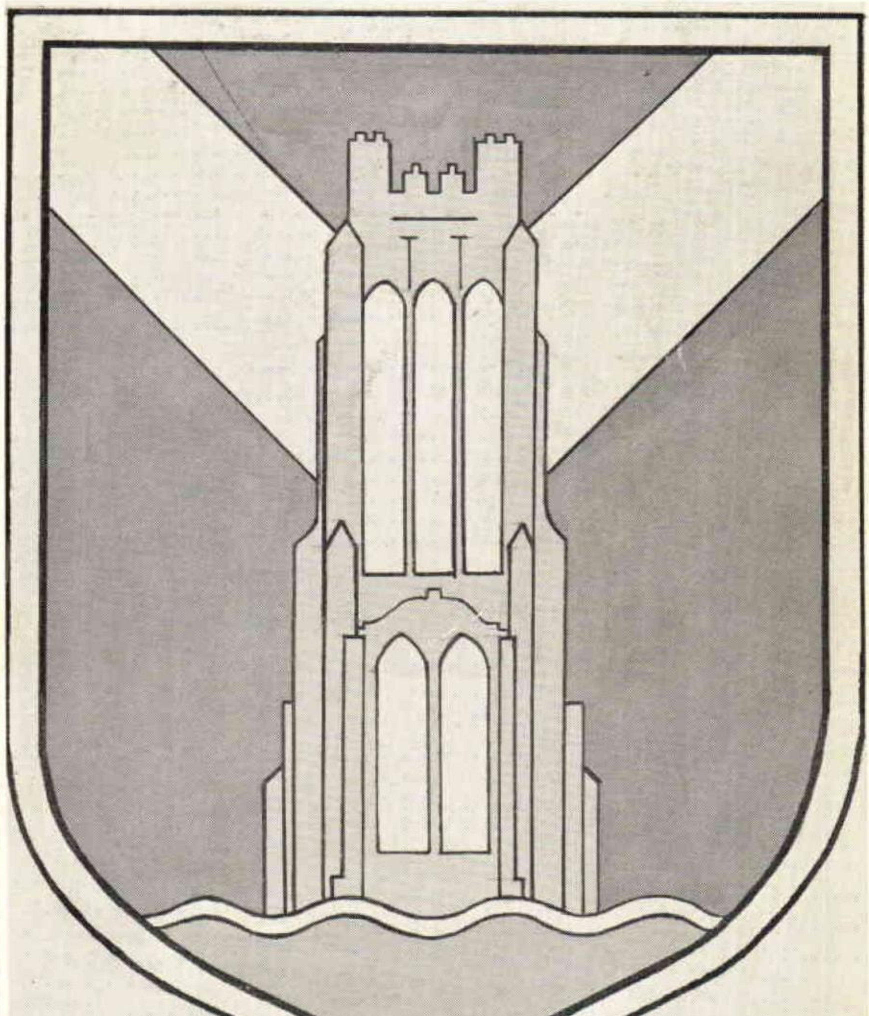
TEMBER, 1962

RTHOPEDIC & PROSTHETIC APPLIANCE JOURNAL

Journal of the
Limb and Brace Profession



SHIELD OF NORTHWESTERN UNIVERSITY MEDICAL SCHOOL—
See "Dedication," page 212, and "Cover Design", inside front cover

publisher: American Orthotics and Prosthetics Association

INVITATION TO THE 1962 ASSEMBLY
To All Interested in the Rehabilitation
of the Orthopedically Disabled
(For Details, see "Where, When, Why," by Program Chairman Herbert J. Hart, page 281)

Cover design
The shield of Northwestern University Medical School. The windows of the Ward Memorial Building Tower form the stem of a golden letter Y, symbolizing the historic Chicago River. This device and the tower are superimposed on a purple field—the University color. Lake Michigan, in blue, appears at the bottom, its waves bordering the Campus.
(Reproduced courtesy of Leslie B. Arey, *Northwestern University Medical School, 1859-1959*. Evanston and Chicago, 1959).

Orthopedic and Prosthetic Appliance Journal

(Title registered U. S. Patent Office)

VOLUME 16 • SEPTEMBER, 1962 • NUMBER 3

Second class postage paid at Washington, D. C.

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The *Orthopedic and Prosthetic Appliance Journal* is issued four times a year—in March, June, September and December. The 1962 subscription price payable in advance is five dollars a year, for delivery anywhere in the Western Hemisphere. The subscription rate elsewhere is six dollars a year.

Publication does not constitute official endorsement of opinions presented in articles. The *Journal* is the official organ of its publisher, The American Orthotics and Prosthetics Association (formerly Orthopedic Appliance and Limb Mfrs. Assn.) and of the American Board for Certification. All correspondence should be addressed to the Editor of the *Orthopedic and Prosthetic Appliance Journal*, 919 18th St., N.W., Washington 6, D. C. Telephone, 296-4160

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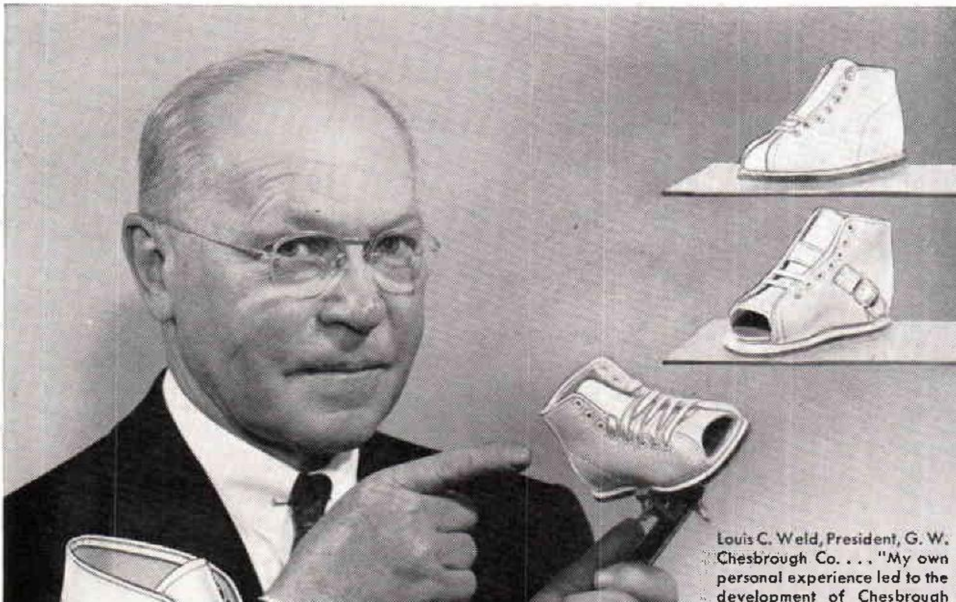

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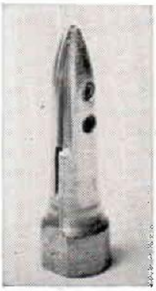

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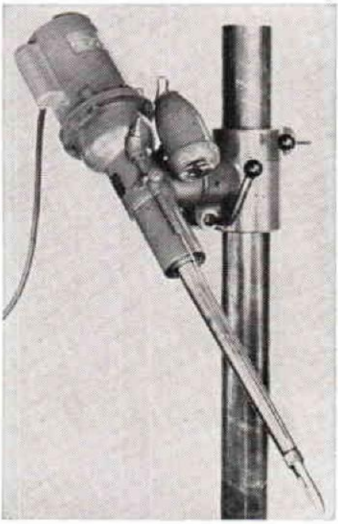

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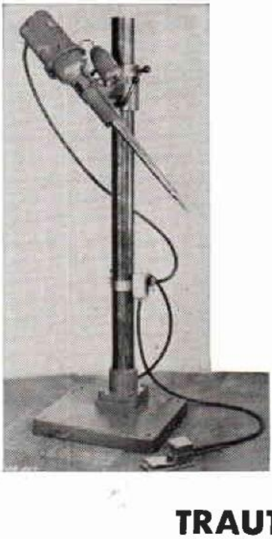

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Dedication

TO: Northwestern University.

It is with much pleasure and satisfaction that we dedicate this September 1962 issue to Northwestern University for its program in Prosthetic-Orthotic Education and Research.

The twelve articles in this issue are contributed by specialists from these programs. The authors and their subjects are as follows:

Prosthetic-Orthotic Education—Past, Present, and Future, by Clinton L. Compere, M.D.; A New Image in Professional Education, by Jack D. Armold, Ph.D.; Student Leaves School: What Then? by Blair Hanger, C.P.; Philosophy of Research, By Colin A. McLaurin, B.A.Sc.; The Patellar-Bearing Total Contact Prosthesis for Below-Knee Amputees, by Robert G. Thompson, M.D.; The Role of Physical Therapy in Prosthetics, by Hildegarde Myers, B.S., R.P.T.; Mechanics of Spinal Bracing, by Robert D. Keagy, M.D.; Mechanics of Spinal Bracing as Related to Immobilization, by Siegfried W. Jesswein, C.O.; Current Concepts in the Management of the Juvenile Amputee, by George T. Aiken, M.D.; Growth Potential in Children, by Claude N. Lambert, M.D.; Development of Motor Capacity in the Normal Child, by Frederick E. Vultee, M.D.; Prosthetic and Orthotic Devices for Nonstandard Protheses in the Management of Limb Deficiencies, by Charles H. Frantz, M.D.

This is the last of three issues of the *Journal* which have been "University Issues." The first was the issue for September 1960, dedicated to New York University. The June 1961 Issue was dedicated to the University of California at Los Angeles.

FRED QUISENBERRY, President,
The American Orthotics and Prosthetics Association

ROY M. HOOVER, M.D., President
American Board for Certification in Orthotics and Prosthetics.

Introduction

This issue of the *Orthopedic and Prosthetic Appliance Journal* consists of articles written by members of the Prosthetic-Orthotic Education faculty. They have been planned to indicate a broad view of the type of instruction available at Northwestern, and show philosophies and developments in the fields of prosthetics and orthotics.

Each author has written material based upon his own specialty. Several articles take the form of an essay; some are in the nature of a report to the profession; and still others contain discussions of current knowledge in the field.

There are three general divisions covering the courses which have been taught and which will be offered in the near future at Northwestern. These are Prosthetics, Spinal Orthotics, and Management of the Juvenile Amputee.

Susan Hastings
Editorial and Admistrative Assistant

Prosthetic-Orthotic Education— Past, Present, and Future

By CLINTON L. COMPERE, M.D.
Associate Professor in Orthopedic Surgery
Academic Advisor
Prosthetic-Orthotic Education,
Northwestern University Medical School

Life is short, and the Art long; the occasion fleeting; experience fallacious, and judgment difficult. The physician must not only be prepared to do what is right himself, but also to make the patient, the attendants, and the externals cooperate. (Hippocrates, 425 B.C.)

The contemporary level of prosthetic and orthotic education in the United States is not the result of accidental growth and development. The current status, with the three solidly established programs at New York University, Northwestern University, and the University of California, Los Angeles; the Michigan Crippled Children's Commission program in Grand Rapids; and the many regional educational presentations are the result of twelve years of dedicated trial-and-error planning by specialists from the Army, the Navy, the Veterans Administration, industry, and many physicians, engineers, and educators from several university centers.

The first research efforts were started in certain of the military amputation centers toward the close of World War II, and these were continued at Walter Reed and in various university centers with financial support from the Veterans Adminstration and from the Office of the Surgeon General of the Army. In 1948, the research activities were coordinated under the supervision of the Advisory Committee on Artificial Limbs of the National Academy of Sciences—National Research Council. Lower-extremity research and development was centered in two laboratories at the University of California: in the Department of Engineering at Berkeley, and in the Medical Center at San Francisco. Basic upper-extremity research was conducted by the Department of Engineering at the University of California at Los Angeles. The Navy Prosthetics Research Laboratory at the U. S. Naval Hospital, Oakland, California, concentrated on lower-extremity development, and the Army Prosthetics Research Laboratory at Walter Reed Army Medical Center, cooperated in the development of upper-extremity components. New York University, with the cooperation of the VA Prosthetic Center in New York, was assigned the responsibility for testing and field application to assure that devices and techniques developed under the program were, before acceptance, useful improvements in amputee rehabilitation.

The earliest organized educational presentations were in the Veterans Administration Suction Socket Schools in 1948-49. The primary purpose was to indoctrinate the new VA Regional Office Clinic Teams with the principles of suction socket prescription, fitting, and training. The background information had been developed at UC, Berkeley, and faculty personnel for the schools was trained in a pilot school in this facility. The suction socket schools were thoroughly successful in accomplishing their limited purpose.

In the meetings of the technical committees of the Advisory Committee on Artificial Limbs, it became increasingly apparent that a planned program for dissemination of research developments was imperative. For a review of the upper-extremity problems an Institute on Upper-Extremity Prosthetics was held at the University of California in Los Angeles in January 1951 under the sponsorship of Craig Taylor. General F. S. Strong, who has been our guiding hand for all programs throughout the years, succinctly stated the objective of this Institute as follows: "The problem then is to prepare a program for practical application so that the results of research and development in the past may be translated to the service of amputees over the years to come." The direct result of this Institute meeting was the developmen of the pilot course for upper-extremity prosthetics, the first of which was held in Los Angeles in January 1952. Since this beginning, there has been a steady expansion of our educational activities.

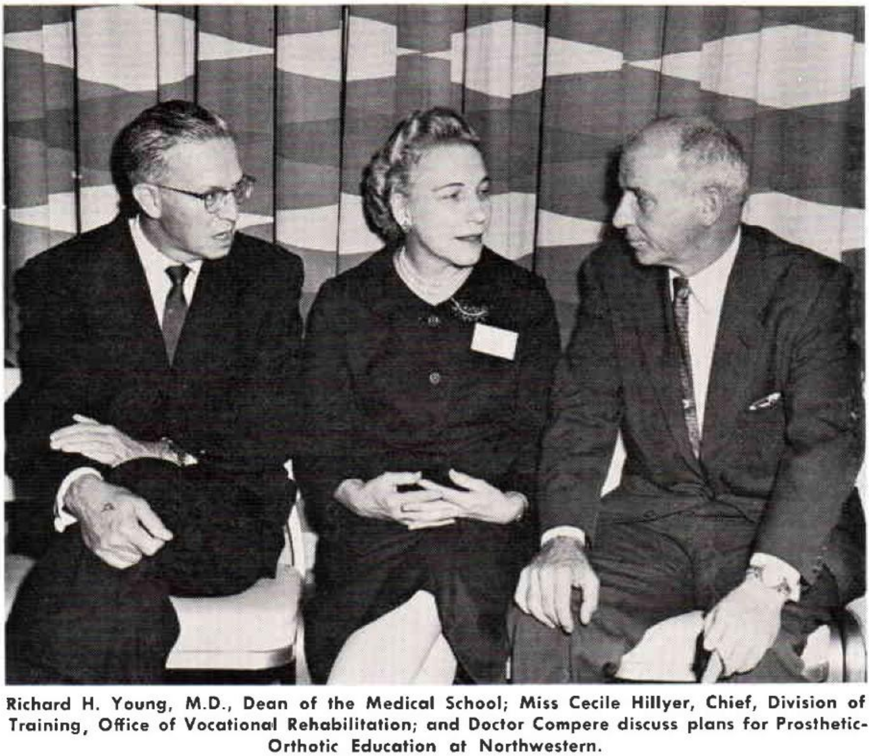
By 1955, twelve successful Upper-Extremity Schools had been held at UCLA. A special Committee on Prosthetics Education had been appointed, and following a meeting in New York City on April 19, 1955, a pilot school program for lower-extremity prosthetics was activated. This pilot school was held at the U.S. Naval Hospital in Oakland, August 15 to September 2, 1955. The New York University Educational Program was activated with the first course to be given in January 1956.

During the latter part of 1955, General Strong dissolved the Panel on Prosthetics Research and Development and the entire program was reorganized under a newly appointed Prosthetics Research Board. The Committee on Prosthetics Research and Development replaced the old panel and a new Committee on Prosthetics Education and Information was appointed. The author was designated chairman of the Sub-Committee on Prosthetics Education and for the next three years this committee functioned actively in an effort to co-ordinate the expanding educational program and to minimize the natural differences of opinion among the participants. In these meetings of the Sub-Committee, the physicians and prosthetists advocated steady expansion of the teaching programs to introduce new components and techniques for industry-wide use without undue delay. The research engineers and those interested primarily in the evaluation-field-testing programs wished to go slowly in this regard. The various viewpoints were equably compromised with Dr. Howard Eberhart summarizing the engineers' stand as follows: "The usual attempts on the part of those interested in education, as we all are, to get material away from the research groups, who are reluctant to release findings before they are confident of their conclusiveness and applicability, will always be a problem. This is true in areas other than prosthetics as well, represents progress after a fashion, and something we have to learn to live with. It does provide some spur to the research groups, and although it may be resented, it is good."

With the demise of the Prosthetic Research Board, the Committee on Prosthetics Research and Development was reorganized under the Division of Engineering, NAS-NRC, and the Committee on Prosthetics Education and Information was placed in the Division of Medical Sciences, with Dr. Al Shands as Chairman and Dr. Hal Glattly as Executive Secretary.

As a natural result of the success of the programs on the east and west coasts, the need for a centrally located educational program in the midwest was increasingly apparent.

In planning for the prosthetic education program at Northwestern University, the experience of the administrative personnel from UCLA and NYU was used to a maximum degree, and their cooperation is hereby appreciated. Our planned program was enthusiastically accepted into the Department of Orthopedic Surgery by Dr. Richard H. Young, Dean of the Medical School. We were fortunate that the new Rehabilitation Institute of Chicago was in a remodeling program, and space was placed at our disposal for use in accordance with our plans. The expensive modernization of the fourth floor of the Institute was financed by a special grant from the Office of Vocational Rehabilitation. Our Prosthetics Research Centre, under the direction of Mr. C. A. McLaurin, was in operation and valuable assistance was rendered by Mac and Fred Hampton in the development of the educational facility.



Richard H. Young, M.D., Dean of the Medical School; Miss Cecile Hillyer, Chief, Division of Training, Office of Vocational Rehabilitation; and Doctor Compere discuss plans for Prosthetic-Orthotic Education at Northwestern.

Of number one importance was our good fortune in obtaining Dr. J. Warren Perry as Director of the Prosthetic Education Program. Warren became enthused with the objectives and possibilities of the program, and he smoothly guided us through the first two years of operation. Herbert Blair Hanger joined our staff as assistant director and his services in both administration and in teaching have been outstanding.

The need for proper coordination of our current university programs caused the organization of the University Council on Orthotic and Prosthetic

Education. UCOPE, with membership limited to the Director and Academic Advisor from each of the three schools, affords direct conversational communication between the three major schools, and the result can only be better quality, more uniform presentations in our individual programs.

Together with the other university prosthetics schools, we are steadily changing annd expanding our curricula. The quality of any program depends upon the personnel preparing the programs and doing the teaching. Major credit for any success we may have achieved must go to our enthusiastic faculty, both part-time and full-time. Many of our faculty are contributing to this issue. We are deeply indebted to Dr. George T. Aitken, Dr. Charles H. Frantz, Dr. Claude Lambert, Dr. Fred Vultee, Dr. Robert G. Thompson, Dr. Raymond Pellicore, Dr. Robert D. Keagy, Miss Hildegard Myers, Miss Toula Latto, and all others who have generously contributed to the success of our program.

With the resignation of Dr. J. Warren Perry to take the position in the Division of Training of OVR, we were most fortunate to replace him as Director with Dr. Jack Armold. Jack is now well-known to most of our readers, as he continues to run a smooth ship in the occasionally troubled waters of Prosthetic-Orthotic Education.

In many of our planning meetings, we have profited from the knowledgeable assistance of an Advisory Committee of The American Orthotics and Prosthetics Association—Mr. Ralph Storrs, past president of AOPA, Mr. Richard G. Bidwell, of Milwaukee, Wisconsin, and Mr. William Scheck of Oak Park, Illinois. They have participated actively in planning curricula and in all major policy decisions, and their help has been of lasting value. In cooperation with the School of Business, we are sponsoring a new course on Business Administration for the Prosthetic and Orthotic facilities. Other special courses are under consideration.

In closing, may I express our combined appreciation for the understanding, advice and monetary support afforded by the personnel of the Division of Training, Office of Vocational Rehabilitation, and also, for the reception of our program by the members of the orthotic and prosthetic profession. We sincerely request suggestions with regard to the direction of our future efforts.

A New Image in Professional Education

By JACK D. ARMOLD, Ph.D.
Director, Prosthetic-Orthotic Education
Assistant Professor in Orthopedic Surgery
Northwestern University Medical School

The *Wall Street Journal* carried the following headline on July 18, 1962, concerning a changing image in the field of higher education: AGRICULTURE COLLEGES SHED HAYSEED IMAGE.[1] Through a combination of advances in agriculture and business procedures the "old cow college ain't what it used to be." The colleges are striving to overcome the notion that agriculture is a dying industry with few opportunities for young people. The new air of vitality and growth in "agribusiness" has attracted many young men from the urban areas.

Other images are changing in colleges and universities. For example, the changes in medical education have been many. Dr. Leslie B. Arey, in his book commemorating the 1859-1959 Centennial of the Northwestern University Medical School remarked that Dr. Nathan Smith Davis, the founder of the School, could never have envisaged the rapid development of medical education in this century.[2]

Historically the universities have been recognized as the institutions organized for students pursuing higher degrees in the traditional fields of theology, law, medicine, and the arts. However, greater specialization in the modern world and new student needs have introduced new curricula into the new universities. A special group of students now take evening courses and post-graduate courses on a part-time basis with no degree in view.

Caught up in the "education explosion," Northwestern is indeed changing. Fittingly, many of these changes directly involve the faculty. The traditional image of the university instructor has been modified. The typical university instructor has been characterized as a full-time teacher who was an "academic man." He allegedly had little concern with practicalities. He conducted his class at a leisurely pace. Time permitted such flexibility of procedure. Today, many instructors are practicing on a full-time basis but teach their specialties at the universities on a part-time basis. Students, who are practicing in businesses and professions, must receive the greatest amount of information in the shortest possible time. Efficient and effective teaching means must be employed.

