December 1972

orthotics and prosthetics

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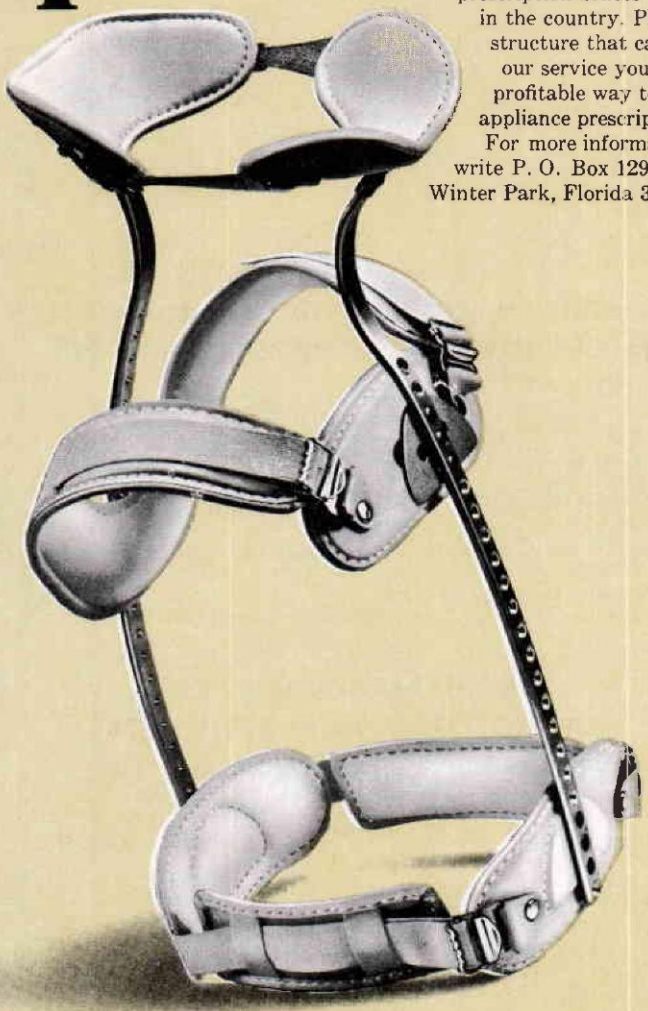

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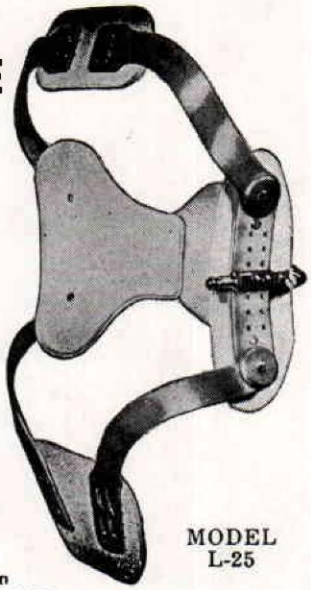

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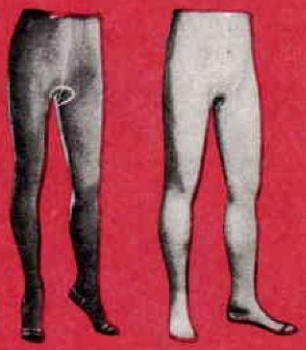

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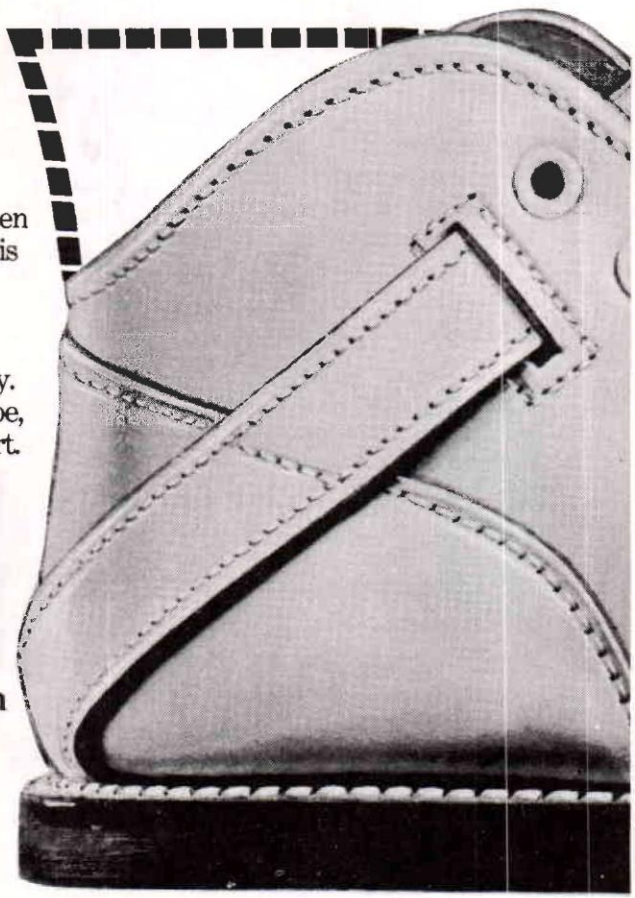

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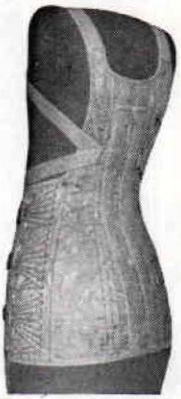

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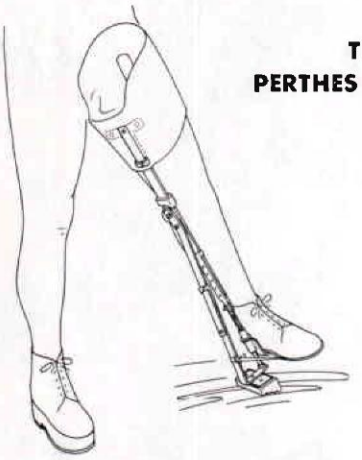

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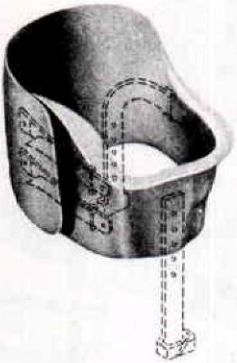

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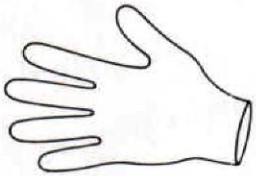

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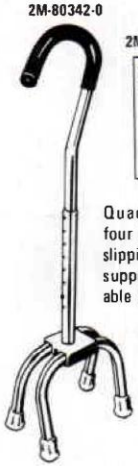

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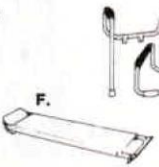

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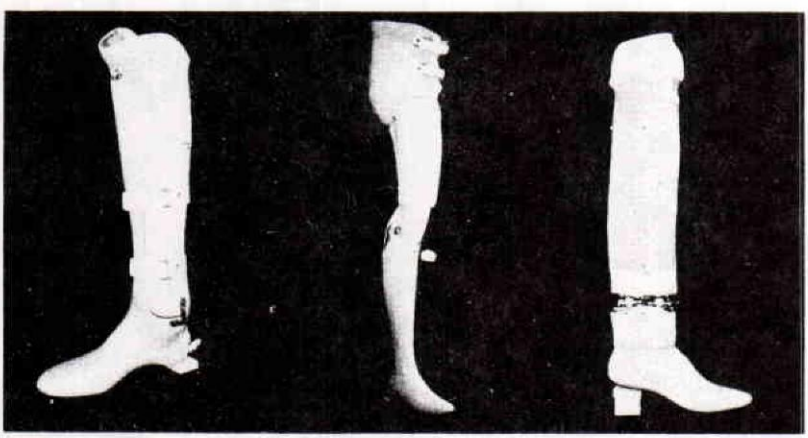

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The TIRR Polypropylene Orthoses[1,2]

THORKILD J. ENGEN, C.O.[3]

Until very recently, the development of new types of lower-limb orthoses which meet the specific needs of individual patients has been largely ignored, owing, partially, to the lack of understanding of the biomechanical principles involved in ambulation. As a result only about four basic types of conventional braces were used for a wide variety and degree of diagnostic conditions. In many cases more control than was needed was applied, resulting in atrophy of normal, or near normal, muscles when they were not permitted to be active.

In 1968 a research and development project, under partial sponsorship of the Social and Rehabilitation Service, was initiated in the Department of Orthotics at the Texas Institute for Rehabilitation and Research (2) to create new design concepts and develop devices for the lower limbs that would meet more accurately the needs of individual patients with drop-foot conditions, mediolaterial instability, and dorsi- and plantarflexion impairments. It was intended that the new devices would, in addition, be less noticeable and lighter in weight than the rather cumbersome conventional orthoses. Initially, effort was concentrated on patients with impairments below the knee. A group of five patients was selected: a hemiplegic with flaccidity; a hemiparetic with spasticity and sensory loss; a unilateral lower-limb paralytic (post-poliomyelitis) with muscular atrophy; a bilateral lower-limb paralytic with muscular disease (muscular dystrophy); and a paraplegic with spasticity secondary to spinal cord malformation (spina bifida). Special forms for recording data were developed for evaluation of the effectiveness of the new devices as they were conceived. A videotape recording system was used to provide an opportunity to compare the

[1] Grant Number 23-P-55233/6-02, SRS, DHEW; R & T Center Number (Grant Number 16-P-56813/6-09) SRS, DHEW

[2] This paper is based on a presentation made at the Fourth Symposium on External Control of Human Extremities, Dubrovnik, Yugoslavia, 1972.

[3] Assistant Professor, Baylor College of Medicine, 1333 Moursund, Houston, Texas, U.S.A.

ambulation patterns of these patients with their conventional orthosis, without any orthotic equipment, and with each new device as it was developed (3).

