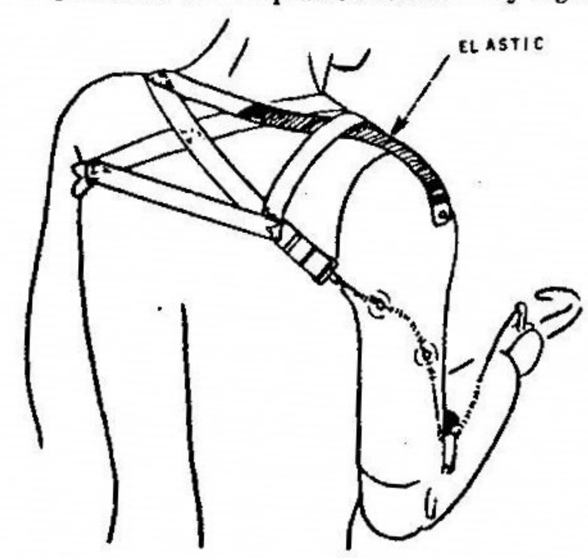


FIGURE IX-15. Harness Modifications for the Short AE

levels. The reduced levering power of the stump must be compensated by more use of scapular abduction. The control and harness placement for the Short AE is shown in Figure IX-15.

A second modification concerned with this amputee type is the use of elastic in the lateral suspensor. This gives more freedom for motions at the shoulder. It should also be noted that the cross-back strap is essential to provide the more nearly cross-back orientation of control path in the Short AE.

SHOULDER AMPUTEE HARNESSING

Control Motions

With the Shoulder amputation, the functions of the hand, wrist, elbow, and shoulder joint are absent. The most commonly used control sources are scapular abduction, shoulder elevation and scapular adduction. In the most drastic form of Shoulder amputation—the Forequarter—the amputee also loses these control motions on the amputation side. The Shoulder prosthesis should provide substitutes for the lost functions of the hand, wrist, elbow, and shoulder joint, and the harness control system should provide power to operate these prosthetic components. Because of loss of the shoulder joint this has been very difficult to accomplish, and at the present stage of development of the upper-extremity prosthetics, the Shoulder prosthesis is the least effective of all those developed for the various levels of arm amputation. No satisfactory active mechanical substitute for the shoulder joint has been developed, resulting in a prosthesis with, at best, a passively positionable upper arm section. For this reason, the harness is required only to provide power for terminal device operation, forearm flexion, and elbow locking and unlocking.

While no means for actively controlling a mechanical shoulder joint have been developed, means have been devised for providing passive motion at this point. Pivoting sectional plates that permit the upper arm section of the prosthesis to be flexed at the shoulder have been developed, and a flexion-abduction joint is available which allows passive positioning in two planes.

As pointed out previously, amputees vary in physical strength, mobility of body parts, and general body build, just as do people in general. In the case of the Shoulder amputee, this fact is critcial, because he has so few control sources upon which to draw that his case is marginal at best. Therefore, the Shoulder amputee who has wide, mobile shoulders, is strong and in good general health, and who has good general body coordination can usually do well with the basic Shoulder harness using a minimum of equipment. The other extreme is the amputee who has the opposite of these physical characteristics, and on whom the prosthetist has to apply every known modification of the basic harness in an effort to achieve success. Because of this situation, the prosthetist is required to study each amputee's requirements with care so he can go as directly as possible to the most satisfactory combination of equipment with a minimum of trial and error. The actual fabrication and fitting of any given harness for a Shoulder amputee is seldom difficult; selecting the correct harness combination for the amputee so that he can function at maximum efficiency with a minimum of equipment is quite difficult.

BASIC SHOULDER HARNESS AND DUAL CONTROL

The basic Shoulder amputee harness pattern is shown in Figure IX-16. The chest strap is similar to those described in previous sections for the BE and AE chest strap harnesses. It is attached to the anterior aspect of the shoulder cap, runs across the chest, under the axilla, and across the back at midscapular level to the control cable hanger. An elastic suspensor strap is fastened to the anterior aspect of the shoulder cap, approximately over the deltopectoral triangle, brought up and over the shoulder to the chest strap, slightly toward the sound side of the spinal column.

The shoulder cap should be fitted accurately to the shoulder with the skirts extending sufficiently to prevent it from dropping or rotating; the harness is required only to hold it firmly on the shoulder.