The "new image in professional education," then, provides instruction

[1] *Wall Street Journal*, July 18, 1962, p. 1.

[2] Arey, Leslie B., *Northwestern University Medical School, 1859-1959*, Evanston and Chicago, 1959, p. 461.

for students, who, for professional, social, or economic reasons, cannot attend the university classrooms as regular students. Recognizing their special training needs, the instructor, who is a specialist in his field, engages in a highly specialized and efficient curriculum in an attempt to meet the demands of his students. These students, instructors, and curricula best characterize Prosthetic-Orthotic Education at Northwestern University.

The purpose of this article is to identify, analyze, and evaluate some particulars in this educational program, a comparatively new development in the University. The attempt to achieve our objective will be made through the following organization: (1) Philosophy, (2) Students, (3) Faculty, (4) Curriculum, (5) Extra-University Activities, and (6) Perspective.

Philosophy

"Why?" the eternal question of philosophy, explores reasons, causes, or purposes. Historical reasons for the development of the prosthetic-orthotic programs at the three Universities have been given in the preceding article by Dr. Clinton L. Compere. Reasons for the departure from the traditional practices in universities in the United States may be traced back to the last century. In 1890, many prominent educators met in Philadelphia at the American Society for the Extension of University Teaching. This marked the beginning of adult extension teaching in higher education in the United States. Dr. William Rainey Harper, the first president of the University of Chicago, led in this development. To make no effort in the direction of a wide diffusion of knowledge, he wrote in 1892, would be "to neglect a promising opportunity for building up the university itself, and at the same time to fall short of performing a duty which . . . is incumbent upon the university.[3]

Northwestern University, seven decades later, following the examples of the University of California at Los Angeles and New York University, recognized the needs of students working with the disabled and also of promising opportunity for service. Dr. Richard H. Young, Dean of the Medical School, wrote:

> Northwestern University Medical School recognizes that courses offered in Prosthetic-Orthotic Education fulfill a need by providing the rehabilitation field with trained personnel. The facilities and knowledge of the University are available to aid students in gaining a better understanding of philosophy and techniques, to provide sources for research, and to improve communications and working relationships among professional groups concerned with rehabilitation of the physically handicapped.[4]

The key objective of this program is to improve services to the disabled. The University can best meet the service objective through education and research.

The wide dissemination of knowledge in prosthetics and orthotics makes a major contribution in the prevention and treatment of disabling conditions. The University is the logical institution for training persons wishing to make this contribution. Professional publications and meetings will always be necessary for better care and improved inter-disciplinary cooperation, but the University has the best available means for communicating priniciples and techniques. The classroom is most conducive to learning. The form and spirit of learning is under the direction of men knowledgeable in their fields and skilled in teaching.

This post-graduate program seeks to be equal in quality and quantity to that done in the University proper. The training must be systematic in form

[3] William Rainey Harper, Bulletin #6, May, 1892. Unpublished works in William Rainev Harper Library, University of Chicago.

[4] Richard H. Young, Personal Communication, August 1, 1962.

and scientific in spirit, and, to be such, it must be done under the direction of university men who have had scientific training. While we have spoken of the "new image," we have thought of it more as an extension of the essence of the University rather than a departure from its essence.

"Putting research findings into service," Miss Cecile Hillyer, Chief, Division of Training, commented, "is the major objective of training grants from the Office of Vocational Rehabilitation." [5] Effective teaching must be supported by sound research. The obligation of advancing present knowledge through investigation is a fundamental concept in any university organization. This program has benefited greatly by research and development efforts of the Northwestern University Prosthetic Research Centre and the other prosthetic and orthotic research projects throughout the country.

The growth of expensively financed research and training programs within medical schools has been accelerated to breath-taking speeds. Consequently, the demands for medical subsidies have grown and will probably continue to grow. There can be no question about the fact that the increased availability of federal funds for research and training has greatly improved the care of the disabled. Dr. Herbert Talbot said: "For just as the chief function of government is to secure the lives and prerogatives of individuals, so it must be the aim of federal medicine to support and supplement individual and community practice." [6] The following discussion of this educational program will show ways in which private-federal planning and funding have improved services to the disabled by training more than twelve hundred rehabilitation personnel in prosthetics and orthotics.

Students

Where does the instructor begin? Does he begin where the student *is* in knowledge and skills, or where he thinks the student *ought* to be? The instructor here is dealing with the reality of student ability and his own expectations for student accomplishment. This problem is made more complex when the teacher instructs one group of students with strong backgrounds in formal education and, at the same time, teaches another group of students with great resources of practical knowledge. For instance, all of the physicians, therapists and counselors in our courses are college graduates. Here we have strength in formal education. The majority of prosthetists are only high school graduates, but they have often had many years of experience which makes them quite knowledgeable in the prosthetic and orthotic fields. The non-prosthetist groups usually have little experience with or knowledge of these fields.

FIGURE 1—A student prosthetist at work in the laboratory.

The combined efforts of each member of the clinic team are indispensable to providing the necessary and desirable prosthetic and orthotic serv-

[5] Hillyer, Cecile. *Upper-Extremities Prosthetics Workshop, July 5-8, 1960, Conference Report Minutes*, Los Angeles, 1960, p. 3.

[6] Talbot, Herbert S., "A Concept of Rehabilitation," *Rehabilitation Literature*, XXXI (December, 1961), 358.

ices. The interdisciplinary approach, with its inherent difficulties in backgrounds, skills, and special interests, seems to be the most satisfactory approach to rehabilitation training. A desire to give better service to patients is the basic motivation of all students. A physician wrote that he intended to utilize the principles taught in the course to aid the amputee "in assuming as normal and useful a place in society as possible, as early as possible, and with a minimum of physical and mental trauma." A therapist wished "to prepare herself better to help the amputee in her community to use his prosthesis to his maximum ability." A prosthetist regarded his training as a "continuation in the work of his choice to rehabilitate people of all walks of life in need of his services." A counselor wished to improve his technical knowledge in the area of prosthetics and orthotics, and to apply this knowledge to the process of rehabilitation counseling.

TABLE A: COURSE ENROLLMENT

	59-60	*60-61*	*61-62*	*Total*
Prosthetists	76-23%	80-18%	79-18%	235-20%
Therapists	97-29%	140-31%	115-27%	352-29%
Physicians	88-27%	141-31%	128-30%	357-29%
Counselors	71-21%	74-17%	105-25%	259-21%
Others	0-0 %	11-3%	0-0%	11-1%
TOTAL:	332-100%	446-110%	427-100%	1214-100%

This table shows the total number of students by course enrollment. It does not show the number of actual students. (See Table B). The Others category includes administrators and observers. Several points may be made about Table A: (1) The total percentages of the first four groups are in the 20% range, which indicates a fairly equal distribution; (2) The decrease of 20 students last year as compared to the previous year is due to two reasons: (a) twenty-five courses were scheduled last year as compared to twenty seven the previous year, and (b) the cancellation of the pilot course in spinal orthotics, due to the lack of funds, reduced the expected enrollment by thirty students; and (3) The policy of limiting the number of students because of limited physical facilities has kept the enrollment fairly constant during the last two years.

The increase of counselors in 1961-1962 to an average of twenty five per class from eighteen seemed to be desirable. This change of policy caused an 8% increase in counselors during the past two years.

TABLE B: ACTUAL STUDENT ENROLLMENT

Prosthetists	177-18%
Therapists	280-28%
Physicians	281-28%
Counselors	259-25%
Other	11- 1%
	1008-100%

This table shows the number of different students who have attended one or more courses. The physicians and therapists groups constitute the largest groups of students because they average sixteen students for each class. The average class-laboratory size of prosthetists is twelve. The class-size factor provides a valid comparison, because all three of these groups have had twenty courses during the past three years. If the courses continue to have an equal distribution, the actual prosthetist enrollment will continue to be the smallest group. The counselors do not figure in this comparison because they had had only thirteen courses. In comparing Tables A and B in the counselors category, one notes that their course enrollment and actual enrollment are the same. Only one course is offered for this group.

TABLE C: PROSTHETISTS—AGES, EDUCATION, CERTIFICATION, DISTRIBUTION

AGES	
20-29 yrs.	28-16%
30-39 yrs.	61-34%
40-49 yrs.	69-39%
50-59 yrs.	13-7%
60-69 yrs.	3-2%
No Record	3-2%
	177-100%

EDUCATION	
Elementary	6-3%
Some High School	16-9%
High School Graduation	112-63%
Some College	29-17%
College Graduation	12-7%
No Record	2-1%
	177-100%

CERTIFICATION	
*Certified in Prosthetics	95-54%
**Not Certified in Prosthetics	82-46%
	177-100%

*Included: 14 Certified in Orthotics also.
**Included: 8 Certified in Orthotics only.

GEOGRAPHICAL	
Mid-West	100-56%
South	59-32%
West	9-6%
East	7-5%
Canada	2-1%
	177-100%

Our focus in this article is upon the prosthetist and orthotist. Several inferences emerge from these statistics: (1) *Age.*—On a comparative basis, the age of the prosthetists, approximately 40 years, is average for the post-graduate student. Only the therapists have a large percentage in the younger range of 20-29 years. In all older groups, however, the instructor would expect to find some lack of flexibility in learning, and some predominance of set patterns of behavior and practice. (2) *Education*—The lack of formal education sets the prosthetists apart from the other groups. The instructor can predict areas of weakness in broad, systematic training in the basic arts and sciences. With older students, however, he may expect some depth in practical knowledge. (3) *Certification.*—The slightly larger percentage of certified students in prosthetics points out that students have regarded further training as necessary for development in the field. The slightly smaller percentage of certified students in prosthetics probably shows that university training is an essential preparation for the certification examination and service. The lack of courses in orthotics for students certified in orthotics reveals one of the weaknesses of the curriculum. (4) *Geographical Distribution.*—The prosthetists reflect the regional nature of the school with 56% of prosthetists coming from the Mid-West and 32% from the South. The greatest number come from these States: Illinois, 22-12%; Michigan, 17-10%; Ohio, 14-8%; Wisconsin, 13-7%; Missouri, 12-7%; Tennessee, 10-6%; and Florida, 10-6%.

The geographical distribution of counselors reveals the most regional aspect of the program. The Office of Vocational Rehabilitation has assigned Region V, Region VI, and the States of Louisiana and Oklahoma to this program. The two regions cover the entire Mid-Central United States. Every State Director in this assigned area has sent counselors to Northwestern.

The national and international character of the program is seen in the enrollment distribution of the physicians and therapists. Most of the foreign students are physicians specializing here in orthopedics. The largest distribution of students is found in the juvenile amputee course because it is the only course of this type offered in the country.

The total student distribution includes fourteen foreign countries, the District of Columbia, and forty states. The foreign countries are; United Arab Republic, Egypt and Syria, Lebanon, Israel, Iran, India, Korea, Denmark, France, Germany, Canada, Argentina, Costa Rica, and Chile. The twelve states not represented in the enrollment are: Alaska, Hawaii, Washington, Oregon, Idaho, Nevada, Arizona, Arkansas, Connecticut, Vermont, New Hampshire, and Maine.

Specialization in medicine and therapy, as a factor of enrollment, has always been an item of interest. The following is based upon actual student enrollment:

TABLE D: SPECIALTIES ENROLLMENT

	THERAPISTS		
Physical Therapy	*Occupational Therapy*	*Corrective Therapy*	*Total*
228-82%	43-15%	9-3%	280
	PHYSICIANS		
Orthopedic Surgery	*Physical Medicine*	*No Specialty*	*Total*
200-71%	76-27%	5-2%	281

Therapists.—The applications from physical therapists have far exceeded the other two groups of therapists. As will be shown in Table G, this is due to the large physical therapists' majority in the lower-extremity courses where nine such courses have been offered. This is five more than upper-extremity courses where the occupational therapists show a more equal distribution. Corrective therapists have always had a very small enrollment. *Physicians.*—Applications from physicians in orthopedic surgery constitute nearly three-fourths of the total physician enrollment at Northwestern. This is in contrast to New York University where "the number of orthopedic surgeons and physiatrists is about evenly divided."[7] Of the two hundred students in orthopedic surgery, ninety seven, or 44%, are residents; of the seventy six students in physical medicine, fifteen, or 20%, are residents. One major cause for this high enrollment pattern of orthopedic residents is the excellent cooperation which Northwestern has enjoyed with fourteen Departments of Orthopedic Surgery and three Departments of Physical Medicine and Rehabilitation. This ratio of physicians in orthopedic surgery and physical medicine seems fairly consistent with certification statistics for both groups. Roughly, there are about seven times more orthopedists than physiatrists.

Curriculum

The curriculum, or course of study, has been called a "blueprint of learning." It generally includes didactic instruction, systematic teaching by lecture, and is correlated with practical experience. The latter includes clinical and laboratory experience.

Didactic instruction must go hand-in-hand with clinical correlation and practical experience.[8] The courses for prosthetists have a greater amount of laboratory time than the other student groups. Approximately 30% of the time is spent in didactic instruction and 70% in laboratory-clinic time. The physicians and therapists receive 55% didactic instruction and 45% practical-clinical experience. Because of the large scope of the counselors' course, which includes both orthotics and prosthetics, 75% of the time includes didactic instruction and only 25% in practical case work-ups and presentations.

[7] Berger, Norman, "Post-Graduate Training in Prosthetics and Orthotics," *Orthopedic and Prosthetic Appliance Journal*, September, 1960, 82.

[8] Arey, *op cit.*, p. 464.

FIGURE 2—Physicians and therapists hear a lecture on biomechanics in the auditorium.

TABLE E: COURSES BY STUDENT GROUPS

	Courses	*Percent*
Prosthetists	20	27%
Physicians	20	27%
Therapists	20	27%
Counselors	13	19%
Total	73	100%

The total number of courses by disciplines reveal that there has been an equal distribution of courses for physicians, therapists, and prosthetists. While equality in the number of courses is desirable, the faculty has primarily considered student demand and the immediacy of teaching new techniques.

TABLE F: SCHEDULE OF COURSES

	A/K			*B/K*			*S/P*	*U/E*			*L/E*		*J/A*			*RCC*	*Totals*
	Pr.	P.	T.	Pr.	P.	T.	Pr.	Pr.	P.	T.	P.	T.	Pr.	P.	T.	C	
59-60	2	2	2	3	3	3	1	0	0	0	0	0	0	0	0	5	21
60-61	1	0	0	3	0	0	1	2	2	2	5	5	0	1	1	4	27
61-62	1	0	0	3	0	0	1	1	2	2	4	4	1	1	1	4	25
	4	2	2	9	3	3	3	3	4	4	9	9	1	2	2	13	73

Code of Courses:

A/K, Above-Knee Prosthetics; B/K, Below-Knee Prosthetics; S/P, Fitting and Fabrication of Special Prostheses; U/E, Upper-Extremity Prosthetics; L/E, Lower-Extremity Prosthetics; J/A, Management of the Juvenile Amputee; RCC, Rehabilitation Counselors Course.

Students:

Pr., Prosthetists, *P.*, Physicians, *T.*, Therapists, *C.*, Counselors.

While there is no recommended sequence of courses for the prosthetists, the pattern of enrollment has been as follows: B/K, A/K, U/E, and S/P courses. After 1959-1960, the A/K and B/K courses for physicians and therapists were combined into an integrated course. These groups tend to enroll first in the L/E and then follow with the U/E and/or J/A courses. The faculty made the completion of one prosthetic course a prerequisite for all applicants for the J/A course during 1962-1963 because of the highly specialized nature of the course.

In the curriculum, the therapists enrollment is the only clear example of specialty preference:

TABLE G: THERAPISTS COURSE ENROLLMENT

	L/E	*U/E*	*J/A*
Physical Therapists	205-96%	38-52%	29-77%
Occupational Therapists	6- 3%	30-41%	9-24%
Corrective Therapists	2- 1%	5- 7%	0- 0%
Totals	213-100%	73-100%	38-100%

In addition to showing the very large representation of physical therapists in all of the courses, they reflect the physical therapists' preference for the L/E course and the occupational therapists for the U/E course. The J/A course shows the strength of physical therapists enrollment, but the preferences are not as clear as in the other two courses. Miss Dorothy E. Baethke, Director, Division of Physical Therapy, University of Pennsylvania, has commented on this enrollment pattern which showed the physical therapists high enrollment in U/E:

> I feel quite certain that the reason that physical therapists are showing a greater interest in upper-extremity prosthetics is the philosophy of patient care by the physical therapist. This is concerned with the treatment of the whole person and not only with treatment of one aspect of the disability. Another reason may be that prescriptions for treatment are being given increasingly earlier in the patient's illness. This leads to utilization of specific treatment by the physical therapist in the preprosthetic and prosthetic stage before function treatment is given by the occupational therapist.[9]

In short, Miss Baethke has suggested that treatment of the whole person and earlier prescriptions are possible answers for the increased interest in U/E courses by the physical therapist.

Students continue to comment that their clinical experiences in the total curriculum are the most meaningful of all their experiences. The teaching patients make an invaluable contribution here. In three years of operation, 667 teaching patients have assisted the faculty in clinical demonstration.

An excellent article on efficiency in technical-medical teaching appears in the June, 1961, issue of this *Journal.* Dr. Cameron Hall, its author, explains the perplexing problem of teaching great amounts of technical information without greatly increasing the amount of classroom time.[10] Efficiency of teaching means is the answer. Following many of the UCLA teaching techniques, Northwestern makes great use of slides, movies, and three dimensional objects as visual aids. Hand-out sheets, which are being bound this year, have been devised to permit students to take well-organized notes.

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[9] Letter of Dorothy Baethke to Jack D. Armold, Philadelphia, July 31, 1962.

[10] Hall, Cameron B., "Efficiency in Technical Teaching," *Orthopedic and Prosthetic Appliance Journal,* June, 1961, 139.

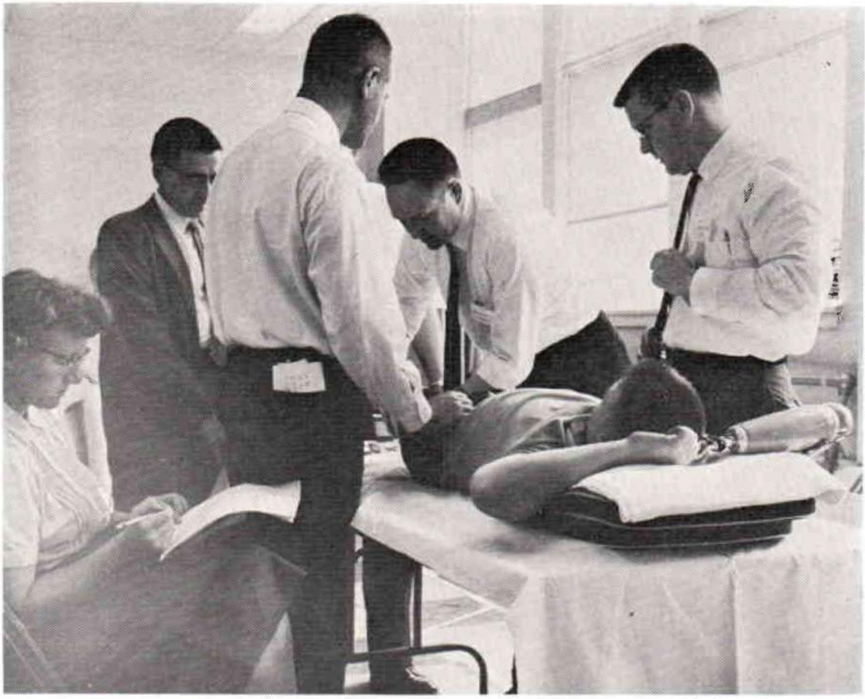


FIGURE 3—A student clinic team evaluates a lower-extremity amputee during the practice session of a recent course.

The emphasis here on efficient teaching is not intended to de-emphasize quality teaching. The efficient means are used primarily in the didactic instruction where scope and time are major considerations. The "depth teaching" is accomplished primarily in the laboratory-clinical sessions where students may pursue their questions and the instructor may reinforce his earlier instruction.

Faculty and Staff

More important in any education program than any curriculum is the faculty. Its quality and its genuine interest in medical and para-medical education will provide the backbone of the entire program. Northwestern President, J. Roscoe Miller, said recently: "We cannot expect to have a great University unless we have excellent teachers."[11]

One of the stated goals of this program is to increase the supply of personnel in the related fields serving the disabled. As the previous material on students has shown, the teacher in prosthetics and orthotics is faced with the dilemma of realistically considering student background and ability, and at the same time, satisfying his own standards of achievement for the student. Forty-three faculty members have and are presently attempting to meet this difficult challenge in teaching.

The basic objectives of a faculty providing medical education, as stated by Dr. Arey, are worthy of consideration:

> . . . To offer the student the opportunity to gain an understanding of the principles of the basic medical sciences—and especially to master the art of experimental method—and to provide him with

[11] Quoted in *Northwestern University Alumni News*, July, 1962, 6.

the further opportunity of extending these principles to the practical study of patients . . . If a superior school, it also encourages students to develop their latent potentialities and arouse interests as far as possible.[12]

The Prosthetic-Orthotic Education faculty seeks to carry out the basic objectives of the Medical School, which include the teaching of principles, methods, practice, and potentiality development.

The interdisciplinary nature of this program may be seen in the sixteen specialties represented by the faculty during the past three years: orthopedic surgery, 8; prosthetics, 8; orthotics, 4; physical medicine and rehabilitation, 4; physical therapy, 4; occupational therapy, 3; rehabilitation counseling, 2; education, 2; dermatology, 1; engineering, 1; psychology, 1; general surgery, 1; neurology and psychiatry 1; medical editing, 1; medical photography, 1; and rehabilitation administration, 1.

The full-time staff assists the faculty in carrying out its objectives. The staff includes: Director, Associate Director and Chief Prosthetist, Chief Orthotist, Instructor in Prosthetics and Orthotics, Editorial and Administrative Assistant, Medical Assistant, Laboratory Assistant, and two Secretaries. The two part-time staff members are a Medical Photographer and the Staff Artist.

