The Upper-Extremity Prosthetics Armamentarium

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

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

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

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

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TERMINAL DEVICES

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

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

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

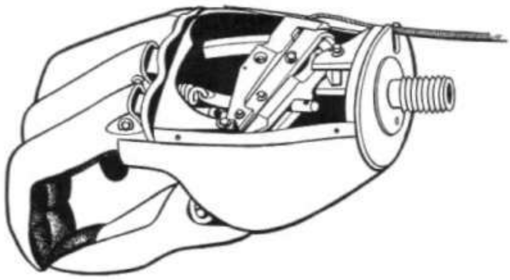

Fig. 1. APRL model 4C voluntary-closing hand.

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

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

APRL VOLUNTARY-CLOSING HOOK

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

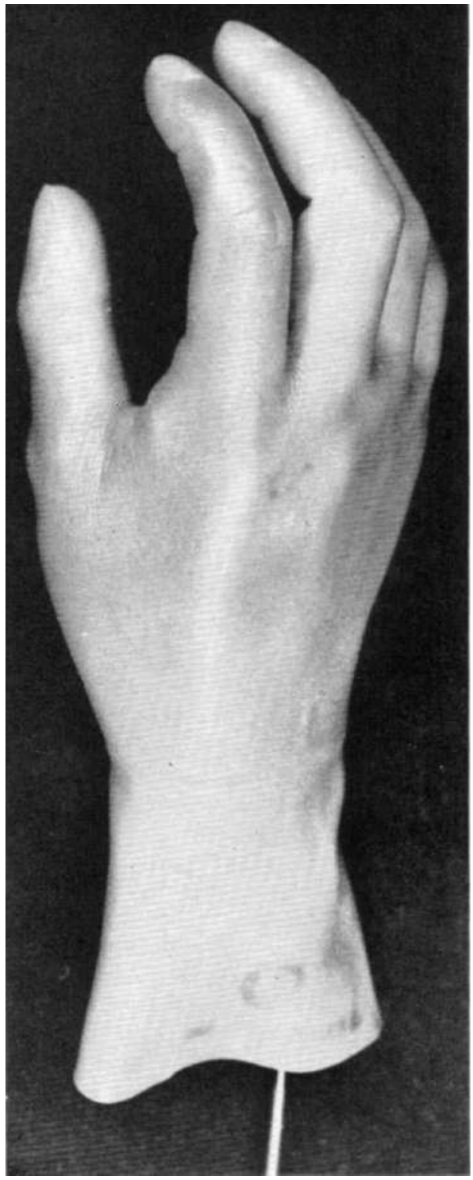

Fig. 2. APRL model 4C voluntary-closing hand covered with APRL cosmetic glove.

NORTHROP-SIERRA VOLUNTARY-OPENING TWO-LOAD HOOK

In the Northrop-Sierra voluntary-opening two-load hook (Fig. 4), designed primarily for bilateral amputees, tension on the control cable causes one hook finger to open against a spring force, which in turn provides prehensile force between the hook fingers when there is no tension on the control cable. The spring force is provided by two identical coil-type springs. When both are engaged, a prehensile force of approximately 7 lb. is available at the finger tips. When only one spring is engaged, 3 1/2-lb. of force are available.

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

DORRANCE VOLUNTARY-OPENING HOOK

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

LENGTH ADAPTERS AND FAIRINGS

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

WRIST UNITS

MANUAL FRICTION-TYPE WRIST UNITS

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

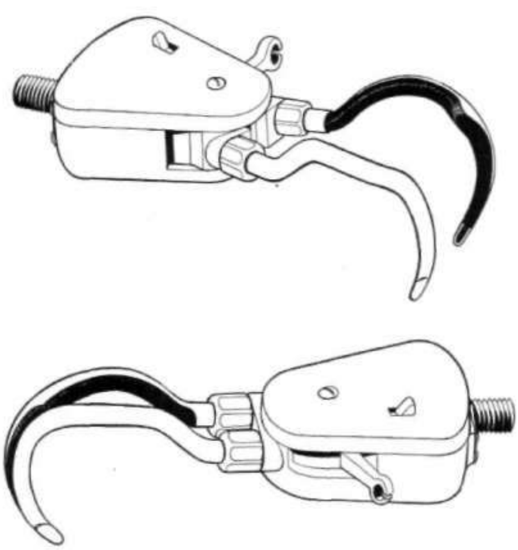

Fig. 3. APRL voluntary-closing hook in open and closed positions.