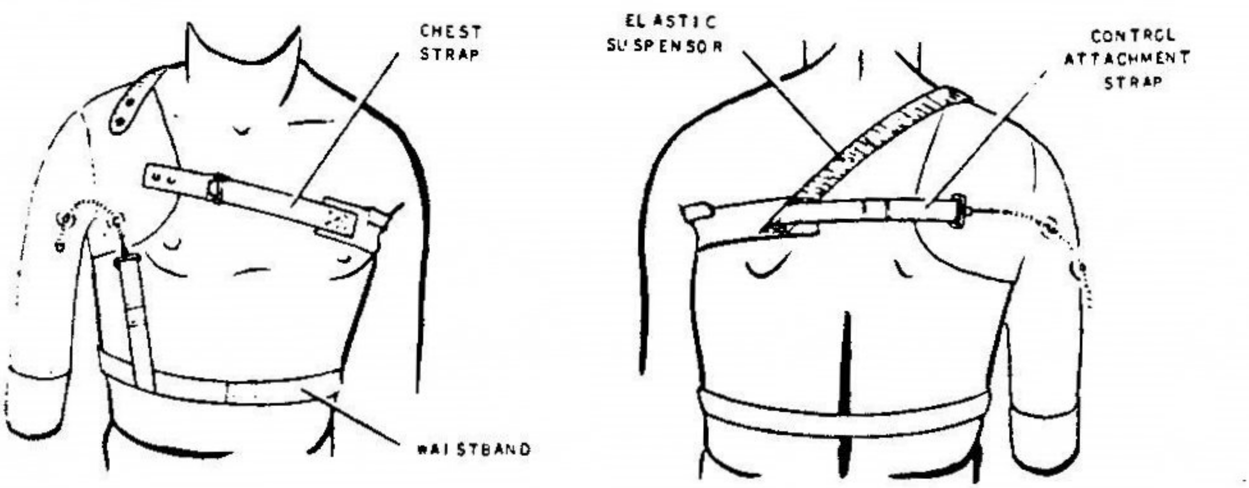
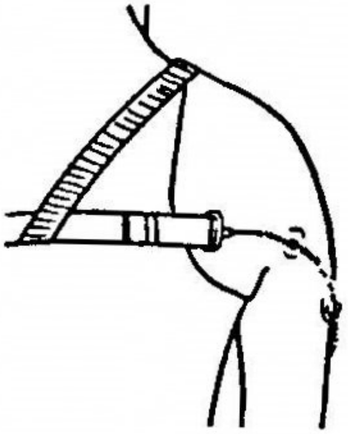


FIGURE IX-16. Basic Shoulder Harness: Scapular Abduction for Dual Control; Shoulder Elevation for Elbow Lock Control

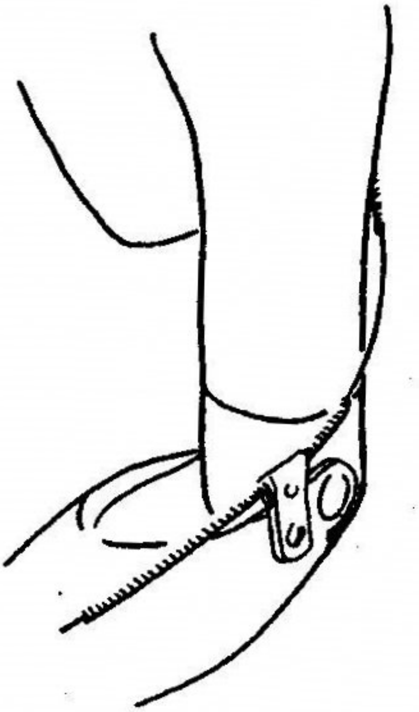
A waistband is provided with a strap that is connected to the elbow lock control cable. The waistband stabilizes the distal end of the strap, so when the amputee elevates his shoulder the elbow lock is tripped.

The fair-lead type control cable is made and connected in the same way as described for the AE prosthesis. Together with the elbow lock control this provides a shoulder dual control system which is similar in its mechanical aspects to the AE dual control system.



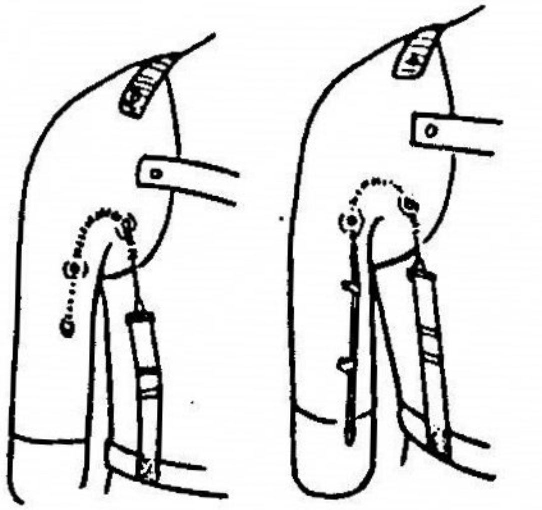
Control Installations

The cable assembly used is essentially similar to the AE dual control system, and is installed in the same way, except for the proximal baseplate and retainer. The latter is placed approximately in the center of the posterior aspect of the socket, but the exact location must be such that the control attachment strap lies across the amputee's back at midscapular level.