Extra-University Activities

Extra-, a prefix, is taken from the Latin word, *exter*, which means "beyond" or "outside the scope of."[13] *Extra-* expresses well an important function of this program which goes beyond and is outside the scope of the two campuses of Northwestern in Chicago and Evanston. The extra-University objective is to participate with professional associations and educational institutions in their efforts to improve the quality of professional preparation for service.[14]

The Organization Chart (opposite) shows the University in the national picture and includes those associations and institutions most directly related to this program. The administrative function belongs to the University. The Office of Vocational Rehabilitation finances the major portion of the program. The University Council on Orthotic and Prosthetic Education coordinates the three University programs. Consultations are frequently held with the two prosthetic Committees of the National Academy of Sciences.

A major example of Northwestern's participation with another professional association may be seen in the activities of the American Orthotics and Prosthetics Association. The faculty has presented papers at three National Assemblies and fifteen Regional Meetings. The Association recently contacted the University to conduct a course in business and administrative procedures for owners, managers, employees, and suppliers of prosthetic and orthotic facilities. The School of Business, in cooperation with the Association and Prosthetic-Orthotic Education, will administer and conduct the course.

Inter-professional cooperation has made possible the production of the film, "Gait Analysis." The Committee on Prosthetics Education and Information and the University produced the film and prepared a supplemental booklet which will be distributed at the film showings. The film has already been shown in Europe and more than twenty States.

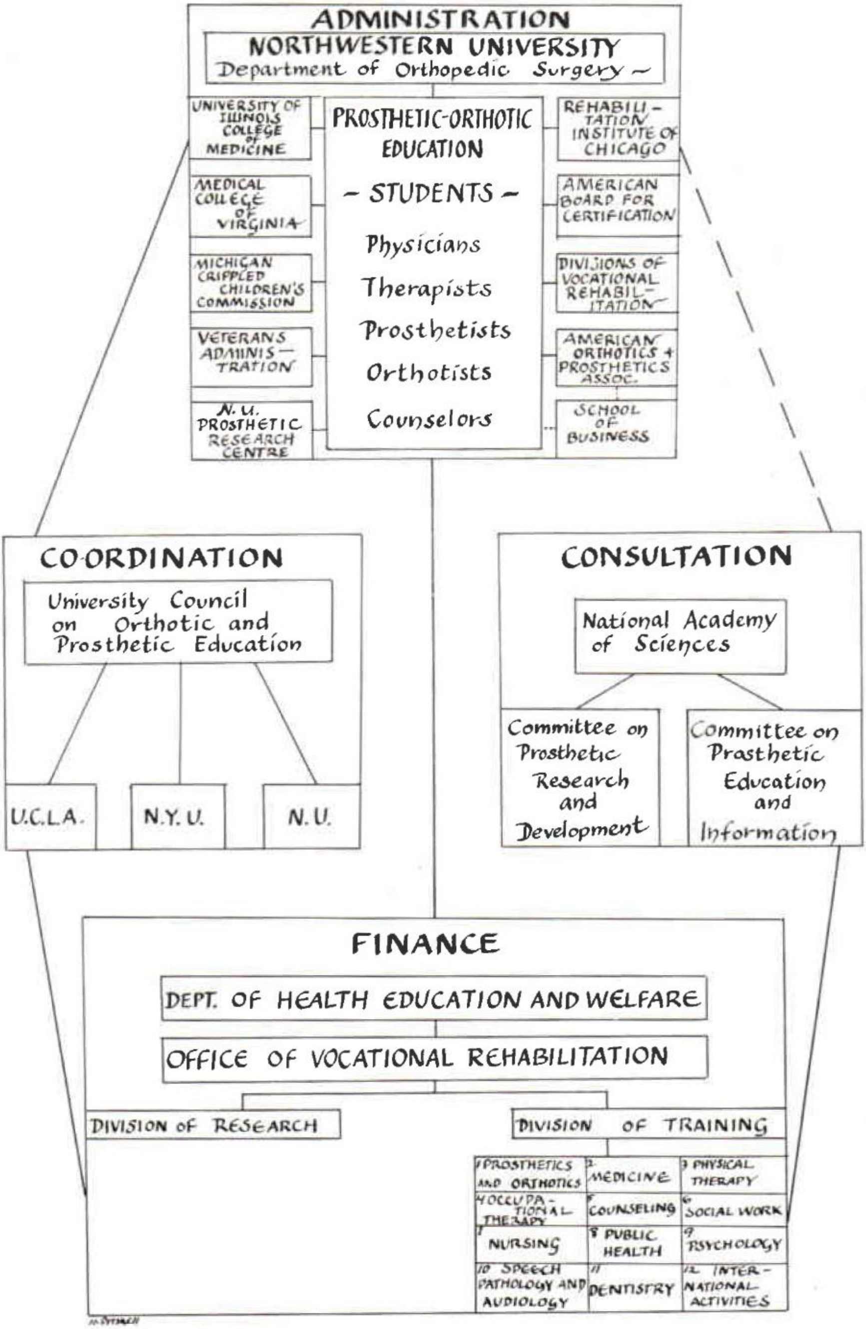
From its beginning, Northwestern has benefited from the experience and advice of Dr. Miles Anderson, of UCLA, and Dr. Sidney Fishman, of

[12] Arey, *op. cit.*, p. 463.

[13] "Extra-" in *Webster's New Collegiate Dictionary*, Springfield, Massachusetts, 1961.

[14] U. S. Department of Health, Education, and Welfare, *Office of Vocational Rehabilitation Training Program*, Washington, D. C., March, 1962, p. 1.

ORGANIZATIONAL CHART



NYU. The University Council on Orthotic and Prosthetic Education, in its second year of operation, has provided the three Universities with the means to facilitate better communication and working relationships in their efforts to serve the professional fields engaging in serving the disabled. The Council has sponsored study groups in A/K prosthetics and examinations for physicians and therapists. These and other cooperative projects have provided positive results.

Perspective

The look into the past of this educational program in prosthetics and orthotics has yielded several observations. The focus has been placed upon philosophy, students, curriculum, faculty, and extra-University activities. With a reference to our historical perspective, it remains for us to project into the future.

Service to the disabled is our *raison d'etre*, our reason or justification for existence. Key to our philosophy are the beliefs that effective teaching, based upon sound research, is our available means to contribute to the service objective and that the University is the logical institution to train personnel to work with the disabled. Supplementing private administration and financing, the Office of Vocational Rehabilitation has assisted the University in meeting rising costs of medical-paramedical education in prosthetics and orthotics with the result that services to the disabled have been upgraded. Mounting costs in research and education will make it most probable that the use of federal funds in these fields will grow.

Student enrollment is the major endorsement of this educational program. Classes have generally been filled to capacity and applications are currently being received at an increasing pace. The future will undoubtedly bring larger numbers of post-graduate students to the University. The 1962-1963 academic year should have an enrollment which will exceed four hundred and fifty. This would be an increase of approximately thirty students over the previous year. Larger physical facilities and tighter scheduling will be required before the enrollment can go beyond five hundred students.

The analysis of student enrollment has shown that the average student in the past three years was forty years of age, from the Mid-West or South, and is certified or seeking certification in his specialty. There is good reason to believe that this typical student will continue to enroll at Northwestern in the greatest numbers, but some degrees of change will probably occur.

Students in other disciplines will enroll in the future. They will probably be younger and will come from both coasts in greater numbers. The spinal orthotic and juvenile amputee courses, which are offered only at Northwestern, will attract students from the entire nation. New disciplines will probably include social workers, rehabilitation nurses, and other medical specialists.

An educational program with an interdisciplinary approach inherits some of the inherent evils of specialization. Specialists naturally stress their particular interests and feel slighted if their needs are not emphasized. Nevertheless, the first principle of service to the patient has transcended the lesser good of intra-specialty considerations in our student body. The special interest factor coupled with variabilities in formal education and practical knowledge make the teaching of heterogeneous students a difficult, but rewarding challenge.

New student awarenesses and the development of new techniques will make considerable changes in the present curriculum. Last year the prosthetists were offered 27% of the courses at Northwestern. However, the development of new techniques has made it necessary to increase the total to 35% next year. Concerning the effect of new techniques on curricula, A. Bennett Wilson, Jr., Chief of Staff of the Committee on Prosthetics Research and Development, said:

> The educational programs can look forward to teaching principles and techniques relating to porous laminates, harnessing, knee-disarticulation, and the polycentric knee. A farther look would include the teaching of external power in prosthetics. A greater emphasis will be placed upon the geriatric patient.[15]

The research groups of the Veterans Administration and the University of California at Berkeley contributed to the three prosthetic programs by developing new techniques in the total-contact above-knee prostheses which will probably be taught in the Universities during the next academic year.

The analysis of the curriculum showed that the physical therapists showed a preference for both the L/E and U/E courses, while a strong majority of occupational therapists chose the U/E in preference to the L/E course. While the degree of preference will probably remain, both groups of therapists should be encouraged to take both courses. In support of this opinion, Miss Baethke wrote:

> Certainly there are general principles of prosthetics common to each of the extremities which would provide the orientation the O.T. needs when a patient has a lower-extremity prosthesis, and the P.T. needs when the patient has an upper-extremity prosthesis. With orientation to these general principles the P.T. or O.T. should be able to transfer the detailed knowledge of prosthetics for one extremity for general use for the other.[16]

The heart of any university is its faculty. Its competences and genuine interest are inextricably interwoven into all aspects of university life. With the addition of new students and new courses, new faculty members will join the present list.

The full-time staff assists the faculty in administering the program by preparing course materials and processing applications. The growth of the program has made additional demands on the staff. During the past year, Miss Susan Hastings joined the staff to edit the publications of the faculty and to assist in administrative duties. Mr. Charles Fryer, an instructor in prosthetics and orthotics, joined the staff September 4, 1962, to assist in teaching the present courses and to develop new courses in the field.

The extra-University function is but an outgrowth of the need to disseminate principles and methods beyond the boundaries of the two Northwestern campuses. There are demonstrable signs that the University is making an impact upon the professions serving the disabled. Correspondingly, the University undergoes change as new ideas are imparted to it, as teachers return from the field. It is a continued process, with the faculty seeking out new seed, then returning to sow it. Henry Adams once wrote: "A teacher affects eternity. He never can tell where his influence stops."[17]

The University continually enlarges its foundation, extends its boundaries and adds to its superstructure. A later look at this part of the University will show the form and manner in which another "new image" in professional education was shaped.

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[15] A. Bennett Wilson Jr., Personal Communication, August 3, 1962.

[16] Dorothy Baethke, *op. cit.*,

[17] Quoted in *Northwestern University Alumni News, op. cit.*, 11.

Student Leaves School: What Then?

By HERBERT BLAIR HANGER, C.P.
Associate Director and Chief Prosthetist
Prosthetic-Orthotic Education
Northwestern University Medical School

During the past three years of prosthetic education at Northwestern we have instructed 177 prosthetist-students. Many were preparing for certification, but the heaviest percentage came from persons already certified. This, we feel, is one of the main reasons for elevated standards in recent years within the prosthetic profession. For persons in any other field which make a claim of professionalism, there is one outstanding bond which joins all such groups—education.

Nothing in this life is static. How successful would we be in fitting a patient, if we concluded everything with static alignment? Dynamic alignment, we know very well, is the final proof. Our overall outlook should be dynamic, if we are to advance as professionals. Our relationship with patients and the service we render might not always improve and move forward by leaps and bounds, but we can be sure that it does move—one way or the other.

It has been a very rewarding experience for me to have taken part in prosthetic education. The gains have been obvious; yet areas in which there seems to be considerable room for improvement have also been evident. For one, let us consider knowledge of anatomy, kinesiology, and locomotion. Perhaps at the present time it is not realistic to expect that everyone who is exposed briefly to these subjects in our short-term courses will return to his respective area a changed man with zeal imbued to become an authority on these topics. There is a minimum goal, however. How can we do our best for the patient, to say nothing of enhancing our professional standing, if we do not continually strive for more understanding of the total problem? There is a long-established language for medical and paramedical people. If we are unable to communicate within this language or are apathetic in our desire to do so, this reduces our potential for rendering complete service.

There are many facets to successful handling of a patient, but if respect and confidence are missing, one can usually discount most of the others. This ability to talk intelligently and correctly with others involved with the patient's rehabilitation is immeasurably important. In our schools we try to stimulate interest in this direction, but sometimes we wonder what degree of success we've had. There is no question but that this part of our schedule does not consume a large part of the time spent. It would be wonderful, if we could be more certain that this particular phase of training carries over into practice after the student leaves, with increased awareness of its importance. We are forced into situations repeatedly where we expose ourselves as being informed or uninformed. Which is to be preferred? "Silence is golden" is only a partial truth. It enables one to cover up lack of knowledge for a time if used judiciously, but the "gold" becomes tarnished from undue exposure.

During the last year we have made it mandatory for each student to purchase a copy of *The Extremities* by Quiring and Warfel. This is an inexpensive book giving very concise and pertinent information about muscles and their action, nerves, and bone structure. It supplies a quick and easy reference source and should have considerable use in daily activities where the desire exists for improvement in usage of correct terms in communicating with others. We have always urged active participation by the prosthetist in our clinic team sessions with the hope that it will provide impetus for such action when he returns to his home town. Knowledge must precede participation, if it is to be meaningful.

After learning words there is the next step of understanding their application. This is where kinesiology and locomotion become important. We sincerely hope that the "whys" are covered sufficiently in our classes. We deal directly every day with the action of the body. The imbalance of muscles, deficiencies in their strength and action resulting from any amputation are things we cannot know too much about. It is discouraging in a way, to realize that the general information which the student is able to take home from the short time spent at schools is so heavily weighted with the techniques of procedure. These are, without question, necessary. If he does not know the "hows," what can he do with the "whys?" He must know how to make the prosthesis being taught and to handle the materials to advantage with the hope that he will retain the ability to perform without the instructor. This is time consuming.

During all of the classes our instructors are available to answer questtions as well as ask them in the practical periods. We feel, for the most part, that the student who comes here to learn how to make a patellar-tendon-bearing below-knee prosthesis leaves with all he can absorb within the time allotted. He has measured and fitted three prostheses and attended classes in all allied subject matter—but it is not infrequent that the final examination shows the subjects of anatomy, kinesiology and locomotion to be his weakest when he departs. There seems to be little more that can be done while he is at school, except to hammer away at the importance of these subjects. Many students will say, "I know this is important, but when I go home we never use these terms." Even if he does not attend clinics or have much outside activities, it is difficult to imagine that a conscious start cannot be made towards using proper nomenclature if only in a limited fashion. Isn't it possible to say that one is going to relieve the tibial crest instead of "the shin bone?" Undoubtedly there are some shop situations where this unfortunately would be greeted with derisive comments by some fellow workers. If this be the case, then a great responsibility lies on the owner of the facility to work at changing such attitudes. As the prosthetist enlarges his scope of contacts with the medical profession and therapists, he *must* make the effort to transmit his thoughts intelligently. We sincerely hope that the schools are the catalysts for such activity.

Another function of our school is to impart knowledge gained from the various research programs in progress. This involves many things such as fitting techniques, fabrication procedures, and special fields of application for prosthetics as with the juvenile amputee. Whatever the subject might be, careful consideration is given to the requirements governing the presentation of the information. When a research department has spent several years investigating a new technique, there is a strong background of experience, and the school is obligated to rely heavily on this foundation. The course is outlined after the teaching staff has gained all possible experience necessary to teach the technique. During this familiarization, often there are further points discovered because of the necessity of organizing the information into teachable form, but usually there are no great deviations. There are very valid reasons for all the steps. During familiarization these must be explored by the teaching staff. Thus, we finally present the course, and from that first one, where knowledge is further increased, we continue with subsequent courses. The growth of information seems never to stop. There are revisions and additions, until three years latter there might be considerable difference from the starting point. This change stems not only from added knowledge gained by the instructors, but every class usually contains ideas which are born during the sessions, or perhaps some zealous student arrives with ideas already tried beforehand.

Thus, we refine the technique but make no changes without having a very firm reason for them. This leads us to discuss now the changes which seem to happen out in the field after the student has attended school. During one of the last certification examinations at which I was assisting, one of the applicants asked me if I knew what technique was being taught on the PTB at Northwestern (he didn't know who I was). Despite the fact that I informed him of my connection with what was taught at Northwestern, he still decided to tell me just what the technique was, and I listened with great interest. There were so many things which I did not recognize; it was very upsetting to learn that the source of this procedure was a former student of ours, and he had been given his certification not more than a year before. He was a man who had performed well, if not outstandingly, while under our watchful eyes.

This, of course, is something which happens from time to time. Once in a while there are some excellent ideas evolving from the continued experience of competent prosthetists in the field. In this instance, however, the departures were apparently not paying off in well-fitted patients. Some deviations are to be expected when the long-term experience begins to indicate that a change in this step or that seems needed. However, when problems begin to appear after a man has attended a school, and he feels he is doing everything exactly as taught; then we feel it is high time for him to communicate with the school. This is one of our areas of responsibility, and we are always most anxious to know of any difficulties arising. We realize that it is often not possible to solve a problem by mail, but the prosthetist owes it to himself and to his profession to communicate persistent problems to his original source of information. If everyone would try to do this, then it should be evident to the thinking person that if his problems were also occurring to several other prosthetists, there would be some action on the part of the school to investigate.

Once in a while we do get letters of this nature, and we generally have some suggestions. If we were to say that we solve most of the difficulties in this way, it would be ridiculous; but the feed-back of information is a vital necessity so that the universities can keep in touch with field activities. As stated above, there must be interchange of ideas between teaching personnel and practicing personnel. This is the only way for the many fine developments discovered by our associates to find their way back into an improved course for the new students. The seminars held in the various regions should be a means used for the two-way exchange of ideas. The universities have, in the past, attended most of these meetings with presentations. It would be highly beneficial if the practicing prosthetist would organize a course for the universities on how they are using the ideas promulgated by the school.

We here at Northwestern have no desire to be labeled "Ivory Tower." We earnestly want our curriculum to reflect the ideas and growth originating from the entire practicing prosthetic and orthotic profession and to disseminate these ideas along with all research developments. We believe this is the only way for our work to increase in what it has to offer the handicapped.

A Message to All Firms in Amputee Census

To insure the prompt mailing of the census card and to avoid missing certain cases, Dr. H. W. Glattly of the National Academy of Sciences suggests that you adopt the following policy: At the time that you begin your facility record of an amputee, including the stump measurements, you can complete all but one of the data items on the census card, and this is "Date Prosthesis Furnished."

In the future, it is suggested that you *estimate* the date and mail the card, marking your record with the words "Census Card Mailed." It is recognized that the delivery of a prosthesis may be delayed for a variety of reasons. In such instances, the completion of the card may be neglected. The above system will be a convenience to both the facility and to the National Academy of Sciences.

The attention of all firms is invited to the fact that the census cards are serially numbered. The National Academy of Sciences must account for all numbers. Should a card be damaged or incorrectly made out, you are requested to mark it "spoiled" and send it to the Academy so that that particular case number can be accounted for.

The amputee census was initiated October 1, 1961. All new cases, as defined in the census instruction pamphlet, that are serviced by the participating firms since that date should be carded. *It is not too late* to join this cooperative effort of AOPA and the National Academy of Sciences, to obtain certain valuable data concerning the amputee population of this country. Firm owners who have not previously participated in the census are therefore urged to write to the address below for a packet of census materials:

Dr. H. W. Glattly, Executive Secretary
Comm. on Prosthetics Education & Information
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington 25, D. C.

EDITOR'S NOTE: *The National Amputee Census is a joint project of CPEI, National Research Council, and the American Orthotics and Prosthetics Association. Any prosthetic establishment in the United States is eligible to enroll under this census project.*

Philosophy of Research

By COLIN A. McLAURIN, B.A.Sc.
Project Director, Prosthetic Research Centre;
Research Associate in Orthopedic Surgery,
Northwestern University Medical School

Webster defines research as "studious inquiry; usually, critical and exhaustive investigation or experimentation having for its aim the revision of accepted conclusions, in the light of newly discovered facts."

In the past, the University has been the stronghold of pure research—loosely defined as "a search for knowledge for its own sake happily pursued without purposeful intent." Nowadays, most such institutions can be fiscally persuaded to conduct investigations with the specific purpose of solving a given problem. This "applied research" is also actively pursued by nearly all branches of industry, who, in their quest for new ideas, employ brainstorming to milk ideas from inarticulate technical men, or even brutally attack a problem by assembling a battery of experts in a "think tank."

The word "research" seems to have a magic effect in raising funds, but no matter what term is used, to those engaged in the prosthetic field the goal is to better the lot of the amputee by seeking improvements in prosthetic design and practice.

Of thirty-three agencies in the United States in prosthetic or orthotic research, several are involved in obtaining specific physical data on both normal subjects and amputees. These studies come close to the field of pure research, and provide a background of well-documented information that can be useful in the design and development of new devices and techniques.

The studies include measurements of the body and distribution of the mass, pressure sensitivity, perspiration loss, energy consumption, gait patterns, and attempts to establish locomotion formulae based on the theory of least work. In locomotion, energy is expended in flexing, extending or resisting motion at each joint, and this theory presupposes that the human body, handicapped or otherwise, will assume a pattern that involves the least total amount of energy. In addition, with particular reference to the upper extremity, investigations are being conducted on possible control sites, electrical and otherwise, and methods by which a sense of position and force may be transmitted from the prosthesis to the body. The search for such numerical data can be conducted independently in laboratory situations. Although it provides invaluable design criteria, information in creating new products must have other sources of knowledge to become effective.

A designer requires, in addition to available experimental data, some means of association with the problem; a facility for fabricating prototypes;

and a local amputee population for preliminary test wearing. It is possible for one man to work out a new device entirely on his own, and since this avoids any communication problem it has advantages in efficiency. It does, however, impose limitations in scope, since the diverse knowledge of the many professions remains unused. A small group, including all the representative disciplines, can develop, through association, a team approach and can function with considerable efficiency with informal means of communication. Thus a development center can operate effectively when flanked by an active clinic on the one hand, as an amputee information source, and by a school on the other for effective dissemination of its products.

