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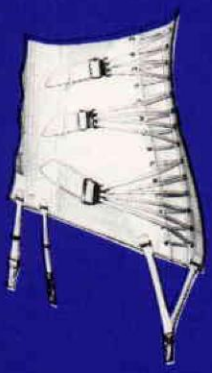

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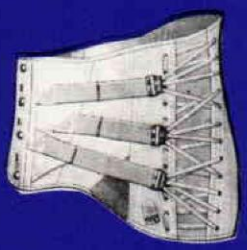

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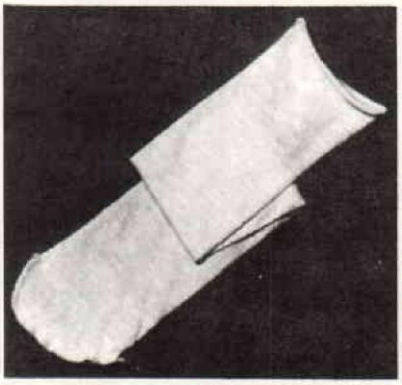

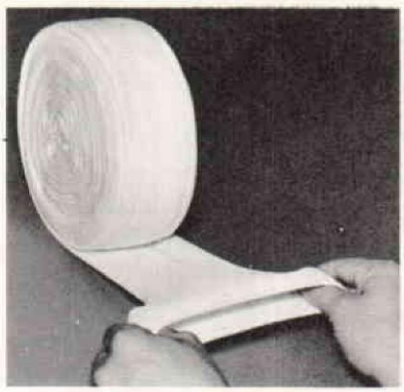

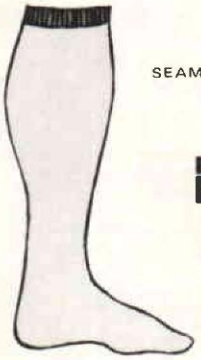

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Fit Lengths:	10" to 14"	16" to 20"	22" to 26"	14" to 18"
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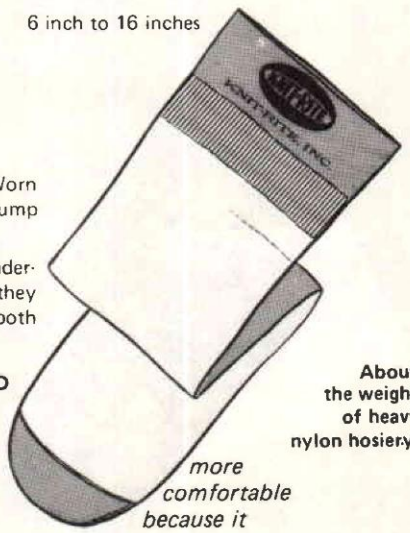
B/K sizes may be worn on small A/K Stumps



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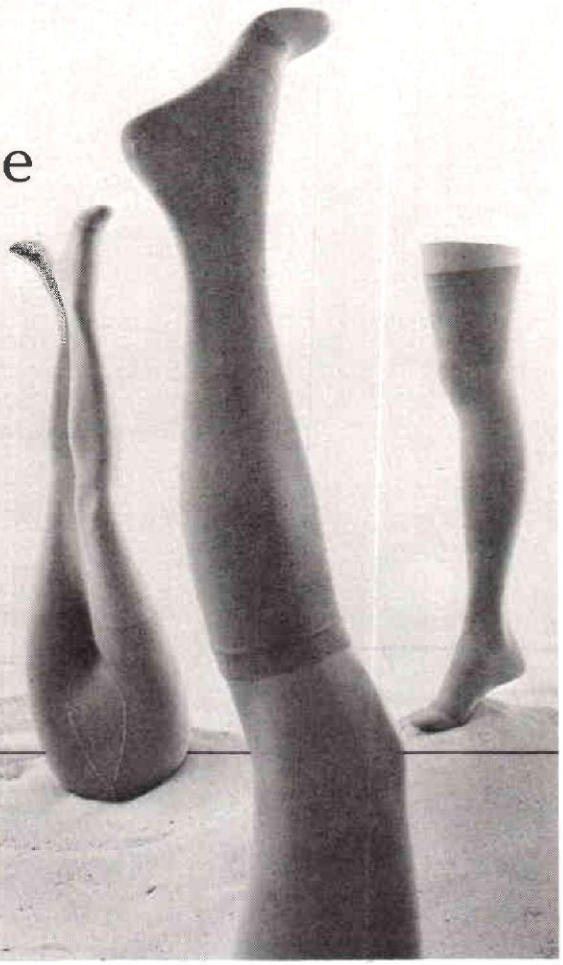

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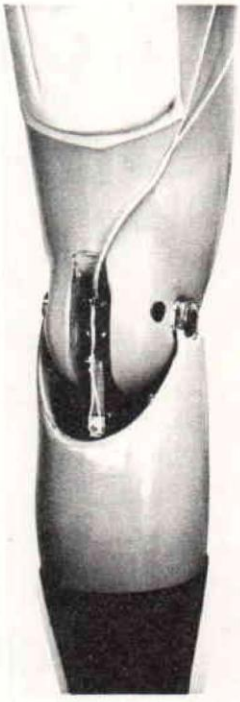

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EDUCATION AND MORE EDUCATION

In 1945 a research program in limb prosthetics was initiated by the National Research Council at the request of The Surgeon General of the Army. The NRC was not interested in simply filing reports on the results of research, but was concerned rather in seeing that positive research findings were used to benefit patients, and, therefore, experiments were undertaken to determine the most effective means for transferring information from the research laboratories to the clinicians who could apply it.

The positive results of the suction socket for above-knee amputees, an American invention originally conceived by Parmalee in 1863, but used by the Germans in the 1930s and refined by the Biomechanics Laboratory, University of California, Berkeley, in 1946-48, afforded the first opportunity for an experiment in transferring information to the field.

With the cooperation of the Orthopedic Appliance and Limb Manufacturers Association, the NRC and the Prosthetic and Sensory Aids Service of the Veterans Administration conducted approximately 40 "suction socket schools" in more than a dozen locations throughout the United States during the 1948-1951 period.

The success of these traveling instructional teams suggested a more permanent approach to the problem. Thus, in 1952 when a body of knowledge concerning the management of the upper-limb amputee had been accumulated, funds supplied by the Veterans Administration were used to set up an experimental education program at the University of California at Los Angeles, where a good deal of pioneering research had taken place.

Because prosthetists had to be taught the technique of plastic lamination, it was necessary for that group to spend six weeks at UCLA. Four weeks later therapists arrived for instruction and during the final week surgeons and physicians joined the group to complete the clinic management team. The success of this program during 1953-54 led to the introduction of material on above-knee prosthetics which had been developed by the University of California at Berkeley. Programs of prosthetics education were also initiated at New York University and Northwestern University. The Office of Vocational Rehabilitation, Department of Health, Education, and Welfare, assumed fiscal responsibility of the education program about 1958. These early programs consisted solely of courses to provide continuing education. More recently programs of basic education for prosthetists and orthotists have also been provided.

The American Orthotic and Prosthetic Association, the American Academy of Orthopaedic Surgeons, and others, have long recognized the need and have made use of these DHEW-sponsored programs. Despite the fact that it can be shown that the Prosthetics and Orthotics Education Program has paid off handsomely, DHEW in compliance with the directives of the U.S. Office of Management of the Budget has given notice that the support for education will be withdrawn completely after the current fiscal year. In fact the programs at UCLA, NYU, and NU have been kept alive during the past year and will be able to continue during the present one only because the Veterans Administration was able to supply the supplementary funds needed.

The future for federal support of education in the allied health field is thus quite uncertain. Without question, formal educational programs for future and practicing prosthetists and orthotists are needed, and some subsidization, like that required for most other undergraduate and graduate programs, will be required. If you agree, letters should be sent to your U.S. Congressman and Senators so that they will be aware of the need for and the usefulness of the federally sponsored programs.

As for continuing education, it is gratifying that the American Academy of Orthotists and Prosthetists is conducting short-term courses to keep practitioners up to date. In coordination with the formal education program, the American Academy of Orthopaedic Surgeons and others, the American Academy of Orthotists and Prosthetists has tremendous possibilities for becoming a very effective component in continuing education programs for orthopaedic clinic teams.

The Veterans Administration has asked the National Research Council to study the past and present education programs, especially with respect to the needs of VA, and to make recommendations for future programs. This of course will be done with respect to the entire country. Any comments and suggestions will be welcomed by the Task Force now being organized to carry out the study. They should be forwarded to: Executive Director, Committee on Prosthetics Research and Development, National Research Council, 2101 Constitution Ave., N.W., Washington, D.C. 20418.

A. Bennett Wilson, Jr.

A. Bennett Wilson, Jr.

FABRICATION OF VACUUM-FORMED SOCKETS FOR LIMB PROSTHESES

Roy Snelson, C.P.O.[1]

It seems to be self-evident that the fit and alignment of an artificial leg are the most important technical factors that enter into the success of individual cases. These two factors are interdependent to a certain extent.

The evaluation of the relationship between the patient and the prosthesis, on both a clinical, individual basis and on a research basis, has been a most difficult problem. Through the years a number of attempts have been made to develop transparent sockets to make these evaluations more reliable.

The Navy Prosthetics Research Laboratory used sockets made of Plexiglas in their studies of above-knee fittings in the 'Fifties and the J. E. Hanger Company of Atlanta in their pioneering work with the total-contact above-knee sockets in the early 'Sixties used Plexiglas, but fabrication of sockets with this material required an extraordinary amount of time because it was not possible to form a socket from a single piece of the material.

The Army Medical Biomechanical Research Laboratory proposed a method of casting a clear socket using an acrylic (2), but the technique required relatively expensive materials and such extreme care for satisfactory results to be obtained that it was not adopted by others.

New York University later developed a simpler technique for casting transparent sockets with polyester resins (1), but the process is sufficiently tedious and time-consuming that it has not been adopted for routine clinical use.

In 1970 with fiscal support from SRS[2], a research group at Rancho Los Amigos Hospital developed a practical, efficient method of making transparent sockets by vacuum-forming polycarbonate sheet over a male model. The original technique was reported in the March 1972 issue of *Orthotics and Prosthetics*. Subsequent experience with polycarbonate indicates that its best use in prosthetics is probably as a check socket, because of the problem of attaching it to an endoskeletal type of prosthesis for long periods of use.

This advantage alone justifies use of vacuum-formed sockets, but the method is also applicable to other plastic materials. Furthermore, vacuum-formed sockets are useful for teaching.

This manual covers the fabrication and use of check sockets made of transparent polycarbonate[3] sheet, and suggests methods of fastening the socket to the rest of the prosthesis when temporary use is desired.

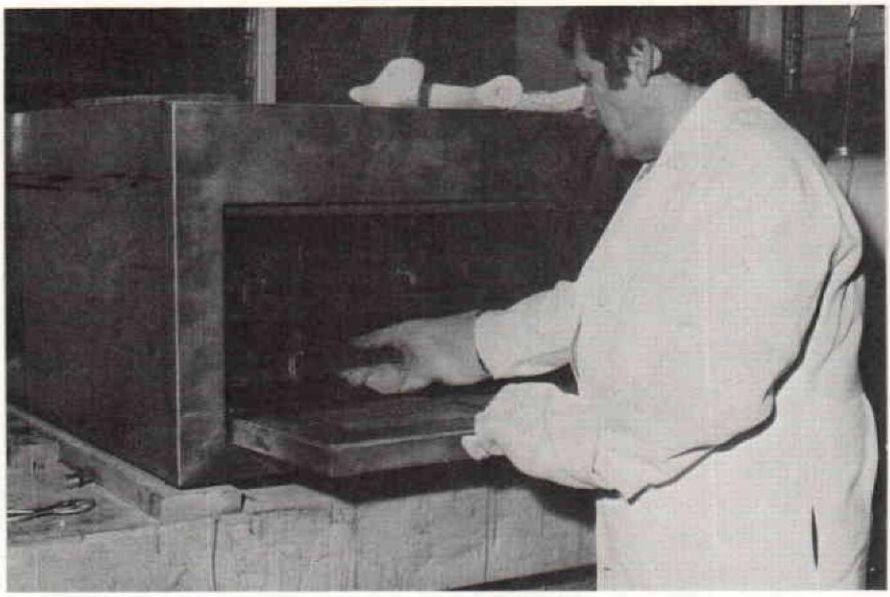
---

[1]President, Orthomedics, Inc., 8332 Iowa St., Downey, CA 90241

[2]This work was supported primarily by Grant No. 23-P-55290/9 from the Social and Rehabilitation Service (SRS), Department of Health, Education, and Welfare, Washington, DC 20201

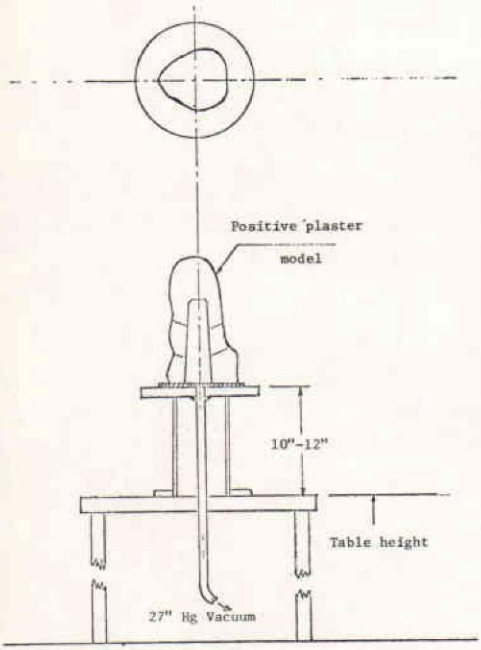
[3]Supplied by General Electric as Lexan. Other suppliers use other trade names.

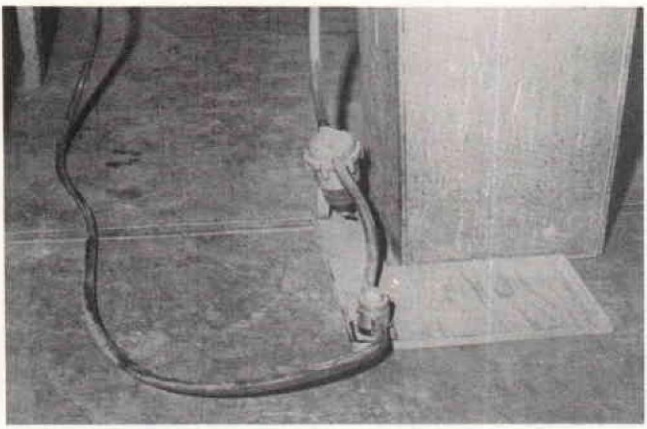
FABRICATION OF TRANSPARENT SOCKETS



Unfortunately, polycarbonate absorbs water from the atmosphere, and to avoid the formation of bubbles and other imperfections during molding it is necessary to remove the moisture prior to vacuum-forming the plastic sheet. The time required to remove the heat varies with thickness of the plastic sheet and the humidity. During the course of the experiments it was found that material ⅜" thick could be rendered free of moisture when subjected to a temperature of 275° F. for 36 hours. A second-hand pizza oven proved to be quite satisfactory for this purpose.

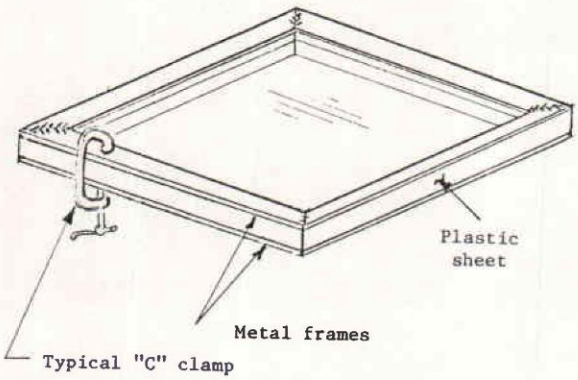
The only special pieces of equipment needed not found in most prosthetics and orthotics facilities are a workstand and frames to hold the sheet plastic and tapered mandrels for use in making the male model. Each of the items can be fabricated easily and very inexpensively in a prosthetics facility.



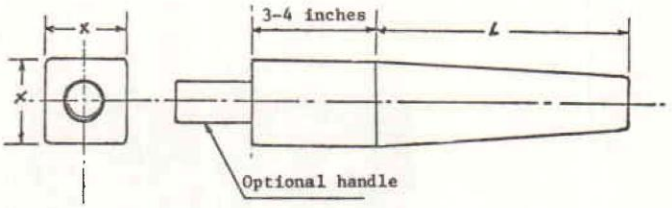


The simple workstand made of wood and pipe provides a base for the positive cast and a point of entry for the airflow into the vacuum system.

A foot-operated valve in the vacuum line makes control of the vacuum easier for the operator, and a water trap should be installed between the air entry and the foot-operated valve to prevent an accumulation of moisture in the vacuum tank.



Metal frames are required so that a firm grip can be provided around the periphery of the plastic sheet during the drawing process. Two ordinary "C" clamps have been found to be satisfactory in holding the assembly together. Steel or aluminum material ⅛" thick provides adequate stiffness.

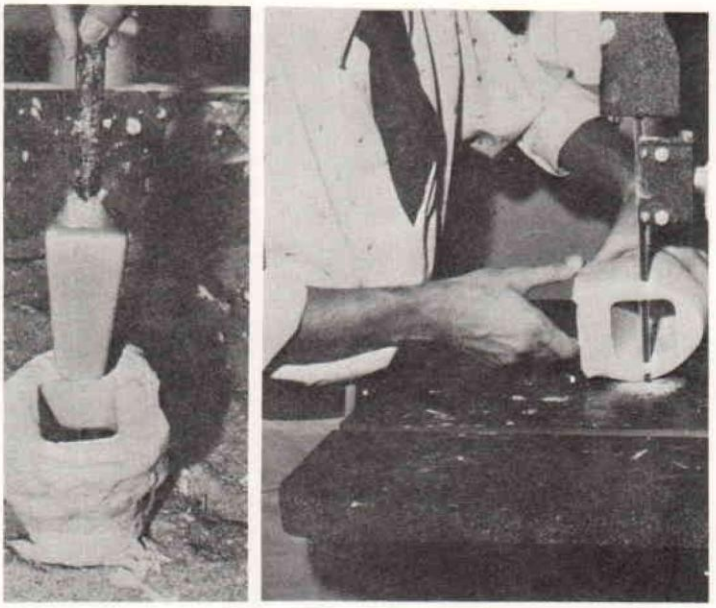


TAPERED MANDREL

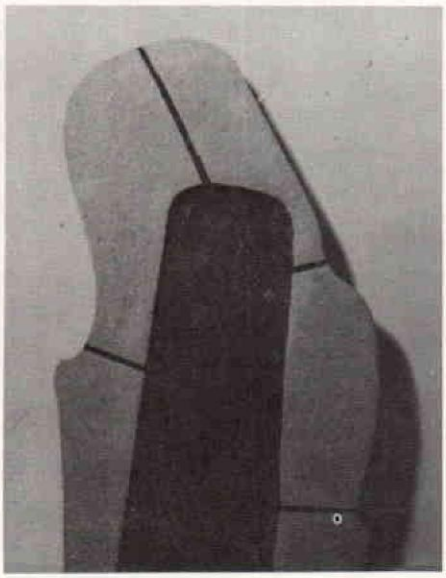
Make from wood--cover with two layers of plastic laminate

Vary cross-section dimensions (x) and length (ℓ) to provide a range of sizes.

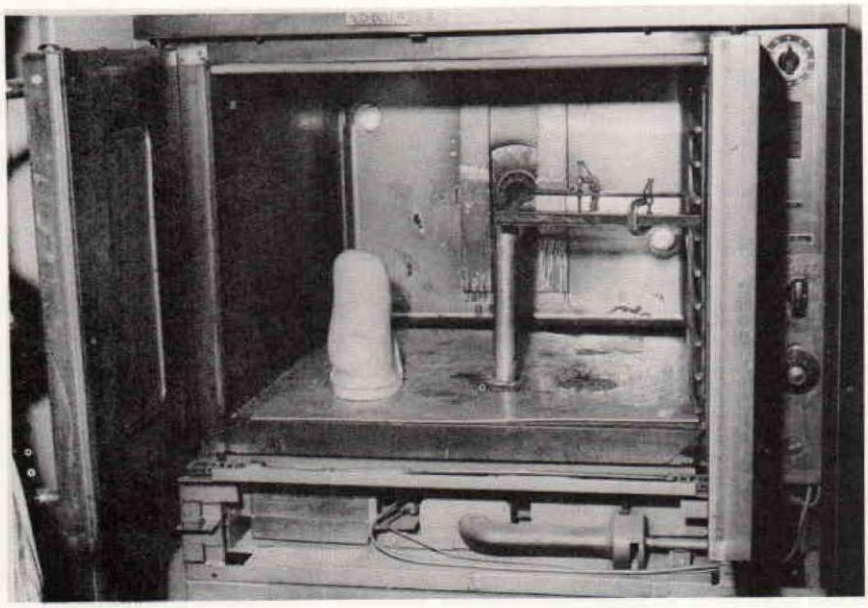
Tapered mandrels are used to provide a lengthwise cavity in the positive cast to insure that the air flows in such a manner that the plastic sheet will not bridge across undercuts on the surface of the cast. They may be made of most any rigid material. Wood covered with two layers of polyester-dacron laminate was used in the course of the development project.