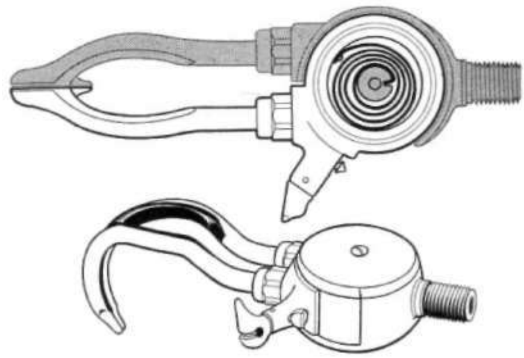

Fig. 4. Northrop-Sierra voluntary-opening two-load hook. Schematic diagram (above) shows arrangement of hook thumb and enclosed coil springs.

Fig. 5. Dorrance #5 utility hook.

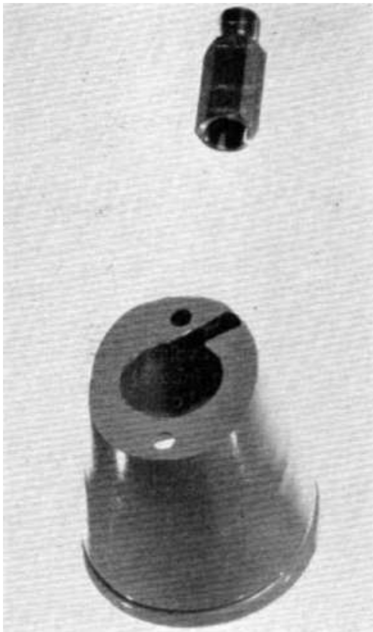

Fig. 6. Wrist fairing and length adapter for APRL model 4C hand.

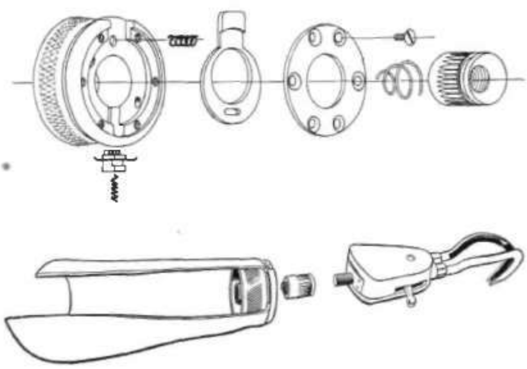

Fig. 7. Hosmer F-M wrist unit, with exploded view showing arrangement of parts.

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

MANUAL LOCK-TYPE WRIST UNITS

Hosmer F-M Wrist Unit

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

Hosmer Quick-Change Wrist Unit

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

NORTHROP-SIERRA WRIST-FLEXION DEVICE

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

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

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

APRL-SIERRA WRIST-ROTATION STEP-UP UNIT

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

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

BELOW-ELBOW HINGES

ROBIN-AIDS FLEXIBLE HINGES

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

LEATHER-STRAP HINGES

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

SINGLE-AXIS HINGES

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

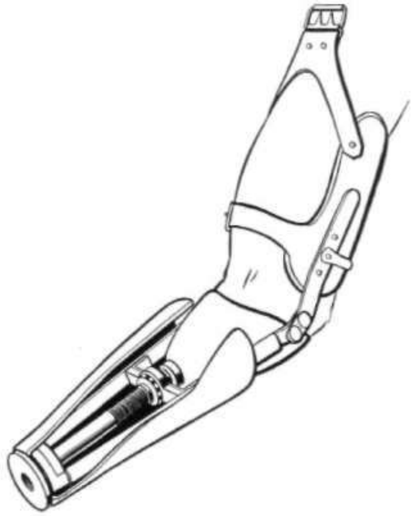

Fig. 9. APRL-Sierra wrist-rotation step-up unit.