The elbow lock control cable housing extends from a point slightly above where the control cable emerges from the elbow unit, well on up onto the anterior aspect of the socket. Here it is shaped into an inverted U, held by retainers, with the free end of the housing directed down and slightly medially.

If the elbow unit is the type in which the control cable is located on the *inside* of the socket, a hole is provided about 2 to 3 inches up from the turntable on the vertical anterior midline of the socket. The housing and cable are brought through this hole and extended vertically up the socket.



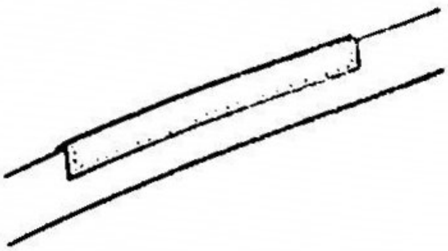
If the elbow unit is the type in which the control cable emerges from an opening on the anterior portion of the elbow unit housing, the cable is brought up the anterior vertical midline of the socket and is held in place with baseplates and retainers or clips.

Harness Fabrication Procedure

1. Cut a piece of 1½-inch webbing to make a chest strap long enough to encircle the thorax from the anterior to the posterior aspects

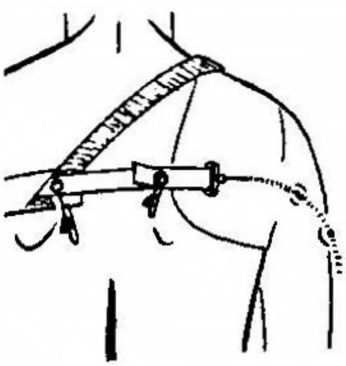
the latter is held firmly in place on the amputee's shoulder. Allow at least ten inches extra for adjustment.

2. Double a piece of 1½-inch webbing over the lower edge of the chest strap to serve as a padding where it passes under the axilla, and sew it in place. It should extend an inch or two beyond the axilla at both ends. Plastic tubing may also be used.



3. Using the chest strap with clamps to hold the prosthesis in place on the amputee, cut a piece of 1-inch elastic webbing long enough to reach from the posterior center point of the chest strap to a point on the anterior aspect of the socket approximately over the deltopectoral triangle. Clamp this elastic suspensor strap in place.

4. Adjust the elastic suspensor strap and the chest strap so the latter lies smoothly across the back at midscapular level.

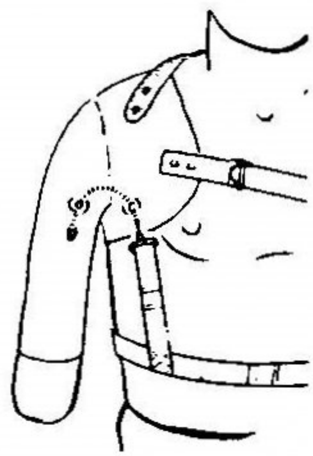


5. Thread the control attachment strap through the hanger, and fasten it with a clamp after removing all slack. Direct the amputee to abduct his scapulae and observe the action of the forearm. The amputee should be able to flex it through its full range.

6. Make a waistband of 1-inch webbing, using a buckle that can be fastened by the amputee using his normal hand. The waistband must fit snugly under the rib cage so it will not pull up when the amputee operates the elbow lock.

The elbow lock control strap can be fastened to the waistband of the amputee's trousers with a button or snap. It is desirable to locate the attachment point near the center of the body so the strap can be brought through the opening in the shirt. All of the amputee's trousers must be equipped with these fastening devices.

7. Make an elbow lock control strap of ½-inch webbing with a buckle for adjustment. The strap must be long enough to extend from the waistband to the elbow lock control cable. Cut the control cable and housing so they terminate well above the edge of the socket skirt, and attach a ½-inch hanger to the cable. Thread the control strap through the hanger and hold in place with a clamp after removing all slack from the system.



8. Direct the amputee to test the action of the elbow lock by elevating his shoulder; adjust the elbow lock control strap until locking and unlocking can be accomplished with a minimal movement, yet not so tight that the lock will be inadvertently operated.

9. Direct the amputee to flex his prosthetic forearm and lock it in different positions. He should be able to flex the forearm through the full range. If he cannot, check the chest strap for looseness. In some cases it may be necessary to relocate the lever loop on the forearm slightly nearer the elbow joint before full range of flexion can be obtained.

10. If the amputee can operate the prosthesis satisfactorily and does not complain of

discomfort from the waistband, it may be assumed that the prosthesis will be adequate. Proceed to assemble all parts with permanent fastenings, make final adjustments with the prosthesis on the amputee, and complete the final fitting and checkout procedures.

