Acceptability of a Functional-Cosmetic Artificial Hand for Young Children, Part I[1]

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The need for a functional and cosmetically acceptable artificial hand for juvenile amputees has existed for many years. A voluntary-opening hook which has been available for a number of years in a variety of sizes was until recently invariably prescribed for children. In response to the demand on the part of both children and parents for a functional device with a more natural appearance, the Army Prosthetics Research Laboratory (now known as the Army Medical Biomechanical Research Laboratory) undertook in 1958 to develop a child's voluntary-opening hand. Earlier studies *(2)* had shown that a spectrum of five sizes should satisfy the needs of the entire arm-amputee population from childhood to maturity. Size No. 1 was the designation given to the smallest. Because it was hoped that a mechanism developed for the Size No. 1 hand might be suitable for use also in Size No. 2 and perhaps in Size No. 3, the smallest size was given the first priority. The Sierra Engineering Company[4] contracted to manufacture this hand and two other companies (Kingsley Manufacturing Company[5] and Prosthetic Services of San Francisco[6]) were enlisted to manufacture suitable cosmetic gloves.

Following preliminary testing of a prototype model, modifications to eliminate certain shortcomings were incorporated in 50 production models. A field test was initiated in April 1960 with evaluation of the cosmetic gloves included as an integral part of the study. Preliminary findings based upon experiences in fitting 20 children indicated that the hand was acceptable cosmetically and provided satisfactory function in the activities typically performed by children *(4)*. The general workmanship and cosmesis of the gloves provided by both manufacturers had also achieved a satisfactory level after certain initial fabrication difficulties. However, several problems had been identified, the most serious of which was a lack of glove durability. Ridges and sharp edges on the exterior of the hand apparently contributed to rapid glove damage.

[1] Part II will appear in the Autumn 1964 issue of *Artificial Limbs.* Both Part I and Part II are based upon *Acceptability of a Functional-Cosmetic Hand,* published by Child Prosthetic Studies, Research Division, College of Engineering, New York University, New York, N. Y., in January 1964 *(1).* Part I covers the history and purposes of the study, a description of the experimental hand, a description of the sample used in the studies, an account of the reactions of the children, their parents, and others to the hand, observations of classroom behavior during the period, and prescription considerations. Part II will cover the children's performance of standard tasks with the hand and its functional capabilities and limitations. The studies reported were conducted under the auspices of the Subcommittee on Child Prosthetics Problems of the Committee on Prosthetics Research and Development, National Academy of Sciences-National Research Council, 2101 Constitution Ave., N.W., Washington, D. C. 20418. The research was sponsored by the Children's Bureau of the Department of Health, Education, and Welfare under a special grant.

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Fig 1 Child holding swing with artificial hand.

Accordingly, the original production-model hands were modified and then refitted to the subjects of the field study. Modifications included eliminating the glove-cutting edges, strengthening the floating-finger attachments and the spring mechanism of the thumb, and raising the cable exit. In November 1960 "old" hands revised in this manner began arriving at New York University Child Prosthetic Studies, and in April 1961 the manufacturer produced a series of new hands which incorporated all the modifications.

An Interim Report (5), summarizing the results of the field study to mid-May 1961, was prepared for the Subcommittee on Child Prosthetics Problems of the Committee on Prosthetics Research and Development, and the results reinforced earlier findings concerning the acceptability of the hand and gloves. The APRL-Sierra Child-Size No. 1 Right Hand was accepted as satisfactory for general use by child amputees on the basis of this report, and the study was terminated in the latter part of 1961.

Following the generally successful outcome of the evaluation of the Size No. 1 Right Hand, manufacture of the Size No. 1 Left Hand was initiated. In May 1961 NYU Child Prosthetic Studies reported the results of a preliminary examination of two units manufactured by the Sierra Engineering Company (7). The hands appeared to be of excellent quality and workmanship with minor exceptions, and in June 1961 the manufacture of 55 additional left hands was authorized for field-test purposes.

During September and October 1961, NYU Child Prosthetic Studies received two shipments totaling 40 hands from the manufacturer. These were found to be unacceptable because of engineering deficiencies, and all were returned for modification. In February 1962, 37 hands were finally accepted for use in the field study. Another 14 hands submitted later were also found to be acceptable, making a total of 51.

Another Interim Report *(6)* on the status of the field study was submitted at the October 1962 meeting of the Subcommittee on Child Prosthetics Problems. It was reported that the APRL-Sierra Child-Size No. 1 Left Hand was considered to be essentially satisfactory both mechanically and functionally, although more rigid quality control in manufacture and assembly was desirable. The recommendation of this report that the hand and cosmetic glove be approved for commercial distribution was accepted by the Subcommittee and the study was terminated in January 1963.

PURPOSES OF THE STUDIES

The APRL-Sierra Child-Size Mo. 1 Hand (both right and left) was developed to provide the juvenile amputee with a cosmetically

acceptable terminal device which would closely resemble the normal hand in size, shape, and coloring. Maximum function—commensurate with cosmesis, simplicity of operation, adequate strength, and reasonable cost—was a concomitant objective.

Since the field study of the left hand was essentially an extension of the study of the right hand, the general goals of both evaluations were identical:

1. To introduce the hand into clinical use.
2. To corroborate findings of laboratory studies.
3. To determine the acceptability, utility, application, and durability of the production-model hand and glove.
4. To investigate indications and contraindications for prescription.

In the light of the experience gained in the study of the right hand, three considerations were given closer attention in the study of the left hand:

1. Performance differences between the experimental hand and the hooks previously worn were investigated in greater detail than was the case in the study of the right hand.
2. The short wear-life of the cosmetic gloves used in the study of the right hand presented a definite and challenging problem. In the course of the study, the exterior of the experimental hand was extensively modified to eliminate sharp edges which might contribute to glove damage. The effectiveness of these changes was of particular interest in the study of the left hand.
3. The effect of wearing the hand on the child's school behavior was a planned aspect of the study of the right hand. Data secured on this significant subject were limited, however, since the study overlapped two school years. With the earlier commencement of the study of the left hand (February 1962), these data were obtained for some children fitted during March and April 1962.

