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1981, January 27-February 1, AAOP Round Up Seminar, Fountainebleau Hilton, Miami, Florida.

1981, April 23-25, AOPA Region IV Meeting, Hyatt Regency, Lexington, Kentucky.

1981, June 5-7, AOPA Region IX and California Orthotics and Prosthetics Association Meeting, Doubletree Inn, Monterey, California.

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1981, June 25-27, AOPA Region VI and Midwest Chapter of AAOP Meeting, Holiday Inn of Merriville, Indiana.

1981, June 16-21, AOPA Regions VII, VIII, X, XI Combined Meeting, Four Seasons Motor Inn, Colorado Springs, Colorado.

1981, October 30-November 1, AOPA Assembly, Sahara Hotel, Las Vegas, Nevada.

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Commentary
A Challenge

In 1945 the National Academy of Sciences, with money supplied by the Office of the Surgeon General and the war-time agency, Office of Scientific Research and Development, initiated the first organized program in the United States to try to solve problems of amputees. Because the NAS has no laboratories of its own, the program was started by contracting with university and industrial laboratories to carry out assigned portions of a "master" plan. In 1946, after the cessation of hostilities, the VA inherited the responsibility for both the patients and the Research Program. In 1947, to save on administrative costs, the VA contracted directly with the research organizations but retained the NAS to coordinate the efforts of the VA contractors and research units of the Army, Navy, and Air Force. When the office of Vocational Rehabilitation, DHEW, was granted permission by Congress to support research programs in rehabilitation, it also called upon the NAS to assist in coordination of their program with the work supported by the VA, the Armed Forces, and others.

At the beginning and for some years afterward most of the leadership in the "Artificial Limb Industry", as it was called then, had grave misgivings about the government being involved in an area in which they were confident that they knew all there was to know, and no college professors or aircraft engineers were going to "tell them what to do". Nevertheless, the "outsiders" did make contributions that are well recognized today, and with the help of Howard Thranhardt, Lucius Trautman, Dan McKeever, and one or two others, results of the research effort were introduced nationwide on a regional basis beginning with the "Suction Socket Schools" in 1948. Success with the Suction Socket Schools led to the formal education programs, as we know them today, which were launched as a result of a pilot education program in Upper Limb Prosthetics held in UCLA in 1953.

I believe few will disagree that as a result of this joint effort between government and practitioners in research and education, the practice of prosthetics and orthotics has been revolutionized to the benefit of all concerned: the patients, the clinicians, and the taxpayers.

However, in 1975 the NAS, for reasons never stated, declined to continue to assume responsibility for this program and, for reasons that I don't understand, the government agencies supporting research, development, and education have not been able to either perform the coordinating services needed or find another group to do so. As a result, very little progress has been made since 1975.

A review of the Fall 1979 issue of the Bulletin of Prosthetics Research, which includes a progress report from each of the research and development projects in rehabilitation engineering supported by the Veterans Administration and the Department of Health, Education, and Welfare, reveals that a relatively small emphasis is being placed on limb prosthetics and orthotics. Just why this is so is not clear, but one can conjecture that part of the problem is the result of a lack of leadership on the part of the government. Certainly there is little apparent effort being directed to coordination of the efforts that are going into prosthetics and orthotics; there is no formal, and very little informal, effort to evaluate the results of research; and there is almost no liaison between research and education programs.

I suggest at this time that AOPA and AAOS consider ways to provide the leadership that is lacking in the present program. Certainly it is in the best interests of both organizations that the maximum benefits be derived from government sponsored research and development. Furthermore it seems self evident that practicing prosthetists and orthotists should have some influence on the direction that the government supported programs take.

A. Bennett Wilson, Jr.

FOUNDED 1917

Orthotics and Prosthetics, Vol. 34, No. 3, pp. 3-16, September 1980

The S.A.F.E. Foot

JOHN W. CAMPBELL, C.O.[1]
CHARLES W. CHILDS, C.P.O.[2]

Inman and Eberhart (6), in their summary of research related to amputees and artificial limbs, postulated that the designer of artificial legs must have detailed knowledge of the normal leg and its role in locomotion in order to reproduce as nearly as possible the features of the normal leg. In our modest way, we have attempted to design an artificial foot that comforms to the shape and mechanism of the human foot.

The letters S.A.F.E. are the acronym for Stationary Attachment Flexible Endoskeleton or, in simpler language, a prosthetic foot bolted to the shin with a flexible keel as shown in Figure 1. To be consistent with other endoskeletal systems, the bolt block of this foot and the flexible keel are encased in a soft foam cover, as shown by section in Figure 2.

The first reaction of many prosthetists to the foot or any other structure so described is apt to be that it lacks stability and therefore is inherently unable to support super-incumbent weight. The foot must not only support weight, or compression, but moving, dynamic, forces that produce torque and shear forces as well. Yet, except for the lack of an ankle joint, we might be describing a human foot in very simplistic terms.

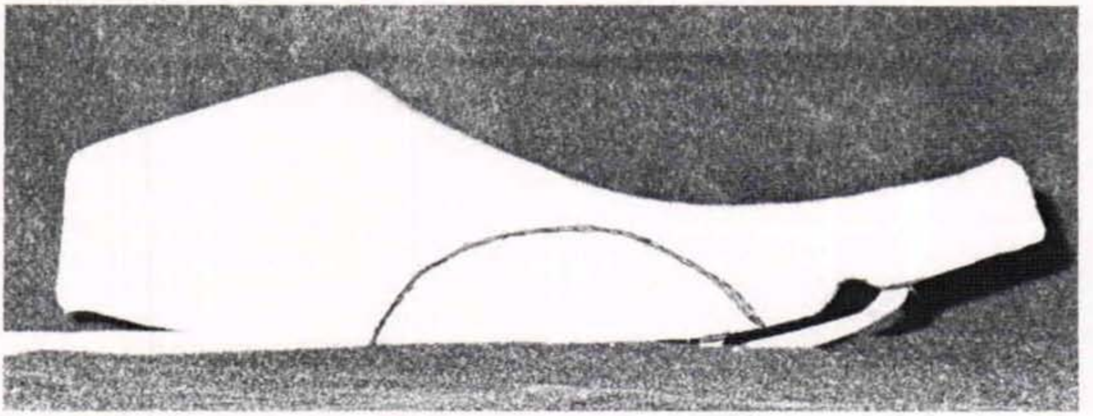

Fig. 1. The endoskeleton.

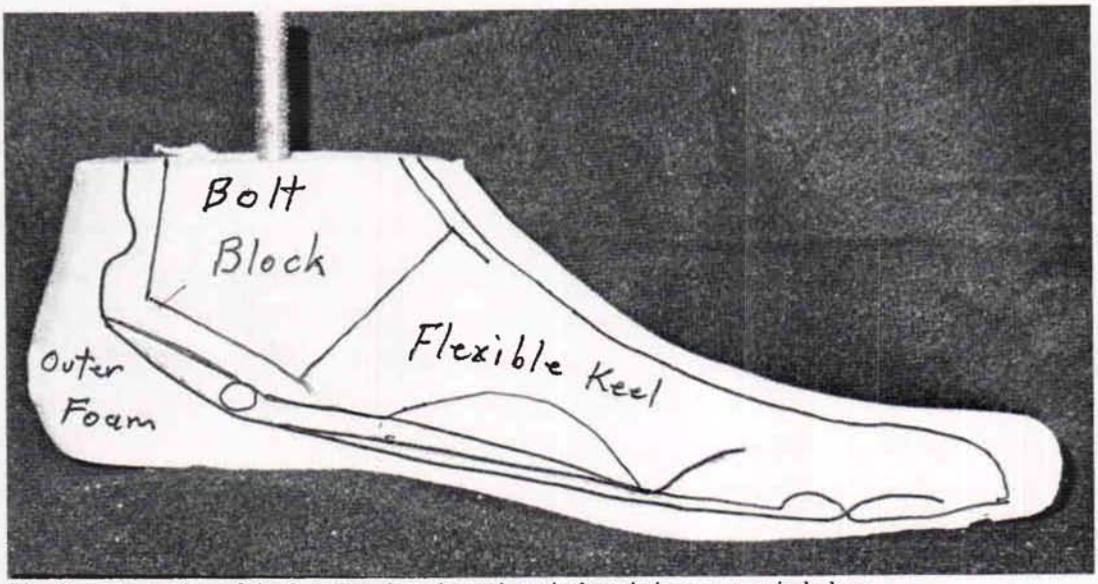

Fig. 2. Cross-section of the S.A.F.E. foot throughout its length in a parasagital plane.

The Arch

In the human foot there are twenty-six bones held together with ligaments, connective tissue, and capsules. Each bone is capable of some motion relative to its adjacent members. The motions of these bones are dictated by the shape of their articular surfaces and the restriction provided by the ligamentous structures. The seven tarsal bones and the five metatarsal bones are usually described as taking the shape of an arch, a very strong geometrical structure when it is rigid, but requiring additional support in the form of trusses or ties when flexible. In the cases of the foot, the trusses or ties are provided by the ligaments, particularly the long plantar ligament and the plantar aponeurosis (fascia).

Although the arch has stability along its long dimension, stability medially and laterally is lacking. A series of arches bound together with ligaments would increase mediolateral stability, and indeed this is the way the foot is seen by many people. However, the arches are arranged in a triangular shape having one common base proximally, the calcaneus, and five bases distally, the metatarsal heads (Fig. 3).

The Arch As a Half Dome

The anatomist, Frederick Wood Jones, (3) in his book *Structure and Function as Seen in the Foot,* described the foot in a way that would make it an even stronger structure. He said, in effect, that if we put our feet together geometrically, the arches form a dome, and, therefore, when we separate them, they each are a one-half dome, a form that is inherently more stable than a series of arches.

Perhaps the two theories are not really far apart, if we concede that most of the time the highest arch of the foot is the medial one as defined by its base, the first metatarsal head, and that each arch as we move laterally is lower at its apex until the fifth member as defined by the fifth metatarsal bone, cuboid, and calcaneus

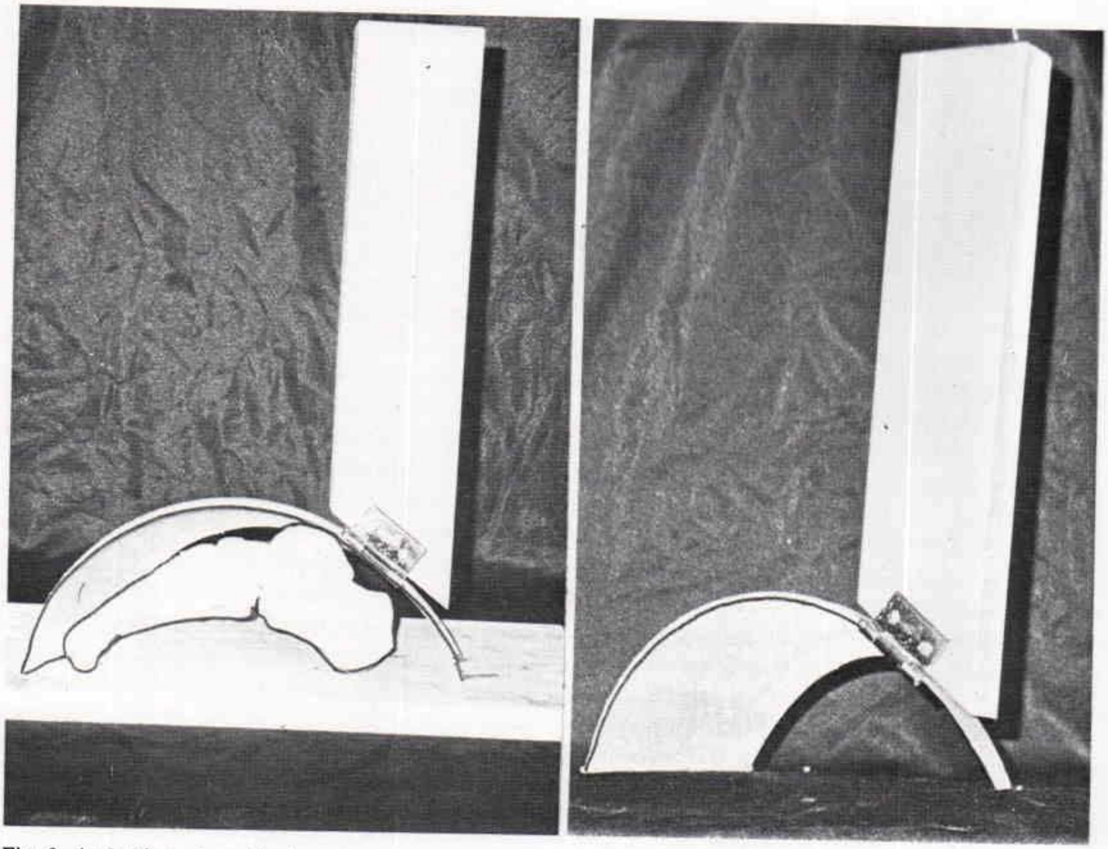

Fig. 3. A plastic arch and its bony counterpart.

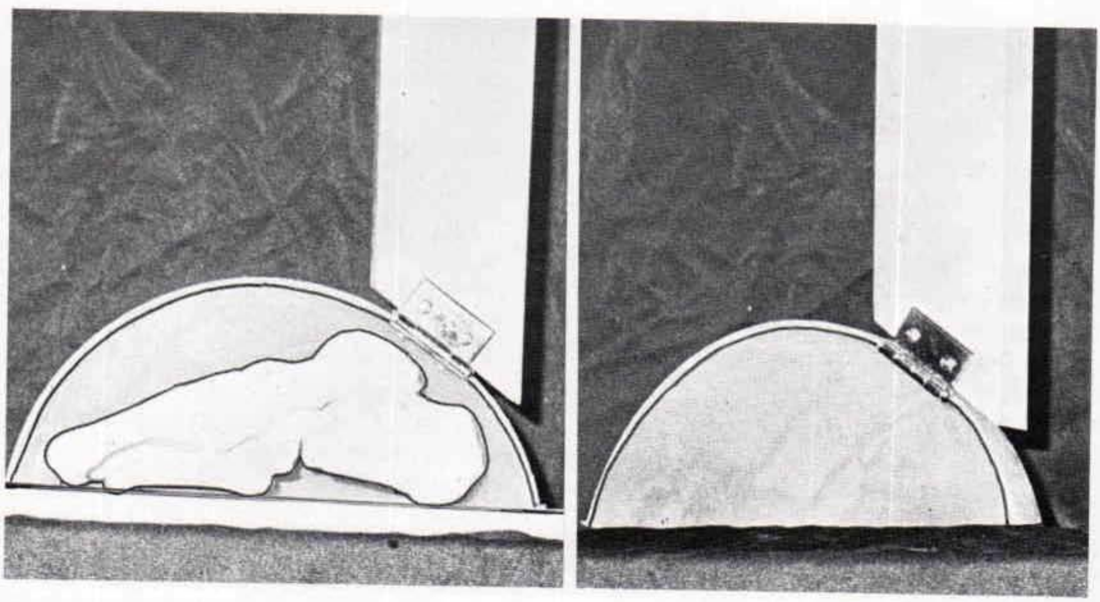

Fig. 4. A plastic dome and its bony counterpart.

has an apex so low that it usually cannot be described as an arch. Therefore, when these conditions are given, we have described a half dome, as shown in Figure 4. One only has to look at wet footprints or Elftman's (4) barograph studies of normal feet to realize that ground contact is primarily from the area of the calcaneus, cuboid, the length of the fifth metatarsal bone, and the metatarsal heads. Since the bones of the foot can articulate each with its adjacent member, the one-half dome is a flexible structure. Consider now the mechanical advantage of a long plantar ligament and a plantar aponeurosis tying the ends of the one-half dome together. The foot then becomes a very strong, stable member capable of resisting the forces of the super-incumbent weight but still retains flexibility when required.

The foot, without aid from muscles, can function when the ligaments remain intact. And thus many patients without muscle activity below the knee can apply weight to their foot without the loss of its integrity. Basmajian (1) made simultaneous electromyograms of six muscles of a group of twenty subjects. The muscles were under a static load of 45.4 to 181.4 Kg. The muscles tested were the tibialis anterior, and posterior peroneus longus, flexor hallucis longus, abductor hallucis, and flexor digitorum brevis. The contribution of these muscles was considered insignificant until the load reached 181.4 Kg, and even then some muscles remained inactive. Basmajian concluded that the passive structures (bone and ligament) are the only ones capable of sustaining an unremitting load.

Campbell and Inman (2) speculated that if the plantar aponeurosis were a major contributor to the stability of the arch, plantar fasciitis might be relieved when the arch was supported mechanically. The UC-BL Shoe Insert was used successfully on thirty of thirty-three patients to relax the plantar fascia and relieve the associated pain.

Mann and Inman (6) found that there was little, if any, significant activity of the intrinsic musculature during quiet standing. They also found that the intrinsic muscles did not elicit a significant response until 30 percent of the gait cycle (midstance) or just prior to heel rise. Therefore in the first half of stance phase, the entire weight of the body is borne by the passive structures (bones and ligaments).

Cunningham (3) found that during about 15 percent of the gait cycle (foot flat) the foot is subjected to 120 percent of body weight. The anterior shear force is as high as 30 percent of body weight and the torque was as high as sixty inch-pounds. These forces are all acting before the intrinsic muscles become active and before the extrinsic muscles fire, except for the anterior group that prevents foot slap. We submit that the one-half dome concept of the foot is the best geometrical shape that can remain flexible and still accept the aforementioned forces without muscular assistance. The one-half dome therefore provided the basic geometry for the design of our new artificial foot.

The Second Half of Stance Phase

Previously the emphasis has been on the first half of stance phase when the foot was required to have "flexible" stability. However, in the second half of stance phase, the function required of the foot changes significantly from a "flexible-stable" member to a semi-rigid lever. In the swing phase and in the first half of stance phase, the entire leg and foot are rotating internally around the long axis of the leg a total of 65 percent of the gait cycle (9). In the second half of stance phase these transverse rotations are reversed and the leg is externally rotated with the foot fixed with respect to the ground. These transverse rotations have been recorded to be as much as 29 degrees, in which case some individuals have to externally rotate their leg twenty-nine degrees in one third of a second when the gait cycle is one second. These transverse rotations of the leg are absorbed in the arch of the foot, but since the foot does not bend in the arch to absorb these rotations, they are converted to rotations in a vertical plane about the long axis of the foot by means of the subtalar joint.

The subtalar joint becomes a motion and torque converter much like two 45-degree beveled gears. Most investigators, including Isman and Inman (7), agree that the subtalar joint is usually close to a 45-degree angle with respect to the foot.

The forefoot must still maintain contact with the floor and therefore the arch mechanism, because of its flexibility, can twist about its axis and absorb these rotations.

Wright *et al* (11) produced a mechanical analogue of the ankle and subtalar joints which could be aligned to a subject so that the motions about these axes while walking could be recorded. They found that the significance of the subtalar joint was easily demonstrated by the fact that motion about the subtalar joint provided approximately half the motion attributed to the ankle joint.

When the foot is released from the ground it does not rotate violently to catch up with the leg, but merely untwists. This kind of motion cannot be attained when transverse rotations are absorbed in the shank of an artificial leg, a point that is demonstrated when an amputee first puts on a prosthesis provided with a rotator in the shank. For the first few steps the amputee usually tries to use all of his normal horizontal rotations. However, after a few steps he will automatically suppress some of these rotations, because if he does not the torque developed in the shank will externally rotate the prosthetic foot violently and strike the contralateral leg as it swings through. This will not occur when the rotation is placed where nature intended it, i.e., within the foot. Therefore our second design criterion for an artificial foot was provision of a subtalar joint, and the third criterion was provision of a flexible endoskeletal structure.

Immediately prior to heel rise, the intrinsic muscles fire off amost simultaneously to raise the arch to help produce conversion of the foot to the semi-rigid level attitude. For obvious reasons muscular control is one criterion that we eliminated. Fortunately, muscular activity is not the only mechanism for converting the foot to a semi-rigid lever.

