

The Munster-Type Below-Elbow Socket, a Fabrication Technique

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The introduction of the Munster technique into the United States in 1958 generated considerable interest in the prosthetics profession, particularly for the management of amputees with short and very short below-elbow stumps. However, in spite of the enthusiasm for this technique, its application has met with varying success in this country. The dearth of precise instructional material has undoubtedly contributed to the lack of consistent results. Each prosthetist has improvised from the limited information

available, sometimes successfully, sometimes unsuccessfully.

The purpose of this article and the manual upon which it is based (5) is to present a detailed description of the Münster technique based upon the procedures utilized in the successful fittings performed in the New York University evaluations of 1963-1964 (1,3). But there can be no substitute for formal instruction and demonstration in the technique. This point is stressed because at least one critical procedure in the fabrication technique, that of cast taking, is quite difficult to learn by the written word and pictures alone.

¹ Based upon *A Fabrication Manual for Die "Munster-Type" Below-Elbow Prosthesis*, published by Prosthetic and Orthotic Studies, Research Division, School of Engineering and Science, New York University, New York, N.Y., in April 1965 (5). The manual was prepared under the general supervision of Sidney Fishman, Ph.D., Project Director, Child Prosthetic Studies, New York University. The studies that provided the material for the manual are supported by the Children's Bureau and the Vocational Rehabilitation Administration, Department of Health, Education, and Welfare. The publication itself was made possible through a grant from the Children's Bureau.

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The procedures presented do not conform in every respect to those promulgated by the developers, Drs. Oskar Hepp and G. G. Kuhn (2). However, it is believed they are a close approximation. For this reason the technique is referred to as the "Munster-type" fabrication technique. In choosing this title, it is intended to give appropriate credit to Drs. Hepp and Kuhn for the original development of the technique, without implying identity with their procedures.

Short below-elbow stumps have always presented fitting problems for the obvious reasons of small attachment area, poor leverage, and a decreased range of useful motion. Split sockets and step-up hinges have commonly been used to provide a full range of elbow flexion (135 deg.) to amputees having very short below-elbow stumps. However, this system is characterized by several features which tend to reduce its over-all 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.



Fig. 1. Anterior-oblique and posterior-oblique views of the Munster-type prosthesis.

During the middle 1950's, Drs. Hepp and Kuhn of Minister, Germany, formulated a new approach to the prosthetic management of short upper-extremity stumps. They developed a technique for fabricating sockets for below-elbow and above-elbow amputations which provides a more intimate encapsulation of short slumps (2).

EVALUATION OF MUNSTER FABRICATION TECHNIQUE

New York University Adult Prosthetic Studies became interested in the Munster technique

for amputees having short and very short below-elbow stumps, following the favorable experiences reported by amputee clinics in fitting preflexed arms (that is, arms bent to provide a certain amount of preflexion) to children (4). Under the auspices of the Subcommittee on Evaluation of the Committee on Prosthetics Research and Development, New York University conducted an evaluation of what was considered the Munster technique in applications to adult amputees (1,3). 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 deg.) in relation to the humerus. Because of the reduced range of useful motion, the socket was flexed to position the terminal device in the most generally useful area.

2. The anterior trim line extended to the level of the antecubital fold, with a channel provided for the biceps tendon to avoid interference between socket and biceps tendon during flexion.

3. The posterior aspect of the socket enclosed the olecranon, taking advantage of this bony prominence to provide attachment and stability to the socket. The trim line was just above the level of the epicondyles.

Because of the high anterior and posterior walls of the sockets, the range of motion for

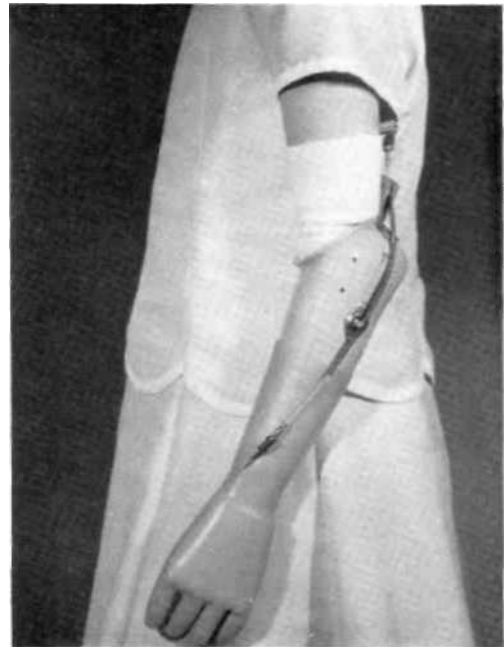


Fig. 2. Maximum extension.

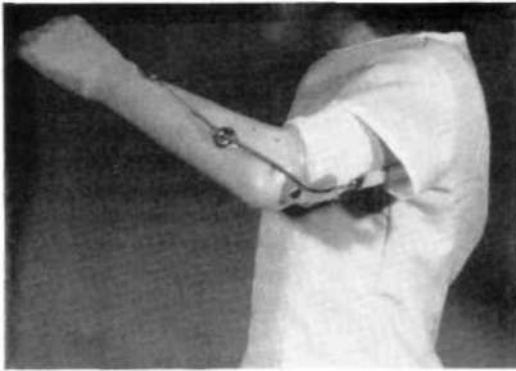


Fig. 3 Maximum flexion,

the average amputee was limited to approximately 70 deg. (from 35 deg. to 105 deg. flexion). The limited range of motion characteristic of Munster-type sockets bears emphasis (Figs. 2 and 3). In current practice, the acceptable checkout standard for maximum elbow flexion with the prosthesis is that it should be within 10 deg. of stump flexion without the prosthesis. This standard is not applicable to the Munster-type prosthesis. 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 extremes of the flexion-extension range.

The results of the New York University study of Munster-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 the performance of tasks close to the body.
3. Lifting and holding forces available to the amputee were generally superior (Figs. 4 and 5).

Following the favorable results obtained in fitting adult amputees, 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 had worn their prostheses for periods ranging from 4 to 14 months.



fig. 4. "Live lift"—resisting vertical downward force while maintaining the elbow flexed.



Fig. 5. "Axial load"—resisting vertical downward force with the elbow extended.

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 article, would be equally applicable to children.

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 per cent of the stumps fitted fell into the short and very short below-elbow categories. Specifically, nine adults (including one bilateral amputee) with stump lengths ranging from 1-1/2 in. to 5-1/2 in. (18 to 52 per cent) and eight children with stumps 2 in. to 3 in. long (25 to 40 per cent) were successfully fitted with Munster-type prostheses.