Amputee information can be effectively gained by association with the patient in all phases of existence from amputation and training to his routine wearing, and the up-to-date rehabilitation center with an active open-minded clinic provides an unequalled opportunity for acquiring the information. Much of the data can be documented and subsequently analyzed, but unfortunately much essential information can only be estimated, and such things as pressure patterns in the socket and comfort can only be guessed. However, it is in this realm that a good clinic team of doctors, therapists, prosthetists and amputees can pool their knowledge to form some statement of the problem.

Once a specific problem has been stated, design and development can begin. Early designs are usually based on some intuitive concept, but before they take any practical form, a working knowledge of possible materials and fabrication techniques must be coupled to an understanding of engineering mechanics and structural analysis. Prototypes invariably lead to modifications, especially after fitting to the patient, and often unsurmountable obstacles necessitate a complete revision. Since a change in one part can affect the entire design, it is often necessary to consider as many as fifty or more possible solutions before making a decision, and a finished product requiring twenty drawings may have involved thousands of preliminary sketches.

The development of new techniques in fittings are even less formal, and although they may stem from some initial concept, the procedure is usually a cut and try process as the research prosthetist and associates work with a patient towards a satisfactory solution. The development of the diagonal type hip disarticulation socket, for example, began with an understanding of the functions of a socket in weight bearing, lateral support and suspension, from which an estimate of the necessary parts of the socket could be made. Then followed a series of cast taking, fitting and checking with several patients, with constant minor revisions, until fitting principles could be established.

Any new device or technique should be proved before it can be released for general use, and this, of course, is the main role of evaluation agencies. Such evaluation has several specific objectives. A device can be tested to see if it lives up to the functional claims; it can be tested for durability; and, most important, it can be checked for amputee acceptance. The first two categories are fairly straightforward, and can employ bench testing and other simulated experiments with some degree of accuracy. Patient acceptance, however, is an extremely nebulous and difficult problem. Test wearing by professional amputees in a laboratory situation, and by selected patients on a trial basis, can be informative, but conclusive evidence usually results from widespread use in various areas by different types of amputees, prosthetists and clinics. A product may be accepted as satisfactory in New York and be quite unacceptable in Minneapolis, and the reasons for this may be due to climate, work habits, prosthetic capacity, or just plain prejudice.

There is, however, one essential point about evaluation, and that is that the results must be forwarded to where they can be used. This usually means some line of communication between the evaluating agency and the design and development groups, so that appropriate modifications may be made, or entirely new design concepts undertaken.

Once a design or fitting method has been proven, it still has to be made available to the amputee. Devices can usually be produced and distributed by the prosthetic manufacturer with little delay. The dissemination of new techniques usually requires re-education of the prosthetist and other members of the clinic team, and it is in this role that the prosthetic schools play an invaluable part. The effective introduction of fitting methods such as the patellar-tendon-bearing total contact below-knee prosthesis could not be in wide use today if it were not for the schools. These formal training periods are agumented by lectures at meetings of the American Orthotics and Prosthetics Association, and by seminars and lectures sponsored by the Committee for Prosthetic Education and Information for the benefit of the medical profession.

The process of research is not an isolated attempt at a new gadget, but a blending of the knowledge of the many members of the prosthetic team, each interdependent and informally organized so that there is a constant flow of information from the patient through the specialists to a device or technique. After fitting a device to the amputee, new information becomes available and the cycle is repeated. Thus the total knowledge builds upon itself like a snail shell and each improvement opens new scope for further work.

A well balanced group, working together in one area, can become an efficient unit in advancing prosthetics. In spite of meetings with other groups, however, there is a tendency to become mentally ingrown. Very little documented evidence is acquired, and much valuable information never becomes available to other agencies. The process is essentially "playing by ear," and although effective in a complex situation, a more scientific approach could be suggested to provide wide scope in a long term situation. Such an approach must be based on more specific terminology and means of communication.

Julian Huxley has shown how our modern society has developed largely through the growth of communication. The term applies in the general sense, including the effectiveness of language, knowledge accumulation through books, transportation and electronics. Modern technical achievements have similarly depended upon widespread scientific knowledge and the means by which new information may be made readily available.

The same reasoning is also true in prosthetics, but there are unfortunate complications. The varied disciplines involved do not have a common language, and many of the physiological characteristics of a human being are difficult to express in engineering terminology. In addition, the physician, prosthetist and engineer have different ways of viewing a problem. The development of scientific theory has been essentially the formulation of order from a chaotic arrangement of facts.

The apparently erratic motions of the planets is easily explained when viewed as elliptical orbits around the sun. Similarly, the complex motions in walking become less formidable when approached as problems in engineering mechanics in the co-ordinate system.

It has been our unfortunate habit to describe a prosthesis by a list of parts, and those familiar with them associate certain characteristics with each part. The total effect, however, is also dependent upon the way they are assembled or aligned. It would be better to describe the prosthesis by the total functional characteristics so that a direct comparison of all models could be made. In time, desirable charactertistics could be determined through clinical observation and laboratory experiments. These characteristics would then become design criteria—providing specific data so that design engineers unfamiliar with prostheses could function efficiently. Any new designs could be evaluated by direct comparison without reference to individual fittings.

With such a system, the benefits to research would be enormous, but it would require not only the blue printing of the system but a radical change in our teaching methods. Although the schools have played a most impressive part in the advancement of prosthetics, guidance in the understanding of principles rather than presentation of facts might prove more valuable in the long run.

Whatever methodology or approach is used, the most important ingredient is the personnel involved. They must not only be competent in their respective fields, but should possess, in the words of Charles F. Kettering, "a friendly, welcoming attitude towards chance."

VA Announces New Appointments

Dr. John Lyford, III, director of professional services at the Veterans Administration area medical office in Atlanta, Ga., has been named director of domiciliaries for the VA's Department of Medicine and Surgery, Washington, D. C. He will head the VA's 16,000-bed domiciliary program in 18 domiciliaries nation-wide, as well as the agency's new restoration center program.

Dr. James S. Glotfelty, director of the Long Beach, Calif., Veterans Administration hospital, has been appointed director of the Oakland, Calif., VA hospital. He succeeds Samuel H. Franks who has been transferred to the West Haven, Conn., VA hospital as director.

Richard G. Jones, assistant director of the West Haven, Conn., VA hospital has been named director of the VA hospital at Walla Walla, Wash., to succeed Dr. Justine E. Gaines, who is retiring.

The Patellar Tendon Bearing Total Contact Prosthesis for Below-Knee Amputees

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Homo sapiens is a very perverse creature. It has often been said, "What is sometimes one man's meat is another man's poison." In any sufficiently large group of amputees may be seen a cross section of humanity, and so an amputee's reaction to any single environmental change may ranged from complete acceptance to complete rejection. Thus, when from several sources, ([1, 2, 3, 5.]) came reports that claimed almost universal acceptance of the new total contact patellar-tendon-bearing prosthesis (Fig. I) by below-knee amputees, the author began to wonder about this seeming inconsistency in human beings.

Prior to 1959, the basic prosthesis for the average below-knee amputee consisted of a thigh corset attached by steel hinges at the knee, to a rigid shank (wood or metal) ; a single axis ankle joint; and a wooden foot (or its counterpart). This type of prosthesis had been in routine use for at least the past hundred years. The literature[8] mentions that in 1826, Serre revived the principle of thigh support in B-K amputations. There are also available references that J. E. Hanger, about 1861, introduced the wood socket for the below-knee amputee.[3] This basic type of prosthesis had been refined about as much as possible and had become more or less accepted as the standard prosthesis for the usual below-knee amputee. However, in past years, a number of amputees have had difficulty tolerating the concentrated weight bearing required over the tibial condyle flares. Various

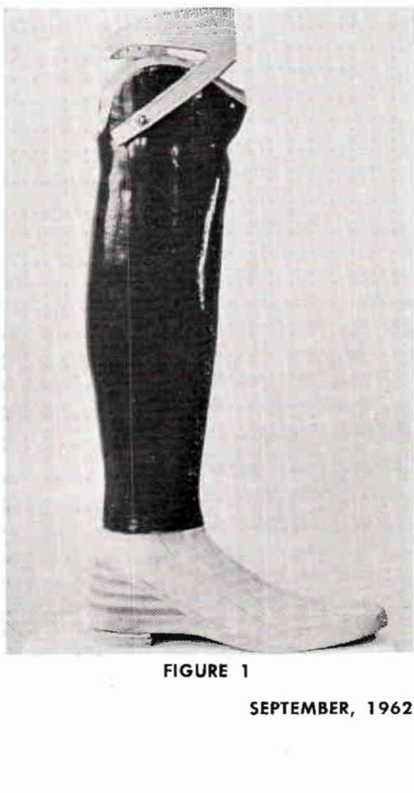

FIGURE 1

types of soft linings were used in the socket of this standard prosthesis including piano felt, sponge rubber, yielding plastic; even an all plastic total contact socket was used.[7] Most of these linings were found to have objectionable limitations when subjected to considerable wear by the amputee.

In 1959, a new approach to the subject was announced utilizing the principle of an older type of prosthesis, namely the Muley leg. The Muley prosthesis was a rigid below-knee socket prosthesis suspended by a simple condylar strap above the patella. This prosthesis, in practice, had serious limitations. The amputee usually had walked with an extended knee, and because of the lack of "back check" or hinge limitations to extension of the knee, the posterior elements of the knee joint gradually stretched, and a hyperextended or "back knee," resulted. To overcome this defect, the new prosthesis was so aligned that the patient passed through the entire phase of stance with his knee in flexion, thereby limiting the stretch on the posterior structures of the knee joint. This flexion attitude also provided a second effect, that of cushioning the downthrust of the stump (during stance) into the socket by controlled elongation of the quadriceps muscle. This new prosthesis provided for the greatly increased use of the patellar tendon and the popliteal area for weight bearing as well as the anteromedial and lateral tibia. Extension of the socket proximally not only enlarged the weight bearing surfaces somewhat, but supplied important stabilization of the stump. Mediolateral stability was also enhanced by using pressure along the lateral aspect of the fibula (sparing the cut end and the fibula head). The socket was closed over the distal stump to provide contact on the soft tissues. The stump was maintained in its position against the patellar tendon bulge in the socket by anterior-posterior pressure in the popliteal area. This is similar to the way the Berkeley suction socket maintains an above-knee stump in its position on the ischial seat by the anterior socket wall bulge in Scarpa's triangle. Fabrication problems of this new prosthesis were quickly resolved, and in 1960, the technique of fabrication of the total contact patellar-tendon-bearing prosthesis for below-knee amputees began to be taught in the prosthetic schools. The Veterans Administration early became convinced of the value of the new prosthesis, and contracts for its fabrication were let to various prosthetic facilities throughout the country.

In the Chicago area, there are five cooperating limb facilities which are qualified to manufacture the new type of prosthesis. The Veterans Administration Central Office published guide lines for its prescription, primarily limiting its use to patients who were unilateral amputees; who had at least a four inch below-knee stump; and who had a sound knee without ligamentous relaxation.

In spite of the fact that this prosthesis has now been in use for several years throughout the country, only the most general and fragmentary statements have been forthcoming as to its efficiency in any large group of amputees. [1, 2, 3, 4, 5, 6, 8.]

In an effort to find out how effective this new prosthesis was, all of the patients who had had below-knee prostheses issued to them from the Amputee Clinic of the Chicago Regional Office of the Veterans Administration during the period from August 1, 1960, to May 31, 1962, were surveyed. This study yielded a total of one hundred and twelve below-knee amputees who had received a new prosthesis from this Amputee Clinic of the Veterans Administration. The average below-knee amputee in this clinic is employed, has a family, uses his prosthesis fourteen to eighteen hours a day, rarely, if ever, uses crutches or cane, and has usually adjusted well to his disability. It was noted that of the group of one hundred and twelve amputees, there were forty-seven "standard" or old-fashioned types of B-K prostheses issued. There were fifty-three PTB prostheses with condylar straps issued in the same period. Four patients had the new PTB prosthesis issued with corset and side hinges applied at the time of manufacture. Three patients were found who had both a PTB prosthesis and a standard type of prosthesis issued during this study period. Five of this group of one hundred and twelve had been issued a slip-socket type of prosthesis.

In reviewing the reasons why the "standard, or "old-fashioned" types of prosthesis were issued during this modern era, they were found to run as follows. 1) Lack of motivation to try something new, and/or a desire not to lose any more time than absolutely necessary from a job, were the main reasons for supplying a standard type of prosthesis to twenty-eight of these amputees. 2) Six of the patients lived sufficiently far from the limb shop that it would not be feasible for them to make the round trips necessary for the possible multiple initial changes in the socket fit or alignment. 3) Stumps in six of the cases were too short (less than four inches) for issuance of the new prosthesis under the VA regulation. 4) Four patients had stumps which were too painful to palpation at the time of initial prescription and evaluation to wear probably successfully a total contact PTB prosthesis. 5) Three patients stated that they needed a leg that would stand up under very heavy laboring activities and felt that the new leg (which they were shown) would not be adequate in strength. 6) Two of the patients were bilateral amputees who stated that they wanted to retain the stability and the security of their previously-worn, standard types of prosthesis. 7) Two patients had an excessive sweating problem, and the clinic team felt that with the use of the closed leather rubber lined socket this sweating problem might be aggravated. 8) One patient stated that he was "too active" for the new type of leg. 9) Another patient had a dermatitis problem that the attending surgeon felt would contraindicate the use of the closed socket prosthesis. 10) A single patient had relatively recently fractured his femur, and needed the thigh corset for support. 11) One patient had a stump that changed quite frequently in shape and it was felt advisable not to issue a closed end, critical fitting socket to him. 12) Another patient had a fluctuating weight problem. These, then, were some of the reasons why the new prosthesis was not issued to this group of forty-seven patients.

The five patients who had prescriptions for slip-socket prostheses all had short stumps, one and one-half to three inches, too short under the VA regulation for the PTB prosthesis. These five patients had used slip-socket prostheses before and had been completely satisfied.

Of the three patients who had both a PTB prosthesis and a standard leg, one patient found that he was not able to use his PTB prosthesis for heavy lifting activities, and used a standard prosthesis on his job, reserving the PTB prosthesis for non-work activities. Two patients were unable to tolerate the patellar-tendon-bearing prosthesis after it was prescribed and fabricated. Because the previous prosthesis had been condemned, new "standard" prosthesis with thigh corset, side hinges and willow socket was made for both. The PTB prosthesis with a corset was initially prescribed for four patients. This was used in one patient because of excessive scar tissue on his stump which was intolerant of weight bearing. One patient's stump was covered with extremely thin skin without subcutaneous fat padding, and he had had a great deal of trouble, prior to the PTB prosthesis, in wearing a leg without an ischial weight bearing corset. Two patients wished the added security of a thigh corset. These last two patients were truck drivers and wanted the response of the prosthesis that they obtained with a thigh corset rather than the perhaps inadequate response of a prosthesis with only a condylar strap. All four of these patients were found to be wearing their prosthesis on a full time basis on a three to four month follow-up examination.

Four patients originally fitted with PTB prostheses and condylar straps were seen at a later date, at which time a thigh corset addition was prescribed. One of these patients was a bilateral amputee with eight-inch below-knee stumps. He was a surgeon and found that after prolonged standing, his stumps became too sensitive for comfort. The thigh corsets were added, and a four month check-up indicated that the prostheses were then completely acceptable. A second patient wore a PTB prosthesis for three months during which time his weight fluctuated considerably. He further noted that on heavy lifting he had considerable stump discomfort, and it was the consensus of the clinic that a thigh corset would aid his further rehabilitation. A third patient, truck driver with a Chopart amputation on one side and a seven-inch below-knee amputation on the other, wanted the additional security of the thigh corset. This was added two weeks after he had obtained his PTB prosthesis. A fourth patient, after four months of endeavoring to wear his prosthesis, had so much difficulty with tender skin, aggravated by sweating, that he wished the addition of a thigh corset. A five month check-up on this patient revealed that this had effectively solved his stump skin sensitivity problem.

Fifty-one patients in the group of one hundred and twelve were found to have been issued a total contact PTB prosthesis with condylar strap. Of this group, sixteen were followed for an insufficient time to warrant any sort of end result pronouncement, and four patients were lost to follow-up. Of this remaining group of thirty-one, six patients were followed from one to six months, fourteen patients were followed from seven to twelve months, eight patients were followed from thirteen to eighteen months, and three patients had a nineteen month or longer follow-up. There were four total failures in the group of thirty-one. One patient, after five months of full time satisfactory wear, suddenly developed a contact dermatitis of the stump. It was found that the patient was allergic to the Kemblo lining. He was not sufficiently motivated to try other solutions and demanded a return to his old willow type prosthesis. The patient made a subsequent complete recovery from his allergy problems wearing a standard type prosthesis. Three patients were unable to adjust to the PTB prosthesis while still on the adjustable leg. No attempts at relief or lining seemed to make them sufficiently comfortable that they could wear this type of leg. These three did not have sufficient motivation to wish to continue attempting to adjust to the prosthesis even with the addition of a thigh corset. They were all returned to their standard prostheses.

Of the group remaining (twenty-seven patients) it was found that only sixteen of this group wore their total PTB prostheses with condylar straps full time; whereas eleven patients, even after prolonged attempts at breaking them in, were only able to wear them part-time. Various reasons were given by the part-time wearers for their inability to wear the prosthesis full-time. Four patients stated that they were not able to tolerate their new prosthesis for more than a few hours at a time because of stump discomfort or pain. These patients had had repeated attempts at relief and/or lining to make them comfortable, but still could never get the complete comfort that they desired. These four patients alternated with their standard prosthesis. Three patients complained that their thigh muscles became quite tired during wearing of the PTB prosthesis, and particularly so when they attempted to wear the prosthesis to work. To them this was a very distracting situation. Three patients complained that whenever they wore the PTB prosthesis for any prolonged period they developed blisters on the stump. Although the stump pumping situation was minimized by the pelvic strap, this condition could not be completely eliminated. Two patients complained of severe discomfort in the stump whenever they were called upon to do heavy lifting, and were only part-time wearers. These two did not wish the addition of a thigh corset, as during the time they were not obliged to do heavy lifting, the new prosthesis was quite advantageous without the thigh corset addition. One patient wore his prosthesis only part-time because he liked the security of his old leg for certain activities such as mowing the grass, heavy lifting or driving an automobile. One patient stated that he was not able to kneel for sufficient periods in this type of prosthesis while on his job as a maintenance man. He therefore did not wear his new prosthesis for work. One patient stated that wearing his total contact prosthesis all day made his stump numb. He thus wore it only in the evenings, and weekends.

Approximately thirty-five of the amputees were further queried by questionnaire. A question, "Is your new prosthesis better for the following activities" listed walking, stairs, ramps or inclines, sitting, kneeling and lifting, and the following answers were obtained. On walking, twenty-eight patients felt they did better, four felt they did not show any improvement; and three patients did not respond. On stairs, seventeen felt they were able to negotiate stairs in an improved manner over their old prosthesis; whereas thirteen did not feel this was true. Five did not respond. Ramps or inclines were negotiated better by twenty of the patients, less well by ten, no response by four; and one patient stated that this answer could be either yes or no. Sitting found twenty-nine amputees with a "yes" answer for an improvement; whereas five stated that there was no improvement, and one patient did not respond. Seventeen patients found that kneeling was less comfortable with the new prosthesis; whereas fourteen felt that it was improved over the standard type of prosthesis. Four patients did not respond. Lifting again found the "no's" predominant with twenty patients who stated lifting was more difficult and painful with the new prosthesis; ten found it was improved; and five did not respond. To the question, "Would you want another prosthesis of the same type," twenty-two patients of this group answered yes, five answered no, and eight did not respond to this question.

In evaluating the above patients with PTB prostheses, certain things were noticed that we felt were important attributes of the new prosthesis. Several of the patients were found to have actually hypertrophied their quadriceps muscle by using this prosthesis without thigh corset, some as much as one inch of increased thigh circumference. This measureable hypertrophy occurred after two to six months of usage. It was further noted that skin problems due to chronic venous stasis such as verrucous hyperplasia showed improvement after wearing this type of prosthesis. (Figures II and III) It was also of interest to note that none of the PTB prosthesis

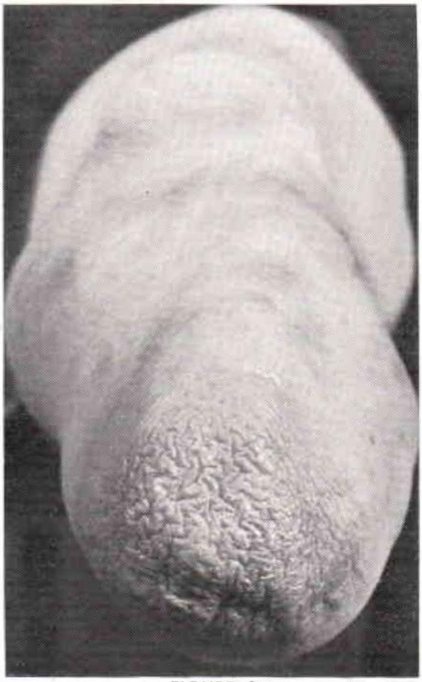

FIGURE 2

Figure 3

wearers developed any evidence of infrapatellar bursitis such as one might expect from concentrated weight bearing in this area. After reviewing our experience, it was the opinion that the total contact patellar-tendon-bearing prosthesis was definitely a new development for the below-knee amputee worthy of consideration when prescribing a leg for either a new or an old amputee. The full-time wearers of the PTB prosthesis in our clinic were quite enthusiastic in their response to the prosthesis, indicating that it was a definite improvement over the previously worn type of prosthesis. However, those who were not able to wear it were equally sure that the old style prosthesis was more to their liking than this new prosthesis. In other amputee clinics where predominately new amputees are seen, it has been our *impression* that the new amputee takes to the PTB prosthesis a great deal easier than does an old wearer such as we encountered in our VA Amputee Clinic. In reviewing this series of cases our prescription indications would seem to be confined to a below-knee amputee, either unilateral or bilateral, preferably who has not worn a prosthesis prior to his appearance at the prescription clinic. The patient ideally should have a stump which is four to seven inches in length or longer, with adequate knee stability, his job should not require heavy lifting or heavy laboring activities, and he should not require excessive stability of his prosthesis. Those amputees who do a great deal of kneeling or standing in their occupation should be carefully evaluated before prescribing this new prosthesis. In addition, the amputee patient should be within a reasonable distance from the limb shop. Arbitrarily a distance of fifty miles is about the maximum the patient should be expected to travel for the necessary fittings.