EVOLUTION OF THE DESIGN

The design developed early in the project involved a posterior spring. In this early design, a precision fitted arch support of stainless steel was attached to a posterior heel spring that followed closely the contour of the bulge of the gastrocnemius muscle. It terminated proximally with a small band below the knee

This device was applied to sixteen patients with diagnoses including post-poliomyelitis, Guillain-Barre syndrome, and hemiplegia. In all cases, the orthosis gave the patient the needed stability and dorsiflexion assistance. Comparison of videotaped recordings of their ambulation without assistance, in their previously used conventional orthoses, and with the new orthoses supported the judgment that the new device was effective. Unfortunately, mechanical failures of the spring steel material were experienced continuously, particularly in the arch support, at the

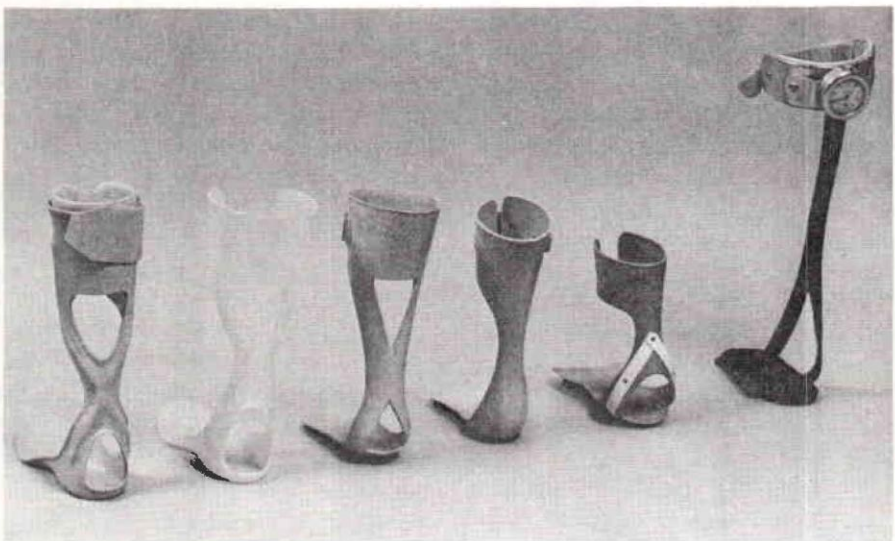

FIG. 1 Various stages of the development and evolution of the TIRR Polypropylene Orthosis. The device on the extreme right is the first approach taken; the one on the extreme left is one version of the latest design.

(Fig. 1, extreme right). Because the arch support fitted inside the shoe, the patient was allowed a choice of shoes, and the device was less noticeable than conventional braces. It provided approximately 20 deg. of dynamic flexion-extension of the foot, in addition to good mediolateral stability about the ankle.

attachment points of the posterior spring where it divided posteriorly to the malleoli, and at the mid-portion of the posterior spring itself. Despite efforts to eliminate breakage by using various means of attachment and methods of hardening the steel, the difficulties persisted. The average lifespan of the devices was increased

only to an average of 300,000 impacts.

It was concluded that the design principle should be retained, but a more suitable material had to be found. Various laminations of nylon and polyester resins reinforced with polypropylene screen weaves of varying sizes were employed. Better durability was achieved initially, but the laminations failed after four to six months of use.

In the meantime sheet polypropylene became available (9) (10) (11) (12), and experiments were undertaken using that material. It was evident, however, that drop-foot orthoses constructed of unreinforced polypropylene were too flexible to provide sufficient dorsiflexion assistance. After considerable experimentation, the idea of incorporating corrugations strategically in the material evolved. This method provided additional strength and stability in stress areas, especially in the transition from the shoe insert or arch support portion of the malleoli area (Fig. 1, extreme right). Success was finally achieved using this method, thus increasing the structural strength and stability without adding unnecessary weight in the form of reinforcing materials (Fig. 1, extreme left, and Fig. 2) (4) (5) (6).

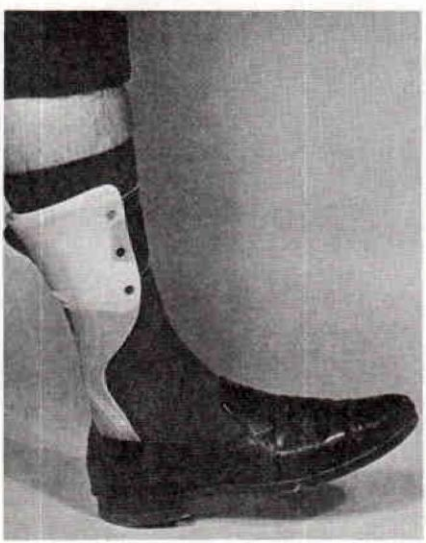

FIG. 2 The TIRR Polypropylene Orthosis at the beginning of the stance phase.

INDICATIONS

The polypropylene orthosis is indicated for most patients with drop-foot impairments and instability where conventional "short leg braces" would be prescribed. In addition, where the weight of conventional braces has contraindicated their use, the lightness (approximately four ounces) of the corrugated polypropylene device has made it possible to assist safely a number of patients who otherwise would be unable to ambulate independently. The orthosis is contraindicated only for patients with severe, uncontrollable spasms and for those with extreme and irreversible deformities of the foot-ankle complex.

APPLICATION

Application of the orthosis requires careful attention to detail but is not complicated. The first step is very important. When the cast is taken of the patient's foot-ankle complex, special care must be taken in positioning the foot in plantigrade position. Any skeletal malalignment should, when possible, be corrected manually. The cast is filled and dried using standard procedures. When dry, it is sculptured and any obvious malalignments or flaws are corrected, and stockinette is drawn over the cast to help provide a smooth finish (Fig. 3).

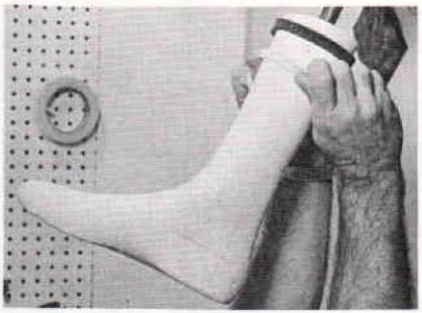

FIG. 3 Application of stockinette over the modified model.

To produce the corrugations in the polypropylene, 3/16" diameter teflon rods are nailed to the cast (Fig. 4),

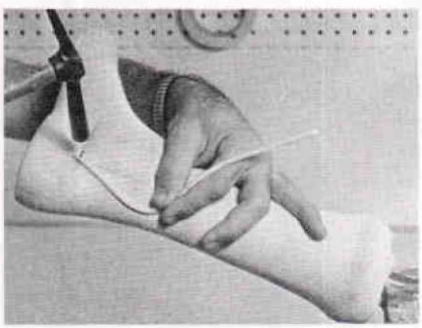

FIG. 4 Installation of teflon rod to provide corrugations.

originating at the calf band (which is two-thirds the distance from the plantar surface to the head of the fibula) both medially and laterally, curving downward, and meeting at the Achilles tendon. There they divide again to follow the division in the polypropylene which exposes the posterior aspect of the heel. They then follow the contour of the medial and lateral aspects of the heel posteriorly to the malleoli, and there they are tapered to a smooth finish (Fig. 5).

A full standard shoe insole is incorporated on the plantar surface of the cast corresponding to the patient's shoe size.

When the cast preparation has been completed, a sheet of 1/8" thick polypropylene is heated in an oven for ten minutes at 400°F. At this point, it becomes limber, like cloth, and will stretch readily over a model. The polypropylene is first folded over the posterior aspect of the cast and then stretched over the

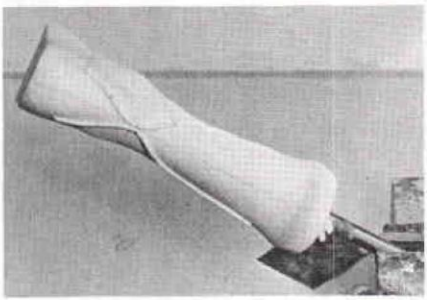

FIG. 5 Teflon rods in place.

heel portion (Fig. 6). A seam is formed on the anterior surface by pinching the two aspects of polypropylene together.

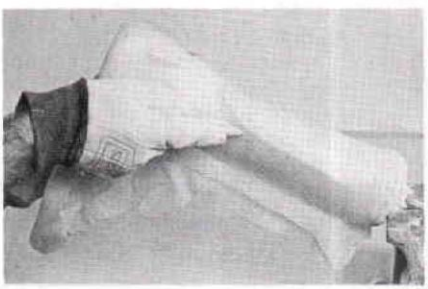

FIG. 6 Application of heated polypropylene from the model.

After the material has been folded over the cast, the surface of the polypropylene is smoothed, using a bluntly pointed instrument to impress thoroughly the corrugation pattern into the material along the edges of the teflon rods. After the polypropylene has set, it is pried open carefully and removed from the

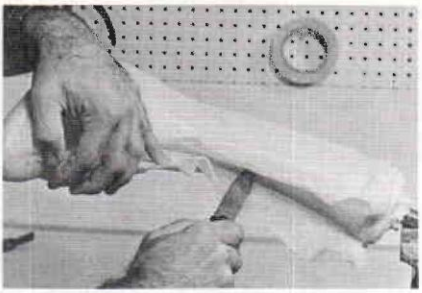

FIG. 7 Removal of the molded polypropylene from the model.

cast (Fig. 7). The outline of the below-knee orthosis is drawn with a soft pencil or marking pen (Fig. 8).

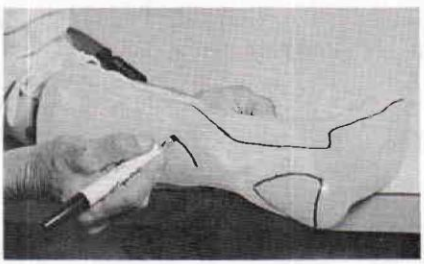

FIG. 8 Outlining the borders, or trim lines.

