Artificial Arm Checkout Procedures

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The story of civilization's slow but steady march of progress from the days of the Roman Empire, through the Industrial Age, and into the present Technological Age is the story of measurements. The standardization of such common units as the inch and the foot required thousands of years, but once that was accomplished, it paved the way for an almost unbelievably rapid technological advance. One need only compare the developments that have occurred since the metric system was devised in 1793 with those of all the preceding centuries. Replacement of the craftsman's personal art with clearly understood, standard methods has enhanced the lives of all of us by making simple necessities, as well as more luxurious items, available in more adequate quantities and at more reasonable prices.

Just as mankind in general profited from measurement standardization, so can those who have lost a limb or limbs and those who devote themselves to replacing lost members. Every person concerned with the manufacture and fitting of a prosthesis—whether he be a prosthetist, amputee, trainer, or representative of the paying agency—has felt the need for some set of standards to determine the worth of the prosthesis. Development of such a "yardstick of performance" was just as necessary to the advancement of the prosthetics industry as was the standardization of the inch to the Industrial Age. The so-called "checkout procedures" provide the prosthetist and other members of the clinic team with an invaluable tool for measuring the biomechanical effectiveness of all upper-extremity prostheses.

Such questions as "Does this prosthesis fit as well as your last one?" or "Can you work it?" receive only a vague, often uncertain, answer, but such criteria are too often accepted as a measure of performance. One of the first steps in establishing a set of standards is to determine which variable factors can be measured accurately. In upper-extremity prosthetics, some of the measurable factors are ranges of motion with and without the prosthesis, control-system efficiencies, forces necessary to flex the forearm, live-lift of the forearm, socket stability, movement of the terminal device when locking the elbow, plus several others. Once the factors are determined, a test program must be set up and carried out. The results of such a test must first be analyzed, then a trial set of standards must be established, and finally the standards must be laboratory-tested on as great a number of amputee subjects as possible.

To this end, a test station was established, and 29 amputees, selected at random from a mailing list, were tested. Approximately 30 tests were applied to these amputees and their prostheses. By combining the test data with research and practical experience, a preliminary set of liberal standards was drawn up. The standards were then applied to more than 70 amputees during the two-year existence of the Case Study Program at the University of California at Los Angeles. Certain modifications and refinements in the tests were made until the procedure attained present form.

One of the prime requirements in establishing the tests was that their application be kept simple, with respect both to the equipment and to the procedures to be followed. Sufficient accuracy of measurement can be obtained with a ruler and a spring scale, and the test standards are liberal enough to allow minor inaccuracies without rejecting the prosthesis. The most important concern is, first, that all tests be applied in a similar manner and, second, that the results be compared to a universally acceptable standard.

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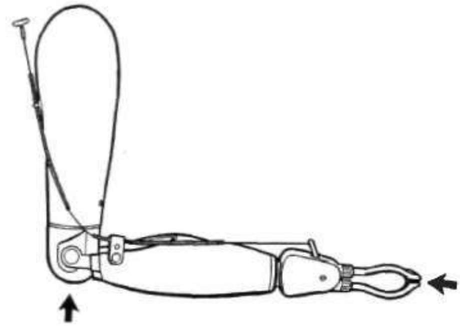

Fig. 1. Test for compression fit and comfort.

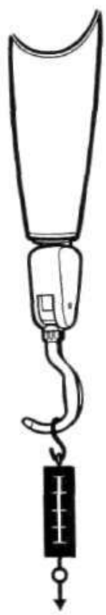

Fig. 2. Test for tension stability.

The tests and standards may be conveniently listed in three groups: general tests, applicable to all types of prostheses; tests for below-elbow prostheses; and tests for above-elbow prostheses.[2]

All tests should be performed with the amputee wearing his prosthesis. In the case of a bilateral amputee, each side should be tested separately, but the amputee should have almost complete independence of action on each side while wearing both prostheses.

GENERAL TESTS

TEST NO. 1—COMPRESSION FIT AND COMFORT

Test: Flex the forearm to 90 deg. (lock if AE). Push the prosthesis onto the stump while the wearer resists the push (Fig. 1).

Standard: The amputee should feel no undue discomfort or pain when the prosthesis is forced onto the stump.

TEST NO. 2—TENSION STABILITY

Test: Straighten the prosthesis at the side (Fig. 2). Hook the scale over the terminal device and apply a force of 50 lb. straight down. (A force of 30 lb. is sufficient for children.)

[2] These tests and standards may not apply in cases where atrophy, bone blocks, loss of muscles, and the like are in evidence.

Standard: The prosthesis should not slip more than 1 in. in relation to the stump, and no part of the prosthesis or harness should fail when a 50-lb. distal load is applied.

TEST NO. 3—HOOK-OPENING FACILITY (NORMAL USE)

Test: Flex the forearm to 90 deg. (lock if AE). Have the wearer actively operate the terminal device.