In summary, 112 below-knee amputees were evaluated, 51 of whom were issued the new patellar tendon bearing prosthesis. Of 31 patients with an adequate follow-up, only 16 were full-time wearers. This prosthesis, however, is a definite addition to the armamentarium for the below-knee amputee.

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The Role of Physical Therapy in Prosthetics

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Much is written and said about team approach and team concept. Much of this, too, is lip service to the concept, with no actual participation in the goals set and desired. However, we find the true structure of the team approach is a necessity in the total treatment of the individual with an amputation of one or more extremities. This may be due to the fact that a group outside the medical profession is a vital and absolutely essential member of this team, and that each team member is wholly dependent on the skills and knowledge of the other members in order to complete the total job successfully.

The role of the therapist is of importance through the entire period of rehabilitating the amputee. The phases of therapy during this period with all amputees, whether upper or lower extremity, can be divided into:

1. Evaluation
2. Pre-prosthetic therapy
3. Training or post-prosthetic therapy

The evaluation of the amputee consists of determining range of motion, muscular strength, coordination, and balance, and whether these are adequate.

The pre-prosthetic therapy period may be short or long, depending on the needs of the amputee. The therapist may aid the surgeon and the hospital staff by explaining and demonstrating to the amputee the replacements available, teaching crutch gaits, emphasizing good posture, by teaching proper bed positioning to prevent contractures, by teaching graduated exercises to prevent contractures and loss of strength, and by instructions in properly applied bandages to shape and shrink the stump. A maintenance program for uninvolved extremities may be carried out at home. The amputee may be given instructions in exercises and bandaging for a home program or kept on a supervised clinic basis.

In the post-prosthetic period the therapist is responsible for the check out of the prosthesis and the training in its use. The time involved is determined by many factors, such as type of amputation, level of amputation, multiplicity of amputations, age of the amputee, motivation of the amputee, plus economic and social factors.

In training the amputee, we find that some patients can carry out a satisfactory home program of exercises and bandaging, if properly taught, between the acute hospital period following surgery and the fitting of the prosthesis; while others will require a more intensive supervised program on a daily or three times weekly schedule. Bandaging must be continued until the amputee is able to wear a prosthesis every day, all day, and can apply the prosthesis without difficulty.

With the lower extremity amputee the ability to balance is of the utmost importance and must be acquired by the amputee, before he can learn to walk satisfactorily. Therefore, we start the amputee in a set of parallel bars, which is a safe and secure environment to learn balance and to regain confidence. We feel the parallel bars should be a minimum of sixteen feet long, so as to allow good heel-toe gait without constantly turning around.

We discourage the use of walkers, except in extreme cases, because we feel an amputee never gains good balance in a walker. It also is extremely difficult to wean the user away from the walker. We discourage the use of crutches during prosthetic training for the same reasons. We resort to crutches with a prosthesis only after all other attempts at safe ambulation have failed.

Training progresses from balance in the parallel bars to ambulation with both hands on the rails, to one hand on the rail, to one cane in hand opposite the prosthesis, to walking outside the bars with therapist as standby support, to independent walking and Activities of Daily Living.

By Activities of Daily Living is meant sitting and getting up from chair, going up and down stairs, up and down curbs, stepping over obstacles, kneeling, falling with safety and getting up, going up and down inclines, walking on rough surfaces, getting in and out of car, and taking public transportation.

The upper-extremity amputee may have more emotional problems, and may need more support from the therapist than the lower-extremity amputee. The length of the training period will vary with the individual patients for

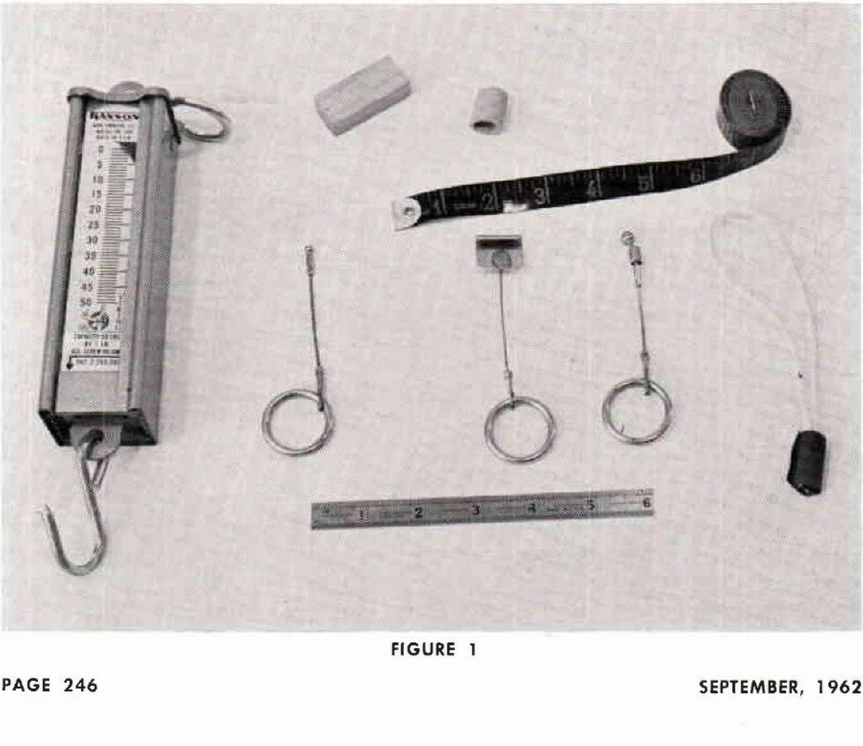

FIGURE 1

the same reasons as with the lower-extremity amputee. As a rule, however, the training period is shorter because fit of the upper-extremity amputee is purely suspensory; while the lower is weight bearing.

In training the upper extremity amputee, the therapist must have a few training aids. First of all, to do a check out requires the use of a scale, adapters, rule, tape measure, goniometer. (Fig. 1) Then, following teaching the controls necessary to open and close terminal device, lock and unlock elbow, position hook, the amputee should be taught approach, grasp, and release of objects. In order to do this effectively, we use a form board, (Fig. 2) which is composed of some twenty objects of different shapes, sizes and material. Some are square; others are triangular, or round. They are of various heights as well as circumference. Some of the objects are soft rubber, and thus spongy and very light weight; others are metal, and thus slick and heavier. The board has definite pockets into which these objects fit, and the amputee practices picking up each object from the table and placing the object in its exact spot on the board. In this way, the amputee uses the motions he has been taught to reach out and grasp an object and release it, under a controlled situation.

This is the only training given as a one-handed situation. All other training is carried out with two-handed activities requiring the use of the prosthesis as a helping device for the remaining good hand.

There are many aids or gadgets that are helpful in training the upper-extremity amputee, which he frequently will continue to use in his Activities of Daily Living. Figure 3 shows a type of hand brush which most upper extremity amputees find useful because the hollow handle allows a firm grasp of the brush with the hook. Figure 4 shows a long finger nail file, so held that it can be anchored in the hook and used effectively by the

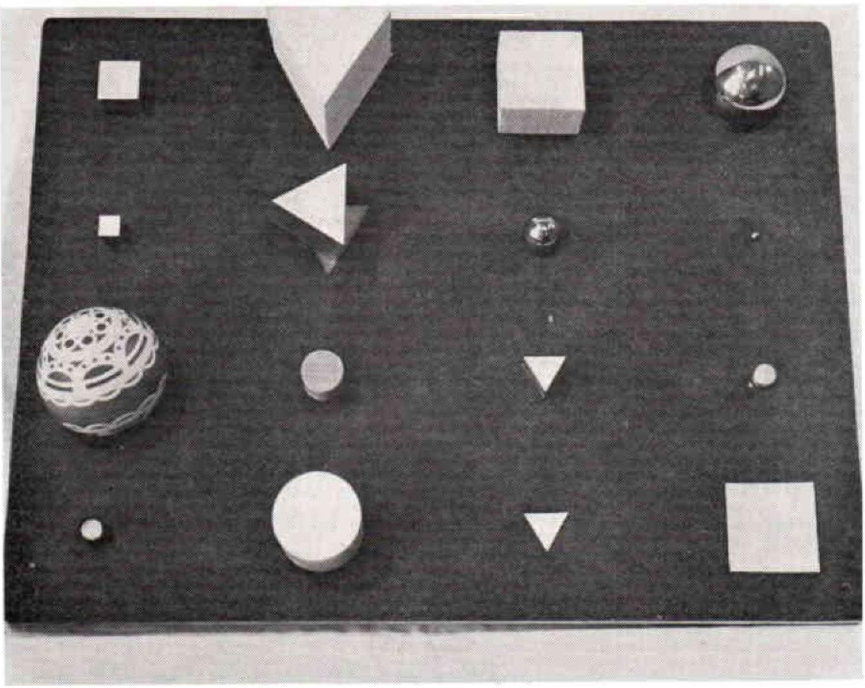

FIGURE 2

FIGURE 3

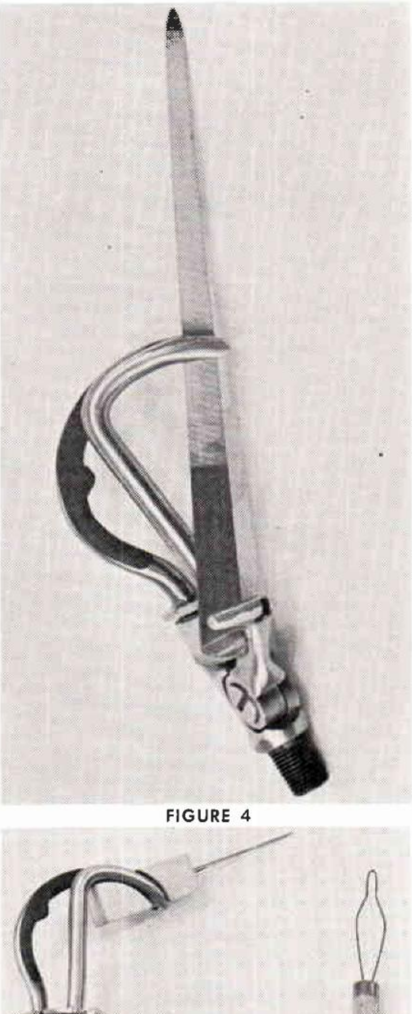

FIGURE 4

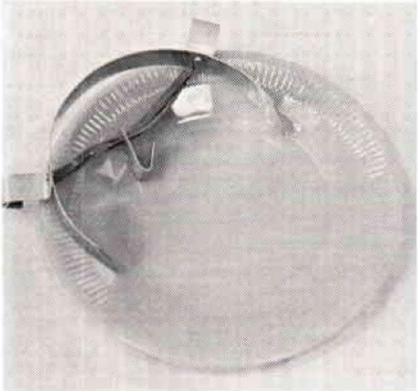

FIGURE 5

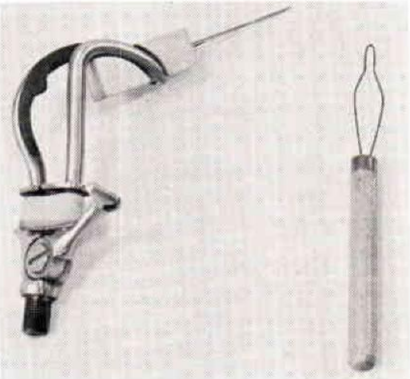

FIGURE 6

amputee. Figure 5 shows a plate guard which is particularly helpful to the upper extremity bilateral in keeping food on the plate while he is eating. Figure 6 shows two types of button hooks which unilateral amputees find helpful in buttoning the shirt sleeve, and the bilateral uses also to button the shirt front.

Many of these gadgets are available commercially, and frequently the amputee himself will suggest equipment which he finds meets his needs.

One of our bilateral amputees figured out a recoiling chain fastened to his feet so that it was easily accessible for his use.

There is no other phase of physical therapy where the therapist has more chance to use her initiative, ingenuity, judgment and personality than with the upper-extremity amputee. The challenge is tremendous and the rewards gratifying, because the amputee responds so gallantly to interest shown, and between the efforts of the two a solution is always found.

I feel quite strongly that the physical therapist expected to work with amputees must have a knowledgeable background, not only in anatomy, kinesiology, and the sciences taught in our physical therapy schools, but also in prosthetics, particularly component parts, gait determinants, socket types, research being done, etc. Our physical therapy schools are incorporating more on prosthetics into their courses, which is one solution. In the meantime, the therapist expected to participate in a prosthetic program should be given the advantage of attending the prosthetic courses offered by Northwestern University, New York University, or University of California, Los Angeles.

New Facilities Certified

By action of the Committee on Facilities of the American Board for Certification, the following Facilities have either been granted Certification, or have been re-instated in good standing, since the publication of the *1962 Registry of Certified Prosthetic and Orthopedic Appliance Facilities.*

CALIFORNIA

San Bernardino:

LANHAM LIMB AND BRACE COMPANY — P&O
1545 North Mount Vernon Avenue — 830-506
Harvey G. Lanham, C.P.O.

MASSACHUSETTS

Boston:

THE REHABILITATION CENTER — P
LIBERTY MUTUAL INSURANCE COMPANY
372 Stuart Street — LIberty 2-4850
Joseph C. Aveni, C.P.

NEW YORK

Syracuse:

FREES AND TYO, INC. — P
1124 East Fayette Street — GRanite 6-9708

OHIO

Cincinnati:

CENTRAL ORTHOPEDIC APPLIANCE COMPANY — O
2815 May Street — CApitol 1-6060
John F. Skahan, Owner

PENNSYLVANIA

Harrisburg:

KEYSTONE ARTIFICIAL LIMB & ORTHOPEDIC CO. — P&O
224 Chestnut Street — CEdar 4-3888
J. H. Shapiro, Owner

TEXAS

San Antonio:

LONE STAR ARTIFICIAL LIMB COMPANY — P
1311 South St. Mary's — LEhigh 4-6390
Robert M. Williams, C.P.

Mechanics of Spinal Bracing

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The problems involved in spinal bracing have been the subject of considerable study at Northwestern University during the past year. In this time it has been found that there are several hundred braces for the spine. Each has at least one proper name, many totally unpronounceable; and most have few or no specifications. Generally there is no concise indication of their particular value other than a suggestion that the author or designer liked one brace better than any other he had been able to make.

The proper use of braces must not be based upon descriptive literature or the intentions of the original designer. The choice should be derived from and related to the configuration and physiology of the part to be treated, and based on a knowledge of the disease process which is occurring—and hopefully on the knowledge that a given mechanical therapeutic technique is helpful for this specific disease. The resultant choice should be presented to the orthotist as a prescription embodying the specific structural components desired in the brace.

The spine functions as a semi-flexible rod resting on the sacrum which is an integral part of the pelvic ring. It consists of a column of articulated vertebral bodies cushioned from each other by the intervertebral discs, and held in place by a series of ligaments anterior and posterior to the vertebral bodies. The attitude of the pelvis is the basic determinant of the posture of the spine. The ligaments and discs together limit the amount and direction of motion of the vertebrae on each other, and of the spine as a whole. This flexible rod will buckle to the side when a certain critical load is applied to the top. If the base of the rod is fixed, and the top is free to move as the spine is within the body, the critical load which will cause buckling is approximately four and one-half pounds. The weight of the head-arms-trunk complex is considerably greater than four and one-half pounds in the erect position.[1] Therefore, it is not the inherent stability of the spine which prevents collapse; it is, rather, the action of the muscles.

It is common to think of the back muscles, specifically the para-spinal muscles, as the sole group of muscles active in normal posture control. Certainly this group of muscles would seem to be solely responsible for the ability to pick up weights. The electromyograph does show that these muscles are active in bending forward and returning to the erect position. However, simple consideration of the bulk of these muscles and their placement close to the spine itself suggests that this group is not sufficiently bulky nor advantageously placed to do the whole job unaided.

Electromyograph studies show considerable activity of the flank and anterior abdominal muscles. Measurement of intra-abdominal pressure during the return to the erect position after bending shows that there is an increase during this effort in proportion to the load.[2]

The abdominal cavity is balloon-shaped. The diaphragm above forms the dome. The abdominal and flank muscles form the sides. There is a pelvic diaphragm below which completes the balloon. It is common experience to hold the breath while lifting a heavy load. This maneuver increases intrathoracic and intra-abdominal pressures. Increased intra-abdominal pressure will relieve the paraspinal muscles of much work in returning the spine to the erect position because the spine lies over the balloon on bending forward.[3] This also reduces the pressure on the lower lumbar discs since the force is active on the same side of the lumbosacral fulcrum as the weight to be lifted. Therefore, it seems apparent that when functional or structural weakness of the lumbar or dorsal spine occurs, a specific component of the prescribed brace or garment should usually be a firm abdominal support. This can be incorporated in the brace along with suitable "three-point pressure" systems.[4]

The general principles of dealing with people apply to the treatment of the back, as well as to other parts, and it is necessary to treat the individual in his individual situation and not to become an idolator of a modality.

Currently progress is being made in the identification and standardization of basic types of braces. An understanding of the complex functions of the back is developing. Careful analysis of these functions of the back, a thorough understanding of the causes of certain diseases of the spine, and analysis of the characteristics of basic brace types should allow us to prescribe a brace that will be most beneficial to the patient with a spinal condition.

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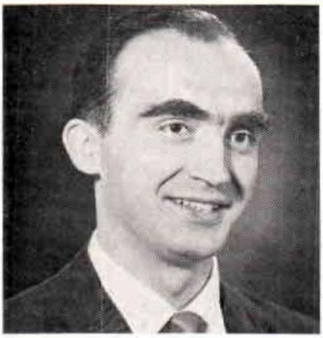
Mechanics of Spinal Bracing as Related to Immobilization



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The physician diagnoses, prescribes, and treats; the orthotists supplies the tools with which to treat. To avoid error, the physician employs scientific knowledge in his endeavor to correct a disability; the orthotist, therefore, must provide tools which conform to the doctor's treatment approach. It is essential, then, that the orthotist be familiar with knowledge which will enable him to supply apparatuses based on scientific concepts so that the combined effort of physician and orthotist will be an enhancing one.

The roots of success are basic knowledge; therefore, the specific aim of this paper is to state the mechanical principles as they are currently thought applicable to the construction criteria of orthopedic appliances—with particular emphasis on the immobilizing spinal devices.

Whenever confronted with the problem of bracing the spine, the orthotist must ask himself three (3) basic questions, namely—what, why, and how to brace.

What to brace. Inasmuch as every structure of the trunk is subject to pathological involvements, the orthotist must be familiar with the anatomy and kinesiology of the trunk components. He must know that even though only a single component may be affected, the method of treatment consists of bracing a whole unit of which the affected component is part. The body units or areas then which may be braced are the pelvis, sacrum, lumbus, thorax, rib cage, and cervix. In addition to this, any one muscle, or group of muscles (and tendons) may be subject to brace application.[1]

Why to brace. The major objective of bracing is to help to restore to normal or near normal some part of the body which has assumed an abnormal characteristic due to the influence of some force or element. The normal and constant forces acting on any living body are tension, compression, torque, and bending. If any one force or combination thereof exceeds in magnitude the inherent structural resistance of the body to that force, abnormal characteristics will occur.

Of course, forces in excess of the inherent structural resistance of the body are not the only causes of abnormal characteristics. Elements attacking the body internally may cause deviations from the normal or may reduce the inherent structural resistance of the body to an external force. Thus, disease is a cause of abnormal characteristics causing the body to weaken and rendering it more susceptible to deformation and to excessive traumatic forces.

How to brace. The force of muscular contraction must be effectively harnessed, if it is to perform useful work. In the case of bracing these forces must be effectively interfered with in order to permit immobilization. Normally the body is able to utilize mechanical principles to operate certain simple machines inherent in its design; however, when an abnormal condition exists, some of the mechanical principles have to be interfered with or re-directed.

Traditionally, spinal braces have been divided into three (3) categories of function, namely, immobilization, correction, and support. The method of bracing may be found in the definition of each of the aforegoing terms. Although the concept of immobilization is propounded in this paper, for accuracy and completeness the latter two definitions are also given.

Immobilization: to alter the forces acting upon a part so as to render that part immobile.

Correction: to effect a change in alignment of one or more affected parts.

Support: to supplement the action of one or more affected or weak parts.

Thus, in immobilization, normal muscular contractions are interfered with through the altering of forces acting upon the affected parts.

Continuing then with this line of reasoning, it becomes apparent that a spinal brace consists of a complex of induced bending moments—these bending moments being induced through one or more forces acting upon the body.

For clarity of thought and comprehension of the mechanical principles of spinal bracing, several definitions of mechanical terms must be given.

What is a force? "A force is the action of one body upon another producing or tending to produce a change in motion." A force may have the nature of a push or pull and is something measurable by a spring scale.

The action of forces is best expressed by Newton's three laws of motion.

1. A body at rest or moving with uniform velocity continues in that state forever unless acted upon by a force.
2. If a force is applied to a body free to move, the body acquires an acceleration in the direction in which the force acts and proportional in magnitude to the force.

   *F*orce = *M*ass × *A*cceleration
3. To every force there is an equal and opposite reaction.

The above defines what forces are and how they act. In general, most orthotists do not think about these concepts when fabricating spinal braces; however, if at any time they were voluntarily to ignore these concepts, no spinal brace could ever be fitted to a patient.

Of Newton's three laws, the third one describes the mechanism of braces; whereas the first one describes the reason for incorporating the third law in the fabrication of appliances. To illustrate this it may be thought that a functional scoliotic condition continues in that state unless acted upon by a force. Therefore, in order to restrict this condition, a force is applied to the convexly deviating side—this applied force being equally and oppositely acted upon by the opposite structure of the brace. Newton's second law can be recognized by the following example: If a pressure pad were applied to the spine with no opposing pressure, the spine would move and continue to move in the direction of the applied force. This movement would be proportional to the magnitude of the force; or in this case to the force with which the pressure pad pushes against the body.