In 1954 Hicks (5) described the contribution of the plantar fasciia in stabilizing the foot from heel rise to toe off. Since the attachment of the plantar fasciia is distal to the metatarsal phalangeal joints, extension of these joints such as occurs with dorsiflexion of the toes causes tension on the plantar fasciia and contributes to the conversion of the foot to a semi-rigid lever. Hicks called this the "Windlass effect" of the plantar aponeurosis (as shown by the model in Fig. 5). Therefore we now have the fourth criterion for the prosthetic foot. It must have a toe break which would flex somewhere near the toe break of the human foot and a plantar fasciial strap from the toe area spanning the toe break and the arch, and fixed to the posterior aspect of the foot.

Design of the S.A.F.E. Prosthetic Foot

To our design criterion we added one more condition: that the foot be made entirely from plastic materials and thus avoid mechanical joints. We then decided that we must start with the outside shape and work inward toward our endoskeleton configurations.

A model of a low profile, conventional, size 13 prosthetic foot was constructed out of plaster (Fig. 6), and a negative of this

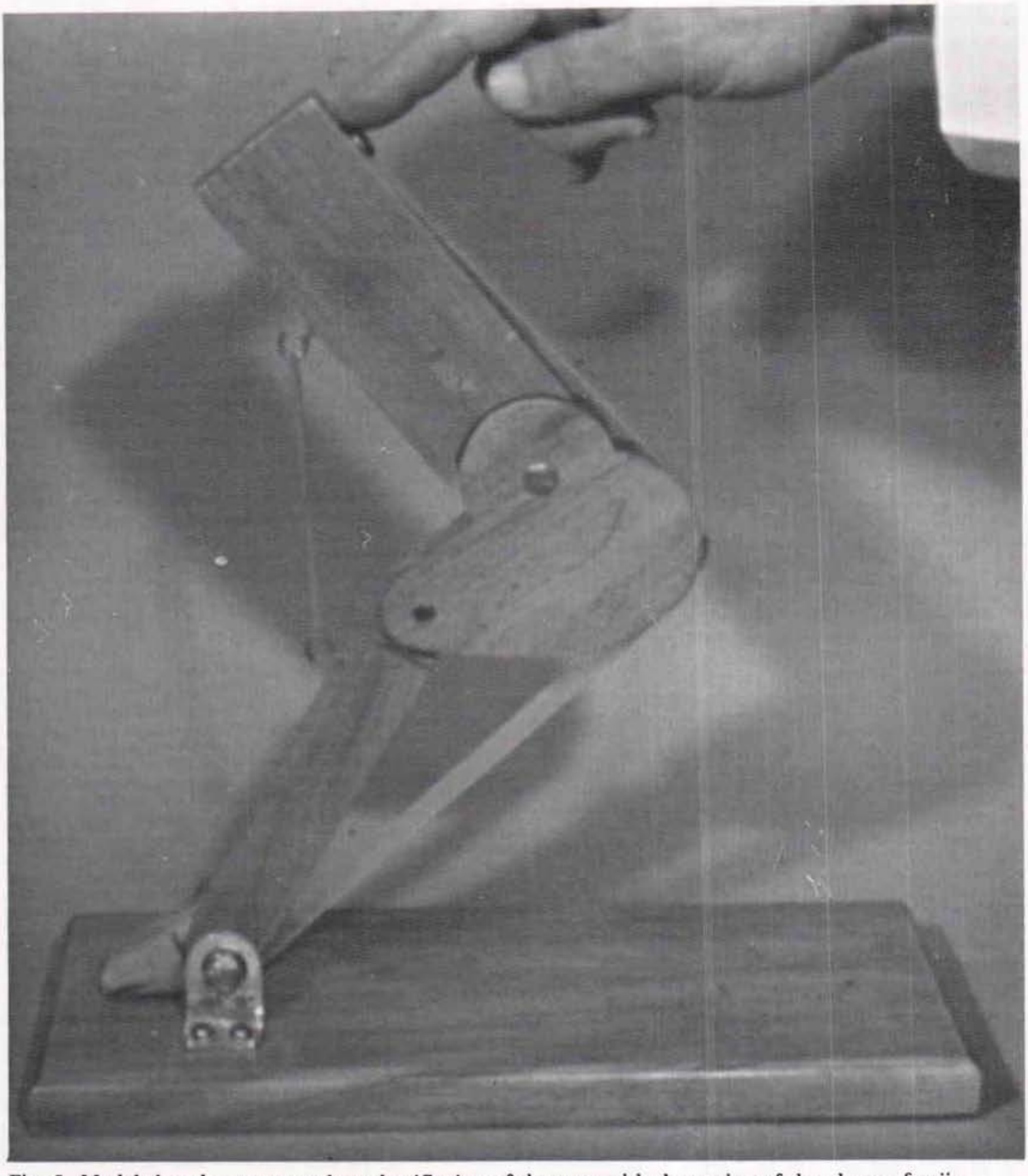

Fig. 5. Model that demonstrates how dorsiflexion of the toes, with shortening of the plantar fasciia, raises and stabilizes the arch.

model was constructed in two pieces, a top portion and a bottom portion. Bolts and wing nuts held the two sections together, and our outside mold was completed.

The Keel Mold

The plaster positive of the foot was modified into the keel shape in the following manner. The foot was divided

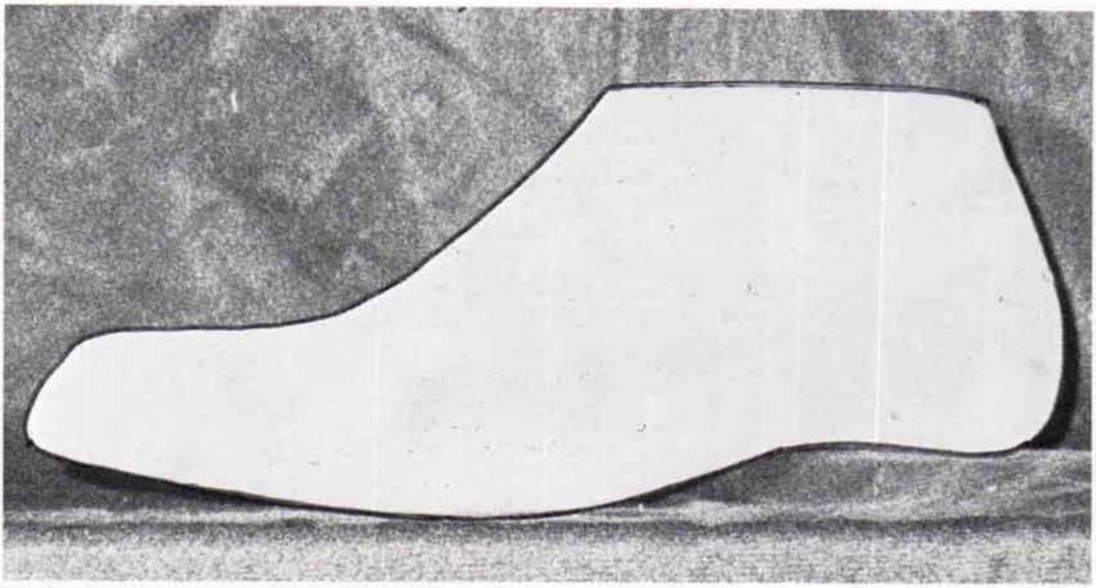

Fig. 6. The plaster foot model.

into three equal sections. The anterior third is the ball (metatarsal heads) toe break and toe section. The middle third is the arch (dome) and the posterior third is the soft heel and bolt block section. In the anterior section a toe break was carved on the plantar surface medial to lateral, one-half inch anterior to the ball line (Fig. 7). The toe-break groove is five-eighths of an inch from the top of the toe section. In the middle third, a dome was formed by carving the plantar and medial surfaces until they were thinned to seven-eighths of an inch from the top and the lateral border of the foot. One half-inch of plaster was cut off of the plantar surface of the foot. The plantar surface of the heel section was cut further from zero anteriorly to one inch at the heel. Three-eighths of an inch of material was then

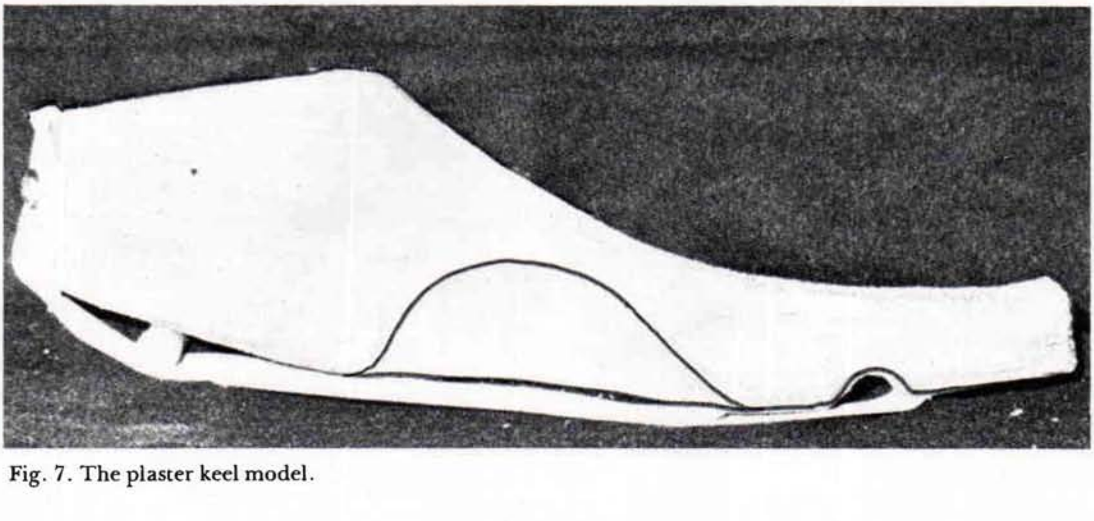

Fig. 7. The plaster keel model.

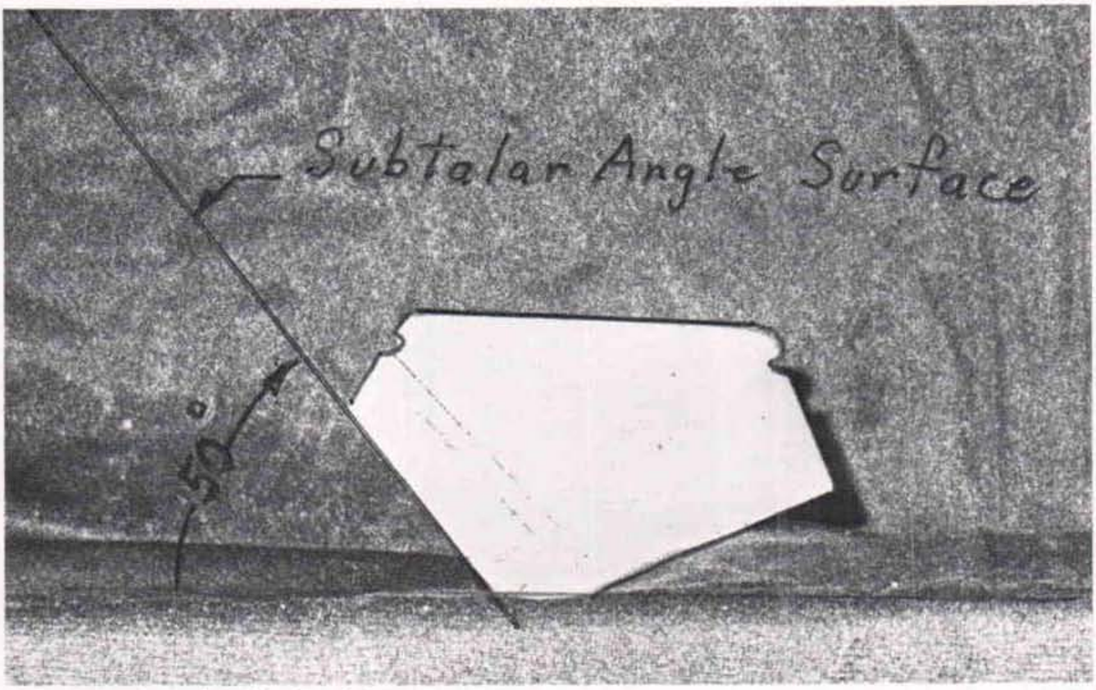

Fig. 8. The plaster bolt-block model.

removed from the top surfaces except where the foot bolts to the shank. We now had our positive keel mold shape (Fig. 7). Negative molds were made in the same manner as our foot molds.

The Bolt-Block Mold

The plaster keel mold was cut through in a mediolateral plane at a 50-degree angle just posterior to the arch area to obtain the posterior section, which became our bolt block. The anterior surface of this section, cut at a 50-degree angle, was rounded to become our subtalar angle surface. One-quarter inch of plaster was removed from the remaining surfaces as shown in Figure 8. A bolt hole was drilled through the center of the block and a clearance hole drilled on the plantar surface deep enough to clear the bolt head and washer. A negative mold of this shape was made with flexible polyurethane potting resin.

Fabrication of the S.A.F.E. Foot

A syntactic material is used to fill the bolt block negative mold. When this resin has set up the bolt block is sanded and bolted into position on the keel mold. The keel mold is bolted together around it's flanges. A polyurethane elastomer system is mixed and poured into the mold which encapsulates the ends of the bands and the bolt block. The keel is now removed from its mold and the two straps are pulled taut and secured with screws to the posterior surface of the keel into the bolt block. Holes are burned into the Dacron bands as they pass over the bolt-block access hole that the bolts may be inserted. The keel is now completed as shown in Figure 9.

The keel is bolted to the upper part of the foot mold; the two halves of the foot mold are bolted together; and a polyurethane integral skin elastomer foam is

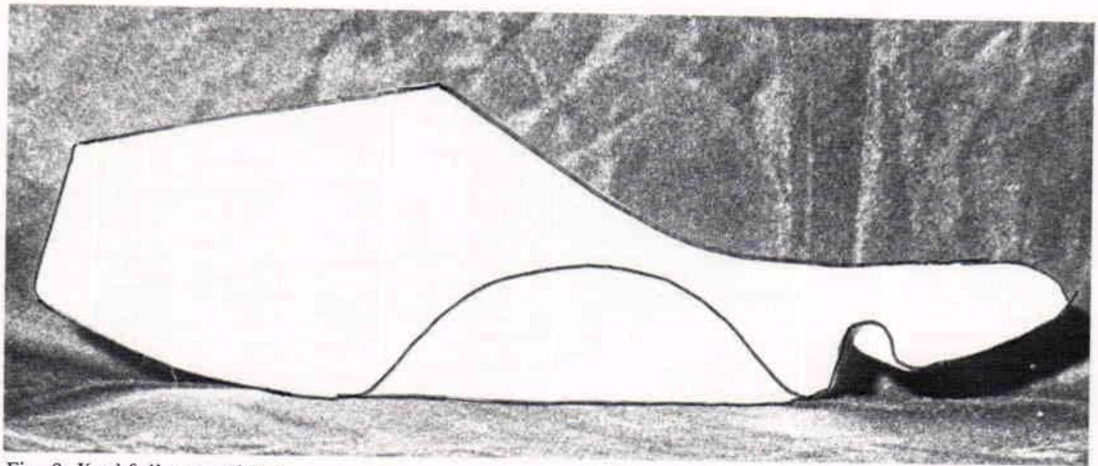

Fig. 9. Keel fully assembled.

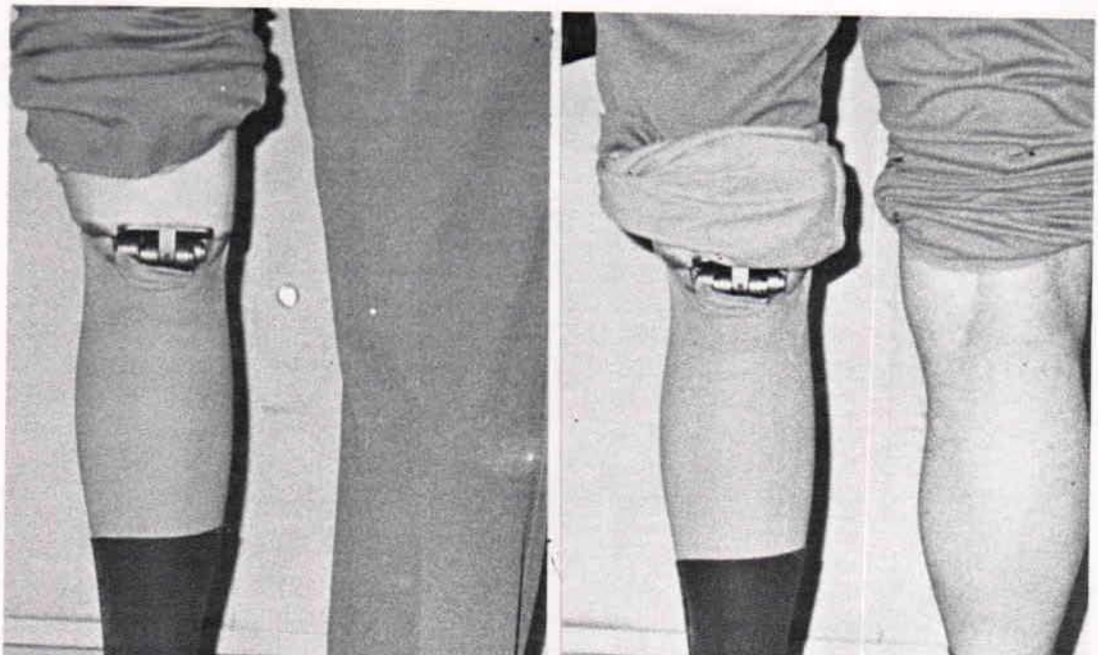

Fig. 10. Patient-subject with foot in eversion (left) and inversion (right).

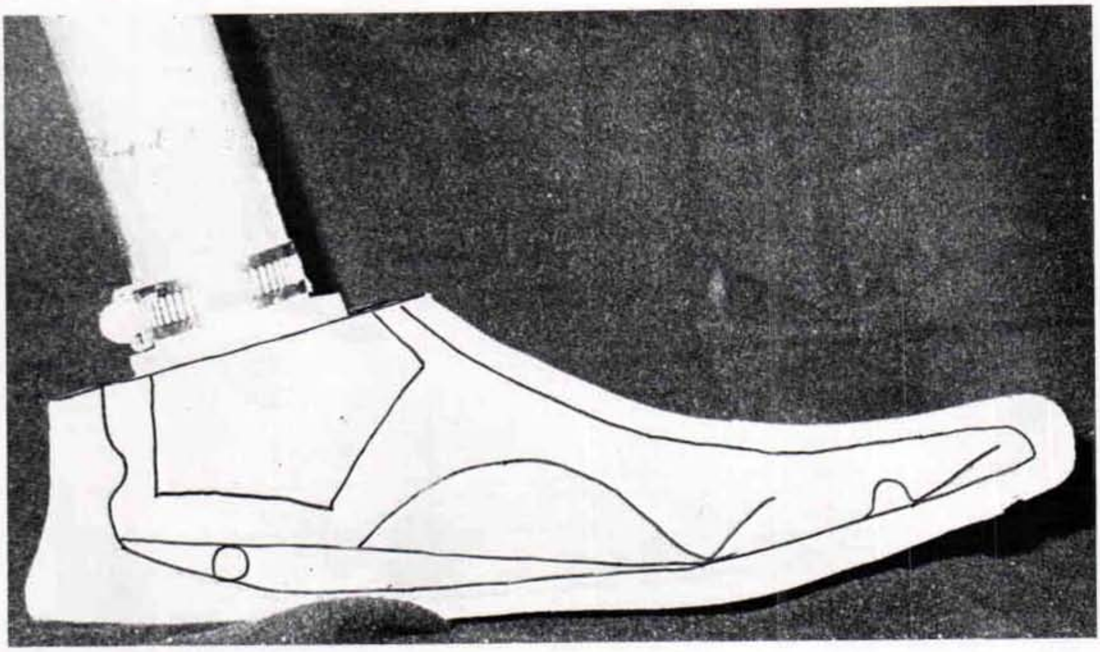

Fig. 11. The S.A.F.E. foot loaded at heel strike.

mixed and poured into the mold and left to foam and cure. The foam will form a skin against the sides of the mold, and bond to the keel, and it will completely encapsulate the keel except for the top of the bolt block. The foot is now completed and ready for use.

