Studies of the Upper-Extremity Amputee

V. The Armamentarium

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One of the most interesting aspects of the evaluation procedures is concerned with comparisons between the prosthetic equipment worn by the participating amputees prior to the NYU Field Studies and that later provided as part of the studies. Some amputees entering the program were found to be wearing modern arms based on the latest components and materials and constructed according to the latest methods of fabrication. Others had outmoded and sometimes outworn prostheses. And a third group either had never worn prostheses before or else were not wearing a prosthesis at the time the program began. Accordingly, the data gathered were not only on the new program prostheses but also on the old arms previously worn, if any, and hence the present analysis deals not only with the effects of program arms but also to a considerable extent with comparisons between the old and the new prostheses.[3] Of the 1630 arm amputees involved in the NYU Field Program, 359 were available for comprehensive investigation throughout the period covered by the evaluation studies. Of the 359, which together form the basis for this discussion, 168 were below-elbow amputees, 158 were above-elbow amputees, 23 had shoulder disarticulations, and 10 were bilaterals. Those who had prior experience with prostheses were used to form the comparative analysis of old *vs.* new.

Although the subjects making up the group were generally available for intensive study, it was not possible to obtain from every amputee an answer to every question. In other instances, the investigators received multiple responses to questions. Moreover, certain areas of investigation called for responses in relation to the number of components involved, in which case the number of responses varied with the bilateral group and with those patients who utilized more than one terminal device. Although the reflection of these factors in the data causes some inconsistency in numbers of replies, it does not reduce the over-all value of the results.

For purposes of identification, all prostheses worn by the amputees prior to inception of the NYU Field Studies are here referred to as "old prostheses" or "preprogram arms," although in a few cases they were rather new and reflected some of the latest techniques and components. All prostheses fitted during the course of the research studies are identified as "program" or "new" prostheses, although some of the components and techniques had for some time enjoyed either limited or general use in the prosthetics field. While the "old prostheses" represent an admixture of various techniques and components, some old, some new, the "program prostheses" represent the best of the old plus the latest innovations in the field of limb prosthetics at the time.

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[3] The data reported here were all recorded on forms similar to those shown in Appendices IIB, IIIA, and HID of the issue of ARTIFICIAL LIMBS for Spring 1958 (pp. 25-28, 29-31, and 40-45).

In passing, it should perhaps be noted that the data concerned were for the most part gathered on program prostheses fabricated shortly after the prosthetists' completion of the prosthetics courses at the University of California at Los Angeles. The skills and experience available for handling the latest components, materials, and techniques were therefore somewhat limited during the early days. As experience and attendant skills increased, the quality of the prostheses improved. No apology for the program treatment procedures and prostheses (which, as will be seen, were clearly superior to preprogram efforts), this circumstance indicates that expansion of present gains can be expected as prosthetists and prosthetics clinics continue to accumulate experience with latest procedures.

TERMINAL DEVICES

The artificial hand or hook is generally considered to be the most important single component of an artificial arm. A major functional purpose of all other components of the upper-extremity prosthesis is to make it possible for the terminal device to be positioned and the function of grasp to be utilized. Moreover, the hook or hand is important from the standpoint of aesthetics, since it is exposed to view almost constantly and is a matter of curiosity to all who recognize it as a prosthetic device. Today's prosthetic armamentarium presents a choice, from a selection of hooks and hands, of terminal devices most likely to meet the wearer's needs. Within this framework are devices which operate on the voluntary-opening or the voluntary-closing principle *(3)*. Available hands are either essentially cosmetic or else are designed to provide prehension as well as cosmesis *(6,7)*. Either type permits the functions of pushing, pulling, and holding down objects.

Were any one of these devices completely satisfactory, it would enjoy exclusive use by all wearers of arm prostheses. Since such is not the case, amputees frequently interchange two or more terminal devices, say a hand and a hook, and some even interchange two hooks of different shapes and operational characteristics. In any event, many factors influence the selection of terminal devices *(2)*, so that whatever is chosen usually represents a compromise based upon consideration of the psychological, environmental, and biomechanical circumstances of the individual amputee.

THE APRL HAND AND GLOVE

One of the most widely publicized developments in the Artificial Limb Program has been the APRL voluntary-closing terminal devices —the APRL hook and the APRL hand with its companion glove of plasticized polyvinyl chloride *(3,6,7)*. Prior studies *(8,9)* had established the usefulness of these devices, and the Upper-Extremity Field Studies presented a unique opportunity to introduce these items into many more clinics over the country and to obtain additional information concerning the value of the devices to amputees. The APRL hand was therefore prescribed in almost all research cases where a prosthetic hand was indicated (285 out of 291). Four patients expressed strong desires to continue with voluntary-opening hands, while two others elected to continue with passive, cosmetic hands.

Tests showed that grasp forces available with the APRL hand, in which grasping force is related directly to the force that can be exerted by the wearer, were much higher than those to be had with other types of functional hands. Almost all wearers of the APRL hand (89 percent) could exceed 20 lb., a force not uncommon in the palmar prehension of non-amputees *(11)*. Voluntary-opening mechanical hands, in which the force is limited to that available from springs or rubber bands, showed a maximum prehension force of 5 lb.

When these tests were completed, the subjects were questioned regarding their reactions toward the APRL hand in the areas of usefulness, appearance, ease of operation, and weight.

Usefulness

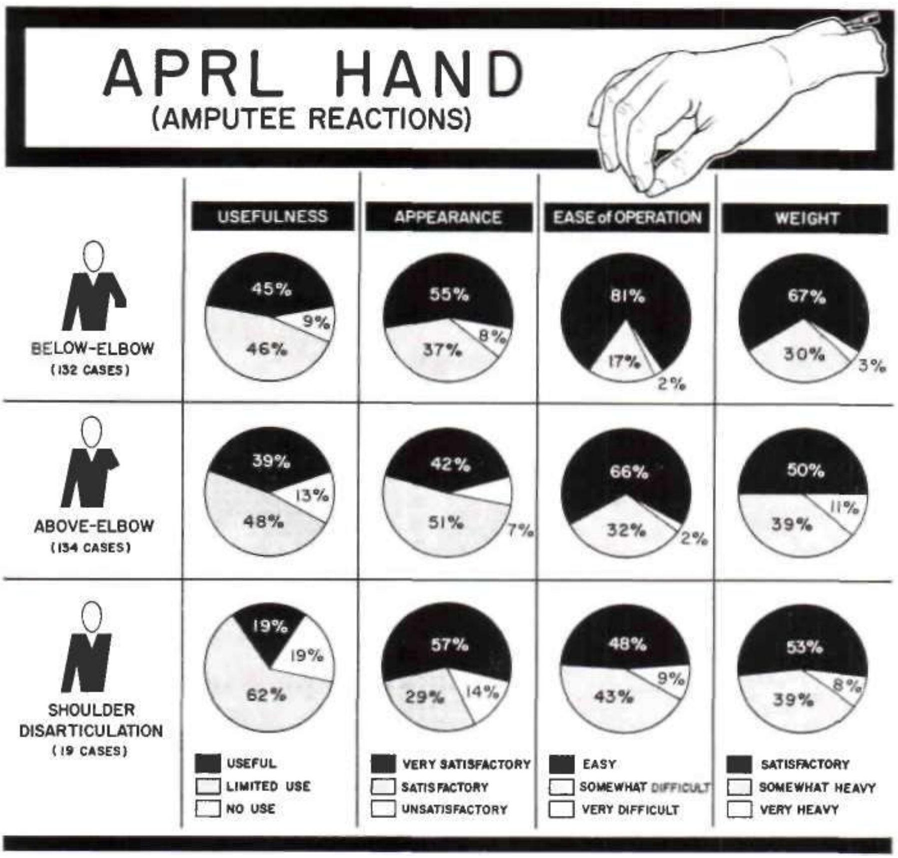
Most of the amputees considered the APRL hand to be a useful device or at least one of limited use. Less than 12 percent considered the hand to be of no use. But the pattern of responses clearly indicates that the hand becomes less useful to the wearer as the level of amputalion becomes higher, presumably owing to the increased difficulty of using a prosthesis with decreasing stump lengths.

The ability to control grasp and to maintain it (by automatic locking) was well received by 50 percent of the amputees for whom APRL hands had been prescribed, and increased function over a wide range of activities elicited important voluntary comments from another 27 percent. The choice of using either the large or the small finger opening prompted positive comments by 11 percent of the sample. When comparisons were made of the amputee reactions to usefulness, the APRL hand was rated considerably higher than other types of hands previously worn.

Appearance

Noted was an exceptionally high degree of amputee satisfaction with the appearance of the APRL hand. As might have been expected, level of amputation did not seem to influence the wearers' reactions in this area. More than 90 percent of all the amputees felt the APRL hand and glove to be either "very satisfactory" or "satisfactory" in appearance. In no other component of the prosthesis do we have such a large number of amputees exhibiting this degree of positive response.

The size of the APRL hand was felt by 6 percent of the wearers to be a problem. Discoloration and difficulty in keeping the glove clean elicited negative comments from 12 percent of

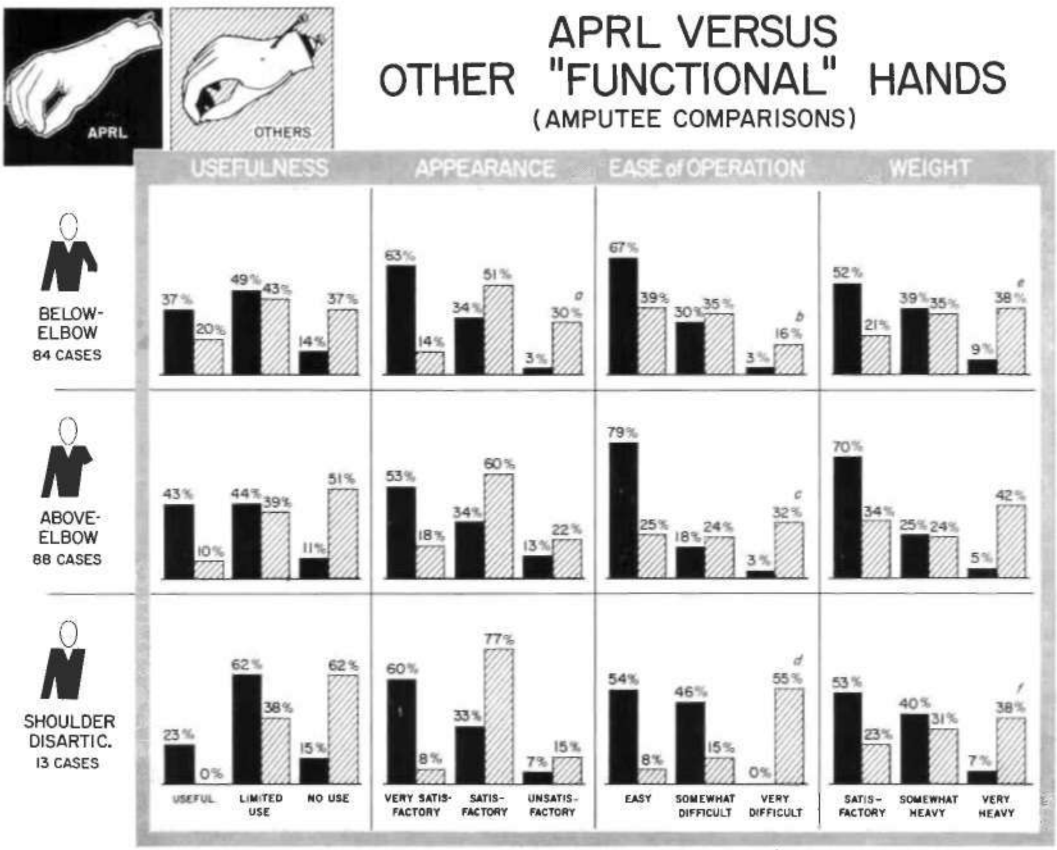


the subjects. Poor wear characteristics of the glove (abrasion, tearing, rubbing through) elicited negative comments from 9 percent of the sample. When amputee reactions to the appearance of the AFRL hand were compared with the corresponding reactions to the appearance of other hands previously worn, the results were very favorable toward the APRL device.