DESCRIPTION OF THE HAND

The APRL-Sierra Child-Size No. 1 Hand (both right and left) consists of a monocoque hand shell of cast aluminum, articulated index and middle fingers, a "two-position" thumb, and nonarticulated but flexible ring and little fingers. A voluntary-opening type of mechanism is housed within the hand shell and the entire unit is covered with a thin plastic glove that can be replaced as warranted (Fig. 2).

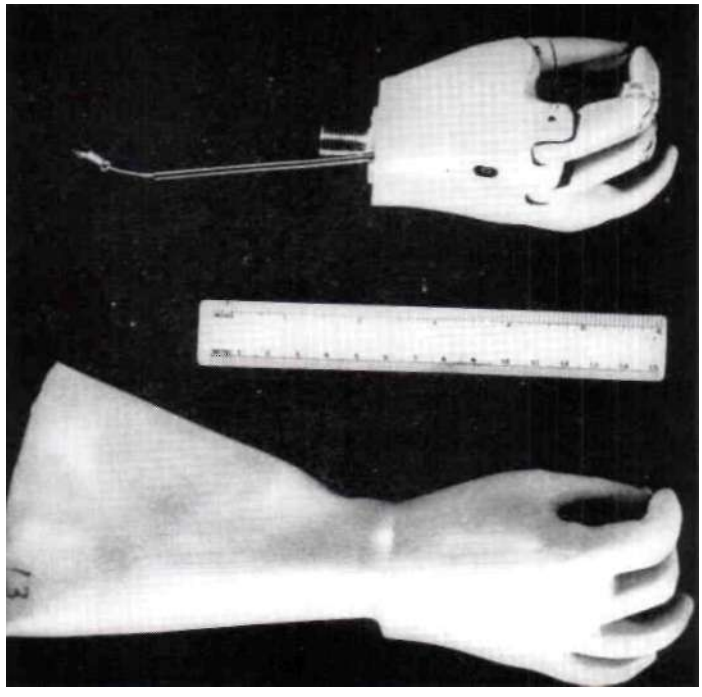

Fig. 2. APRL-Sierra Child Size Model No. 1 Hand.

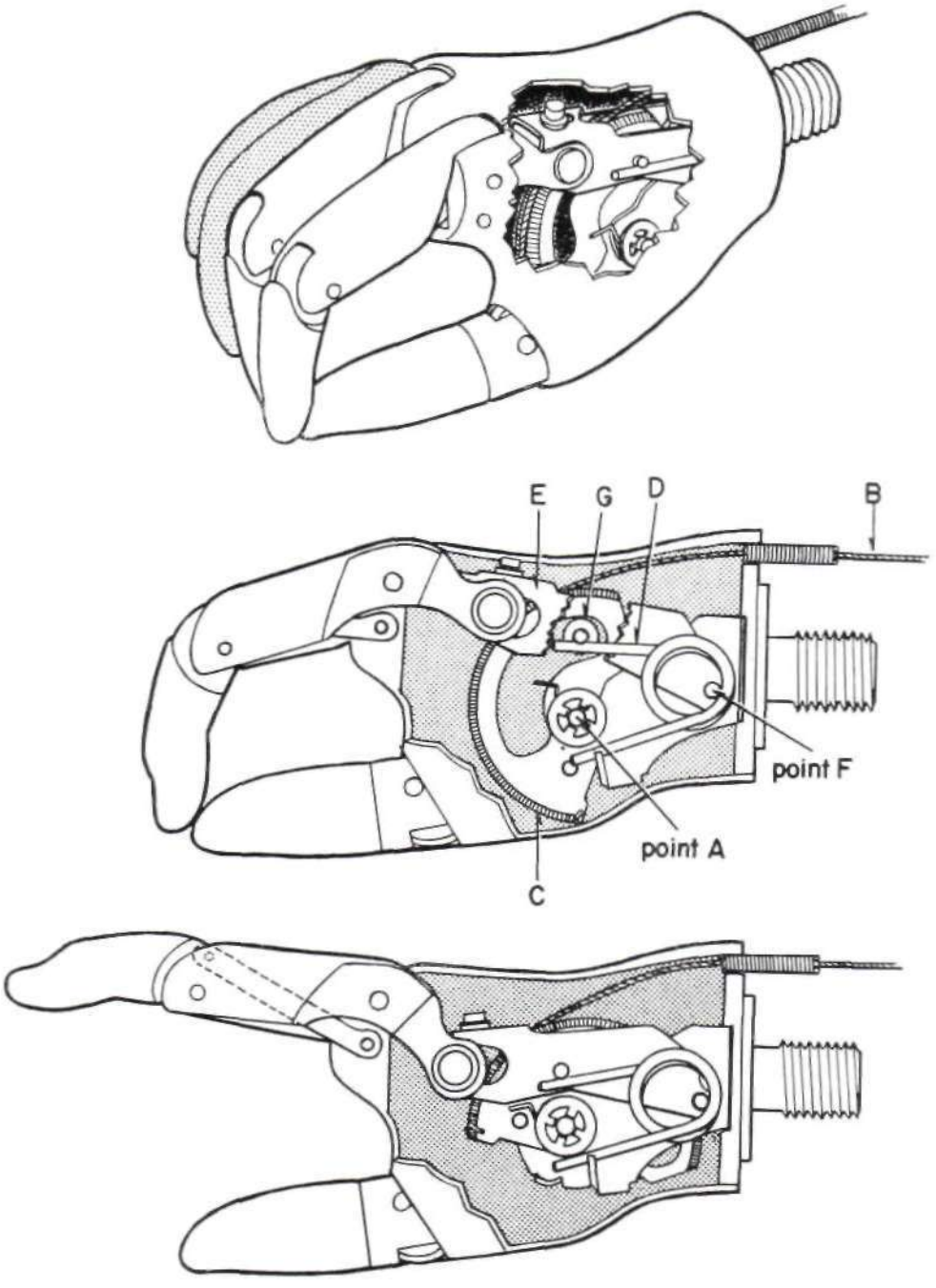

Fig. 3. Cutaway views of the APRL-Sierra Model No. 1 Hand *(3).* When no tension is applied to the control cable *B,* spring *D* forces the index and middle fingers toward the thumb to provide prehension of the three-jaw-chuck type. Tension in the control cable *B* causes the quadrant C to rotate about point *A,* a point displaced from the true center of quadrant *C.* The cam action thus provided by the outer edge of the slot in quadrant *C* against roller *G* forces lever *E* to rotate counterclockwise about point *F,* in turn causing the index and middle fingers to open. A small brass plate is mounted within lever *E* in such a fashion that, when little or no tension is applied to the control cable, the plate wedges against the periphery of the quadrant C. The wedging action, known as "Bac-Loc," resists opening of the fingers when force is introduced through the finger linkage but has no effect on the system when force is applied through the control cable.