The foot is easily capable of sustaining the patient's weight due to the dome shape of the arch, and its tie, the long plantar ligament band. It can be inverted or everted by standing sideways on an incline as shown in figure 10. The equivalent of plantar flexion is provided by the soft heel and the fact that the bolt block has some motion relative to the rest of the foot (Fig. 11). Some degree of dorsiflexion can be simulated due to the movement of the bolt block relative to the rest of the foot (Fig. 12). It will permit transverse rotations due to the ability of the flexible keel twisting within the shoe (Fig. 13). When this twisting occurs from heel-off to toe-off the plantar faciial band is tightening as the windlass action takes effect, holding the forefoot tightly against the walking surface. The windlass action converts the foot to a semi-rigid lever (Fig. 12). The gradual tightening of the windlass band produces a smooth roll-over to toe-off without the usual snapping of the knee caused by a rigid keel or the toe bumper of an ankle-jointed foot.

Alignment

Static alignment of the S.A.F.E. prosthetic foot should be the same as used on ankle-jointed feet in the anterior-posterior plane. For static alignment of a below-knee prosthesis, we place the lateral reference line at brim point of the socket anteriorly one-half the distance normally used. All other alignment is done in the conventional manner in both below-knee and above-knee prostheses.

Results

As of this date we have tested the S.A.F.E. foot on thirty-five patient-

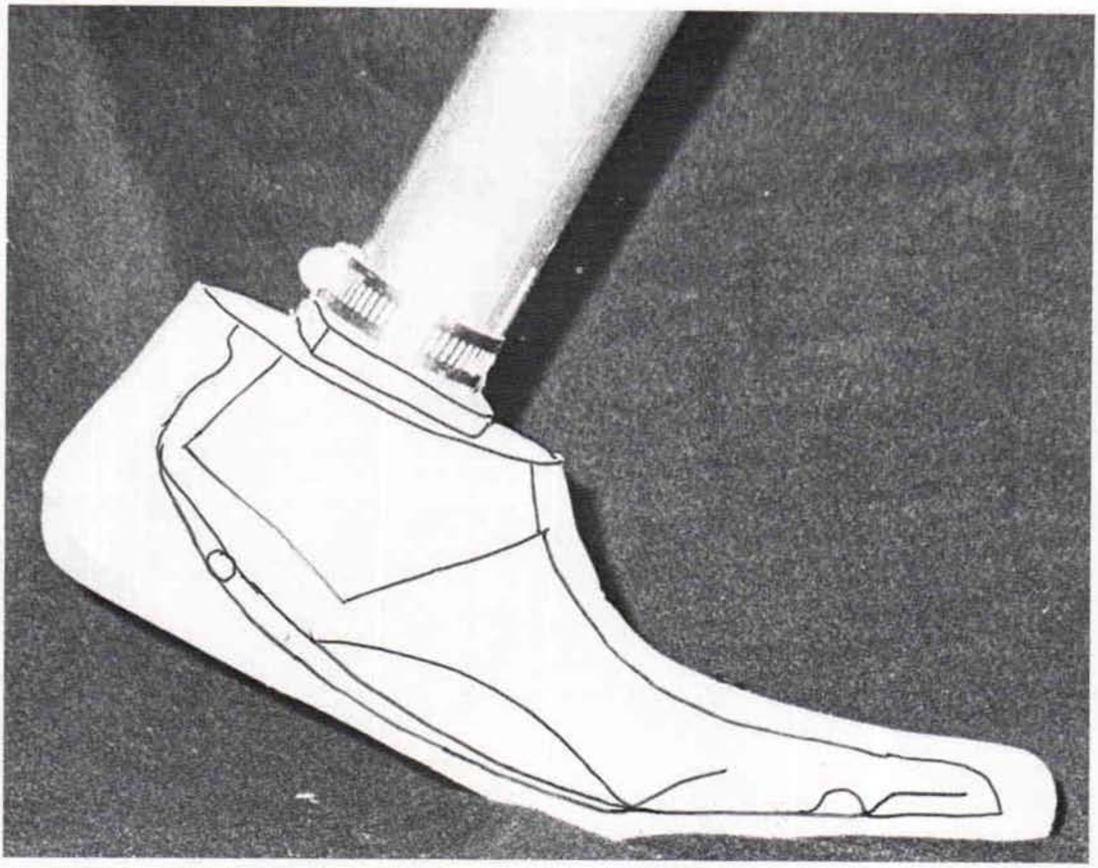

Fig. 12. The S.A.F.E. foot loaded at toe off.

subjects. Two of these feet were given to other facilities. One has not reported back as yet and the other put the foot on a BK patient-subject and reported that he was pleased with its performance. Of the remaining thirty-three feet, thirty-one are on patient-subjects.

Two subjects rejected the foot. The two rejections were BK patient-subjects with prostheses aligned for the SACH Foot. Of the remaining thirty-one patient-subjects nine are AK and eight are BK amputees.

The gait patterns of all of the thirty-one patient-subjects improved immediately. Their arm swings became equal and the lateral movement of the upper body and head was reduced to better than half of what it was previously. Their walking base was reduced to two inches or less in most cases. In the BK subjects the flexibility of the foot produced a smooth knee motion all through the stance phase and the acceleration of knee flexion through toe off was equal to the sound side.

Patient Reaction

One of the subjects is an AK amputee and a prosthetist. This subject has been an amputee for thirty two years. He has worn every type of prosthetic foot available. Three months ago he was wearing a Hydracadence leg. We removed the

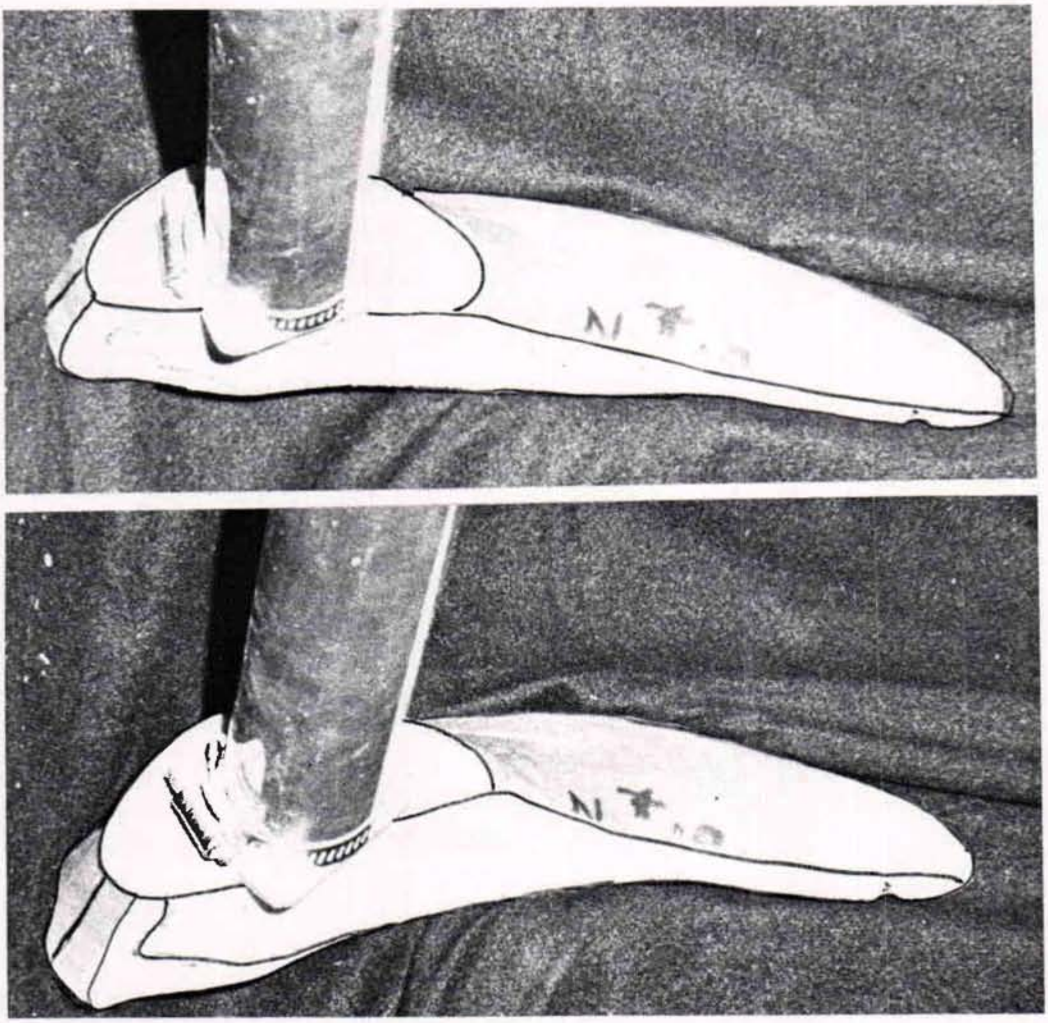

Fig. 13. The foot twisted to demonstrate transverse rotation.

Hydracadence unit from his socket and put on an O.H.C. Polycentric knee with a Dynaplex Swing Phase Control Unit and then bolted the S.A.F.E. Foot to the shank. We did not change the alignment and he was worn this combination for the last three months. He reports that energy expenditure has been reduced dramatically and that the torque and shear forces have diminished to a point that he cannot feel them. He states that the smooth transition of motion from heel strike through to toe off, caused by the flexibility of the arch and the gradual restraint of the toe, has solved almost all of his chronic socket problems. All other subjects expressed similar reactions but were not as explicit as the prosthetist-amputee subject.

One thirty-two-year-old woman, a left BK amputee, was a very athletic person before her amputation. When we used her as a subject she returned two weeks later to report that she was able to jog without injury to her stump for the first time. She returned one month later to report that her jogging endurance is up to one-half mile three times a week.

Summary and Conclusion

A prosthetic foot was designed and built to meet five predetermined criteria: a dome shaped arch and a long plantar ligament band, a flexible endoskeleton, a subtalar joint, a windlass mechanism (toe break and plantar fasciia), and made entirely out of plastic materials with no mechanical joints. All of the criteria were met in our design except the subtalar joint motion.

It was first thought that we could simulate both joints by merely thinning the plastic in appropriate areas. Although the toe break action was accomplished in this manner, the subtalar joint proved to be more elusive. At first, thinning of this area produced a definite instability in the foot. Elimination of this criterion produced a foot which worked so well for a while, we dropped this condition. However when we sectioned the foot lengthwise, we could see that to a certain extent the anterior edge of the bolt block dictated the motion of the flexible portion anteriorly in a coronal plane. Therefore we decided to cut the anterior surface as close to a 45 degree angle as possible, that is, 50 degrees. The cut was made approximately where the average subtalar joint of a human foot would be located. When we sectioned this model lengthwise the motion of the flexible keel was definitely influenced by this oblique angle. We designated this the subtalar angle of the bolt block (Figs. 2 and 7).

When the patient-subjects were given the new model, the rotation of the heel section inverted in a much slower and better controlled manner.

Summary

With the aid of research previously carried out on the mechanics of the foot by various research groups, particularly the investigators at the Bio-Mechanics Laboratory of the University of California, San Francisco and Berkeley, we have developed a new prosthetic foot. During the last six months, thirty-five patient-subjects have been fitted. Successful results have been obtained by thirty-two subjects. Two subjects rejected the new design, and report on the one remaining subject could not be obtained.

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Footnotes

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Developmental Factors In The Care Of The Adolescent Amputee

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Amputation is an extremely stressful event for any individual and the entire health team must call upon all its professional talents and resources to provide a therapeutic environment, both physically and psychosocially. When the patient is an adolescent there are several factors related to his developmental stage that are pertinent to the physical and emotional aspects of the situation. These factors must be considered in order to provide care that is appropriate to the patient in terms of his adolescence as well as his physical condition.

An holistic approach where the patient is viewed as a total entity, comprised of many facets, is necessary. The foundation of this approach is a keen understanding of adolescence per se in order to plan and implement measures effectively to help the patient achieve optimal physical and psychosocial functioning. This calls for interdisciplinary action and diligent communication by the health team in the postoperative period. Therapeutic support, appropriate to the developmental stage of the patient, is vital at this time since the immediate and stark reality of the situation may negate much of the preoperative support and instruction he received. All health team members should be aware of the mind set and perceptions of adolescents which lead to behaviors characteristic of this particular stage of development.

Adolescence is defined as a descriptive term of the period during which an emotionally immature individual in the second decade of life approaches the culmination of his physical and mental growth (1). The adolescent is in a stage of transition, and is neither child nor adult. During this time the individual experiences considerable turmoil in striving for identity, maturity, and independence, and certain behaviors common to most adolescents surface. The adolescent is egocentric and has an inflated sense of his own worth. He invariably places his needs and interests above those of others. In other words, he feels the whole world should revolve around him.

Adolescents are also idealistic and tend to view issues in terms of what might be possible with little regard for the practicality of the situation (2). This idealism often leads to a high degree of criticism of others, especially adults. Though the adolescent may think and speak idealistically, he manifests the childlike behavior of wanting immediate gratification. He tends to operate on the urgency of instinctual and emotional needs. Patience is not often found in adolescents. Ambivalence is an expected trait since the youngster is changing his role. He is leaving behind familiar childhood behaviors and attempting to be mature. This cannot happen instantly and consequently mercurial behavior develops whereby the adolescent behaves as a child in one instance and an adult the next.

Acceptance is a critical issue since adolescence is a time for social development and expansion. Peer relations take on major importance. Since the adolescent tends to feel insecure as a result of his changing status and lack of experience, the peer group may serve as a refuge. Acceptance by peers is highly valued. Despite a desire for individuality, the adolescent strives to fit into the current acceptable pattern. He is greatly influenced by the expectations of his cohorts.

Extremely pertinent to the subject of amputation is the importance adolescents place on their bodies. This is a time of rapid change and the individual may not be able to adapt as quickly as the changes occur. Consequently coordination can be affected. In addition, not all parts of the body grow at the same rate at the same time during this growth spurt, a condition that leads to periods when the youngster is dissatisfied because he is not as perfectly proportioned as he thinks he should be.

It is at this point in life when the youngster begins to take great interest in grooming. Hours may be spent in front of a mirror combing each strand of hair into place. These hours are not necessarily idle preening since he may be "taking inventory" of himself for comparison of his own characteristics with those of his peers. A large degree of self perception in the adolescent results from comparison with others (3). An intact body image is vitally important to the self concept of the adolescent. The impact of amputation is further compounded by the fact that adolescents have a heightened sense of indestructibility. They ascribe to the "it can never happen to me" syndrome more so than other age groups.

These traits lead to numerous implications for the health team to consider in the postoperative and rehabilitation phases. Many disciplines comprise the health team, and the various members view the patient from different perspectives. This allows the team to develop a truly holistic approach and to set immediate and long term goals that utilize many and varied resources.

The role of team coordinator may be assumed by different members at different times as dictated by the priority of the needs of the patient. Initially, the physician is usually the coordinator. As the postoperative period progresses, the nurse may function as team leader since this professional role allows for long periods of direct contact and opportunity for thorough physical and psychosocial assessment. As recovery progresses into the rehabilitation phase the roles of the physical therapist and the prosthetist take on increasing importance. Each discipline serves as coordinator at the appropriate time, yet has an important role throughout the entire process.

The extent and diversity of the team is determined by the needs of the individual patient and may include social worker, tutor, psychologist, clergy, community health nurse, and others. Continual assessment by the entire team is essential to modify goals and plan and implement appropriate care. Communication is a key factor in efficient and effective team activities. It is especially important to include the adolescent in planning since, by nature, he wants to have some influence and a degree of control over the plans proposed for him. This arrangement will also help to increase his self esteem at a time when it may be severely threatened.

The timing and nature of the amputation will have considerable impact in the postoperative period. Was the surgical procedure done on an emergency basis? Was it an elective surgery that gave the patient time to begin the grieving process early? Did the incident cause him to miss a significant event in his life such as graduation or a prom? To the adolescent these are important issues. Does the nature of the surgery hold threat or promise for the patient? Was the surgery of a type that will increase cosmetic or functional worth, as in the case of a congenital defect? Did the surgery entail loss of a part vital to the lifestyle and aspirations of the patient? Did the procedure shatter visions of a career and numerous hours of labor already spent in preparation to be an accomplished athlete or artist; or simply just be like everybody else? These are sobering thoughts at any age, but can be particularly devastating when one is a teen-ager and sees his life as just beginning.

The health team must understand each of these factors in order to function efficiently and effectively. The team sets the tone for recovery, and can do many things to help the adolescent cope with his situation and participate in the treatment regime. The immediate postoperative physical needs of the patient involve basic therapeutic measures such as those that promote healing, prevent infection, and decrease pain. Care of the operative site is essential for future functional and cosmetic value, but attendance to the physical needs should not preclude meeting psychosocial needs as well. The team should strive to keep the patient informed of the nature and purpose of various treatments and procedures, in order to increase his level of cooperation and sense of participation. Since the adolescent seeks immediate gratification, it is important to praise and reassure him as he makes efforts. It is also important to set several short term goals rather than a few long term goals to give the patient a sense of achievement and motivation for continuing his efforts. A chart of daily and/or weekly goals can be used when the patient is engaged in exercises to maintain muscle tone and circulation and prevent edema or atrophy prior to application of a prosthesis. A similar chart or checklist can be a helpful tool when the patient is learning to use and care for his prosthesis.

A supportive team will take steps to strengthen and maintain the body image of the adolescent. If not possible before surgery, the patient should speak with the prosthetist early in the postoperative period to help develop an understanding and allay fears and misconceptions regarding the prosthesis. It also allows the prosthetist to gain insight into the lifestyle and capabilities of the patient, factors that affect selection and application of the prosthesis. Since adolescents tend to be active individuals, durability of the prosthesis is a prime consideration. The patient should be allowed a role in making decisions that involve cosmetic versus functional aspects. Adolescent growth spurts require the prosthetist to anticipate more frequent prosthetic modifications than with other patients. These considerations along with early fitting and use of the prosthesis will allow the adolescent to incorporate the prosthesis into his body image more readily. Delay in use of a prosthesis can not only cause physical problems but also increases the number of psychosocial accommodations the patient must undergo.

Hospitalization interferes with peer relations which are very significant to the adolescent. The team must provide for means to maintain existing peer relations. When the patient is able to keep in contact with friends there are many beneficial effects. Peer visits not only provide diversion and recreation but offer support and encouragement. In addition, contact through the recovery process facilitates understanding and acceptance of the situation by friends. It can also alleviate the growing apprehension by the patient as to what his friends will think of him when he returns to his daily routine. Team members should review visitation policies and hospital recreation activities to insure for appropriate growth and development of the adolescent during his confinement. Access to a telephone, the lifeline of teenagers, is important especially when distance prohibits visiting.

The team should encourage interaction with other adolescent patients. These interactions are not only recreational but offer the patients an opportunity to share feelings and exchange information about their situations. These types of relationships are very supportive and beneficial.

The immobilization imposed by both the amputation and hospitalization can have a profound effect on independence. The adolescent finds the independence that he sought and was achieving gradually has been severely limited. This can lead to a high level of frustration and depression. Since the life experiences and coping mechanisms of the adolescent are not as developed as those of the adult, the health team must emphasize capabilities and talents, large or small, and help develop new ones when necessary. Allowing for choices in the daily routine is a simplistic yet effective way of giving a semblence of independence.