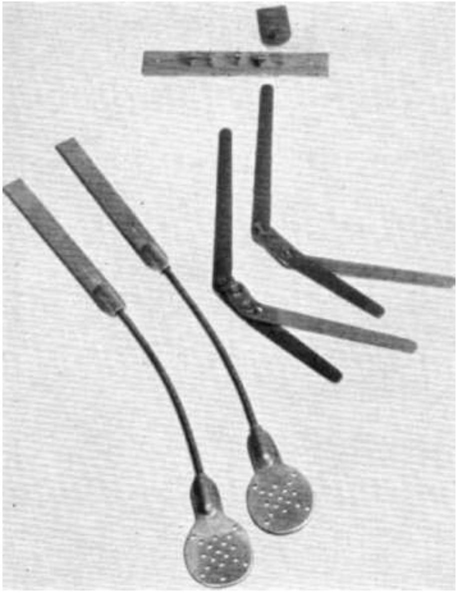

Fig. 10. Below-elbow hinges. Top, Sierra insert hinge; center, Hosmer variable-ratio step-up hinge; bottom, Robin-Aids flexible hinge.

POLYCENTRIC HINGES

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

NORTHROP-SIERRA INSERT HINGES

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

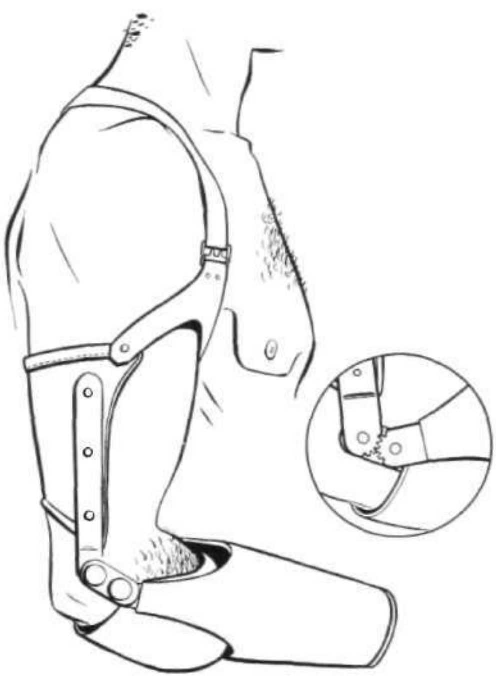

Fig. 11. Hosmer MA-100 step-up hinge.