The index and middle fingers each consist oi three aluminum castings which, along with a portion of the hand shell, form a four-bar linkage to provide coordinated articulation at points corresponding to the metacarpophalangeal and the proximal interphalangeal joints (Fig. 3). This arrangement results in a minimum amount of glove distortion through the range of motion required.

The thumb is an aluminum casting mounted to the hand shell through a locking mechanism that permits it to be held in either of two positions—one for maximum opening between fingers and thumb, the other for a smaller opening for conservation of excursion.

The ring and little fingers, the two consisting of a one-piece casting of foam rubber, are simply fastened to the hand shell and left to move with the cosmetic glove.

A threaded stud (1/2 x 20) attached to the wrist section of the hand is provided for use with currently available wrist units.

Maximum allowable weight is 6 3/4 oz. (without the glove). Less than 9 lb. of tension in the control cable (measured at the point of entry into the hand) is needed to open the fingers and a minimum of 2 lb. of prehension force is provided.

Cosmetic gloves for the hand are available in a minimum of seven Caucasian and six Negroid shades from each manufacturer.

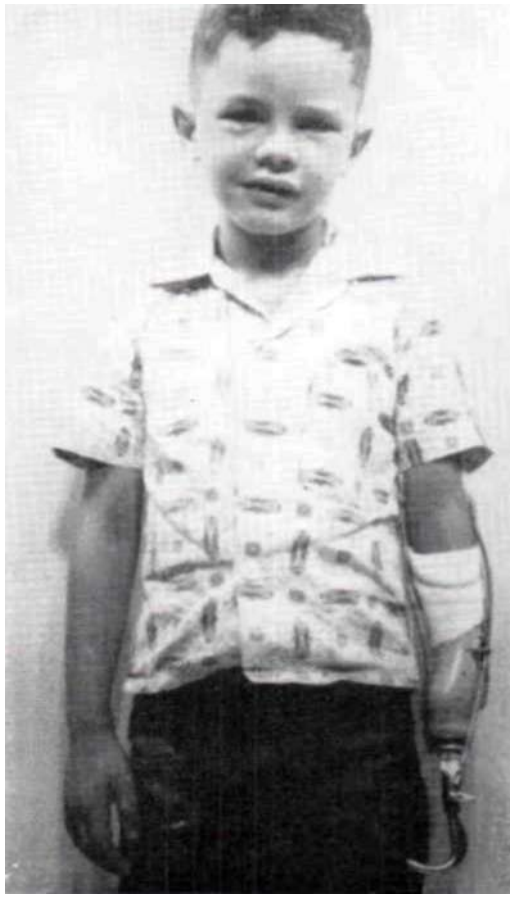

Fig. 4. Boy wearing Dorrance hook.

SAMPLE

The sample, which included a variety of upper-extremity types, consisted of 77 subjects, one of whom was fitted with hands bilaterally. All the children in the study, except two, had previously worn Dorrance-type hooks (Fig. 4).

A total of 39 children, of whom 36 were unilateral arm amputees, were fitted with the right hand (Table 1). Of the three remaining subjects one (with bilateral shoulder-disarticulation amputations) was fitted with a right hand only and continued to wear a hook on the left side; one (with right above-elbow and left short below-elbow amputations) was also fitted with a right hand and retained a hook on the left; and a triple amputee (with bilateral long below-elbow and left knee-disarticulation amputations) was given hands on both sides. This last subject was included in both the right- and left-hand samples.

Thirty-nine children, of whom 36 were also unilateral arm amputees, were fitted with the left hand (Table 2). Of the three remaining subjects one amputee (with bilateral shoulder-disarticulation amputations) was given a left hand only; a triple amputee (with bilateral long below-elbow and right below-knee amputations) received a left hand and kept a hook on the right; and the third subject was the aforementioned triple amputee who was included in both samples.

PROCEDURES

The fittings in both the Right- and Left-Hand Studies were conducted through the clinics participating in the Child Amputee

TABLE 1. SAMPLE: APRL-SIERRA NO. 1 RIGHT-HAND STUDY.

(N = 39)

Age	4		5		6		7		8		9		10		11		12		Total	
Sex	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Partial Hand, Wrist-Disarticulation, or Long Below-Elbow	—	—	1	1	1	1	—	1	—	—	—	—	1	—	—	—	1	—	4	3
Medium or Short Below-Elbow	—	1	2	1	3	2	1	3	1	—	1	—	—	—	—	—	—	—	8	7
Very Short Below-Elbow	—	2	—	1	—	1	1	—	—	1	—	—	—	—	—	—	—	—	1	5
Elbow Disarticulation or Standard Above-Elbow	—	—	—	1	—	1	—	2	—	—	—	2	—	—	—	—	—	—	0	6
Shoulder-Disarticulation	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	0
Bilateral	—	—	—	—	—	—	—	1[a]	—	—	—	—	—	—	—	1[b]	—	—	0	2
Triple	—	—	—	—	—	—	—	—	2[c]	—	—	—	—	—	—	—	—	—	2	0
Total	—	3	3	4	4	5	2	7	4	1	1	2	1	—	—	1	1	—	16	23

[a] Bilateral Shoulder-Disarticulation Amputations.

[b] Right Standard Above-Elbow, Left Short Below-Elbow Amputations.

[c] One boy had Right Short Below-Elbow, Left Syme, and Right Above-Knee amputations, and was the only child in the sample who had not worn an arm prosthesis before. The other boy had a Left Knee-Disarticulation and Bilateral Long Below-Elbow amputations and was fitted with hands on right and left sides.

TABLE 2. SAMPLE: APRL-SIERRA NO. 1 LEFT-HAND STUDY.