Generally speaking, however, the orthotist is primarily concerned with Newton's third law; thus, the "three point pressure principle" is nothing more than two forces acted upon by another equal and opposite force.

An integral part of the law of forces is the concept of "bending moments." A bending moment is defined as "the product of the force times the perpendicular distance." It may be expressed in the following equations: $F \times D$, $(F1 \times D1 = F2 \times D2)$ or $\Sigma M = 0$. The latter equation refers back to Newton's third law of motion because it reads, "the sum of all vertical forces (or horizontal forces) must equal zero." In the 3-point pressure system the magnitude of one force (pad) must equal the magnitude of the other two forces (pads). Thus, when bracing the spine for immobilization, the forces acting on the spine must produce moments of equilibrium.

One further concept may be indicated for better understanding of the mechanics of spinal bracing, and that is the concept of "reaction points." "A reaction point is any point against which a force acts." Thus in a typical Chair-Back brace three (3) reaction points are observed. They are:

a. abdomen, anteriorly
b. lower thorax, posteriorly, and
c. lower sacrum and pelvis, posteriorly.

A brace may, however, consist of a complex system of reaction points. For example, in the Taylor brace, in addition to the ones observed in the Chair-Back brace, the presence of axillary straps add the following reaction points:

a. lateral aspects of the pectorals
b. superior margins of the scapulae, and
c. at mid-thorax, posteriorly.

The term reaction point is a very mobile description; yet a very efficient one. In the aforegoing, rather than describing the reaction point with reference to the body they can be described just as easily in terms of mechanical components. This description is dependent only upon the standpoint from which a mechanism is illustrated.

The fallacy of force. Previously the statement was made that spinal braces are a complex of induced bending movements. This, of course, is only partially true. It might be more accurate to say the human body is a complex of induced bending moments. Although this may seem contradictory, it really is not. The following example may clarify this statement.

It is known that an anterior hyperextension brace with tightened worm-gears or straps exerts a force in the anterior direction inducing a bending moment in the sagital plane. However, this force is present only as long as the patient permits his body weight to resist this advancing pad. Since most patients do not care to tolerate this pressure exerted by the pad, they activate their musculature so as to retreat from this force. In other words, the patient activates a "force-avoidance behavior." As soon as the patient has gone through this force-avoidance behavior, the force is transmitted to the musculature in the form of a contraction. Following transmission of this force the apparatus simply becomes a passive structure reminding the patient not to flex or extend the spine (whatever the case may be).

Knowing this phenomenon Doctors Brown and Norton of Massachusetts designed a sacro-lumbar brace which had as its first objective to keep forces (pressures) localized over bony prominences so that prompt and somewhat uncomfortable pressure accompanied forward bending or slumping—flexion of the spine being undesirable in this case. Thus, the successful application of this brace depended upon this force-avoidance behavior.[2]

However, it should not be thought that all spinal braces depend upon this principle, that externally applied forces become transmitted to the musculature; otherwise the correction of scoliosis through bracing would not be possible. In scoliosis the patient has lost a great deal of ability of "directed muscle contracture;" therefore, the pads will retain the force as applied. Of course, some force-avoidance behavior will occur but that will be of reduced magnitude.

In summary, it may be said that it is fallacious to state that all braces do the immobilization. Although a brace may be the initiator of immobilization, the force or moments it induces may become transmitted to some other part, this part doing the actual immobilization. Thus, a force is never lost. A force will always work, but how well it works does depend largely upon the mind.

Immobilizing the spine. Immobilization has been described as "the altering of forces acting upon a part so as to render that part immobile." This term was further defined as complete or effective immobilization. The purpose for this sub-division will be clear when considering the problems of bracing for immobilization.

A recent scientific investigation on the effectiveness of spinal bracing has shown that complete immobilization through external fixation is impossible. Anyone who has observed a patient wearing a Taylor, Bennett, or Knight brace must have noticed a certain amount of gapping at either or both the inferior or superior margins of the brace during sitting or forward bending. This gapping, seeming discrepancy in fit, or seeming improper application of the orthosis may not be necessarily the fault of the orthotist. More often than not it may be due to the inherent mechanical disadvantages of the brace in relation to the body. The inherent mechanical disadvantages may be attributed to the following factors:

1. Discomfort toleration
   A brace can never be applied so snugly as to prevent motion because the force required to accomplish this would be excruciatingly painful to the patient and might upset the normal physiological function of the body.
2. Presence of soft tissue
   A brace cannot be placed directly against bony areas of the body, because all bones are covered with soft tissue which permit a certain amount of sliding and compression. Many of the posteriorly directed forces are exerted solely against soft tissue—meaning the abdomen which offers extremely poor rigidity (mechanical advantage).
3. Transmission of adjacent motion
   Due to the connection of contractile tissue between the lower extremities and trunk any motion occurring in the lower extremities is to some degree transmitted to the trunk. Thus, elimination of motion in the hip joints could appreciably reduce motion in the spine —that, however, is an impractical solution to the problem.

From the aforegoing factors it may be concluded that complete immobilization can never be achieved. But the question may be asked whether or not effective immobilization can be obtained. Effective immobilization may be defined as "to sufficiently alter the forces acting upon a part so as to render that part sufficiently immobile to encourage healing of the part."

How does an orthosis contribute to the healing process and/or prevent an increase in the pathological condition of the patient? The following quotation from the research paper by Dr. Paul L. Norton and Dr. Thornton Brown may serve to answer this question.

"The effectiveness of supports (braces) with respect to immobilization seemed to be related more to the discomfort produced than to the magnitude of force developed between the apparatus and the back."[2] Thus, in effect, these authors support the concept of force-avoidance behavior as promulgated earlier.

With this consideration in mind it becomes evident that brace components must be carefully fitted and strategically located to achieve the effects of immobilization. Thus, it is immaterial whether or not a brace, because of its mechanism, immobilizes the spine as long as that brace induces restriction of motion through an external force, force-avoidance behavior, or the discomfort of the appliances. Effective immobilization then can be said to exist when the brace prevents the patient from executing unwanted motions of a part to favor healing of the part.

It may now be asked, what is the best type of brace for immobilizing any given part of the trunk or spine? Inasmuch as past experience has been puzzling, and research has not yet provided an answer, the following may be considered in the meantime. From the mechanical principles of bending moments, forces, and reaction points it may be promulgated that "a numerical increase of any one of these principles would tend to increase the stability and effectiveness of a spinal apparatus." The spine, particularly the lumbar spine, may be considered as a flexible rod. If a flexible rod is to be kept from bending, the most efficient means would be to enclose it in a snug-fitting cylinder. A cylinder being full of reaction points is capable of inducing more moments or moments of equilibrium than any other device. It may be observed that the original Hessing Corset consisted of a steel frame encompassing the parts to be braced and was completely contained in a canvas corset. A typical Hessing corset, therefore, had incorporated the concept of increased numerical reaction points.

Summary. The aforegoing has been an attempt at re-familiarization with basic mechanical principles as they are thought applicable to the construction criteria of many orthopedic devices. They are principles which apply to all machines. A brace is a simple machine consisting of levers, capable of inducing forces, and bending moments on the human body in order to achieve immobilization of the spinal column and its neighboring parts.

It is to be realized that no new concepts have been formulated, but that the major purpose of this paper was to reiterate basic princples to encourage clarity of thought and a more uniform approach to the problems of bracing the orthopedically handicapped.

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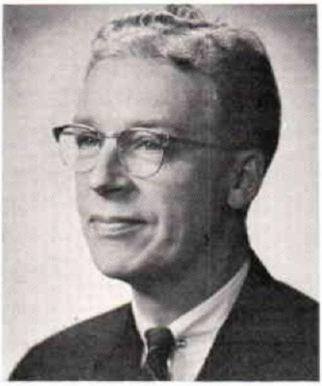
Current Concepts in the Management of the Juvenile Amputee



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Amputations and their prosthetic restorations have, at least in adults, a very long history. Initially wars and then the trauma secondary to a mechanized civilization have produced a large number of amputations in the adult population. Throughout the years an effort has been made to restore these otherwise productive people to a meaningful place in society.

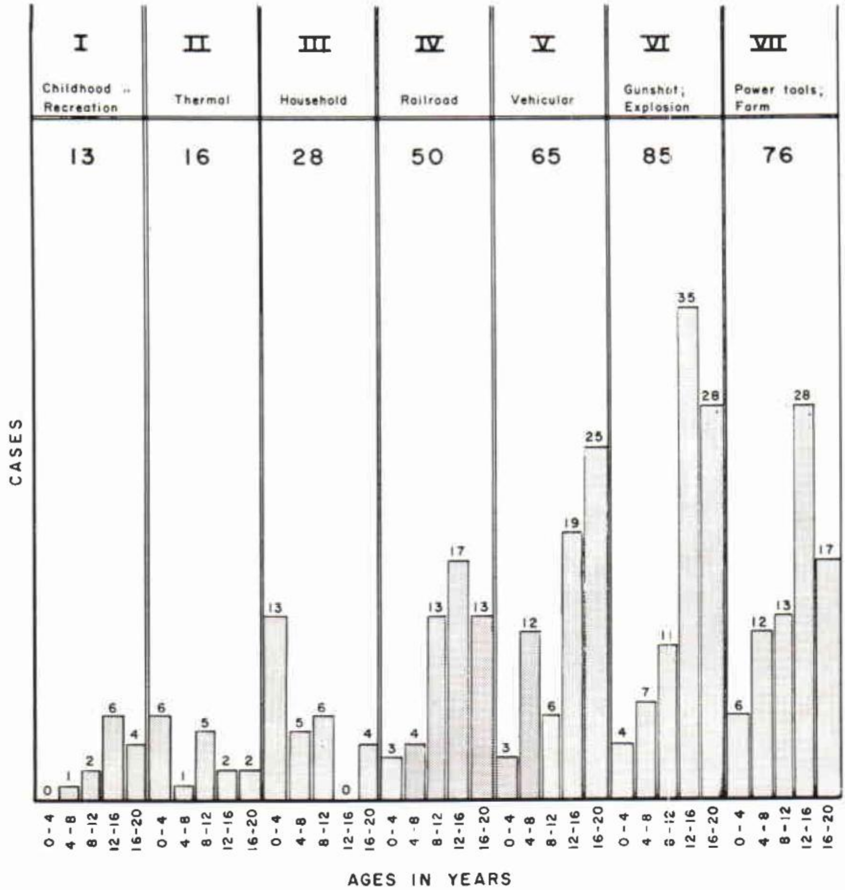
Amputations in children were a relative rarity for many years. As our civilization has become more mechanized, children have been exposed with increasing frequency to the kinds of trauma that may produce loss of extremities (see Table 1). Additionally, there have always been a certain number of children who presented themselves for treatment with a terminal transverse deficiency, sometimes mistakenly called a congenital amputation. The numbers of these patients, even in large general crippled children's services, have been quite small.

In children as in adults, there is very little resistance to the application of lower extremity prostheses. In spite of mechanical inadequacies, most juvenile lower extremity amputees have had some type of fitting early and have continued to use the prosthesis. The upper extremity is an entirely different problem. Historically there was very little in the English literature prior to 1950, concerning age of fitting of upper extremity prostheses and indications for their application in children.

With the tremendous improvement in commercially available components and fabrication techniques of both upper and lower extremity prostheses following World War II, there followed a logical increase in interest in the management of all amputees. As an outgrowth of this, children with amputations were treated more vigorously. There slowly evolved more clear-cut indications for prosthetic restoration, better training techniques, more satisfactory limb fabrication, and eventually well organized prosthetic clinics utilizing the team concept and devoted entirely to the care of children.

As a result of this increased interest in prosthetic restoration, children with congenital limb abnormalities (whose treatment by standard orthopedic reconstructive procedures had been less than ideal) were fitted, on a trial basis, with prostheses. Slowly there developed a new concept in the

ETIOLOGY of TRAUMA



CASE LOAD:

University of Illinois, College of Medicine	130	Cases
Michigan Crippled Children Commission Area Child Amputee Program	203	
	333	Total

management of certain limb deficiencies. At the present time prostheses are utilized in several groups of children:

1) The true post-surgical amputations, regardless of etiology;
2) The terminal transverse limb deficiencies (congenital amputations);
3) Congenital limb deficiencies that do not present themselves as amputations.

The sum of these three groups represents a small but definite portion of the crippled children population. There are, unfortunately, no reliable figures available anywhere concerning the incidence per unit of population of any of these groups.

Prosthetic-Orthotic Education at Northwestern University has instituted as a portion of its regular curriculum a course devoted entirely to the management of the juvenile amputee. This course, which represents a joint effort of Northwestern University School of Prosthetic Education and the Michigan Crippled Children Commission's Area Child Amputee Center, is specifically concerned with the principles of management of the three types of juvenile amputees that have been mentioned.

Age of Fitting

Lower-extremity amputees or children with abnormalities who are to be fitted as lower-extremity amputees should be fitted at the time that the patient is ready to walk, or as soon after surgery as the stump will permit prosthetic application. Normal children develop the ability to stand and walk in an orderly manner. The time sequence is relatively constant within a six months' variation. It is difficult to state categorically that children with lower extremity amputations or limb deficiencies should be fitted at a specific month, but somewhere between twelve and eighteen months of age most children are capable of maintaining satisfactory balance in the erect posture and many have initiated independent bipedal ambulation. When there is observed motor kinesthetic maturation to permit independent standing balance, a lower extremity prosthesis can be applied and ambulation will follow.

In the upper-extremity group, the age of prosthetic fitting may be determined by the goals that are desired from limb application. In the congenital terminal transverse deficiencies, early fitting can be utilized providing all concerned (doctor, patient, family, therapist, etc.) recognize that the prosthesis will not produce a level of function that is greater than the child's potential, i.e., a four-year is not as skillful as a six-year-old.

If one desires skillful prehension functions from an upper-extremity prosthesis, fitting must be delayed until the child has matured to the point that he would be capable of similar functions with a normal upper extremity. In short, then, there are two basic concepts in the fitting of upper extremities: 1) fit as early as the patient is seen, and 2) defer fitting until six to twelve months before the entrance into the public school system (four to four and one-half years of age). Early fitting theoretically accomplishes certain desirable things. It produces equal length of the extremities and thus encourages the child to carry out manual tasks at a normal arm's distance from the body, preventing the development of substitution patterns that bring many of the manual functions to the level of the deformed extremity; prosthetic application masks the sensory function of the stump; the dependence upon visual clues is encouraged; prosthetic tolerance is developed early. For these theoretical but probably valid reasons, early fitting with a passive terminal device—followed by gradual transition to an active terminal device, when the patient's motor skills permit, is recommended.

Surgery

The surgery of the juvenile amputee is different from the surgery of the adult amputee in that the juvenile patient has a growing skeletal growth, and therefore a stump can be fashioned at the time of the original surgery which will not change in length because of growth. Amputations in children with immature skeletons must always be fashioned with a full understanding of the logitudinal growth potential that exists in the stump skeleton. A precise knowledge of the contribution of each of the long bone epiphyses is essential. As a general rule, amputations in children are not done at pre-determined sites of election, but the rule of "save all length possible" is recommended. Preservation of epiphyses is imperative; disarticulations, therefore, are more frequently done in children than are classical supra-epiphyseal amputations.

Short stumps, neuromas, scars and spurs are not major complications in children. Tenotomies to make short stumps functional are done much less frequently in children than they are in adults.

The major post-surgical complication in juvenile amputation surgery is "overgrowth." This problem has been recognized for years, and the literature mentions several methods of management. Clinically, overgrowth is an increase in length of the amputated bone with subsequent irritation of the soft tissue, sometimes producing a bursa and in the extreme cases, a perforation of the bursa and skin with secondary superficial infection at the area of perforation. Radiologically the overgrowth presents itself as a sharp spicule of poorly trabeculated bone extending from the end of the stump skeleton. It may or may not perforate the soft tissues. This phenomenon ceases when skeletal maturity is reached. It is seldom seen in congenital terminal transverse deficiencies unless there has been some kind of surgery done on the stump. The relationship of this complication with skeletal immaturity has probably led some authors to believe that this "overgrowth" is related to proximal epiphyseal growth, and epiphysiodesis has been recommended as a treatment. Implantation of metal markers at the tip of the stump skeleton at the time of amputation and subsequent observation by x-ray has demonstrated without doubt that overgrowth is not the result of proximal epiphyseal overgrowth, but represents appositional bone growth from the end of the stump skeleton. In a series of 200 surgical amputations this complication was present in only 8% of the cases. The treatment for this condition is stump revision and removal of the overgrowth. Those patients who develop it once are prone to recurrences. Depending upon the degree of skeletal immaturity when this phenomenon makes its first appearance, a knowledgeable surgeon often can predict whether one or two additional revisions may be necessary. It is believed that this complication does not in itself represent a valid contra-indication to elective amputation in children. Statistically it is insufficient reason to delay an otherwise indicated procedure.

The management of the true post-surgical amputation, the congenital terminal transverse deficiency and the congenital limb deficiency have many similarities, but they are sufficiently different in some aspects so that they should be separated.

Post-Surgical Amputations

Most post-surgical amputations in children are homologues of similar amputations in adults, and in general their prostheses are scaled-down adult models. The fabrication techniques are similar or identical to the adult ones. There are commercially available miniaturized components for both upper and lower extremity prostheses. The principles of fitting and alignment currently taught in adults are applicable in general to children. There are, unfortunately, less accurate check-out procedures for children than there are for adults. This is true both in the upper and lower extremity.

In children with lower extremity prostheses, gait and alignment must be determined on the basis of the child's age and of how children of a similar age walk, rather than by adult standards. In the upper extremity, prehension forces, excursion ranges, maximum openings of terminal devices and percentage calculations of efficiencies of the mechanism must be modified realistically in relationship to the child's age, size, sex and strength. Precise standards have not yet been developed, but experienced therapists and prosthetists are capable of making these modifications very satisfactorily.

Terminal Transverse Deficiencies

Most terminal transverse deficiencies present themselves as homologues of traumatic or post-surgical amputations. The congenital acheiria is a homologue of a wrist disarticulation; the terminal transverse partial hemimelia, upper, is the homologue of a very short below-elbow. Because they are congenital developmental deficiencies, there may be variations in the external configuration of the stump that are not seen in post-surgical amputations. Vestigial remnants of the upper or lower extremity digits, invaginations on the distal end, the presence of redundant skin folds—all are frequently seen. Such external stump abnormalities in this group seldom need any surgical revision. This group in general is readily fitted with standard prostheses using standard components and fabrication techniques. The fit and alignment criteria are similar and sometimes identical to the post-surgical group.

Anomalies

Congenital abnormalities of the longitudinal type in children present bizarre and in many instances nearly indescribable types of deformities. It is very important to recognize that even if the evident defect seems to involve only a portion of the extremity, critical examination will reveal hypoplasia of the remaining mesodermal structures of the remainder of the limb. There are no specific rules concerning the management of these children. Each case is an individual problem and must be evaluated critically as an individual. Such factors as age, sex, family background, rural or urban living, educational facilities and multiplicity of limbs involved all enter into the formulation of a plan of treatment.

The lower-extremity cases of this group generally manifest themselves by leg length discrepancy of a severe degree, malrotation of the limb, inadequate musculature and limited motion in one or more joints.

The upper-extremity group usually manifests itself by arm length discrepancy, alterations in prehension function varying from complete absence to marginal functional ranges of grasp, strength and placement. Here, too inadequate musculature and alteration in range of motion in joints are factors.

In evaluating this group for prosthetic replacement, it is necessary to translate the presenting deformity into an amputation type. From a medical record standpoint, it is desirable that we accurately describe the deformity and give it a name, but from a treatment standpoint we must cease to think of it as a type of deformity and must think of it as an amputation prototype. In order to do this, it is necessary to determine which is the most distal stable joint beyond which there is adequate extremity to function as a stump. Once this level has been determined, then it can be decided whether the presenting abnormality represents a below-knee, above-knee, below-elbow or above-elbow amputation type. The team can then formulate an adequate prescription and with the services of a skilled prosthetist a nonstandard, comfortable socket and prosthesis can be devised. Malrotation can be accommodated for by alterations in alignment of the prosthesis in relationship to the extremity. Nonstandard components are sometimes necessary. Nearly all sockets are nonstandard and of a custom type. Final alignment, fit and gait characteristics in the lower-extremity case must be interpreted in relationship to the specific patient concerned and that patient's particular problem, rather than against a standard.

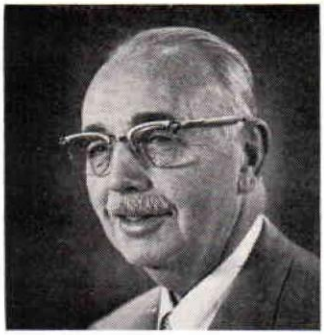
In the upper-extremity cases, force, excursion and percentage of efficiency must also be modified in relationship to the specific patient, not compared to a standard.

Surgical conversion or reconstruction of upper and lower extremity anomalies in order to fashion more desirable stumps for prosthetic fitting are helpful adjuncts. In a series of 137 lower extremity anomalies, surgical conversion or reconstruction was done in 78 cases (57%). In 108 upper extremity anomalies, surgical conversion was necessary in only 16 cases (15%). It is currently recommended that all upper and lower extremity anomalies be fitted without conversion unless the anomaly is of such a specific nature and with a well enough known life history to establish that conversion is desirable. If at a later date following trial of fitting without conversion it can be prognosticated that conversion will be a benefit, then it should be done.

The problems in this group are further complicated when the patient presenting has more than one limb involved. Decisions then must be made concerning which extremity should be treated first, and next what degree of function should be planned for and whether or not (in the upper extremities particularly) bilateral fitting should be carried out. These are difficult decisions and sometimes can only be resolved on a trial and error basis. It is currently believed that the "multihandicapped" child should not be fitted until sitting balance is established. If the child has both upper- and lower-extremity involvement, the decision as to fitting uppers or lowers first is difficult. Fitting of the lowers improves torso balance, and if the child has one useful upper extremity, the lower extremities should be treated first. If the child has no useful upper extremity, then an attempt should be made to fit for as much upper extremity function as is possible relative to the child's age and abilities. There is probably no place for the truly inert terminal device for the bilateral upper extremity amelia. Passively operated voluntary-opening terminal devices seem to be indicated even in initial (very early) fittings in this group. Currently it is believed that the bilateral upper amelia should be fitted prosthetically unilaterally, and which side should be fitted can either be decided arbitrarily or, if foot function has developed, fit on the side of the leading foot.