Standard: The wearer should be able to obtain full range of terminal-device operation actively with the forearm flexed to 90 deg.

TEST NO. 4—HOOK-OPENING FACILITY (AT MOUTH AND PERINEUM)

Test: Flex the forearm so the terminal device is near the mouth (lock if AE). Have the wearer actively operate the terminal device. Repeat this procedure with the terminal device near the perineum.

Standard: The wearer should be able to obtain at least 70 percent of full range of terminal-device operation actively at the mouth and perineum.

TEST NO. 5—CONTROL-SYSTEM EFFICIENCY

Test: a) Disconnect the control cable from the terminal device, and attach the scale to hook-operating lever or hand-operating cable (Fig. 3a). Place a 3/4-in. block between the fingers and pull until the block slips out of a voluntary-opening hook or until the fingers of a voluntary-closing hook or hand just close on the block. Note the force at this instant.

b) Reconnect the control cable to the terminal device, and apply the scale to the T-bar, or terminal, at the other end of the control cable. Pull along the line of the harness until the block slips or the fingers touch, as before (Fig. 3b). Note the force at the instant this occurs.

c) Multiply the force measured at the terminal device by 100. Then divide by the force measured at the cable terminal as in the following formula:

$$\text{Efficiency} = \frac{(\text{Force measured at terminal devices}) \times 100}{(\text{Force measured at cable terminal})}$$

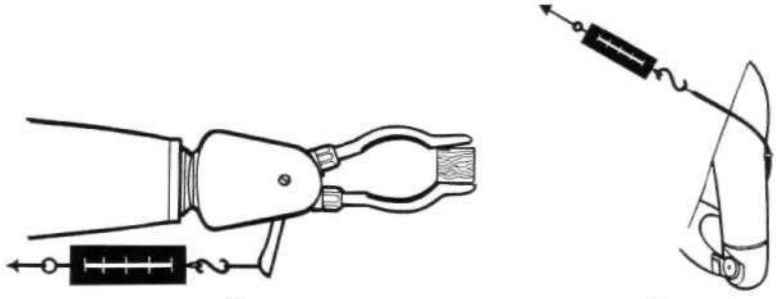

Fig. 3. Test for control-system efficiency.

Standard: The control-system efficiency should be at least 70 percent.

BELOW-ELBOW AND BELOW-ELBOW BICEPS-CINEPLASTY TESTS

All of the following tests apply to the conventional below-elbow prosthesis and to the below-elbow biceps-cineplasty prosthesis.

TEST NO. 1—FOREARM FLEXION

Test: Compare the amputee's maximum range of forearm flexion with and without the prosthesis.

Standard: Active flexion with the prosthesis on should be as great as active flexion without the prosthesis.

TEST NO. 2—FOREARM ROTATION[3]

Test: Compare the amputee's maximum range of forearm rotation (extreme pronation to extreme supination) with and without the prosthesis (Fig. 4).

Standard: Active rotation with the prosthesis on should be at least half that obtained without the prosthesis.

ABOVE-ELBOW AND SHOULDER-DISARTICULATION TESTS

All of the following tests apply to the above-elbow prosthesis, and most of them apply to the shoulder-disarticulation prosthesis. Those which do *not* apply to the shoulder-disarticulation case are marked with an asterisk.

TEST NO. 1—RANGES OF STUMP MOTION*

Test: Have the amputee straighten the prosthesis and lock the elbow. Then move his stump and prosthesis through the maximum ranges of flexion, extension, elevation, and rotation.

[3] This test need not be applied when the stump is only half the normal forearm length or less.

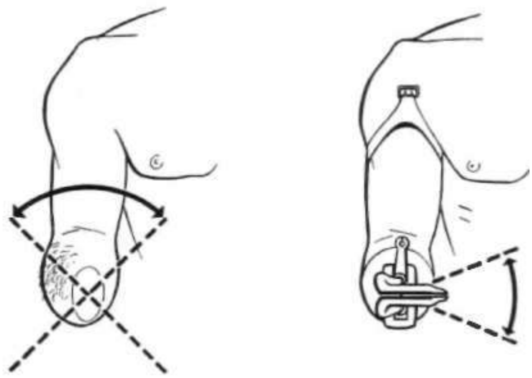

Fig. 4. Test for forearm rotation.

Standard: The amputee should be able to satisfy the following minimum requirements while wearing the prosthesis: flexion, 90 deg.; extension, 30 deg.; elevation, 90 deg.; rotation, 45 deg.

TEST NO. 2—RANGE OF FOREARM FLEXION

Test: Compare the amputee's maximum active range of prosthetic forearm flexion with the maximum manual range. Note the amount of initial forearm flexion built into the prosthesis.

Standard: The amputee should be able to flex actively to 135 deg. of forearm flexion, no more than 10 deg. of which should be due to initial flexion.

TEST NO. 3—HUMERAL FLEXION REQUIRED TO FLEX FOREARM*

Test: Have the amputee flex the prosthetic forearm actively through its entire range using humeral flexion, and note the degrees of flexion of the humerus required to do so.