The entire health team must be mindful not to focus on the amputation to the point that sight is lost of the fact that a total individual is involved. A therapeutic environment will address every facet of the adolescent. The patient does not live in a vacuum, and will require physical and psychological support from family. Family members have also suffered a loss by this experience and are not apt to be supportive when their needs are not considered. Efforts must be made to help parents accept and understand the situation. The health team must be prepared to deal with parental needs that range from coping with guilt feelings to financial concerns. In the frenzy of activity to meet the needs of the patient, the needs of siblings can be easily neglected. The brothers and sisters need explanations of events and should be given opportunities to express their own fears and feelings. It is important that younger brothers and sisters understand that amputation will not necessarily happen to them when they get older. Siblings should be helped to understand why so much attention is directed to the patient, and how they themselves can be helpful. Undue focus on the patient will only increase his dependence and lead to misconceptions and conflicts within the family setting.

Summary

The health team must function to meet the needs of all patients in an holistic manner. Inherent in that concept is the understanding of the developmental stage of the patient. The needs of adolescents are different from those of children and adults and must be addressed accordingly. Though commonalities exist among the behaviors and needs of adolescents, individual differences must be anticipated. Interdisciplinary communication and application of the expertise of each team member will involve all facets of the patient and facilitate optimal recovery. The health team must implement a plan of care that is based on developmental concepts, yet formulated as individually as the prosthesis is designed.

Footnotes

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Prosthetic Management of High Bilateral Upper-Limb Amputees

A Case Report

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LARRY EICKMAN B.A.; R.P.T., C.P.[2]

In the December 1977 issue of Orthotics and Prosthetics, LeBlanc (1) noted that one of the future goals for upper-limb prosthetics is to give the bilateral, high level, upper-limb amputee a significant measure of independence. It is obvious that this type of patient has sustained a considerable loss, and clinically presents a very difficult problem. The Department of Prosthetics and Orthotics at the Medical Center Rehabilitation Hospital of the University of North Dakota has developed a prosthetic system that has been used with good success for amputees in this category (Fig. 1). Particular success has been noted with the bilateral upper-limb amputee with an above-elbow amputation on one side and an inter-scapulothoracic amputation on the other side. The prosthesis as developed, combined with a total comprehensive amputee rehabilitation program, has provided a significant level of independence for those amputees using it.

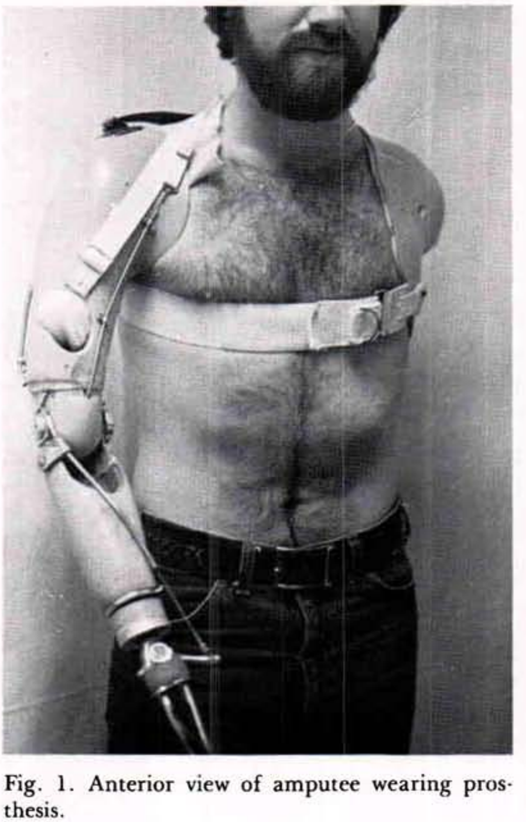

Fig. 1. Anterior view of amputee wearing prosthesis.

The case presented is that of a 24-year-old white male (Fig. 2) who sustained

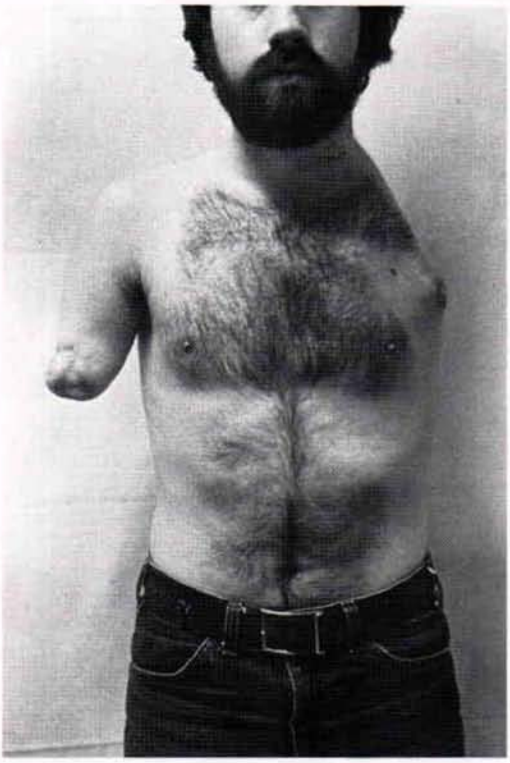

Fig. 2. Anterior view of amputee without prosthesis.

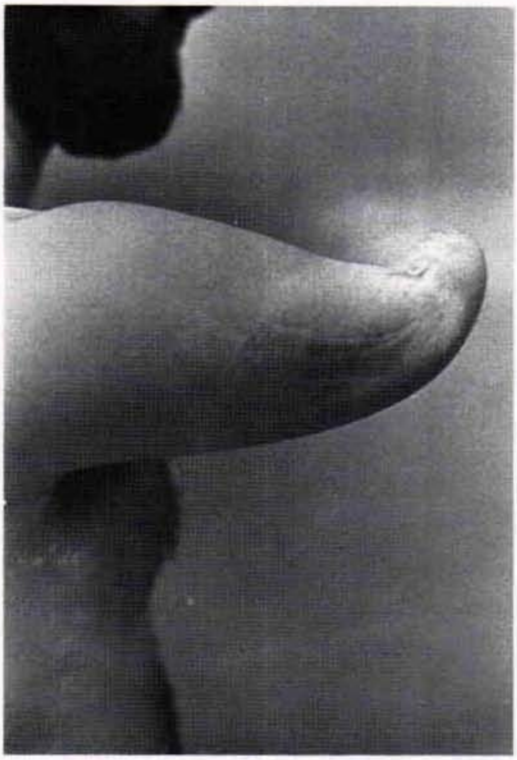

Fig. 3. Lateral view of stumps showing effect of humeral osteotomy

traumatic injuries in a farming accident. Clinical examination revealed a forequarter amputation on the left. Skin coverage is good with a minimal amount of scarring. On the right side is an above-elbow stump approximately five inches long. A wedge osteotomy had been performed on the distal three centimeters of the humerus resulting in an anterior angulation of approximately 55 degrees (Fig. 3). Range of motion and strength of the shoulder were essentially normal.

The primary goal of prosthesis system design centered around providing this amputee with optimal appliance function without sacrificing his functional level of independence. It was obvious that included at this level of function is the necessity of donning and doffing the prosthesis without assistance. Preliminary research also dictated that a stable point of fixation must be included in the design to provide two essential functions: 1) support and suspension of the appliance when being worn and used, and 2) maximal efficiency of the cable-type control system.

An above-elbow prosthesis was fabricated for the right side. The design took advantage of the presence of the humeral osteotomy, which proved to be very valuable in facilitating "live lifting" and control of rotation of the socket about the humeral axis.

Because the patient placed very heavy demands on the appliance, specific consideration had to be given to the function and effect of the wrist unit. Initially a

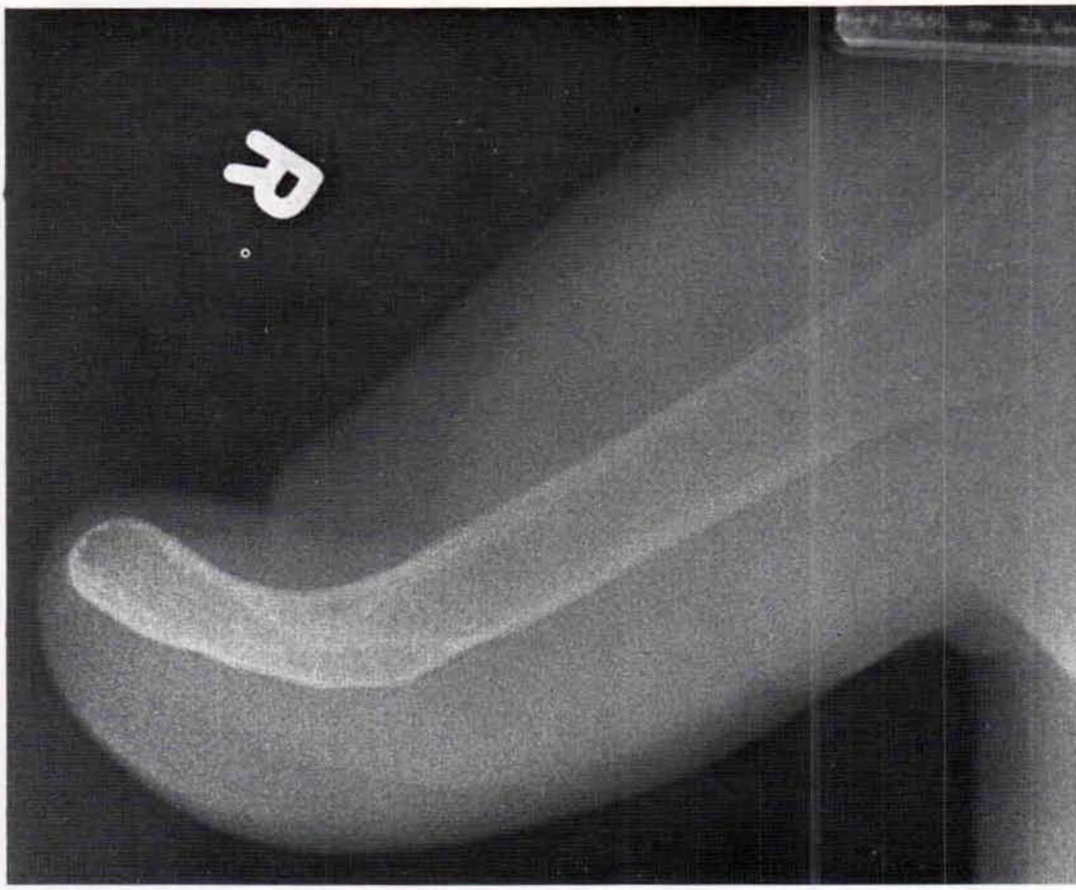

Fig. 4. X-ray view of stump showing humeral osteotomy

Hosmer Flexion Wrist (FW-500) was used, and it provided adequate accessability to the body with use of the prosthesis in the areas required for personal hygiene and eating, but finite control of wrist rotation was not consistent. It was also very difficult for the patient to be adjusting the friction mechanism constantly. In order to remedy the problem, a Hosmer Quick Change Wrist (FM-100) was used for attachment of the flexion wrist (Fig. 4). With this adaptation, terminal device flexion could still be accomplished with the rotation locked out of the flexion unit, and control of pronation-supination was then managed with the FM-100 rotation element. This combination ultimately proved to be very satisfactory.

With the appliance properly fabricated, emphasis was shifted to a harness system that would offer an effective point of fixation without impeding the amputee's ability to get into and out of the unit independently. A shoulder cap that provided three functions was fabricated for the left side. First, it serves as a cosmetic body build-up. Second, because approximately three and one-half pounds were incorporated into it during fabrication, the patient feels that he has proper body balance when wearing and using the

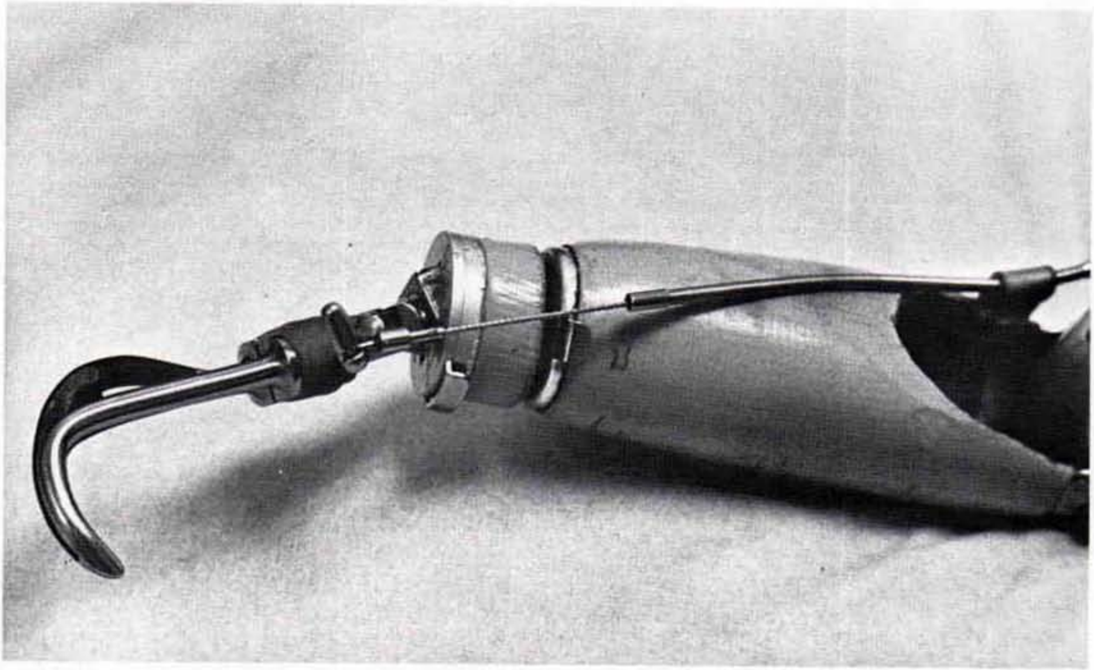

Fig. 5. View of prosthesis showing wrist components.

prosthesis. Third, it was designed to serve as a stable point to properly support and suspend the appliance and to provide an anchor point for the control system.

Some problems soon became evident, however. When only a chest strap harness was used, the shoulder cap migrated posteriorly when the prosthesis was activated, the motion being caused by the forces transmitted from the control attached to the shoulder cap, and the other end attached to the above-elbow steel strut, (Fig. 6), with one end being attached to the shoulder cap, and the other end attached to the above-elbow socket. It should be noted that the point of attachment on the socket is critical, since it must be located as near as possible to the center of rotation of the shoulder when viewed from the transverse plane. This connection was made possible by the design and fabrication of a shoulder joint (Fig. 7) which allowed for shoulder flexion, extension, and rotation (Fig. 8). Abduction and adduction are possible because of the spring in the strut.

With the strut and shoulder joint fixed in proper alignment, a constant distance between the fixed point of the control strap on the shoulder cap and the above-elbow socket is guaranteed. With this insurance, all excursion generated by the motions of humeral flexion and shoulder protraction is available to operate the elbow mechanism and the terminal device, with no loss of effort due to excessive harness migration (Fig. 9).

Donning and doffing the prosthesis was not a problem. The chest strap harness was modified so that it can be opened and closed by using the prosthesis. Because of the rigidity of the posterior strut, both sockets became essentially one integral part in a functional position, thus allowing the amputee to get into and out of the appliance without assistance.

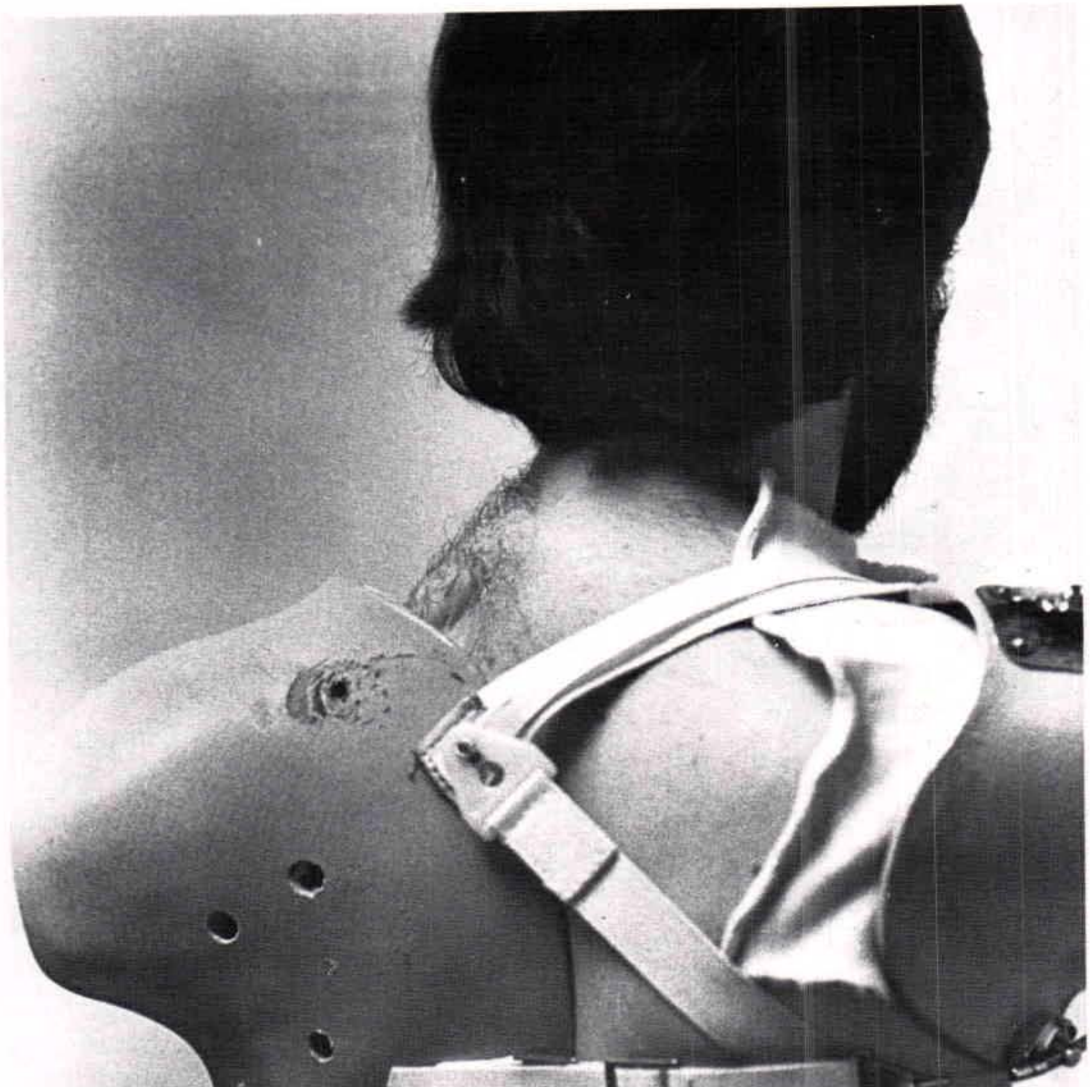

Fig. 6. View showing migration of shoulder cap when conventional harnessing is used.