The precise limits of applicability of the Miinster-type prosthesis (that is, the minimum and maximum stump lengths) must be determined individually for each patient. However, based upon a somewhat limited investigation of these considerations, the following guidelines are offered:

Minimum length: Very short stumps virtually disappear at 90 deg. of elbow flexion. Hence, the maximum prosthetic flexion angle obtainable with stumps in this category is limited accordingly. The shortest stump fitted at NYU was 1-1/2 in. (18 per cent) in length. The maximum flexion angle obtained (with prosthesis) was 80 deg.

Thus, fitting of Miinster-type sockets to stumps as short as 1-1/2 in. depends upon the acceptability of a very limited amount of elbow flexion (usually less than 90 deg.).

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 Miinster-type fitting. The question to be decided is whether other advantages of the Miinster-type prosthesis adequately compensate for the loss of rotation in a given case.

2. The configuration of the Miinster-type socket (proximal opening at an angle to the socket) presents progressively increasing difficulty in 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. The 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.

NYU has fitted several adult and juvenile amputees whose stumps fell into the long classification; that is, 55 per cent of sound side or longer. One adult at the borderline of the long classification (5-1/2 in.—56 per cent) and a child well within this category (4 in.—66 per cent) 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.

However, an adult with a 7-in. stump (66 per cent) required considerable modifications to the proximal brim before the prosthesis could be delivered successfully. The anterior trim line was reduced approximately 1/2 in. below the cubital fold to facilitate passage of the stump. The subject had about 55 per cent of residual stump rotation; but, since this rotation had not been utilized in the previous prosthesis, no deprivation was imposed by the Miinster-type arm.

One child with a 6-in. (92 per cent) stump was also successfully fitted with two different modifications of the Miinster-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 Miinster-type prostheses can apparently be fitted without difficulty to stumps

UPPER EXTREMITY MEASUREMENT CHART

Prosthetist _____ Date _____
Patient's Name _____ Amputation Date _____
Amputation Type _____ Left ___ Right ___ Race: Caucasian ___ Negro ___
Height _____ Age _____ Sex: Male ___ Female ___
Socket: Double Wall ___ Single Wall ___ Split ___ "Muenster" Type ___
Monolith ___ SD Socket ___ Section Plate ___ Abduction ___
Other _____
Hook ___ Hand ___ Wrist ___ Elbow ___ Hinge ___
Harness _____ Control System _____
Cuff _____ If no cuff is used, indicate attachment point for housing cross
bar assembly _____
Range of Motion of Stump: Elbow Flexion _____ Pronation _____
Elbow Extension _____ Supination _____
Condition of Stump (irritation, abrasion, etc.): _____
Special Considerations: _____

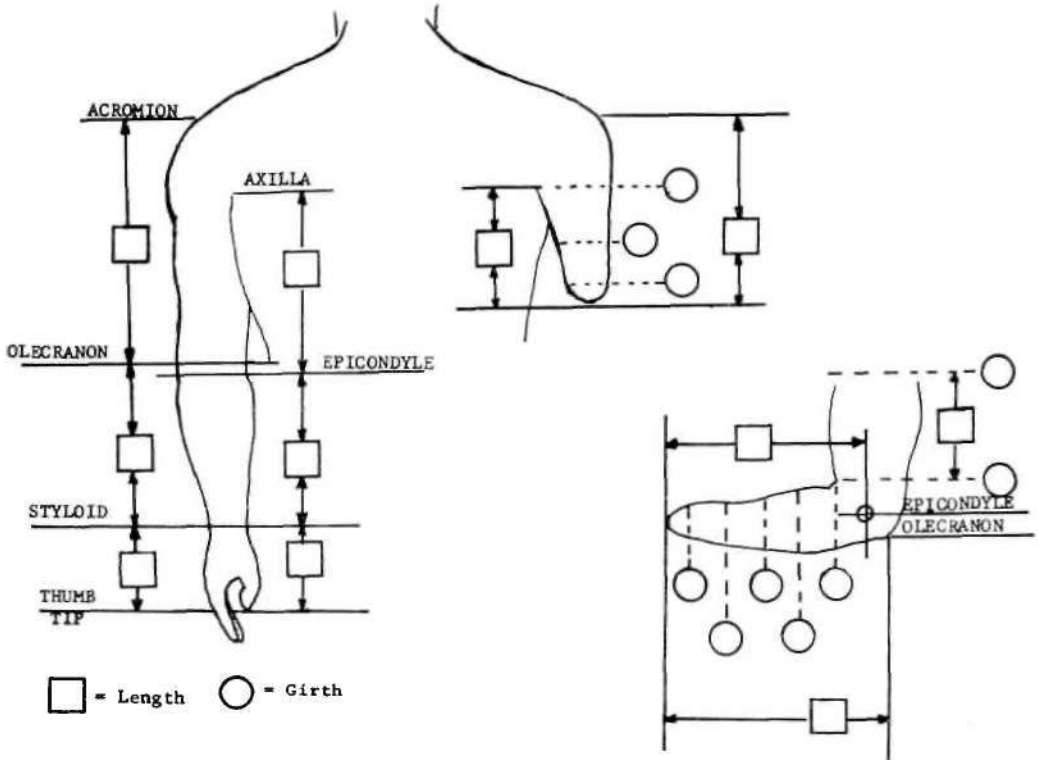


Fig. 6. Measurement form.

up to the limit of the short below-elbow classification (55 per cent). The fitting of longer stumps involves consideration on an individual basis of the factors discussed.

BILATERAL FITTINGS

The question of fitting Miinster-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 elbow flexion, particularly on the dominant side.

NYU has had no experience in fitting children bilaterally but has successfully fitted one bilateral adult amputee (4-in. and 5-1/2-in. 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.

PROCEDURES

STUMP EXAMINATION AND MEASUREMENTS

Materials required for stump examination and measurements are:

- Measuring tape
- Ruler
- Goniometer
- Measurement form (Fig. 6)

A thorough stump examination is an important prerequisite to any prosthetic fitting procedure. In the Miinster-type fitting, a 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.

Consistent with sound prosthetics practice, it is advisable to follow the conventional measurement procedures described in the *Manual of Upper Extremity Prosthetics* (6) so that a com-

prehensive record will be available for future reference. The appropriate below-elbow measurements are recorded on the modified Upper-Extremity Measurement Chart shown as Figure 6. 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 pleasured 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.