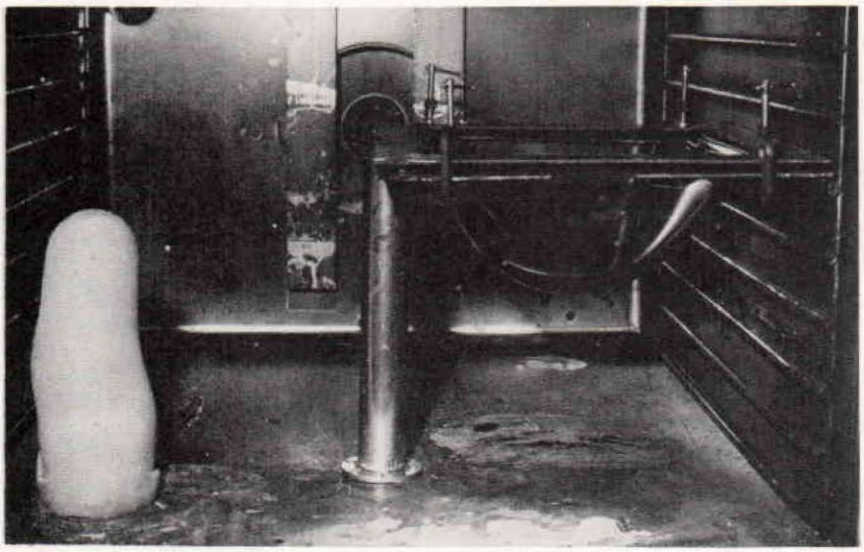


The plaster-of-Paris wrapped cast is taken in the regular way and a positive model is poured using a well-greased tapered mandrel to form a lengthwise cavity. A flat surface is provided on the proximal end so that it will stand firmly on the work pedestal.

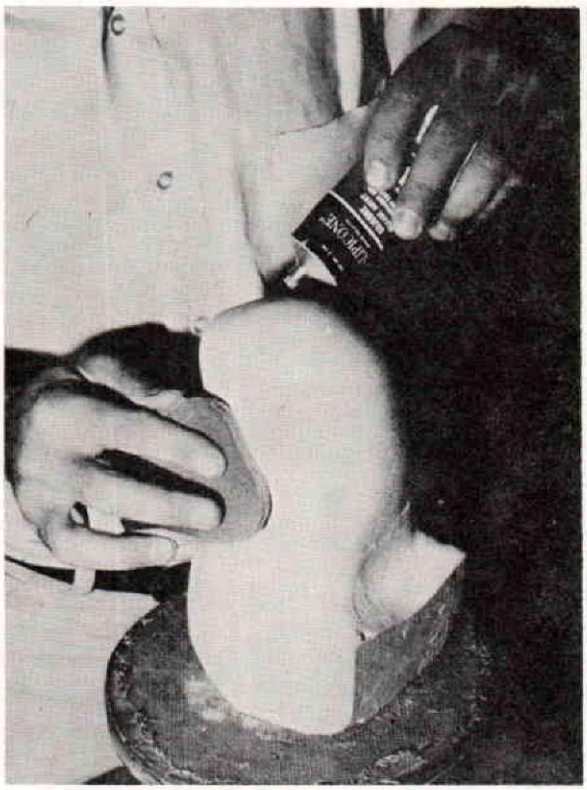


After the positive model has been modified according to the regular practice of the prosthetist, 1/16″ diameter holes are drilled from the outer surface, especially in the undercut areas, to the inner cavity to prevent "bridging."



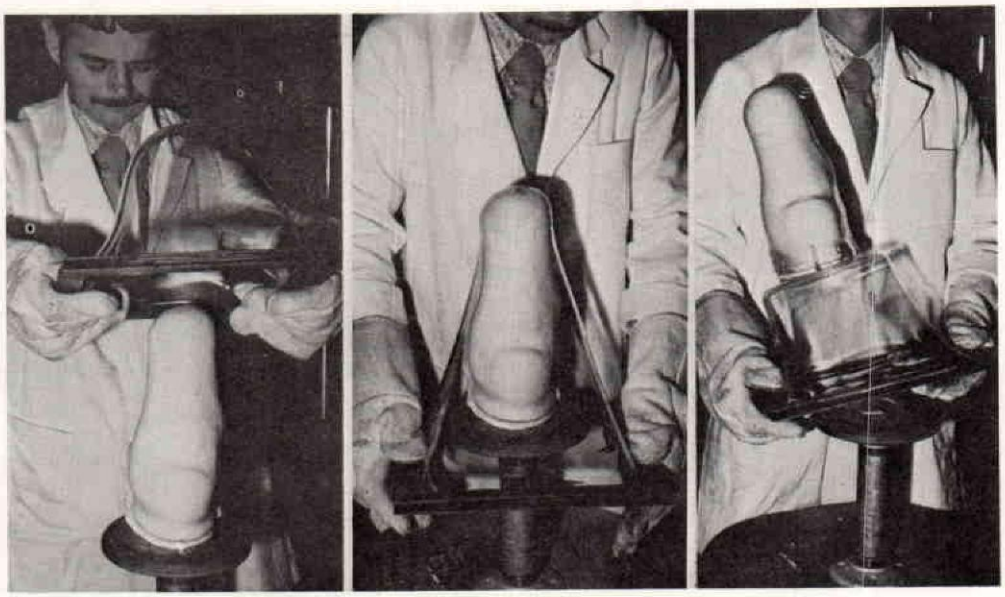


The polycarbonate sheet (12 × 12 × 3/8" for the average below-knee amputee) that has been placed in the metal frame and dried adequately is removed from the drying oven and placed in a circulating oven at 400° F. until the sheet sags under its own weight to a distance about 2/3 the length of the positive cast. Because the rate of heat loss of polycarbonate is quite high, it is a good idea to heat the positive cast at the same time, but, of course, caution should be exercised because a wet cast will explode if subjected to high heat too rapidly.



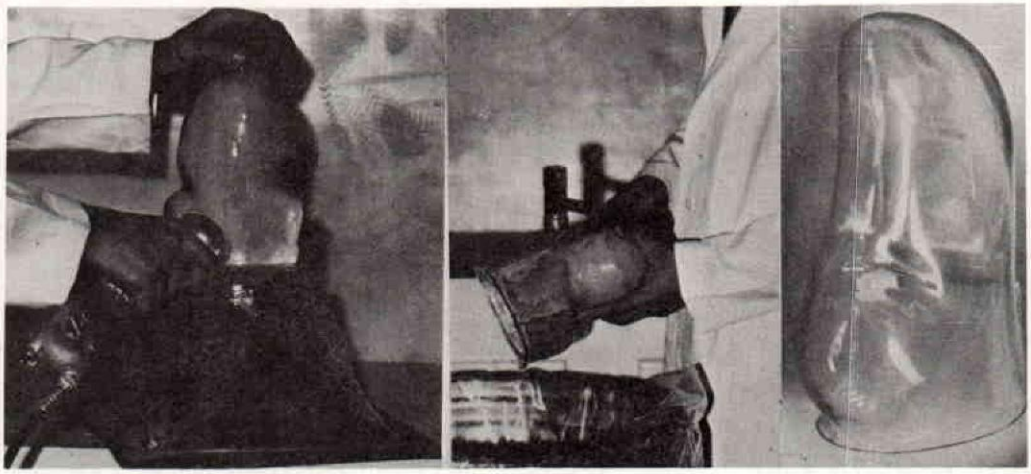
The positive cast is placed on the screen wire on the pedestal of the workstand, and Slipicone[4] is applied as a parting agent.

[4] Dow Corning Corporation, Midland, MI.

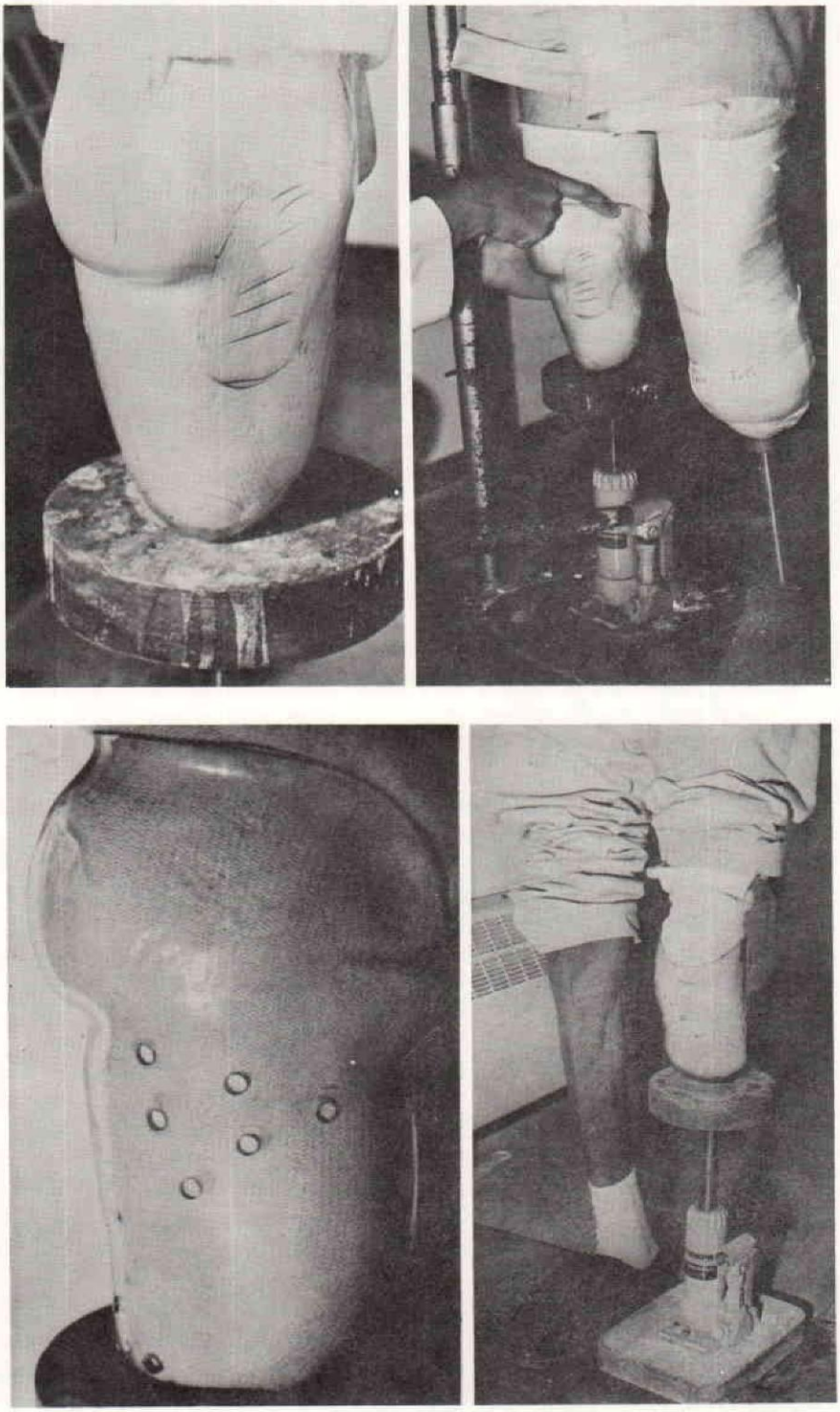


The plastic, in its frame, is removed from the oven, rotated 180° about the horizontal axis, drawn down over the positive model, and the vacuum is applied. The result is a perfect, clear reverse reproduction that conforms to every contour on the surface of the positive model.

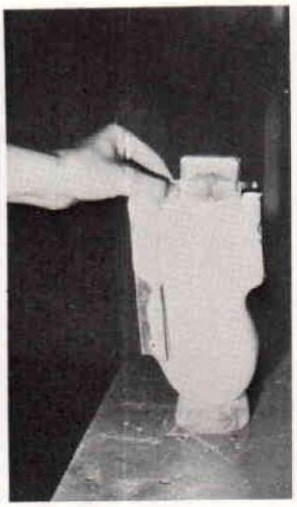
Cooling is quite rapid but can be accelerated by using air from a compressed air system.

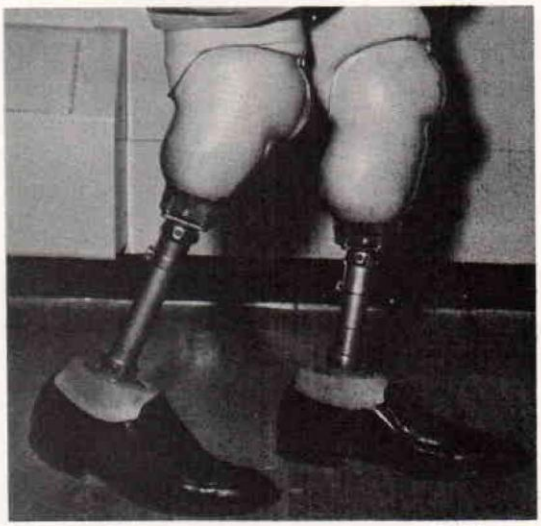


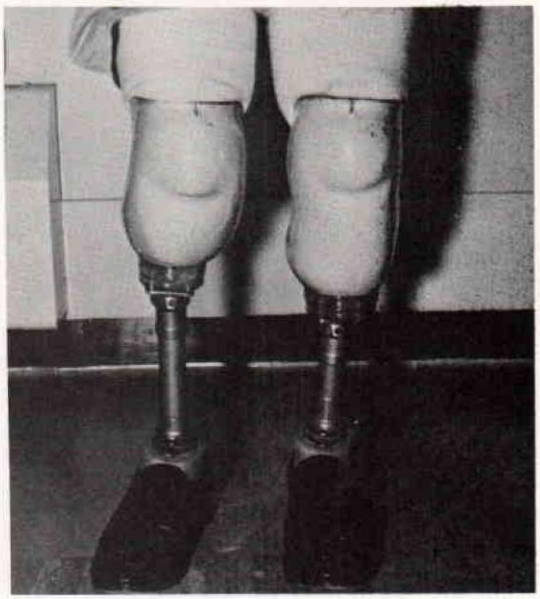
After the excess material and the frame have been cut away, the plaster, because of the cavity formed by the mandrel, is removed easily by hammer blows on the outside of the newly formed socket. The socket can now be trimmed and made ready for use.



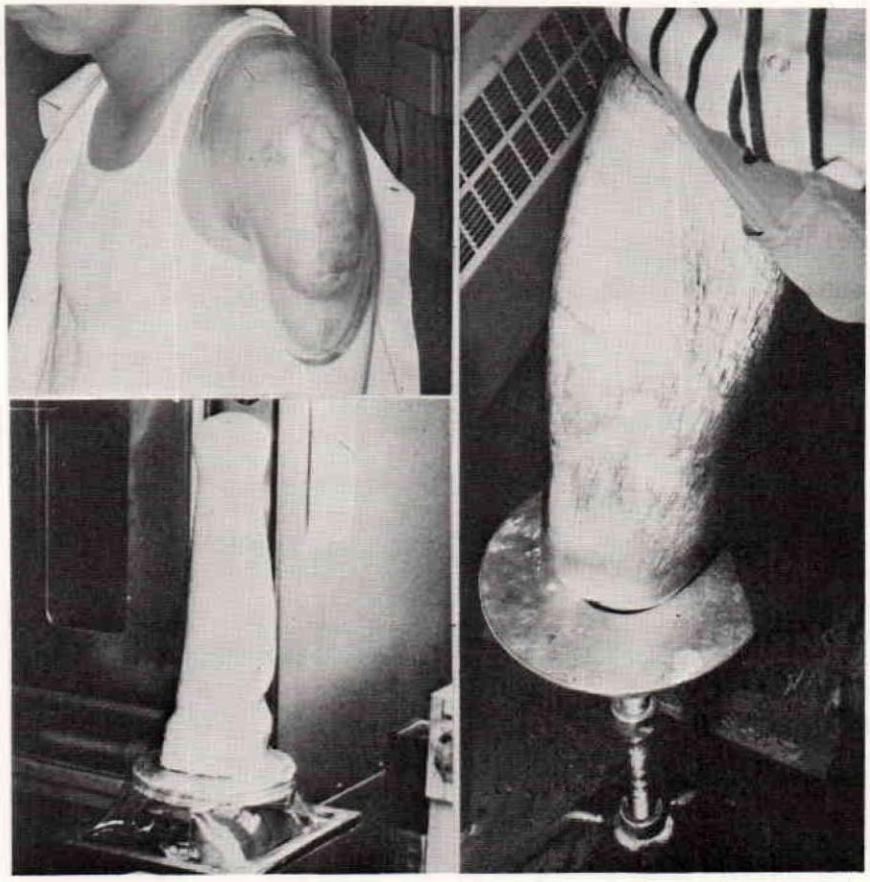
If it is to be used as a check socket ¼"–⅜" holes are drilled at points that are considered to be troublesome and observations can be made to determine what further modifications to the positive model seem indicated.







If the socket is to be used temporarily, whether for clinical, teaching, or research purposes, it may be mounted on a pylon-type prosthesis by cementing the distal end to a disc of polycarbonate which in turn can be bolted to the proximal part of the pylon. Care must be taken, though, to provide a gradual change in cross-section at the junction in order to avoid fractures at this point. For extremely active and heavy patients, the retaining straps supplied with most pylons may be used to provide additional security, but their use, of course, reduces the areas of the stump that can be observed.



The example shown has been a socket for a below-knee amputee, but the technique is equally applicable to other levels of amputation.

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CRITERIA FOR USE OF SUPRACONDYLAR AND SUPRACONDYLAR—SUPRAPATELLAR SUSPENSION FOR BELOW-KNEE PROSTHESES

James W. Breakey, B.Sc.[1]

A number of articles have been published on the "PTS" or a variation. Supracondylar with suprapatellar suspension has been described by several authors (2, 5, 6). A method of medial brim supracondylar suspension (1), a medial supracondylar wedge suspension (3), and a detachable medial brim suspension (4) have also been described. All these articles have reported a high incidence of success with their particular approach.

I began using the "PTS" approach in late 1967 and have fluctuated between supracondylar plus suprapatellar suspension and supracondylar suspension alone. Because, when both methods were tried on the same patient one method was preferred to the other, study was initiated to determine which was the method of choice in meeting the suspension needs of the below-knee amputee.

Careful analysis of changes of the stump-thigh relationship determined by measurement, combined with subjective information gained from patients having worn both suspension types, led to the grading system to be presented here.

GRADING SYSTEM

For determining the mode of suspension for a BK prosthesis, a grading system has been developed and used. The system uses 0 to 2 points allowance per category. There are six categories, two major and four minor. The distribution of points is given in Table 1.

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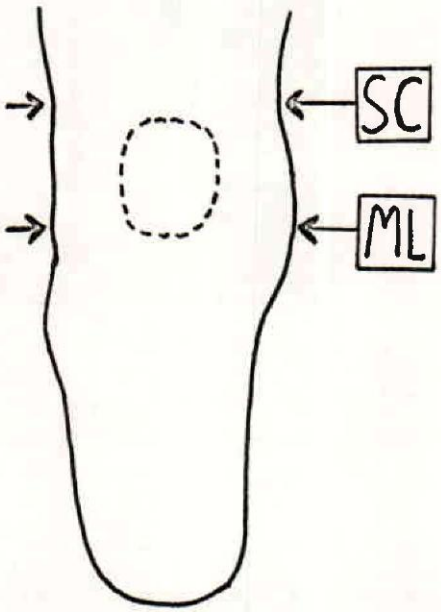

Fig. 1. Diameter measurements at the supracondylar (S/C) and mediolateral (M/L) knee levels.

Major Category:

1. Relationship between the diameters of the mediolateral (M/L) knee measurement and supracondylar (S/C) measurement (Fig. 1).

2. Relationship between the circumferential measurement at the patellar tendon (P/T) level and at the supracondylar (S/C) level (Fig. 2).

GRADING SYSTEM

			SUPRACONDYLAR	SUPRACONDYLAR PLUS SUPRAPATELLAR
MAJOR				
1. ML/SC	Difference between			
	1 inch or less		0	2
Diameter	1⅛ inch to 1½ inch		2	1
	Greater than 1½		0	2
2. PT/SC	S/C circ:	P/T circ:		
	Larger	Smaller	0	2
Circumference	Equal	Equal (within ½ inch)	2	1
	Smaller	Larger		0
MINOR				
1. Stump Length:				
Less than 3″			0	2
Between 3″ to 4½″			1	2
Greater than 4½″			0	0
2. Prominent Rectus Femoris Tendon			2	0
3. Desirability of Full Knee Extension			2	0
4. Knee Flexion Contracture			0	2
5. Bilateral B/K Amputee			0	2
6. Cosmetic Factor			0	2

TABLE 1.