(N = 39)

Age	4		5		6		7		8		9		10		Total	
Sex	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Partial Hand, Wrist-Disarticulation, or Long Below-Elbow	2	2	—	1	2	—	1	—	2	—	—	—	—	—	7	3
Medium or Short Below-Elbow	3	2	1	1	—	3	1	1	—	2	—	—	—	1	5	10
Very Short Below-Elbow	—	1	1	—	—	2	—	1	—	—	—	1	—	—	1	5
Elbow-Disarticulation or Standard Above-Elbow	1	—	—	1[a]	—	—	—	1	—	—	—	1	—	—	1	3
Shoulder-Disarticulation	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1	0
Bilateral	—	—	1[b]	—	—	—	—	—	—	—	—	—	—	—	1	0
Triple	—	—	—	—	—	—	—	—	2[c]	—	—	—	—	—	2	0
Total	6	5	3	3	2	5	3	3	4	2	—	2	—	1	18	21

[a] Plus Right Anomalous Hand and Foot.

[b] Left Standard Above-Elbow Amputation and Right Paraxial Hemimelia (Ulnar). He wears no prosthesis on the right side.

[c] One boy had Right Below-Knee and Bilateral Long Below-Elbow amputations, and was fitted with the experimental hand on the left side. He continued to wear a hook on the right side. The other was the Bilateral Long Below-Elbow and Left Knee-Disarticulation amputee who was fitted with experimental hands on both sides and is included in both Right- and Left-Hand Study samples.

Research Program.[7] In order that wearers of the hand might secure the longest possible wear period before growth of the child caused an objectionable size discrepancy, it was recommended that the clinics select candidates whose nonamputated hand size was such that they should be able to wear the experimental hand for at least a year.

The experiences of the clinics were evaluated on the basis of: first, the reactions of the children, their parents, and others to the experimental hand and to other previously worn terminal devices; second, observations of classroom behavior during the treatment period; third, ratings of the children's performance of standard prehensile tasks using the experimental and old terminal devices; and fourth, maintenance.

In the course of the studies the children were required to make four visits to the clinic servicing them during a minimum period of five months.

FIRST CLINIC VISIT: SCREENING

A screening session was conducted during the first visit. The children and their parents were oriented to the purpose of the survey, the number of visits required, and the need to follow through with experimental procedures. Parents and children expressing a willingness to participate selected glove shades from shade guides provided by both manufacturers. Neither the experimental hand nor a complete cosmetic glove was shown to the patients or their parents during the first visit. A selection form, recommending the child as a participant in the study and furnishing information concerning him, was completed and sent to the NYU Child Prosthetic Studies.

The candidates were evaluated on the basis of information provided on the selection form and sampling requirements. Upon approving a candidate NYU sent the clinic a hand and glove for the child and a questionnaire to be completed by the child's classroom teacher prior to fitting the experimental hand.

The questionnaire pertained primarily to the child's psychosocial adjustment to the school environment. The teacher was asked to fill out the questionnaire before the experimental hand was fitted and to fill out a similar form at the conclusion of the study. The purpose of this procedure was to determine whether the child's behavior or performance with a prosthesis in school was affected as a result of wearing the experimental hand. In order to provide comparability of data, it was important that the same teacher provide both pre- and post-fitting observations.

SECOND CLINIC VISIT: FITTING

At the second clinic visit a prosthetic performance test utilizing the old terminal device was administered and the reactions of children and parents to the old device were ascertained. The child was fitted with an experimental hand and initial reactions to the new component were secured from child and parents. The child and parents were then given instructions that the experimental hand was to be worn exclusively until the next clinic visit two months later.

THIRD CLINIC VISIT: TWO-MONTHS POST-FITTING EVALUATION

Two months after the fitting the reactions of child and parents to the new component were again recorded at the clinic. Comparisons between old and new terminal devices with respect to weight, ease of operation, and usefulness were noted, and a prosthetic per-

[7] Area Child Amputee Center, Michigan Crippled Children Commission, Grand Rapids, Mich.; Amputee Clinic, Children's Division, Institute of Physical Medicine and Rehabilitation, New York, N. Y.; Amputee Clinic, Newington Hospital for Crippled Children, Newington, Conn.; University of Illinois Amputee Clinic, Chicago, Ill.; Birmingham Child Amputee Clinic, Birmingham, Ala.; Duke Orthopedic Amputee Clinic, Duke Medical Center, Durham, N. C; Georgia Juvenile Amputee Clinic, Crippled Children's Service, Emory University Branch, Atlanta, Ga.; Amputee Clinic, Children's Rehabilitation Center, Buffalo, N. Y.; Child Amputee Prosthetics Project, University of California Medical Center, Los Angeles, Calif.; Amputation Clinic, Kernan Hospital, Baltimore, Md.; Child Amputee Prosthetic and Congenital Deficiency Clinic, Children's Orthopedic Hospital, Seattle, Wash.; Juvenile Amputee Clinic, Florida Crippled Children's Commission, Orlando, Fla.; Amputee Clinic, Home for Crippled Children, Pittsburgh, Pa.; Child Amputee Clinic, State Hospital for Crippled Children, Elizabethtown, Pa.; Juvenile Amputee Clinic, Crippled Children's Hospital, New Orleans, La.

formance test, in which first the new hand and then the old terminal device were evaluated, was also conducted. The parents were then told to permit the wearing of either the old or the new terminal device as the child desired and were scheduled for a further clinic visit two months later.

FOURTH CLINIC VISIT: FINAL EVALUATION

The final evaluation was conducted four months after the initial fitting. The reactions of child and parent to the new hand were again obtained, and the old and new devices were compared in the same manner as earlier. The clinic summarized its data on a form provided for the purpose, and the child's classroom teacher was asked to complete another questionnaire.

RESULTS—SUBJECTIVE REACTIONS

PARENT AND CHILD PREFERENCES

At the conclusion of the test period, the 77 children participating in the study and their parents decided almost unanimously in favor of retaining the experimental hand with only seven rejecting it completely. In contrast to these seven rejections, 21 children expressed a desire to wear the hand exclusively. The remaining 49 children took intermediate positions ranging from a predominantly-hand to a predominantly-hook preference. All in all 42 children and their parents clearly preferred the hand; 15 were ambivalent or offered contradictory opinions; 20 preferred the hook.

HAND USED EXCLUSIVELY

Of the 21 children (13 girls and 8 boys) who chose to wear the hand exclusively, 20 were prior hook wearers, one had previously worn a Becker Plylite hand, and one had never worn a prosthesis before because his parents had refused to accept a hook. Cosmesis was extremely important to this group and was often the only factor mentioned by the child.