The excess plastic is then removed to give the final shape. All edges are

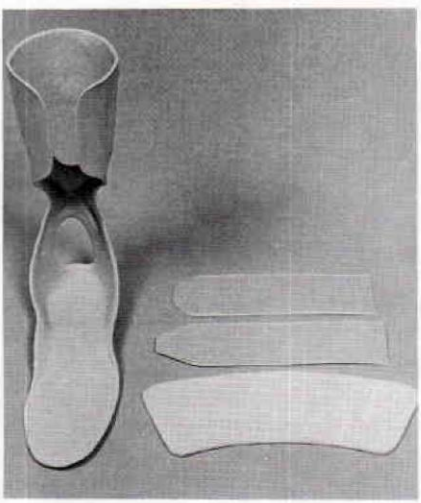

FIG. 9 Components of the TIRR Orthosis.

carefully sanded and smoothed. A light, padded insert with a tongue is then placed inside the calf portion, and a Velcro strap is attached for fastening the orthosis in position (Fig. 9).

The rigidity and/or flexibility of the device is regulated by selectively adjusting the width of the polypropylene cross-sectional area at the posterior junction, just above the heel. For the initial fitting, this area is purposely left wider than needed. It is gradually narrowed to provide the correct amount of dynamic dorsiflexion assistance needed by the

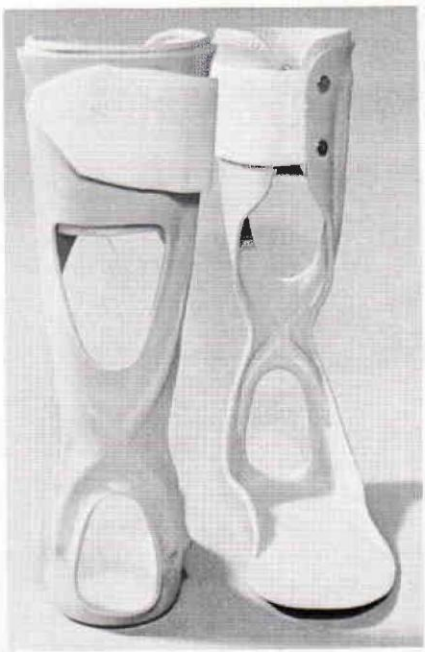

FIG. 10 Two views of the completed orthosis.

individual patient (Fig. 10). This "fine-tuning" of the device to the exact requirements for assistance needed by each patient enables the orthosis to meet a wide variety of patient disabilities while allowing maximum use of residual function.

RESULTS

At this time, 154 applications of the below-knee corrugated polypropylene orthosis have been made to patients with a wide variety of disabilities.

Forty-five percent of applications have been hemiparetic patients. Gait patterns of the hemiparetic using the experimental orthosis as compared to the conventional brace show certain characteristic changes. Improvement is noted in gait rhythm, with changes in the swing phase of the affected extremity. Improved alignment control of varus and valgus instability at the ankle has been observed during the weight-bearing portion of the stance phase.

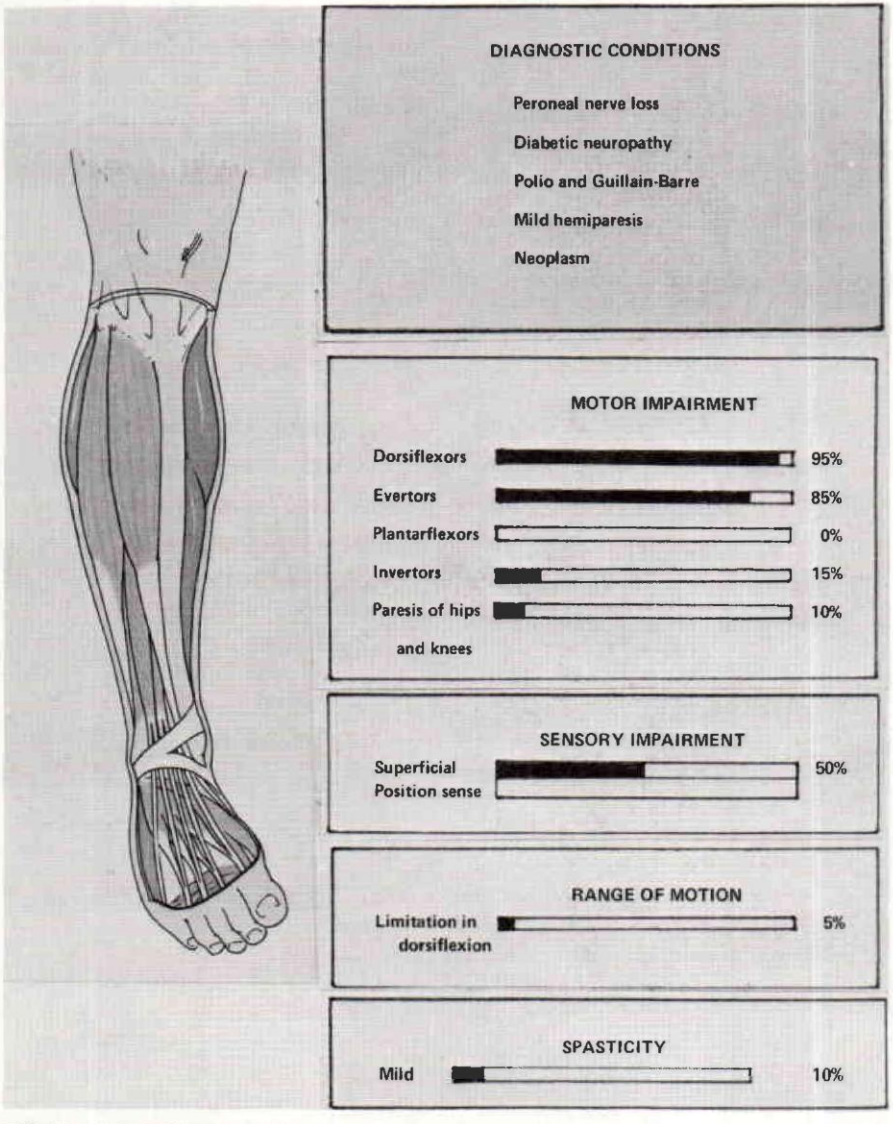

FIG. 11 CATEGORY I - Minimal impairment. Twenty-six of the first one hundred patients provided with the TIRR Orthosis fell into this category.

Fifteen percent of the case load have residual unilateral or bilateral weakness of the lower limb due to poliomyelitis or Guillain-Barre syndrome. For such disabilities, the light weight of the below-knee polypropylene device has been a great assistance in improving stability.

Forty percent of the patients represent other diagnostic conditions. Several patients with progressive disabilities were included in the research program; and it is felt that the experimental orthoses provided sufficient improvement to enable some patients to remain ambulatory longer, despite the

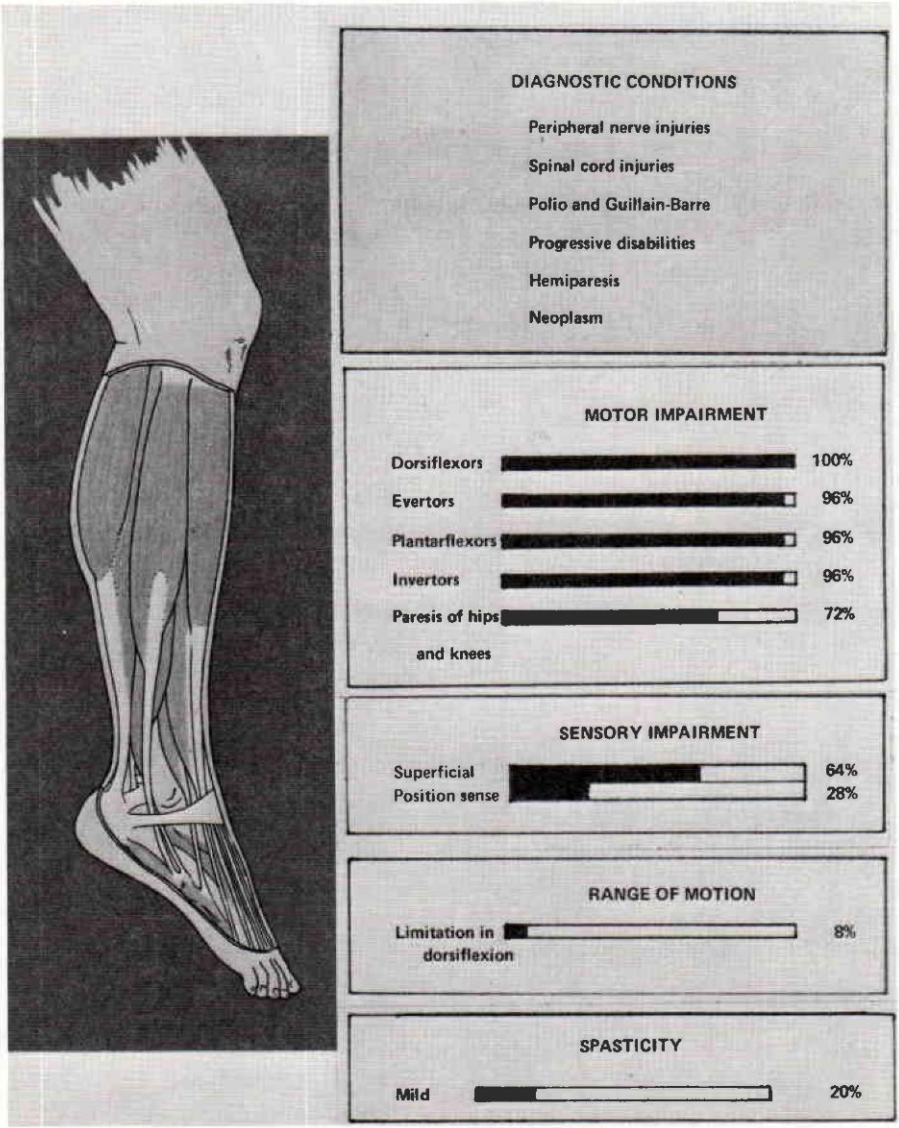

FIG. 12 CATEGORY II - Moderate impairment. Thirty-four of the first one hundred patients provided with the TIRR Orthosis fell into this category. Included were patients with progressive disorders such as muscular dystrophy and amyotrophic lateral sclerosis.

increasing severity of their disabilities. Ten patients with peroneal nerve loss due to trauma were fitted, and it was found that the experimental orthoses permitted them more flexibility than conventional bracing, allowing them to run, jump and participate in active sports.