MODIFICATIONS TO INCREASE DUAL CONTROL FUNCTION

If the amputee cannot successfully operate the prosthesis with the basic Shoulder harness, three remedial modifications or variations have been found helpful in some cases. These modifications are:

a. Addition of an axilla loop
b. Addition of a shoulder sling with the axilla loop
c. Addition of an excursion amplifier

Axilla Loop

The basic harness with an axilla loop added on the sound side is shown in Figure IX-17.

The axilla loop utilizes in some amputees a substantially larger amount of the motion produced by a scapular abduction because it makes a positive connection with the shoulder, whereas the chest strap does not. The disadvantage of having both the chest strap and the axilla loop under the arm on the sound side is considerable; some amputees may find this too uncomfortable to tolerate considering the somewhat limited function yielded by the shoulder prothesis, even when the latter is performing at its maximum.

Shoulder Sling

The basic shoulder prosthesis harness with a shoulder sling in addition to the axilla loop on the sound side is illustrated in Figure IX-18.

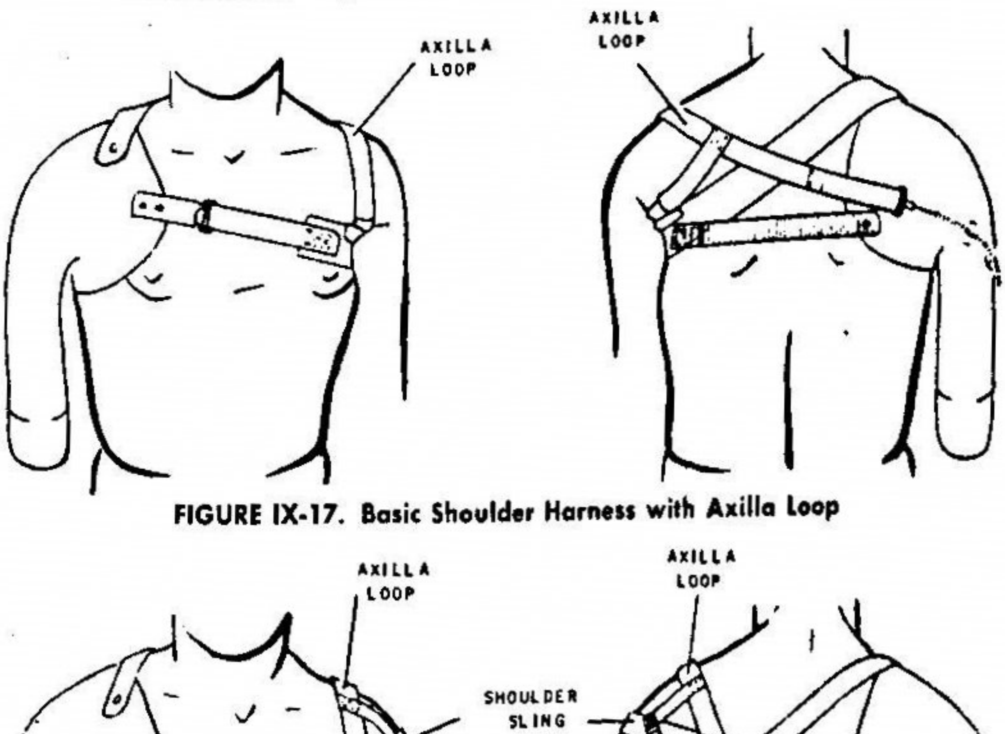


FIGURE IX-17. Basic Shoulder Harness with Axilla Loop

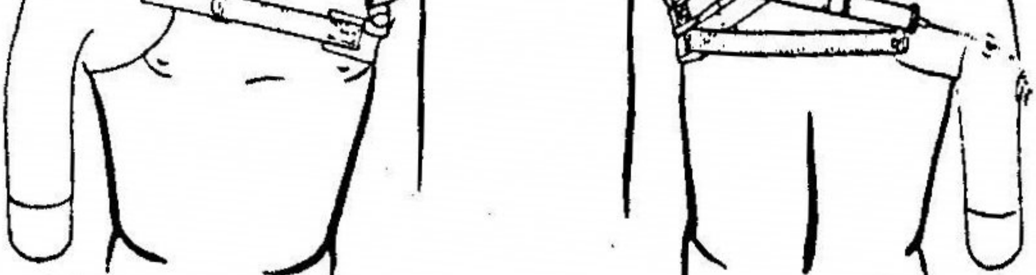


FIGURE IX-18. Basic Shoulder Harness with Axilla Loop and Shoulder Sling

The shoulder sling is made up of four straps so assembled to the axilla loop that in addition to the positive connection to the shoulder made by the latter, a strap is held in place on the point of the shoulder. The shoulder sling harnesses much of the excursion available as a result of the wider arc through which this extreme tip of the shoulder swings when the scapulae are abducted.

