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Artificial Limbs

A Review of Current Developments

COMMITTEE ON PROSTHETICS RESEARCH AND DEVELOPMENT

COMMITTEE ON PROSTHETIC-ORTHOTIC EDUCATION

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Projects, Programs, and Perspectives

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For a quarter of a century, the National Research Council has played a major role in the coordination of research in limb prosthetics in the United States. Originally conceived as a short-term effort likely to terminate at the end of the fiscal year, the program is now mature—solidly based on major accomplishments, yet fully aware of many problems as yet unsolved in artificial limbs, bracing, aids to the blind, hearing aids, and other areas of bioengineering related to rehabilitation.

The NCR's Committee on Prosthetics Research and Development and Committee on Prosthetic-Orthotic Education, which are the descendants of variously named groups with slowly rotating memberships, carry the responsibilities for stimulating and coordinating research, advising sponsors, and speeding the diffusion of knowledge among the many disciplines concerned with rehabilitating patients.

The work of the committees has expanded over the years, not only in sponsorship but in projects, programs, and priorities. In this anniversary year, a review of the history and present status of the program may provide some perspective for a wise, vigorous, and zealous attack on the many remaining problems.

Late in World War II, the Surgeon General of the Army, faced with conflicting claims for the efficacy of various artificial limbs and with criticisms of those supplied in military amputation centers, asked the National Research Council to arrange a meeting to recommend the "best" limbs from which the army could select for standardization. The three-day meeting produced numerous claims and little evidence, but a general recognition of the fact that the "best" were not good enough and that intensive research was needed. The army therefore arranged to have the wartime Office of Scientific Research and Development (which was already supporting the Committee on Sensory Devices investigating mobility and reading aids for the blind) sponsor a contract with the National Academy of Sciences to "conduct with the utmost dispatch . . . studies and experimental investigations in connection with prosthetic devices." The academy, through its National Research Council, set up the Committee on Prosthetic Devices, composed

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of distinguished surgeons and engineers, and proceeded to develop nonprofit subcontracts with a variety of organizations. Some of these in turn made second-tier subcontracts with smaller specialized companies. In addition to a subcontract on hip-disarticulation prostheses with the tiny laboratory then operated by the Artificial Limb Manufacturers Association, there were subcontracts with some of the best-known industries. The latter were busy with war work, but they were willing, for humanitarian and patriotic reasons, in addition to the personal enthusiasms of key officials, to undertake nonprofit work toward inventions which generally were expected to be made available royalty-free to civilians as well as veterans. Northrop Aircraft, Goodyear, International Business Machines, and United States Plywood were among the firms expecting that modern technology could quickly improve the simple and seemingly crude artificial arms and legs and resolve the major complaints of amputees, surgeons, and others. Indeed, some dramatic improvements were quickly made in laboratories, though sometimes years were to intervene before they were widely used, and many ideas never reached the stage of clinical usefulness. Concurrently, major universities—the University of California at Berkeley and at Los Angeles, Northwestern University, and New York University—undertook a variety of tasks.

In August 1945, the surgeons on the committee developed a "bill of complaints" and presented it to the engineering members. It may be instructive to trace the frontal attacks on one of the items prominent on the surgeons' list—an artificial knee which would not buckle. Some discussion of a number of devices followed, including knee friction for control of swing phase, but the primary concern was for a lock which would prevent buckling in stance phase. The demand for knee locks was further underscored by a study undertaken later by New York University on the opinions of surgeons, limb fitters, and amputees (both veterans and nonveterans). In that survey, only the amputee nonveterans gave any significant emphasis to the need for improved fitting and alignment, but even they felt that a locking mechanism for the knee was the more important need. Crash programs on knee locks were launched at a number of laboratories, with the emphasis understandably on mechanisms rather than on man-machine combinations.

These various efforts to develop knee locks led to a great variety of test models of mechanical locks, band brakes, disk brakes, and hydraulic devices with many types of control systems from numerous laboratories, which were tested first on local amputees and later independently at New York University. For a number of years after, there followed complaints about breakage, clicks, hydraulic swishing and squealing noises, hydraulic leaks, and deficiencies of control systems during patients' activities other than level walking. In the mid-1950s, much of the emphasis shifted to swing-phase control by variable mechanical friction or by hydraulic or pneumatic devices, which simplified some of the design problems and led to the commercial availability and widespread use of several devices which permitted amputees to walk easily and gracefully at a wider range of speeds. Finally, the Mauch S-N-S hydraulic stance-and-swing-phase unit, the principal survivor of a multitude of stance-phase controls, has reached acceptance for routine availability in the past year or so, several hundred being in use, with the demand growing rapidly.

This long delay in the availability of a versatile and reliable stance-phase control, and its relatively minor use even today, is more acceptable if one recognizes the substantial improvements in alignment and freedom from buckling of conventional above-knee artificial legs with simple, single-axis knee joints. These were developed largely as the result of studies of improved fitting of the socket to the stump and of the alignment between the socket, knee, shank, and foot. Such studies, and the subsequent codification of biomechanical principles, arose largely from the attempt to reintroduce a venerable invention, the suction socket.

The concept of holding an artificial limb on the body by atmospheric pressure was originally patented by Parmelee in 1863. Relatively simple changes from older conventional alignment greatly increased knee stability during stance, yet allowed controlled bending of the knee late in stance to prepare for swing phase. Correspondingly, proper mediolateral alignment not only allowed stability on the suction-socket prosthesis without sidesway or limping, but also, when applied to conventional prostheses (which continued to be used by large numbers of amputees, particularly the elderly) greatly reduced the stresses in the hip joints and pelvic bands.

Thus a relatively small program (conducted primarily by engineers) on biomechanics and fitting, working in parallel with the development of a growing number of engineering designs of knee locks, achieved substantial progress toward safety against knee buckling long before a truly satisfactory hydraulic stance-control device became available.

The foregoing is but one example of successful flanking attacks on complex problems in prosthetics. CPRD and CPOE have helped to create the climate for other similar successes in their roles of coordinators in the research and education activities of the program.

In fulfillment of that role, the Committee on Prosthetics Research and Development, with the help of its subcommittees and their panels, serves very effectively as an architect for an entire coordinated program and as advisor to the several sponsors. Organization of frequent workshops and conferences, review of proposals, and conduct of occasional site visits are typical duties. Occasionally, formal recommendations are made through official channels, but participation of liaison representatives and circulation of minutes and reports on a routine basis usually are sufficient to keep sponsors informed. Frequently, the climate of substantially unanimous opinion developing out of informal discussions, staff work, and conferences on workshops leads to actions by sponsors and laboratories without formal recommendations to sponsors, instructions from scientific officers to contractors, or detailed amendments of the broad subject-work clause typically used in contracts. The dedicated, distinguished people who have worked in this program over the past quarter century have been anxious to aid the patient as rapidly as possible without awaiting formal orders. No one wants to work in a fruitless field or to duplicate unwittingly work done elsewhere (though systematic replication or checking may prove necessary). Typically, delicate