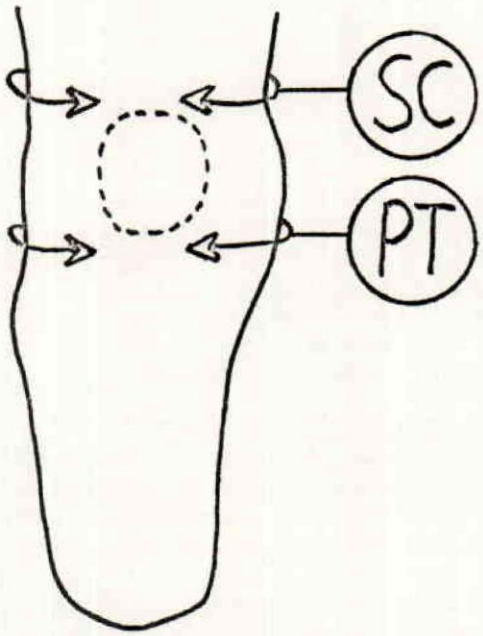

Fig. 2. Circumferential measurements at supracondylar (S/C) and patellar tendon (P/T) levels.

Minor Category:

1. Stump length
2. Prominence of rectus femoris tendon
3. Patients' desirability of full knee extension
4. Presence of knee flexion contracture
5. Bilateral B/K amputation
6. Cosmesis

The rationale for a major and a minor category is based on a relationship between the stump and thigh. The two determinants of the major category are directly related to the measurements of both structures. I have found that this measurement relationship largely determines the mode of suspension (Table 2). The determinants of the minor category which are not related to the stump-thigh measurement relationship can influence the suspension choice (Table 3).

MAJOR CATEGORY

Grading points are allotted in favor of one suspension method or the other (Table 1) depending on the measurement difference between the ML/SC relationship and the PT/SC circumference.

	SUPRACONDYLAR	SUPRACONDYLAR PLUS
MAJOR:		
1. S/C: 3¼″		
M/L: 4 ″	0	2
Difference: ¾″		
2. S/C: 15½″		
P/T: 14 ″	0	2
Difference: 1½″		
MINOR:		
1. Length: 6½″		
2. No		
3. No		
4. No		
5. No		
6. No		
TOTAL	0	4 POINTS

TABLE 2.

The knee M/L is measured at the widest point of the knee joint in the mediolateral plane. A measurement from a point just above the insertion of the adductor magnus muscle medially, (adductor tubercle) to the ilio-tibial band laterally defines the S/C diameter (Fig. 1).

Circumferential measurements are taken at the same level as the S/C diameter measurement, and at the patellar tendon level in line with the anatomical knee joint (Fig. 2).

In reference to Table 1, the reason for favoring supracondylar plus suprapatellar (PTSPC) suspension when the difference between the M/L and S/C measurement is 1 inch or less relates to the S/C circumference which usually is larger than the P/T's circumference (second determinate major category) in these cases. With this stump-thigh relationship, the thigh tapers towards the stump with extra subcutaneous tissue found in the supracondylar region (Fig. 3a). In this situation the addition of the suprapatellar brim increases suspension area from soft tissue as well as underlying bone structure.

In cases of ML/SC relationship greater than 1½ inches with a S/C circumference smaller than a P/T circumference (Fig. 3c). I have found this type of stump-thigh relationship presents a socket donning problem. Use of a two-piece socket consisting of a semi-flexible liner which can be donned and then inserted into a rigid receptacle has overcome this problem (1). The socket is fitted less intimately in the S/C region and additional suspension is gained from the area above the patella. Fillauer's detachable medial brim (4) would also solve this donning problem.

In the above two situations a 0 to 2 point allotment is made but in the ML/SC of 1⅛ inch to 1½ inch and in the PT/SC of equal (within a ½ inch) the grading is 2 to 1. I have found that this group tends to prefer the supracondylar (PTSC) suspension but have managed on a PTSPC with little or no difficulty.

MINOR CATEGORY

Stump Length. The addition of the suprapatellar socket brim to supracondylar suspension offers the shorter B/K stump (4½ inches and less) support during stance in the forward direction as well as to act as a check to hyperextension at the knee joint. As shown in Table 1, a long stump is not biased in favor of either suspension method.

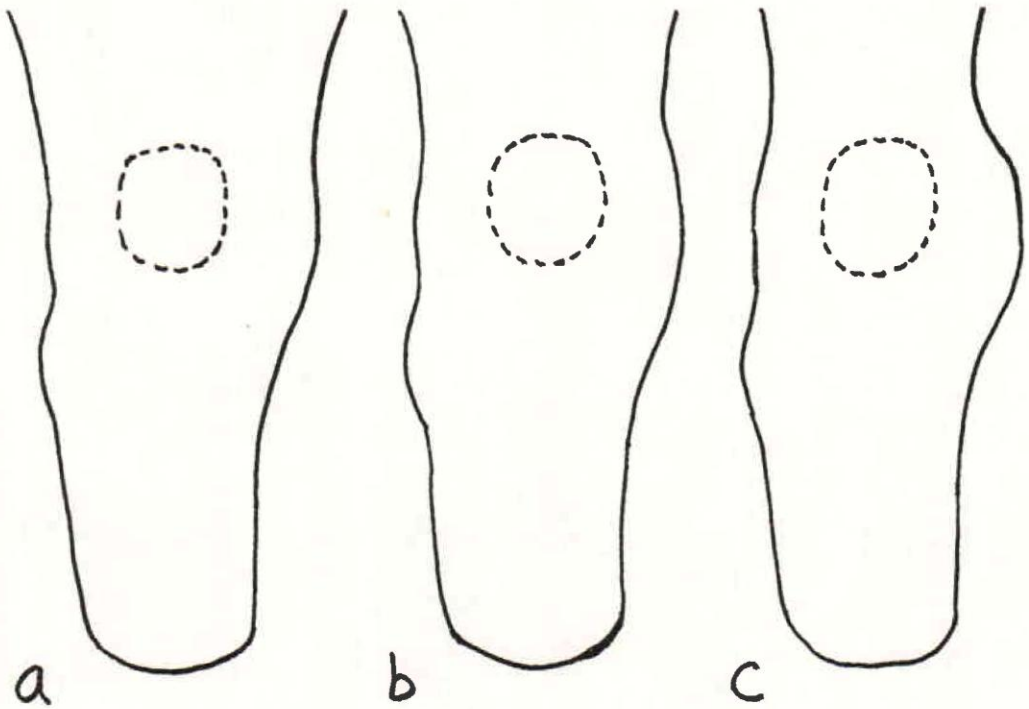

Fig. 3. The shapes of various stump-thigh relationships.
a) The difference between the M/L and S/C circumference is larger than the P/T circumference.
b) The difference between the M/L and S/C diameters is between 1⅛ inch and 1½ inch, and the S/C circumference is equal to the P/T circumference.
c) The difference between the M/L and S/C diameters is greater than 1½ inch, and the S/C circumference is smaller than the P/T circumference.

Prominent Rectus Femoris Tendon. If the patient has a prominent tendon, he may complain of discomfort by the suprapatellar brim. A prominent tendon scores high in favor of supracondylar suspension. No points are allotted to either suspension method if the tendon is not prominent. This determinant alone should not bias suspension choice, especially if more points are in favor of supracondylar plus suprapatellar. The suprapatellar brim depth can always be reduced. In the case of a tie in points I have found more success in choosing supracondylar suspension.

Desirability of Full Knee Extension. Two points are allotted in favor of supracondylar suspension, in the case of a former prosthetic wearer who desires unresisted full knee extension. The suprapatellar brim can be an annoyance to these patients. Re-education of the patient's knee joint control and/or a less prominent brim has often solved this problem in cases where suprapatellar brim was indicated.

Knee Flexion Contracture. A two point allotment to the addition of suprapatellar brim is made in cases of apparent uncorrectable knee flexion contracture. The top edge of the patella offers a good suspension area, especially if the tissues are on the lean side and the patella is prominent. No points are allotted when a contracture is not present.

Bilateral B/K Amputee. These amputees normally maintain slight flexion of the knee while standing and during walking. This presents a situation similar to knee flexion contracture and two points are given in favor of the suprapatellar brim addition, because the brim augments stump support in stance in the forward direction, and acts as a check to full knee extension.

Cosmesis. Patients often prefer addition of the suprapatellar brim when considering cosmesis. In these cases the cosmetic factor indicates 2 points towards addition of the brim.

CLINICAL EXPERIENCE

During the past 3½ years a total of fifty-two patients have been fitted at the Eastern Ontario Rehabilitation Centre with supracondylar and

	SUPRACONDYLAR	SUPRACONDYLAR PLUS SUPRAPATELLAR
MAJOR:		
1. S/C: 2⅝″ M/L: 3⅞″ Difference: 1¼″	2	1
2. S/C: 12¾″ P/T: 12 ″ Difference: ¾″	0	2
MINOR:		
1. Length: 5″		
2. Yes	2	0
3. Yes	2	0
4. No		
5. No		
6. No		
TOTAL	6	3 POINTS

TABLE 3.

supracondylar plus suprapatellar suspension. This time period has allowed follow up and refitting (due to stump shrinkage) of a large number of these cases.

Supracondylar suspension was used on 21 patients. Those fitted with supracondylar plus suprapatellar totaled 31. Three of the 31 were bilateral cases.

Of the patients re-fitted due to stump shrinkage, 18 continued with the original suspension type. Six changed from supracondylar plus suprapatellar suspension to supracondylar, and eight others altered suspension type in just the reverse. In all cases, maintaining or changing the suspension modality was supported by the criteria and reinforced by patient acceptance.

SUMMARY

A grading system for assisting in deciding between supracondylar or supracondylar-plus-suprapatellar suspension has been presented. The grading system offers points in favor of one type of suspension or the other. Point allotment is based upon measurement relationship between the thigh and BK stump, and also on subjective information obtained from the amputee.

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A POROUS, FLEXIBLE INSERT FOR THE BELOW-KNEE PROSTHESIS

Gustav Rubin, M.D., FACS[1]
and
James L. Byers[2]

When an amputee using a total-contact patellar-tendon-bearing (PTB) prosthesis or one of its variations perspires excessively his stump becomes immersed in a pool of fluid, a condition that produces not only discomfort but, also, a potential cause of skin maceration and breakdown. It is the purpose of this paper to present an approach to the solution that permits retention of "total contact" while allowing for escape of the fluid from the stump-socket interface.

BASIC SOCKET DESIGN

The positive model of a BK stump is modified by removal of ⅛" of the distal portion. A soft insert of Cordo (1,7) with a distal end of nylon mesh is fabricated over the model and thus an open space is retained in the distal end of the socket to act as a fluid trap. An external lip, added to the proximal end of the insert, overlaps the socket brim and prevents distal displacement of the insert within the socket as the patient bears weight during the stance phase. As weight is borne over the stump the elastic compression of the mesh against the stump aids in expressing fluid from the intervening stump sock into the compartment below.

The insert with the nylon mesh is shown in Fig. 1. The space beneath the mesh has been made excessively large in this transparent polycarbonate socket for demonstration purposes. Laxity of the mesh without weight-bearing and total contact upon weight-bearing, left and right, respectively (Fig. 1), can be seen. An accumulation of liquid perspiration outside of the insert and in the trap after several hours of wear can be seen in Figure 2. The nylon mesh should be flushed each evening with a solution of soapy water and allowed to dry overnight. The trap should be wiped dry.

CASE HISTORIES

Five patients have been fitted over the past two years; one case, a bilateral was fitted on both sides.

CASE NO. 1

J.K.B., a 53-year-old part-time grocer with a 6" left BK amputation stump, secondary to shell fragment wounds sustained in WW II, was seen by the VAPC clinic team on July 15, 1971, when he presented with two abrasions over the distal stump. He had been using an open distal-end prosthesis with a thigh corset. After a period of not wearing the prosthesis and soaking the stump regularly, the lesions cleared up, only to recur shortly after he began using the prosthesis again. In view of the recurrent episodes of abrasions of the distal stump area associated with a tendency to perspire a great deal, the clinic team decided to try to achieve total contact and, at the same time, minimize the adverse macerating effect on the skin produced by constant immersion of the stump in a pool of perspiration.

On November 10, 1971, the patient received a supracondylar-suprapatellar prosthesis with an open-mesh distal-end soft-socket insert. The stump has remained in good condition and abrasions have not recurred. At the date of most recent examination, April 20, 1973, he stated that he no longer had a problem with perspiration. Stump shrinkage had occurred and the patient

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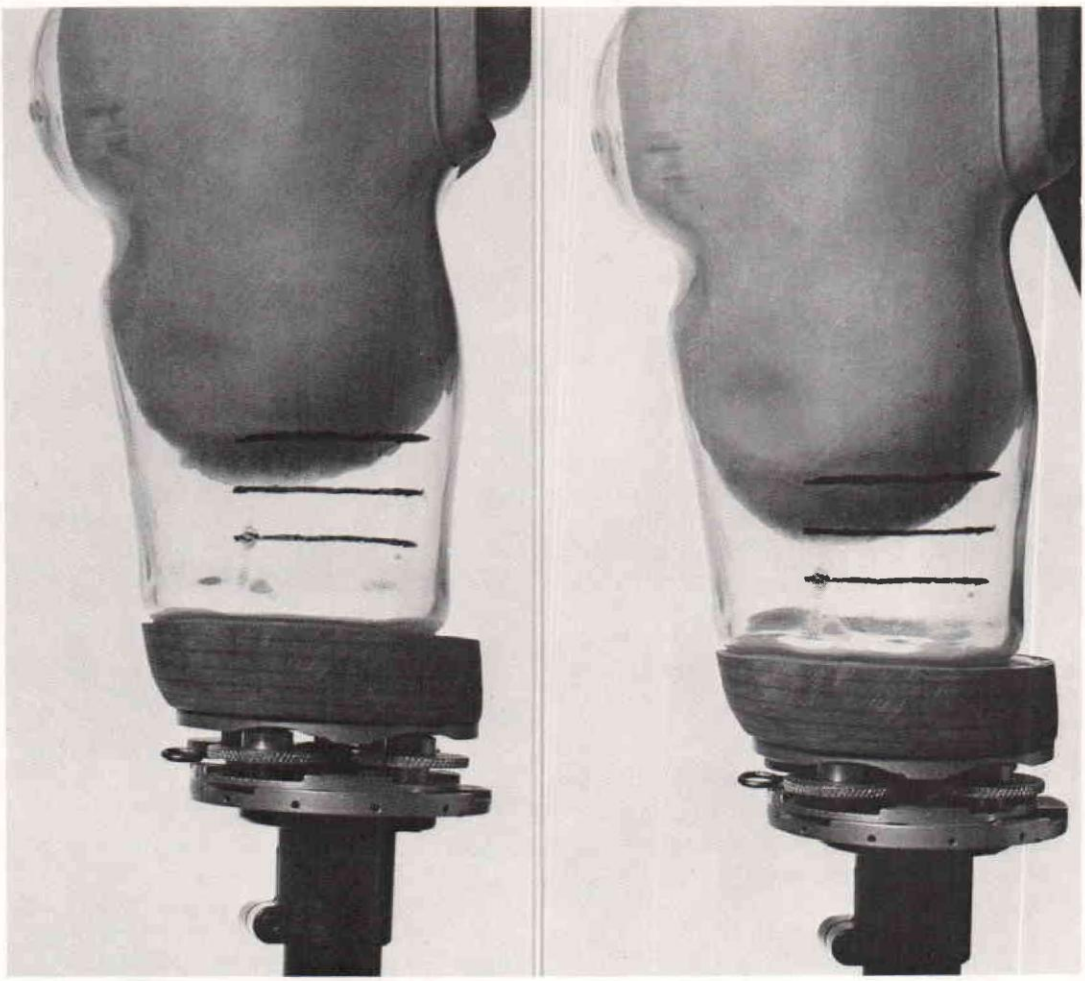

Fig. 1. The porous, flexible (open-mesh) insert for a below-knee prosthesis shown installed in a transparent polycarbonate socket. Left, the stump is not bearing weight; right, the stump is bearing weight.

requested a new limb fabricated in a similar manner, and this was prescribed.

CASE NO. 2.

C.A.R., a 27-year-old bilateral BK congenital amputee, is a research physiotherapist. The patient consented to participate in the program involving the open-mesh socket because there was a tendency toward excessive perspiration of the stumps. The prostheses were prescribed July 31, 1972, and delivered on October 14, 1972. When last examined April 20, 1973, the following note was recorded by the clinic team:

> "The patient was pleased with the open-mesh distal-end soft socket inserts and demonstrates a perspiration pool in the trap below the mesh on each side. It was estimated that two tablespoonfuls of fluid were removed from each socket trap every night."

CASE NO. 3.

J.S.F., a 32-year-old elevator operator was amputated on the right side below the knee in May 1969, following an injury by a land mine. His stump was revised in September 1969, to a 7½" length. An Ertl procedure (3, 4, 5, 6) was carried out. When he was seen by the clinic team on November 19, 1970, he complained of pain in the distal part of the stump. Only a limited amount of weight-bearing could be tolerated in spite of the Ertl procedure. A PTB prosthesis with a Plastazote distal pad was prescribed. In February 1972, an ulcer appeared on the distal end of the stump. The ulcer healed finally, after several socket adjustments, by June 1972, but the distal end continued to cause discomfort. An open-mesh distal-end soft-socket insert was prescribed. The prosthesis was delivered on September 5, 1972.

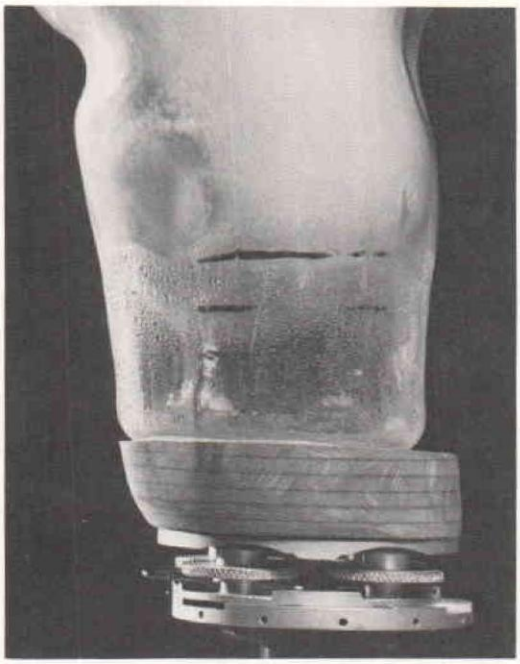

Fig. 2. Photograph showing accumulation of fluid in the distal compartment.

On re-examination December 14, 1972, it was recorded by the clinic team that the patient was pleased with the open-mesh socket. He was referred to Internal Medicine for treatment of generalized edema, ascites, and a palpably enlarged liver. The stump was in good condition, fitted well in the socket, and was not edematous. After he was placed under medical care, his generalized edema was controlled.

When examined February 5, 1973, he reported that, although he formerly had noted a good deal of perspiration in his socket, he no longer had had this problem with use of the open-mesh insert. His stump sock was damp in the evening, but not wet.

At his last examination, April 23, 1973, he indicated that he was pleased with the insert, stated he had no problems, and requested a similar type for a spare. The stump was in good condition.

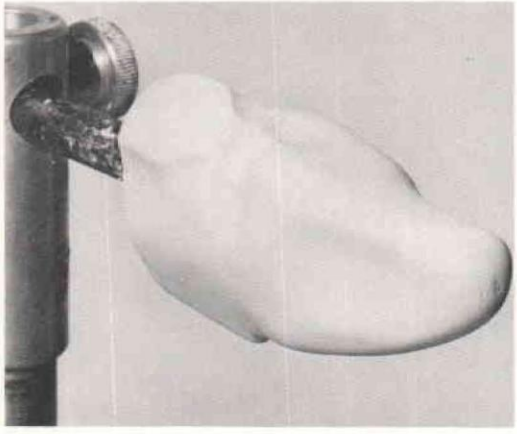

Fig. 3. Modified positive model of the below-knee stump.

CASE NO. 4.

M.C.S. is a 50-year-old, unemployed BK amputee whose left leg was amputated in September 1971 for Buerger's disease. A once-inch-wide split-thickness skin graft had been used to achieve closure along the entire transverse length of the fishmouth scar. The stump was in good condition otherwise. In September 1972, the right side was amputated, also at the BK level. On this side there was tenderness at the distal end, and the patient could not tolerate total contact. A prosthesis with an open-mesh distal-end socket insert was delivered to the patient in September 1972 for the left leg. In view of the distal pain, the right side was provided with an open-end socket. On January 8, 1973, it was recorded by the clinic team that his left stump was relatively free of moisture.

On February 28, 1973, the clinic team reported that, after the amputee used his prosthesis for four hours, about a tablespoonful of fluid was accumulated in the compartment below the mesh on the left limb. The stump sock felt damp, not wet. The patient's stump was shrinking progressively and a new prosthesis of the same type was prescribed.

CASE NO. 5.