Applications were made for a number of severely physically impaired children, including several with a diagnosis of spina bifida, one with congenital myopathy, and one with arthrogryposis multiplex congenita. The mothers of these children report that the plastic orthoses cause much less wear and tear on clothing. Furthermore, where bladder control is poor, the nonabsorbent material of these devices is helpful in personal care.

APPLICATION WITH RESPECT TO PATIENT CLASSIFICATION

Regardless of specific diagnosis, however, the severity of the impair-

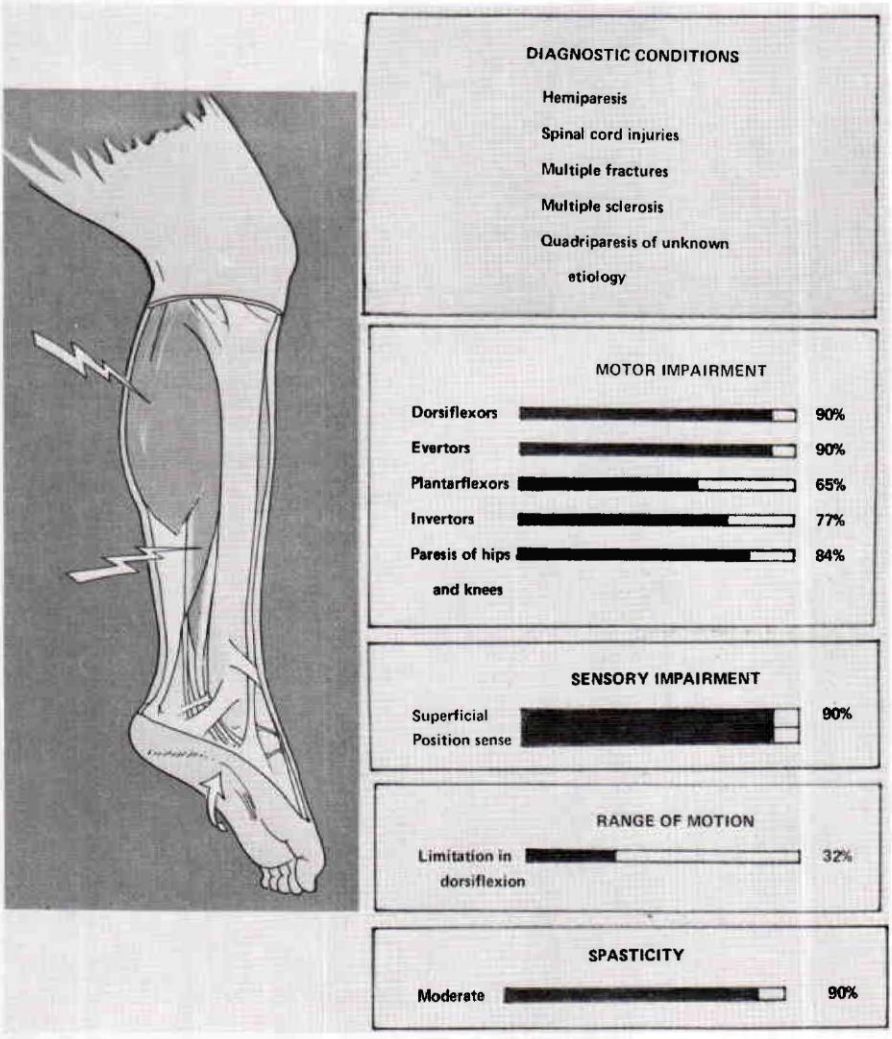

FIG. 13 CATEGORY III - Severe impairment. Forth of the First one hundred patients fell into this category.

ments represented by the first 100 patients fitted in the study tend to fall into three categories, with three overlapping, yet generally distinct, patterns of motor loss (1). These categories have been designated "Minimal", "Moderate", and "Severe" Impairment. A schematic presentation along with average degrees of impairment of each category are given in Figures 11, 12, and 13.

MINIMAL IMPAIRMENT

Twenty-six of the first 100 patients fell into the Minimal Impairment Group (Fig. 11). The major disabilities exhibited by most of these patients are impairments in the dorsiflexors and evertors, causing minimal to moderate impairment of mediolateral stability in 70% of these patients. Although half of the patients show some sensory loss, in all cases the loss is spotty and includes only superficial modalities. Therefore there are usually no problems because the loss is substituted for effectively by remaining sense modalities and overlap. Joint mobility is within normal limits or is minimally limited. Where spasticity is present, it is very mild.

In matching the orthosis to the individual patient's condition, these orthoses were "programmed" for more flexibility and less rigidity than those for patients with more severe impairments.

Many of the patients of this group attained symmetrical gait patterns with the polypropylene orthosis. It enabled them to attain heel-toe

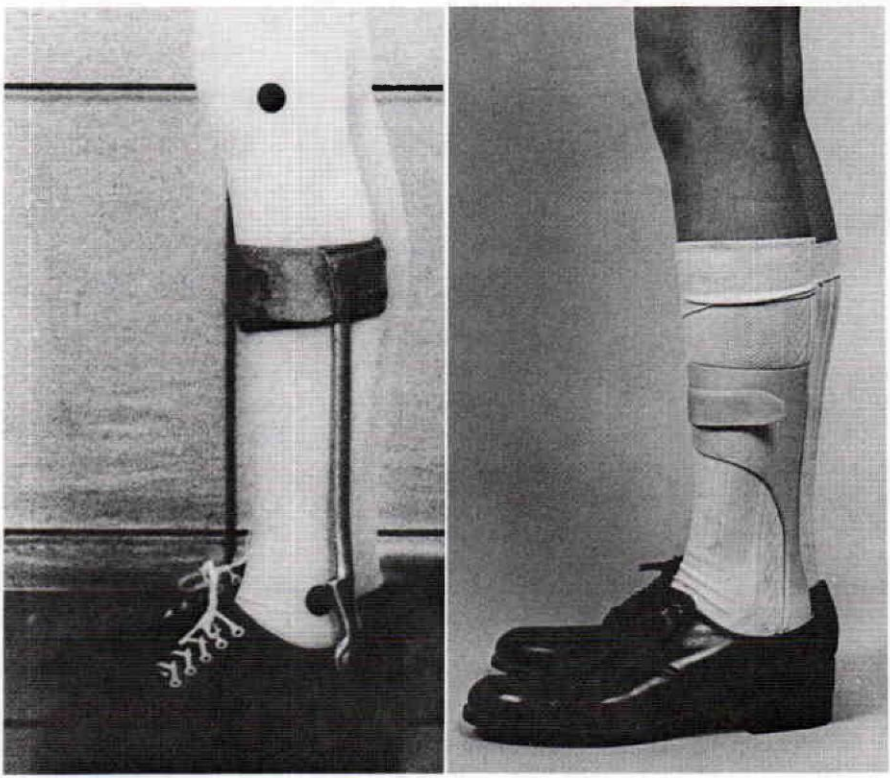

FIG. 14 Mild hemiparetic patient, age 12. Left - Conventional brace. Right - Corrugated polypropylene orthosis.

placement rather than flat-foot placement. The gait pattern exhibited by these minimally impaired patients does not differ markedly when comparing the polypropylene and the conventional orthosis, but the patients all preferred the polypropylene orthosis because of weight and appearance factors.

Typical of this group is a 12-year old girl with mild left hemiparesis secondary to cerebral thrombosis of the left middle cerebral artery, shown here with her old conventional brace and her new corrugated polypropylene orthosis (Fig. 14). Approximately two years ago when the polypropylene device was first applied, her left below-knee conventional orthosis was causing an increase of spasticity in her foot-ankle complex, possibly due to the weight of the device. With the new orthosis, she is able to ambulate further and more easily, averaging from a rating of "Fair" with the old brace to "Good" with the new orthosis[4]. She states that the orthosis is more comfortable than any she has used previously.

MODERATE IMPAIRMENT

The Moderate Impairment Group (Fig. 12) comprises 34% of the initial 100 applications. As shown, almost all of these patients have impairments of most of the principal muscle groups in the foot-ankle complex. The percentage and degree of sensory impairment is higher, with a significant number showing loss of position sense, and the frequency and severity of spasticity is also higher. Five of the patients in this group who suffered from progressive disabilities were unable to wear conventional bracing because the weight of the braces offset any positive gains.