Stump length: The stump length is measured from the posterior aspect of the olecranon (Fig. 7). If distal redundant tissue is present, the measurement should include the redundancy.

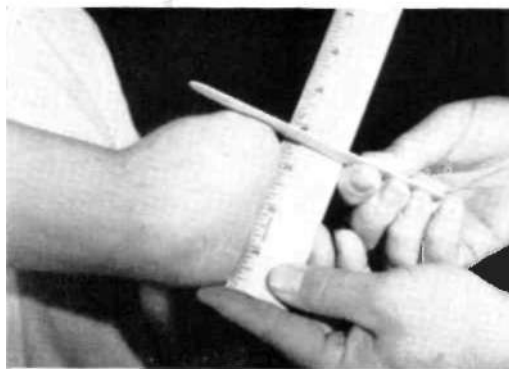


Fig 7. Measuring stump length.

Forearm length: With the patient's sound forearm flexed at approximately 90 deg., and held midway between pronation and supination, measurements are made 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 (Fig. 8).

THE WRAP CAST

Materials required to take the wrap cast are:

- Cotton stockinette (appropriate size for stump)

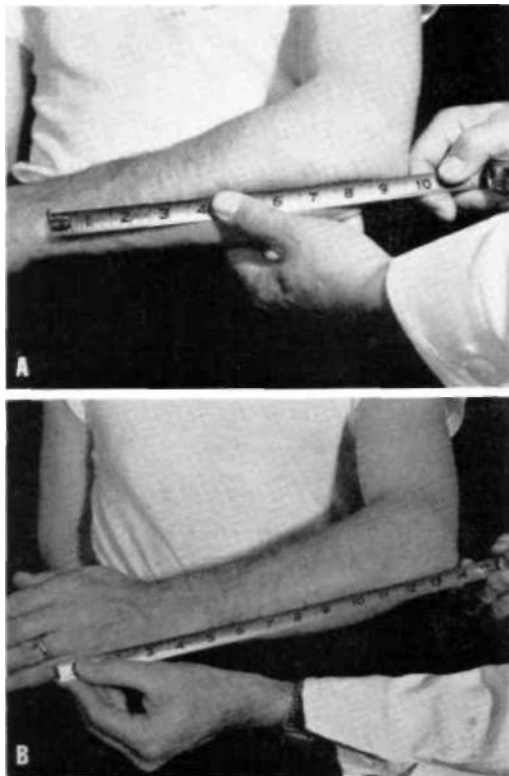


Fig. 8. Measuring forearm length. A, Measuring from the proximal aspect of the olecranon to the distal aspect of the ulnar styloid; B, measuring from the olecranon to a point on the ulnar border of the hand which corresponds to the thumb tip.

Dacron tape for temporary harness
 Yates clamps
 Indelible marking pencil
 Three rolls of plaster-of-Paris bandage
 (6 or 8 cm. elastic-type preferred)
 Pail of water

A snug, form-fitting cotton stockinette is placed over the stump to insulate the skin and hair from plaster. The assistance of the amputee or a temporary figure-eight harness may be used to keep the stockinette free from wrinkles. The harness method is generally preferable for children.

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 better able 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 child amputees sit on a table or stand on a raised platform.



Fig. 9. Practicing the molding grip. The prosthetist exerts moderate pressure on either side of the biceps tendon.

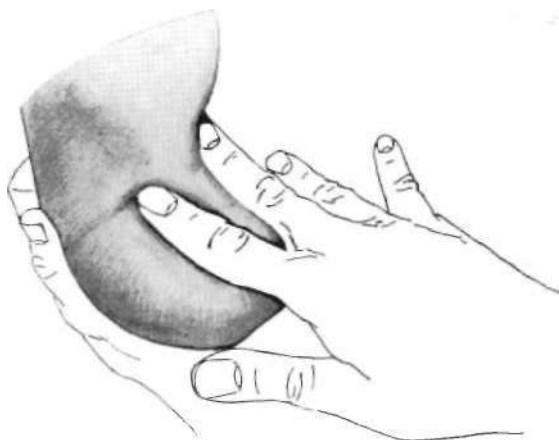


Fig. 10. Another view of the prosthetist exerting pressure on either side of the biceps tendon, simultaneously into the cubital fold and downward on the anterior surface of the stump.

In this article, 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 the correct molding grip, this aspect of the fabrication procedure is illustrated with both photographs and drawings.

With the amputee's stump flexed to 90 deg., the index and middle fingers of the prosthetist's right hand are placed on the anterior surface of the stump. The prosthetist's right 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 ante-

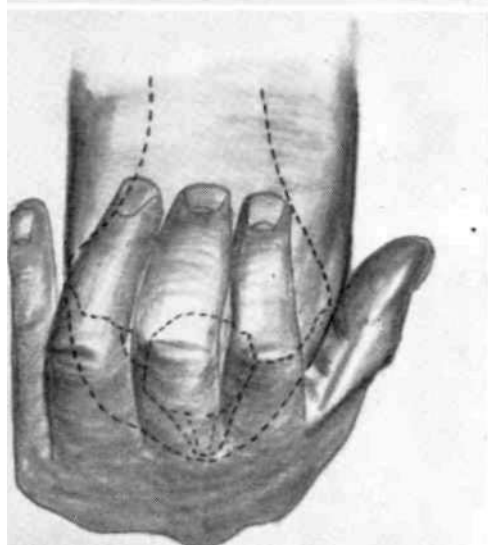


Fig. 11. Practicing the molding grip. *A*, The wedge-shaped ulna as viewed from the rear; *B*, channel formed in the prosthetist's hand; *C*, the ulna fitted into the channel.

rior surface of the stump. Moderate pressure is exerted (to the point of firm resistance) simultaneously into the cubital fold and downward on the anterior surface of the stump, but an concentration of pressure distally is avoided (Figs. 9 and 10).

The dorsal aspect of the proximal ulna is distinctly wedge-shaped. The prosthetist's left hand is shaped so that the thenar and hypothenar eminences form a channel into which this wedge will fit (Fig. 11). The grooved hand is then positioned against the underside of the stump to provide stability and support without distortion. The metacarpal joints of the prosthetist's left hand should be located just below the amputee's olecranon (Fig. 12).

The index, middle, and ring fingers of the prosthetist's left hand are cupped and positioned on the distal posterior surface of the humerus just above the level of the epicondyles (Fig. 13). Gentle downward pressure is applied with the pads of the fingers. Care must be taken to avoid pressure between the palm of the hand and the olecranon. Thus 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 *not* exert any pressure.