Excursion Amplifiers

An excursion amplifier is a mechanical device that converts a large force with small excursion into a lesser force with increased excursion. Levers can be used for this purpose, as can gears, pulleys, and hydraulic cylinders. In most cases the Shoulder amputee has an abundance of strength in his shoulders; in many cases he lacks excursion. The excursion amplifier makes it possible to convert some of this surplus force into additional excursion. Most commercially available terminal devices require 1½ to 1¾ inches of excursion for full operation, and 2 to 3 inches are required to elevate the forearm through a range of 125°. Two types of excursion amplifiers have been used with some degree of success as part of the harness for shoulder prostheses in an effort to attain this amount of excursion: the lever and the movable pulley or sheave.

Lever Type Excursion Amplifier An excursion amplifier can be made using a third class lever, which is one on which the force is applied between the fulcrum and the resistance or load. An example is shown in Figure IX-19. It is apparent that the ratio between the force arm and the resistance arm on this lever is approximately 2:1; therefore, 1 inch of excursion with a force of four pounds exerted by the amputee at A will be converted to 2 inches of excursion with a force of 2 pounds at B.

External Movable Sheave Type Excursion Amplifier An excursion amplifier can also be made by using a movable pulley or sheave. This device can be used to amplify the excursion produced by scapular abduction, and can be mounted in either of two ways: externally as an extension of the control attachment strap; and internally, inside the arm section of the prosthesis, as part of the control cable assembly.

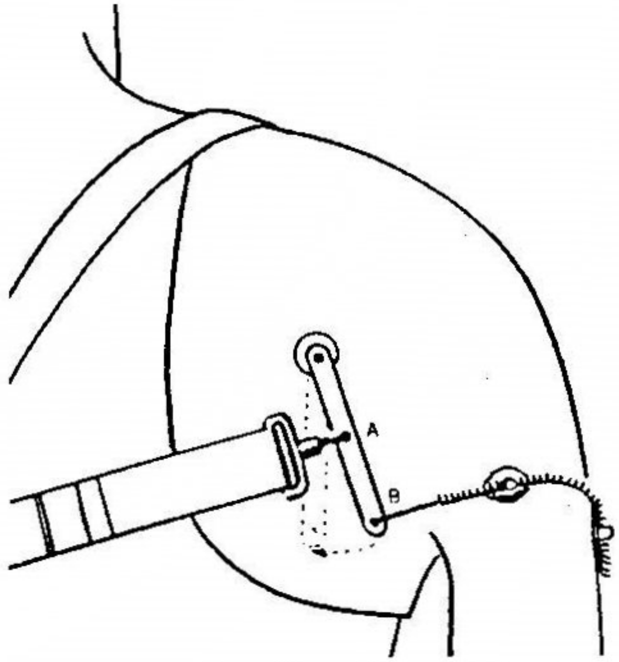


FIGURE IX-19. Lever Type Excursion Amplifier

The externally mounted sheave excursion amplifier is illustrated in Figure IX-20.

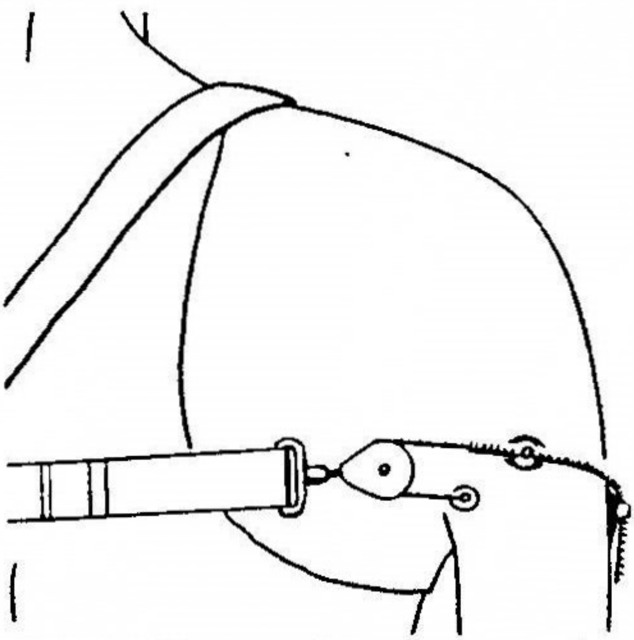


FIGURE IX-20. External Movable Sheave Type Excursion Amplifier

Internal Movable Sheave Type Excursion Amplifier The internally mounted excursion amplifier is shown in Figure IX-21. In principle this device is the same as the externally