One of these patients, a young lady age 32 with a diagnosis of

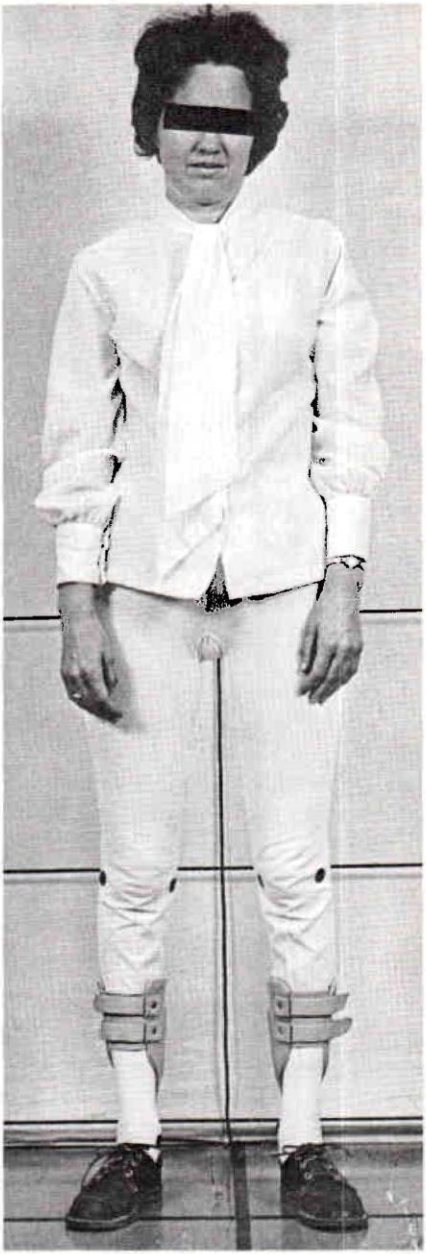

FIG. 15 Patient with Charcot-Marie-Tooth syndrome, age 32, with bilateral below-knee corrugated polypropylene orthoses applied.

[4] Grading Key developed for Functional Evaluation of Independence (8).

Charcot-Marie-Tooth syndrome, was ambulating in the "Poor" range with no devices because the weight of conventional braces made ambulation almost impossible. Because of the progressive nature of her disability, the time was imminent when she would be confined to a wheelchair. Bilateral below-knee corrugated polypropylene orthoses (Fig. 15) were fabricated and fitted for her in November 1970, improving her ambulation grade at that time from the "Poor" to "Fair" range. She is still using the orthoses; and although her condition continues to deteriorate, she is still employed as a medical secretary and still able to ambulate in the "Poor" range with the devices.

SEVERE IMPAIRMENT

The Severe Impairment Group (Fig. 13) comprises 40% of the original patient population for whom the polypropylene devices were adapted. These rather severely impaired patients usually show additional complications, as well as motor impairment. Patients in this group do not exhibit a clear-cut pattern of motor impairment, but a high percentage show weakness in hips and knees, as well as loss of the

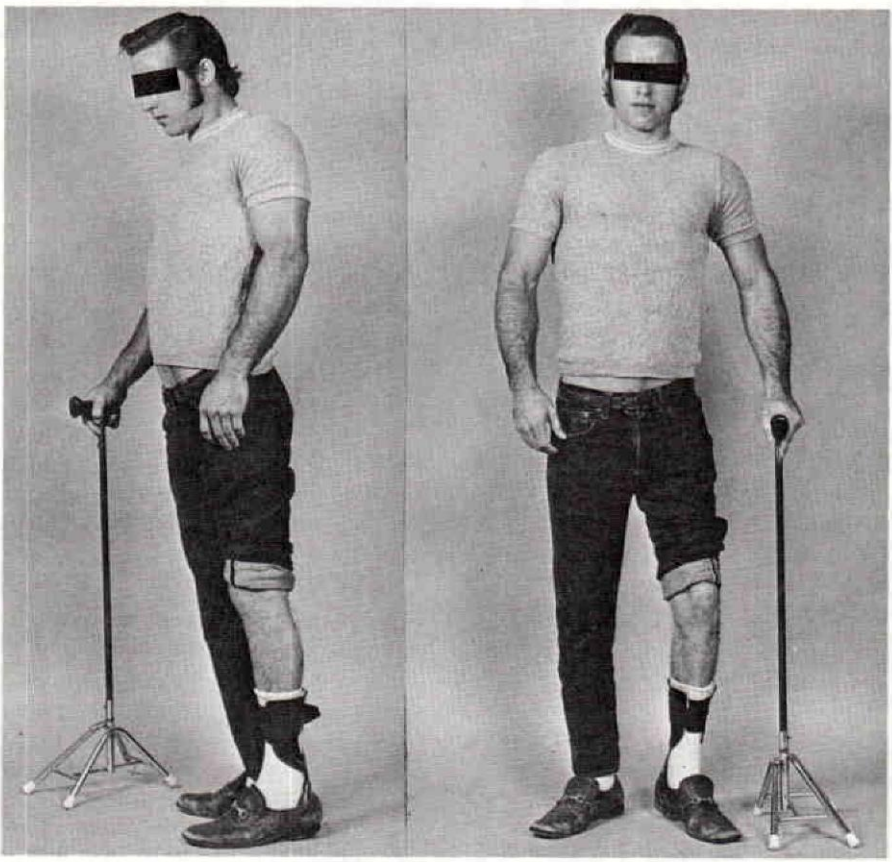

FIG. 16 Patient with incomplete paraplegia at T-6, age 21. Left - lateral view of corrugated polypropylene orthosis. Right - anterior view of corrugated polypropylene orthosis.

major muscle groups in the foot-ankle complex. The high proportion of sensory impairment complicated their motor losses. The majority of these patients whose etiology is cerebrovascular accidents have diffuse superficial sensory loss, as well as position sense loss, requiring the most careful follow-up of the contour-fitting polypropylene devices. Devices for patients in this category, in general, were provided with more rigidity to meet their biomechanical impairments.

In this group, spasticity is the largest additional complication, as the moderate and sustained clonus creates a deforming force which requires greater rigidity in the orthosis.

The limitations in range of motion noted in the chart were primarily of inability to reach plantigrade. There were also a number of patients who exhibited genu recurvatum. Other complications in this group include uncoordination, ataxia, synergistic movement, tremor, perceptual disability, and mental confusion, secondary to cerebral pathology.

An example of a severely impaired Group III patient is a young man, age 21, with a diagnosis of incomplete paraplegia at T-6 secondary to a gunshot wound (Fig. 16). In October 1970, bilateral above-knee conventional orthoses were prescribed for him. He experienced thereafter some motor return bilaterally, especially in the right lower limb. There remained moderate spasticity in the left leg and mild spasticity in the right leg. Mild tightness is found throughout the range of motion of both lower limbs, and severe limitations are recorded in dorsiflexion. He has bilateral drop-foot, complicated by skeletal limitation in dorsiflexion on the left, and is dependent on a quad cane during stance phases of ambulation. A left below-knee corrugated polypropylene orthosis was prescribed and fitted for him in August 1971. Because of his severe disability, his gait is quite unstable, and his endurance is poor. However, the patient is satisfied with his orthosis because it is providing adequate support.

EVALUATION AND EDUCATION

Additional clinical evaluation of the corrugated below-knee polypropylene orthosis was conducted under the auspices of the National Academy of Sciences, Committee on Prosthetics Research and Development, at Moss Rehabilitation Hospital, Krusen Research Center, in Philadelphia. Two patients were fitted and clinically tested for effect on gait performance. Moss's preliminary report indicates that the new devices were effective in providing the necessary assistance for the patients.

At the request of the Committee on Prosthetics Research and Development, a course in fabrication and fitting of the below-knee orthosis was held at the New York University in January 1972, and in March 1972, that University included a one-week seminar in construction of corrugated polypropylene orthoses in their orthotic curriculum.

An *Instruction Manual for Fabrication and Fitting of a Below Knee Corrugated Polypropylene Orthosis* (8) has been prepared, giving in detail the necessary steps for construction and application of the device. This manual is available from the Texas Institute for Rehabilitation and Research.

DISCUSSION

Although successful prolonged usage of these below-knee devices is now a reality, adaptation demands that the orthotist perform a precision fitting process. Because the contour of the orthosis is critical to the function, application requires more care than is usually necessary for conventional orthoses. If the patient is hyperesthetic, a longer period of observation and initial adjustment of the orthosis is critical. Also, the same precautions are taken where there is reduced or lack of sensation in the lower limbs.

For the more severely impaired hemiplegic who has the functional use of only one hand, independent application and removal of the device can be very difficult, and in approximately 3% of the patients fitted to date, impossible.

According to the patient's reactions, any disadvantages of the polypropylene orthosis are exceeded by the following advantages:

1. the brace-shoe attachment has been eliminated;
2. the device is much lighter in weight than conventional braces;
3. ambulation is made easier;
4. it is less conspicuous; and
5. the assistance needed can be tailored to the individual patient and can be used without discomfort.

ABOVE-KNEE STUDIES

Efforts have been made to apply the design principles and material which were successfully used in the below-knee orthosis to above-knee devices. The fabrication and fitting methodology are similar to that used for the below-knee devices, except that a cast is taken of the patient's entire lower limb. The reinforcing corrugation is extended on the medial and lateral sides to just below the knee joint and is continued proximally to include the thigh area. Places where pressure points could occur are identified, and small discs are attached to the cast to produce indentations in the molded polypropylene at these points on the inner surfaces.

Above-knee devices have been fabricated and applied to eight patients. Six of these applications incorporated conventional prefabricated metal knee joints. Also investigated was the possibility of eliminating metal knee joints by using the polypropylene material itself. Flexible polypropylene hinges of special design have been tried in several applications with one successful adaptation. In this case, for a child with a diagnosis of spina bifida, the thigh and below-knee portions of the orthosis were joined using a narrow strap of polypropylene which acts as a hinge. This arrangement freely allows passive polycentric skeletal knee articulation and reduces the mechanical hindrance which can cause undesirable sliding motion, eliminating a common problem seen in conventional orthoses

Means to provide adequate articulation still present an unsolved problem, locking the unstable knee. Efforts are being made to develop a different method of stabilizing the knee which will complement the experimental polypropylene hinge.

SUMMARY

As a result of three years of research and development in attempting to improve designs for

lower-limb orthoses, a device using polypropylene with corrugations has been developed for patients with "drop-foot."

By incorporating corrugations into polypropylene, which is extremely resistant to fatigue, the ratio between total flexibility and rigidity can be controlled selectively to match the specific deficits in the individual patient without the need for reinforcing materials. This orthosis may be considered as an analog of the ligaments, permitting musculoskeletal functions while compensating for various deficits in the patient's biomechanical system.