JM, a long below-elbow amputee who was 6 years and 11 months old at the initiation of the study, is typical of the children in this category. When asked what he liked about the hand after four months' wear, he replied, "I like it—the way it looks." He disliked the appearance of the hook and could think of nothing favorable to say about it or anything unfavorable to say about the hand. The hand functioned better, he said, and was important to him for use at school. Schoolmates stared at first, but liked it. JM's mother thought he had better function with the hook, but only because he had not had the new hand very long. She also remarked that he should wear the hand all the time because "it gave him more confidence." The hook's only contribution was that it prepared the child for the hand, she said.

Sandra, a short below-elbow amputee, was 5 years and 9 months old at the beginning of the study. She cited better function as the reason for preferring the hand: "... can move things better—holds lots of things better." She disliked nothing about the hand, liked nothing about the hook, and said she wanted to wear the former all the time. Her mother preferred the hand for reasons both of appearance and grasp; schoolmates found it easier to hold on to when playing games, and it didn't slip when the child tied her shoes. Sandra should not wear a hook at her age, her mother declared.

HAND USED PREDOMINANTLY

The hand was the terminal device of choice for an additional 21 children (15 girls and 6 boys). The hook was preferred for rough outdoor activities in which hook function was superior.

Typical of the group was Curtis, age 5, a very short below-elbow amputee, who liked "everything" about the hand: it resembled his other hand, held paper when he wrote, and grasped a baseball bat better. However, he felt that the hook was lighter, was easier to open, and superior for playing with certain toys. His mother was pleased with the appearance of the hand, Curtis's attitude toward it, and the fact that other children were willing to hold it in games. However, she thought he should wear the hook at home for activities that might damage the glove. During the last two months of experimental wear, when parents and children could choose which device would be worn, Curtis used the hand exclusively, except when repairs were required.

Diana, age 5, a short below-elbow amputee, expressed a desire to wear the hand most of the time and the hook only for swimming *(sic!).* The reason for her preference was that "it looks like my other hand." Earlier she had found the hand somewhat harder to operate and had experienced difficulty releasing it from bicycle handles. Her mother was concerned about tears on the glove fingers, but Diana said, "It doesn't matter what the glove looks like." Her mother agreed that the hand should be worn in most circumstances, but thought the hook could be used for swimming and as a replacement in case the hand broke.

HAND AND GLOVE USED ABOUT EQUALLY

Seven children (5 girls and 2 boys) and their parents desired to retain both hook and hand and to use them on an approximately 50-50 basis. For example, Carol, an 8-year-old short below-elbow amputee who lived on a farm, preferred the appearance of the hand: "It gives me another hand and people don't stare"; and the function of the hook: "I don't drop things with the hook or worry that someone might bump into me and knock them out of my grasp." She also was concerned about tearing the glove. Carol chose to wear the hand both to regular and Sunday school and the hook for farm chores and play. Her father agreed with the child's viewpoint. He thought the glove not rugged enough, but the hook handy and sturdy.

PARENT AND CHILD DISAGREEMENT

There were eight children (6 boys and 2 girls) whose primary choice of terminal device differed from that of their parents. In five instances, the child chose the hand and the parent the hook; in the other three cases, the positions were reversed. The basis for disagreement was usually a relative emphasis upon appearance and function.

Michael, age 6, whose partial hand amputation was fitted as a wrist disarticulation, was pleased that the hand "looked like my other one," but acknowledged that the hook was lighter and easier to use. If he could retain only one device, he would choose the hook, since he could do much more with it; however, his mother and friends preferred the hand. The latter were sometimes afraid of the hook. Michael's father preferred the hand for cosmetic reasons and cited other advantages: "... more chance to play cowboy and wrestling . . . children not afraid . . . danger of bumping into others when playing with the hook."

HOOK USED PREDOMINANTLY

Six boys and seven girls preferred the hook for daily use and the hand for dress occasions. Five of the children were under 5 years of age (one, age 3 and four, age 4), and four of these had not yet attended primary school, kindergarten, or play school. Eleven of these children rated the hook function better and ten specifically said the hand was heavy or hard to operate; one older boy complained that the hand did not afford a tight grasp and a younger girl said the hook held things in a better position. Parents of twelve of these children declared hook function was better; the other parent expressed no preference.

Danny, with an elbow disarticulation and split-ray hand, was the youngest child in the study—barely 4 years of age when fitted with the hand. To open it, he had to hold his elbow completely extended with maximum tension on the cable. Even in this position, full opening required more effort than he typically cared to exert, although he was pleased that the hand looked like his natural one. Danny stated that the artificial hand was heavier and harder to operate than the hook and did not pick up objects as well. The hook was better for grasping a swing chain and for holding his bread to push food. The child's mother hoped that his skill with the hand would improve, but after four months she reported that he wore it only for "going visiting." She thought the hand would be of greater use when he was older.

HAND REJECTIONS

In view of the fact that complete rejection of the experimental hand was rare, it is interesting to note the instances when it occurred. Seven children rejected the hand completely; four of these were 4- or 5-year-old boys, one was a 7-year-old girl with bilateral shoulder disarticulations, and the other two were a boy

and a girl, both 9 years old, who were excellent users of their hooks and apparently were not concerned with the appearance of this device.

Various factors contributed to these rejections. Several of the younger boys and the 9-year-old boy and girl obtained better function with the hook and seemed relatively unmindful of appearance. The bilateral shoulder-disarticulation amputee was a marginal user of any prosthesis and found the increase in operating forces and the difficulty of positioning the hand without a wrist-flexion unit intolerable. Three children experienced excessive hand malfunctions and two others, because of frequency of glove damage or difficulty in getting replacements, wore unsightly gloves for prolonged periods.

AGE AND SEX IN RELATION TO ACCEPTANCE LEVEL

The data contained in the last two categories of acceptance level (Hook Used Predominantly and Hand Rejections) suggest that age is a strong consideration governing hand or hook preference. Such a relationship would not be surprising, since younger children may be expected to: first, experience difficulty with hand weight and operating forces because of limited physical development, and second, be more careless in their use of a device, less concerned with the niceties of appearance, and would not be subject to the social pressures of the school environment.