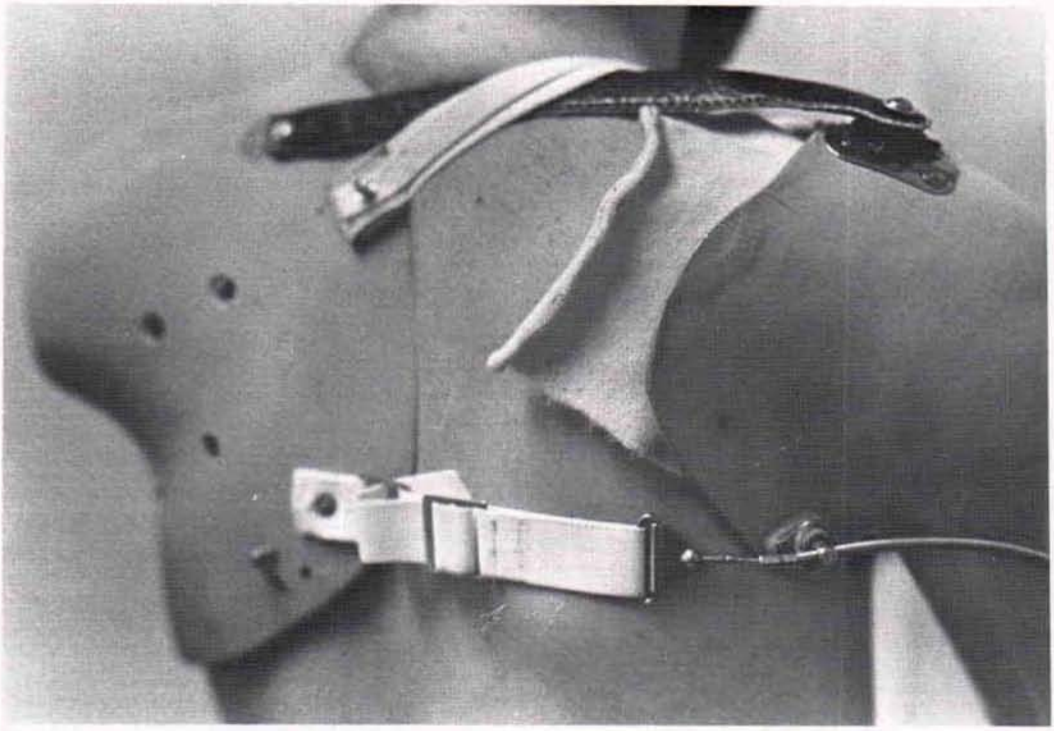

Fig. 7. The posterior strut in place.

Fig. 8. Lateral view of prosthesis showing shoulder joint.

Results and Conclusions

This case report demonstrates the adaptation of a prosthetic device for the high level, bilateral, upper-limb amputee. The client, a 24-year-old white male, with traumatic, bilateral, upper-limb amputations, had attempted to use commercially available electric elbow-hand components on the left side. However, because of recurring mechanical failures of the elbow, and because of a decreased level of independence, especially in the areas of dressing and undressing, it was his desire to go on with only the unilateral appliance which has been presented. This particular amputee has been using the prosthetic system described here for the past two and one-half years. He has demonstrated a very significant, high level of independence. He has now graduated from the University, and during his last two years as a student was indepen-

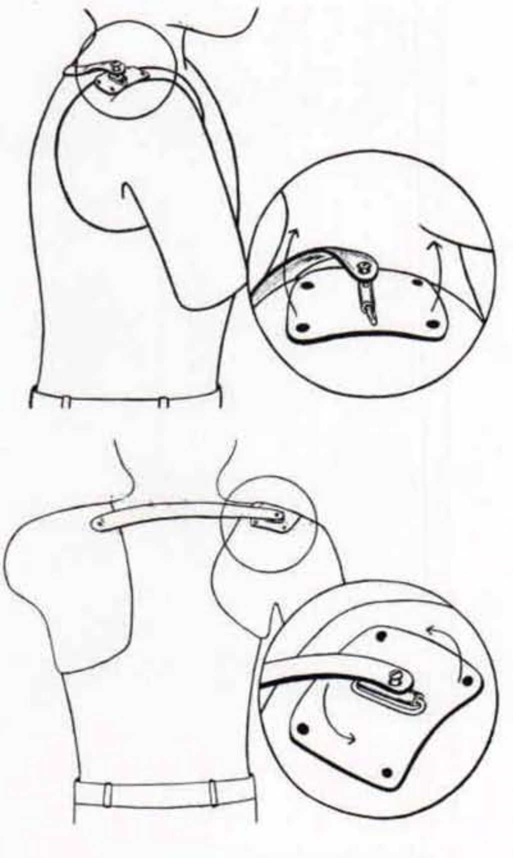

Fig. 9. Two schematics demonstrating motion allowed by shoulder joint and strut.

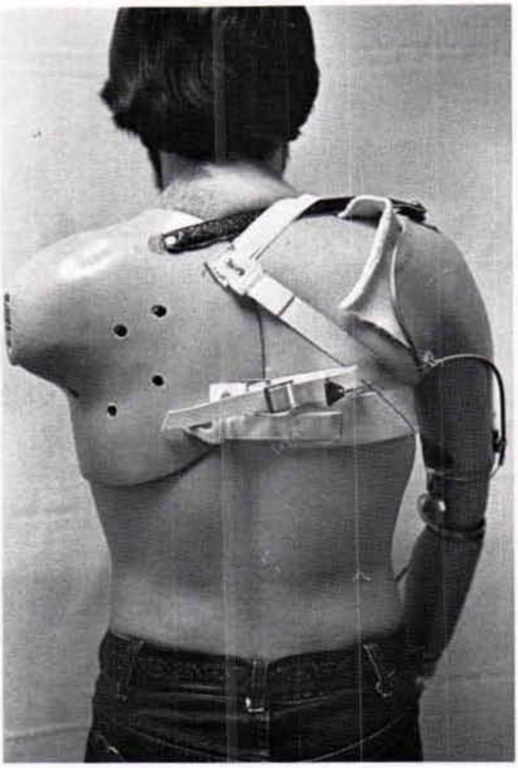

Fig. 10. Posterior view of the prosthesis.

dent in all self care skills. Summer employment has consisted of maintenance work for a custodial firm. His hobbies continue to be those of skiing, hunting, and fishing.

Footnotes

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A New Material in Orthotics and Prosthetics

MELVIN STILLS, C.O.
A. BENNETT WILSON, JR.

Thermosetting plastics were first introduced into prosthetics for fabrication of sockets and structure components for artificial arms about 1952 (3). Although thermosetting plastics have disadvantages, their use in both upper-and lower-limb prosthetics has grown to the point where it is now rare to see a socket formed of any other material. However, when orthotists and engineers tried to use thermosetting plastics in orthopaedic bracing they found that the laminates fail quickly when subjected to the repeated bending loads that occur during use of functional lower-limb orthoses.

Although Volume I of the Orthopaedic Appliances Atlas (7), which was published in 1952, contains a detailed description of the use of vacuum to form cervical orthoses from the thermoplastic, Plexiglass, it was not until about 15 years later that serious efforts were made to use thermoforming of sheet plastics in fabrication of orthoses or prostheses.

The first reference to thermoforming sheet plastics in lower-limb orthotics seems to be a brief article by Gordon Yates that appeared in a 1968 issue of *Orthopaedics, Oxford* (9), and in which he describes a simple ankle-foot orthosis made of polypropylene. Stimulated by presentations made by Dr. Yates during a visit to North America in 1969, research and development groups in Canada and the United States began using sheet plastics, especially polypropylene and polyethylene in serious experimental work (1,2,4,5,6). Clinical application of the results of these studies has spread gradually, and these techniques are now taught in the formal prosthetic and orthotic education programs (8).

Because of a combination of characteristics, especially low forming temperatures and resistance to fatigue in bending, polypropylene and polyethylene have proven to be extremely useful in nearly all types of orthoses where high unit stresses are present. Orthoses formed from these materials not only are usually lighter in weight but present a neater appearance as well. However, no material is perfect in all respects, and because the relatively small volume needed in orthotics when compared to other fields precludes the expenditures required to develop materials specially "tailored" to orthotics, every orthotist is on the lookout constantly for new plastics as they become available commercially, and contemplates whether or not it has a place in orthotics.

Surlyn, a thermoplastic whose main use for a number of years seems to have been for golf ball covers, is the latest example of such a material. Physical char-

SOME MECHANICAL CHARACTERISTICS OF THREE THERMOPLASTIC MATERIALS

Characteristic	Units	Polypropylene	Polyethylene	Surlyn (Thermo-Vac)
Tensile Strength	PSI	4080	4200	4500
Elongation	%	390	500	380
Specific Gravity	%	.904	.940	.950

Table 1

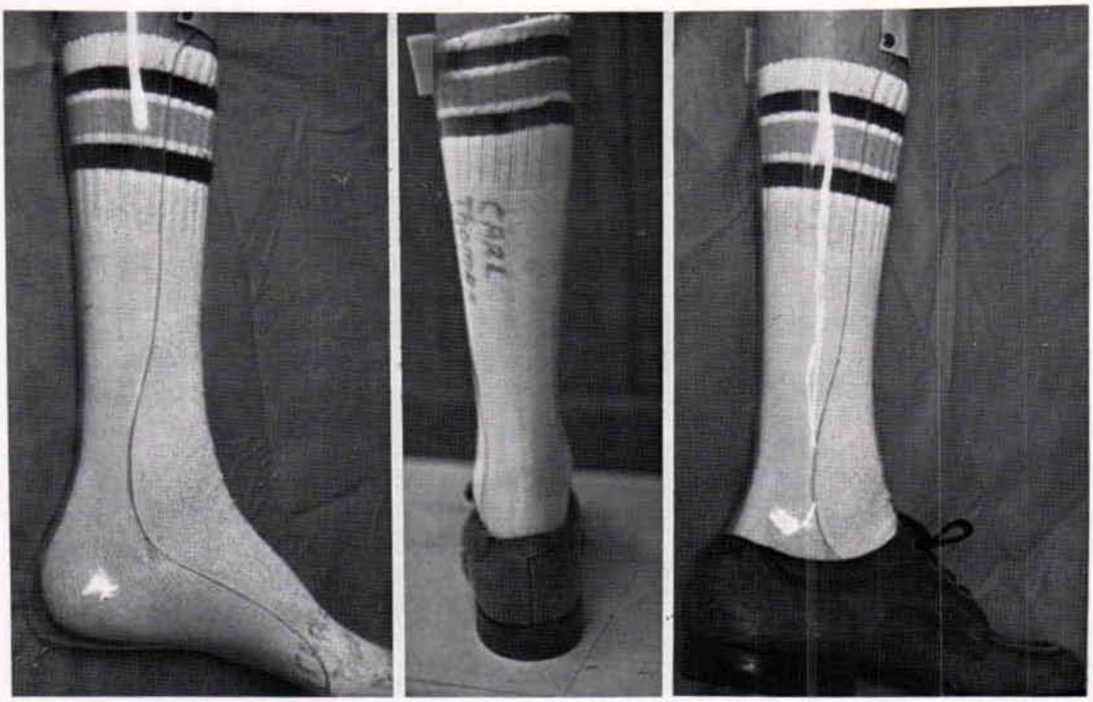


Fig. 1. Three views of a typical ankle-foot orthosis made of Surlyn.

acteristics (Table 1) of Surlyn, are quite similar to polyproplyene, but, in addition, it is transparent (Figs. 1 & 2). A sheet ¼-inch thick is almost totally transparent, and newsprint can be read through sheets of greater thickness. Surlyn is also more flexible than polypropylene.

Surlyn is the DuPont Company's registered trademark for ionomers which are resins consisting of thermoplastic polymers that are "ionically crosslinked." The ionomers are derived from ethylene/methacrylic acid copolymers and thus posess many of the characteristics found in olefin polymers such as polyethylene

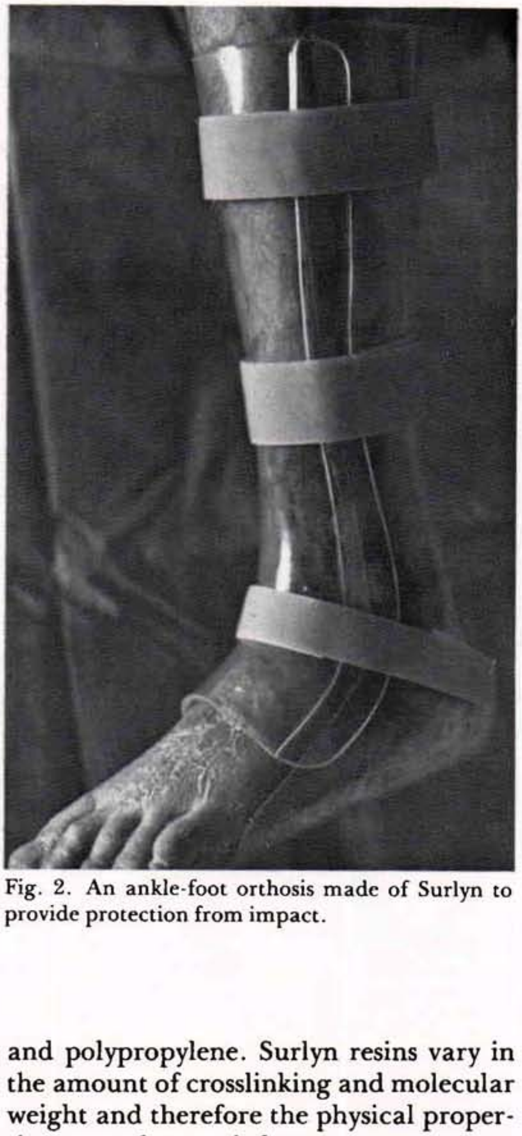


Fig. 2. An ankle-foot orthosis made of Surlyn to provide protection from impact.

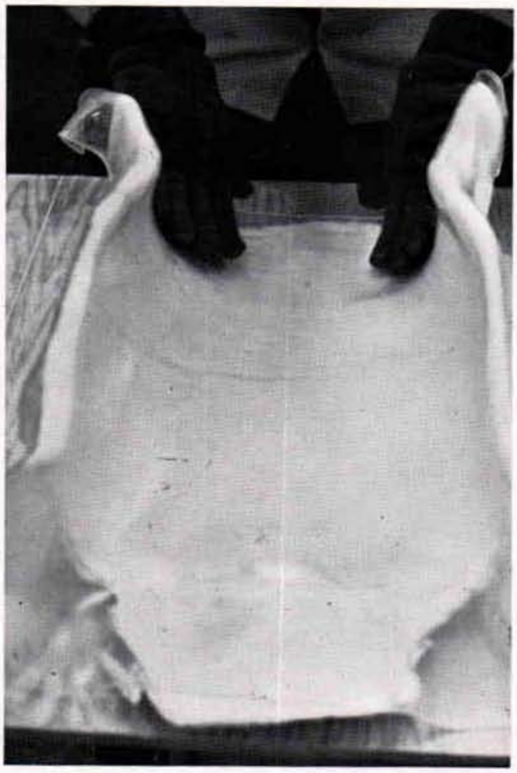


Fig. 3. Surlyn can be molded to the concave side of a body cast to eliminate need for a positive model in some instances.

and polypropylene. Surlyn resins vary in the amount of crosslinking and molecular weight and therefore the physical properties can be varied to some extent. Thermo-vac is the name given by U.S. Manufacturing Company[2] to the type of Surlyn most useful in orthotics and prosthetics.

Surlyn can be formed in the same manner as polypropylene, the working temperature range being from 200 to 500 degrees F. The temperature used varies according to the amount and type of forming to be done and the thickness of material being worked. The selection of time and temperature varies according to the job and the technique used for forming. Hand draping of the material to the concave side of a negative spinal impression (Fig. 3) is probably best done at 250-350 degrees F. with an oven time of approximately 7 minutes. Higher temperature and time of exposure permit more penetration of the heat causing the plastic to become more fluidlike, and thus permitting more and better forming detail. The use of vacuum for forming ¼-inch thick Surlyn contained in a frame is best done with an oven temperature of from 350 to 400 degrees F. and an exposure time of approximately 7 minutes.

Of course, the selection of thickness of material is dependent upon the amount of immobility required and control desired in the orthosis. Obviously, the thinner the material, the less heat and time needed to bring it to a formable state. A desirable characteristic of Surlyn is that it can be formed about a wet, cold cast without producing appreciable internal stresses or expansion of the orthosis after it is removed from the model and trimmed. It can be formed directly over the model without a cloth or any other type of barrier between the material and the model. The degree of clarity to a great extent depends upon the smoothness of the surface of the model.

More than 200 spinal, upper-limb, and lower-limb orthoses, have been fabricated from Surlyn at this institution. Examples of various applications are included in the following Case Reports:

I—A patient with a peripheral neuropathy that resulted in drop foot, secondary to second-and-third-degree burns over the majority of his body, has problems with hypertropic scarring, contractures, fragile skin, and volume changes that do not permit the use of conventional polypropylene materials. A plaster cast was taken and an AFO was fabricated from Surlyn. Total contact was provided to aid in control of the scarring. Because of the flexibility of Surlyn no pressure lines appeared along the borders of the orthosis and sufficient rigidity to maintain the foot and ankle in a neutral, 90-degree angle was achieved as a result of the shape of the cross-section. The patient can walk with a heel-toe type of gait, is free to don and doff the AFO independently, and can change shoes to meet his immediate needs.

II—A young female patient with a closed head injury resulting in hemiplegia required an orthosis to prevent drop foot. The patient exhibited a mild degree of spasticity in the plantar flexors while the plaster impression was being made. An ankle-foot orthosis was fabricated from Surlyn that prevented the foot from dropping (Fig. 4). The patient is able to ambulate with a heel-toe gait using an orthosis that is cosmetically acceptable to her.

Fig. 4. The ankle-foot orthosis provided case II.

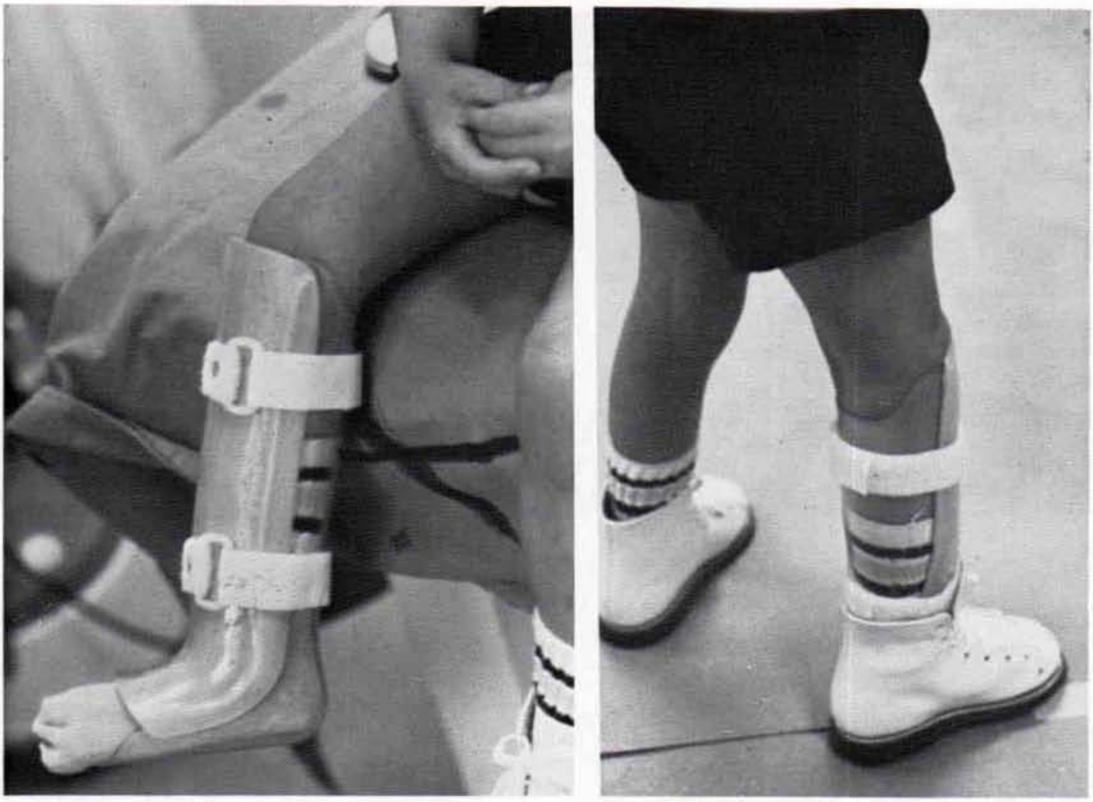
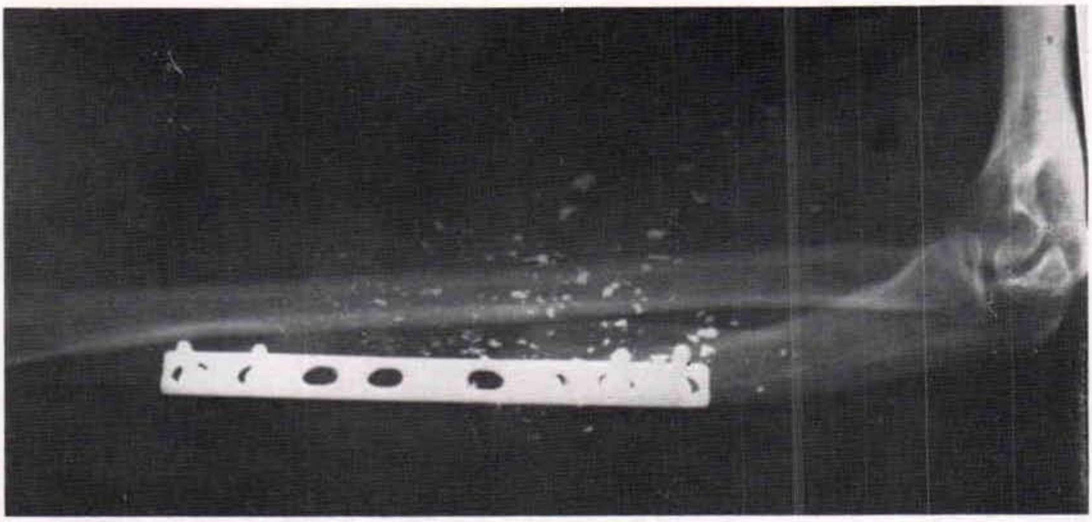


Fig. 5. The ankle-foot orthosis provided case III.