In view of the intimate fit which characterizes the Munster-type socket, tender areas and bony prominences such as the olecranon and the epicondyles must be clearly defined for the provision of the necessary reliefs. While the

stump is flexed at 90 deg., these areas are marked with an indelible pencil so that they may be easily identified on the wrap cast (Fig. 14)".

A preliminary trim line is marked on the cast sock by drawing a line posteriorly connecting two points 1 in. superior to the medial and the lateral epicondyle, respectively; and the



Fig. 13 Practicing the molding grip; gentle downward pressure being applied by the pads of the index, middle, and ring fingers of the prosthetist's left hand.



Fig. 12 Practicing the molding grip; positioning the grooved left hand of the prosthetist against the underside of the stump.



Fig. 14. Marking tender areas and bony prominences

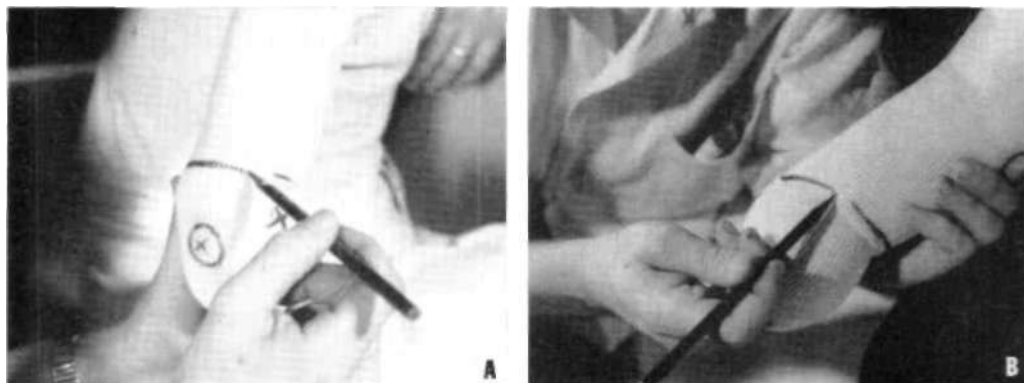


Fig. 15. Marking the preliminary trim line on the cast sock. *A*, A line is drawn posteriorly connecting two points 1 in. superior to the medial and the lateral condyles; *B*, the line is continued to pass anteriorly 1/2 in. above the mid-cubital space.

line is continued anteriorly so that it passes through a point 1/2 in. above the mid-cubital space (Fig. 15).

The critical relationship between the stump and the Munster-type socket cannot be over-emphasized. Every effort should be made, therefore, to obtain 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 the patient together may choose the best of the series. Elastic or non-elastic plaster-of-Paris bandages may be used, but the elastic is preferable since it results in a more accurate configuration.

While the stump is flexed at 90 deg. and the humerus is held midway between internal and external rotation, the wrap is commenced with two circular turns above the elbow joint (over the olecranon and the cubital fold). Only very slight tension should be applied to the plaster-of-Paris bandage (either elastic or nonelastic) in the process (Fig. 16A). The wrapping proceeds to the distal end of the stump in a figure-eight or a spiral pattern (Fig. 16B). The wrap is continued at least 1/4-in. above the reference marks made earlier.

When the wrapping has been completed, the molding grip practiced earlier is applied (Fig. 17). Finger pressure should be sufficient to displace all loose tissue (to the point where firm resistance is reached). Pressure is maintained until the plaster has set.

After the plaster has hardened, the proximal end of the wrap cast is reinforced with several

turns of nonelastic plaster-of-Paris bandage in order to minimize distortion. Then the stockinette is pulled down over the cast (Fig. 18A). As the cast is gently worked off the stump, upward pressure is applied to the arm to increase skin tension at the proximal end of the cast in order to break the vacuum seal (Fig. 18B).

The stockinette is removed from the cast, and the indelible markings which have been transferred from the stockinette to the inner wall of the cast are accentuated (Fig. 19).

These procedures should be repeated until a minimum of two, and preferably three, casts have been taken.

THE CHECK SOCKET

Materials required to prepare the check socket are:

- Knife
- Scissors
- Fresh plaster
- Water

All of the wrap casts taken should be prepared in accordance with the procedures described below and used as check sockets. The one agreed upon by both the prosthetist and the patient as providing the most comfortable fit and the greatest range of motion and maximum security is selected for use in the preparation of the positive plaster model.

A hole is cut in the cast, just large enough to allow the passage of a stump pulling sock and as



Fig. 16. Wrapping the stump. A, The wrap is begun with two circular turns around the elbow joint—over the olecranon and the cubital fold; B, the distal end of the stump is included in either a figure-eight or a spiral pattern; C, the wrap is continued at least 1/4 in- above the reference marks made earlier.

close to the distal end as possible so that shortening of the cast is minimized (Fig. 20A). The final trim lines for every socket must be determined individually for each amputee. However,



Fig. 17. Application of the molding grip to the wrap cast.

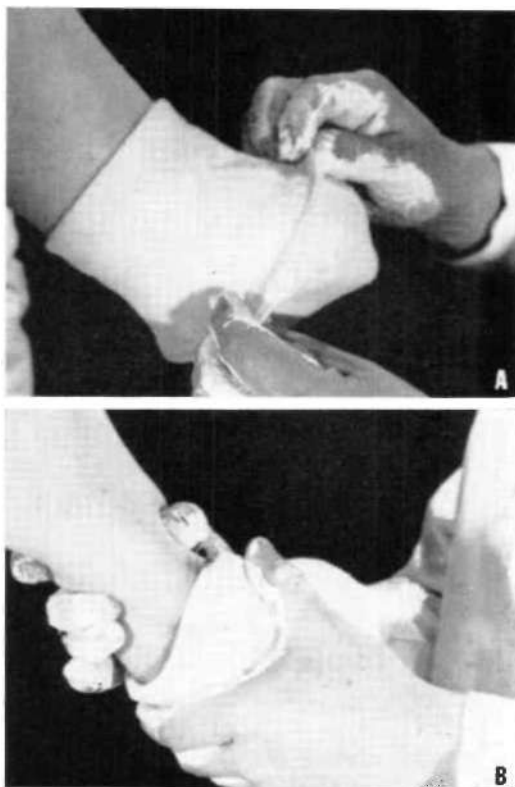


Fig. 18. Removal of wrap cast. A, Pulling the stockinette down over the cast; B, applying upward pressure on the arm as the cast is gently worked off the stump.

as an initial step, the proximal end of the cast is trimmed to the level of the reference line made earlier (Fig. 20B).