R.LaC., a 50-year-old clerk sustained a post-traumatic amputation below the knee in 1944. The stump was revised in 1949. The patient did not have a problem with excessive perspiration, but he did have a fitting problem. By February 9, 1971, two months after he had been converted from a thigh-corset side-joint limb to a PTB with a foamed-in-place distal end he developed an ulcer over the distal end of the stump. The patient was very cooperative, and extremely anxious to discard the thigh corset. On February 17, 1971, a precursor of the open-mesh distal-end socket was fabricated for him. Cordo-impregnated nylon mesh was used with a view to simulating the air-cushion socket (8), yet with retention of the ability to modify the socket or replace the insert. This approach failed, although there was some improvement in the condition of the stump. However, the ulceration did not heal completely and he continued to have discomfort.

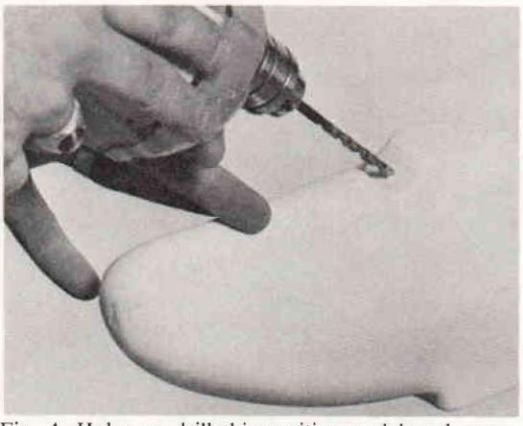

Fig. 4. Holes are drilled in positive model so that use of vacuum pump will avoid bridging of laminate.

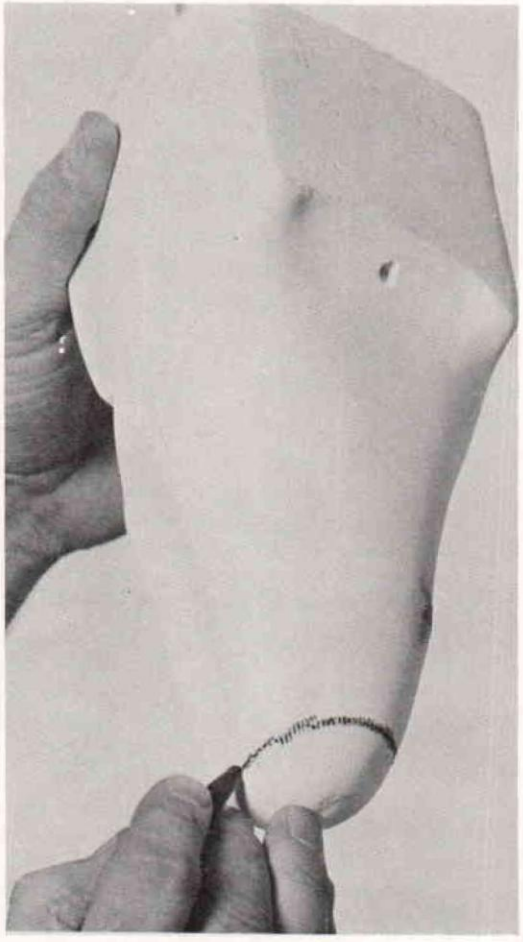

Fig. 5. Making the circumferential line to delineate the area of the open mesh.

He reverted to the thigh-corset limb, but persisted in his wish to have a PTB.

On October 20, 1972, a PTB with an open-mesh distal-end soft socket insert was delivered to him. He could not obtain comfort with this and, when last seen in April 1973, he had finally accepted the thigh-corset side-joint prosthesis as the most comfortable limb for him. This patient is considered a failure although it is quite evident that the problem was one of inability to obtain comfort without a thigh corset rather than failure of the open-mesh procedure.

FABRICATION OF THE OPEN-MESH LINER

For the open-mesh liner to function properly the usual modified male model of the stump must be modified further by the removal of ⅛" of plaster from the distal end of the male cast (Fig. 3).

A ⅛" diameter hole is bored in the patellar tendon area and another in the popliteal area to the inside of the cup to permit maximum use of a vacuum pump during lamination (Fig. 4).

A circumferential line is made one inch proximal to the distal end of the cast (Fig. 5) to delineate the area for location of the open-mesh. Obviously this area should not be coated with "Cordo" at any stage in the procedure.

A woman's nylon hose is then placed over the cast to prevent damage to the latex balloon that is then invaginated over it (Fig. 6).

Two coats of "Cordo solution plain" are applied directly to the latex balloon, but not extended past the mark on the distal end of the cast. A shrinker sock is rolled onto the cast over the balloon (Fig. 7). Care should be taken not to bridge the popliteal or patellar tendon areas with the shrinker sock. The shrinker sock is coated twice with "Cordo solution plain" up to the marked area, leaving the distal end free. As indicated previously, the free end of the shrinker sock will constitute the flexible open-mesh distal end of the completed insert.

A length of tube gauze, closed at the distal end, is pulled over the liner and coated with two applications of "Cordo solution 50", again leaving the distal end uncoated (Fig. 8).

The distal end of the gauze is cut along the previously outlined circumferential mark and discarded (Fig. 9).

A second layer of tube gauze is applied and coated in the same manner. This layer is trimmed to a level ¼" proximal to the trim line of the previous layer. Two coats of "Cordo solution 50" are applied. This procedure is repeated, re-

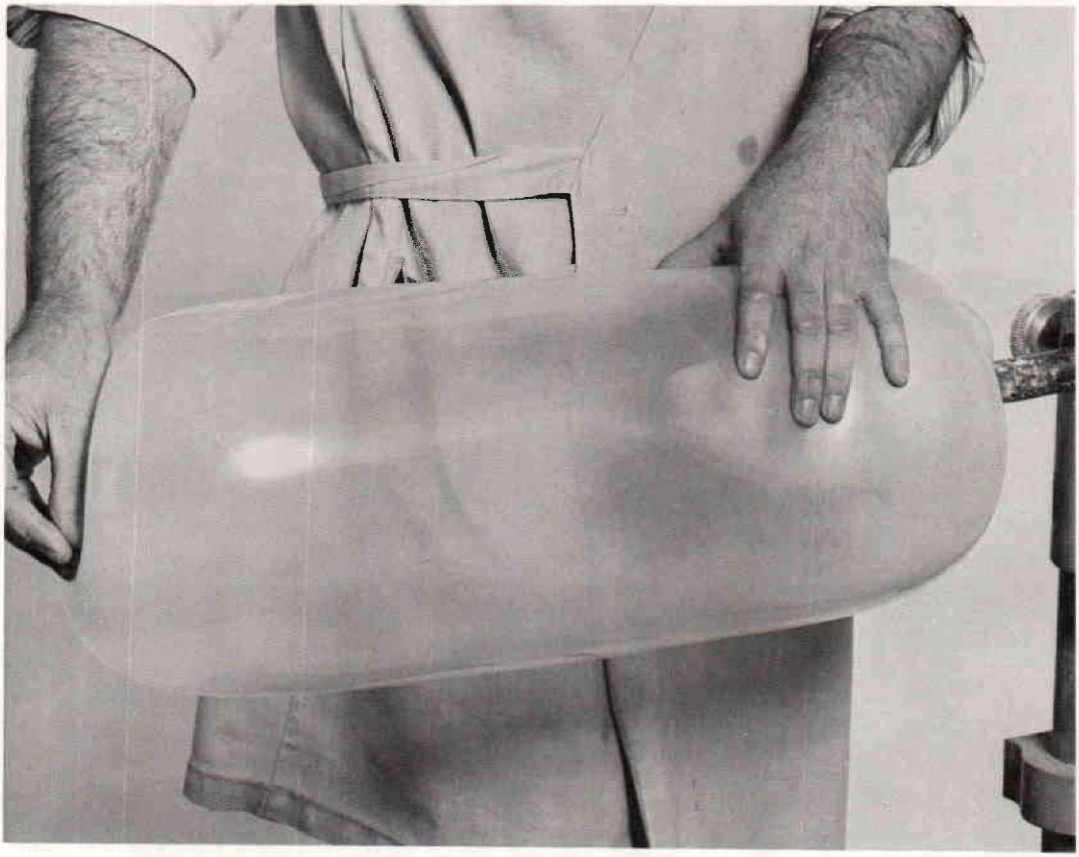

Fig. 6. Invagination of the balloon that acts as a separating agent, over the positive model.

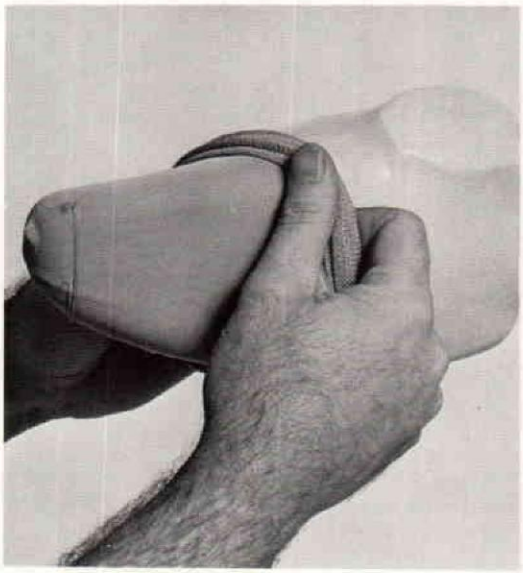

Fig. 7. Application of shrinker sock after application of two coats of "Cordo solution plain".

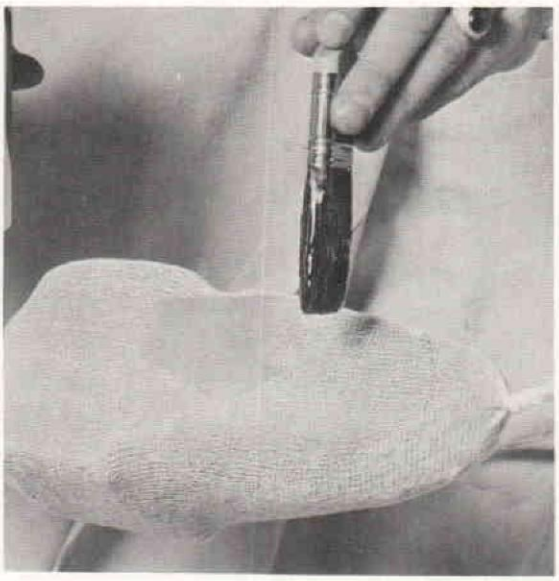

Fig. 8. Application of "Cordo solution 50" to the tube gauze that has been applied over the shrinker sock (Fig. 7).

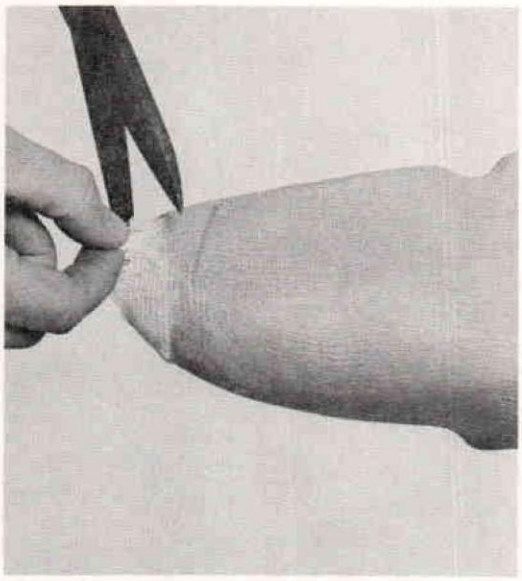

Fig. 9. Cutting of the tube gauze, so that the distal end can be removed to expose the open-mesh area.

treating proximally at ¼" increments until a total of six layers of tube gauze have been applied, each with two applications of "Cordo solution 50" (Fig. 10).

Finally, a prosthetic sheath or a woman's stocking is applied and similarly coated with "Cordo." The liner is allowed to air cure for at least five hours to insure that the ketones have evaporated fully. Curing can be done in less than two hours by use of a convection type of oven with a high-speed blower. The temperature should not exceed 125°F.

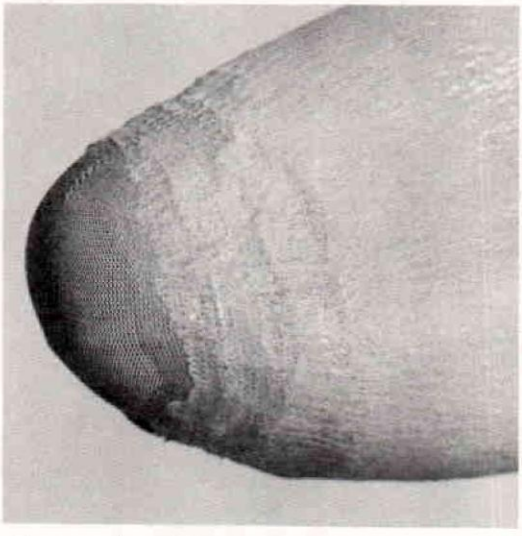

Fig. 10. View of distal end of liner after successive layers of tube gauze have been applied, each about ¼" above the other to develop a tapering distal end.

Upon completion of the liner, and prior to lamination of the socket, a ½" thick cap is placed over the distal end of the liner, which, when removed after lamination of the socket, will leave an open space beneath the distal end of the mesh to provide a perspiration trap. The cap may be made of either plaster of Paris or polyurethane foam. For each, the fabrication technique is essentially the same. A sheet of PVA is stretched over the distal end of the liner to protect it from the foam or plaster of Paris. A polyethylene bag or PVA sheet is then wrapped around the distal end of the liner and polyurethane rigid foam (or plaster) is poured into the extension. This is shaped to the contours of the cast to provide the ½" extension required (Fig. 11). The liner and cast are laminated in the conventional way. The male cast should be knocked from the liner, because when it is pulled delamination of the liner may occur.

Because the relationship of stump to socket is crucial, the ⅛" differential built into the distal end of the liner must be protected against any slight downward displacement of the entire insert within the socket. This could occur during the stance phase when stump pressure is applied intermittently. To prevent such displacement a supporting lip that overlaps the socket brim is built into the brim of the insert. The liner is trimmed to the same contours as the socket but a ⅜" extension above the socket brim is left. A tracing of the proximal portion of the socket is made and a paper pattern developed to be used in cutting a piece of moding leather that will follow the contours of the ⅜" extension (Fig. 12). The leather and the liner are coated with a cement such as Superbond. After the cement has dried, the leather is soaked in water until it is pliable, and then it is attached to the liner and sewn into position.

The fit of the prosthesis may be checked by X-ray. The liner will show up distinctly if the exposure is not too heavy, as in Figure 13 left, or it may require demarcation with a coin in the bottom of the socket as in Figure 13 right.

SUMMARY

A BK soft socket with an open-mesh distal end has been presented. This insert will retain total contact while allowing the escape of perspiration fluid bathing the stump of the patient with hyperhidrosis. The insert has been successfully employed for four patients. One patient is included as a failure, but the failure was not due

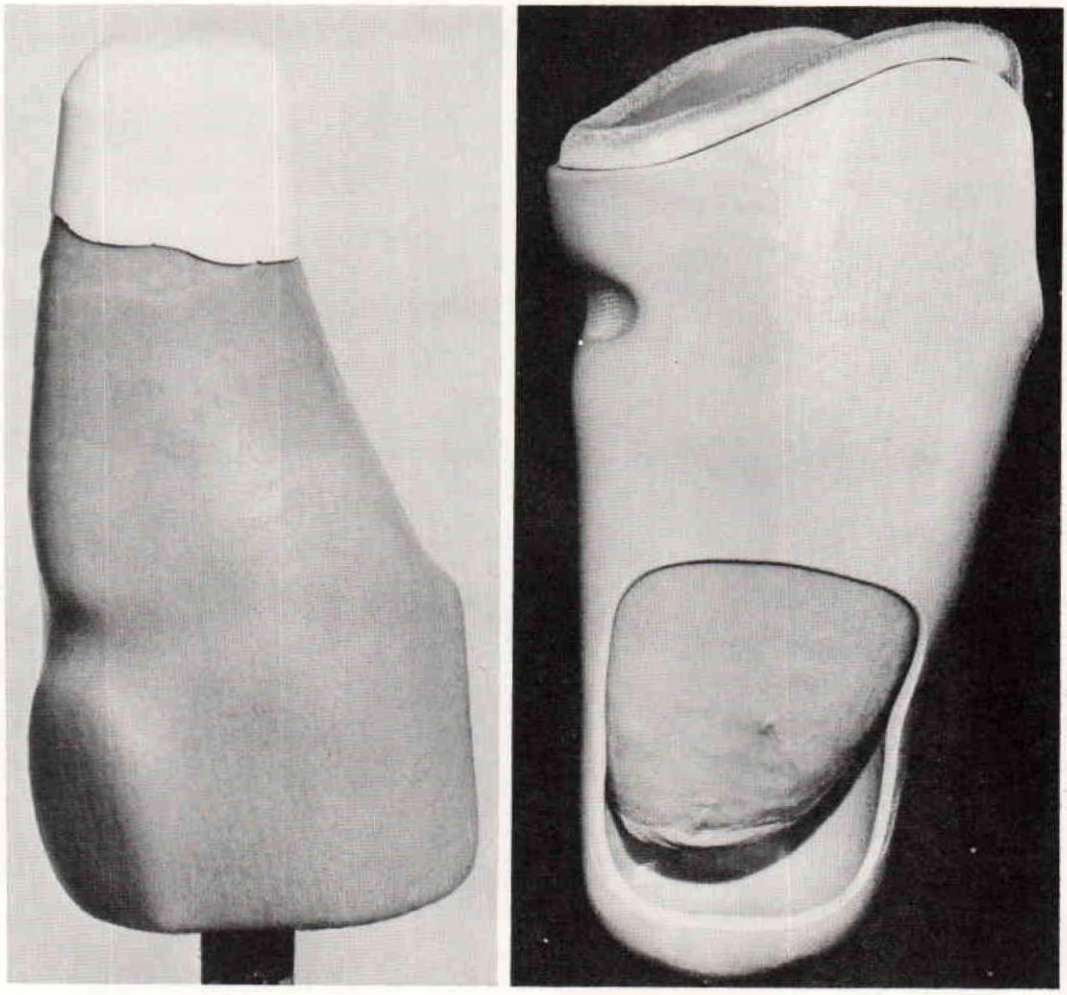

Fig. 11. Left, cap applied over distal end of liner-mold to provide space below liner in finished prosthesis; right, cutaway view of finished socket showing space between end of liner and the bottom of the socket.

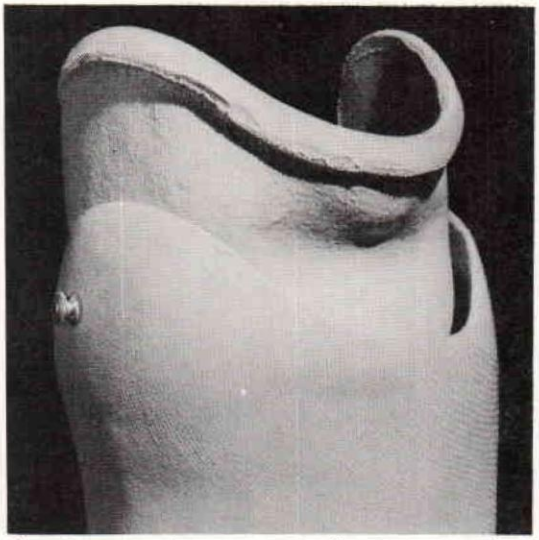

Fig. 12. View of the supporting lip. See, also, Fig. 11.

to dissatisfaction with the open mesh but rather inability to adapt to the change from a thigh-corset side-joint prosthesis to a PTB type. The liner has also been fabricated successfully for PTS and thigh-corset types of prostheses as well as the standard PTB.