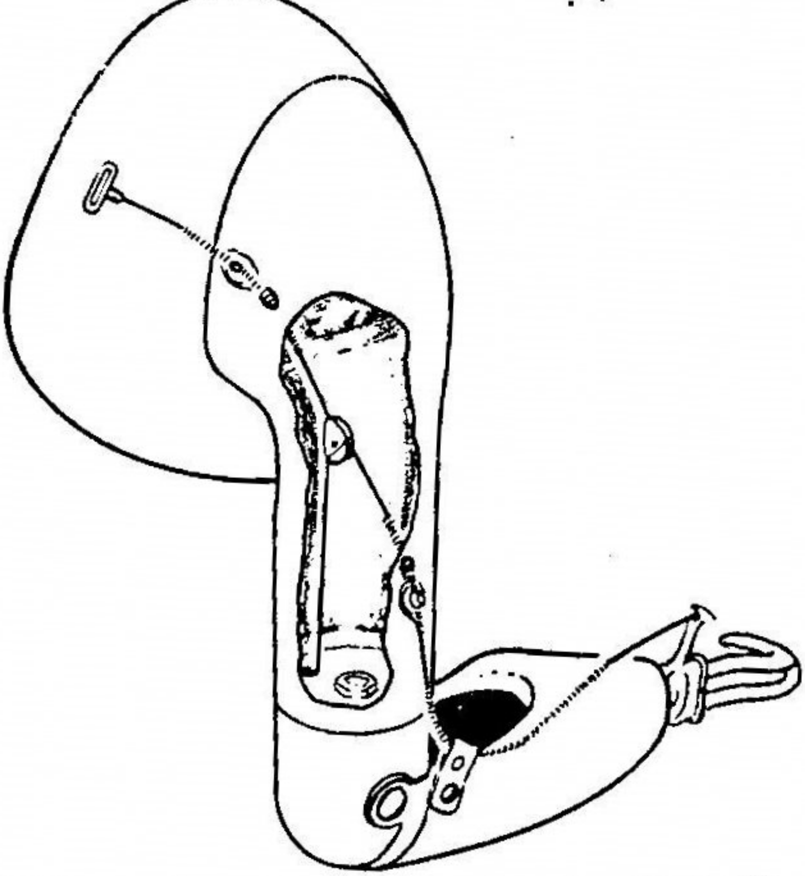


FIGURE IX-21. Internal Movable Sheave Type Excursion Amplifier

mounted amplifier. The advantages of internal mounting are less interference with clothing and a considerably more clean-cut appearance.

Comparison of Various Excursion Amplifiers Of the excursion amplifiers we have discussed, the *lever type* has the advantage of variable ratios that may be obtained by locating the attachment points for the cables in different relationships to the fulcrum; however, it has the disadvantage of interfering with clothing and giving the prosthesis a gadget-laden appearance. The *externally mounted sheave* interferes with clothing, appears gadgety, and is limited to a 2:1 ratio of amplification. The *internally mounted sheave* makes by far the neatest installation, but is also limited in range of amplification.

VARIATIONS IN BASIC SHOULDER HARNESS ELBOW LOCK CONTROL

If the amputee objects to wearing a waistband for use in controlling the elbow lock, three other means for accomplishing this control have been devised, one of which may prove satisfactory to the amputee. These variations in elbow control are:

a. Shoulder flexion on the sound side
b. Shoulder extension on the amputation side
c. Nudge control

Shoulder Flexion on the Sound Side

A harness pattern using this type of elbow lock control is illustrated in Figure IX-22.

From the illustration it can be seen that a form of shoulder sling is used to harness the excursion at the tip of the shoulder to operate the elbow lock. It is important to fit the chest strap at midscapular level and to keep the shoulder sling as high as possible. This makes it easier for the amputee to separate the two controls. Because of the frictional losses in the long elbow lock control cable, the return spring in the elbow unit is seldom able to return the mechanism to the starting position.

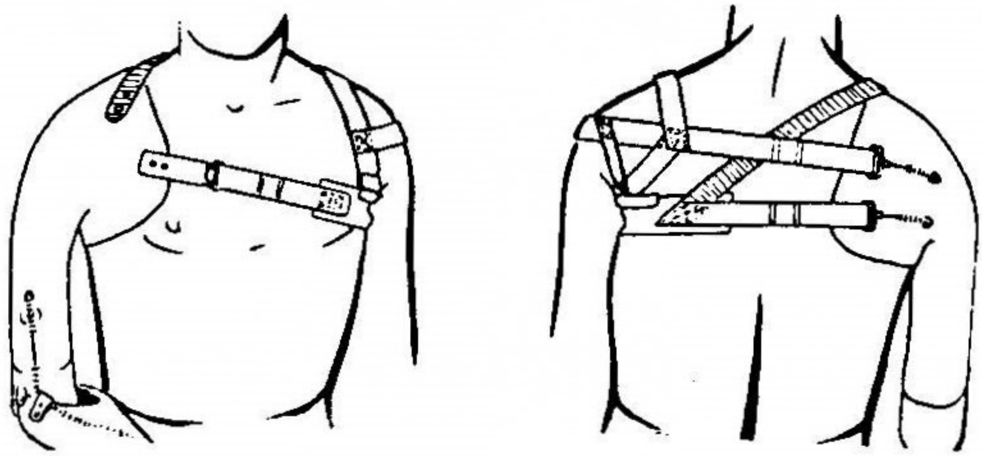


FIGURE IX-22. Basic Shoulder Harness: Scapular Abduction for Dual Control; Shoulder Flexion on the Sound Side for Elbow Lock Control