The cast is then moistened, and the inside of

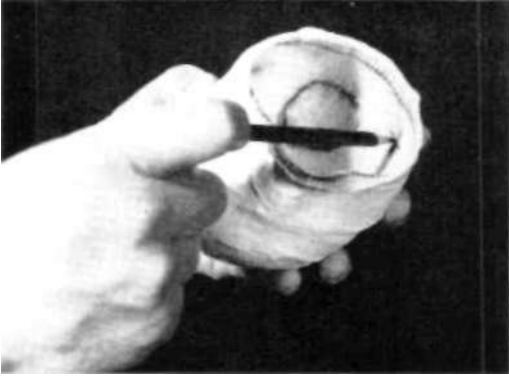


Fig. 19. Accentuating the indelible markings transferred from the stockinette to the inner wall of the cast.



Fig. 21. Smoothing the inside of the cast.

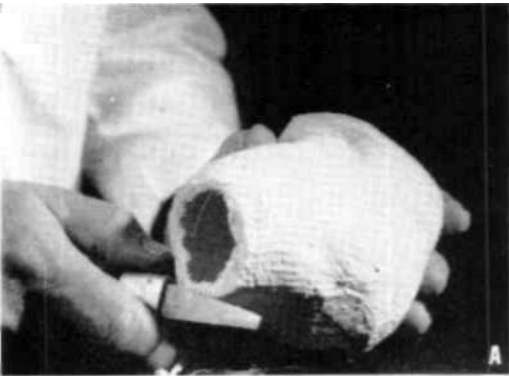


Fig. 20. Trimming the cast. *A*, The hole cut in the distal end should be just large enough to permit passage of a stump pulling sock; *B*, trimming the proximal end at the level of the reference line made earlier.

the cast is smoothed with fresh plaster to remove all gauze marks, except in the area of the epicondyles and the olecranon (Fig. 21). *No* plaster should be added in these critical areas.

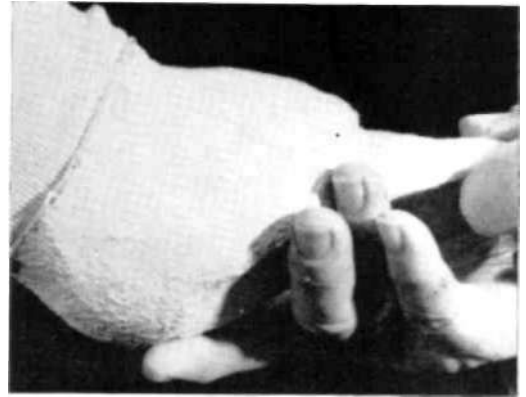


Fig. 22. Pulling the stump into the check socket.

FITTING THE CHECK SOCKET

Materials required for fitting the check socket are:

- Cotton stockinette (stump pulling sock)
- Indelible marking pencil

A length of stockinette is placed on the amputee's stump, and the distal end of the stockinette is drawn through the hole in the check socket. The stump is pulled into the socket, care being taken that all flesh is drawn inside the cast (Fig. 22).

With the check socket on the amputee, the usual tests are made for adequacy of fit, comfort, and range of motion by having the amputee exert force against resistance in elbow flexion, extension, and rotation (Fig. 23). 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



Fig. 23. Determining the adequacy of the fit.



Fig. 24. Marking an area which requires relief.

socket is not satisfactory, the socket should be rejected.

If the check socket causes any pain or discomfort, the appropriate area should be marked on the outside of the socket so that relief can be provided (Fig. 24).

The same procedures are repeated with the other check sockets and the best socket is selected for use in completion of the prosthesis.

ESTABLISHING THE RANGE OF MOTION IN CHECK SOCKETS

The maximum forearm flexion and extension positions attainable with the Miinster-type prosthesis will be significantly less than those achieved in conventional prostheses. Experience has shown that the maximum flexion range for the typical short below-elbow stump fitted with a Miinster-type socket is approximately 70 deg. (from 35 deg. initial flexion to

105 deg. maximum flexion) (1,3). 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 attributable to one or more of the following conditions:
 - Insufficient relief for the olecranon
 - Too small a channel for the biceps tendon
 - Too high an anterior wall
2. Restriction in extension attributable to too high a posterior trim line.

However, it must be emphasized that lowered trim lines or loose fit will adversely affect the 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 or increased range of motion, or both.

Materials required in establishing the range of motion are:

- Indelible pencil
- Scissors or knife
- Goniometer
- Ruler

A line is drawn on the lateral side of the check socket coincident with its long axis (from the lateral epicondyle to the mid-distal end) to serve as a guide in measuring flexion and extension (Fig. 25).

The center of the goniometer is placed on the lateral epicondyle. The lower arm of the goniometer is placed on the long axis line, and the upper arm of the goniometer is lined up with



Fig. 25. Drawing a line on the check socket coincident with its long axis.



Fig. 26. Placement of goniometer to measure maximum flexion and extension angles



Fig. 27. Trimming the check socket to provide increased range of motion.

the acromion (Fig. 26). Maximum flexion and extension angles are measured from these points of reference.

If motion is restricted, the specific cause for the restriction should be determined and corrective action should be taken (Fig. 27).

If the amputee cannot achieve the proposed 35 deg. of initial flexion in the check socket, the discrepancy is compensated for in the alignment of the forearm shell. Therefore, while the stump is maintained in an actively extended position, a second line is drawn on the check socket at an angle of 35 deg. between the humerus and the stump (Fig. 28). This line will serve as a guide in aligning the forearm shell.

The adequacy of the proposed initial flexion angle is tested by placing a ruler along the 35-deg. line drawn on the check socket (Fig. 29). The ruler is placed to correspond to the intended length of the finished prosthesis; that is, the olecranon-to-thumb-tip measurement



Fig. 28. Drawing a second line at a 35-deg. angle between the humerus and the stump to serve as a guide in aligning the forearm shell.

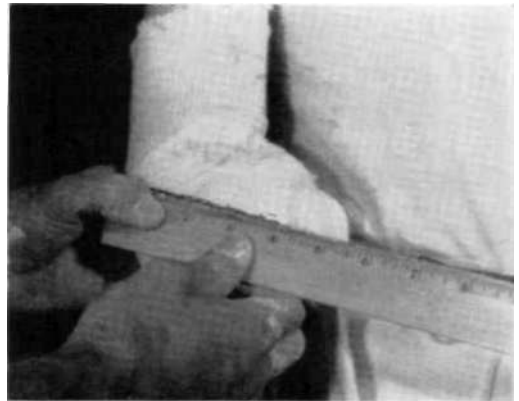


Fig. 29. Placing a ruler along the 35-deg. line to test the adequacy of the proposed angle of initial flexion.

recorded on the Upper-Extremity Measurement Form (Fig. 6).