III—A young child with a psuedarthrosis of the tibia and fibula has had three recurrent fractures in the same location and had worn a conventional metal orthosis and numerous casts. A total-contact posterior-anterior shell was molded over a positive plaster model to provide complete circumferential control (Fig. 5). The orthosis, which requires no shoe modifications, was used to manage the fracture during the acute stage, and afterwards to prevent recurrence.

IV—A patient with a non-union of the ulna having approximately 4 cm of bone missing required an orthosis to stabilize the forearm, while permitting voluntary flexion and extension about the elbow, but inhibiting supination and pronation of the forearm. An orthosis was fabricated consisting of a distal section that contains and controls the forearm about the elbow, a polycentric joint at the elbow to permit voluntary flexion and extension but inhibiting supination and pronation, and a proximal section to provide the stability needed (Fig. 6). Owing to the nature of Surlyn the orthosis can be adjusted to the patient, and therefore we do not feel that it is necessary any longer to make this type of orthosis on an individual basis. Left and right models in three different sizes are maintained for a modified off-the-shelf type fitting program.



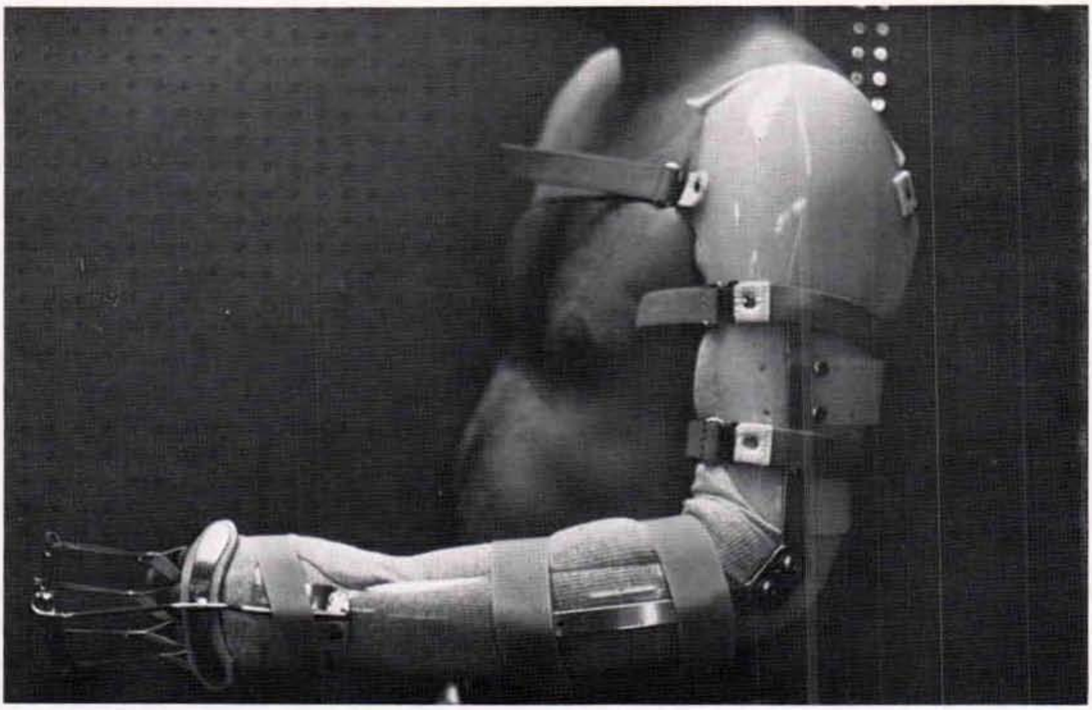


Fig. 6. Upper photo: x-ray of forearm of Case IV; lower: lateral view of the orthosis provided Case IV.

V—Patient sustained vertebral fractures of C7 and T9 and has had Harrington rod instrumentation for her thoracic fractures. A prescription was written asking for an anterior-posterior molded plastic spinal jacket with a SOMI cervical orthosis attached. The spinal jacket was to cover the area between the sternal notch and the symphysis pubis anteriorly and between the sacrum and T3 posteriorly. A plaster-of-Paris cast of the patient was made, and the positive model was modified and corrected in the usual manner. Surlyn was vacuum formed over

Fig. 7. The body jacket with SOMI cervical orthosis attached provided Case V.

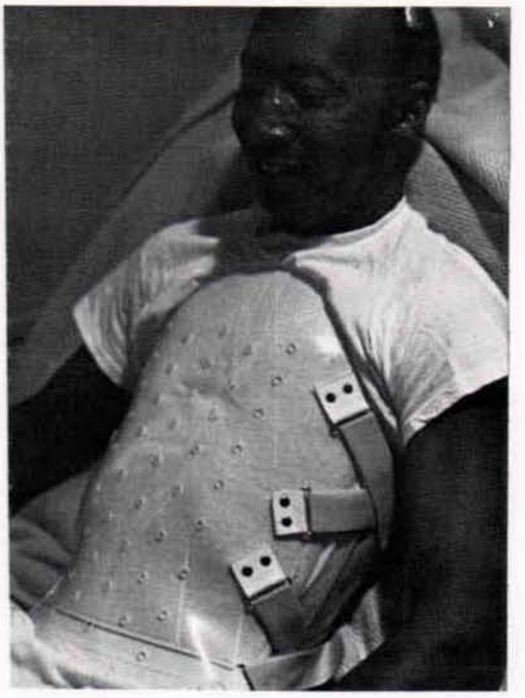


Fig. 8. Antero-lateral view of body jacket provided Case VI.

the model in a two-stage procedure. The posterior section was formed and trimmed, replaced on the model, and the anterior section was formed. At the time of the first fitting, the SOMI orthosis was attached, final trimlines were established, and the definitive orthosis was fitted the following day (Fig.7) This patient has no neurological deficits. She progressed from wheelchair to limited ambulation quickly and now is fully ambulatory and independent in ADL with her orthosis.

VI—Patient sustained compression fracture of T9 as a result of bone demineralization. A prescription was written for an anterior-posterior spinal jacket extending anterioraly from the sternal notch to the symphysis pubis and posteriorly from the sacrum to T3. A routine plaster-of-Paris cast was taken and normal procedures for modification of the positive were followed. Surlyn was vacuum formed in two stages as in Case V (Fig. 8)

A posterior view of the spinal orthosis is shown in Figure 9. The patient is primarily a wheelchair user, and does very limited ambulation.

VII—Patient was three-months post-Harrington rod instrumentation for correction of idiopathic scoliosis. Posterior section of her orthosis was formed using the concave side of the plaster jacket which she had been wearing for three months. An anterior section of cloth was used. The orthosis (Fig. 10) provides lateral stability while permitting limited anterior flexion. It was formed and fitted in a total time of approximately three hours.

VIII—Patient sustained a navicular fracture while working as a scrub nurse on the Orthopedic Service. Prescription was written for a long opponens orthosis

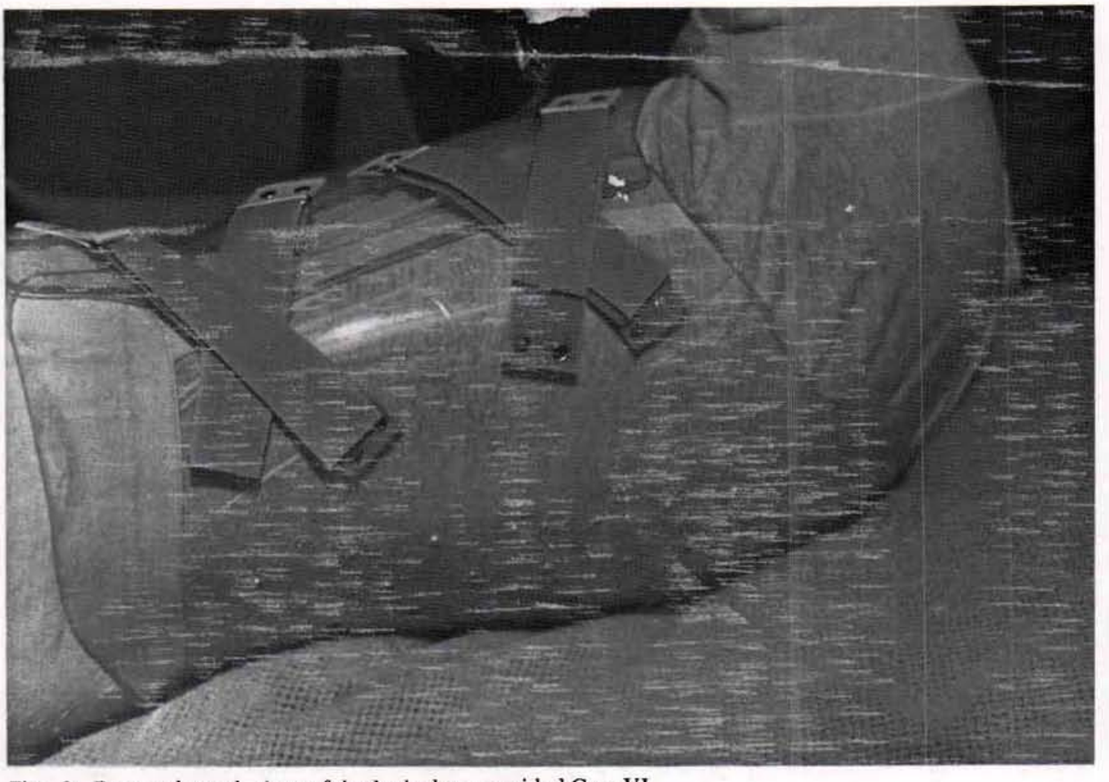


Fig. 9. Postero-lateral view of body jacket provided Case VI.

with a thumb post to stabilize the navicular fracture. A plaster-of-Paris cast was taken and the positive model was modified in a routine manner. The patient was placed in a short arm navicular fracture cast and returned to the Orthotic Clinic the following day for fitting of the Surlyn orthosis. Patient continued in her duties in the OR as a circulating nurse and no time was lost from work.

Conclusions

Experience at our center which has been limited to applications in orthotics, indicates that Surlyn is the material of choice where more flexibility is desirable than that provided by polypropylene. Use of Surlyn in body jackets and upper-limb orthoses seems to be especially desirable. Fewer applications seem to be indicated in lower-limb orthoses where high unit stresses are expected.

Other centers are encouraged to experiment with Surlyn in both orthotics and prosthetics.

Acknowledgement

We wish to express our appreciation for the assistance provided us by J. Morgan Greene and George Irons of the United State Manufacturing Company[2] in carrying out this study.

[1]Division of Orthopedics, University of Texas Health Science Center at Dallas, 5323 Harry Hines Boulevard, Dallas, Texas 75235.

Fig. 10. Posterior view of body jacket provided Case VII.

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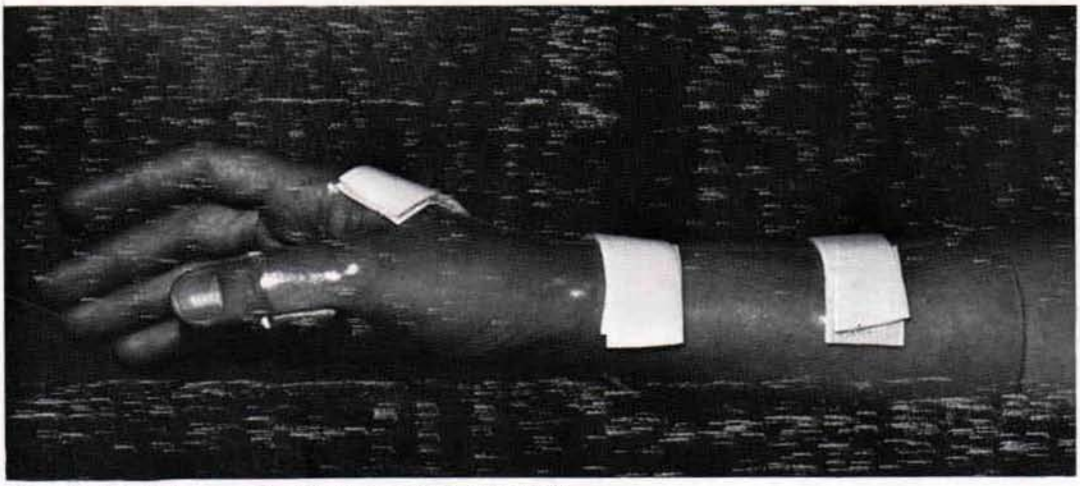

Fig. 11. Medial view of orthosis provided Case VIII.

Orthotics and Prosthetics, Vol. 34, No. 3, pp. 38-40, September 1980

Rationale for Orthotic Residency Programs

TERRIE L. NOLINSKE, C.O., O.T.R.[1]

Although not yet required by the American Board for Certification in Orthotics and Prosthetics (A.B.C.), a formal orthotic residency is extremely important in continuing the education of a prospective orthotist for several reasons. First of all, while attending the orthotics certificate program at Northwestern University Medical School's Prosthetic-Orthotic Center (NUPOC), the student spends only five and one-half months attending lectures, clinics and working in the lab. This represents a total of 678 hours, as compared to the 430 hours required by A.B.C.

The student spends time learning basic principles, biomechanics, characteristics of available components, fabrication methods and pathologies as they relate to spinal, upper-, and lower-limb orthotics. But how much can be digested and integrated in that short time period? This five and one-half months is of necessity only an introduction to the field of orthotics. Upon graduation, the student needs a structured environment in which he may feel secure to practice those basic skills learned without the pressure of producing devices and making money for a facility or institution.

Secondly, a shift in orthotic education has produced a need for the orthotic residency. In 1967, NUPOC began teaching short term orthotic courses. Students came with orthotic technician experience and some patient contact; few had clinical experience. Few knew the biomechanics necessary to design an orthosis, and that is what they came to learn. They needed to find a rationale for what they were doing in the laboratory.

The short term orthotic education changed when, in 1972, A.B.C. issued the statement saying that by 1983 short term courses by themselves would no longer be acceptable in fulfilling requirements towards orthotic certification. NUPOC then began offering long term orthotic certificate courses where, in five and one-half months, orthotic academic education would be complete. The certificate program attracted many students with no previous orthotic background, although some came from such related fields as occupational and physical therapy.

The residency program was begun in 1977 by James Russ, C.O., Director of Orthotics at NUPOC in order to ease these students into the world of clinical orthotics. The residency was designed as an option to give the student work experience under actual clinical conditions, away from the shelter and control of the school. It was established to give the student with no prior orthotic experience a chance to gain supervised experience in the areas of spinal, upper and lower limb orthotics. It was designed to give students patient contact, and to familiarize them with clinical situations as well as working with other members of the rehabilitation team. The residency also gave the student work experience needed to meet A.B.C. requirements for the orthotic certification exam.

Considerations in Placement

There are four basic considerations when placing a student into a residency site. First, the student's preference for geographic location is considered, for this is often conducive to maintaining a good mental attitude. Secondly, the residency site must be able to absorb the cost of a resident. It must be clear to all involved that the resident is there to learn and contribute whatever he can, but not make money for the employer. Thirdly, the resident must be supervised by a certified orthotist working in an accredited facility or institution, the ideal ratio of supervisor to student being one to one. Finally, the ideal supervisor may be a person who himself received orthotic education in a clinical university setting versus a technical program. This academic mutuality allows the supervisor to empathize with the resident's experience in academia as well as to remind him how little one really knows upon leaving school!

Once the geographic location is established, it becomes a matter of selecting a residency site within those confines that meets the three criteria previously described. This process involves conversations between NUPOC, prospective supervisors and the student. Calls are made to hospitals, private facilities and rehabilitation centers in order to assure the student the most balanced orthotic experience possible in that particular location.

Residency Program Objectives

After the residency site is established to everyone's satisfaction, the final details are worked out, with both supervisor and student being informed of the program objectives, time allotments, remuneration and residency content structure.

Program objectives help assure that the resident is exposed to extensive patient contact and patient evaluation experience, clinical contact with emphasis on the clinic team approach as well as technical skills and fabrication techniques. Patient management with concentration on biomechanical and pathological considerations should also be addressed.

Time allotment for the residency is usually one year following successful completion of the orthotic certificate program, with time off for standard holidays as recognized by the employing facility or institution. Remuneration for the year's residency may range from ten to eleven thousand dollars, varying with the geographical location.

Residency content will vary. The first established residency program was at Mary Free Bed Hospital in Grand Rapids, Michigan. This program, under the auspices of Greg Fryling, C.O., involves extensive work in the hospital orthotics laboratory and attendance at a variety of local clinics.

By contrast, four NUPOC residents yearly undergo an intensive residency program under the direction of Thomas Lunsford, M.S.E., C.O., at Rancho Los Amigos in Downey, California. The residents rotate through six specialty areas including strokes, post-polio, muscle disease, spinal injury/deformity, cerebral palsy and fractures. They are responsible for their caseloads as well as the supervision of other students. There is also a 120-hour lecture series which has been assembled to acquaint residents with advanced biomechanics, pathologies, and orthotic designs. Residents are required to give frequent oral presentations to staff and other residents as well as to conduct research. A certificate is awarded at the end of the residency program.

Other formal placements have included the University of Kansas Medical Center, under the direction of Paul Trautman, C.P.O., where residents gain experience with a hand rehabilitation program, and a six-month residency in pediatrics at Gillette Children's Hospital in St. Paul, Minnesota, supervised by Martin Carlson, C.P.O.

Regardless of how it is achieved, each residency should afford the residents extensive patient contact, and opportunities to deal with other members of the clinic team. They should attend special clinics and grand rounds at institutions and hospitals in the surrounding area, increasing their own involvement in such clinics as the year progresses. Clinical content of the residency must allow the resident to become proficient in patient evaluations, taking measurements and impressions, cast modifications and general fabrication techniques used in designing spinal, lower- and upper-limb orthoses. It is important that the resident achieve a level of competency in all of these areas and be instructed, when necessary, in any special techniques in patient mangement or fabrication. Regularly scheduled meetings between resident and supervisor should provide feedback in meeting these goals.

Follow-Up

In an attempt to both follow-up NUPOC residents and provide an on-file information for future students, a four-page form was adapted and sent to supervisors at residency sites. The form includes such information as the type of facility or institution involved, professional/experiential background of employees, types of field experiences offered other than orthotics, types of services to which orthotics residents may be exposed, as well as work hours, dress code, reimbursement, medical and insurance policies. Any behavioral objectives and additional comments that the supervisor wishes to make may be included on this form.