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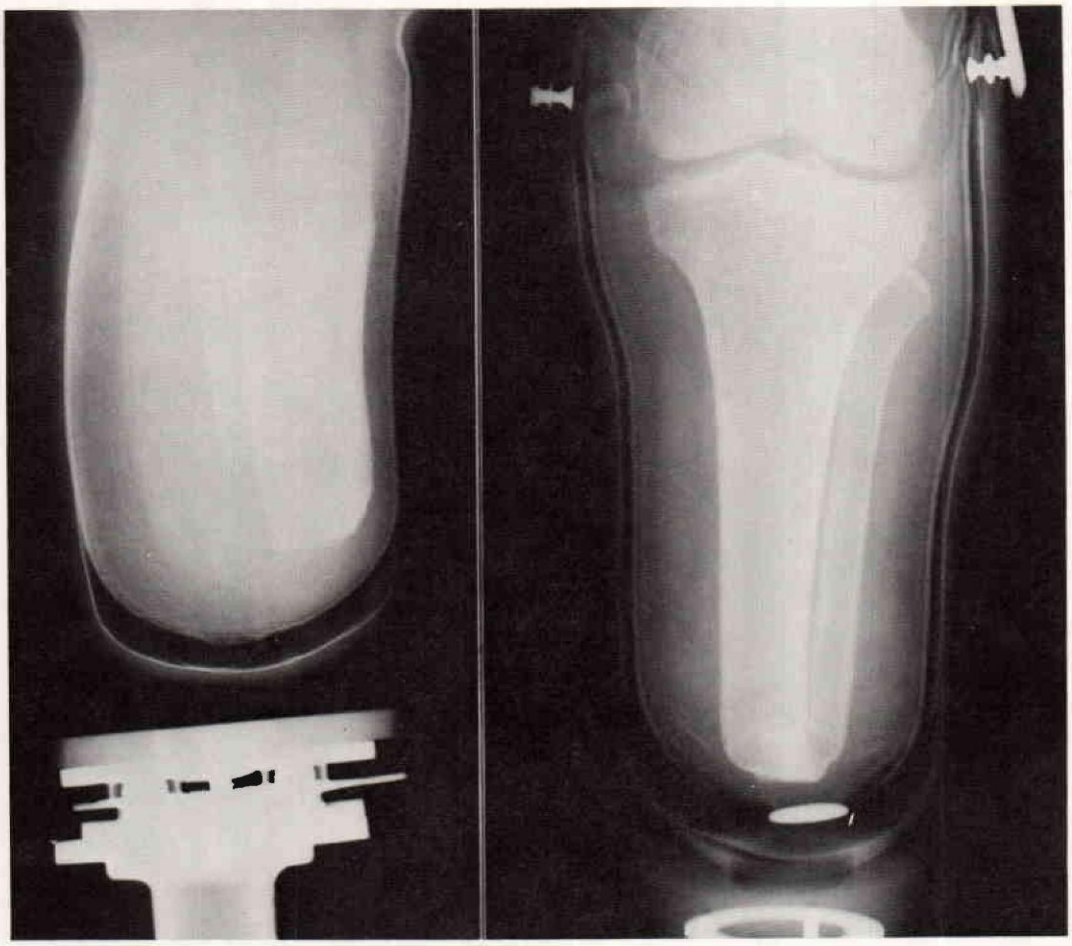

Fig. 13. X-ray views of patient in the prosthesis. On the right a coin has been placed on the distal end of the stump for reference.

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COLOR STANDARDIZATION FOR LAMINATED PLASTIC PROSTHETIC COMPONENTS

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In the past, prosthetics research has been concerned primarily with the mechanical aspects of limb design and construction. We are now capable of making very good, lightweight, durable prostheses of plastic laminate. In our laboratory we have had an occasional experience in which the artificial limb, though technically very adequate, did not quite satisfy the patient. On questioning patients about this reaction, it gradually became evident that the problem was in the mismatch between the color of the prosthesis and that of the patient's skin. We have particularly noted this with our Black patients.

As the Blacks and other minority groups become more conscious of their racial identities, they are rightfully demanding that their individualities be recognized. Those of us in prosthetics must recognize this.

In view of the emerging importance of more adequate esthetic treatment, we developed a system of color comparison and color matching which we hope will aid the prosthetist or orthotist in:

1. Accurate determination of the skin color of the patient.
2. Reproduction of the selected matching color in the laminated plastic prosthesis.
3. Recognizing the importance from the psychological standpoint of matching the color of the prosthesis with that of the patient's skin.

THE RESEARCH STUDY

EARLY METHODS OF SKIN MATCHING

Serious attempts at matching skin colors and tones began early in World War II. The Navy Dental Department at Bethesda made certain original contributions to coloring polyvinyl chloride for their own requirements. Using their experience, the NPRL made several hand molds that made it possible to produce experimentally a limited number of cosmetic gloves. These gloves were used with the Navy articulated artificial hand (Fig. 1).

The Army Prosthetics Research Laboratory (now Army Medical Biomechanical Research Laboratory) were also developing improved devices, including esthetic improvements, for upper-limb amputees. To avoid duplication of effort, NPRL abandoned further research on artificial hands and gloves. The Army has subsequently developed a hand and glove combination which today may be among the best in existence.

Using the experiences of the Navy Dental and Army units, we attempted the cosmetic treatment of artificial legs, concentrating on those

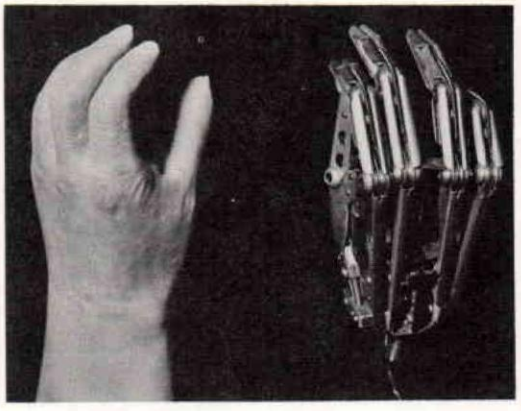

Fig. 1. EXPERIMENTAL POLYVINYL CHLORIDE GLOVE AND ARTICULATED ARTIFICIAL HAND—The NPRL molded polyvinyl cosmetic glove was individually colored at time of fabrication to match the skin tones of the patient.

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[2]Research Director, NPRL.

for female patients, with some success.

Two types of cosmetic treatment were devised:

1. Sponge Rubber Sections.
   Cut sections of thin, sponge rubber were applied to the external surface of the laminated plastic leg in such a way that the closure line corresponded with the seam line of the nylon hose on the posterior surface of the leg. This presented a smooth, resilient, conforming cover. A paint, mixed to match the skin color and tone of the contralateral leg, was applied. A pledget of cotton gauze was used to gently stipple the wet surface thus providing a life like skin texture. Sheer nylon hose were worn directly over the cover without difficulty. Later work resulted in a method of applying "pancake makeup" to the surface, allowing the patient to change the shade of her prosthetic leg to match the changes due to exposure to the sun. The cover could be cleaned with soap and water.
2. Molded Polyvinyl Chloride
   This consisted of a thin, molded, polyvinyl chloride. The material was formed by a dipping process using a mold made of thin, sheet copper in the shape of the leg. The cover was formed by repeatedly dipping the copper mold until the desired thickness was obtained. Repeated dippings also permitted considerable latitude in achieving proper and pleasing color matches.

Neither of these techniques proved to be practical in making large numbers of limbs and both have been abandoned.

PRESENT COLORING METHODS

Currently we have eight color pigments[3] available to us when we prepare plastic laminated prosthetic components. These are:

1. White
2. Caucasian
3. Mexican
4. 3-A
5. 4-A
6. 6-A
7. Burnt Umber in G-62
8. Black in G-62

Often these do not match very closely the true skin color of the patient. As a consequence the prosthetist mixes two or three colors together until he has a color which looks as though it will be close to the patient's skin color. Sometimes it is. The prosthetist, however, usually does not record how much of each pigment he has used, thus it is impossible to duplicate that specific color later if it becomes necessary.

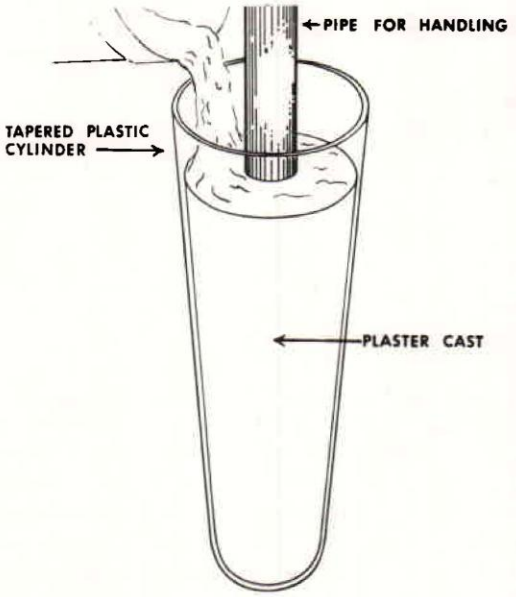

Fig. 2. POURING MOLD—Tapered and rounded mold was used for forming standard plaster models. They were poured with a mandrel in place.

In many instances limbs consist of several different laminated plastic components which are made at different times by different technicians; for instance, the hip disarticulation prosthesis. Often, the several components come out with slightly differing colors.

With this in mind we decided to attempt to standardize our color system. Our goal was to allow the patient to choose the color that most nearly matched his skin. We had hoped that this procedure would make the patient feel he was a member of the "production team" as well as add to the accuracy of the result. Additionally, we wished to identify the color shadings numerically so that any prosthetist might exactly reproduce a color used earlier.

PRODUCTION OF TEST MODELS

The eight basic pigments, listed above, were used to make up a Master Skin Tone Table (Table 1) in which each of the commercial pigments was mixed as indicated, in a total of forty-one combi-

[3]Obtained from Kingsley Manufacturing Company, Costa Mesa, California

(1) White	(1) White	(1) White	(2) Caucasian	(3) Mexican	(4) 3-A	(5) 4-A	(6) 6-A
3% of 1 + 1% of 2	2% of 1 + 1% of 2	1% of 1 + 1% of 2	1% of 2 + 1% of 3	1% of 3 + 1% of 4	1% of 4 + 1% of 5	1% of 5 + 1% of 6	1% of 6 + 1% of 7
3% of 1 + 1% of 3	2% of 1 + 1% of 3	1% of 1 + 1% of 3	1% of 2 + 1% of 4	1% of 3 + 1% of 5	1% of 4 + 1% of 6	1% of 5 + 1% of 7	
3% of 1 + 1% of 4	2% of 1 + 1% of 4	1% of 1 + 1% of 4	1% of 2 + 1% of 5	1% of 3 + 1% of 6	1% of 4 + 1% of 7		
3% of 1 + 1% of 5	2% of 1 + 1% of 5	1% of 1 + 1% of 5	1% of 2 + 1% of 6	1% of 3 + 1% of 7			
3% of 1 + 1% of 6	2% of 1 + 1% of 6	1% of 1 + 1% of 6	1% of 2 + 1% of 7				
3% of 1 + 1% of 7	2% of 1 + 1% of 7	1% of 1 + 1% of 7					

Basic Colors

1—White
2—Caucasian
3—Mexican
4—3-A
5—4-A
6—6-A
7—Burnt Umber in G-62
8—Black in G-62

TABLE 1—Matrix of Mixtures to Obtain Color Swatches. Colors 7 and 8 are deleted because both are jet black.

nations of pigments. We wanted to duplicate, in miniature, exactly the same structure as our laminated limb components, each containing graduated amounts of color pigments. The standard form used to produce identical plaster casts was a tapered, plastic cylinder with a closed, rounded end filled with plaster (Fig. 2). A mandrel is used to facilitate handling and application of suction during polymerization of the laminated plastic. On removal from the mold each test model was dried thoroughly, sanded lightly, and then covered with a thin layer of polyvinyl acetate. The laminating materials (Fig. 3) consisting of a first layer of dacron fleece followed by four layers of nylon stockinet were applied.

Standard quantities of polyester plastic with graduated amounts and kinds of pigments shown in the Master Skin Tone Chart were used to saturate the laminates now in place. Methylethylketone peroxide was used as the catalyst and each unit was polymerized under suction.

When completely polymerized the top brim was cut away (Fig. 4) and the conical cup removed from the plaster. The cups were then cut into four longitudinal fourths and the elements shaped into "paddles" to provide four sets of color samples for use in the production shop. Each paddle was coded to show the color and percentages of each component—the numerical identification referred to earlier—to allow accurate color duplication. Apothecary scales were used in all weighings, because considerable accuracy is required in this procedure. When completed, each of the four sets of paddles were strung together on a nylon cord, ready for use in directly matching the skin color (Fig. 5).

The actual matching (Fig. 6) should take place in ordinary daylight, and not under artificial light. However, special lights are available which are color corrected and permit inside color matching. These are used inside a special light booth which masks out other kinds of artificial light.

MATCHING SKIN COLORS

In use, the paddle most nearly matching the

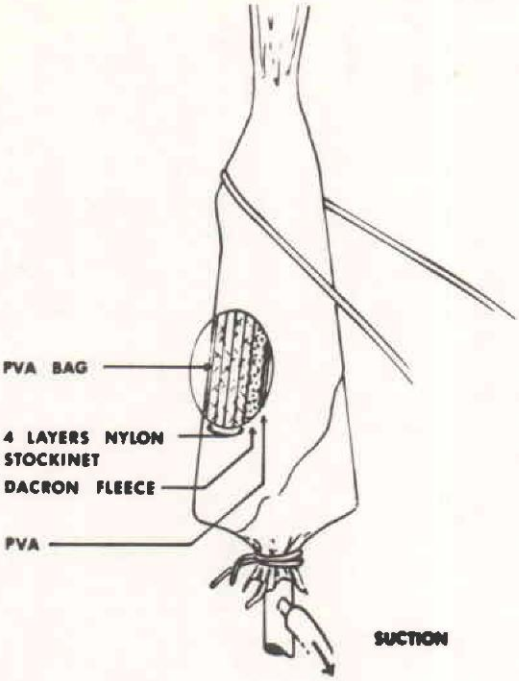

Fig. 3. LAMINATE OVER MODEL—The standard laminated structure was duplicated over models similar to a laminated shin. Suction was used during polymerization.

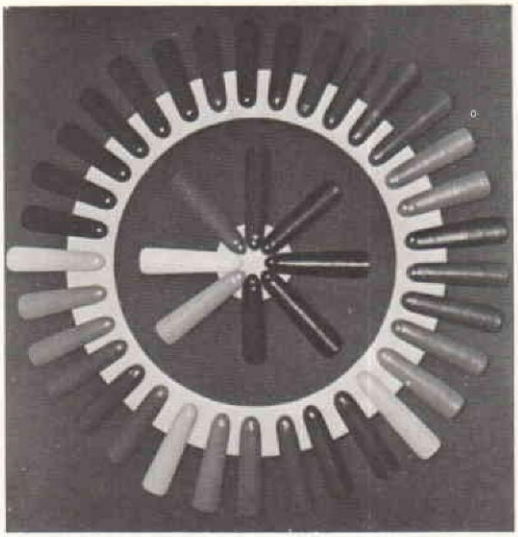

Fig. 5. SKIN TONE COLORS—Paddles in array show the eight basic colors in the center plus the remaining thirty-three skin tones arranged around the periphery.

skin color of the subject is selected, using daylight only. Referring to the Master Skin Tone Chart, the formula on the back of the paddle

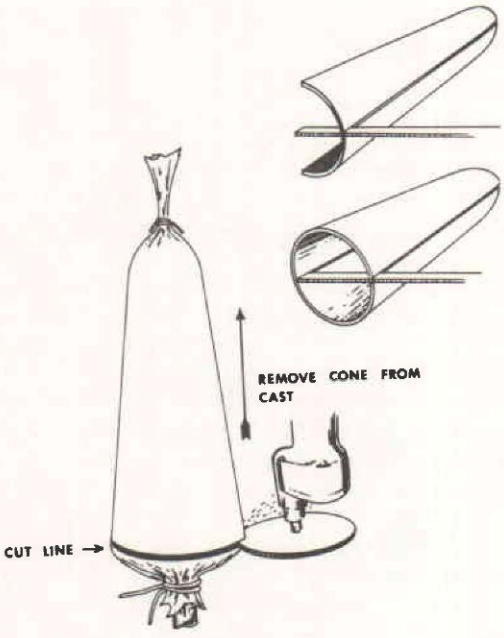

Fig. 4. REMOVAL & QUARTERING—The cone is shown being removed and quartered.

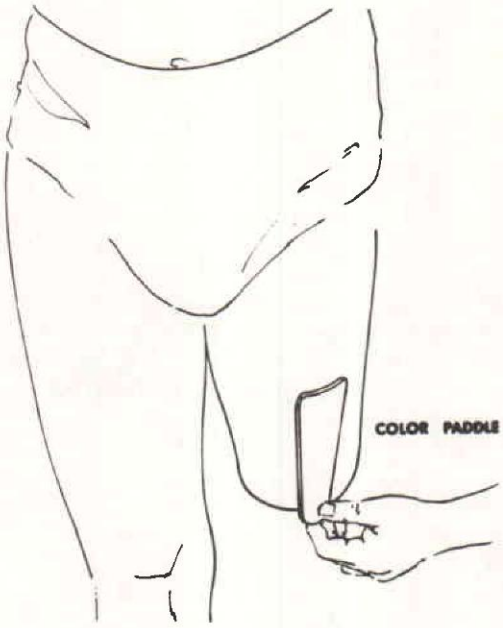

Fig. 6. MATCHING SKIN COLORS—Appropriate paddle is selected by comparing with skin.

selected is located. For example, suppose the formula is—"1% of 3 + 1% of 8". This means that when the amount of plastic is determined which will be required for lamination of the component at hand—for instance, 600 grams—then the calculation will be as follows:

600 grams of polyester
6 grams of #3 (1% of Mexican)
6 grams of #8 (1% of Black in G-62)
___ plus catalyst
612 grams—total

When mixed, applied and polymerized under suction, the resulting lamination will accurately match the skin tone paddle selected and, if the original matching was properly accomplished, it will accurately match the skin of the patient.

DISCUSSION

This color-matching system requires some care and a few precautions. The quantities noted are exact. Materials used must not become contaminated by careless use and storage. The scales must be accurate enough to weigh the small quantities involved. We have found that the plastic laminate color is affected somewhat by the underlying material. The same color will appear darker over wood. It will appear lighter over white foam.

One problem which still is unsolved is that there is some variation in the pigments as they come from the supplier. It is hoped that better quality control can be instituted, and we hope to make recommendations in the future to the prosthetic-orthotic profession relating to standards. We feel that patient participation is very important. The patient is given the samples and is encouraged to try them out in various lighting conditions. It is left up to him to choose the proper color. When he does this he feels he has become part of the clinic team, because he has some say in how his artificial limb will look. We have received favorable response from our patients since we have instituted this system. In those few cases in which the color match has not been as good as we might have hoped, the patient feels he is at least partially to blame, and thus is not so critical of the prosthetist.

SUMMARY AND CONCLUSIONS

The prosthetics profession has an obligation to improve the color matching of artificial limbs to the respective skin colors of patients. Our minority patients, as they become more proud of their racial identities are beginning to insist on it.

We have presented our preliminary efforts at developing a standardized color system for use with plastic laminate prosthetic components. It involves forty-one plastic laminate color samples which cover the spectrum from the lightest Caucasian to the darkest Negro and include many tones suitable for the Mexican-American. Each color sample is numbered so that the prosthetist can refer to a chart and quickly determine what proportions of the basic pigments to use to reproduce it. The patient is asked to choose that color which most nearly matches his skin color. Variables are introduced by lighting, by the material over which the plastic laminate is applied and by variations in the pigments as they come from the supplier. These were discussed briefly.

Further development of a color matching system and better standardization of colors are required. We intend to continue working on this. As we learn more about the pigments and the color matching process, we hope to be able to extend the system to prosthetic feet, our molded plastic knees and our plastisol coatings for orthoses.

THE ABOVE-KNEE FRACTURE ORTHOSIS

Virgil Faulkner, C.P.O.[1] and
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The Prosthetic and Orthotic Division of the University of Virginia with the cooperation of the Department of Orthopedics has conducted over the past eight months a limited investigation of the treatment of femoral fractures with a temporary orthosis made from prefabricated components and plaster of Paris. Until recently it had been generally held that the only suitable method for good osteosynthesis of fractures was rest and rigid fixation. If the fixation could not be achieved by external means, internal fixation would have to be accomplished. There has been good laboratory evidence showing the detrimental effect on healing of motion at the fracture site (5). However, it is well known that the clavicle and ribs heal very nicely while under fairly constant motion.

With this in mind, there were some advocates of early ambulation and weight-bearing on the fractured tibia. During the 1950s the United States Army conducted a study of this concept that resulted in the closed weight-bearing treatment becoming the one choice in the military (1). Sarmiento's work (6, 7) with the functional below-knee cast for tibial fractures that resulted in the development of the functional below-knee brace has now almost completely eliminated any need for open treatment of tibial fractures. The concept that the soft tissues of the leg act as a "fluid" and the ends of the fractured tibia are pistons within this "fluid" defines a hydraulic system (7): that is, when a snug-fitting cast or brace imposes definite boundaries on the soft tissue, the soft tissue then acts as a rigid cylinder when loaded. This rigid cylinder then is inherently stable and no appreciable shortening or displacement can occur. This principle has been proven adequately in the case of the tibia, and can also be applied to the femur.

The femur, however, poses a problem more difficult than the tibia. The thigh contains considerably more soft tissue than the tibia and has a much greater cross-sectional area at each end allowing the soft tissue to escape from the rigid cone that is formed by an enclosing cast or brace when the leg is loaded, thereby allowing some shortening. Furthermore, the femur is considerably more lateral to the line of force from the center of gravity of the body than is the tibia so that there is a greater force present to cause angulation. Consequently, treatment of the fractured femur while ambulation is permitted is not as satisfactory. Sarmiento has been somewhat disappointed with functional bracing of femoral fractures when compared to tibial fractures (7). Mooney *et al.* (4) have found that this form of treatment is superior to the conventional spica-cast treatment for distal femoral fractures.