An additional spring must be installed in the arm section of the prosthesis to provide enough tension to overcome this frictional loss. This spring is attached as shown in Figure IX-24. The extra force required to operate the lock with the auxiliary spring installed also makes it easier for the amputee to avoid operating the lock inadvertently.

It must be clearly understood that this method of elbow lock control cannot be used successfully unless the Shoulder amputee has sufficient excursion from scapular abduction alone to flex the forearm and operate the terminal device with dual control.

Shoulder Extension on the Amputation Side

A harness which uses shoulder extension on the amputation side to operate the elbow lock is illustrated in Figure IX-23.

Study of this illustration will reveal that the elbow lock is operated by adducting the scapula on the amputation side, which causes the prosthesis to move slightly to the rear; as the elbow lock control cable is anchored to the chest strap, a relative motion is produced that trips the elbow lock. The lower leg of the split chest strap must be made of elastic to permit this motion.

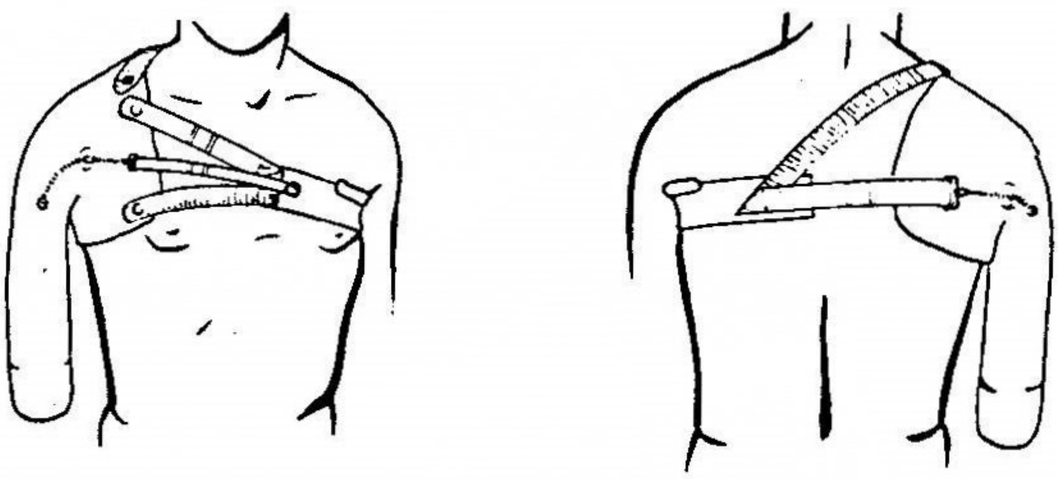


FIGURE IX-23. Basic Shoulder Harness: Scapular Abduction for Dual Control; Shoulder Extension on the Amputation Side for Elbow Lock Control

There is some evidence that this harness pattern is most useful for the Shoulder amputee who retains the neck of the humerus or has an Above-Elbow stump that is so short that it must be treated as a Shoulder case. These amputees seem better able than true Shoulder Disarticulation cases to coordinate the two body motions required to make the harness function.

Nudge Control

The nudge control is a paddle-shaped lever assembly mounted on the shoulder prosthesis

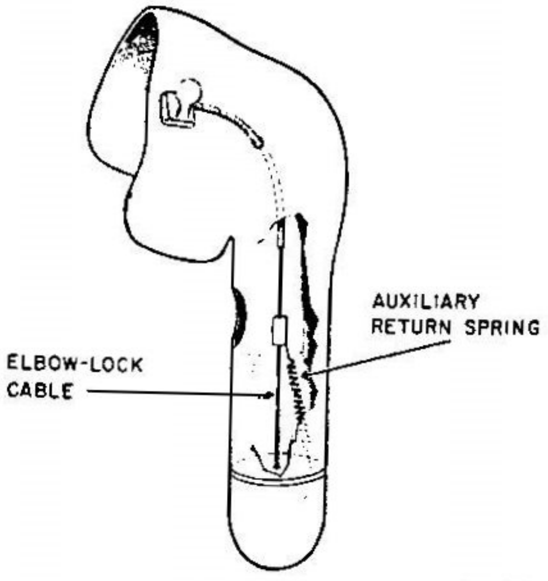


FIGURE IX-24. Nudge Control for Shoulder Prosthesis Elbow Lock Control

socket so that it can be operated by "nudging" it with the chin, or by the sound hand. The lever is coupled with a control cable so that pressure on it causes the cable to retract in its housing, and so trips the elbow lock.