Whether the residency site is established through NUPOC or independently by the student himself, most students do take advantage of some residency program. They find that even though the income is minimal, the residency structure provides them with an opportunity to continue the clinical portion of their academic education in a relatively low-key environment. After the year's residency, some residents are given a promotion and join the staff, while others move on to a different setting and new challenges. Either way, both the employer and resident have gained new information and insights into the practice of orthotics from both an academic and clinical point of view.

Acknowledgements

The author would like to thank Mr. Charles Fryer, Director of Orthotics and Prosthetics and Mr. James Russ, C.O., Director of Orthotics, both of Northwestern University Medical School's Prosthetic-Orthotic Center for their assistance in preparing this article.

Footnotes

[1]Assistant Director of Orthotics, Northwestern University Medical School's Prosthetic-Orthotic Center, 345 E. Superior Street, 17th floor, Chicago, IL 60611.

Orthotics and Prosthetics, Vol 34, No. 3, pp. 41-45, September 1980

Technical Note

Cosmetic Hand Prosthesis—A Case Report.

A 60-year-old woman, who had lost her right hand in an accident involving a corn-picking machine, was referred to the Facial Prosthetic Laboratory, University of Iowa, for the fabrication of a hand prosthesis. The remaining part of her hand (Fig. 1) had been covered with grafts raised from the abdomen, and it felt soft and spongy. The patient insisted that she be provided with

Fig. 1. The stump and contralateral hand.

Fig. 2. The wax skin invested to its widest diameter in dental stone in a metal flask.

a cosmetic prosthesis that would match her own left hand. She agreed to remove the prosthesis when working around the farm and in the kitchen if one were provided.

Arrangements were made for her to be available for four consecutive days. A lady whose right hand matched the patient's left hand in size, length and thickness of fingers, approximate shape of fingernails, and overall age-appearance agreed to serve as a model for the cast.

An Alginate[1] impression was taken of the donor's hand and lower arm up to the intended length of the prosthesis. The impression was filled and emptied repeatedly with a mixture of 50 percent beeswax and 50 percent paraffin until a wax "skin" with an even thickness of approximately one mm was obtained. An Alginate-impression was also taken of the patient's stump and lower arm and filled with dental plaster.

After the wax skin made from the impression of the donor's hand and arm was split on the under side of the arm and through the palm area, it was softened carefully in warm water, pushed over the patient's stump, and molded to the shape of the stump. The position of the wax skin was corrected to match accurately the position of the patient's own hand while it was in the "hanging" position. The wax skin was then removed and placed onto the plaster replica of the stump. The missing wax skin in the palm was added and sculpted. Characteristics of the patient's left hand, such as shape and size of fingernails, protruding veins, etc. were now reflected exactly in the wax model of the right hand.

The wax skin was then invested along its long axis in dental stone in a metal flask up to the point of widest diameter of arms and fingers (Fig. 2). After a separator was applied to the dental stone, the upper half of the flask was filled with dental stone. The wax was softened by immersing the flask in boiling water before it was opened (Fig. 3). Copper wires were fixed into the plaster stump model (Fig. 3) to serve as armatures for the

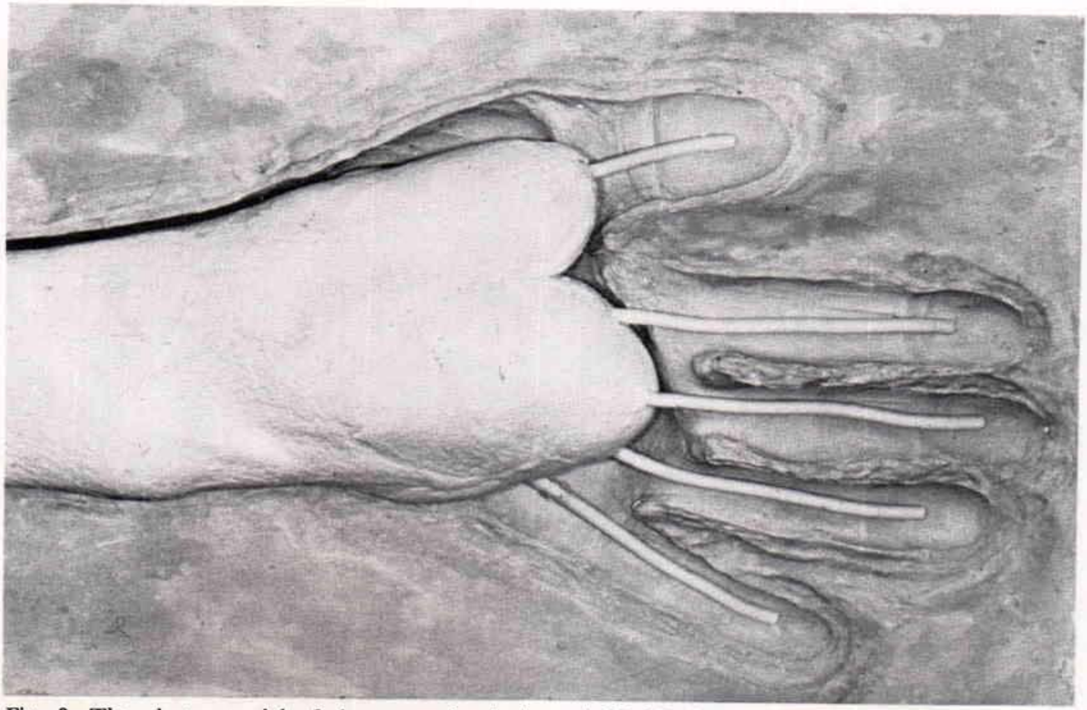

Fig. 3. The plaster model of the stump in the lower half of flask after the wax has been removed and the copper wire armatures have been inserted.

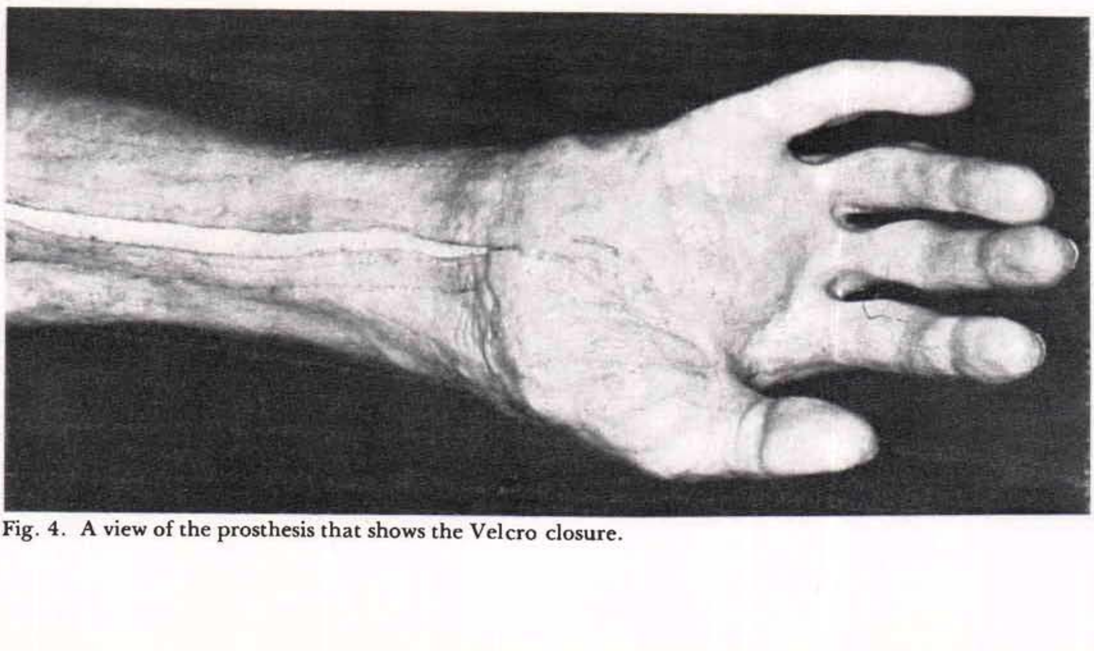

Fig. 4. A view of the prosthesis that shows the Velcro closure.

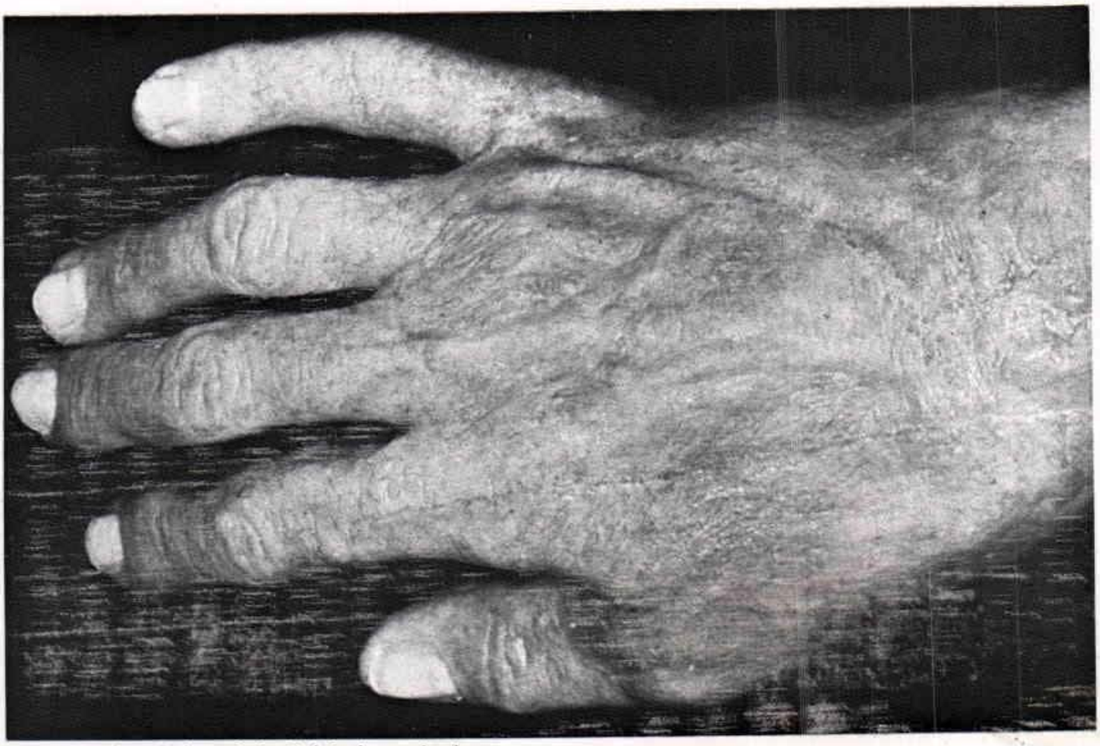

Fig. 5. A dorsal view of the finished prosthesis.

Fig. 6. The finished prosthesis in place.

fingers and thus allow the patient to bend the fingers of the finished prosthesis passively to any desired position.

The Silicone[2] material is colored with Rayon Flocking[3] and then packed into the dental stone mold. The flask is closed and the material is polymerized. The Silicone skin is recovered from the investment stone and the plaster model of the stump, and then cleaned thoroughly.

It was necessary to slit the Silicone skin on the underside of the arm and palm area to the point of the largest diameter of the stump to allow the positioning without tearing of the Silicone material. A Velcro[6] closure was sewn into the cut to give retention of the prosthesis (Fig. 4).

The arm, hand, fingers, and fingernails were colored on the outer surface to match the patient's unimpaired hand. A few hairs were incorporated into the arm (Fig. 5).

The patient was instructed in proper care of the prosthesis. The prosthesis in situ is shown in Figure 6.

According to the author's experience with facial prostheses, the Silicone material will outlast the material that has been used for years in factory-made hand prostheses. Silicone will resist discoloration and staining when cared for properly.

The photographs accompanying this note are the work of Ruben Barreras, for which we are grateful.

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Footnotes

[1]The L.D. Caulk Company, Milford, Delaware
[2]Dow Corning Corporation, Midland, Michigan
[3]Claremont Flock Corporation, Claremont, New Hampshire

Orthotics and Prosthetics, Vol. 34, No. 3, pp. 46-48, September 1980

Technical Note

Whangarei Spina Bifida Orthosis

As a reader of *Orthotics and Prosthetics* for many years, I have appreciated its contents and the help it has given me as an orthotist. I would like therefore, to offer a contribution as a small return for all the information the American Orthotic and Prosthetics Association members have so generously given me.

The number of children in our Spina Bifida Center at the Northland Base Hospital, Whangarei, New Zealand is small enough so that the Orthotics Department is able to provide special devices and modifications to accepted ambulatory orthoses when such modifications seem indicated. Publication of the details of the ORLAU[1] Swivel Walker (4), no doubt reminded orthotists of their own experience in modifying earlier designs of ordinary calipers, the dynamic orthotic system of Glancy (1), the swivel walker of Motloch (2), the Shrewsbury Splint (3), or the Standing Brace Mark II (5).

The development of the English "ORLAU[1] ORTHOSIS" has prompted me to outline the construction details of our successful method of marrying two concepts, the Parapodium and the Shrewsbury Swivel Walker, to produce a rigid body support frame with no hip or knee joints but one that allows some degree of locomotion.

Anterior and lateral views of the Whangarei Spina Bifida Orthosis are

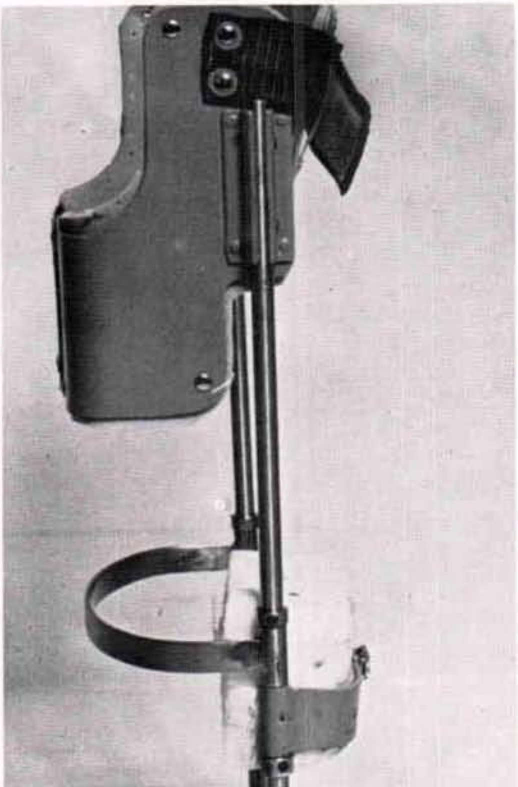

Fig. 1. Lateral view of the Whangarei Spina Bifida Orthosis.

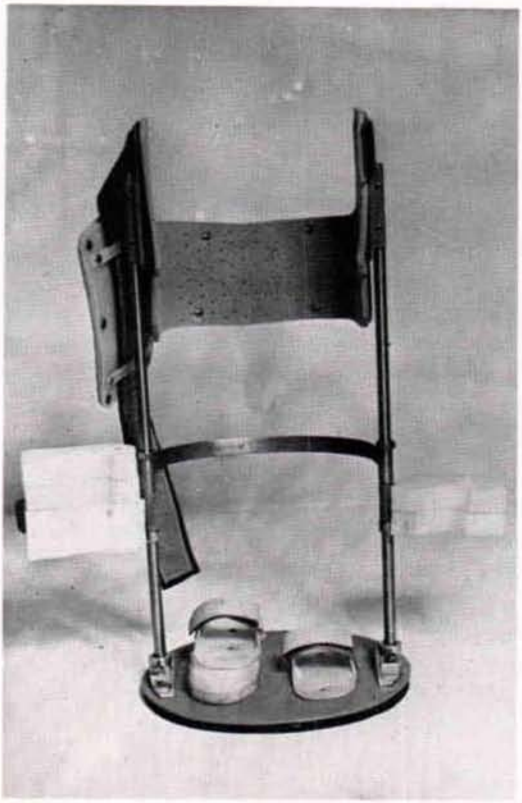

Fig. 2. Anterior view of the Whangarei Spina Bifida Orthosis.

Fig. 3. Patient in his Whangarei Spina Bifida Orthosis with swivel "feet" attached. This particular patient has cerebral palsy.

shown in Figures 1 and 2 respectively, and an anterior view of the device and patient is shown in Figure 3. Note that the swivel "feet" are not shown in Figures 1 and 2.

Construction Details

Swivel foot plates made of aluminum 3mm x 330mm are mounted on double-row ball bearing races. A 6-degree dihedral angle between the plates is used. Aluminum base plates, 3.5mm thick are made in a range of sizes to suit the development of the child. Moulded plastic shoe supports with Velcro straps hold the feet in position. A Plastazote block is placed under a shoe support when required to compensate for leg length discrepancies. Lateral base support blocks are made of aluminum and drilled to accommodate a stainless steel tube 13mm in diameter which is held in place by a 3mm Allen-head screw.

The knee clamp assembly is made of aluminum, 40mm x 340mm x 3mm. Plastazote blocks are bonded to these and carved to fit the child's knees. The two hinged sections are joined by a toggle clamp. Stainless steel collars 19mm I.D. are used distally and proximally to hold the knee clamps in the correct position along the side bars. Allen-head set screws, 6mm in diameter, are used to hold the collars in place.

The pelvic support is made of aluminum sheet and is fixed to side members by means of a casting that is riveted to the lateral walls (Figs. 1 and 2). The pelvic support is dipped in nylon and lined with Plastazote.

The thoracic pad is made from polythene, 2mm thick, lined with 6mm thick Plastazote, and held by a 5mm-wide nylon belt and Velcro fastening.

The concept of crutchless mobility has been achieved with our present orthosis. The modular construction makes assembly and adjustment quick and easy. The swivel foot plate is used on very young children with hand impairments and in early confidence training for independent mobility. Children with cerebral palsy have also benefited from using this orthosis (Fig. 3). When the upper limb has developed sufficiently for the child to use a parallel pusher frame the swivel plates are removed.

The child is able to apply and remove the orthosis with little assistance. The confidence of independent mobility of our children using this orthosis to stand erect and move with a lift-up and swing-through action with the frame has proved this to be a successful development. Low cost of construction and maintenance and ease of adjustment over the years has been appreciated by the parents and children concerned.

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(4) Stallard, J., G.K. Rose, and I.R. Farmer, "The Orlau swivel walker", *Prosthetics and Orthotics International, 2:2, August 1978.*

(5) Variety Village Electro Limb Production Centre, 731 Danforth Avenue, Scarborough, Toronto, Ontario, Canada.

Acknowledgement

I wish to thank John Austin of the Whangarei Base Hospital for the photographs used here.

Maurice Arthur, Orthotist
Northland Base Hospital
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New Zealand

Footnote

[1]Orthotic Research and Locomotor Assessment Unit (The Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry, England)

Orthotics and Prosthetics, Vol. 34, No. 3, pp. 49-50, September 1980

NEW PUBLICATIONS

Understanding the Scientific Bases of Human Movement—Second Edition. Barbara A. Gowitzke and Morris Milner, Williams and Wilkins, Baltimore/London, 358 pages, 252 illustrations.

This is the second and greatly revised edition of a very popular kiniesology text that is used in schools of physical education, medicine, and allied health. The authors of the original edition, which appeared in 1972, were Alice L. O'Connell, Ph.D. and Elizabeth B. Gardner, Ph.D. both from the faculty of Sargent College of Allied Health Professions, Boston University. Two additional printings were required to meet the demand, one in 1973 and one in 1976.