Ease of Operation

Almost 72 percent of the amputees for whom an APRL hand had been prescribed felt that it was easy to operate, another 26 percent considered it somewhat difficult to operate, and less than 3 percent found it very difficult to operate. Below-elbow amputees experienced the least difficulty in hand operation. As expected, fewer found the APRL hand "easy" to operate as the level of amputation became more proximal.

Some of the amputees had worn other "functional" hands prior to the APRL device. When they compared ease of operation of their old prosthetic hand with that of the APRL hand, the APRL model was preferred. It is interesting to note that the shoulder-disarticulation and above-elbow cases exhibited dramatic changes in their reactions to use of functional hands, a fact which would suggest that the APRL hand has much greater applicability than the older hands. For one thing, in the dual-control system *(10,11)* the cable-excursion requirements are lower for voluntary-closing devices than for voluntary-opening devices,



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and this circumstance exerts an important influence on the use of above-elbow and shoulder-disarticulation prostheses. Apparently the additional control motions needed for operation of voluntary-closing devices did not constitute an objection insofar as ease of operation was concerned.

Weight

Judging from amputee opinions relating to the weight of the APRL hand (15 oz. with glove), the below-elbow group found the weight more satisfactory than did any other. In view of the greater residual anatomy in the below-elbow case, this result is generally understandable even though the short below-elbow case, without assistive forearm lift *(1,10)* is at a disadvantage. It is significant to note that 42 percent of all amputees for whom a hand had been prescribed felt that the APRL hand was somewhat heavy or very heavy, an indication that further improvements, aimed at weight reduction, are needed. Nevertheless, amputees who had worn other hands considered the APRL hand lighter. All in all, the wearers' reactions consistently favored the APRL hand.

Discussion

It should be understood that amputee reactions toward the APRL hand were of special interest to the research program. Consequently, many such hands were prescribed not for specific vocational or avocational reasons, nor because of patient interest, but to observe the effects upon a rather large number of amputees who had no specific objections to being fitted on a trial basis. Many confirmed hook wearers were therefore included in the group fitted with APRL hands.

The data show that mass fitting (285) of the APRL hand caused an additional 27 percent of the patients to wear hands on a more or less regular basis. Very few amputees expressed serious over-all negative feelings toward the APRL hand and glove.[4] Apparently, however, 25 percent of the patients for whom APRL hands had been prescribed wore them less than one day a week. Some, after a brief experience with the hand, declined to wear it at all and preferred to return to exclusive use of a hook. Since this response cannot be related to any specific dislike for the APRL hand and glove, it appears to relate more to a basic preference for a hook.

A number of improvements in the APRL hand were suggested during interviews with the amputees. One was that a range of sizes would be most welcome since the one size available at the time was often either larger or smaller than the corresponding normal hand. Amputees with large hands seemed to feel that the APRL hand and glove were too small and effeminate. Another, cited especially by those with the higher levels of amputation, concerned the need for reducing the weight of the APRL hand. Other proposed improvements related to appearance and durability (especially of the glove) and to the complexity of function arising from the double control motion required for locking and unlocking.

In brief, the APRL hand, with its two-position prehension range, its voluntary-closing self-locking mechanism, and its cosmetic glove, showed superior grasp forces and was considered to be more useful, easier to operate, and much better in appearance than other mechanical hands. Although the wearers indicated that weight reduction in the APRL hand would be welcomed, the existing hand was considered more satisfactory than other mechanical hands. Despite these positive findings, it was apparent that design changes directed toward weight reduction, improved durability in the cosmetic glove, establishment of a range of sizes, and simplification of operating requirements would improve the device significantly.

RUBBER-BAND-LOADED HOOKS

The type of hook which, historically, is the standard in the prosthetics field, and the one to which all other designs are compared, is the steel or aluminum voluntary-opening split hook in which the fingers rotate about a single pivot and are held in the closed position by the contraction of rubber bands that stretch during opening (2). Addition of more and more rubber bands increases the maximum available finger forces at the expense of added work in opening.

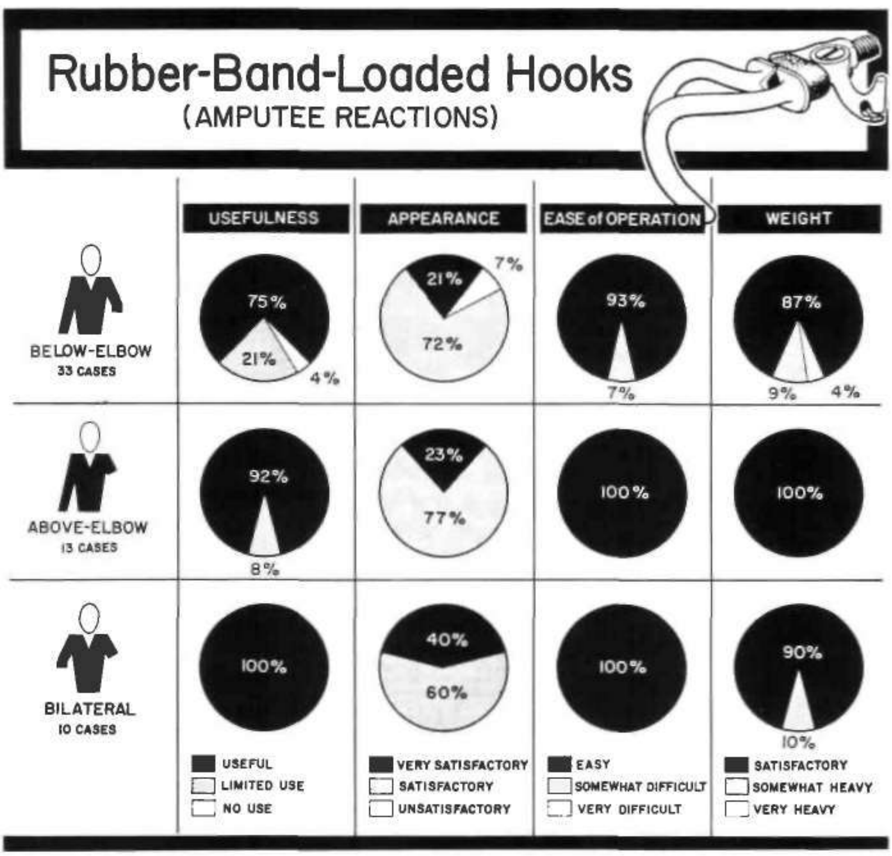
[4] Less than 3 percent had over-all negative reactions to the hand; 6 percent had over-all negative reactions to the glove.

Many variations in finger shape are to be had. Some fingers are lined with rubber to reduce slippage, others are unlined. In the studies concerned, prescription of rubber-band-loaded hooks was often on the basis of previous amputee experience. Sometimes clinical judgment favored them, especially for use with bilaterals, because of the simplicity of operation as compared with voluntary-closing, self-locking terminal devices which, although superior in grasp forces, demand additional control motions, a requirement generally considered to be a shortcoming. In tests involving 68 of these simple hooks as worn by amputee subjects, it was found that the rubber bands had been selected to yield prehension forces ranging from 1 lb. to 14 lb. (average, 4.3 lb.), depending on individual preference.

With regard to usefulness, appearance, ease of operation, and weight, amputee reactions to rubber-band-loaded hooks are rather consistent regardless of level of amputation. Although in general there is a high degree of acceptance, 21 percent of the below-elbow amputees and 8 percent of the above-elbow cases indicated that rubber-band-loaded hooks are of limited use only. Thus again improvement is needed. The subjects themselves suggested more durable rubber inserts for the fingers, elimination of rubber bands, and reduction in the conspicuousness of the hook without reducing its functional value.

SIERRA TWO-LOAD HOOK

A relatively new design for voluntary-opening hooks, which traditionally have used rubber bands for closing, is the Sierra two-load hook featuring a spring to close the fingers *(2,3)*. Heavy or light closing forces are selected by positioning a small mechanical switch



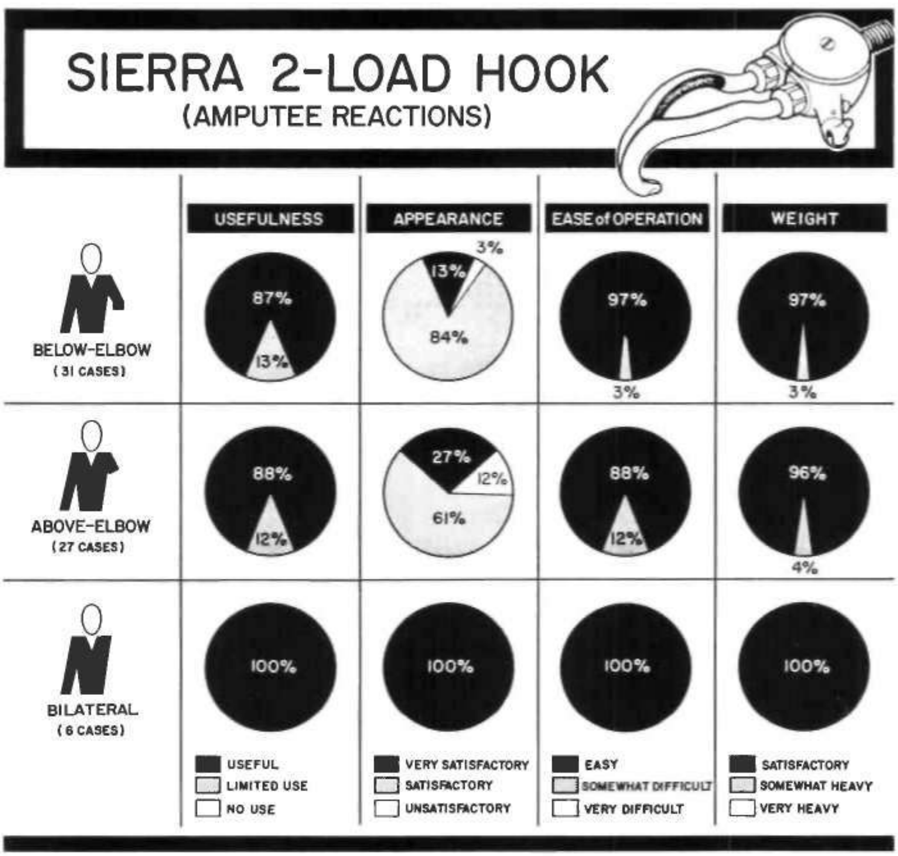
located on the post provided for attachment of the control cable. The case which houses the operating mechanism is made of aluminum, and the hook fingers, also of aluminum, are lyre-shaped and lined with neoprene for increased security of grasp.