STEP-UP HINGES

Hosmer MA-100 Hinges

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

Hosmer Variable-Ratio Step-Up Hinge

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

ROBIN-AIDS STUMP-ACTUATED ELBOW LOCK

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

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

ELBOW UNITS FOR ABOVE-ELBOW CASES

NORTHROP MODEL C ELBOW

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

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

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

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

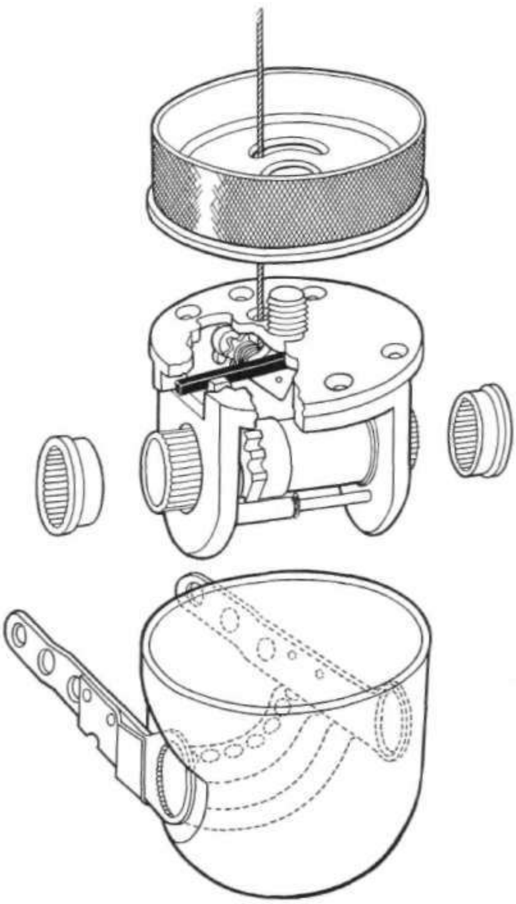

Fig. 13. Northrop model C elbow unit.

HOSMER ELBOW UNIT

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

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

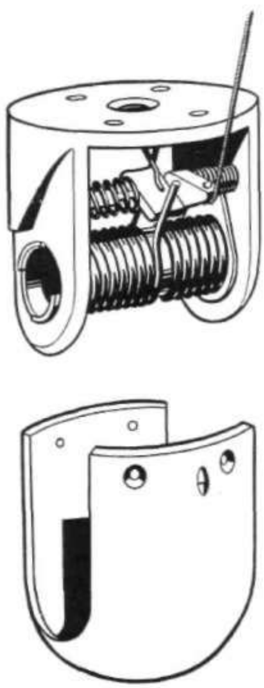

Fig. 14. Hosmer elbow unit, without turntable or forearm saddle attachments.

ELBOW-DISARTICULATION PROSTHESES

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

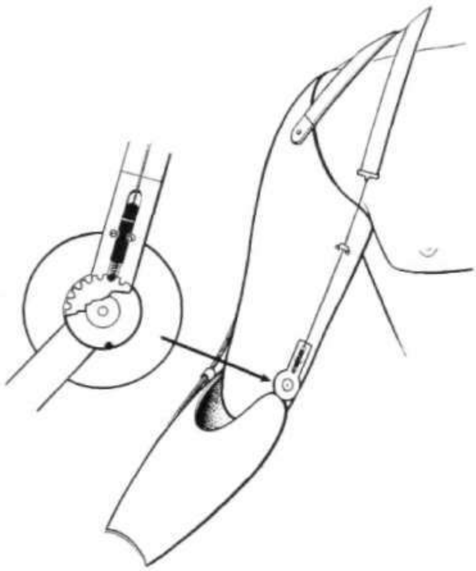

Fig. 15. APRL-Sierra outside-locking elbow hinge.

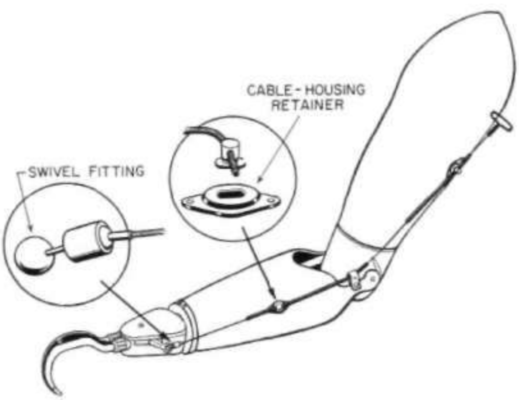

Fig. 16. Bowden-type control cable and attachments.