In addition to providing the patient with dorsiflexion assistance and mediolateral stability of the foot-ankle complex, the TIRR orthosis has three distinct advantages over conventional devices:

1. The weight is much lower.
2. A permanent attachment between the shoe and the orthosis is not required.
3. The appearance is more acceptable to patients.

The TIRR device is indicated for all conditions where conventional below-knee orthoses would be prescribed. It also can be used effectively when the weight of a conventional brace would contraindicate its use, but where ankle stability and active dorsiflexion assistance would be helpful.

Contraindications for use are severe, uncontrollable spasms and severe, irreversible skeletal deformities of the foot-ankle complex.

ACKNOWLEDGEMENTS

Acknowledgement is made of the many reports and publications, in addition to those listed in this report, which have served as sources of information and assistance for this project. Valuable contributions have also been received from the countless people who have participated in meetings and conferences during the past three years. These exchanges of ideas have stimulated the researchers and helped further this project.

Acknowledgement is also made to the entire professional and non-professional staff at Texas Institute for Rehabilitation and Research who contributed both ideas and service.

Special thanks are due to the entire staff of the Department of Orthotics for their full-time daily involvement in the furtherance of the project.

Finally, and most importantly, our grateful thanks are extended to the many patients who have cooperated with us in the clinical evaluation of our orthotic developments.

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The Northwestern University Supracondylar Suspension Technique for Below-Elbow Amputations[1]

J. N. BILLOCK, C.P.O.[2]

The use of myoelectric control for the below-elbow amputee has eliminated the need for the harness for power transmission. Therefore, the major function of the harness in relation to a myoelectrically controlled prosthesis is suspension; and, with the use of self-suspending socket, such as the NYU Muenster-type socket described by Kay et al. (3), it is possible to eliminate the harness completely.

It has been found that the NYU Muenster-type socket has disadvantages which can affect the overall use and function of a myoelectrically controlled prosthesis because of its high anterior and posterior trimlines. The design is applicalbe to only rather short below-elbow amputations and provides a somewhat limited range of motion at the elbow, as pointed out by Gorton (2) and Friedman (1).

A supracondylar suspension technique for below-elbow amputations has been developed as part of NU Myoelectric Below-Elbow Prosthetic System and was designed to provide more below-elbow amputees with the advantage of self-suspension, regardless of the length of their amputations. This socket, utilizing supracondylar suspension, will accommodate all lengths of below-elbow amputations and will provide an improved range of motion at the elbow.

Data collected on a total of twelve amputees fitted at the NU Prosthetic Research Laboratory over a period of 2 1/2 years are given in Table 1. Three of the amputees have been refitted since their initial definitive sockets because of atrophy or a change from one myoelectric system

[1]This work was supported by Veterans Administration Contract V101 (134) P-5.

[2]Coordinator, Prosthetic Research and Education, Northwestern University Prosthetic-Orthotic Center.

TABLE 1. CASE HISTORIES AND BIOMECHANICAL DATA

#	PATIENT	AGE	SEX	CAUSE OF AMPUTATION	RIGHT OR LEFT	STUMP LENGTH	PRESENT OCCUPATION	DATE FITTED	STUMP LENGTH	EXTENTION*	FLEXION*	RANGE OF MOTION*
1	R.T.	24	M	Traumatic	Right	9 1/2	Office work	1-22-70	9 1/2	12°	127°	115°
2	D.M.	21	M	Traumatic	Right	7	Student	1-23-70	7	24°	105°	81°
3	D.S.	25	M	Embolus	Left	5 3/4	Farmer	3-17-70	5 3/4	12°	120°	108°
4	N.B.	14	M	Congenital	Left	5 1/8	Student	4-27-70	5 1/8	7°	110°	103°
5	T.S.	20	M	Traumatic	Right	6 3/4	Student	9-25-70	6 3/4	13°	120°	107°
6	P.W.	21	F	Congenital	Left	4 1/2	Housewife	10-26-70	4 1/5	10°	111°	101°
7	W.L.	26	M	Traumatic	Left	7 5/8	Laborer	10-31-70	7 5/8	13°	123°	110°
8	W.D.	54	M	Traumatic	Right	7 3/8	Photographer	11-17-70	7 3/8	11°	125°	114°
9	M.R.	18	F	Congenital	Right	4	Student	12-14-70	4	11°	111°	100°
10	B.R.	37	F	Tumor	Right	5	Housewife	4-12-71	5	17°	119°	102°
11	W.V.	39	M	Traumatic	Left	4 3/8	Office work	5-26-71	4 3/8	15°	120°	105°
12	R.S.	24	M	Traumatic	Right	4 3/4	Student	8-23-71	4 3/4	14°	115°	101°

*With prosthesis on
**Patient has limited range of motion without prosthesis.

to another. One amputee, a juvenile, has been fitted four times because of longitudinal bone growth. His approximate time between fittings was 6 months.

The Veterans Administration is presently conducting a field study on externally powered components which include the supracondylar suspension technique on the below-elbow patients fitted in the study. Some 60 prosthetists involved in the study attended a special course which included instruction in this

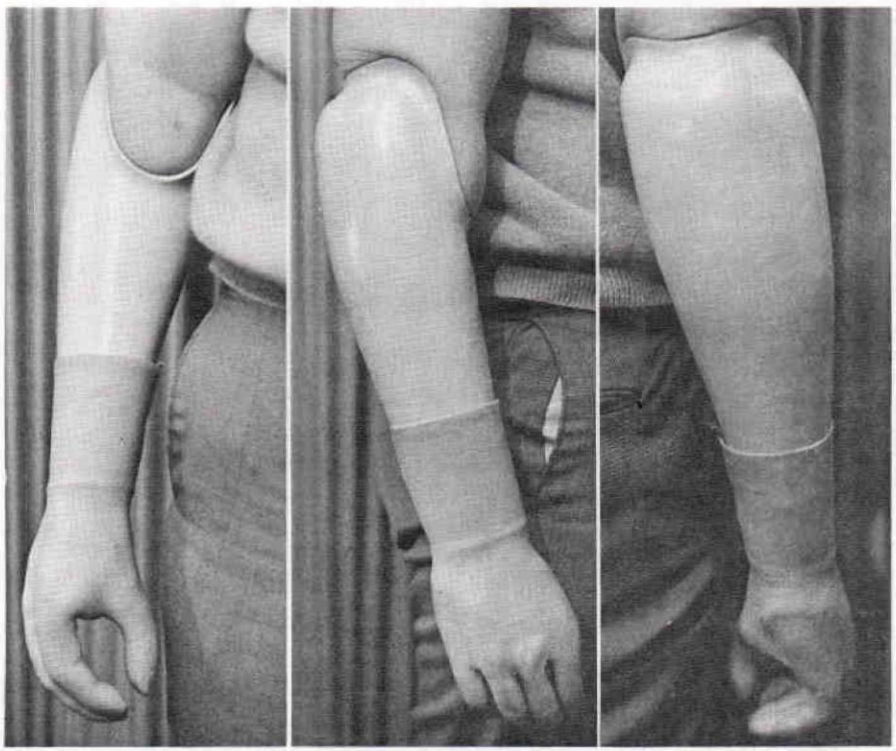

FIG. 1 Left, Anterior View of Socket Trimline. Center, Lateral View of Socket Trimline. Right, Posterior View of Socket Trimline.

fitting technique. A total of 26 such fittings have been completed since the field study began in April of 1971, and many of the prosthetists have applied this technique to conventional fittings as well as externally powered fittings.

The NU Myoelectric Below-Elbow Prosthetic System that utilizes this suspension technique, is shown in Figure 1. Note the contours of the socket trimline in the anterior, lateral, and posterior views.

Figure 2 illustrates the range of elbow flexion which can be obtained on most below-elbow amputees

FIG. 2 Range of Elbow Flexion Possible.

because of the low anterior trimline.

CASTING PROCEDURE

The most important step in fitting a socket of the type being considered is to record accurate anatomical data. In addition to the data normally recorded, it is necessary to measure the medial-lateral distance between the humeral condyles. This is best done with a double-headed combination square or the VAPC caliper. The measurement should be snug, being sure that it is taken at the apex of the condyles. The length measurement of the amputated limb should be taken from the posterior edge of the olecranon to the end of the longest cut bone, when the elbow is flexed to 90°. This measurement not only is important for determining the length of the prosthesis, but it is necessary in determining how low the anterior trimline can be in relation to the length of the amputation limb. All other measurements are recorded in the conventional manner.

Two layers of #56 Tubegauz are applied to the amputation limb and suspended with a figure-of-eight elastic webbing strap. Tubegauz is preferred for the cast sock because it maintains contours well and provides adequate definitiion of the bony prominences of the olecranon process and humeral condyles. It is very *important* that the olecranon process and humeral condyles be outlined accurately with indelible pencil in order to provide accurate references for modifying the positive mold.

The elbow must be flexed 45° when the cast is taken to insure a proper contour of the posterior aspect of the upper arm, superior to the humeral condyles. This is necessary in order to maintain an optimum range of extension when modifying the positive mold.

It has been found that a more smoothly contoured cast can be obtained if elastic plaster bandage is used for the initial wrap. It is reinforced with regular plaster bandage after it has set. The plaster

wrap should extend no less than one inch superior to the olecranon process and humeral condyles. No attempt should be made to distort the cast in any manner while it is setting because this will disrupt the general contours of the amputation limb and displace the outlined areas of the olecranon process and humeral condyles which are very important references needed for modifying the positive mold. Once the cast is removed, it should be checked to see that the outlined areas were not displaced and the areas should be remarked to insure good transfer to the positive mold.

CAST MODIFICATIONS AND BIOMECHANICAL PRINCIPLES

Before one attempts to modify a positive mold for a socket of this type, he should fully understand the biomechanical principles involved and how they are related to the suspension, flexion, and extension features of the socket. Suspension, the most important feature, must be considered at all times during the modification of the positive mold. Also, it is necessary to point out that the modifications described in this report do not account for the thickness of a prosthetic sock. Therefore, it is necessary to adjust the measurements to accommodate for the thickness of the prosthetic sock, if the amputee is to wear one.