The amputee should flex and extend this improvised forearm composed of the check socket and the ruler (Fig. 30). Maximum flexion should be about 105 deg., except for very-short stumps, where it probably may not exceed 90 deg. Because of the inherent limitation of motion associated with the Münster-type prosthesis, 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.

If the maximum flexion angle obtained with 35 deg. of initial flexion is not acceptable, the angle of the ruler is adjusted to provide greater



Fig. 30. Checking the flexion and extension of the improvised forearm composed of check socket and ruler.

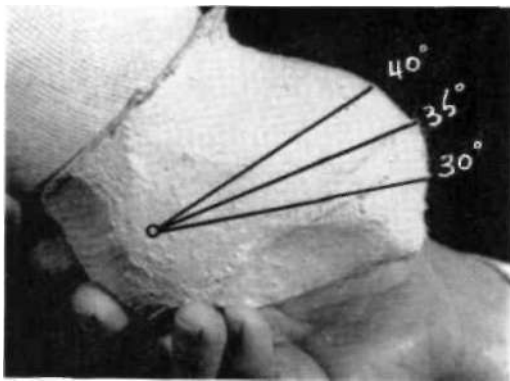


Fig. 31. Alternative angles of initial flexion: 30 deg., increased extension, decreased flexion; 40 deg., increased flexion, decreased extension.

initial flexion. Initial flexion angles to a maximum of 45 deg. have been used, but at the expense of decreased cosmesis (Fig. 31). If less than 35 deg. 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.

PREPARATION OF THE POSITIVE MODEL

Materials required for the preparation of the positive model are:

- Plaster-of-Paris bandage
- Talcum powder
- Hollow pipe (approximately 12 in. in length and 1/2-in. in diameter)

- Awl
- Two roundhead screws
- Fresh plaster
- Water
- Sanding screen
- Indelible marking pencil
- Vaseline or other parting agent

The distal end of the check socket is closed with plaster-of-Paris bandage or with masking tape (Fig. 32) and a small extension (approximately 1 in.) is constructed at the proximal end of the check socket (Fig. 33), again with plaster-of-Paris bandage or with masking tape. This extension will provide the prosthetist with a margin of safety in smoothing the positive stump model without disturbing the desired trim line.

After the inner surface of the check socket has been sprinkled with talcum powder, the

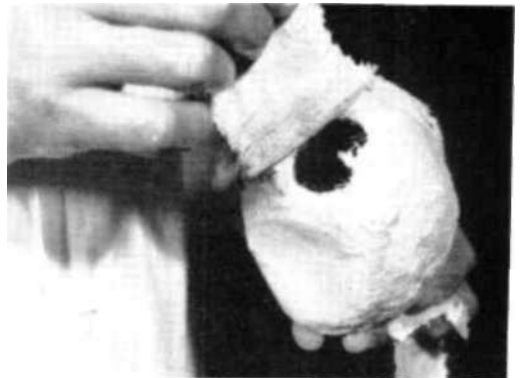


Fig. 32. Closing the distal end of the check socket.



Fig. 33. Construction of extension at proximal end of the check socket

check socket is filled with liquid plaster of Paris (Fig. 34). Before the plaster hardens, a hollow pipe is inserted into the plaster. A recess approximately 1 in. to 1-1/2 in. deep is made in the plaster at the proximal end of the mold. A small hole, approximately 1/4 in. in diameter, should be drilled in the pipe toward the bottom of the recess to facilitate vacuum lamination.

After the positive model has hardened, the check socket is punctured with an awl at the proximal and distal ends of the forearm-extension reference line (Fig. 35). The punctures should penetrate into the positive stump model. An indelible pencil is inserted into the holes to mark the positive model.

The plaster wrap (check socket) is removed, and major irregularities, for example, super-

fluous plaster, are trimmed from the positive model (Fig. 36). All reference marks should be accentuated on the positive model.

The junction between the positive model of the stump and the mold extension is faired with liquid plaster of Paris to provide a smoothly curved radius (Fig. 37).

The olecranon area on the positive stump model is built up approximately 1/16 in. with liquid plaster of Paris (Fig. 38). This build-up will provide additional relief for this bony prominence.

The distal end of the positive model is built up approximately 1/2 in. with liquid plaster of Paris. This build-up will increase the length of the socket slightly and provide space for the hole through which the stump sock is pulled (Fig. 39).

The positive model is sanded smooth, and roundhead screws are inserted into the two reference holes made on the lateral side of the



Fig. 34. Check socket filled with liquid plaster of Paris and a hollow pipe inserted into the plaster. The small hole drilled in the pipe will facilitate vacuum lamination.

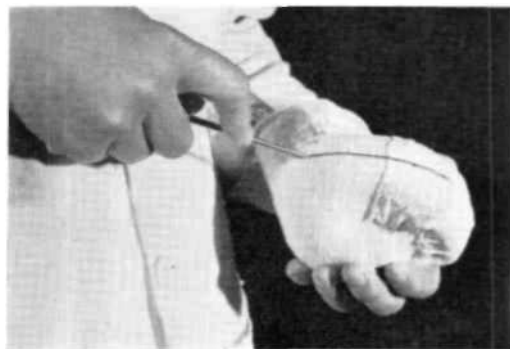


Fig. 35. Puncturing the check socket with an awl in order to mark on the positive model the proximal and distal ends of the forearm extension reference line.



Fig. 36. Trimming irregularities from the positive stump model.

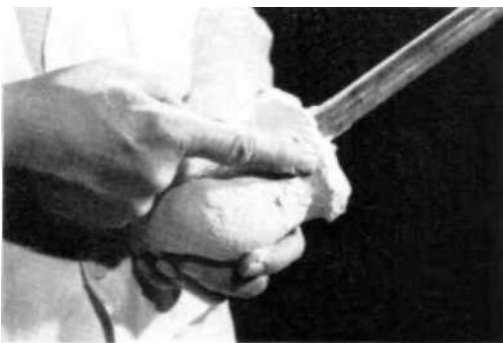


Fig. 37. Fairing the juncture between the positive model and the mold extension.



Fig. 38. Building up the olecranon area on the positive model to provide relief for this bony prominence.