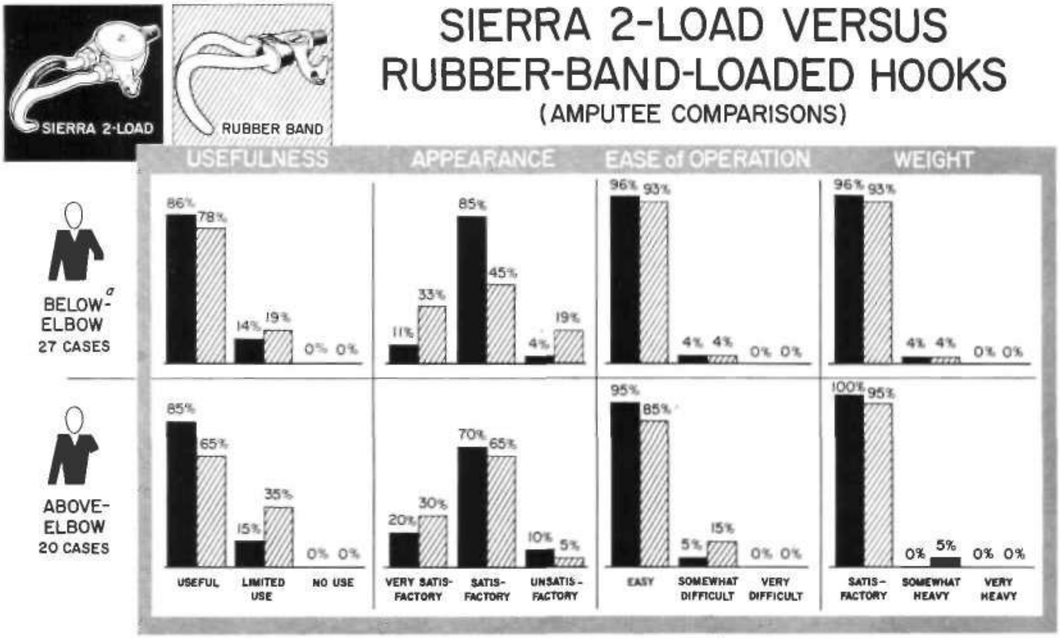
The novel design of the two-load hook, with its simplicity of operation (voluntary-opening) and choice of two grasp forces, interested both clinics and amputees. Consequently, 64 of these devices were prescribed in the study. Data taken on 51 subjects show that pinch forces averaged 3.4 lb. for the light-load setting of the mechanism, 6.6 lb. for the heavy loading.[5]

[6] The prehension forces of the two-load hook are predetermined at time of manufacture and are not readily adjustable as are those in the simpler hooks, where rubber bands can be added or removed.

Amputee reactions to the two-load hook were generally positive insofar as usefulness, ease of operation, weight, and, to a lesser extent, appearance were concerned. As with rubber-band-loaded hooks, there were indications of need for improvement, for 13 percent of the below-elbow amputees and 12 percent of the above-elbow cases indicated that the two-load hook was of limited use only. That 12 percent of the above-elbow amputees felt the device somewhat difficult to operate is a finding hard to interpret, unless perhaps these particular subjects had been accustomed to extremely light loadings on hooks operated by rubber bands.

In general, there was a favorable reaction toward the availability of two levels of grasp force from which to select. Although apparently the light load was used most often, the wearers found that the heavier loading was





[a] *In below-elbow cases wearing rubber-band-loaded hooks, 3% of the wearers did not respond.*

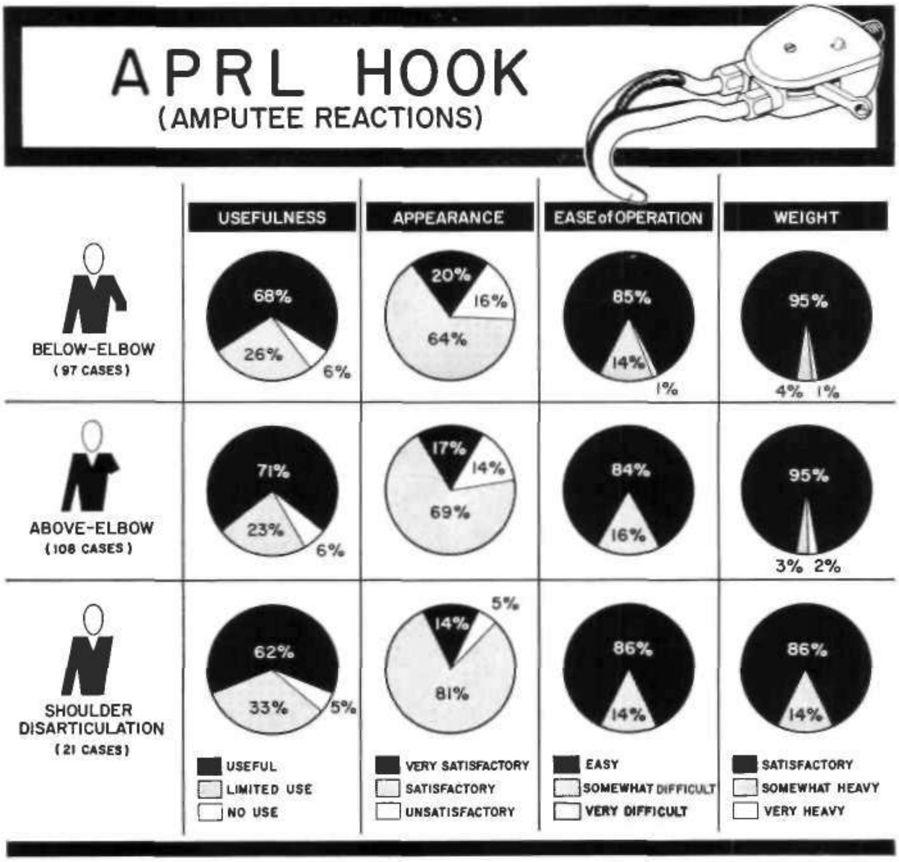
sometimes very desirable. The indications were that a desirable improvement could be effected if the ranges of prehension force could be made adjustable by the wearer (perhaps by use of a simple tool). When amputee comments were compared (two-load hook versus rubber-band-operated hooks worn previously), there was no clear-cut preference for either type, although the two-load fared slightly better in all areas except appearance.

APRL HOOK

The APRL hook is, like the APRL hand, a voluntary-closing, automatic-locking terminal device *(3)*. The body and fingers are of aluminum to keep weight within reasonable limits, the fingers being lyre-shaped and lined with neoprene to increase the security of grasp. Opening ranges of approximately 1-1/2-in. or 3 in. are selected by manipulation of a small switch protruding from the hook case. The control cable attaches to a lever arm projecting from the side of the housing for the mechanism. As with the APRL hand, prior studies *(8)* had established the general acceptability of the hook, and the NYU Field Studies presented a unique opportunity to gain additional insight into its application and to introduce it into more climes throughout the country.

The basis for prescription was to furnish the APRL hook in a majority of cases where a hook was required. The only exceptions were those cases where a clear contraindication was apparent (for example, in cases of patient refusal to wear any type of hook, or to change from some other type to the APRL hook, or where occupational requirements demanded extremely rugged construction, or where the subject was interested in trying the Sierra two-load hook). Consequently, rather large numbers of amputees in the study were equipped with the APRL hook.

The data obtained with 228 hooks were similar to those obtained with the APRL hand when it was compared to voluntary-opening hands. Grasp forces were found to be considerably higher with the APRL hook than with voluntary-opening hooks. Eighty-nine percent of the wearers could exert forces over 9 lb., 54 percent over 20 lb.



Although amputee reactions to the APRL hook were generally positive, the present design evidently leaves much to be desired in the area of appearance and, to a lesser degree, in the area of usefulness. In interviews, the amputees mentioned:

1 The possibility of reducing length and bulk by incorporating the terminal-device mechanism in the forearm.

2. Dissatisfaction with the reliability of operation (locking after closing), although some wearers were generally aware that the fault might lie with themselves in not permitting the mechanism to alternate.

3. Backlash, which in varying degrees caused some wearers distress.

4. The potential advantages (aesthetic as well as functional) of having the hook "thumb" as well as the moving finger on the medial aspect. At present, when the "thumb" is on the medial side the moving finger is on the lateral side and opens away from the wearer's body. If the wearer wants the moving finger to open toward him, the "thumb" is placed on the lateral side.

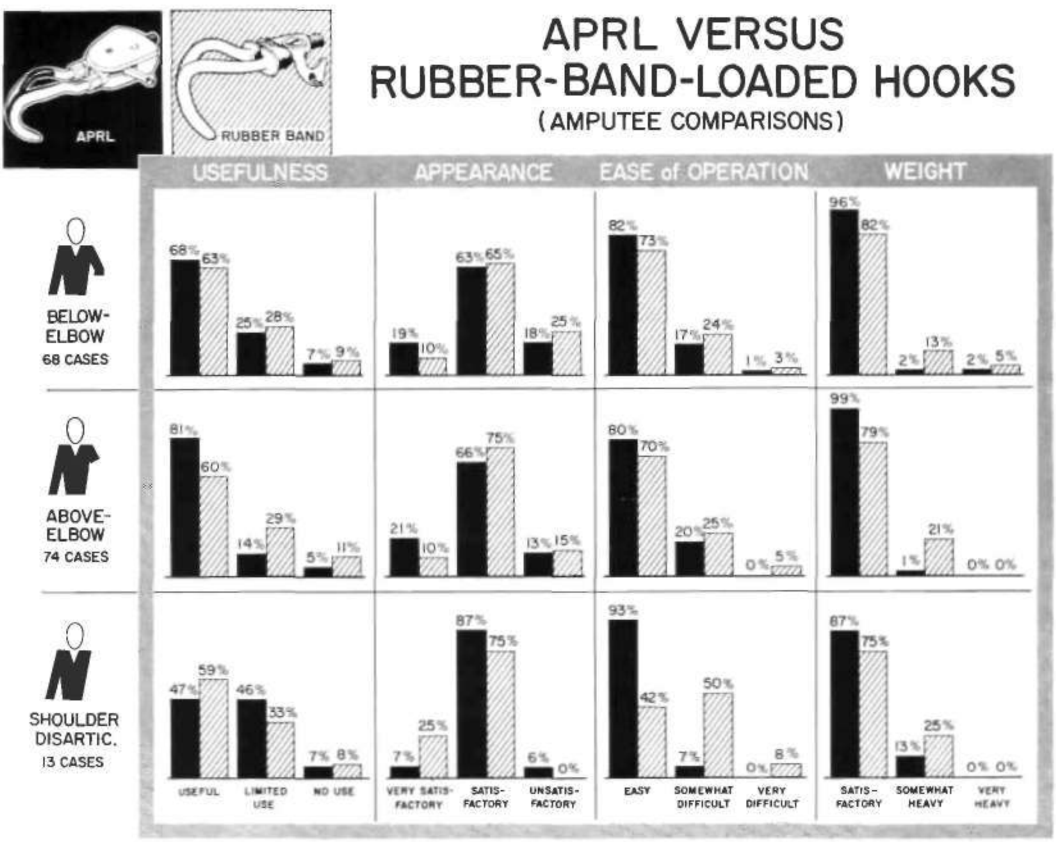
Some interesting points are observed when we compare the responses to the APRL hook with those to the APRL hand. Since in general hooks are conceded to be more functional than artificial hands, it comes as no surprise that in the area of usefulness the APRL hook rated higher than did the hand. As regards appearance, reactions were much more favorable to the hand than to the hook, but, in the case of the latter, amputation level had no apparent effect on amputee feelings. In any event, a significant number of patients found both hand and hook unsatisfactory in appearance.

More than 80 percent of the amputees wearing the APRL hook indicated that it was easy to operate regardless of amputation level. Conversely, responses by wearers of the APRL hand indicated that operation became somewhat more difficult at the higher levels of limb loss. By far the majority of wearers registered satisfaction with the weight of the hook (8-1/4-oz.), whereas the weight of the gloved hand (15 oz.) was less well received. The higher the level of amputation the more critical weight became.