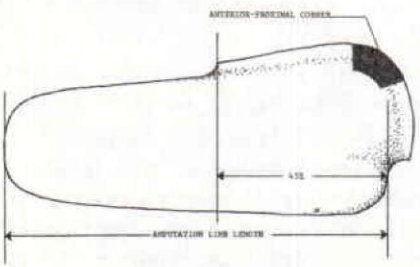

FIG. 3 Lateral View of Socket and Trimline.

In Figure 3 the shaded area at the anterior-proximal corner of the socket trimline is the point at which the humeral condyles enter the socket. The distance between the two corners at the trimline must be 1/8 inch smaller than the measured M-L dimension at the condyles so that the condlyes can pass through with only a slight expansion of the socket. The measurement should be divided in such a manner that each side of the trimline cups over the condyles 1/16 inch. If the M-L dimension is too small, the condyles will not pass into the socket; if it is too large, the suspension will be inadequate in this area. The suspension also is affected by the flexibility of the resin in the definitive socket. The best results have been obtained with a 60% rigid and a 40% flexible mixture of acrylic resin; if polyester resin is used, the mixture should be 70% rigid and 30% flexible.

In some cases the proximal M-L measurement of the positive mold will be too small even before it is modified. Generally this occurs with an upper limb that is thin or atrophied, causing the medial condyle to be more prominent than usual. When this is the case, the positive mold must be built up on the medial side and plaster removed on the lateral side to insure that each side cups over the condyles 1/16 inch.

When the amputation limb is longer than 5 inches, the distance between the lowest point of the anterior trimline and the olecranon process, also illustrated in Figure 3, should be approximately 45% of the total length. This percentage is necessary for long below-elbow am-

putations in order to allow entrance into the socket without impinging on the anterior-distal trimline. Also, this will provide adequate room for tissue bunching in the cubital fold during flexion and allow the optimum range of elbow flexion. If the amputation limb is less than 5 inches in length, it is necessary to establish an anterior-distal trimline which will provide an adequate anterior weight-bearing area.

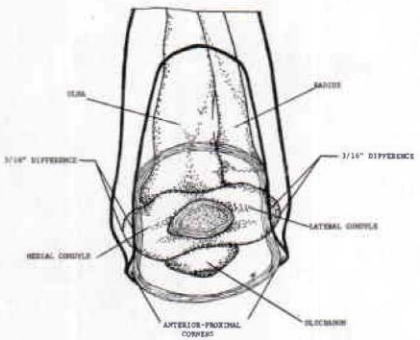

FIG. 4 Anterior-Superior View with Elbow Flexed to 90°.

Figure 4 illustrates the relationship between the socket trimline and the skeletal structure of the elbow. This is an anterior-superior view of a transverse section through the upper arm and humerus with the elbow flexed to 90%. Of particular interest is the ralationship of the anterior trimline to the humeral condyles. The anterior trimline, superior to the humeral condyles, should be at least 3/8 inch smaller than the measured M-L dimension at the humeral condyles in order to provide adequate suspension in a flexed position. This measurement allowance also should be divided equally so that the trimline cups over the condyles 3/16 inch on each side. This is very important during extreme flexion because the forces being exerted against the socket by tissue bunching in the antecubital fold are acting so as to push the socket off.

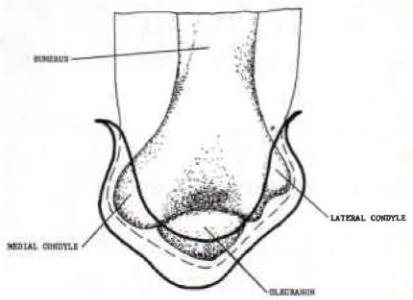

FIG. 5 Posterior View with Elbow Flexed to 90°.

Figure 5 is a posterior view of the elbow flexed to 90%, again illustrating the relationship of the anterior trimline to the humeral condyles. Notice how the socket cups over the humeral condyles and how the proximal trimline is flared outward to prevent irritation of the tissues in that area. Generous flaring of the entire trimline will increase the overall comfort.

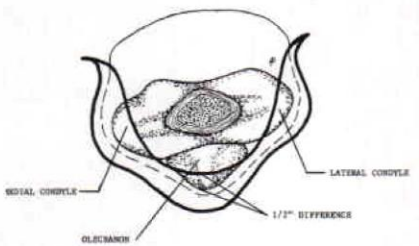

FIG. 6 Transverse View Just Superior to the Epicondyles.

Figure 6 is a transverse view just superior to the epicondyles, illustrating the relationship of the posterior-superior trimline to the humeral condyles and the olecranon process with the forearm in full extension. In order to allow a maximum range of extension, it is necessary that the posterior trimlines be well rounded

to accept the contour of the upper arm, proximal to the humeral condyles. As mentioned in the section on the casting technique, this contour is best obtained by taking the cast with the elbow flexed 45°.

In order to maintain good suspension in the fully extended position, the posterior trimline must cup over the olecranon process at least 1/2 inch. The reason for modifying the area over the olecranon process more than the areas over the condyles is to take advantage of the excellent pressure-bearing area provided by the triceps tendon. This is the major pressure-bearing and suspension area when carrying or lifting heavy objects. In some instances, it is necessary to modify the positive mold more than the prescribed 1/2 inch in order to insure that the condyles are not subjected to excessive pressure. One should be cautious of overmodifying in this area because it will have a direct effect on the range of extension in the definitive socket. The amount of modification in this area is best evaluated during the check-socket fitting by applying a force to the socket which simulates the forces acting on the prosthesis when the amputee is lifting or carrying an object.

Figure 7 illustrates the forces which affect the amputation limb when lifting or carrying and object with the prosthesis. These forces create a torque which causes pressure on the anterior-distal aspect of the radius and pressure on the olecranon process and triceps tendon. This is a desirable reaction because it enhances suspension and comfort by insuring that the posterior-proximal trimline is cupped over the olecranon process and

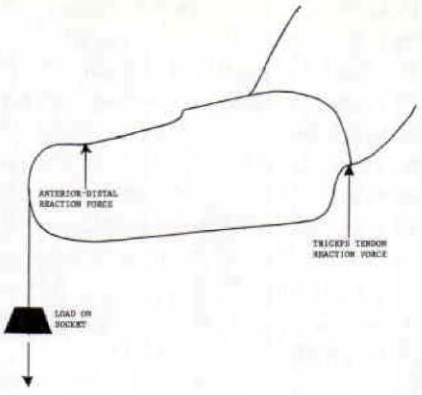

FIG. 7 Reaction Forces Created by a Load on the Socket.

creating pressure on the triceps tendon instead of the humeral condyles.

The reliefs for the humeral condyles and olecranon process should not be added to the positive model until the entire trimline is well established. The reliefs for the humeral condyles should be at least 1/8 inch thick and extend to the border of the outlined areas before tapering into the positive mold. The relief for the olecranon process also should be at least 1/8 inch thick and positioned toward the proximal edge of the olecranon as illustrated in Figure 8.

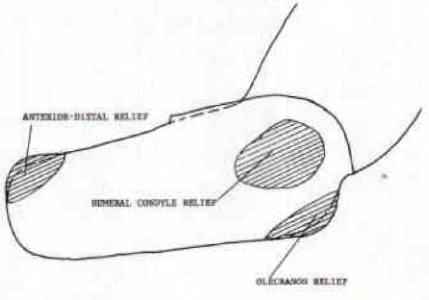

FIG. 8 Socket Relief Areas.

CHECK-SOCKET FITTING PROCEDURE

To properly evaluate the suspen-

sion of the socket, it is necessary to do a check-socket fitting before fabricating the definitive socket. A synthetic balata, such as Polysar X-414[3], has proven to be an excellent material for check sockets because it can be easily molded and can be re-formed readily when a remodification of the cast is necessary.

A Polysar tube with a 2-inch inside diameter and a 1/4-inch wall thickness is generally adequate for the average amputation limb. The length of the tube should be 1 1/2 inches longer than the overall length.

The synthetic rubber tube is heated and then pushed over the modified positive mold on which a generous application of vaseline has been made. Once the tube is well over the proximal trimline, it should be molded into the contours of the trimline.

To remove the check socket from the positive mold, it is necessary to cut a slit on the anterior surface. This will permit the medial and lateral wings of the socket to expand while pulling it off the positive mold. After the socket is removed, the slit should be closed and held together with pressure-sensitive tape, and all excess material should be cut away to the proximal trimline.

The synthetic rubber has a higher coefficient of friction than polyester or acrylic; therefore, it is necessary to powder the check socket with talc before the amputee attempts to don the socket.

The inability of the humeral condyles to pass into the entrance of the socket is generally caused by a proximal M-L dimension that is too small or an anterior trimline that is too high or too narrow, causing tissues to bunch up against the anterior trimline. The positive model should be remodified and the check socket reheated and re-formed. Although the synthetic rubber can be reheated in localized areas and remodified, this is not recommended because it is difficult to heat a local area without distorting other areas of the socket.

Once the humeral condyles are seated well in the socket, the suspension is checked. This is best done by applying a force to the socket which simulates the weight of the prosthesis distal to the end of the amputation limb. If the socket displaces easily without resistance from the amputee, the suspension is inadequate. This is an indication that the proximal M-L dimension in the anterior-proximal corners is too wide. The socket should displace with a fair amount of force without the amputee offering resistance, but if the amputee offers resistance, the socket should not come off. In most instances the forces acting on the socket tend to enhance the suspension by keeping the posterior wall over the olecranon process at all times.

POSSIBLE POST-FITTING PROBLEMS

The humeral condyles tend to be rather tender during the first few days after the initial fitting. Tenderness may also develop in the tissues of the antecubital fold. This tenderness should diminish as the tissue and bones build up a tolerance to the socket. It is therefore advisable to build up this tolerance gradually and not overuse the prosthesis during the first week or so after the initial fitting.