It is currently believed that prosthetic replacement is desirable in children with post-surgical amputations, congenital terminal transverse deficiencies or congenital limb abnormalities of the longitudinal type. Experience has demonstrated that children, if properly fitted and adequately trained, will accept and utilize both upper- and lower-extremity prostheses. In the longitudinal anomalies there is little doubt that prosthetic replacement with or without surgical conversion has in most instances offered more than previous standard reconstructive surgical techniques. Most children with amputations or limb abnormalities treated as amputations have a good rehabilitation potential. With the exception of the "multi-handicapped" group it is believed that these children should be educated in public school systems and they generally demonstrate their ability to compete successfully in spite of their handicaps.

Growth Potential in Children



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The question of growth potential in a child has always been of interest and only recently have the Orthotists and Prosthetists begun to inquire more about this. They have become interested chiefly due, I believe, to the marked increase in juvenile patients in the amputee programs and to a slightly lesser but still important orthotic problem. With the decrease in *poliomyelitis*, the orthotists perhaps will not see as many new cases but, on the other hand, will still be faced with bracing of those children who did have polio and are still in their growing years.

To open the discussion on growth potential I should like to quote from *Pediatrics* by L. Emmet Holt, Jr. and Rustin McIntosh, pages 13 to 17 as follows:[1]

"Growth in height is more slowly responsive to untoward influences than growth in weight. In infancy the measurement is a difficult one to make with accuracy; in older children height assumes increasing importance. A serial record of both weight and height, preferably a graphic one, is an important part of a child's health record and may give the first clue to the pressures of chronic illness.

"The puberal increment in height and weight is much more abrupt than inspection of average curves would indicate. Since puberty occurs in widely different ages in the individual members of any group of normal children, the sharp peaks in growth become blurred when averages are constructed.

"The prediction of ultimate adult height is a matter of concern to especially tall or especially short children and even more so to their parents. It can be said in general that the average height of a man is slightly more than double his height at two years and that the average height of a woman is slightly less than double her height at two years. However, the error associated with a prediction based on such limited information is large. Bayely has shown that after the age of eight years more accurate predictions can be made if skeletal age is considered, since physiologically mature children are taller than others. Such children cease growing earlier, however, and so do not become unusually tall adults. Early adolescence is associated with relatively precocious physical growth in height and epiphysial ossification and with an early puberal growth spurt and early cessation of growth. Individuals who mature late are also late in these features of growth and, since they grow for a longer period of time, may ultimately become average or even tall adults. Girls who mature late have somewhat less feminine body proportions than do girls who mature early.

Changes in Body Proportions with Growth

"The two most prominent changes in body proportions, are the growth of the extremities as compared with the trunk and the relative increase in the size of the body as compared with the head.

"The relation of the length of the trunk to that of the extremities is disturbed in cretinism, chondrodystrophy and many other forms of dwarfism. A rough index of this relationship is that of the ratio of what may be called the 'upper measurement' (crown to symphysis) to the 'lower measurement' (symphysis to sole). This ratio decreases from about 1.7 at birth to 1.0 at 10 years, after which it does not change much. When a question of chondrodystrophy or other disease affecting the growth of the extremities arises, one may obtain more accurate measurements from roentgenograms, taken at a tube distance of 6½ feet (2 meters).

"The relation of body length to width changes less conspicuously. The body tends to become more linear up to the time of puberty and broader thereafter. Coincident with the increased activity of children after they learn to walk there is a marked change in their appearance and the transition from the aspect of an infant to that of a young child may be abrupt.

"The head, like the brain, grows rapidly during infancy but even then does not keep pace with the rest of the body, and its subsequent growth is slow. It is important to follow the growth of the head during infancy by means of measurements of its greatest circumference. Undue increase in the size is usually the result of hydrocephalus; occasionally it is caused by subdural hematoma, neoplasm, megacephaly or disease of the bones of the calvarium. A small head is usually associated with defective development of the brain. . . . In evaluating the size of the head it is useful to compare the circumference with that of the chest or with body length. The head is normally larger than the chest at birth, about the same during the second to six months and smaller in circumference thereafter.

Muscle, Fat and Bone

"Stuart, Hill and Shaw have presented a roentgen technic whereby the shadows cast by the soft and hard tissues of an extremity can be measured. Their standards are useful in evaluating the relative proportions of muscle, fat and bone in cases where marked deviation is suspected. Actual measurement of autopsy material shows that at birth only about 25 percent of the body weight is due to muscle, in adults the average proportion is 43 percent.

Osseous Development

"The appearance and union of epiphysial centers of ossification follow a fairly definite pattern and time schedule from birth to maturity; those can be followed by x-ray. The 'skeletal age' or 'bone age' so determined is used as an index of physiological maturity. Its usefulness as a measure of maturity arises from the fact that the roentgen characteristics which the skeleton will have at maturity are known in advance, whereas the adult values for such numerical measures as height and weight are not. For this reason bone age indicates more clearly than other feasible observations the progress of the child toward maturity.

"Bone age is found to be advanced ahead of chronological age in precocious puberty adrenal hyperactivity, and at times in long continued hyperthyroidism. It is retarded in hypothyroid states and in certain other types of dwarfism; in cretins the retardation is striking. Malnutrition also is known to retard ossification.

"The bone age of girls is considerably ahead of that of boys, the advantages amounting to two years in adolescence. Throughout childhood, children destined to mature sexually at an early age are tall and have an advanced bone age; the converse is true in children destined to mature late. Obese children are apt to be tall and to have a bone age above the mean. Differences between the sexes with respect to bone age are present at birth. It is also of interest that Negro infants display a more advanced state of ossification than do whites.

"The normal variations in skeletal maturation are large, a feature which limits the diagnostic usefulness of the measurement. Bone age may differ from chronologic age by a year in either direction in early childhood and by two years later on without necessarily being abnormal.

"The bone age of an individual may be determined in one of several ways; (1) The total number of secondary centers of ossification seen in roentgenograms of the extremities on one side of the body may be counted and compared with the expected number as given by Sontag, Snell and Anderson. This method is suitable for children with a bone age up to five years. (2) A film of the hand or foot may be compared with a set of outline drawings showing epiphysical development at different ages, as given by Vogt and Vickers. This method is also unsuited to older children. (3) For older children, the times of appearance and union of various centers may be noted and compared with tables given in most textbooks of anatomy. This method is not reliable, because of the paucity of suitable centers and the wide variations in the times for any one center. For older children the best method is that of Todd (as revised by Graulich and Pyle); in fact his Atlas is suitable for use at all ages.[2] According to Todd, stress should be laid on the size, outline and finer details of structure of all bones, including both the shafts and the epiphysial centers. The Atlas consists of reproductions of x-rays of the hands and wrists of children with average maturation at six month intervals. The film most closely matching that of the child in question is selected by inspection, with consideration being given to all the features that indicate maturation and not just to the number and appearance of the carpal centers."

The Atlas of Todd is perhaps the most universally accepted means of determining skeletal age. This comparison is done at six month increments but is not too simple a comparison. It takes considerable experience to compare properly the individual child's x-rays with those as shown in Todd's Atlas, and variations as much as six months to one year are not infrequent. Thus the actual determination of skeletal age should not be left to a prosthetist or orthotist who would use the determination infrequently but rather to orthopaedic surgeons who are more familiar with all the details.

Many other methods or tables have been devised for predicting adult height, knowing the skeletal age of the child, as well as his present height. A very excellent article on this is contained in the *Journal of Pediatrics*, Volume 26, pages 49-64.[3] This would make for interesting reading, but the details are so extensive that they almost become impractical except as a research problem. The author does bring out however, several critical points. For example: children who mature early follow a different course of growth than children who mature late, and there are definite sex differences in the patterns of growth of both the early and late matures.

It is definitely known from the studies done at Harvard University that each succeeding generation of entering freshmen at that institution has been taller and heavier. What general factors may have influenced this gradually increasing growth pattern? Better and more nutritious food certainly has been important. Contrast our present generation of American children with those who were victims of World War II living on barely more than subsistence food, and we see a striking difference in overall growth and development. A second factor is that of better housing, and the third, and, to me, a very important factor is the decrease of childhood infections. The old, severe childhood diseases of scarlet fever, diptheria, whooping cough and measles have almost been eradicated by means of preventive medicine, vaccination, immunizations, etc. And also the complications of these diseases have been brought fairly well under control. With the advent of the anti-Polio vaccine, this disease in the last four years has almost ceased to exist, but we will still have many of the older cases to observe and to treat in their growing years. And last, but not least, is Tuberculosis. With the advent of antituberculosis drug therapy and earlier diagnosis, much of the severe crippling and deformities associated with this disease are now brought to a minimum. Thus, the child of today has a better chance for normal to increased growth than the child of even ten years ago, because he is not being constantly "knocked down" by the above diseases.

Another factor for our gradual increase in height is the general stress of physical fitness throughout our schools, including grade schools, high schools and colleges, and such programs should be encouraged.

Of particular interest to the orthotist and prosthetist is what can be done to equalize leg lengths when there is a lower extremity inequality. It is quite evident that for prosthetic fitting this inequality often can be made up by merely making that portion of the prosthesis longer as is necessary. Orthotically this is not as easy unless one should use an extension type of brace which cosmetically may not be acceptable. Surgically three things may be done: (1) An attempt to stimulate growth of the shortened extremity. This has not proved very satisfactory. Many different methods of growth stimula-

AFTER GREEN-ANDERSON, CHILDRENS HOSPITAL, BOSTON tion have been tried but the results, at least at the present, are not consistent nor predictable.

Secondly, attempts have been made to do bone lengthening procedures. This has been done by cutting either the femur or tibia and fibula and actually stretching out the bone at the fracture site. This has very limited application. The surgical techniques are difficult and should not be done except by those who are thoroughly familiar with a bone lengthening procedure and are acquainted with all of the potential dangers.

A third method of leg length equalization is that of slowing down or stopping completely further growth in the longer extremity. This, of course, makes the individual shorter in overall height than what he would have been with normal growth, but this decrease in height may be justified by having lower extremities of equal length. This type of procedure can be done by completely stopping growth at one or more epiphyses (usually upper tibia, lower femur or both) or stapling of the epiphysis to slow down growth. This is a very useful procedure when done properly, but here again the skeletal age of the individual must be known, and the further growth potential determined from definite charts as those shown by Dr. Green.[4]

The fourth and last procedure for leg equalization would be to do a bone shortening procedure by resecting and removing a portion of bone usually in the femur to equalize lengths. This procedure has many advocates but of course should not be done until all growth is completed.

In summary the growth factors of children are most important to both the prothetist and orthotist because they see the child outgrowing the appliance in both longitudinal and circumferential growth.

The above discussion has brought out some of these factors in relation to anticipated growth. It must be admitted that this is a very complex problem, and perhaps we should consider the old adage that as far as growth is concerned we are actually a combination of those growth factors given to us by our parents and grandparents.

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Development of Motor Capacity in the Normal Child

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The ability of a child successfully to develop skilled use of his extremities is determined in large part by his attention patterns, his motor development and the presence or absence of neuromusculoskeletal defects. The typical juvenile amputee, whether congenital or acquired, differs little from the normal child in requiring these factors for successful use of his prosthesis. The fact—that is that the juvenile amputee differs not significantly from the normal—must be borne in mind by all persons working with the amputee. It follows, then, that one must have a basic understanding of the capabilities of the normal child at appropriate ages, if one expects to achieve success with the amputee. While a detailed consideration of neuromusculoskeletal abnormalities is beyond the scope of this presentation, some aspects of attention patterns and motor development of the normal child are presented.

Attention Patterns

In any situation, the child's attention patterns will invariably influence his actions. Attention patterns are determined by several factors—age and maturity, well being and temperament, visual and auditory experiences and finally simply the newness of the stimulus offered the child. It is these factors which may permit the prosthetist the best opportunities to attract and maintain the child's interest and cooperation. Let us see, however, how the child's attention patterns develop with increasing age.

At birth the child is attracted by three things only—a full stomach, a warm bath and exposure to light. By the time he is six or eight weeks old he is beginning to notice moving objects. Although it is barely perceptible, the child at this age does have an attention span, which must be measured in terms of only a few short seconds.

At three or four months of age the infant attains the ability to raise the head, and his attention patterns expand quite evidently. While at this age the infant may seem to stare at one object or in one direction interminably, one must not interpret this as true attention, but rather recognize it as simply one manifestation of persistent inability to coordinate eye movements. Attention patterns continue to be restricted to a given situation because of poor head-eye coordination as well.

By the time he reaches the age of six or seven months, the infant has begun to sit up and his attention becomes even more evident. His attention might be termed selective yet restrictive. He can, for a brief period, sustain attention to an object in front of him, but when confronted with a second object he plays with it or the first, but not yet with both together.

The child of ten months of age can begin to keep in mind two or three playthings at a time. He now actually prefers several objects to just one. Adding an additional two months to the child's age permits him to include a whole room in his attention scope, and the attention becomes much more durable. It usually remains, however, related to objects, events or persons in front of him.

As the child begins to walk, between twelve and eighteen months of age, his attention is highly diversified. He is very easily distracted, his interest shifts rapidly, and he is quite difficult to work with. After he has become relatively secure in walking, and the newness of the experience is fading—usually in about six months more—his attention becomes fixed again. By the age of two years he can keep one object in mind while he surmounts an intermediate one to get to it. He will cross a room to get a toy from the corner, and his attention span now reaches approximately two minutes. It is extremely important to realize that while children of this age may keep themselves entertained and seem to play by the hour alone, the attention span for a given object or goal still remains only two or so minutes—a very short period in which to attempt meaningful cooperation and understanding.

Even when the child reaches the age of five years, his attention span remains at or slightly under five minutes for a given goal. As this time limit is reached, it becomes necessary to introduce something new, if attention is to be maintained. Of course, at all times the other factors which were mentioned earlier must be considered, particularly fatigue. Finally, it should be remembered that a child's attention will invariably be better if the task is one which he has selected, rather than one selected by another.

Motor Development

The motor development of the child is another factor which is to be understood when working with the juvenile amputee, since this will influence the manner in which the prosthesis can be used. Upper extremity patterns of prehension and release offer an interesting example of motor development, since they reflect not only function of the hand but of the arm as a whole.

Until the child reaches the age of six or seven months he mobilizes every resource he has in the hand and arm to grasp an object—usually in a poorly coordinated fashion which is sometimes termed total hand prehension. At this age of six or seven months he begins to use the index and middle fingers more obviously together with a more well-developed pattern of opposition by the thumb. Some call this radial-palmar grasp, recognizing a combination of early palmar prehension, using the radial side of the hand. Also at this age the child begins to demonstrate the rudiments of handedness, usually evident by his almost immediate one-handed approach to objects. Another function which becomes evident at about this stage of growth is the element of true release. Prior to this age, he will simply pull the object from his hand—now he will pass it from hand to hand.

At the age of eight months the child begins to show what is commonly termed connection grasp. While he is holding a block or cube in each hand, he cannot release only one to pick up a third—both blocks are released.

As nine months of age is reached, more true release is evident, and connection grasp disappears. The pattern of grasp is much more mature as well, but still sufficiently incoordinated to be clumsy at times. This must not be interpreted as being due to finger function alone, since it is a more direct relationship between brain and hand, and requires nerve development. For this reason, it can be anticipated that children of nine months of age or younger cannot reasonably be expected to operate a terminal device.

By the age of ten months, the child is beginning to show specialization of the individual digits. For the first time he uses a particular finger to point. He no longer simply drops an object; he is able to place it just about where he wants—his concept of release is more mature.

As the child reaches the age of eleven months an early sense of depth and dimension is becoming apparent. While he can reach into a cup to pick up a cube, he cannot yet drop the cube back in the cup. Typically he will put the hand holding the cube into the cup, then release the cube and remove the hand from the cup. One month more—twelve months of age—he is able to drop the cube into the cup. Now he begins to try and build a tower of cubes, but the coordination between eyes and hand has not developed sufficiently to permit this. This, of course, is true for the child with a prosthesis or with a normal hand.

Attaining the age of fifteen months allows a remarkable increase in proficiency. His release is under sufficient voluntary control so that he can begin to build a tower of two, sometimes three, cubes. His finger and eye coordination has also developed to the point at which he can put a small pellet in a bottle. The attention span is of importance now, because it is sufficiently long so that he can put four or five cubes in a cup at one time.

By the time the child reaches eighteen months his eye-hand coordination movements have become sufficiently skillful so that he can build a tower of three or four cubes. At this time, more control of rotary movements of the forearm has come, so that he can rotate the forearm to spill a pellet from the bottle. His attention span has increased to the point where he can fill a whole cup with cubes before becoming distracted.

At two years the child can build a tower of six or seven cubes. His sense of vertical dimension is developing along with a concept of horizontal dimension—he can put the cubes in a line. The three-year-old child has a much more complex sense of vertical and horizontal dimension. He begins to show some concept of coordinated movements of the shoulder girdle musculature. He can copy a cross, a triangle and even more complex designs when he elects to do so.

At four years of age the child can throw a ball overhand, indicating even more skilled control of shoulder and arm movements. His sense of dimension is excellent. By the age of five, he has an attention span of about five minutes, and for very limited periods can be treated as an adult.

Ambulation

As most authorities agree, walking is simply alternately losing and successfully regaining one's balance. Balance, therefore, is the keynote to successful ambulation—whether on two normal lower extremities or with prosthetic replacement. Balance does not come easily to a child, hence some understanding of its development also will lead to more appropriate demands placed on a juvenile lower extremity amputee.

Until the child reaches somewhere between the ages of twelve and twenty months his balance is rigidly restricted—he cannot stand alone on one foot except during ambulation. Beyond this age, and for the next few months, he begins to be able to stand on one foot with some external support. By the age of three years, he can balance on one foot independently for momentary periods. At four years this time is increased to several seconds, and by the age of five years, approaches the normal adult in independent balance times. To require more than these usual accomplishments of the normal child from an amputee is certainly not justified.

Prosthetic and Orthotic Devices for Nonstandard Prostheses in the Management of Limb Deficiencies

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During the past decade great interest in the child amputee has been manifested by the development of many amputee clinics in this country that devote their efforts exclusively to the child. Paralleling this interest, industry has made an increasing number of prosthetic components available for the child amputee both by miniaturization of standard devices and by special components designed specifically for the child.

In the last ten years, two phenomena have occurred:

1) A tremendous increase in the number of *young* children wearing standard types of prostheses. (Most clinic teams have become very adept at prescription-writing and training these young children.)

2) The appearance of many young children with anomalous extremities at child amputee clinics. Usually their problems cannot be answered by the application of standard appliances or prostheses. These anomalous extremities present problems to the prosthetist and orthopedic surgeon because of gross variation in limb contour, substandard muscle power and serious underlying skeletal deficiencies.

In this evergrowing group of anomalous extremities, restoration of function usually cannot be obtained with the so-called standard prosthetic prescription. The preparation of the mold of the anomalous extremity for socket fabrication requires careful technique to obtain an accurate positive model of the limb (see figures 1-A, -B, -C).

The standard joints which are currently available may not be suitable. The difficulty of suspending prostheses on or across a substandard joint presents complex problems. Many times the team is 'hard-put' to obtain functionally significant power in the transmission system.

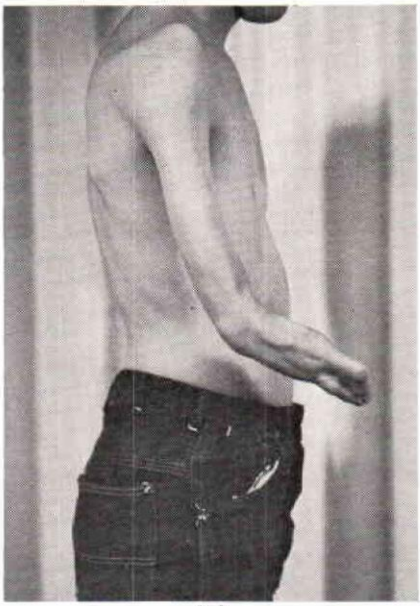
In many instances to obtain a comfortable socket or bucket, techniques in mixing the polyester resins must be varied to obtain the desired degree of flexibility and at the same instant maintain durability. Perforations in buckets, large or small, for abnormal contours and relief from underlying bony pressure areas may be frustrating. Energy expenditure and heat dispersion are important considerations when large areas of the body must by necessity be covered.

The multihandicapped child with a plurality of limb deficiencies challenges the skill of the prosthetist. He may be called upon to work in close cooperation with the orthotist. The orthotist may be required to modify upright braces and joints in a nonstandard manner to allow for laminations in the plastic sockets. It is quite evident that these "nonstandard" situations will call for a considerable breadth and depth of knowledge.

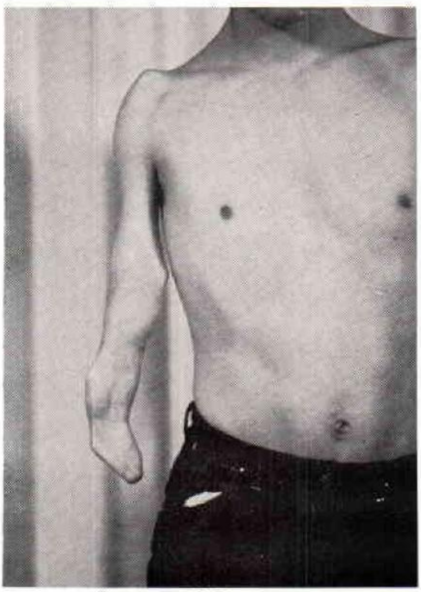
The detailed variations in body contour and lack of power and mobility of proximal joints must be appreciated by all members of the team (see figures 2-A, -B, -C, -D). With an understanding of the basic deficiencies, the necessary modifications in techniques of fabricating a socket and applying a suspension system may proceed (see 3-A, -B). The orthotist may provide crutch modifications to permit ambulation in the lower extremity amelia (see figures 4-A, -B).