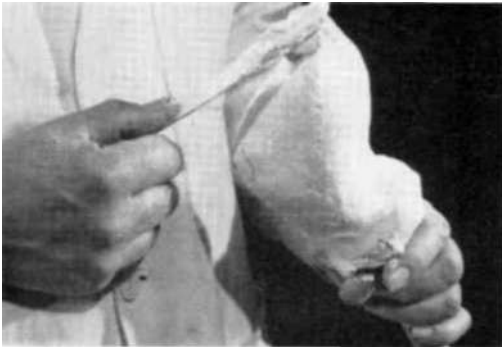


Fig. 39. Building up the distal end of the positive model to increase the length of the socket slightly and to provide space for the hole through which the stump sock is pulled.

model. These screws will produce projections on the laminated socket through which a line will be drawn to align the forearm extension cone.

LAMINATION

Materials required for lamination are:

- Drill with 1/8-in. bit
- PVA sheets
- Dacron blanketing
- Nylon stockinette
- Polyester resin
- Promoter
- Masking tape
- Vacuum pump
- Wrist unit
- Manila paper

The socket and forearm shell are laminated in accordance with standard procedures (6). Vacuum lamination (7) is recommended to provide a truer reproduction of the model.

Holes, 1/8 in. in diameter, are drilled through the undercut areas at the proximal end of the positive model in order to draw the PVA bag into those areas during vacuum lamination (Fig. 40). The holes should exit in the vicinity of the previously mentioned hole in the pipe.

After the stump model has been lubricated, the inner PVA bag, dacron blanketing (for a smoother inner surface), the nylon stockinette, and the outer PVA bag are applied in the usual manner (6), under a vacuum pressure of 12 in. of mercury (Fig. 41). (This is equivalent to 5.9 psi.)

Polyester resin is applied in the standard manner (6,7). Special attention should be paid to working the resin into the undercut areas (Fig. 42). The layup is oven-cured as usual.

After the socket has cured, an opening is cut in the extreme distal end of the socket (Fig. 43). The hole should be of sufficient diameter to allow the passage of the stump pulling sock.

A reference line is drawn on the outer wall of the socket by connecting the two screwhead projections. A forearm extension cone is applied in the usual manner, with the long axis of the cone coincident with the reference line (Fig. 44).

The lamination procedure for the forearm is the same as for the socket, except that dacron blanketing is not used (Fig. 45). The forearm extension may be laminated as a separate sec-



Fig. 40. Drilling 1/8-in. holes through undercut areas at proximal end of the positive model to draw in PVA bag during vacuum lamination.



Fig. 41. Inner PVA bag, dacron blanketing, nylon stockinette, and outer PVA bag ready for lamination on lubricated stump model.



Fig. 42. Working resin into undercut areas.



Fig. 43. Cutting an opening in the distal end of the socket to allow passage of the stump pulling sock.

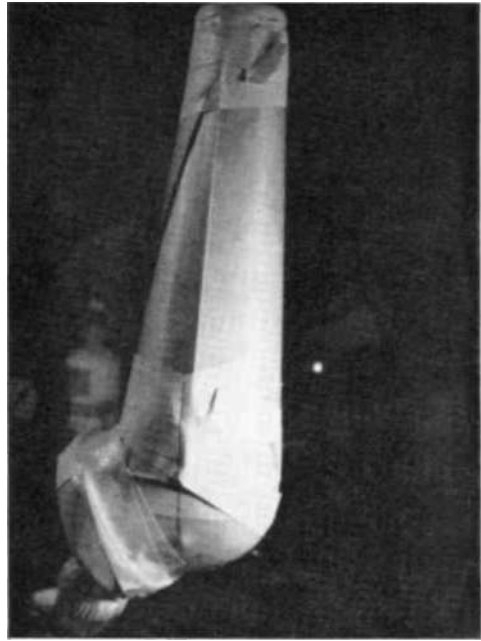


Fig. 44. Forearm extension cone aligned with reference line established by screwheads on socket.

tion or directly over the socket, using a wax melt-out. Both procedures work satisfactorily.

After the forearm laminate has been cured, the prosthesis is cut along the proximal socket brim and the mold is broken out.

FITTING OF THE PROSTHESIS

A 1-in. hole is drilled through the medial wall of the forearm shell close to the distal end of the inner socket to permit passage of the

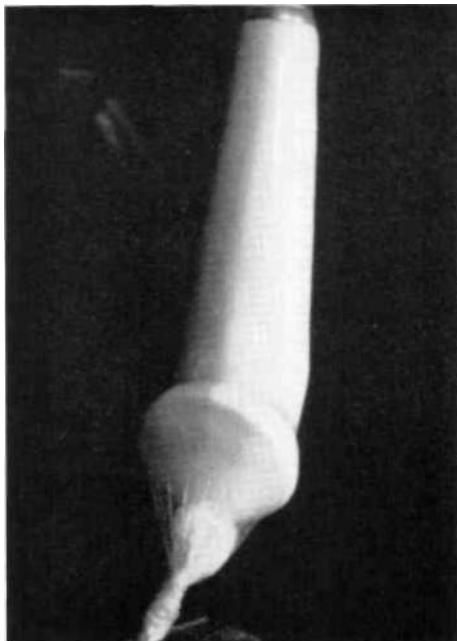


Fig. 45. Forearm extension laminated over socket and cone.



Fig. 46. Polishing the edges of the hole for the stump pulling sock.

stump pulling sock. The edges of the hole are polished with a grinding cone (Fig. 46).

Wearing a length of stockinette (approximately 8 to 10 in.) as a stump sock, the amputee inserts his stump into the socket and pulls the distal end of the sock through the hole (Fig. 47). The application of tension on the stump sock facilitates the complete insertion



Fig. 47. Application of tension on the stump sock facilitates the complete insertion of the stump into the socket.



Fig. 48. Checking the adequacy of socket fit,

of the stump into the socket. The sock is left on the stump and the end of the sock is tucked into the forearm shell.

The socket is checked for the adequacy of fit. Reliefs are provided and trim lines are modified (Fig. 48) where necessary for comfort and range of motion.

HARNESSING

Three different harness arrangements have been used successfully at New York University with the Munster-type sockets.

Initially, the arms were fitted with a conventional figure-eight harness with triceps pad, flexible hinges, and inverted Y-strap. However, the intimate stump encapsulation, flexion attitude, and high trim lines of the Munster 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 Xew York University stud}' with adult amputees were able to resist high axial loads (in the order of 50 lb.) 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 axilla-loop harness systems which will be described have proved adequate for most patients.