Because of the tremendous expansion of knowledge in kiniesology in the seventies, the need for a second edition was clearly indicated, and the baton was passed to the team of Drs. Gowitzke and Milner. Dr. Gowitzke is Assistant Professor of Physical Education at McMaster University and Dr. Milner is Director of Rehabilitation Engineering at the Ontario Crippled Children's Centre in Toronto. A review of this book shows them to be a good team indeed, because neither students in engineering or the life sciences should have any problem understanding this comprehensive text. The basic material is presented in such a manner that if it is well known in one discipline those pages can be skipped over to reach material basic to the other discipline after which all of it is applied to a better understanding of movement of the parts of the body with respect to the whole and to each other.

This book, of course, contains a lot more information than the practicing orthotist or prosthetist needs to know, but it is certainly a must for anyone engaged in research and development in prosthetics and orthotics.

A. Bennett Wilson, Jr.
Director of Rehabilitation
Engineering Program
Southwestern Medical School

Orthopaedic Traction Manual by Andrew F. Brooker, M.D. and Gerhard Schmeisser, Jr., M.D., Williams and Wilkins, Baltimore/London; 110 pages, 52 illustrations; paper back.

This clearly written and well illustrated treatise is a handbook designed to meet the needs of the hospital staff responsible for the care of patients needing traction.

The three major sections deal with spinal traction, upper-extremity traction, and lower-extremity traction. Three very short chapters cover equipment, knots, and traction of pelvic or acetabulum fractures. Each of the major chapters contains a selected list of references, and there is an index for the entire book.

For each technique or device, indications for use are given, followed by instructions concerning application, which are followed, in turn, by a discussion of the risks involved.

Although this book is not aimed directly at the orthotist, it does contain a great deal of information about methods of treatment of many types of patients that the orthotist will find useful when the patient is sent to him for orthotic services. Therefore, I feel that this small volume will be a most worthwhile addition to the orthotist's library.

A. Bennett Wilson, Jr.

Orthotics and Prosthetics, Vol. 34, No. 3, pp. 51-52, September 1980

IN MEMORIAM

Colonel Maurice J. Fletcher, U.S.A.—1907-1980

Colonel Maurice J. Fletcher passed away May 13th in Ely, Minnesota. He is survived by his wife, Norma, his daughter, Mrs. Patricia Wheeler, and two granddaughters.

"Fletch" as he was known to his many friends within and without the field of prosthetics, was born in Avoca, Iowa. However, at an early age he moved with his family to Des Moines, Iowa where he followed in the footsteps of his father and brother in the study of Law.

This experiment was a short one, once he had decided that the field of engineering was much more interesting. All his life Fletch was fascinated with outdoor activities, especially fishing, hunting, and riding. These were supplemented with aviation.

With a spirit of adventure, he joined the Citizens Military Training Corps (C.M.T.C.) in the early thirties, little realizing that this step was the beginning of a long and distinguished military career. Moving on from the C.M.T.C. to the regular army, he continued his interest in guns, an interest that led to an appointment to the staff of General Patton as a small arms expert in World War II, during which he spent considerable time in the European Theater of Operations.

After the War, the Surgeon General of the Army decided something special must be done for amputees. Col. Fletcher was selected for the job with orders to organize the "Army Prosthetics Research Laboratory" at Walter Reed Army Hospital in Washington. Priority was given to the development of an artificial hand and hook. The development of a mechanical hand demanded improvements in cosmetic gloves. Thus, the APRL hand, the APRL hook, and the APRL cosmetic glove were born.

The Colonel served as director of the laboratory for seventeen years, until his retirement in 1961.

The many who were privileged to have been associated with Fletch will not soon forget his humor, sage advice, and coinage of whimsical expressions such as "engipedic prosthaneer".

A few of us knew him also as the only "Great Chief" of the "Muckleshoots". The regional subchiefs wish their blood brother peace.

Fletch was truly a man's man.

Howard R. Thranhardt

Verne T. Inman, M.D., Ph.D., 1905-1980

The Prosthetic-Orthotic Industry is particularly indebted to a few men who have brought science into our craft and thereby helped us become a profession.

One of these men was Dr. Verne T. Inman who died this past February 5th, 1980.

Dr. Inman was an Orthopaedic Surgeon who rose to the position of Chairman of the Department of Orthopaedic Surgery at the University of California School of Medicine, San Francisco, California. He was also a Ph.D. in Anatomy and taught formally in that discipline from 1940 to 1945.

Shortly after World War II he brought this ideal combination of practical physician, dedicated scientist and brilliant educator to the task of understanding human locomotion. This task he felt was crucial to the development of improved prosthetic and orthotic devices. In 1957 he became the Director of the Biomechanics Laboratory at the University of California, Berkeley/San Francisco and remained in that position writing his observations until his last days.

The man himself was a warm, friendly, compassionate individual who knew and spoke to everyone indiscriminately. His knowledge and intelligence was obvious to everyone, but the facet of his personality that was pure genius to me was his ability to put people at their ease regardless of their position in life. I worked for Dr. Inman for eleven years, the last five on an almost day-to-day basis and in all that time I never failed to marvel at this particular aspect of the man. He had a manner of posing questions to investigators that would get them interested without creating defensive reactions. In a few minutes a new project had been born and Inman would step aside and let the person use his special discipline and skills to solve the problem. This happened to me many times and soon I realized that the way I achieved the answer that I ultimately provided was not nearly as important as the formulation of the original question.

Dr. Inman taught me all that I ever knew about the human foot. That information I used with Mr. Charles Childs to produce a prosthetic foot which will be presented in this journal. Dr. Inman's name should really be listed on the credits of that article, but I was one day too late.

John W. Campbell

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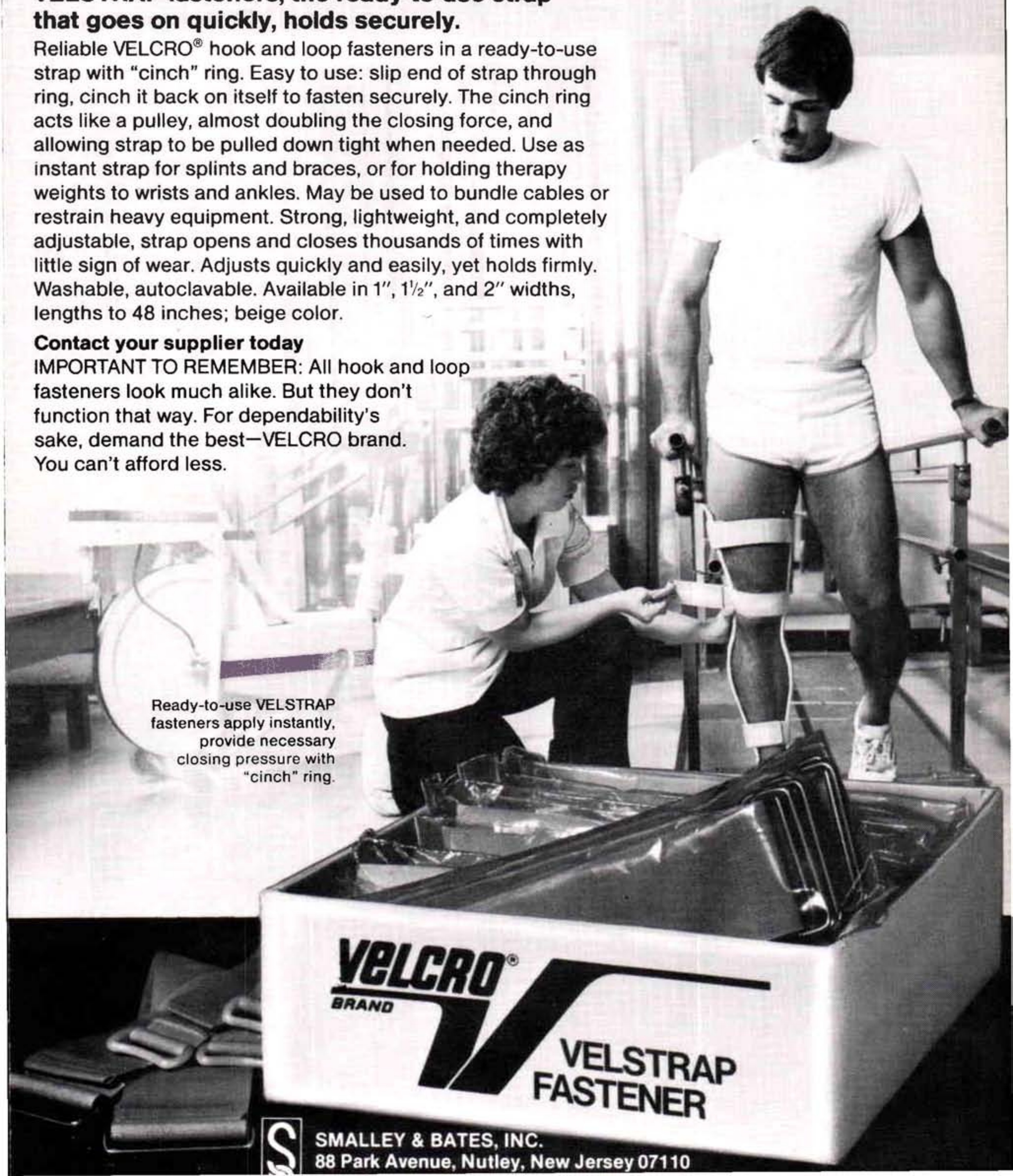

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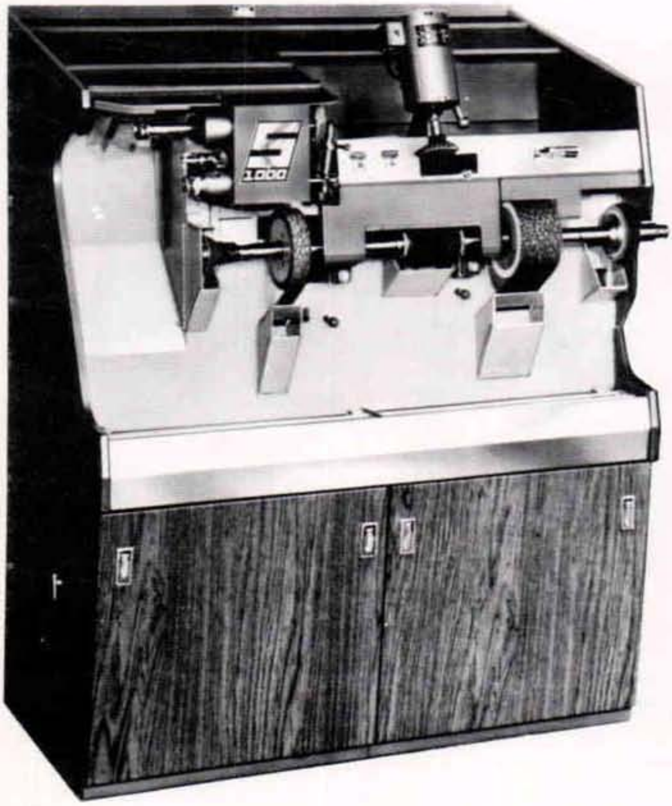

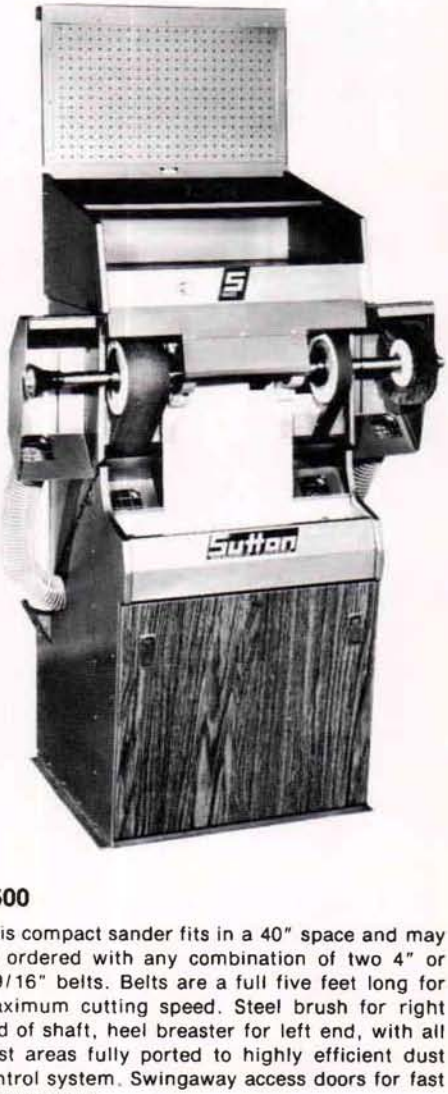

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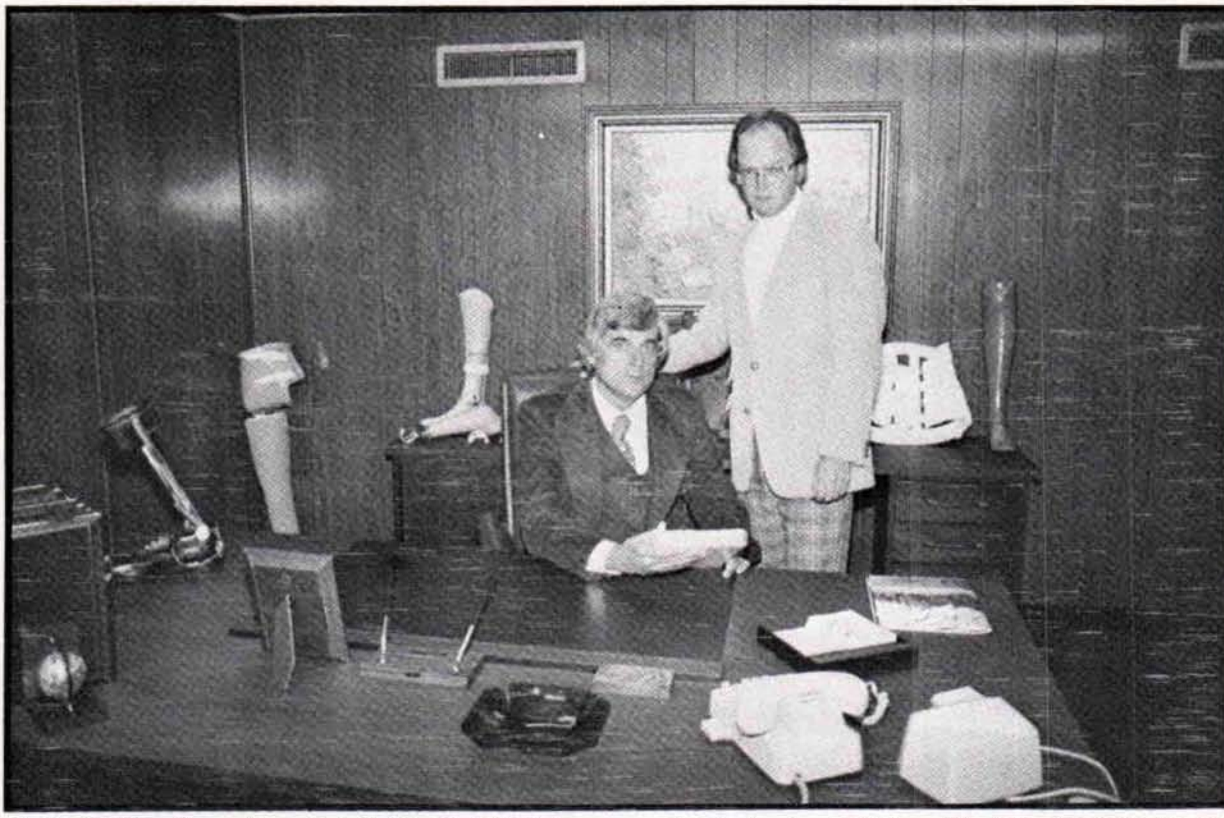

President Bill Hamilton and Immediate Past President Bill Brady announce that the American Orthotic and Prosthetic Association has published a book entitled *Selected Reading—A Review of Orthotics and Prosthetics* **which presents an outstanding review of orthotic and prosthetic procedures. Mr. Brady and Mr. Hamilton have announced that as a membership benefit each AOPA member will receive a free copy.**

The American Orthotic and Prosthetic Association (AOPA), representing firms that manufacture and fit orthoses and prostheses (braces and artificial limbs), is publishing a book entitled *Selected Reading—A Review of Orthotics and Prosthetics*, to fill a long-standing need for a comprehensive orthotic and prosthetic reference. AOPA has recognized the needs of the orthotist, the prosthetist, and the entire rehabilitation clinic team regarding a good reference book.

Mr. Brady and Mr. Hamilton state that this book is the first of its kind and is not only a must for every orthotist and prosthetist, but also a requirement for the library of every medical doctor, physical therapist, occupational therapist and nurse who work with orthpedically handicapped.

The prosthetist is a key member of the rehabilitation team that returns an amputee to a productive life. The orthotist works with a similar team to do the same for the person requiring a supportive device.

"Reference texts are the foundation of every profession. Books like this are long overdue."

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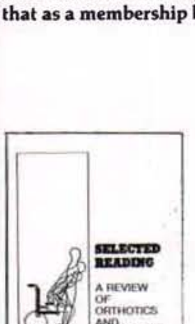
"This anthology will be an invaluable resource to the many dedicated orthotists, prosthetists, therapists, and physicians."

Michael Quigley



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The U.S. National Committee of the International Society for Prosthetics and Orthotics with the cooperation of the Texas Scottish Rite Hospital for Crippled Children and the Orthopedic Division of the University of Texas Health Science Center at Dallas will present a multidisciplinary course in Lower-Limb Orthotics, March 9-13, 1981. The course will be held in the Texas Scottish Rite Hospital for Crippled Children in Dallas, Texas, and is designed to bring all members of the orthopedic team up to date concerning orthopaedic bracing. For details contact: A. Bennett Wilson, Jr., Division of Orthopedics, University of Texas Health Science Center, 5323 Harry Hines Boulevard, Dallas, Texas 75235.

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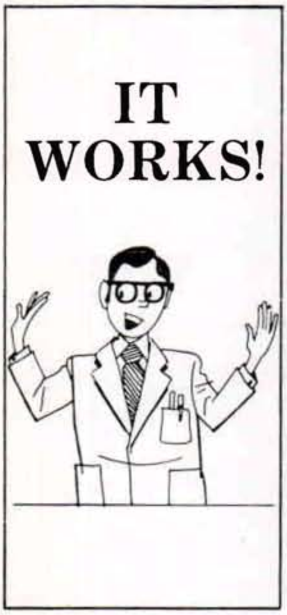

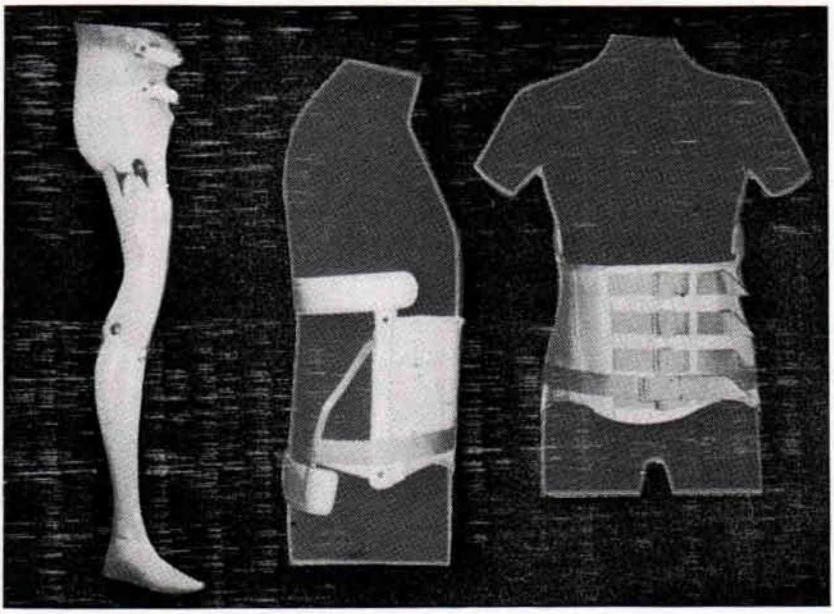

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