The major difference in treating the two types of fractures is that in the femur some inherent stability of the fracture through healing must have taken place before ambulation is encouraged. This is accomplished by applying traction for a period of time sufficient to obtain stability, usually about seven weeks for adults. The best results occur when the distal half of the femur is involved. Fractures more proximal will angulate because of the impossibility of providing a cone of support high enough to counteract the natural tendency for lateral angulation. As in the case with the tibia, the cast about the thigh provides a truncated cone with the soft tissue becoming rigid when loaded. The addition of a quadrilateral-socket contour to the thigh piece provides some rotational stability.

Only the thigh portion of the orthosis is func-

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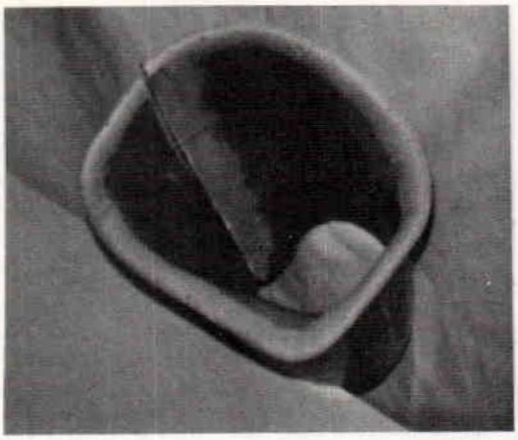

Fig. 1. Prefabricated plastic quadrilateral-type socket brim used to provide rotary stability about the thigh.

tional, the remainder of the orthosis being used only to hold the thigh portion in place. Most of these orthoses are supported from below by knee hinges attached to a cast about the shin or by a cable attached to the shoe. Deyerle (2) suspends the thigh piece from a waistband leaving knee and leg entirely free.

The use of the cast brace permits the patient to get out of bed and to leave the hospital sooner and in a more functional capacity than is the case when a spica cast is used. The risk of osteomyelitis from internal fixation is eliminated and the healing time is shortened. In a study by Mooney (4), the average time of treatment was 14.5 weeks compared to 24.7 weeks using spica casts.

This form of treatment can be used in children but should be restricted to those under the age

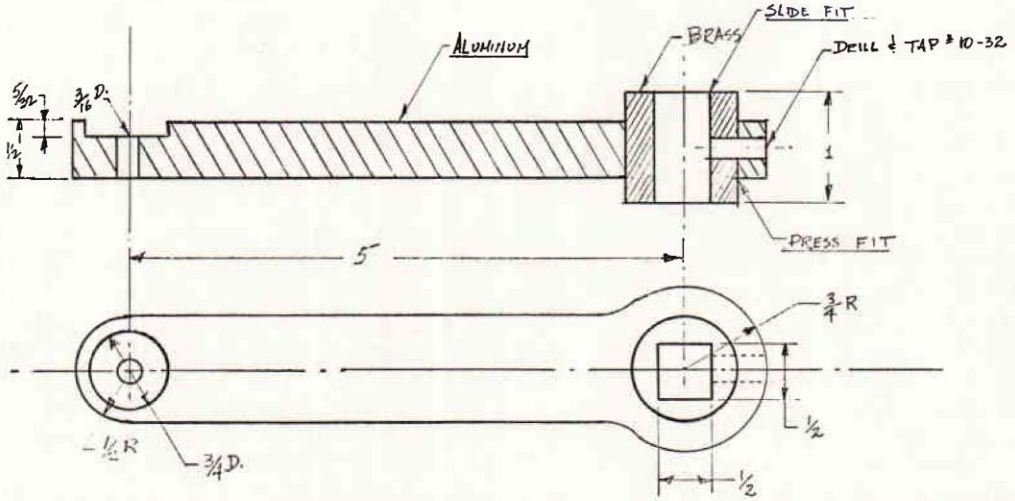

Fig. 2. Alignment fixture, upper left, and sketches of two of the major components. The connecting slide-bar is simply brass stock ½" × ½" about 13" long.

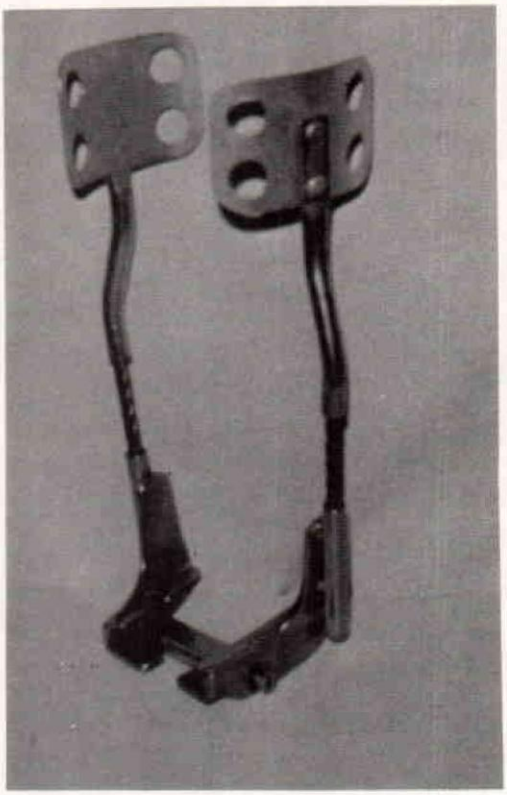

Fig. 3. Ankle "joint" developed at the University of Miami.

of ten with a well-contoured leg after at least four weeks of traction. If angulation is noted after ambulation it should be corrected, or it will progress (3).

THE TECHNIQUE

The orthosis is applied to the patient's limb after a period of traction to gain bony stability, usually about seven weeks. The design of the orthosis is intended to create a total-contact appliance that will give stability to the fractured femur. A quadrilateral-type socket brim is used to provide rotary stability about the long axis and a close fit about the thigh (Fig. 1). The orthosis is only intended to be partially weight-relieving.

Careful alignment of the knee joint is obtained by the use of an alignment fixture designed and fabricated by the Biomedical Engineering Department at the University of Virginia (Fig. 2). In most cases no ankle joint is used. However, when one is used, it is the one developed by Sinclair at the University of Miami (Fig. 3)[3].

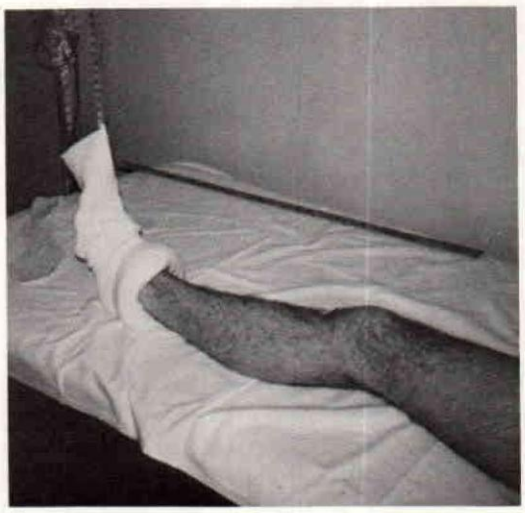

Fig. 4. Application of cast-fracture sock.

MATERIALS AND COMPONENTS NEEDED FOR APPLICATION

1. One cast-fracture sock[4]
2. One split quadrilateral socket
3. Five rolls, resin-impregnated plaster of Paris
4. Four rolls, elastic plaster of Paris
5. Two malleolar pads
6. One calcaneal pad
7. One pair of knee hinge joints
8. One alignment fixture (Fig. 2)
9. One can, medical adhesive
10. One fracture boot

APPLICATION OF THE ORTHOSIS

When traction is discontined the cast orthosis is applied to the patient in the following manner: a cast-fracture sock, a prefabricated, split, quadrilateral socket brim, and a pair of conventional orthotic knee joints with drop locks are selected, and the joints are prepared and attached to the alignment fixture. If an ankle joint is to be incorporated into the orthosis, it is also selected at this time.

After the traction equipment has been removed, the cast fracture sock is slipped over the patient's limb while he is still in bed (Fig. 4). He is then transferred to the fracture table.

[3]United States Manufacturing Co., Glendale, CA 91209

[4]Knit-Rite, Inc., Kansas City, MO 64106

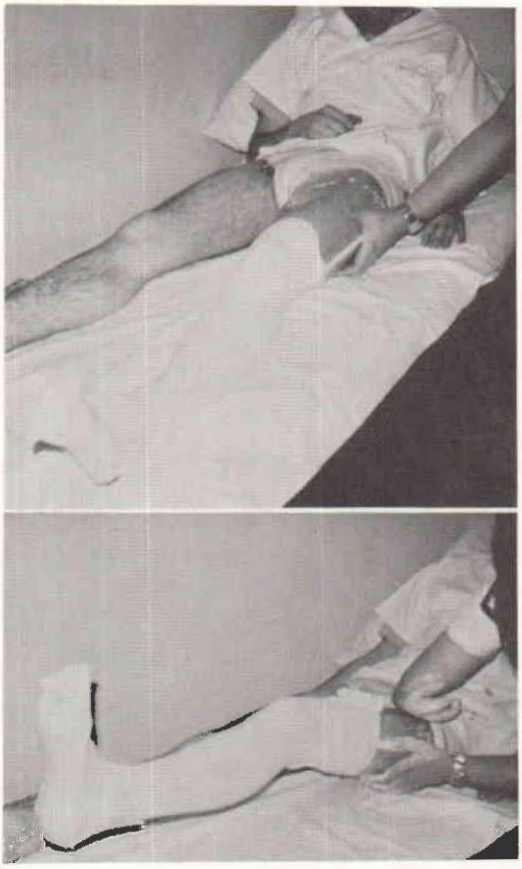

Fig. 5. Application of the quadrilateral-socket brim.

(The use of the fracture table is recommended because it allows the practitioner complete freedom to work around the limb. If a fracture table is not available, the procedure can be carried out on a bed or a stretcher.) The quadrilateral-socket brim is applied as high as possible on the thigh and is secured by two circular wraps of resin-impregnated plaster[5] (Fig. 5).

The practitioner must at this time make sure that the quadrilateral socket is providing total contact. The malleolar and calcaneal pads are applied, and the extremity is held with the knee in slight flexion and the ankle at 90° (Fig. 6) so that the cast sock adheres closely to the skin as the wrap is made.

Starting at the distal end of the quadrilateral socket, the limb is wrapped with elastic plaster-of-Paris bandages. Each wrap overlaps one half of the previous wrap. Use of elastic plaster bandage is essential to insure total contact. This wrap is carried all the way to the heel and toes.

[5]Merck, Sharp, and Dohme, West Point, PA 19486

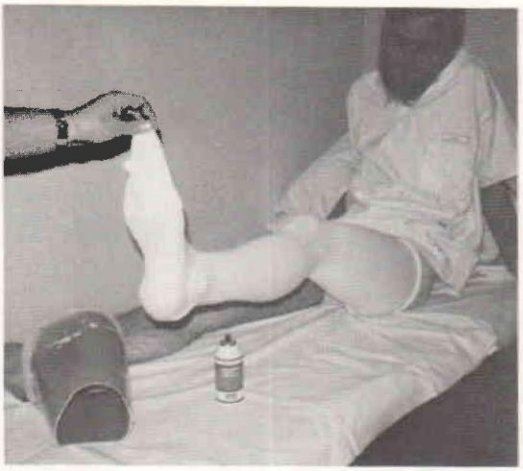

Fig. 6. Making sure that the cast sock adheres to the skin to, in turn, insure that total contact between cast and limb will be obtained.

Particular care must be given to the area surrounding the foot-ankle complex because the elastic plaster bandage will shrink as it hardens, and may cause excessive pressure in this area. After the elastic plaster has hardened, two layers of resin-impregnated plaster to provide adequate strength are applied starting at the most proximal section of the orthosis and carried all the way to the toes.

After the cast has hardened, rectangular sections on both the medial and lateral sides at the level of the knee are cut out of the cast (Fig. 7) and the knee joints are attached utilizing the

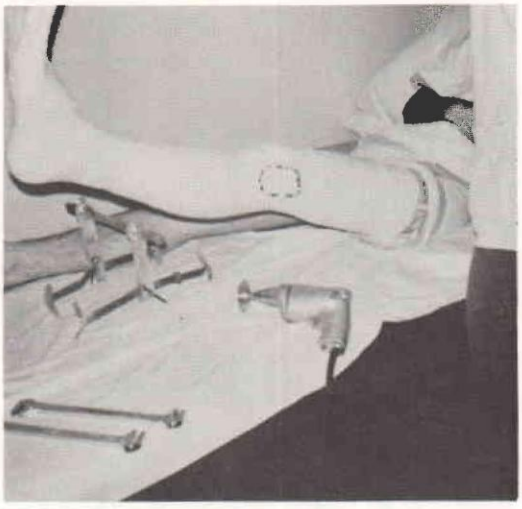

Fig. 7. Rectangular sections are cut out of the cast in the area corresponding to the knee joint.

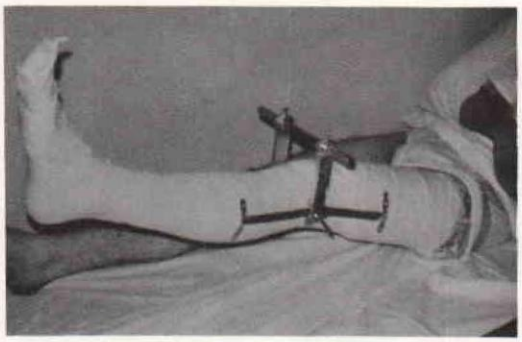

Fig. 8.Attachment of the knee joint by use of the alignment fixture (Fig. 2).

alignment fixture (Fig. 8). The axis of the knee hinge should be as close to the axis of the knee joint as possible.

After twenty-four hours, the patient may be allowed to bear partial weight with crutches using his orthosis (Fig. 9). After forty-eight hours the remainder of the knee section is removed to allow

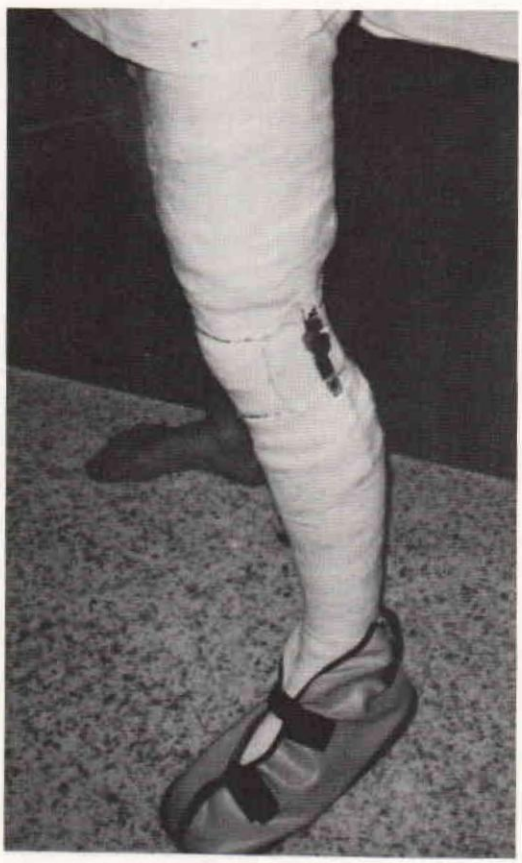

Fig. 9. Partial weight-bearing is generally allowed after 24 hours.

Fig. 10. View showing trim lines on proximal and distal portions of cast made approximately 48 hours after application.

knee motion (Fig. 10). The Orlon cast sock should not be cut because it helps to prevent edema around the knee.

At this time it is important to assure a good range of motion of the knee by cutting away plaster in the popliteal area if necessary. After two weeks of training with crutches, knee exercises, and cast adjustments for comfort, the patient usually may be discharged. The average patient will require no more than two to three months of use of his orthosis. After this time if X-ray and clinical signs show good healing, he may walk with crutches but without any other means of external support.

CONCLUSION

As stated previously, the ambulatory treatment of fractures of the femur with a cast orthosis is considered to be a reliable method. Our experience with more than 30 patients closely parallels that of Mooney (4). Shortening should remain the same as accepted during traction. Knee edema if present should disappear in a month's time; however, all patients should elevate the limb for approximately ten minutes each hour.

The indication for use of the cast orthosis is any patient with a fracture of the distal femur with a well-contoured thigh who has no other injury that would preclude ambulation. Contraindicated is the patient with a short obese thigh unless he has a very low fracture. Epiphyseal fractures should not be treated by weight bearing. If angulation is accepted during traction it will probably worsen in the fracture brace. This form of treatment allows the patient to get out of the hospital sooner and to better care for himself as well as shorten the overall healing time.

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PATIENT POPULATION AND OTHER ESTIMATES OF PROSTHETICS AND ORTHOTICS IN THE U.S.A.

Maurice A. LeBlanc, M.S., C.P.[1]

Because of the way health services are delivered in the United States, no accurate figures are available concerning the orthopaedic patient population, treatment methods, and other information that would be useful to administrators, clinicians, and research groups.

In July 1969 the Committee on Prosthetics Research and Development (CPRD) collected information that permitted certain estimates concerning amputees and orthotic patients in the U.S.A. (1). This article, compiled in May 1973, updates the 1969 effort. Further searching for more accurate information has emphasized that only rough estimates can be made, especially in orthotics.

PROSTHETICS

NUMBER OF AMPUTEES

The best sources of information on the total number of amputees in the country are the household interview surveys conducted by the National Center for Health Statistics (NCHS)[2]. For the time periods 1963-1965 (7), 1965-1967 (8), 1969 (8), and 1971 (8), these surveys resulted in estimates of 257,000, 305,000, 260,000, and 274,000 amputees respectively in the civilian, non-institutional population. Taking an average of these figures and guessing at the number of amputees in military and Veterans Administration hospitals, convalescent homes, and other institutions, brings the total to at least 300,000 or about 1.5 amputees per 1000 population[3]. This figure corresponds quite well with statistics from Great Britain.

The NCHS surveys show that the ratio between upper-limb and lower-limb amputees is 30% to 70%.

LEVELS OF AMPUTATION

For use in estimating the distribution by level of amputation, only the results of surveys conducted by the Committee on Prosthetic-Orthotic Education (CPOE) in 1961-1963 (3) and 1965-1967 (2) are available (Table 1).

These surveys consisted of contacts solely with prosthetics facilities and include only those amputees showing up for prosthetic treatment. The 1961-1963 study consisted of data only from the initial fitting of patients for a given period. The 1965-1967 study consisted of data from all patients fitted at a selected number of prosthetics facilities for a given period. The first study involved approximately 12,000 cases; the latter, about 4,000. Since not all amputees wear prostheses, the CPOE surveys obviously do not yield a complete picture. Therefore, it seems appropriate to show the distribution by level of amputation in upper- and lower-limb groups (Table 2).

The results of the two surveys are quite similar. The noticeable change is the reversal in numbers of above-knee and below-knee amputations. Presumably this is because of the benefits of immediate postsurgical prosthetic management and improved methods of elective surgery allowing greater length to be saved. A repeat of the 1961-1963 survey is currently underway as a cooperative effort of CPRD-CPOE and the American Orthotic and Prosthetic Association (AOPA).

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[2]National Center for Health Statistics, Health Services and Mental Health Administration, Public Health Service, Department of Health, Education, and Welfare, 5600 Fishers Lane, Rockville, Maryland 20852.

[3]Based on a population of 200,000,000.

Level of Amputation	1961-1963 CPOE Survey		1965-1967 CPOE Survey	
Shoulder	1.1%		0.6%	
Above-Elbow	3.7		3.2	
Elbow	0.3	14.5%	0.4	13.5%
Below-Elbow	8.6	Upper-Limb	7.7	Upper-Limb
Wrist/Hand	0.8		1.6	
Hip	1.8		1.3	
Above-Knee	44.1		35.2	
Knee	1.1	85.5%	1.3	86.5%
Below-Knee	36.8	Lower-Limb	46.4	Lower-Limb
Ankle/Foot	1.7		2.3	
TOTAL	100 %		100 %	

TABLE 1

Level of Amputation	1961-1963 CPOE Survey	1965-1967 CPOE Survey
Upper-Limb		
Shoulder	8%	5%
Above-Elbow	26	23
Elbow	2	3
Below-Elbow	59	57
Wrist/Hand	5	12
TOTAL	100%	100%
Lower-Limb		
Hip	2	2
Above-Knee	52	41
Knee	1	1
Below-Knee	43	53
Ankle-Foot	2	3
TOTAL	100%	100%

TABLE 2

AMPUTEES BY AGE

There are several sets of figures available from which amputees can be broken into age groups. One useful breakdown is given in Table 3. Taking an average of these figures gives about 10%, 60%, and 30% in the under 21, 21-64, and 65-and-over age groups respectively.

USE OF PROSTHESES

It has long been a rule of thumb that 50% of arm amputees and 75% of leg amputees wear prostheses. These estimates are reinforced by a 1969 NCHS survey (10) which cites the use of 46,000 upper-limb prostheses and 126,000 lower-limb prostheses or 52% and 76% of the arm and leg amputees respectively in that survey of the civilian, non-institutional population.