Next to be considered are the reactions voiced in regard to the usefulness, appearance, ease of operation, and weight of rubber-band-loaded hooks (voluntary-opening) worn prior to the studies and of the APRL hook (voluntary-closing) supplied during treatment. The below-elbow and shoulder-disarticulation wearers considered the rubber-band and APRL hooks approximately equal in usefulness, while the above-elbow wearers felt the APRL hook to be somewhat more useful. As for appearance, about 70 percent of the subjects found both APRL and rubber-band hooks generally "satisfactory." Whereas 15 percent indicated dissatisfaction, the remaining 15 percent said that in appearance both hooks were "very satisfactory." When ease of operation was considered, the below-elbow and above-elbow wearers favored the APRL hook slightly, although both hooks were rated highly with regard to operating characteristics.

The wearers of shoulder-disarticulation prostheses showed a distinct preference for the APRL hook with respect to ease of operation, probably because of the ease with which closure can be effected and because of the low excursion requirements peculiar to voluntary-closing terminal devices. This finding may indicate that rather light prehension forces are used by most wearers of shoulder prostheses, for were this not the case they would react against the difficulty of reopening the hook. There is no indication from the data that the additional control motions required for use of the APRL hook made hook operation less "easy."

Hook weight appeared to present no major problem regardless of level of amputation.



Although the 8-1/4 oz. APRL hook was generally considered by the wearers to be more satisfactory than the Dorrance No. 555 (3 oz.), the Dorrance No. 5 (7 oz.), or the Dorrance No. 7 (8-3/4 oz.), the responses may have been influenced by the use of a new prosthesis, which very often was better fitted, more comfortable, and more efficient than the old arm with the rubber-band hook.

It is apparent from the foregoing discussion that functional, split hooks were rather highly valued regardless of type. In all cases, usefulness, ease of operation, and weight were apparently quite acceptable to almost all wearers. Only in the area of appearance did a significant number of subjects indicate dissatisfaction, and even then most of the amputees accepted prevailing appearance.

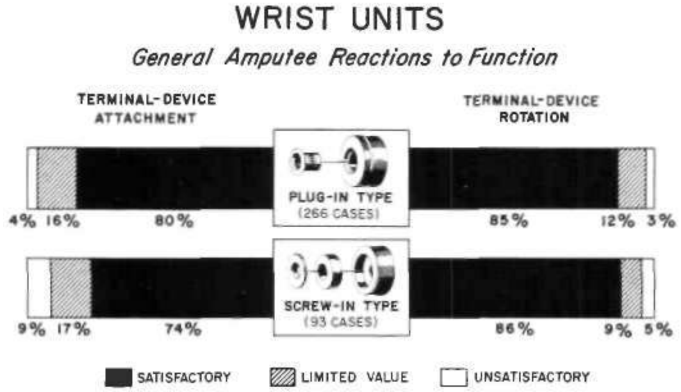
The amputees who used rubber-band-closing hooks prior to the study and changed over to the APRL hook during the study were in an excellent position to compare terminal devices. The below-elbow amputees felt that the APRL hooks and those of the rubber-band type were approximately equal in usefulness, the responses favoring the APRL hook slightly. The above-elbow cases seemed to favor the APRL hook rather strongly, the responses indicating an attitude considerably more positive toward the usefulness of the new hooks. The shoulder-disarticulation cases seemed to favor the rubber-band hooks slightly with respect to usefulness, but the smallness of the sample (13 patients) prohibits drawing any conclusions in favor of either type of hook for this special group.

In sum, it appears that the rubber-band and the APRL types are about equal in usefulness, the data favoring slightly the APRL design. No clear-cut advantage in the use of one over the other is evident from amputee reactions. In all probability, personal preference based on past experience, influence of the clinic team, or other intangibles are contributing factors. The entire area affecting the choice of terminal devices is one that should be given additional study.

WRIST UNITS

Prosthetic wrist units are designed to facilitate attachment of the hand or hook to the forearm and to permit pronation-supination of the terminal device (4,5). The most common type (screw-in type) bears a female thread such as to accept the terminal-device stud, and a rubber washer and retaining plate are used to control the tendency toward excessive loosening or tightening when the terminal device is rotated. A newer type of wrist unit, intended to provide not only for easy rotation but also for easier interchange of terminal devices, incorporates a control button which, when depressed, frees the hand or hook for rotation. Further depression of the control button permits removal of the terminal device from the wrist unit, the need for unscrewing being thus eliminated. In still another wrist, also designed for quick interchange of terminal devices, the turn of a knurled ring releases the hand or hook for rotation or removal.

In the NYU Field Studies, prescription of wrist units favored the button- or ring-operated wrist (plug-in type) wherever more than one terminal device was to be used. When a single terminal device was prescribed, the screw-in type was generally favored, since then interchange was not a major consideration. Plug-in



wrists fitted to 266 research patients and screw-in types fitted to 93 were followed over an average wear period of six to nine months, and amputee reactions were obtained concerning two aspects of wrist function—attachment and removal of the terminal device, and pronation-supination to achieve acceptable attitudes of approach. Of the 359 amputees wearing program arms, those equipped with plug-in units were slightly more satisfied with the attachment function than were those who wore screw-in wrists. Pronation-supination was fairly satisfactory with both types.

Despite the general amputee acceptance of both types of wrist, however, there was also evidence of substantial dissatisfaction. Interviews with the amputees and observation of their performance revealed that a simpler and faster method of exchanging terminal devices was required, as were also improvements in the cable connections, which were then cumbersome and difficult to manipulate with one hand. Evidently, improved rotation mechanisms were needed to permit easy correction of terminal-device attitude for best angle of approach.

When specific wrist features (ease of operation, usefulness, weight, and appearance) were explored (page 16), the wearers were even more positively inclined toward the plug-in wrist unit. The reactions of 138 amputees who had screw-in wrists on their old arms and plug-in wrists on their program arms show that, insofar as exchanging terminal devices was concerned, the plug-in wrists were favored by a greater percentage of the below-elbow wearers than were the screw-in wrists. The opinions of the above-elbow amputees showed only a slight trend in favor of the plug-in wrists. Because only a small number of shoulder-disarticulation cases changed to plug-in wrists, their reactions were not recorded. The responses of 107 amputees who had used screw-in wrists on their old arms and plug-in wrists on the program arms showed that the plug-in type of wrist was considered by below-elbow wearers to be easier to rotate than was the screw-in type.

Opinions concerning the locking function of wrist units are of interest since only the plug-in type locks the hook or hand in its selected attitude, the screw-in type depending upon friction to maintain terminal-device orientation. In 106 cases, both below-elbow and above-elbow wearers considered the plug-in type of wrist (with its ability to permit rotation of the terminal device as well as to lock it) somewhat more useful than the screw-in, nonlocking type.

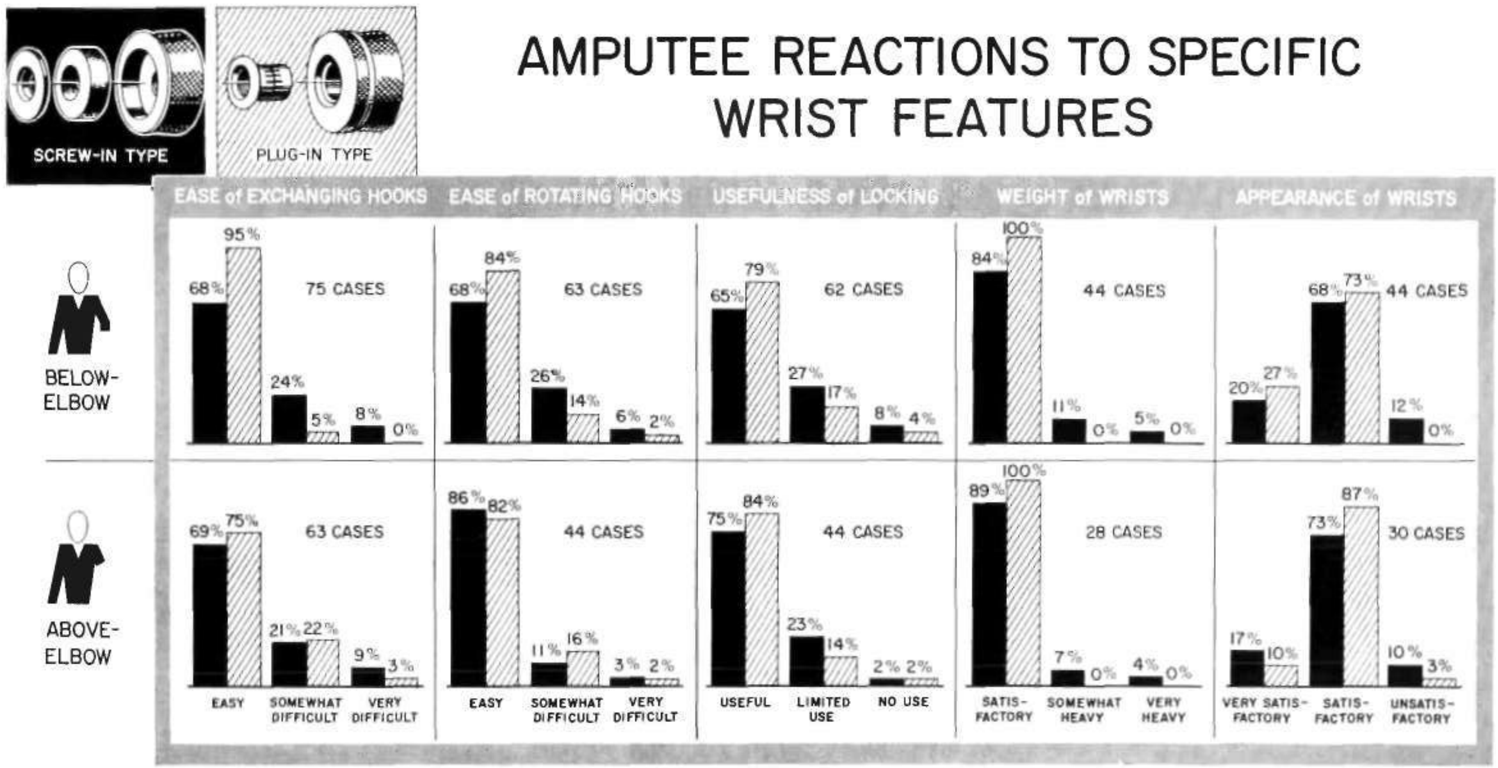
In the areas of weight and appearance, the plug-in type was again, and somewhat surprisingly, favored over the simpler, screw-in unit. Despite the fact that the plug-in wrist is actually heavier than the screw-in type, amputees favor it. Apparently the "halo effect" of the new prosthesis with its generally superior comfort, appearance, and efficiency may be responsible for the positive responses in the areas of wrist weight, wrist appearance, and ease of wrist rotation.

In summary, the plug-in type of wrist was favored slightly over the screw-in type, first because of the relative ease with which terminal devices could be exchanged and second because the hand or hook could be locked in any desired attitude of pronation-supination. Below-elbow amputees seemed to favor the plug-in type more than did the above-elbow group, an understandable result when it is considered that below-elbow wearers are generally more active with their prostheses and more inclined to exchange terminal devices than is the case with above-elbow amputees. In any event, it was apparent from observations and from amputee remarks that improved cable attachments were needed to facilitate ease of connecting and disconnecting hands or hooks. Despite the fact that some below-elbow wearers considered rotation of terminal devices easier with plug-in wrists, observation leaves little doubt but that the screw-in type is superior in rotation features. It seems clear that attitudes toward the rotational qualities as well as toward the weight and appearance of the plug-in wrist were positively affected by concomitant reactions toward superior locking and attachment qualities.