The conventional harness is fabricated according to standard prosthetics 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 triceps pad constructed of light-gauge aluminum covered with leather was used exclusively (Fig. 49). The general pattern of the templates used as a guide in shaping this pad is shown in Figure 50. The exact size of the

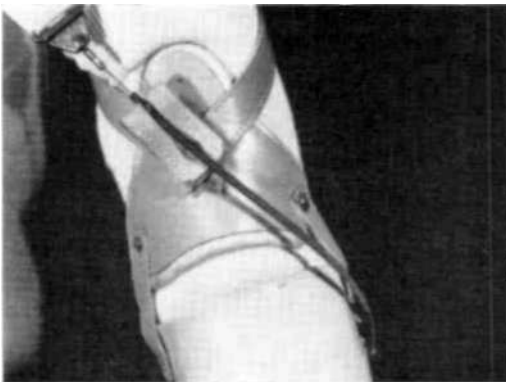


Fig. 49. View of conventional harness showing triceps pad fabricated of light-gauge aluminum covered with leather.

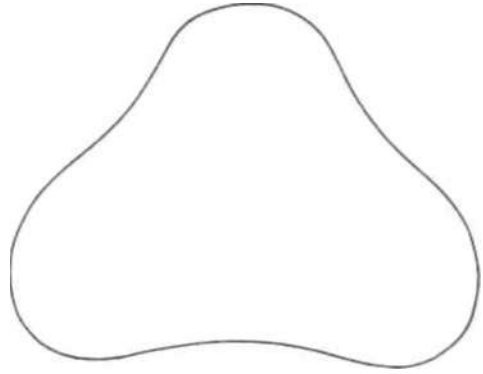


Fig. 50. Pattern of template for triceps pad (not actual size).

template for each subject is determined as follows:

1. The width is equal to one-half the circumference of the arm measured just above the epicondyles.
2. The length is three-quarters of the width.

There is no significant functional difference in the two simplified axilla-loop harness systems. In one system the reaction point is located at the proximal socket, while in the other it is located over the triceps. The choice between the two systems depends upon the amputees' preferences regarding the position of their control cables.

To locate the reaction point on the proximal socket, a standard housing crossbar assembly is riveted to the *midline* of the posterior wall of the socket approximately 1/2 to 3/4 in. distal to the proximal brim (Fig. 51). The crossbar portion of the loop is directed upward.

The distal retainer base plate is located 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 crossbar and the terminal device.

The cable-housing assembly is attached in the usual manner. The cable should be maintained as short as possible without interfering with function in order to reduce the incidence of the cable rubbing on the flesh or clothing.

The harness is completed with an axilla-loop arrangement (Fig. 51). An additional suspensory strap (that is, a front-support strap) or flexible hinges are not needed.



Fig. 51. Simplified axilla-loop harness with reaction point on proximal socket. *Upper*, standard housing crossbar assembly riveted to the midline of the posterior wall of the socket. *Lower*, harness completed with an axilla-loop arrangement.

The simplified axilla-loop system is appropriate for most patients. But some patients will object to the low position of the control cable, which may interfere with the sleeves of shirts or blouses. To meet such objection, the reaction point may be located on a small leather triceps pad (3 in. X 3 in.) (Fig. 52). A small

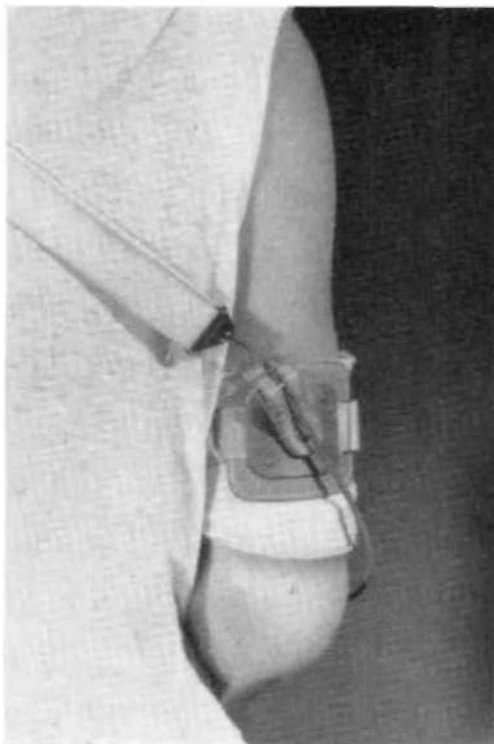


Fig. 52. Reaction point on small triceps pad.

strap, preferably Velcro, is sewn across the middle of the posterior surface of the triceps pad to provide a means of securing the pad to the arm. A standard housing crossbar assembly is attached over the strap and centered on the triceps pad. The distal retainer base plate is placed on the forearm in the same manner as described in the previous system. The cable-housing assembly is attached in the usual manner. The harness is completed with an axilla-loop arrangement.

CHECKOUT PROCEDURES

Standard below-elbow checkout procedures (1,6) are applied to the Munster-type prosthesis and the usual requirements should be met except for the following:

1. Since prosthetic forearm rotation is eliminated, the pronation-supination measure is not applicable.
2. Since a decreased flexion range is an integral feature of the socket, the checkout standard of a 10-deg. loss of flexion with prosthesis does not apply. Maximum flexion for most amputees will range between 100 deg.

and 115 deg., which may be approximately 30 deg. less than stump flexion with the prosthesis off.

3. Because of the decreased elbow flexion, the requirement for opening of the terminal device at the mouth may not apply. However, full opening of the terminal device should be available at maximum flexion of the elbow.

In following the checkout procedures, particular attention should be paid to the unique features of these sockets; namely, the critical importance of the fit of the socket around the epicondyles and olecranon and the built-in suspension of the sockets. The application of compression and torque forces (particularly a vertical downward force at the terminal device with the elbow flexed at 90 deg.) should indicate the presence of any pressure areas around the elbow. Additionally the axial-load test (1,3)—application of a vertical downward force at the terminal device with the elbow fully extended—should reveal any deficiencies in the suspension feature of the sockets.

It must be recognized, however, that, because of the close fit of the socket over the epicondyles and olecranon, some adults will not be able to tolerate the accepted axial-load standard of 50 lb. (or, for children, one-third of the body weight). Special caution to avoid injury to the amputee should be taken when

applying the axial-load force. Failure to meet the 50-lb. standard should not in itself be sufficient cause to reject the prosthesis.

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