Standard: Humeral flexion required to flex the prosthetic forearm fully should not exceed 45 deg.

TEST NO. 4—FORCE REQUIRED TO FLEX FORE-ARM

Test: Tape the fingers of the terminal device closed and unlock the elbow. Insert I lie spring scale through the cable attachment, and flex the forearm to 90 deg. while holding the socket stationary. Pull along the normal line of the cable until further flexion of the forearm just starts, and note the force.

Standard: The force required to start flexion of the forearm from 90 deg. should not exceed 10 lb.

TEST NO. 5—LIVE-LIFT

Test: Tape the fingers of the terminal device closed and unlock the elbow. Hook the spring scale over the prosthesis at a distance of 12 in. from the elbow pivot using a leather strap if necessary (Fig. 5). Flex the forearm to 90 deg., and have the amputee actively resist while applying a straight-down pull on the scale. Note the scale reading when the amputee can no longer completely resist the pull and the forearm slips below 90 deg.

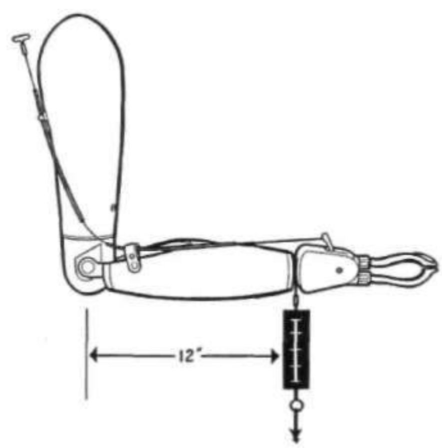

Fig. 5. Test for live-lift.

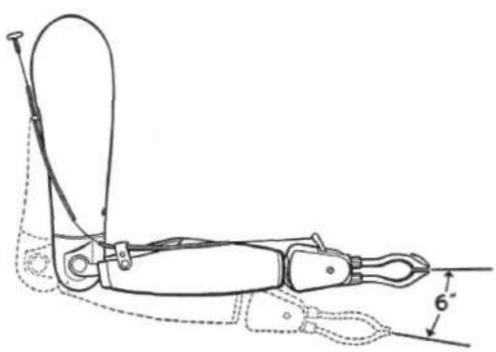

Fig. 6. Tes for motion of terminal **device when** locking elbow.

Standard: The amputee should be able to resist actively a downward force of at least 3 lb. located 12 in. from the elbow center when the forearm is flexed to 90 deg.

TEST NO. 6—INVOLUNTARY OPERATION OF THE ELBOW LOCK*

Test: Face the amputee and have him abduct the prosthesis 60 deg. Note whether or not the elbow lock operates. Then have him walk a short distance swinging the prosthesis in a normal manner, and note whether the elbow lock operates involuntarily or not.

Standard: The elbow lock should not operate involuntarily when the prosthesis is abducted 60 deg. nor during normal walking. In addition, a natural-appearing arm swing should be exhibited while walking.

TEST NO. 7—MOVEMENT OF TERMINAL DEVICE WHEN LOCKING ELBOW*

Test: Have the amputee actively flex the forearm to 90 deg. Then have him actively lock the elbow. Note the movement of the* terminal device as the elbow is locked.

Standard: The terminal device should not move more than 6 in. during active operation of the elbow lock when the forearm is flexed to 90 deg. (Fig. 6).

TEST NO. 8—SOCKET STABILITY DURING ARM ROTATION*

Test: Flex the forearm to 90 deg. and lock the elbow. Have the amputee abduct the prosthesis 60 deg. and rotate his stump and prosthesis. Note any slippage of the socket about the stump.

Standard: The amputee should be able to control the prosthesis during arm rotation, and there should be no slippage of the socket about the stump (Fig. 7).

Fig. 7. Test for socket stability during arm rotation.

TEST NO. 9—STABILITY OF SOCKET AGAINST TORQUE*

Test: Flex the forearm to 90 deg. and lock the elbow. Hook the scale over the prosthesis at a distance of 12 in. from the elbow center, using a leather strap if necessary. Have the amputee resist while pull is applied, first laterally, then medially, on the socket with a force of 2 lb. Note any slippage of the socket about the stump, or of the turntable, which may occur.

Standard: The amputee should be able to resist both lateral and medial pulls of 2 lb. located 12 in. from the elbow center, and the turntable should not turn with this force.

CONCLUSION

That the test procedure has reached a sufficient degree of refinement to be used successfully in the field is evidenced by its widespread adoption. Such agencies as the United States Veterans Administration, the State Departments of Vocational Rehabilitation of California and Illinois, and others include fulfillment of the standards as a contract stipulation. It must, however, be borne in mind that these test procedures are not to be considered as the final answer. Additions, revisions, and general improvements constitute a never-ending project in the field of prosthetics evaluation.