ELBOW JOINTS FOR BELOW-ELBOW PROSTHESES

Almost all below-elbow prostheses are suspended from cuffs fitted above the bony prominences of the elbow joint. The cuff and prosthetic forearm are connected by means of mechanical elbow joints, some of which (rigid

AMPUTEE REACTIONS TO SPECIFIC WRIST FEATURES



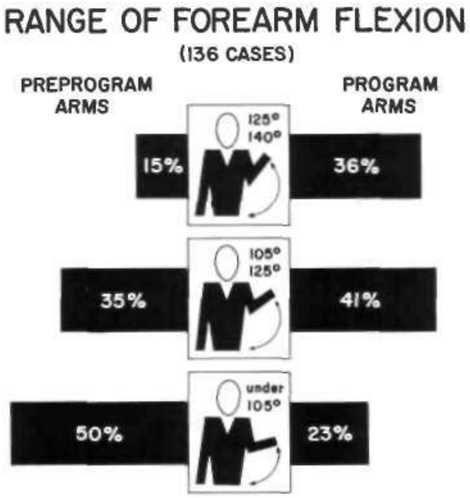
hinges) are designed to permit flexion and extension only, others (flexible hinges) permitting also pronation and supination (*1,4,10*). Metal hinged joints are generally used for shorter stumps where stability against inadvertent rotation is a major requirement. Flexible leather, steel-cable, or fabric-type joints are generally used in prostheses for longer stumps where residual, natural forearm rotation can be utilized. Short stumps typically have limited purchase in the prosthesis and therefore require a snug, high-fitting socket in order to obtain forearm stability *(1)*. But the high-fitting socket often restricts the wearer's range of flexion owing to crowding of flesh as the forearm is raised. Special joints, known as "step-up" joints *(1)*, are designed to relieve this condition and to produce an increased range of flexion. Since in such a case the range of motion increases at the expense of lifting power, it is sometimes necessary to use an assistive forearm lift similar to that commonly used with above-elbow prostheses *(10)*. Whenever the very short below-elbow stump is unsuited for lifting the prosthetic forearm, it is fitted with locking joints actuated either by movement of the stump or by a cable control similar to that used for the above-elbow case (1).

Evaluated comprehensively with both old and new prostheses were 136 unilateral below-elbow amputees, the elbow components of the prostheses being as follows:

Type of Elbow	*Old Arm*	*New Arm*
Flexible Hinges	17	74
Rigid Hinges	110	40
Step-Up Joints	9	20
Locking Joints	0	2
	136	136

The data show that in general the new arms permitted a greater range of forearm flexion than did the preprogram arms, partly no doubt because of an increased use of step-up joints in the new prostheses and partly because of improved socket shaping to avoid restriction of flexion through crowding of flesh at the brim of the socket.

Before the advent of the Upper-Extremity Field Studies, use of flexible elbow joints had



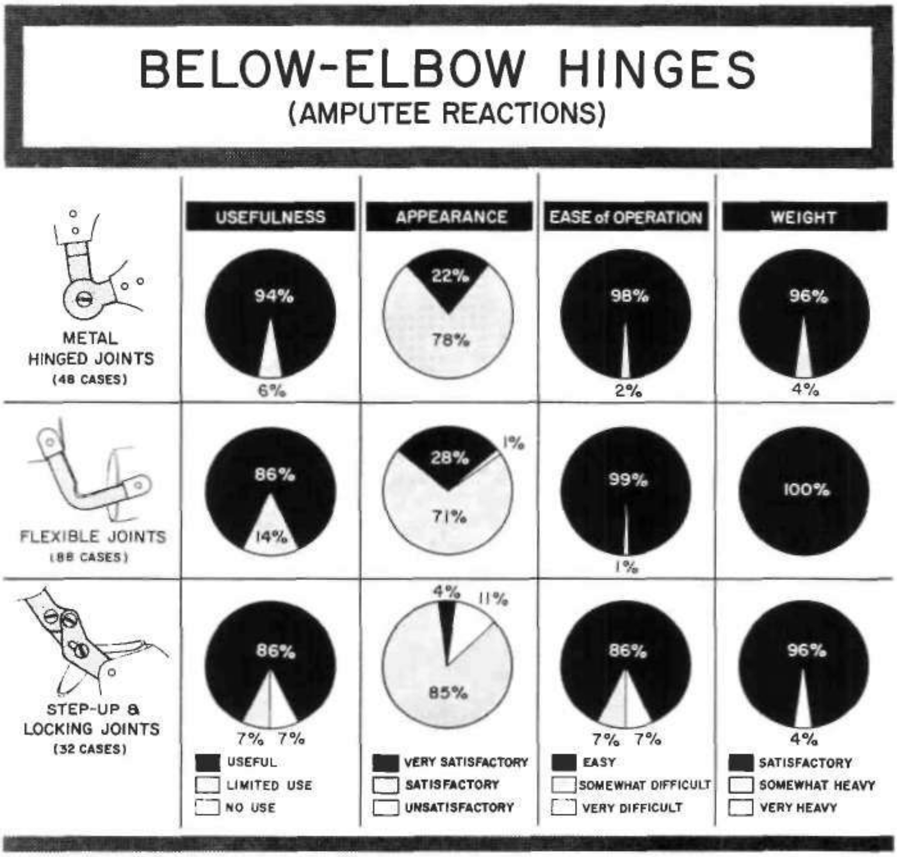
been reserved almost entirely for patients with wrist disarticulations or long below-elbow stumps. Of all the amputees in the group investigated, only 17 had had flexible joints in their preprogram arms, and of these only one had a stump shorter than 6-1/2 inches. Moreover, the available stump rotation was rather good, only one having less than 20 deg. of pronation-supination. Experience indicated that even still shorter stumps might retain slight but useful rotation and that patient comfort might be increased and clothing damage decreased with use of flexible hinges. Consequently, during the program many stumps within the group of 136 amputees (74 arms) were fitted with flexible joints even though the rotation possibilities were knowingly limited (22 cases with residual stump rotation of less than 20 deg., 13 patients with stumps shorter than 6-1/2 in.).

As expected, the average rotation range for the entire group with the new prostheses decreased as compared with the average rotation range of the 17 who had been provided with flexible hinges on their old arms. But it must be pointed out that many more amputees now had not only the facility of active pronation-supination but also the greater comfort and reduced clothing damage inherent in the use of flexible joints. The 16 amputees who used flexible hinges on both old and new arms exhibited the same range of pronation-supination with the two prostheses.

The reactions of the below-elbow subjects to the various elbow joints evaluated during the study were in general very positive in the areas of usefulness, ease of operation, and weight but a great deal poorer in the area of appearance. Although the step-up and stump-actuated joints were unacceptable to a few amputees, negative generalizations are impossible because the size of the sample was too limited (24 step-up joints, 7 locking joints). And indeed these components must be widely acceptable, judging from the overwhelming percentages of positive responses. The negative comments made by wearers of step-up joints indicate an inability to stabilize the forearm sufficiently to obtain effective use of the terminal device. The development of locking step-up joints has been suggested as a means of stabilizing the prosthetic forearm for amputees with short or very short stumps.

The principal findings with regard to elbow joints for below-elbow prostheses center around a shift toward increased use of flexible hinges and a corresponding decrease in the number of rigid joints used.[6] Of special interest is the finding that stumps shorter than 6-1/2 in. should also be considered for flexible elbow joints. Although the shorter stumps can be expected to provide only minimal pronation-supination, even slight gains in rotation are important for hand and hook positioning. There was no reported instance of socket instability on the

[6] See ARTIFICIAL LIMBS, Spring 1958, p. 77.



shorter stumps fitted with flexible joints on program arms, and the gains in patient comfort and in reduction of clothing damage lead to the conclusion that use of any joint other than flexible should be advocated only after serious consideration of the specific needs of the individual patient. Although the sample using step-up or locking joints was small, and although it is apparent that the joints were generally satisfactory, development of a step-up joint capable of locking the prosthesis in flexion seems quite desirable, since stabilization of the forearm for effective terminal-device operation or for lifting objects appeared to be difficult with the step-up joints used both before and during the study.

ELBOW JOINTS FOR ABOVE-ELBOW AND SHOULDER-DISARTICTJLATION PROSTHESES

Positioning of the prosthetic forearm and terminal device of a modern above-elbow or shoulder-disarticulation prosthesis in the flexion-extension plane requires that the elbow be unlocked. Locking of the elbow permits control-cable forces to by-pass the forearm lift and to act upon the terminal device.[7] Rotation of the prosthesis about the humeral axis to facilitate mediolateral positioning of the forearm is accomplished by means of a turntable incorporated in the elbow and controlled by a friction element which resists free movement (5).

In general, about 2 lb. of force and half an inch of cable travel are needed to lock present mechanical elbows, about 5 lb. to unlock. But the exact figures vary slightly from elbow to elbow and from manufacturer to manufacturer. Program arms fitted during the early phases of the study were built around Sierra Model C elbows (4,5), which had unlocking forces (6.3 lb.) and excursion requirements (9/16-in.) slightly higher than those of the Hosmer E-400 units (4.0 lb. and 1/2 in.), which in turn became available to the clinics later in the study and which were identical in operating principle. Besides this, the Hosmer E-400 *(4,5)* was at the time a new component, clinics were therefore particularly interested in its application, and consequently it was prescribed almost routinely during the latter part of the program. Of the 170 internal elbows fitted and evaluated during the study, 110 were Sierra Model C's, 42 were Hosmer E-400's, and 18 were Hosmer E-300's (an earlier elbow incorporating a locking mechanism of quite different design, now discontinued). External elbow locks *(1),* intended for amputees with long humeral stumps or with elbow disarticulations, were used in 11 cases.

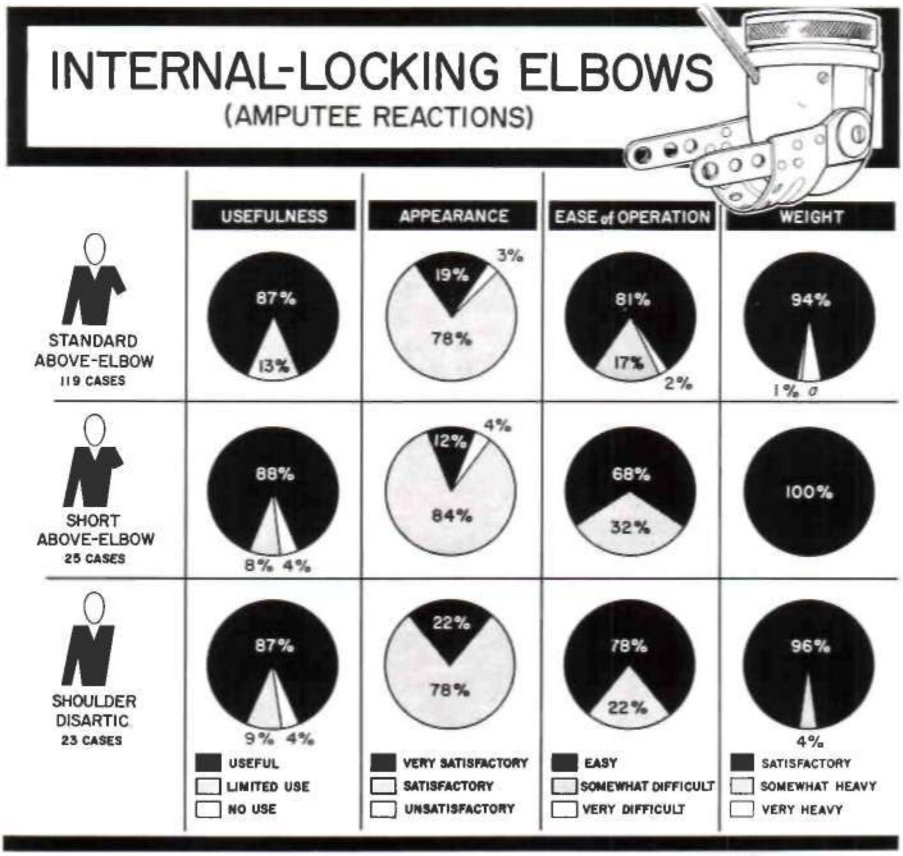
Above-elbow and elbow-disarticulation amputees achieve elbow locking and unlocking by a combined extension-abduction of the humeral stump, a motion which exerts pull upon a control cable attached between the elbow and the shoulder harness *(11,12).* Alternate pulls on the elbow-lock control cable result in locking and unlocking or vice versa. Shoulder-disarticulation amputees usually control the elbow lock by elevating the shoulder on the side of the amputation, thus exerting pull on a control cable attached between elbow lock and waistband *(10).*

All of the elbow-disarticulation, above-elbow, and shoulder-disarticulation prostheses provided in the program were equipped with locking elbows of the alternating type. Of the 181 cases (170 internal locking, 11 external locking) available for study, 76 had had prior experience with prostheses incorporating the older manual locks, and 18 had worn arms without locking elbows. Fifty-two had previously used alternating elbows of the type used in the program arms. In 35 cases, either the patient had not previously worn an arm or else the type of elbow was unknown.