A 1964 NCHS survey (9) of homes for the aged and chronically ill estimated 2,100 artificial limbs being used by residents.

MANPOWER

Records at the American Board for Certification (ABC) office indicate that there are 395 certified prosthetists and 235 certified prosthetist-orthotists for a total of 630 certified prosthetists (including 1972 examinees). Therefore, the ratio of amputees to certified prosthetists is 300,000/630 or 476/1 and the ratio of artificial limbs to certified prosthetists is 203,000/630[4] or 322/1. From a CPOE manpower survey (14) and other indications from the field, additional qualified prosthetists are needed.

ORTHOTICS

NUMBER OF ORTHOTIC PATIENTS

The total number of orthotic patients is difficult to estimate because orthotic treatment is usually more complicated than prosthetic treatment and because records are not kept in a way so this information is accessible. A list of various

[4]Assuming 50% upper-limb and 75% lower-limb usage.

Age*	1961-1963	1965-1967	1963-1965	1965-1967	1969	1971
	CPOE Survey			NCHS Survey		
Under 21	12%	12%	7%	7%	14%	7%
21-64	60	59	62	58	55	65
65 & over	28	29	31	35	31	28
TOTAL	100%	100%	100%	100%	100%	100%

*In some cases interpolation of given statistics has been used to arrive at figures for some of the age groups.

TABLE 3

neuromuscular dysfunctions for which orthotics is commonly part of the treatment scheme is given in Table 4. We have insufficient knowledge at present to arrive at the total number of orthotic patients from this table showing neuromuscular dysfunctions or from surveys or records in the

Neuromuscular Dysfunction	Estimated Patient Population
Paralysis/Paresis of Upper Limb(s)	172,000[5]
Paralysis/Paresis of One Lower-Limb	330,000[5]
Hemiplegia/Hemiparesis	340,000[5],[6]
Paraplegia	77,000[5]-200,000[7]
Quadriplegia	38,000[5]
Cerebral Palsy	153,000[5]-750,000 (12)
Spina Bifida	27,500 (12)
Multiple Sclerosis	500,000 (12)
Muscular Dystrophy	200,000 (12)
Osteogenesis Imperfecta	10,000-30,000 (13)
Parkinson's Disease	1,000,000 (12)
Disabling Arthritis	2,201,000[8],[9]
Upper-Limb Deformity	819,000[5]
Lower-Limb Deformity	2,916,000[5]
Spinal Deformity	1,135,000[5]

TABLE 4

[5] All figures for paralysis and deformity are averages of the statistics from the NCHS household interview surveys of 1963-1965 (7), 1965-1967 (8), 1969 (8), and 1971 (8).

[6] In reference (11) the National Institute for Neurological Diseases and Stroke estimates that there are 2,000,000 total cases of stroke (CVA—cerebralvascular accidents) in the U.S.A. However, there is no way to arrive at the number of hemiplegic and hemiparetic people from this estimate.

[7] In reference (12) the National Paraplegic Foundation guesses there are 125,000 to 200,000 paraplegic people in the U.S.A.

[8] The NCHS survey reported in reference (5) estimates that due to arthritis and rheumatism there are 3,248,000 people with limitation of activity and 1,541,000 people with limitation of mobility among the civilian, non-institutional population.

[9] The Social Security Administration survey reported in reference (4) estimates that among the civilian, non-institutional population between ages 18-64 there are 2,201,000 people with major disabling arthritis and rheumatism causing limitation of work.

field. Thus, the best estimate now is the rule-of-thumb ratio 10 to 1 of orthotic patients to amputees, which gives about 3,000,000 orthotic patients or 15 per 1,000 population.

USE OF ORTHOSES

NCHS surveys of 1958-1959 (6) and 1969 (10) showed 695,000 and 1,102,000 braces respectively being used in the civilian, non-institutional population. A 1964 NCHS survey (9) of homes for the aged and chronically ill estimated 5,400 braces being used by residents.

MANPOWER

Records at the ABC office indicate that there are 515 certified orthotists and 235 certified prosthetist-orthotists for a total of 750 certified orthotists (including 1972 examinees). Therefore, the ratio of potential orthotic patients to certified orthotists is roughly 3,000,000/750 or 4,000/1 and the ratio of actual braces to certified orthotists is roughly 1,107,000[10]/750 or 1,476/1. From a CPOE manpower survey (14) and indications from the field, additional qualified orthotists are in serious demand, especially in view of the large number of patients and the changing practice of orthotics away from the use of metal toward the use of plastics and new fabrication methods.

COST OF SERVICES

In fiscal year 1972 the Veterans Administration (VA) spent about $5,106,000 for prosthetic services (15). From the CPOE surveys of 1961-1963 and 1965-1967, it was estimated that the VA paid for 12.7% and 14.3% respectively of the prostheses in the country. (With Medicare going strong, the lower figure probably is more accurate now.) Therefore, we can extrapolate that $5,106,000/12.7% or roughly $40,000,000 was spent in fiscal year 1972 for prosthetic services in the U.S.A.

If we assume that the ratio of certified prosthetists to certified orthotists is proportional to the cost of prosthetic and orthotic services, then $40,000,000 × 750/630 or $48,000,000 was spent for orthotic services in fiscal year 1972. Consequently, a total of roughly $40,000,000 + $48,000,000 or $88,000,000 was spent on prosthetic and orthotic services.

EXPENDITURES IN RESEARCH

Actual funding figures obtained from the VA and Department of Health, Education, and Welfare (including both the Social and Rehabilitation Service and the Maternal and Child Health Service) and estimates of funding from various other sources show a total of $5,709,000 spent on research (including design, development, and evaluation) in prosthetics and orthotics during calendar year 1972. This figure is $5,709,000/$88,000,000 or about 6½% of the total spent on services:

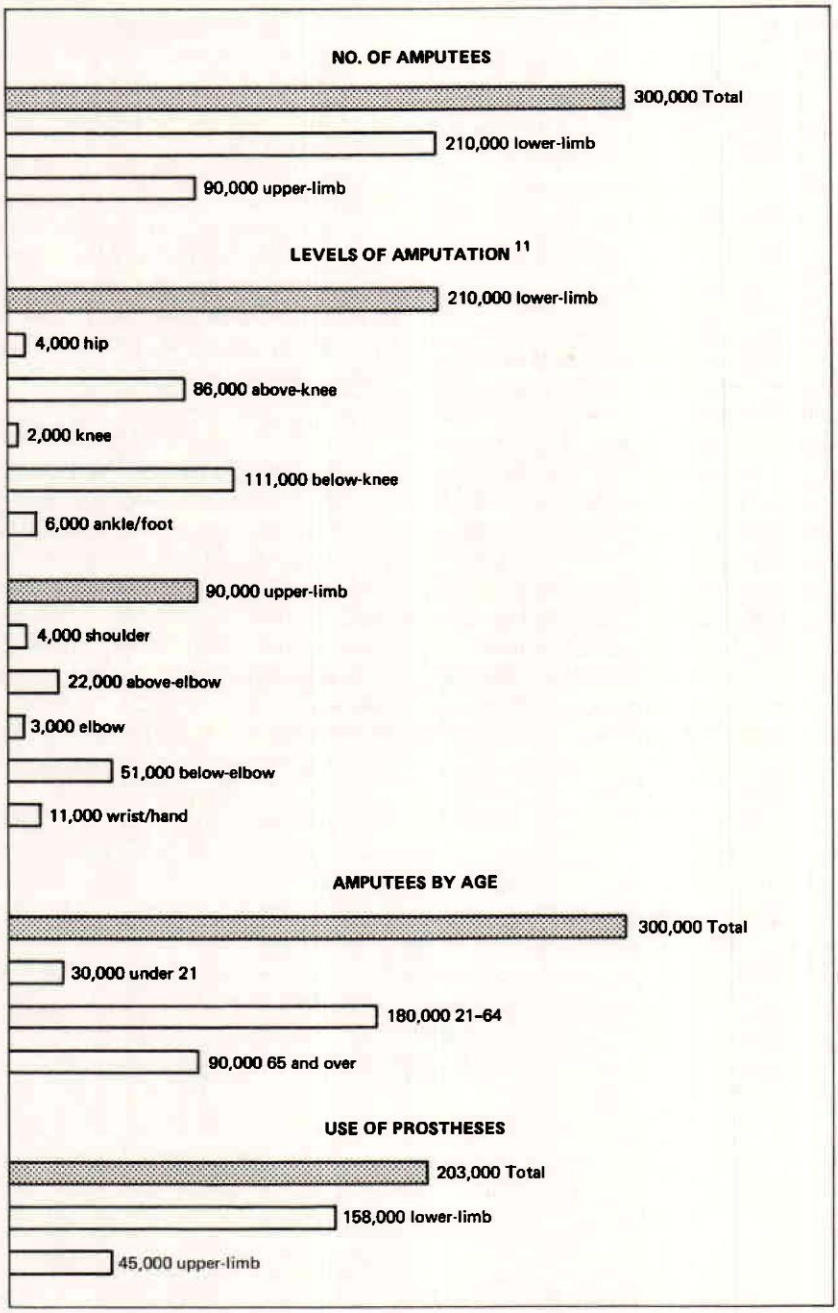
Cost of Prosthetic and Orthotic Services	$88,000,000
Expenditures on Prosthetics and Orthotics Research	$ 5,709,000
Percentage of Research to Services	6½%

TABLE 5

[10] 1,102,000 in the civilian, non-institutional population (10) plus 5,400 in the institutional population (9).

SUMMARY

Figures 1 and 2 provide a graphical summary of the information presented on prosthetic and orthotic estimates. Figure 3 provides a graphical display of information only partly presented in the text on the numbers of certified personnel in prosthetics and orthotics over the years.



[11] Based on 1965–1967 CPOE survey percentages (2).

Figure 1. Estimates in Prosthetics.

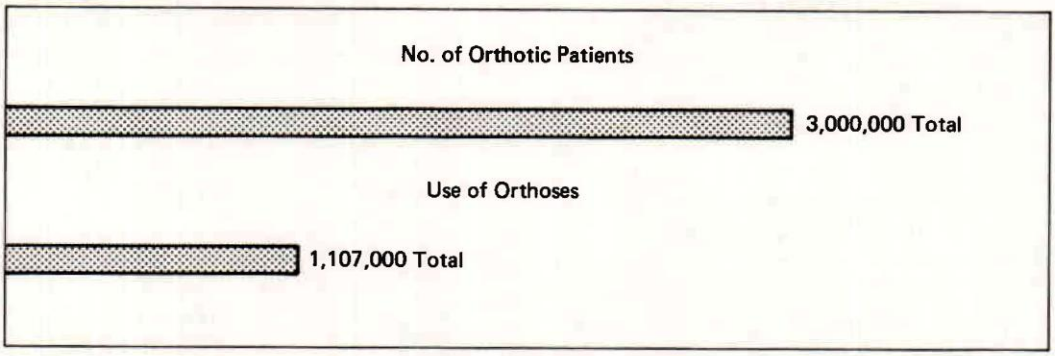


Figure 2. Estimates in Orthotics.

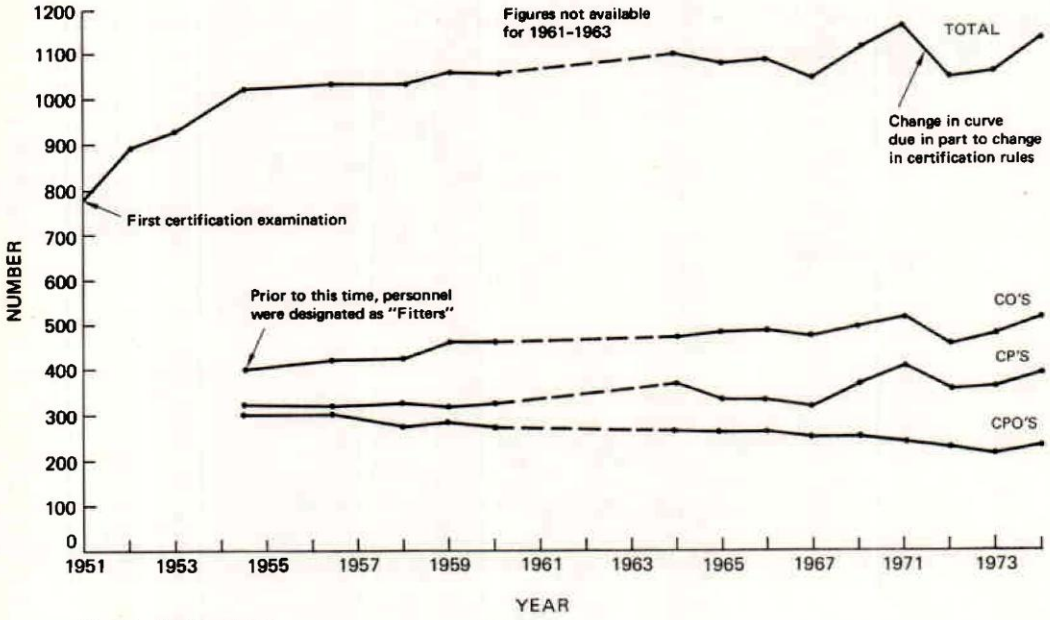


Figure 3. Manpower in Prosthetics and Orthotics[12]

[12]These figures were obtained from the ABC registries for the years shown.

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6. National Center for Health Statistics, *Distribution and Use of Hearing Aids, Wheelchairs, Braces and Artificial Limbs–United States–July 1958-June 1959* (Publication Series B, No. 27), June 1961.

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8. National Center for Health Statistics, *Unpublished figures.*

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TECHNICAL NOTE

AN IMPROVED CRUTCH GRIP

One of the recurrent complaints made by our patients who require additional support from the arm, or arms, is discomfort of the hands. When the lower limbs cannot support the body weight, the burden is placed on the upper limbs and is transmitted to the body through the hands. Canes provide a small, often non-anatomically positioned, grip for the hands that tends to blister because of the forces that are needed to avoid slippage for any significant length of time. With this in mind a handle has been designed and tested on patients with short-term disabilities and on patients with long-term disabilities. Some of the patients with long-term disabilities, especially the active ones, have benefitted greatly from the handle and continue to use it.

The handle (Fig. 1) is anatomically shaped to conform to the palm. The gripping fingers are provided with a supporting area which protrudes radially and extends obliquely to the gripping surface. The thenar and hypothenar eminences are provided with a weight-bearing surface. The handle offers a maximum area for distribution of the force between hand and handle so that unit pressure over the inner surface of the hand is relatively small.

The handles are designed for the left and right hand and may be made of materials that are easy to shape, such as wood or, preferably, plastic. The only tools needed in the production of the grip are a bandsaw and a "Trautman" router. The overall length of the grip should be about

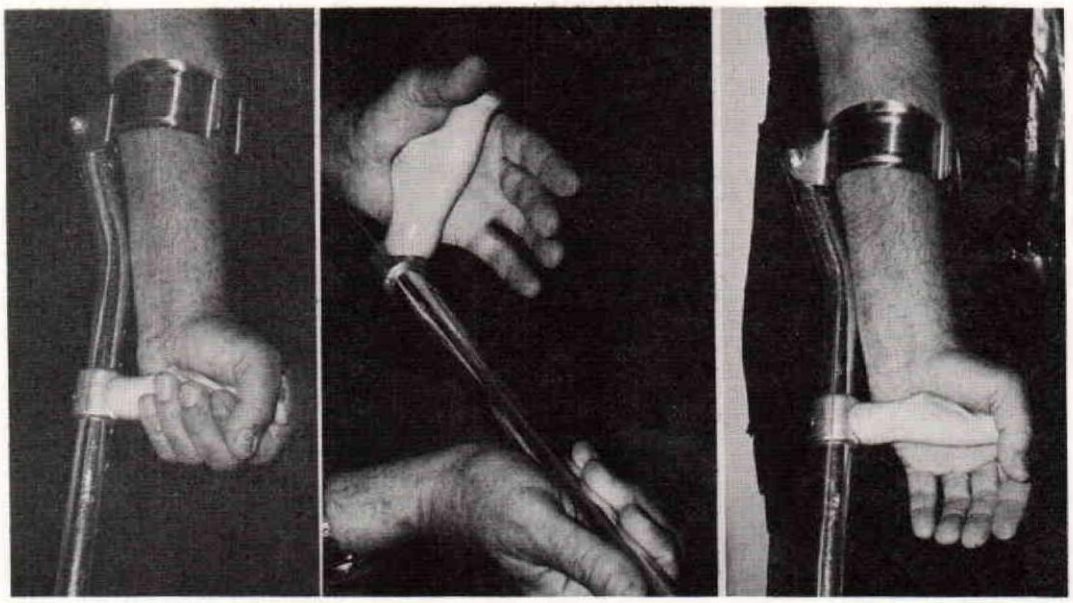


Fig. 1. Three views of the new crutch grip.

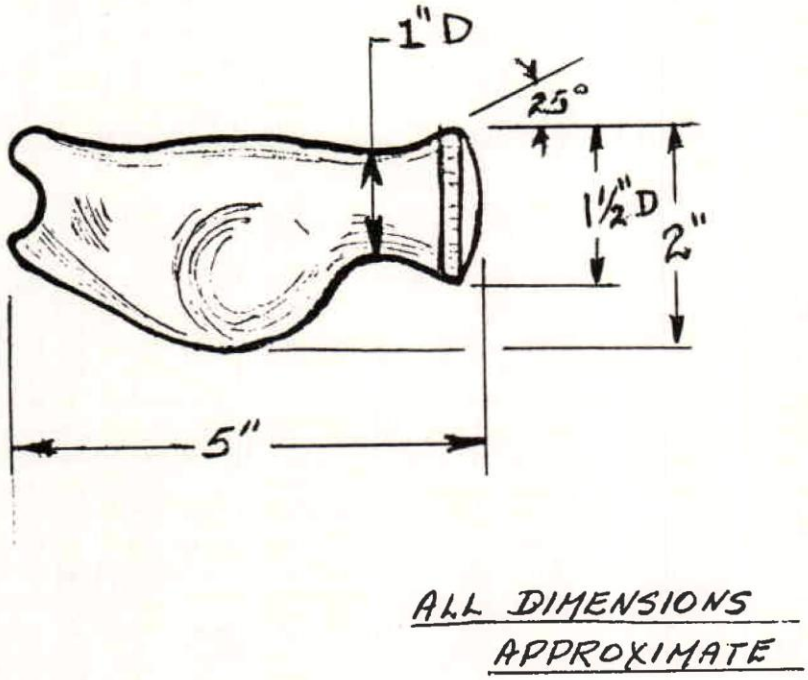


Fig. 2. Top View, Left Handle. The outboard end of the handle has a knob-like thickening which, via a throating, extends into the handle with a large radius so that an adherent surface is formed for the inner thumb blank that extends from the root of the thumb to the outer thumb member, forming, at the same time, a supporting area for the index finger.

five inches. (Fig. 2). The maximum overall width is two inches. The knob end is 1½ inches in diameter, with a throating angle of approximately 25 degrees to a cross-section of approximately 1 inch in diameter. The weight-bearing surface suggests a 45 degree angle downward. The overall depth should not be any more than any regular wooden crutch handle.

The benefits of this handle have been conclusive after having been tested clinically for approximately six months. Among the patients testing the handle on the Lofstrand-type crutch were six different long-term disabilities, three high lesion paraplegics, two lower-limb compound fractures, and one hip-disarticulation amputee. All of them, including two who had already used Lofstrand-type crutches for many years, found the newly designed handle superior as it lowered pressure in the palm area and the outer borders of the hand. This, naturally, lowered the force necessary for gripping. Crutch motion and placement were improved, and the fingers could be stretched when tired while the palms were used for leaning on the handles with safety.

A hip-disarticulation amputee, a young, active patient, agreed to use the prototype handle on the left (prototypes were designed for both left and right) while continuing to use the conventional handle on the right. After four months of rigorous daily activity, including some mountain hiking, he asked for a right prototype. He had quickly grown accustomed to the left-hand prototype while his right hand had blistered and his right forearm continued to be sore. He has now been using both new handles contentedly for several months.

Rainer Schmid, C.P.

NEW PUBLICATIONS

AMPUTEE CLINICS IN THE UNITED STATES AND CANADA—1973, Committee on Prosthetic-Orthotic Education, National Academy of Sciences, Washington, D.C. 20418; 69 pages; gratis.

The 1973 edition of *Amputee Clinics in the United States and Canada* is now available. This annual document was developed originally as a mailing list for use in the distribution of educational materials by the Committee on Prosthetic-Orthotic Education (CPOE). Because of the encouragement and cooperation of amputee clinic personnel and others in the field of rehabilitation, the listing has gradually been enlarged to include information that might be useful for patient referral. Therefore the types of services offered and the meeting schedule for each clinic, as well as the clinic address and names of chiefs and co-chiefs, are presented.

Each new edition of the amputee clinic roster includes any appropriate changes and corrections in information on clinics previously listed and provides data on clinics more recently identified. Every effort is made to ensure the accuracy of the recorded information.