Age, however, cannot be regarded as an absolute criterion, since several of the children in the study who selected the hand as their primary choice were 4-year-olds. In fact, when the age and sex of the children are tabulated against indicated levels of preference (Table 3), sex appears to be more significantly related to choice of device than does age. Thus, girls of all ages for whom the hand is of appropriate size appear to be potentially the best candidates for the No. 1 Hand, while younger boys would seem to be less likely to accept the device.

EFFECTS ON SCHOOL ADJUSTMENT

The questionnaire to be completed by the classroom teacher was designed to secure pertinent information concerning the behavior of the child in school while wearing the old terminal device and the experimental hand respectively. It was hypothesized that the child's classmates and teacher might react more positively to a hand than they had to a hook and as a result adjustment of the child to the school situation would show discernible changes. This type of improved behavior had been noted previously when a child who had been a nonprosthesis wearer was fitted for the first time *(8)*.

Historically, two significant problems frequently encountered by juvenile amputees wearing hooks to school have been the indignity of being called "Captain Hook" and

TABLE 3. RIGHT- AND LEFT-HAND WEAR PATTERNS.

Girls (N = 44)										Boys (N = 33)									
Age When Fitted with Hand										Age When Fitted with Hand									
Total	4	5	6	7	8	9	10	11		3	4	5	6	7	8	9	10	11	Total
13	1	4	4	2[a]	—	1	1	—	Hand Used Exclusively	—	1	1	2	2	2[b]	—	—	—	8
15	4	1	2	4	2	1	—	1	Hand Used Predominantly	—	—	1	1	1	2	—	1	—	6
5	—	1	1	1	1	1	—	—	Hand and Hook Used About Equally	—	—	—	1	—	1	—	—	—	2
2	1	—	1	—	—	—	—	—	Child-Parent Disagreement	—	1	1	1	1	2	—	—	—	6
7	2	1	2	2	—	—	—	—	Hook Used Predominantly	1	2	—	1	1	—	—	—	1	6
2	—	—	—	1	—	1	—	—	Hand Rejections	—	1	3	—	—	—	1	—	—	5
44	8	7	10	10	3	4	1	1	Total	1	5	6	6	5	7	1	1	1	33

[a] Previous terminal device was Becker Hand; became a 100% No. 1 Hand wearer.

[b] No prosthesis used prior to hand; became full-time (or at least school-time) hand wearer.

similar names by classmates and refusal by other children to hold their hooks in hand-holding games. Elimination or reduction of these difficulties was anticipated when the child was fitted with a functional terminal device that closely resembled a normal hand.

The teacher's opinion was obtained concerning various aspects of the child's school behavior: attendance, homework, conduct, friendships, social participation and leadership, and extent of use of the prosthesis. As provided in the study plan, the teacher's questionnaires were to be completed twice: once while the child was still wearing a hook, and again after four months of hand wear when the child would presumably have acquired sufficient skill in the use of the hand, and changes in school behavior would have had an opportunity to develop.

When it became apparent that a majority of the children in the Left-Hand Study would not have worn the hand for four months before the end of the 1961-1962 school year, the original plan was modified to provide for completion of the second questionnaire just prior to the end of the academic year regardless of length of time the hand had been worn.

Unfortunately, comparable hook-and-hand questionnaires (that is, both completed by the same teacher) are available for only 16 of the 77 children in the sample. The majority of the remaining 61 children were of pre-school age or were fitted with the hand toward the end of the school year or during the summer, so that they did not have the same teacher at the beginning and the end of the study. The data from the teachers' questionnaires were, therefore, supplemented by information concerning school and personal adjustment from other sources wherever available.

REACTIONS AND REPRESENTATIVE COMMENTS

Of the 29 boys and 21 girls in the sample who were 6 years of age or over, 26 boys and 21 girls were either wearing the hand in school at the termination of the experiment or stated that they intended to do so when the fall term began. Included in this group were four of the children whose preferred device was the hook. Nevertheless, they wore the hand to school. One boy, age 8, summarized the opinion of these four children when he said, "I wear it because the kids like it better."

As mentioned previously, a number of children reported that prior to using the hand they had been called "Captain Hook" by other children and that this had disturbed them. There is considerable evidence that the effects of this name-calling can be quite destructive to social relations among children. One girl, in fact, refused to wear the prosthesis to school after such an incident. When the hand was worn these difficulties tended to disappear. The essence of the reaction to and acceptance of the hand may be gathered from the large number of favorable comments made by playmates, schoolmates, teachers, and others.

Representative statements *reported by the children* included the following:

"My schoolmates were excited about the hand because I have five fingers on the left hand now."

"It smells nice, looks nice, and works nicer than the hook."

"I like the feel of the hand; it looks real."

"One little girl thought my hand had grown back."

"They said it was prettv. The girls aren't scared of it."

"I wanted to look at it. I always wanted to know when I was going to get it. It drives me out of my mind."

"My school friends stared at first; they liked it."

"At school they all liked the looks, especially how real it looked, including the fingernails."

"Kids like to see the way I can bend the fingers (floaters) all the way back. They like to feel it. One boy bit it to see what it would do."

Representative reactions *reported by the parents* included these remarks:

"They were surprised when they found out he could move the fingers and thumb."

"Children in school were not aware of his prosthesis until he wore a short-sleeved shirt. They displayed curiosity and then seemed to be very casual."

"In many cases the fact that it is not a natural hand has had to be brought to their attention, even when it was worn without long sleeves."

"Danny will start school this fall and the principal was amazed to see the hand. He said he had to look twice to make sure it was the same child. Danny's playmates were sure he had gotten a 'real' hand."

"His friends are afraid of the hook. But with the hand, they will take hold of it and play games."

"The child said she used to like the hook and wore it all the time, but now some of her friends don't like it and are afraid of it."

"Her schoolmates noticed the change and they completely accepted it. Her sisters were quite proud and anxious for their friends to see she had a new hand."

"When he played games with other children, most of them were afraid to hold his hook. Since he's worn the hand they aren't afraid."

"Cindy is happy about the better attitude of the children around her, especially in school."

"She said that one of her best friends 'almost fainted,' she was so delighted to see her with two hands."

"The appearance has done wonders for her at school."

"The children at school crowded around him and asked to see how it worked."