INTERNAL-LOCKING ELBOWS

The data show that a considerable number (36 out of 101) of the preprogram arms provided little or no initial elbow flexion, owing chiefly, no doubt, to fabrication technique and workmanship rather than to the nature of the elbow units themselves. Program arms tended to group around the standard of 10-15 deg. of initial flexion, a feature that tends to make initiation of forearm lift less difficult. Moreover, forearm flexion was restricted in the old arms, less than a third of them being capable mechanically of approaching 135 deg. of flexion. In general, program arms could be flexed to

[7] "Dual control." See Pursley *(10)* or Taylor *(11).*



[a] *Not responding, 5%*

much greater extent, almost two thirds of the subjects reaching or surpassing 135 deg.

As for other deficiencies in the new arms, 35 cases exhibited serious impairment of elbow-lock operation, primarily because of harnessing inadequacies. A considerably larger number of prostheses showed less than optimal elbow function, mostly because of poor arrangement of the elbow control cable and the front support strap. In 12 cases, malfunction of the elbow mechanism was apparent, and 37 of the new prostheses required adjustment for insufficient initial elbow flexion. Thirteen arms required attention to correct friction characteristics in the elbow turntables.

Generally, then, more careful attention to adjustments and to harnessing detail for elbow-lock operation was obviously required. Direct amputee reactions to the cable-controlled, internally locking elbows were quite favorable, only 4 of the 170 wearers experiencing negative feelings when all aspects of elbow use were considered. Of the few negative comments made (25), the majority related to lack of dependability in elbow operation, probably because of such factors as careless harnessing or inadequate training in the required operational pattern. As might have been expected, the cases with the shorter stumps found operation of the lock more difficult than did those with the longer stumps. Except where the fitting of the short-above-elbow patient was expertly done, the shoulder-disarticulation cases had less difficulty in elbow locking and unlocking by means of shoulder elevation than did the short-above-elbow cases using the same control motion.

EXTERNAL-LOCKING ELBOWS

External-locking elbow joints are sometimes used for elbow disarticulations and for very long above-elbow cases *(1).* Although in the study 11 elbow-disarticulation amputees were fitted with external joints, only 8 had had experience with internal-locking elbows on their old arms. From the viewpoint of usefulness, they favored the internal mechanism slightly, perhaps because of the rotation turntable and because of the greater number of available locking positions in the internal elbows. As for appearance, the arms fabricated with outside-locking elbows seemed to be more acceptable than those constructed with internal units because, while the outside-locking units protrude on the medial aspect of the arm, internal units may be fitted to elbow disarticulations and to very long above-elbow cases only by lowering the elbow center abnormally.

Ease of operation gave rise to some differences in amputee reactions toward internal as compared with external elbows. Since the forces and control motions are essentially identical in the two types, the discrepancies probably relate more to the nature of the harnessing or to the skill of the patient than to the particular characteristics of the elbows themselves.

As one might have anticipated, amputee reactions to weight favored the outside-locking units, which are somewhat lighter than the internal elbows.

SUMMARY

To summarize, only 29 percent of the 181 amputees studied were known to have worn on their preprogram arms locking elbows of the alternating type. In the studies, all unilateral above-elbow patients were fitted with the more modern locking units, thus freeing the normal arm from the responsibility of operating a manual lock for the amputated side. Program arms had greater ranges of forearm flexion and were adjusted to provide greater initial flexion so as to make it easier for the patient to lift the forearm. But elbow-lock operation with the new arms was often impaired by poor harnessing arrangements that required correction. While in general the amputees were quite favorably disposed toward the cable-controlled, locking elbows, infrequent negative complaints of lack of dependability related to inadequacies in harnessing and to poor operational patterns on the part of some wearers. A limited number of amputees fitted with external-locking joints provided sufficient positive evidence to ensure the future of these components in the array of items available for long-above-elbow or elbow-disarticulation patients.

HARNESSING

If the upper-extremity prosthesis is to be of functional use to the amputee, two basic needs must be met. A suitable attachment of the prosthesis to the body must be made, and power must be provided for operating and controlling the limb. Although the socket is made to conform to the stump, it tends to become displaced, especially during lifting. The prosthesis is therefore suspended from the shoulder by means of a harness which keeps the socket in close contact with the stump and resists any tendency for the prosthesis to shift out of position. Usually the same harness serves as the force-transmitting medium between body sources of power and the cable system of the prosthesis *(10,12).* For both above- and below-elbow amputees, two basic types of harness are in common use today—the figure-eight harness and the chest-strap harness *(10).* Commonly, the chest-strap design is applied in the shoulder-disarticulation case too *(10).*

Of all artificial arms, the unilateral below-elbow prosthesis is perhaps the simplest to suspend and to power. In the figure-eight method, suspension is obtained by a loop of 1-in. fabric tape passing under the axilla on the sound side and over the shoulder on the amputated side, the front end of the tape being attached to a biceps cuff (which in turn supports the elbow joints connecting to the prosthetic forearm), the other end (the back) to the control cable for the terminal device. Forward rotation of the arm upon the shoulder on the amputated side causes forces to be applied to the cable and gives the excursion necessary to operate the hook or hand. In the chest-strap method, suspension of the biceps cuff is achieved through use of adjustable leather or fabric straps attached to the anterior and posterior aspects of a leather shoulder saddle, and the control cable is attached to an adjustable fabric tape sewn to the chest strap in the region of the seventh cervical vertebra. Although the figure-eight type of harness is used almost universally for the unilateral below-elbow prosthesis, it is considered by some that the chest-strap type, with its broader weight distribution over the shoulder, is indicated for amputees anticipating extremely heavy-duty services or for those who cannot tolerate the axilla pressures typical of the figure-eight loop *(10).*

For the unilateral above-elbow prosthesis, the figure-eight and the chest-strap harnesses enjoy in general a more equal popularity. Program arms tended strongly, however, toward the simpler figure eight, in which the fabric tape loops over the sound shoulder, under the axilla on the sound side, and then over the shoulder on the amputated side *(10).* It is generally conceded that the above-elbow chest-strap harness, which uses a leather or fabric saddle to reduce the unit pressure on the shoulder, is preferred whenever the patient anticipates activities involving heavy lifting or when he cannot tolerate the axilla pressure characteristic of the figure-eight harness *(10).*

For the unilateral shoulder-disarticulation or forequarter amputation, the most common harness in use today is that of the chest-strap type, elbow locking and unlocking being achieved by elevation of the shoulder on the amputated side. A fabric tape extends from the elbow-lock control cable and attaches to another surrounding the waist. Scapular abduction gives power and excursion for forearm lift or, when the elbow is locked, for terminal-device operation *(10).*

In the evaluation studies, harnesses were individually prescribed according to type and made in accordance with the latest techniques. But because the harness is always a custom-made item fitted by the prosthetist according to the requirements of the individual patient, there were introduced a number of variables involving such intangibles as skill and judgment. Although in program prostheses each harness had to meet certain requirements designed to ensure proper suspension and adequate power and excursion, it was apparent almost from the beginning that serious harnessing problems existed. About 45 percent of all arms showed harness deficiencies at checkout. The above-elbow prostheses were notably troublesome, 375 harnessing faults showing up on the 303 arms going through checkout. The below-elbow prostheses, though considerably simpler, were also a source of difficulty, 150 harnessing faults being discerned on 361 below-elbow patients. The shoulder-disarticulation group of 53 patients had 39 harnessing faults. Tables 1, 2, and 3 reflect the types of harnessing faults found at clinical checkout of the program arms.

It should be pointed out that the prostheses were rated at checkout according to criteria evolving from material presented at the prosthetics courses offered as part of the program. Accordingly, any deviations from the accepted harnessing practices taught in the courses were considered "faults." But it was recognized that arm harnessing is an individualized procedure and that therefore certain faults might be less critical than others depending upon the amount of deviation from the standard, the physique of the patient, his threshold of tolerance for discomfort, and other intangible considerations. Consequently, it should be made clear that recognition of a fault did not necessarily mean the prosthesis was unusable but, more often than not, that the limb simply was not operating at a peak level of performance and/or comfort. Fortunately, the problems encountered with the harnesses at checkout were markedly reduced as the prosthetists gained experience. Strict adherence to the checkout standards, along with increased understanding and skill, served to ensure that each arm wearer was ultimately harnessed so that he could use the prosthesis in a functional manner. After checkout (and prosthetic corrections, when indicated), the amputees embarked upon a long-term period of wearing the new prosthesis.

Amputee reactions to the new arm harnesses were checked with regard to comfort, appearance, and fit as these matters affected the function of the prosthesis. Generally, the wearers' reactions were quite favorable, and it was apparent that the subjects generally had a higher regard for the new harnesses than they had for the old (Table 4). Although program harnesses scored highly with all

Table 1
HARNESS FAULTS RELATING PRIMARILY TO FUNCTION
(Forearm Lift, Elbow Lock, Prehension)

Fault	No. of Occurrences			
	Below-Elbow (361 cases)	Above-Elbow (303 cases)	Shoulder Disarticulation (53 cases)	Total (717 cases)
Control attachment strap not at mid-scapular level	28	78	3	109
Harness cross too far toward amputated side	31	32		63
Front support strap, elastic strap, elbow-lock lanyard not in delto-pectoral triangle	13	35	1	49
Harness inadequate (not further identified)	1	25	5	31
Bilateral cross not centered on back and/or too high on back	3	25		28
Difficulty in elbow-lock operation		22	1	23
Harness control too far toward sound side	10	5		15
Additional, nonprescribed straps	1	14		15
Control attachment strap too short	8	4		12
Insufficient control-cable excursion		2	7	9
Nonstandard materials used	4	4		8
Improperly located harness cross (not further identified)	3	4		7
Harness not as prescribed		2	3	5
Figure-8 harness improperly laid up, restricts range of motion		5		5
Harness stretched	1	3		4
Elastic suspensor missing		2	1	3
Chest strap improperly placed, restricts range of motion		1	1	2
Totals	103	263	22	388

amputee groups, the above-elbow amputees consistently rated their harnesses slightly lower than did the below-elbow or shoulder-disarticulation groups, probably because the above-elbow figure-eight harness is more complex and in comparison with below-elbow harnesses somewhat more snug-fitting.