HANDBOOK FOR THE ORTHOPAEDIC ASSISTANT, by F. Richard Schneider, M.D., C. V. Mosby Co., St. Louis, Mo.; 198 pp.; Publication Date: March 20, 1972; $10.75.

This concise, well-illustrated book relates in clear, easily understood terms the basic types of orthopedic treatment with which the orthopedic assistant should be familiar. Included are explanations of fractures, dislocations, subluxations, sprains, strains, contusions, and their treatment. The use of common types of casts (arm, leg, body and spica), and traction (circumferential, skin and skeletal) are described.

The author makes no attempt to relate the professional role of the orthopedic assistant. Rather, the book is intended as an orthopedic primer. As such, its contents are of general professional interest to prosthetists and orthotists. Though it is a little expensive ($10.75) for a 198-page primer, this book would seem a worthwhile addition to the reading list for students of prosthetics and orthotics.

Maurice A. LeBlanc, C.P.

ROENTGENOLOGIC ATLAS OF THE HAND AND WRIST IN SYSTEMIC DISEASE, Morrison E. Kricun, M D. and Jack Edeiken, M.D.; Williams & Wilkins, 324 pp., $19.50.

This is a well-produced, beautifully illustrated book with concise and clear description of the diseases.

The authors claim that the X-rays of the wrist and hand "may be the primary clue to underlying systemic disease", and may be "pathognomonic of the disease".

In fact, most of the examples are of advanced disease when the diagnosis is shouting from the housetops.

Some examples, particularly in the chapter on "Abnormalities of Growth and Development", list a number of syndromes so that further examination is necessary to establish a diagnosis.

Nor do they establish that the wrist is involved before other joints so that it would necessarily be the choice for diagnostic purposes. From personal experience I know that the lower limb can have gross changes in renal rickets with a nearly normal radiological appearance in the upper limb.

I would wish that there was instruction in recognizing the very early pathognomonic signs before the diagnosis is otherwise evident.

Nevertheless I would think this was a valuable addition to any orthopaedic department's library.

E. E. Harris, F.R.C.S.

DIRECTORY OF SPECIALIZED CAMPS FOR CHILDREN WITH HANDICAPS

The National Easter Seal Society has announced the 1973 edition of its directory of residential camps for the disabled—the most comprehensive in the camping field—is now available.

Titled "The Easter Seal Directory of Resident Camps for Persons with Special Health Needs", the 77-page booklet lists by states more than 240 camps organized to serve children and adults with physical, mental, social, and/or emotional handicaps. Camps are also classified by the handicapping conditions served.

Directory information includes name and location of camp, types of disabilities accepted and any qualifications of degree of independence required, age range, length of camping sessions, fees charged, camp capacity, and the name and address of the sponsoring organization.

Published to assist parents planning a camping

experience for disabled children requiring special care, the Easter Seal directory can also be used as a source of information for health agencies compiling camping facts for clients and their families, students seeking summer camp jobs, and colleges offering placement services to students interested in careers in rehabilitation.

Among the disabling conditions classified in the directory are cerebral palsy, mental retardation, cardiac disorders, speech and hearing defects, visual impairments, organic brain damage, respiratory diseases, and emotional disturbances.

The directory is obtainable from the National Easter Seal Society, 2023 West Ogden Avenue, Chicago, IL 60612, at $1 a copy.

EQUIPMENT FOR THE DISABLED, The National Fund for Research into Crippling Diseases, Vincent House, 1a Springfield Road, Horsham, Sussex, England.

The National Fund for Research into Crippling Diseases has published "Equipment for the Disabled" since 1960. Described as "an essential reference for anyone involved with handicapped people" the first and second editions of "Equipment for the Disabled" were issued in loose-leaf form for easy amendment. As a result, the publication has grown to four thick volumes. Further amendments and new sections in preparation would bring "Equipment for the Disabled" to six unwieldy volumes.

To ensure that "Equipment for the Disabled" continues to fulfill its purpose as a complete and easily handled reference, it has been decided to issue the 3rd edition as a set of individually bound A4 booklets. These booklets will be released over the next year—after which complete revised booklets will be published. The content and purpose of "Equipment for the Disabled" remain the same and the editorial work will continue to be carried out at the Nuffield Orthopaedic Centre, Oxford. Orders can be placed for the complete set of "Equipment for the Disabled" or for individual sections.

The complete set consists of the following booklets or sections:

Wheelchairs and Outdoor Transport—Special supplement
Communication
Home Management
Clothing and Dressing
Housing and Furniture
Personal Care
Gardening and Leisure
Hoists and Walking Aids
The Disabled Child
Binder to hold sections 1-9

All sections priced at £1.05, binder at 95p (includes post and packing).

Reviews of each section will be carried in "Orthotics and Prosthetics" as they are issued. The December issue will include reviews on "Wheelchairs and Outdoor Transport—Special Supplement" and "Communication."

NEW YORK UNIVERSITY PROSTHETIC AND ORTHOTIC MANUALS

Manuals developed by New York University to cover various aspects of prosthetics and orthotics practice are available to members of the prosthetics and orthotics profession.

The basic manual in each of the four subject-matter areas is designed to meet the professional needs of physicians, surgeons, and therapists. To meet the requirements of prosthetists-orthotists, supplementary materials which include detailed measurements, fabrication, and fitting procedures have been prepared. The supplements are designed to be used in conjunction with the basic manuals as they are too incomplete to be used alone.

Manuals Available	Price
Upper-Extremity Prosthetics	US $ 7.50
Upper-Extremity Prosthetics (including prosthetist supplement)	12.50
Spinal Orthotics	5.00
Spinal Orthotics (including orthotist supplement)	7.50
Lower-Extremity Orthotics	10.00
Lower-Extremity Orthotics (including orthotist supplement)	12.50
Lower-Extremity Prosthetics	10.00
Lower-Extremity Prosthetics (including prosthetist supplement—below- and above-knee procedures)	25.00
Prosthetics and Orthotics for Rehabilitation Counselors	10.00

The prices quoted include charges for shipment by surface mail. Because NYU has no facilities for billing, prepayment by check or money order is required. Orders should be sent to *Prosthetics and Orthotics, NYU Post-Graduate Medical School, 317 East 34th Street, New York, NY 10016, U.S.A.*

METRIC SYSTEM

Conversion Factors

LENGTH

Equivalencies

angstrom	= 1 x 10^{-10} meter (0.0 000 000 001 m)
millimicron*	= 1 x 10^{-9} meter (0.000 000 001 m)
micron (micrometer)	= 1 x 10^{-6} meter (0.000 001 m)

To Convert from	To	Multiply by
inches	meters	0.254†
feet	meters	0.30480†
yards	meters	0.91440†
miles	kilometers	0.6093

AREA

To convert from	To	Multiply by
square inches	square meters	0.00064516†
square feet	square meters	.092903

VOLUME

Definition

1 liter = 0.001† cubic meter or one cubic decimeter (dm^3)
(1 milliliter = 1† cubic centimeter)

To convert from	To	Multiply by
cubic inches	cubic centimeters	16.387
ounces (U.S. fluid)	cubic centimeters	29.574
ounces (Brit. fluid)	cubic centimeters	28.413
pints (U.S. fluid)	cubic centimeters	473.18
pints (Brit. fluid)	cubic centimeters	568.26
cubic feet	cubic meters	0.028317

MASS

To convert from	To	Multiply by
pounds (avdp.)	**kilograms**	**0.45359**
slugs‡	kilograms	14.594

FORCE

To convert from	To	Multiply by
ounces-force (ozf)	newtons	0.27802
ounces-force (ozf)	kilogram-force	0.028350
pounds-force (lbf)	newtons	4.4732
pounds-force (lbf)	kilogram-force	0.45359

*This double-prefix usage is not desirable. This unit is actually a nanometer (10^{-9} meter = 10^{-7} centimeter).
†Exact conversion, all subsequent digits are zeros.

STRESS (OR PRESSURE)

To convert from	To	Multiply by
pounds-force/square inch (psi)	newton/square meter	6894.8
pounds-force/square inch (psi)	newton/square centimeter	0.68948
pounds-force/square inch (psi)	kilogram-force/square centimeter	0.070307

TORQUE (OR MOMENT)

To convert from	To	Multiply by
pound-force-feet	newton meter	1.3559
pound-force-feet	kilogram-force meters	0.13826

ENERGY (OR WORK)

Definition

One joule (J) is the work done by a one-newton force moving through a displacement of one meter in the direction of the force.

1 cal (gm) = 4.1840 joules

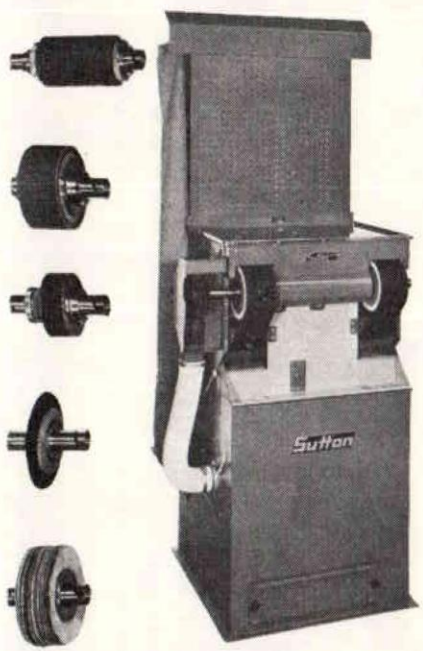
To convert from	To	Multiply by
foot-pounds-force	joules	1.3559
foot-pounds-force	meter-kilogram-force	0.13826
ergs	joules	1×10^{-7}†
b.t.u.	cal (gm)	252.00
foot-pounds-force	cal (gm)	0.32405

TEMPERATURE CONVERSION TABLE

To convert °F to °C $\quad °C = \dfrac{°F - 32}{1.8}$

°F	°C
98.6	37
99	37.2
99.5	37.5
100	37.8
100.5	38.1
101	38.3
101.5	38.6
102	38.9
102.5	39.2
103	39.4
103.5	39.7
104	40.0

*A slug is a unit of mass which if acted on by a force of one pound will have an acceleration of one foot per second per second.



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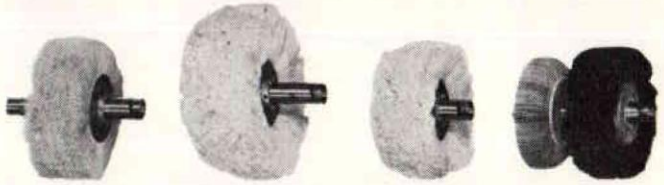

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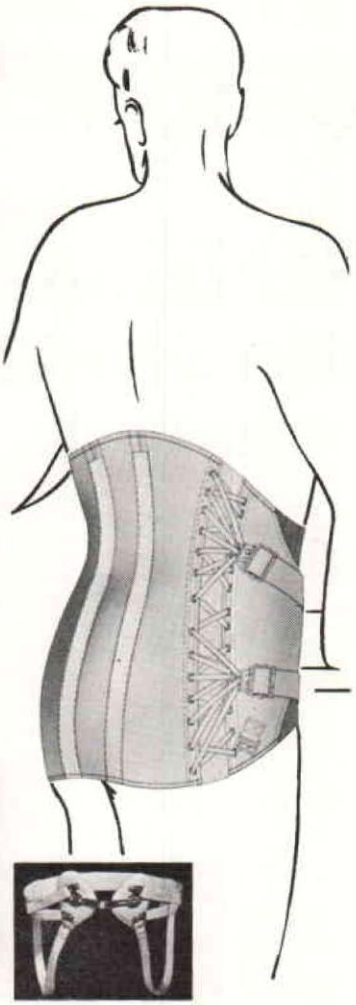

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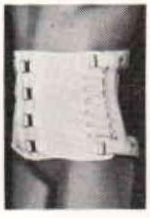

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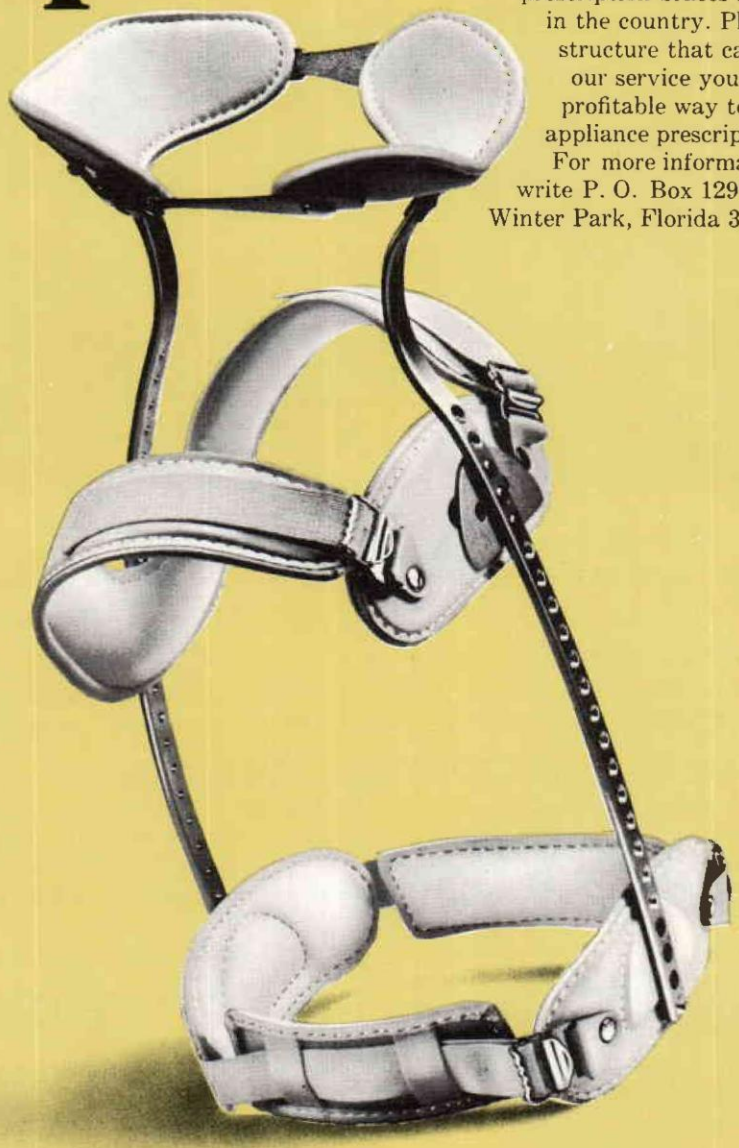

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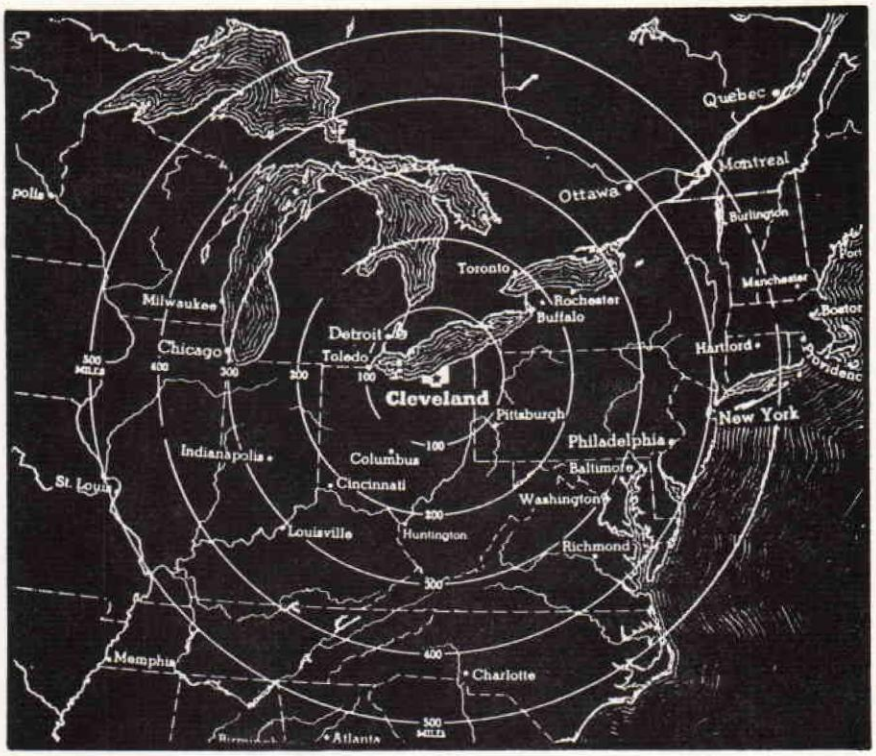

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All submitted manuscripts should include:

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2. BIBLIOGRAPHY. This should be arranged alphabetically and cover only references made in the body of the text.
3. LEGENDS. List all illustration legends in order, and number to agree with illustrations.
4. ILLUSTRATIONS. Provide any or all of the following:
   a. Black and white glossy prints
   b. Original drawings or charts

   Do *not* submit:
   a. Slides (colored or black & white)
   b. Photocopies

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2. Indicate FOOTNOTES by means of standard symbols (*).
3. Indicate BIBLIOGRAPHICAL REFERENCES by means of Arabic numerals in parentheses (6).
4. Write out numbers less than ten.
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6. Use the word "Figure" abbreviated to indicate references to illustrations in the text (. . . as shown in Fig. 14)

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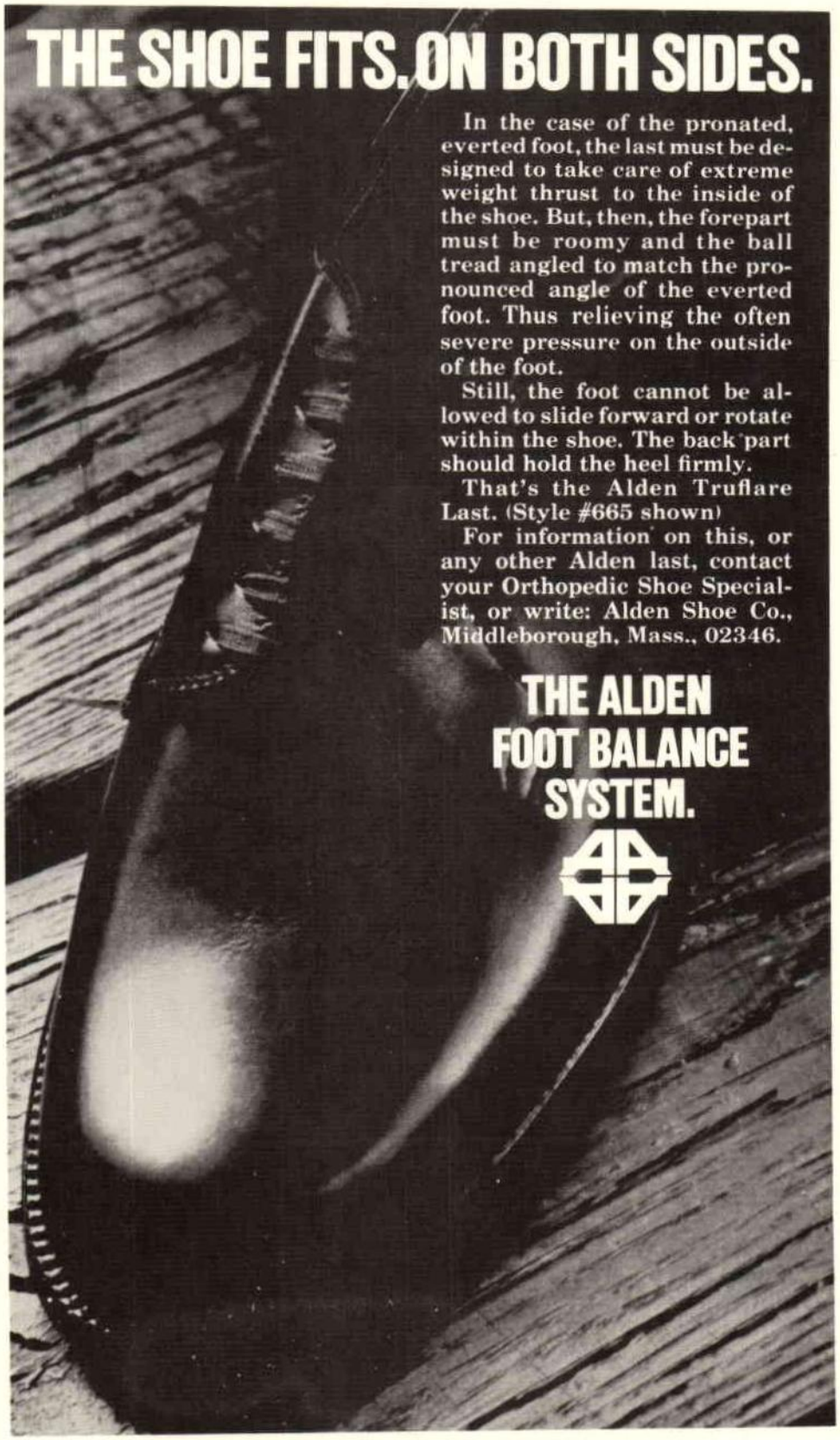
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