Frequently the orthopedic surgeon will elect to manage an anomalous extremity during the early years with a standard type of orthopedic appliance (see figure 5-A). This appliance of course falls within the field of the orthotist. At a later stage, the knowledgeable surgeon

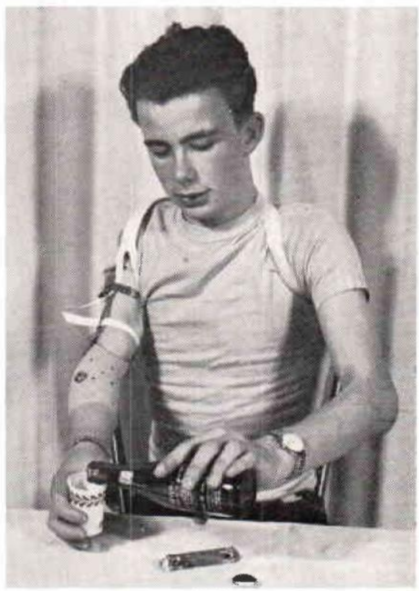
(Continued on page 278)



1-A

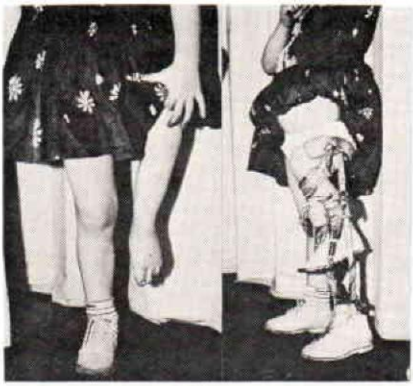


1-B

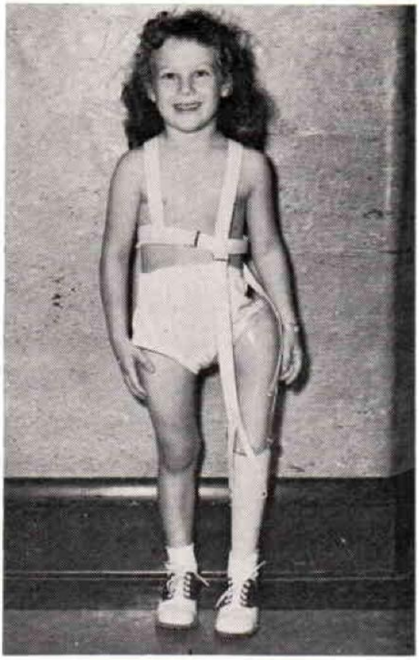


1-C

FIGURES 1-A, -B, -C: This fifteen-year-old boy with a deficient forearm is very adept without a prosthesis. He desired length and cosmetic restoration. The anatomical wrist joint has been made the elbow joint. The socket by necessity was padded and relieved to accommodate bony landmarks.

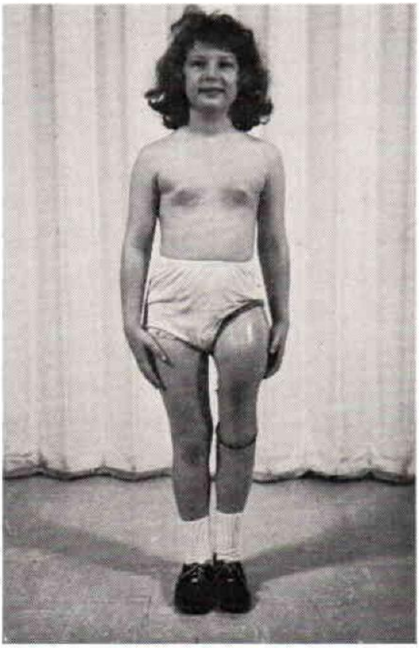


2-A



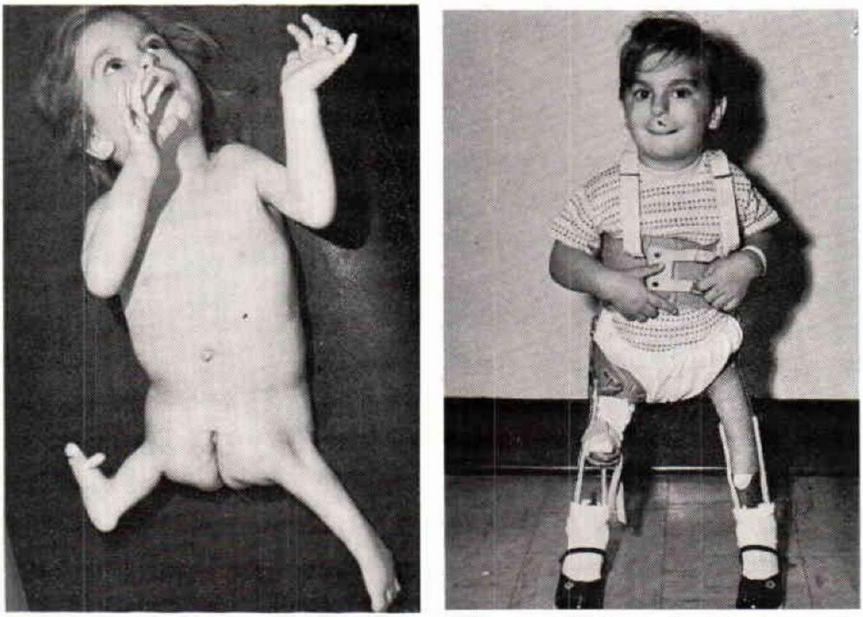
2-B

2-C

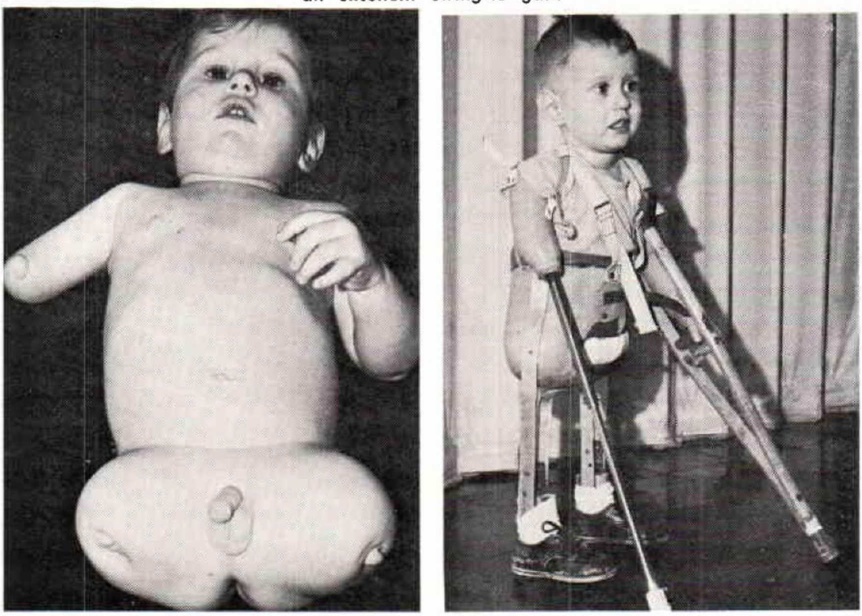


2-D

FIGURES 2-A, -B, -C, -D: This girl was born with a proximal femoral focal deficiency; she had an extremely short leg and non-existing hip joint. She managed for four years with the old type of classical ischial-bearing brace and shoe. At age four and one-half the foot was disarticulated, and an ischial-bearing above-knee prosthesis was prescribed. Note that the limb from the knee to the hip is externally rotated, and the socket is in the coronal plane and shaped much like a ship's funnel. The initial suspension was a toddler's harness. Two years later the child was able to maintain stability without harnessing.

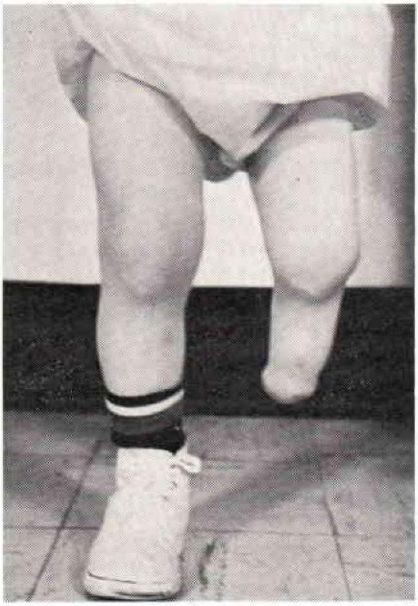


FIGURES 3-A, -B: This child is a lower extremity proximal phocomelia (the femurs are absent). The proximal tibial plateaus rest against the pelvic wall with no sockets. These limbs are unstable and can be rotated much like the hands of a clock. The feet were disarticulated. Polyester laminates were used for sockets and for a thoracic support. Note she has hip-locks and aluminum uprights with SACH feet. She is ischial-supported with the lumbar spine stabilized with hip-locks and suspended with over-the-shoulder harness. She has an excellent swing-to gait.



FIGURES 4-A, -B: This bilateral lower amelia is fitted with a stabilizing bucket and aluminum uprights without knee joints. Note the right upper hemimelia. Here a prosthetic crutch is used (standard aluminum tube laminated into an upper arm socket with lateral suspension). (Illustrations 4A and 4B reproduced by permission of the C. V. Mosby Co. from "Management of the Child Amputee," by Charles H. Frantz, M.D., in the "Instructional Course Lectures of the American Academy of Orthopaedic Surgeons," Vol. XVII, pp. 246-295).

5-A



5-B

5-C

FIGURE 5-A: This toddler has a paraxial hemimelia, fibular, with an extremely short lower leg segment. The classical ischial-bearing brace is used for ambulation.

FIGURE 5-B: One year later the ankle was disarticulated to preserve the distal tibial epiphysis.

FIGURE 5-C: He is fitted with a modified standard type of below-knee prosthesis. At a later date he will be fitted with a Syme type of prosthesis.

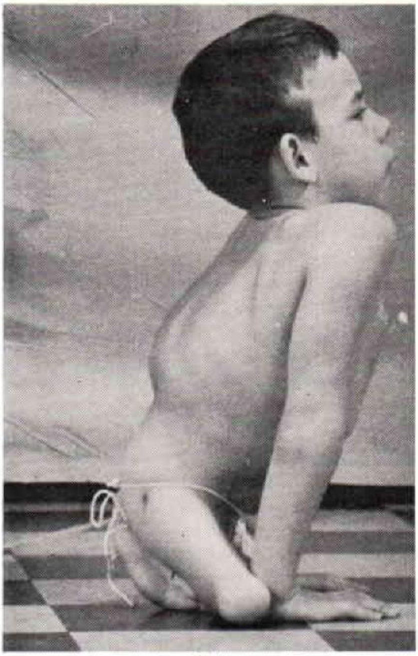
6-A

6-B

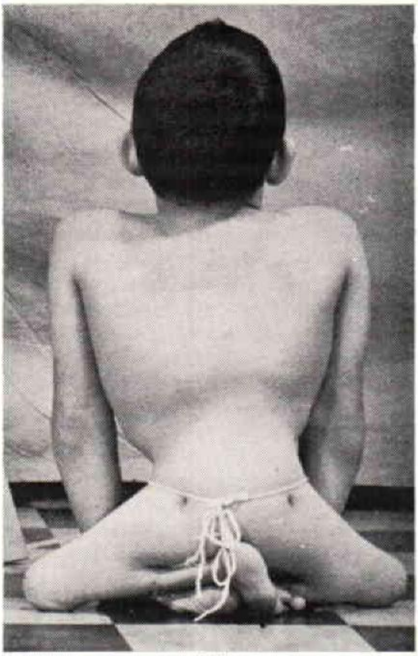
6-C

FIGURE 6-A: This seven-year-old boy is a spina bifida (L 3, 4, 5) with resistive clubfeet, lack of sensation, and ulcerations. There is no lumbar musculature to allow him to stand upright; he buckles forward.

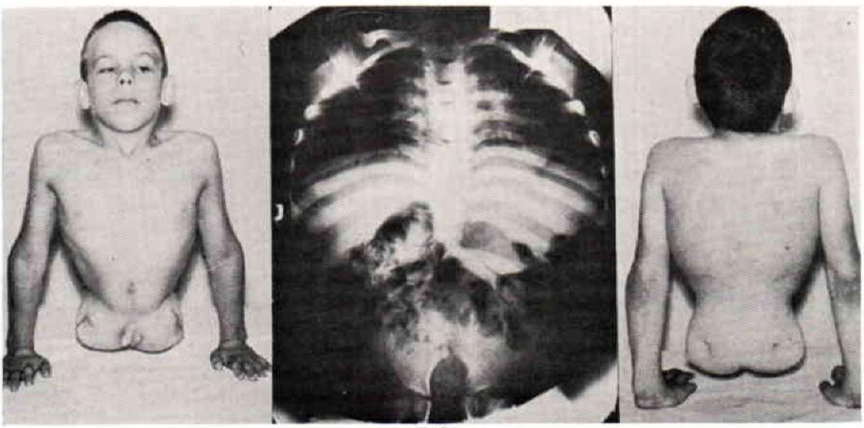
FIGURES 6-B, -C: His feet were disarticulated and he was fitted with polyester endbearing sockets which were fabricated into a modified Williams type of backbrace. He stands erect and is able to swing-to.



7-A

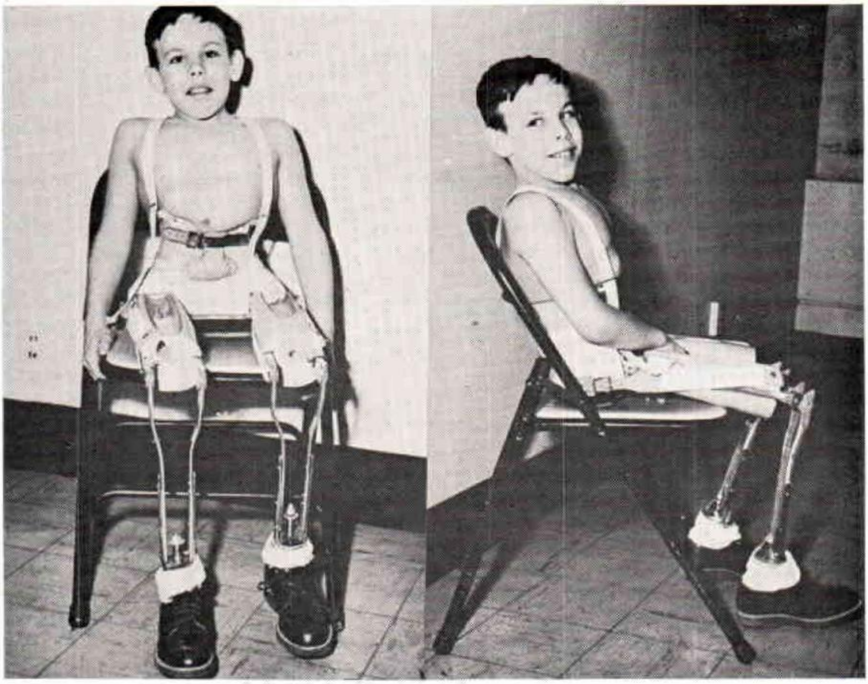


7-B



7-C

FIGURES 7-A, -B, -C, -D: This boy is the classical attitude of congenital absence of the lumbar spine and sacrum. The "Buddha" postion usually is encountered. He has incontinence of bowel and bladder. There is no musculature in the lower extremities. It is completely replaced by fatty tissue. The knees are acutely flexed with a very deep, broad, popliteal web. Sensation is present. The patient underwent bilateral subtrochanteric amputations and was fitted in a plastic laminate bucket with an opening for a urinal bag. Canadian hip joints were utilized with willow-wood thigh pieces. The below-knee segments consist of aluminum double uprights to lessen the weight. SACH feet have been prescribed. Suspension is obtained by over-the-shoulder straps. This boy attends school regularly and is able to get in and out of a chair independently. He has a wide swing-through gait. He is essentially managed as a Paraplegic. (Illustrations 7A, 7B, 7C and 7D reproduced by permission of the C. V. Mosby Co. from "Management of the Child Amputee," by Charles H. Frantz, M.D., in the "Instructional Course Lectures of the American Academy of Orthopaedic Surgeons," Vol. XVII, pp. 246-295).



(Continuation of text from page 272)

who is well acquainted by experience with the life history of the abnormal limb may amputate or disarticulate to obtain a "fitable" stump (see figures 5-B, -C). The emphasis therefore has shifted to the prosthetist who possibly may fit a standard appliance, or more likely a nonstandard socket. These changes in the management of a child with an anomalous extremity may involve either foot, knee, hip, forearm or elbow levels.

A variety of complex nonstandard appliances have been fabricated to meet the needs of many bizarre limb deficiencies when the trunk musculature is substandard. Here a Williams type of backbrace may be attached to two below-knee thigh cuffs (see figures 6-A, -B, -C). There may be the classical aluminum double upright braces fabricated into a pelvic bucket with droplocks (see Figure 3-B).

With these complex situations it is very evident that the orthopedic surgeon, prosthetist and orthotist must combine their skills and judgments to produce satisfactory and functional appliances for the multihandicapped child (see figures 7-A, -B, -C, -D).

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WHICH: Which way to get there? *BY AIR*—American, Continental, T.W.A., Western, Apache, Bonanza and Frontier Air Lines. *BY RAIL*—Southern Pacific & Santa Fe. *BY BUS*—Greyhound, Continental, drive your own car—or Hitchhike.

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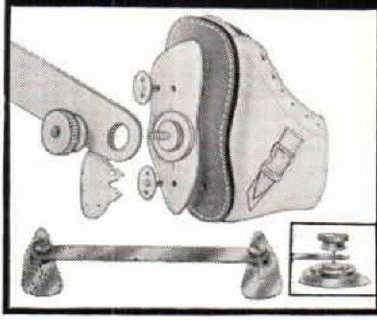

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FROM AOPA'S AUXILIARY

Mrs. Lorraine Scheck
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Vice President

Mrs. Esther Pava
Secretary-Treasurer

Mrs. Pearl Leavy
Past President

Dear Members:

I have just received a couple of letters from Phoenix, and here are the latest details of the ladies' Assembly program:

Sunday morning, October 14, will be our first meeting, which will be held in the Arcade Room at 10 a.m. Coffee and rolls will be served. Sunday evening at 7 p.m. the Western Pool-Side Party and Buffet Supper is scheduled, as reported in the August *Almanac*. Sounds like fun!

Mrs. Frances Aunger has made arrangements for the ladies to have a luncheon on Monday at "The Mountain Shadows," which she writes is one of Phoenix' fine resorts and a beautiful place. After lunch we will go over to the famous Scottsdale Area to browse and shop as we desire.

A bus tour of the Valley has been arranged for the late afternoon on Tuesday. According to present plans we will leave about 2 p.m. and return about 4. Wednesday afternoon has been left free so that you ladies can rest and/or get your hair done before the Banquet that night.

A further note about "What to Wear" which may be of interest—Mrs. Aunger writes that in addition to cocktail dresses for the Banquet, there is also a trend toward wearing long formal dresses too. You can take your choice! She adds that white shoes are much worn for daytime.

Mrs. Margaret Jachowski is getting together pamphlets of other attractions in the area which she feels will be of interest to both you ladies and your husbands during your stay in Phoenix.

Ladies, I sincerely hope you are planning to come out to Phoenix with your husbands this year. I am sure that we are all going to have a wonderful time. I know the men will be busy with their programs, which look very interesting and which will prove to be of benefit to anyone attending. The ladies' program should also prove interesting, educational and just plain fun.

See you all in Phoenix!

Sincerely,
Lorraine Scheck

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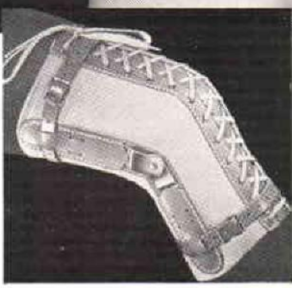

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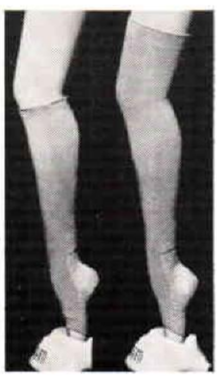

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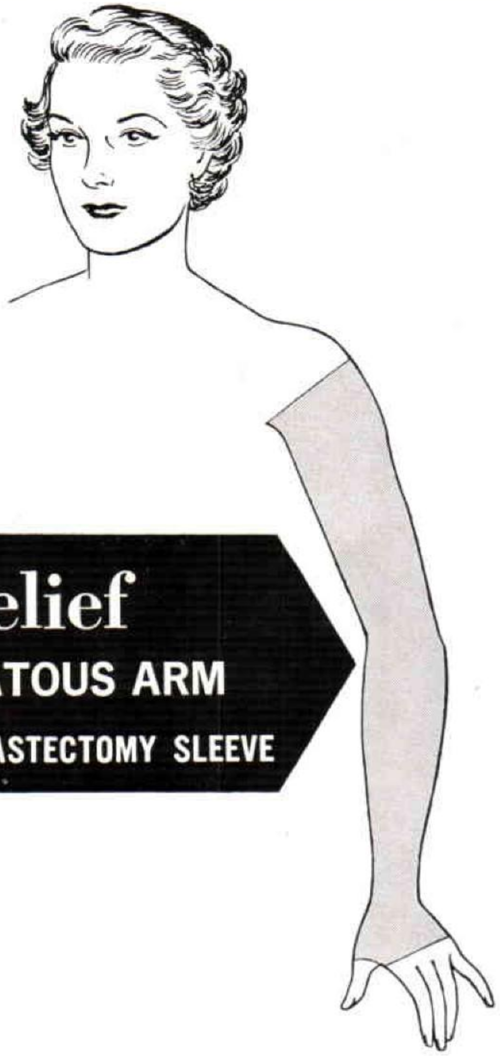

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