"Her friends had called her 'Captain Hook' (when she wore the hook). Little ones cried and would run away from her, afraid. We actually had to *bribe* her to wear the hook to school. Now we have no difficulty getting her to wear her arm with the hand all the time."

"Children don't call him names ('Captain Hook')."

"School children are delighted and fascinated with the hand."

". . . interested because it is different; want to see how it works. Betsy will show it."

"It is easier to hold on to when playing games."

"The change from the hook to the hand caused a lot of questions to be asked at first. But it was soon accepted."

"Danny wore the hand every day for two weeks and some of his classmates were not aware that it was not his own hand."

Only a few *children* volunteered negative remarks:

"His brother got scared of the hand, but later liked it."

"Sister afraid of it at first."

"Pammy (sister) thought it was a 'weirdy.' "

ATTENDANCE, PREPARATION, AND CONDUCT IN CLASS

The teachers' reports concerning the children's attendance, preparation, and conduct in class yielded very little information of significance. Only one child (a triple amputee) was considered below average in attendance as a result of absences related to his prosthesis. The factors of preparation for class and conduct showed slight changes in ratings from the first to the second questionnaire, but there were no differences specifically attributable to hand wear.

FRIENDSHIPS, PARTICIPATION, AND LEADERSHIP

Ten of the 16 children for whom teachers' questionnaires were available appeared to have achieved excellent to adequate adjustment and participation in class with both the hook and the experimental hand. Despite these satisfactory relationships, these children still found the appearance of the hand advantageous in the school setting as a means of decreasing social prejudice. Several of these 10 children remarked that their classmates were now more willing to hold hands in games and seemed friendlier. This pattern of increased acceptance tended to enhance the self-concept of the children in the study.

Five children were reported as improved in class participation or friendships after being fitted with the artificial hand, although the prosthetic performance of two of this group was considered to have deteriorated. However, the improvement in appearance was obviously more important than the decrease in function. For this small group of children regardless of their skill in or amount of hand usage there was a discernible change in the type and extent of their social interactions. This took the form either of an increased number of social contacts with various children or of an improved relationship with one or two selected classmates.

An example of the personal importance attached to the hand is apparent in the report of one child's physical therapist which describes his behavior after being fitted:

"On the way back on the train, Randy patted his hand against his face and scratched the tip of his nose several times before settling down to sleep. Until then, he couldn't keep his eyes off it, and when he lay down he put the hand on his chest 'for all the world to see.' As we neared Bloomington, he wondered if we shouldn't go by the school because 'perhaps Mrs. Sheveland (the teacher) will still be there.'

"After dinner he put his prosthesis on and toured the neighborhood to show everyone his hand. His mother reportedly was greatly pleased; so much so that she could not hold back the tears on more than one occasion during the evening, so that when Randy said his prayers, she had to leave the room. He wanted to wear his hand to bed but when his mother explained that it had to be put into the plastic bag, he accepted the explanation.

"This morning he arrived at school in 'clam-digger' pants and a long-sleeved shirt. He had told his father yesterday that if he wore long-sleeved shirts no one would ever know his hand was not real."

Other examples of the significance of the hand follow:

"The teacher said the boy is actually using the hand more than he had ever used the hook. (This was in spite of the fact that all reports indicated that his functional capabilities with the hook were greatly superior.) His mother said, 'We were very pleased that he had the hand for his first Holy Communion.'

"The nun said Randy did not need to hold hands in prayers or going to and from the altar, since she thought this might be a difficult thing to do, but he did as the other children were doing and was very proud."

Another child, Sheila, had reconciled herself to the reluctance of other children to hold the hook:

"Some children don't like to touch it (the hook), but I know a girl who has long fingernails and I don't like to touch her hands, either. When I first got it, I thought the kids in school will be surprised. They will think I don't belong in a crippled children's school!"

Another child, Philip, used his artificial hand to shake hands.

The last of the 16 children for whom data were available, a girl of 6, did not have a good relationship with her teacher or with the other children. There was no discernible improvement in the situation after she was fitted with a hand. Still, by the time of the second questionnaire report, she was somewhat more willing to display her prosthesis in public and make use of it.

CONCLUSION

Although there was no clear-cut evidence of widespread, dramatic changes in behavior attributable to the use of the APRL-Sierra Hand, the data all point in the direction of improved self-perceptions as well as better social attitudes and relationships. With the exception of the 10 per cent of the sample who rejected the hand for a variety of reasons, the remaining amputee children and their parents, teachers, and classmates reported a variety of positive social consequences related to hand wear. For the most part these reports referred to improved *feelings, opinions, and attitudes* of the subjects, although a small number of positive *behavioral* changes could also be documented. In general, the children themselves as well as their classmates and parents were socially more comfortable as a result of the introduction of the hand.

The functional limitations of the hand in comparison to a hook will be documented in a subsequent article in *Artificial Limbs.* In contrast, the evidence concerning the cosmetic benefits of the device, particularly its concomitant psychosocial implications, is most impressive.

RESULTS—PRESCRIPTION CONSIDERATIONS

SIZE of SOUND HAND AND AGE

For the purposes of the Right-Hand Study, the No. 1 Hand was hypothesized as being appropriate for child amputees between the ages of 4 and 10. Consequently, experimental wearers were selected on the basis of this age range rather than of size. In the course of the study, however, it became apparent that the hand was undersized for many of the children selected.

The clinics were then requested to report the following dimensions in all cases of noticeable discrepancy: circumference at the metacarpophalangeal knuckles, excluding the thumb, with hand in closed position *(5%* in, on the No. 1 Hand); and the length from the styloid process of the radius to the tip of the thumb (3 5/8 in. on the No. 1 Hand). Several clinics also reported hand dimensions of children for whom the No. 1 Hand was considered of appropriate size.

Table 4 presents the measurements of sound hands of children in the Right-Hand Study for whom the No. 1 Hand was too small; small, but acceptable; and well matched, according to the opinion of clinic personnel.