Interviews with the amputees disclosed that most participants who had worn prostheses prior to the studies felt that the new harnesses

Table 2
HARNESS FAULTS RELATING PRIMARILY TO SOCKET ATTACHMENT AND STABILITY OF PROSTHESIS

Fault	No. of Occurrences			
	Below-Elbow (361 cases)	Above-Elbow (303 cases)	Shoulder Disarticulation (53 cases)	Total (717 cases)
Lateral support straps improperly located for socket stability		31		31
Harness does not stabilize socket (not otherwise identified)		11	4	15
Elastic suspensor misplaced so as to cause socket rotation		1		1
Totals	0	43	4	47

Table 3

HARNESS FAULTS RELATING PRIMARILY TO COMFORT AND APPEARANCE

Fault	No. of Occurrences			
	Below-Elbow (361 cases)	Above-Elbow (303 cases)	Shoulder Disarticulation (53 cases)	Total (717 cases)
Discomfort at axilla	14	27	1	42
Inverted Y-strap improperly sized	22			22
Discomfort, other than at axilla (not further identified)	2	13	1	16
Buckles improperly attached	2	11	1	14
Harness-tape ends not sealed	3	7	2	12
Discomfort, lateral suspensor strap irritates neck		7		7
Discomfort, front support strap too high on neck	4	1		5
Chest strap of improper width		2	3	5
Discomfort, chest-strap tightness			2	2
Shoulder saddle bulges		1	1	2
Waist strap (elbow lock) improperly sized			2	2
Totals	47	69	13	129

were much better than the old ones. Particular comments evidenced satisfaction with reduction in amount of harness needed to obtain satisfactory prosthetic function with the new arms. Some wearers commented upon possible areas of improvement, a response which almost always involved the desire to be burdened with no more harness than necessary to control the arm. A number of subjects indicated discomfort at the axilla, and problems relating to shift of the harness out of place were not uncommon. Although difficulty in operating the elbow lock was corrected in most cases, some wearers felt that other means should be sought for control of elbow lock.

POWER-TRANSMISSION SYSTEMS

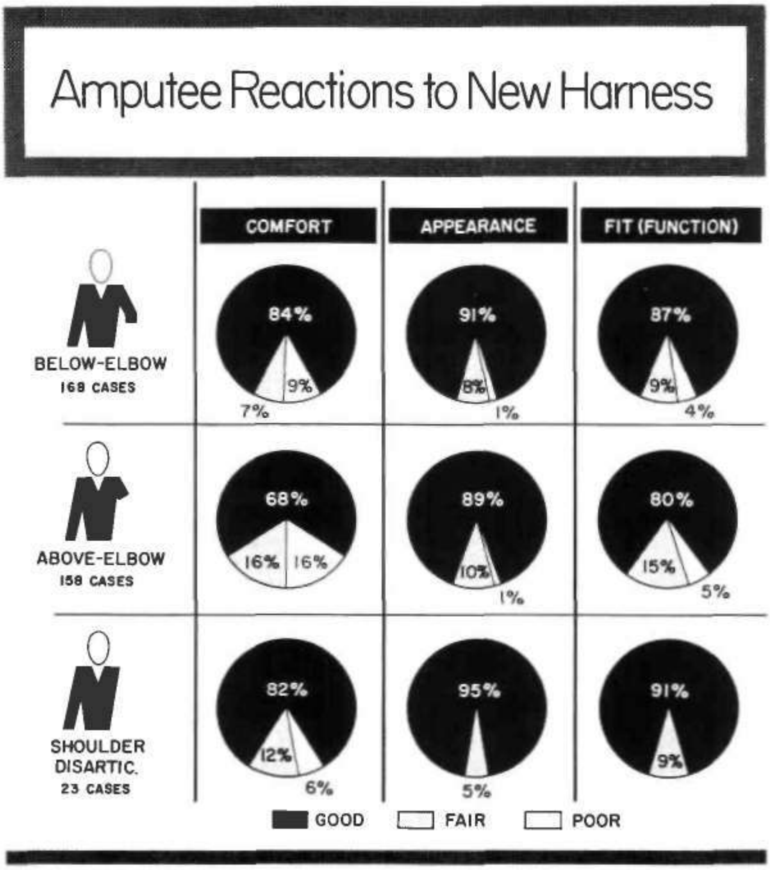
To achieve functional use of a prosthesis, the amputee must be able to avail himself of residual sources of body power. Flexion, extension, and abduction of the arm, extension of the forearm, shoulder elevation, scapular abduction, and chest expansion are the most common power sources harnessed by the prosthetist to provide movement of the artificial arm *(10,11,12)*. Transmission of the forces thus generated is accomplished by the use of Bowden cables connecting the points of force generation (harness components) and the points of force application (forearm or terminal device). In the below-elbow prosthesis, forward movement of the shoulder on the sound side, flexion of the arm on the amputated side, singly or in combination, exerts against the

Table 4

AMPUTEE PREFERENCE IN HARNESS

(No. of Occurrences)

Harness Type	Amputee Type	Preference		
		Prefer Old	No Preference	Prefer New
Figure-8	Below-Elbow	13	25	85
	Above-Elbow	20	8	73
Chest-Strap	Below-Elbow	—	3	—
	Above-Elbow	—	8	—
Totals		33	44	171



harness system a force that is transmitted for operation of the terminal device, the forearm being lifted by the stump. Above-elbow and shoulder prostheses utilize the same type of power-transmission system, except that with arms of this type the cable is used also to lift the prosthetic forearm whenever the elbow is unlocked (dual control).

Prior to the Upper-Extremity Field Studies, many arm amputees had been using Bowden cable for power transmission. Others used steel cable without housing, nylon cord, leather or rawhide thongs, and other miscellany, as shown in Table 5. But *all* program arms were equipped with Bowden cable and subjected to checkout procedures to ensure that minimum standards of power-transmission efficiency (below-elbow prostheses, 70 percent; above-elbow and shoulder-disarticulation prostheses, 50 percent) were met. When checked, the program arms showed for every amputation level substantial increases in efficiency over the standards shown by the power-transmission systems of the corresponding old prostheses. Indeed, the new arms exceeded the minimum efficiency standards with such regularity that raising of the standards is now indicated.

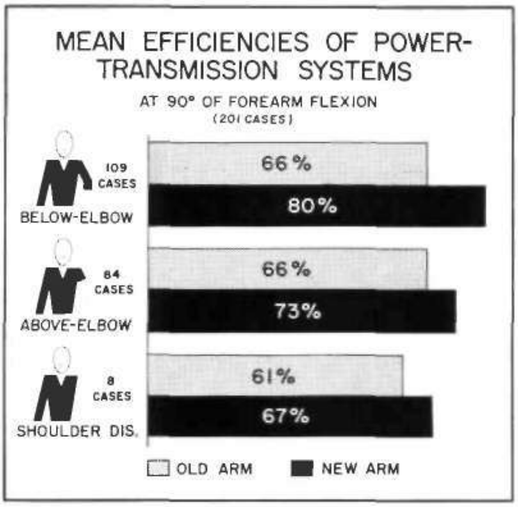
Full opening and closing of the terminal device was possible for an increased number of amputees through use of the new arms. When function of the terminal device was tested at each of four operating positions (at full extension, at 90 deg. of flexion, at waist, and at mouth), the results showed a marked increase in opening range for each amputee type at all four positions. Doubtless this improvement was due to the use

Table 5

POWER-TRANSMISSION SYSTEMS ENCOUNTERED

(285 Old Prostheses)

Prosthesis Type	Power-Transmission System				
	Bowden Cable	Steel Cable, No Housing	Leather Thong	Nylon Cord	Miscellaneous (Shoelace, String, etc.)
Below-Elbow	83	11	30	14	4
Above-Elbow	80	10	18	12	10
Shoulder Disarticulation	7	1	3	1	1



of better harness and belter-fitting sockets, with better transmission of force and excursion through the cabling system, if not to application of the voluntary-closing terminal devices, which inherently use less excursion than do the voluntary-opening hooks that predominated in the old prostheses.

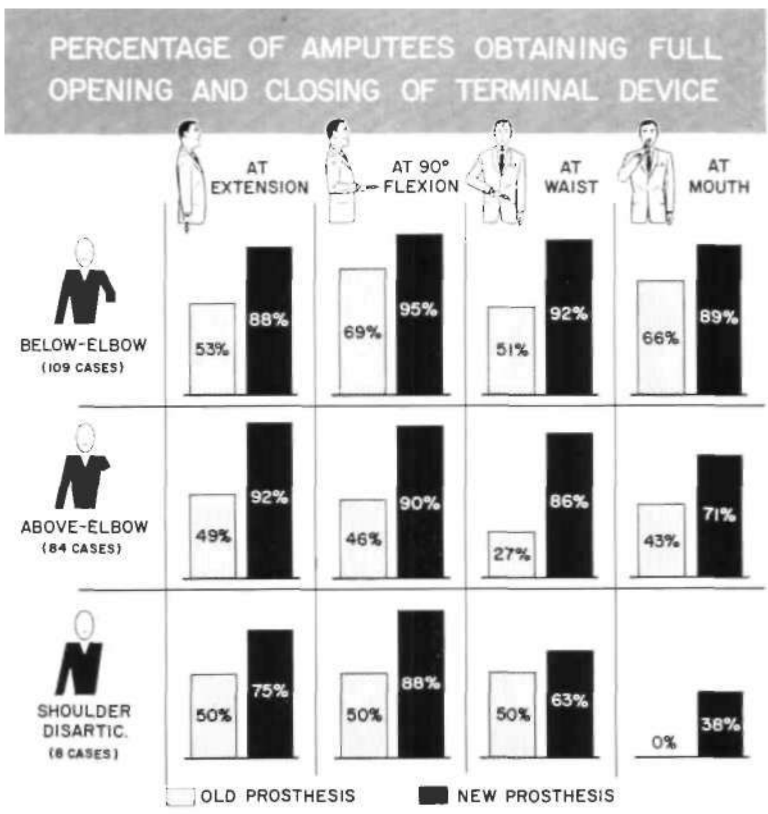
Initial checkout of all patients provided with program arms revealed some problems in application of the Bowden cable (Table 6). faulty placement of retainers, improper cable lengths, and poor. soldering of connections were the main sources of trouble. Of course some of the arms had more than one fault, whereas about half of the 790 arms fitted and checked out in the study had no faults at all in the transmission system.

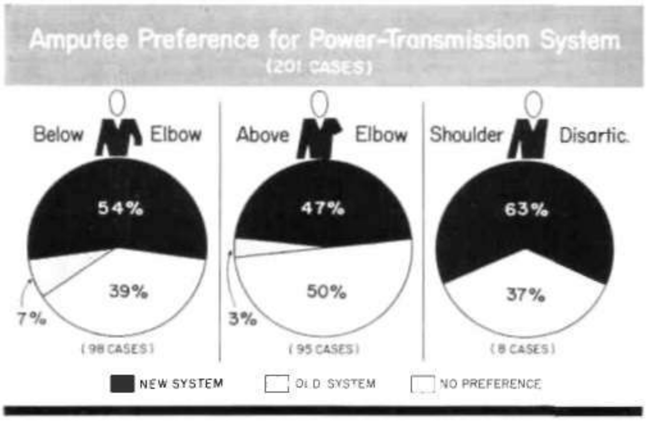
Table 6

DEFICIENCIES IN POWER-TRANSMISSION SYSTEMS
(Based on Initial Checkout of 790 New Prostheses)

Prosthesis Type	Deficiency: Cable and/or Cable Housing of Improper Length	Retainers Improperly Aligned	Poor Solder Joints	Faultless
Below-Elbow	64	77	49	231
Above-Elbow	102	86	67	148
Shoulder Disarticulation	21	16	8	27

Those in the study who had used power-transmission systems in both old and new arms (285) generally found the Howden-cable system easy to use, acceptable in noise level and in appearance, kind to clothing, and free of





excessive maintenance requirements. Of these amputees, 201 responded to questions intended to elicit preference either for their old or for their new cable systems. Only 10 of the 201 in the group preferred their old power-transmission systems, 103 preferred the new. Yet 88 had no preference, which indicates that a significant number of preprogram arms had the advantage of an adequate power-transmission system.