The nudge control requires the amputee to use an awkward motion to operate it with his chin; if he must use his sound hand for the purpose, two-handed activities are interrupted, and much of the value of the prosthesis is lost. For these reasons the nudge control has not received wide acceptance.

SHOULDER PROSTHESIS HARNESS FOR FEMALE AMPUTEES

Most female Shoulder amputees cannot wear a chest strap harness because of the discomfort and irritation in the area of the breasts. It is necessary to use a harness design that does not require the chest strap. Some success has been achieved by using as a foundation for the harness a diaphragm strap either separate from or attached to a brassiere made of sturdy material. An arrangement using such a garment is illustrated in Figure IX-25.

A 1-inch webbing band is sewn to the lower edge of the brassiere and is attached with snap fasteners to a projection of the shoulder cap in front. In back it serves as the control attachment strap. A piece of elastic strap is attached to this band in back and slightly to the sound side of the spinal column, then is placed diagonally across the back and over the shoulder to a point of attachment on the shoulder cap where it serves as a suspensor. The elbow lock control is anchored to a waist-

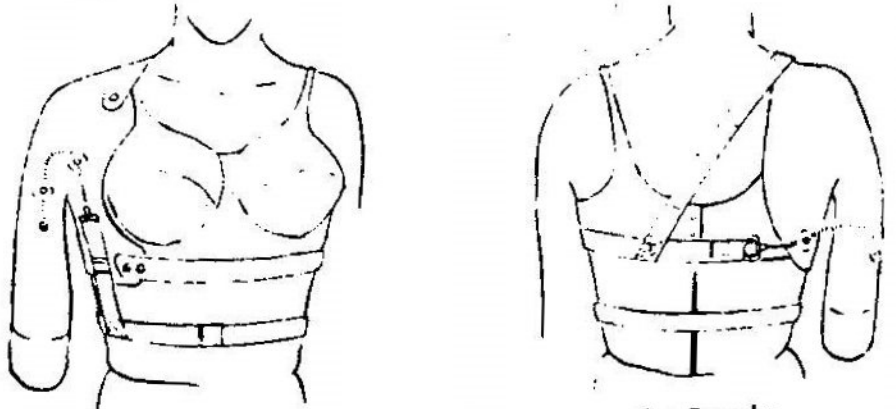


FIGURE IX-25. Shoulder Prosthesis Harness for Female: Scapular Abduction for Dual Control; Shoulder Elevation for Elbow Lock Control

band in the same manner as described earlier for the basic shoulder prosthesis harness.

When the dual control is operated, there is a force exerted on the band around the lower edge of the brassiere that causes it to rotate about the body in those cases where the amputee is comparatively flat-chested. To overcome this problem it is necessary to add a shoulder sling-axilla loop combination to serve as the anchor for the control attachment strap as shown in Figure IX-18.

PERINEAL CONTROL

Perineal control is accomplished by fitting a padded webbing loop around the thigh at the crotch and extending a webbing strap from the loop to the prosthesis where it is connected to the control system. The amputee elevates his shoulders to operate the control.

Perineal control can be used with any prosthesis designed for dual control, but many amputees find the perineal loop too uncomfortable to tolerate. For this reason it is used only as a measure of last resort in most instances. A bilateral Shoulder case who is unable to get any useful control from other sources might accept this control to avoid almost complete helplessness.

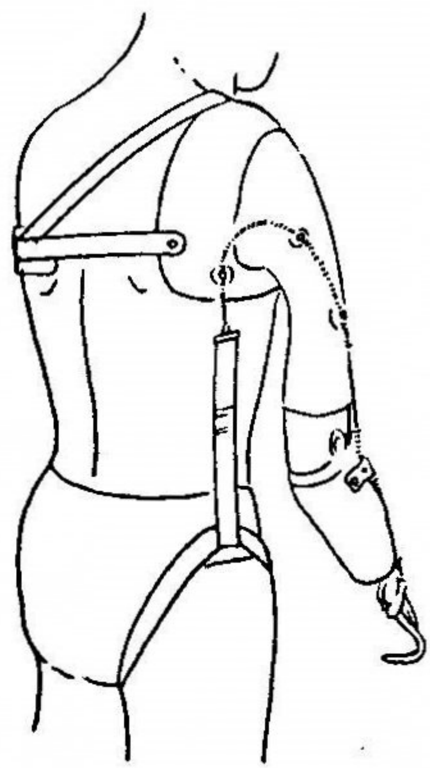


FIGURE IX-26. Shoulder Prosthesis with Perineal Control