CONTROL SYSTEMS

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

BELOW-ELBOW BICEPS CINEPLASTY CONTROL SYSTEMS

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

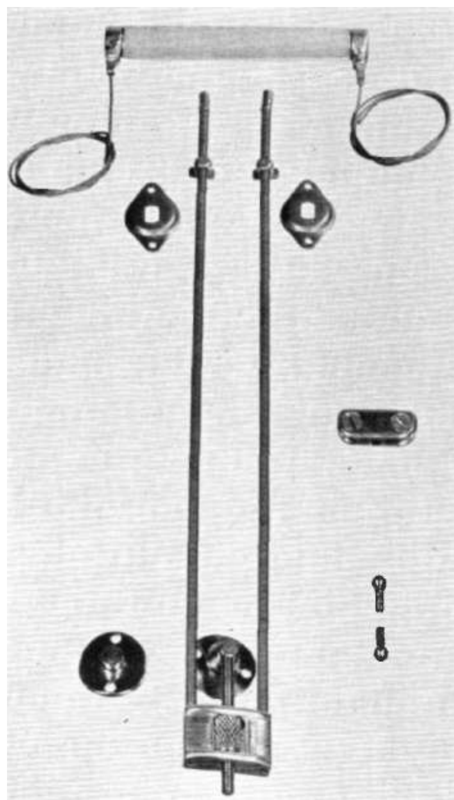

Fig. 17. Twin-cable control system for below-elbow biceps cineplasty.

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

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

NUDGE CONTROL

For the shoulder-disarticulation case, in which it is impossible to provide from shoulder

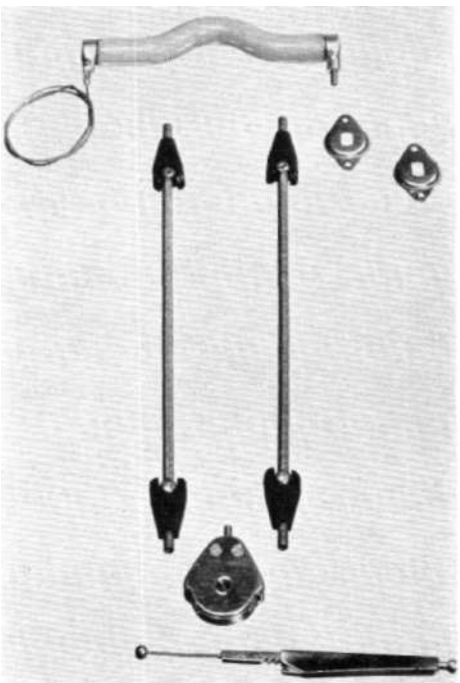

Fig. 18. APRL single-cable control system for below-elbow biceps cineplasty

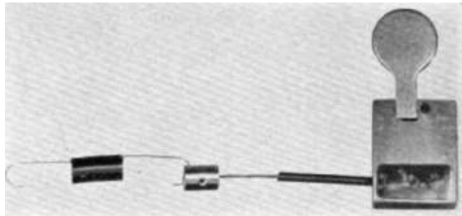

Fig. 19. Nudge control for operation of elbow lock in shoulder-disarticulation case.

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

CONCLUSION

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

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

Needless to say, each existing armamentarium item is being accorded careful study by the various research groups in an effort to increase efficiency and utility. Many new devices are now in the research stage; some are approaching the transitional period; others are known to be necessary and steps have been taken to prove such devices and to production-engineer them to the point where they will be marketable from the standpoint of increased efficiency, decreased maintenance, and economics. To mention a few items, the goals sought include improved terminal devices, both hand and hook; the cosmetic glove; improved elbow-lock mechanisms and elbow mechanisms themselves; the cosmetic approach to the entire prosthesis, up to and including the shoulder; and improvement of the over-all control systems to make them more efficient and more durable than are those now available. Already existent items of the armamentarium, such as harnesses, harness materials, and fittings, have been passed by purposely in this discussion, since they are well known to the industry. The use of some of the new synthetic materials, such as nylon, orlon, and dacron webbing, is standard practice in most limbshops. These new webbings are perspiration-resistant and possess adequate strength to meet the requirements of modern prosthetic devices. New webbings of various types and structures are constantly under study and test. Steady improvement has been made in the process of weaving these materials to prevent stretching.

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