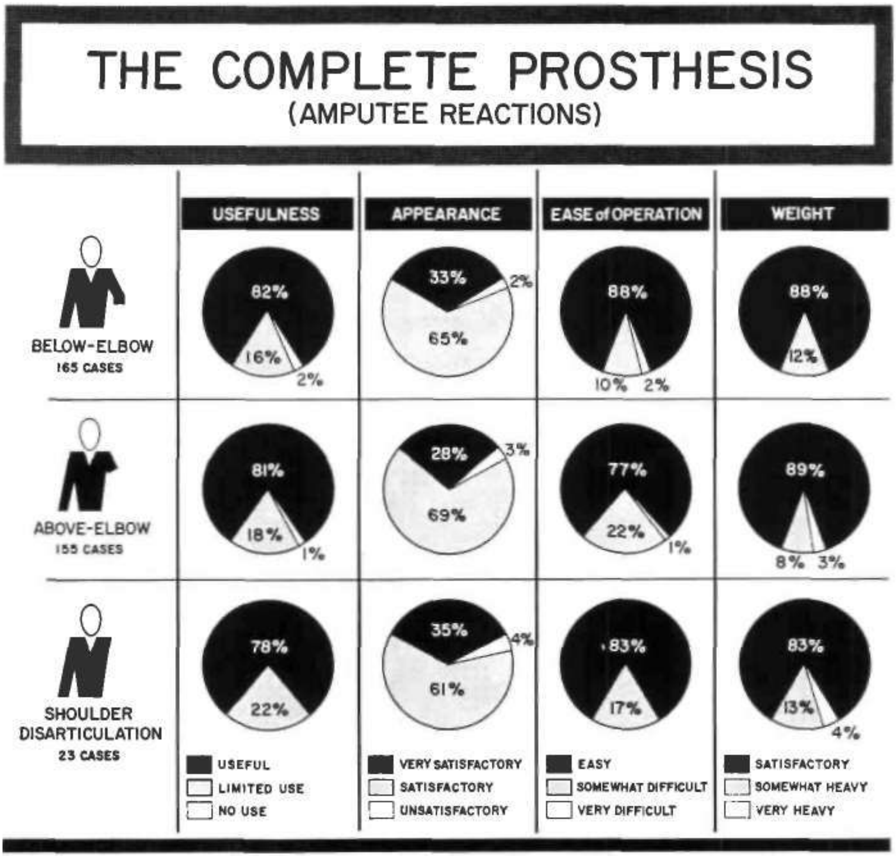
Suggestions for improvement indicated that the amputees would have liked to have seen the cables concealed within the prosthesis, although the existing appearance was not considered unsatisfactory. Easier and quieter operation might also constitute an improvement, although here again there appears to have been no major criticism.

THE COMPLETE PROSTHESIS

Thus far we have considered only the individual elements of the prosthesis. A matter of equal importance, however, is the consideration of the prosthetic appliance in its entirety and of the effects of clinical treatment and training with the prosthesis. Although the data presented here concern the below-elbow, above-elbow, and shoulder-disarticulation cases only, findings from the 10 bilateral amputees who were available for evaluation may also be considered indicative of probable trends. The responses of the small bilateral group, consistently positive toward the new program arms, were substantially in agreement with the responses from the other amputees.

Although most wearers considered their new arms to be useful, the desire for further improvement was reflected in the significant percentage of wearers who considered the arms to be of limited use only. When the amputees compared the general usefulness of the old prostheses with the general usefulness of the new arms, the new arm was preferred. The greatest improvement showed up in the shoulder-disarticulation and above-elbow groups. When all amputation levels were considered together, only 59 percent of the wearers felt that the old prosthesis was "useful." With the new arms, the figure went up to 79 percent. While nearly 5 percent of the wearers felt the old arm to be of no use, less than 1 percent reacted in this manner to the new arms.

Perhaps the most meaningful gains in function were made in the area of harnessing and in routine use of locking elbow joints for above-elbow and shoulder-disarticulation cases. Although harnessing problems existed initially with program arms, the checkout procedures brought the difficulties to light so that suitable improvements could be made. Certainly arm harnessing was a major problem prior to the Field Studies also, as indicated by the fact that the new harnesses were preferred over the old by a ratio of five to one (Table 4). Locking elbow units, which stabilize the forearm and terminal device for above-elbow and shoulder amputees, are obviously superior to nonlocking elbows from a functional standpoint. For without elbow lock, prehension is handicapped, pushing and pulling with flexed elbow are seriously impaired, and carrying with flexed elbow (as in carrying a coat over the arm) is so difficult as to be impractical. Although manual elbow-locking mechanisms are effective, the newer elbows, operated through the harness system, free the sound hand for more important services. But it must be remembered that all these gains, which now



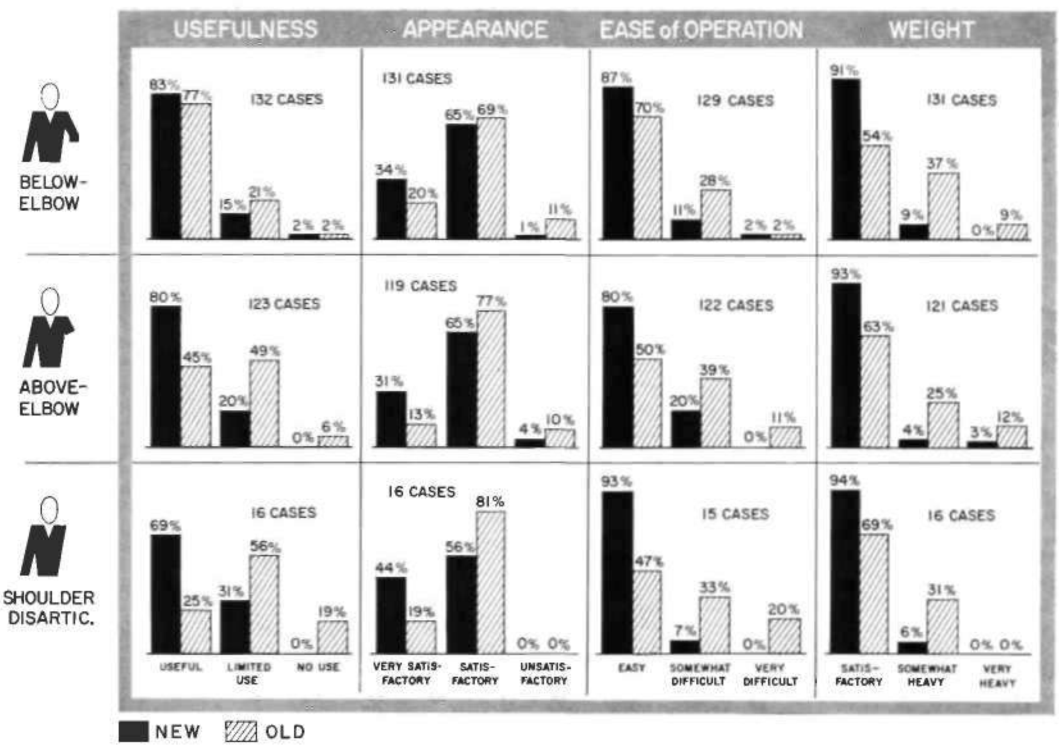
bring prostheses for all types of arm amputation to a relatively high level of usefulness, depend upon a number of factors, including prescription of suitable components, quality of design and construction, and training in prosthesis use, all of which doubtless contributed to the positive attitudes displayed by the test wearers.

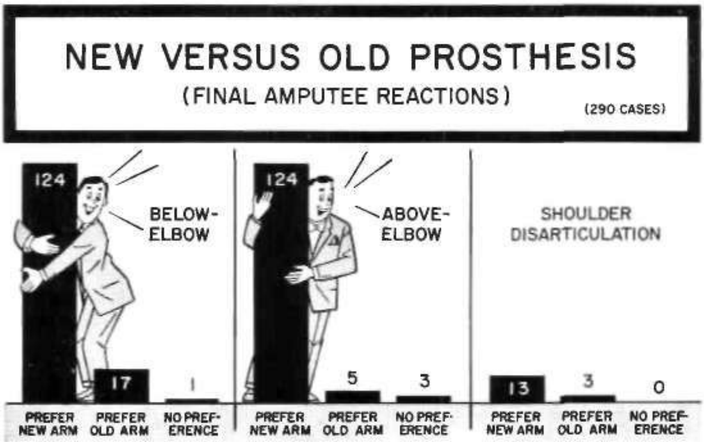
The appearance of the new plastic-laminate arms was accepted in a perfunctory way only, most of the arms being considered "satisfactory." When 266 amputee responses were compared (appearance of new arm *vs.* that of old arm), it was evident that positive changes in reaction had taken place. In general the amputees favored the newer arms. It is in the area of appearance alone that the responses indicate serious reservations in acceptance of any artificial arm, old *or* new. Since under certain social conditions amputees might well be inclined to limit their activities rather than bring attention to the fact that an artificial arm is being worn, sensitivity toward appearance is extremely important. Even the best arm prostheses available today fall far short of being cosmetically adequate and cannot hope really to satisfy either wearers or observers.

Ease of operation of the new prostheses apparently left something to be desired for a substantial number of the amputees, especially those of the above-elbow and shoulder-disarticulation types. Simpler elbow-lock operation and reduction in the difficulties of terminal-device positioning (perhaps by providing more mobility at the wrist) were mentioned as important areas requiring improvement. When the amputees compared old and new prostheses with respect to ease of operation, the new arms nevertheless proved superior. Many amputees (59 percent) felt that operation of their old prostheses was "easy." But when later they were asked to comment on the ease of operation of their new arms, 84 percent replied that operation was "easy." Slightly over 7 percent of the wearers felt that operation was "very difficult" with the old arms, whereas less than 1 percent felt that way about the new arms. Although again these important gains were most prevalent among the shoulder-disarticulation and above-elbow cases, significant improvements were noticed among the below-elbow amputees also.

Although to date very little attention has been given to study of its significance, the weight of the prosthesis has always occasioned a great deal of interest. Generally speaking, the practice has been to keep weight at a minimum, since amputee weight tolerance has not as yet been determined specifically. The data indicate that the below-elbow arms furnished in the program were slightly lighter than the corresponding preprogram arms (1.8 lb. compared with 2.1 lb.). Above-elbow prostheses weighed an average of 2% lb., there being no significant differences between the old and the new. The average weight of the new shoulder-disarticulation arms was about 3-1/2 lb., about 1/2 lb. heavier than preprogram types. Amputees at all levels generally felt that the total weight of the new prosthesis was satisfactory, although

NEW VERSUS OLD PROSTHESIS
(AMPUTEE COMPARISONS)





there were some indications that further weight reduction would be welcomed. About 7 percent of the subjects felt that the prostheses were somewhat heavy, less than 2 percent that they were very heavy. But 33 percent of the wearers considered the new prostheses *more* acceptable in terms of weight than the old arms, even though only slight differences in actual weight were noted. Such reactions are thought to be related to increased function, improved comfort, better fit, and/or improved weight distribution in the new arms.

When comparisons were made between amputee reactions to the old and to the new arms, the data for all levels of amputation clearly favored the newer, program-type, plastic-laminate prostheses. Such endorsement by wearers reflects not only the superior construction and the improved mechanical components incorporated into the newer prostheses but also the values of the patient-management procedures advocated by the program—prescription of carefully selected arm components, checkout to ensure basic adequacy of the fitting, and finally proper training in the use of the prosthesis.

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