It would appear difficult to derive a precise range of sound-hand sizes or ages for which the No. 1 Hand provides an acceptable match. In one case, where the sound hand was 6 5/8 in. in circumference and 4 1/2 in. in length, the clinic rated the hand as unacceptably small, but in another instance it was considered suitable for a child whose hand was 7 1/4 in. in circumference and 4 1/2 in. in length. It should also be noted that while the majority of the

TABLE 4. SAMPLE: ADEQUACY OF NO. 1 HAND IN RELATION TO NATURAL-HAND SIZE
(N = 21)

	Size of Sound Hand		Age When Measured		Sex
	Circumference (In Inches)	Length	Years	Months	
No. 1 Hand too small; prescription contra-indicated.	*	*	12	7	M
	(bilateral)		11	7	F
	7 5/8	4 3/4	11	1	M
	7 1/2	4 1/2	10		F
	6 7/8	4 3/8	6		F
	6 5/8	4	8	1	F
No. 1 Hand smaller than sound hand, but acceptable.	7 1/4	4 1/2	9	9	M
	6 5/8	5	9	4	F
	6 1/2	4 3/8	9		F
	6 1/2	4	6	11	F
	6 1/4	4	9	1	F
	6 1/8	3 7/8	5	10	M
		3 3/4	9	5	F
	6 1/2		7	7	F
	6		9	3	M
	6		8	9	M
	6		7	5	M
No. 1 Hand "matches" sound hand.	6 1/4	3 1/2	6		M
	5 1/2	3 7/8	5	7	M
	5 3/4	3 1/4	7	8	F
			4	4	F

* Data not reported.

"oversized" children were 8 years of age or older several younger children fell into this category. Furthermore, even hands regarded as unacceptably small by the clinics were retained by the children and worn, at least for dress, for several months longer.

In the selection of candidates for the Left-Hand Study dimensions of the children's sound hands were taken into consideration. In general, an effort was made to accept as wearers only those children with a sound-hand circumference of not over 6 1/4 in. and a length up to 3 7/8 in. It was also anticipated that the majority of such children would fall into the age range of 4 to 8 years. As a consequence, there were few complaints about size in the Left-Hand Study.

Christine, age 10, had sound-hand dimensions of 6 3/8 in. circumference and 3 7/8 in. length at the time of selection. These became 6 1/2 in. and 4 1/2 in. by the time of the four months' check and the clinic was then of the opinion that the hand was too small. Christine and her parents agreed, but strongly preferred even a poorly matched hand to the alternative of a hook. There were six other children in the sample with sound hands of excessive circumference or length, i.e., larger than 6 1/4 in. in circumference and 3 7/8 in. in length. There was indication that all the children in this group were not completely satisfied with the size of the No. 1 Hand, but their lack of enthusiasm was generally expressed in the comment, "a little small, but still all right."

Thus, as a general guide in considering the prescription of a No. 1 Hand, it is possible to state:

1. For children whose remaining hand dimensions do not exceed 6 1/4 in. in circumference and 3 7/8 in. in

length, the No. 1 Hand can probably be fitted without objectionable size disparity. Naturally the closer the children are to this level when fitted the faster they will outgrow the No. 1 Hand.

2. Children with these hand dimensions will typically fall into the age range from large 3-year-olds to small 8-year-olds, with a predominance of 4- to 6-year-olds. However, considerations of hand weight and operating forces may exclude some children at the lower end of this age range.

CLINIC OPINIONS

Clinic opinions concerning various aspects of the No. 1 Hand were obtained in both phases of the study. Clinic personnel were also asked to express themselves on the question: "Are there any contraindications to prescribing this hand (age, sex, performance, etc.)?" Responses, however, were confined primarily to the experiences of the particular child under observation as each questionnaire was completed. Hence the comments made were essentially confirmatory of information gathered from other sources.

Expressions of a general attitude toward prescription and use of the No. 1 Hand were relatively rare. Thus, it is possible that the typical reaction of the clinics participating in the study was one of reservation concerning the experimental item—of not wishing to take a strongly positive or negative position until more experience had been acquired and "all the returns were in."

This situation reflects the fact that the majority of the clinics participating in the program appeared to be "functionally oriented," some of them strongly so. Hence, a device which historically and in fact provides lesser function was likely to be viewed with skepticism. Some clinics were also concerned about the initial cost of the hand and glove and the expense of repairs and replacements particularly of the glove.

If this interpretation of the prevailing frame of reference is correct, such comments as were made concerning "contraindications to prescription" take on added significance by their infrequent occurrence. To cite the Left-Hand Study data again: For only nine of the 36 children discussed was dissatisfaction with some aspect of the hand strong enough to be mentioned as a possible contraindication to use. These instances were:

No. OF CHILDREN	CONTRAINDICATIONS
2	Discrepancy in size
2	Frequent breakage or malfunction
2	Force requirements excessive for particular child
1	Functional limitation as compared with hook
1	Rapid wear of glove a possible contraindication for a *wry* active child
1[8]	Emotional difficulty

Excerpts from a letter written by one of the clinic chiefs might be appropriate as a summary statement of prescription considerations. His comments not only reaffirm reactions to the hand which appear to have been fairly typical, but also express an approach to prescription which seems to be conservative yet reasonable:

"The mother's comment with regard to cosmesis is that the hand is 'beautiful.' She is perfectly willing to go to all extremes in cosmetic appreciation. The mother feels that the child's reaction to the appearance of the hand was one of 'being proud of it.' This was exemplified by the child's desire to always wear the hand at school. It was interesting to me that, after approximately six months of wear, Debra was anxious to wear the hand all the time and not to wear the hook any more. However, in the recent episode, when the hand became no longer functional, she was perfectly agreeable to return to the use of the hook. This is particularly interesting to me, because the mother feels that Debra actually lost no function in the transition from the hook to the hand.

"At age 6, Debra learned to operate the thumb adjustment and, as a consequence, was able to continue with the prosthetic hand as the assisting side at school in such functions as holding a book while reading so that she could turn the pages with her normal hand; holding papers while writing; and holding papers while cutting. At home, she was able to hold fork and knife with the prosthetic hand but, at age 7, is still able to cut only soft meat, such as a hamburger. She uses the hand in all bi-manual activity.

"Our own opinion here is that we will prescribe this hand for children who are already using a hook. In the unilateral case where there is reasonable dexterity, I feel that with the prosthetic side being the assisting side we can sacrifice the minimal loss of function which one

[8] One clinic felt strongly that prescription would be a dubious practice where cosmesis was highly important for child and parent if the next larger hand size was unavailable later.

probably gets in the transition from hook to hand. The only criticism is the amount of force necessary to operate the hand."

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