[3] Polymer Corporation Ltd., Sarnia, Ontario, Canada.

Experience has shown that an amputee may initially have some difficulty in donning the prosthesis. This problem disappears quickly as he gains experience in putting it on.

ACKNOWLEDGEMENTS

The author wishes to thank Dr. Dudley S. Childress, Miss Carole Herhold, and Mrs. Margaret Mitchell for their help in the preparation of this report.

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Accelerated Drying of Plaster Casts with a Microwave Oven

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GERALD PORTER, B.S.M.E.—RESEARCH ENGINEER[1]

Calcined gypsum (calcium sulphate hemihydrate, CaSO4 - 1/2H20), commonly known as plaster of Paris, is used extensively in forming casts to immobilize parts of the body and for making molds used in the manufacture of orthotic and prosthetic devices. Plaster models and casts have several advantages, and a few disadvantages. Widely available, plaster is inert, sufficiently stable dimensionally, for the use at hand, and is inexpensive. Its major disadvantage involves the time required for it to dry sufficiently so that it may be modified and used for forming orthoses and prostheses.

During its manufacture, plaster is prepared for use by reducing it to its powdery state. When it is used, it is mixed with water in approximately the proportions of two parts plaster to one part water. Plaster bandages are crinoline fabric strips in various widths and convenient lengths, rolled in the plaster to fill the interstices of the fabric with the powder. These are packaged and ready for dipping or wetting in water followed by application to the body or limb.

When plaster is mixed with water, crystallization occurs in a few minutes. The chemical reaction generates heat. Molding over the desired contours is done by rubbing and shaping with the hands before crystallization. When freshly poured, plaster passes through a glossy, creamy, intermediate stage to promptly become thickened and dull to light. This is the "setting" stage and further manipulation must be avoided because proper interlocking of the calcium crystals will be hindered.

Plaster models of limbs, extremities, and amputation stumps, are made by first wrapping the member with plaster bandages, removing them after they have set, and then pouring liquid plaster into the

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female cast. On setting and removal of the outer bandage cover an exact plaster model of the member remains. This model is used to shape and form the plastic and other materials required to produce the device.

Plaster casts will dry in time, of course, by simply exposing them to air at room temperature. Most often, however, they are dried in a warm, forced-air oven, at about 150 degrees F. Higher temperatures tend to crack casts and produce spalling. In our experience the times generally required for drying in 150 degree F. oven are:

Hand or arm casts	12 Hours
Partial foot & Syme casts	12 Hours
Above-knee casts - medium size	12 Hours
Shoulder-disarticulation casts	18 hours
Above-knee casts, large size	18 hours
Hip-disarticulation casts	24 hours
Body casts	24 hours

In an effort to reduce the present drying time of 12 to 24 hours, presently attained with hot-air ovens, experiments have been performed wherein "set" samples of wet plaster have been dried effectively in a microwave oven.

EARLY CONSIDERATIONS

In trying to reduce the time required before the model could be used we considered several different ways, including:

1. Procedures and tools that would minimize the problems of wet plaster occluding the tools used to modify the casts.

2. Providing a moisture barrier on the surface of the cast to eliminate the need for drying. Two procedures examined were:

a. Application of a chemical or paint to the wet surface to prevent migration of cast moisture.

b. Application of a film of sheet material or preformed bag to the wet cast to serve as a moisture barrier.

Retained moisture in the improperly dried cast may also affect the polymerization of certain plastic laminates in that it prevents the development of smooth surfaces needed for contact with the skin of the patient. To date, no really satisfactory moisture barrier has been found. Physical barriers such as rubber balloons reflected over the cast, tend to prevent passage of moisture but also disintegrate on contact with the laminating resins. Chemical solutions of several types were found to be similarly inadequate.

Our earlier considerations of the use of microwave energy had not preceeded beyond the academic stage until we were encouraged by Drs. Williams and Kesting, visiting from Chemical Systems, Inc. Our tests, using three approaches involving microwave equipment, included units belonging to Sears-Roebuck, Litton Industries, and the Bechtel Corporation.

SEARS-ROEBUCK MICROWAVE OVEN

The oven used (Fig. 1) was a demonstrator unit from the sales floor of the local Sears outlet. It was designed for use in the home and was Model #103 9927102-115 VAC/1560 watts - 14.5 ampere. The interior dimensions were slightly over 43 cm. W x 35 cm. D x 17 cm. H. This size would take care of our needs in smaller size casts but it would be

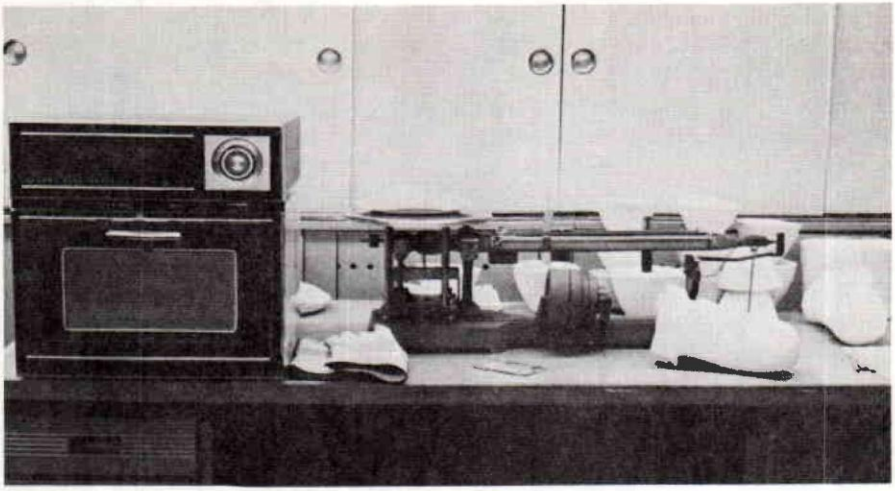

FIG. 1 Oven shown was supplied without charge by Sears. Also needed for the study were scales, plaster of Paris, water, a standard mixing bowl and a pair of heavy leather gloves—the latter for handling the hot plaster casts.

inadequate for "long leg" or large body casts. It did, nevertheless, alllow us to determine the feasibility of drying plaster with microwave energy.

To form the test models (Fig. 2) standard rubber bowls of the type used to mix small batches of plaster were used. The resulting models were bowl-shaped to thus represent a

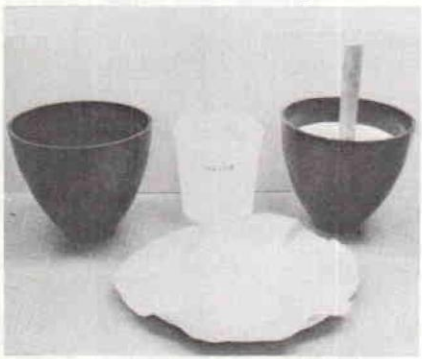

FIG. 2 Standardization of test models was achieved by using identical amounts of plaster and water, as determined by weight. All were mixed in standard mixing bowls, as shown, thirty minutes before each test.

thick structure possessing both flat and curved surfaces. To further standardize the models we adopted the proportions of 800 grams of plaster to 400 grams of water for each model.

For our initial experiments we placed the test model on a paper plate, which is unaffected by microwave energy, in the center of the oven and exposed the model for four-minute intervals (Fig. 3). The freshly mixed model was weighed

FIG. 3 Models were placed on standard paper picnic plates and energy was applied in increments of four minutes. Between each application the model was removed from the oven, weighed, replaced and drying continued.

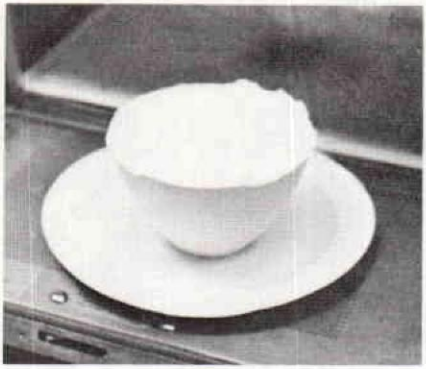

FIG. 4 After four minutes the outer surface of the plaster model was warm, damp, and water vapor was arising from the surface. There was a moderate drop in weight due to vapor loss.

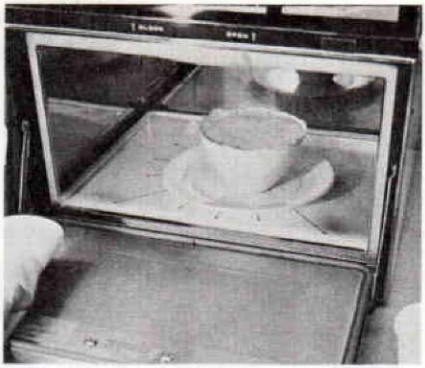

FIG. 5 Droplets of water appeared on the surface of the model and a small puddle of water had formed on the paper and plate, soaking into same. Weight loss was almost three times that of the first drying interval.

initially and reweighed at the end of each drying interval. After four minutes the model felt damp and warm and wisps of water vapor arose from its surface (Fig. 4). There was no evidence of water absorption in the paper plate. At the end of the second four-minute interval the cast was warmer, there was more vapor, and a suggestion of dampness on the paper plate was noticed (Fig.5). At the end of the third four-minute interval, drops of water were present on the surface of the cast, and the plate was almost filled to the brim with water.

The same procedure was continued for four additional four-minute intervals. The cast was perhaps dry enough to work at the

DRYING TEST OF PLASTER MODEL — SEARS MICROWAVE OVEN

Starting Weight = 1,166 grams - freshly mixed

Time (min.)	Weight (grams)	Weight Loss (grams)	Comments
4	1,152	14	Warm/vapor from surface
8	1,112	40	Hot/vapor + puddle of water
12	1,062	50	Same
16	1,015	47	Hot/water boiling
20	942	73	Hot/surface dry for work
24	902	40	Hot/surface damp
28	842	60	Hot/surface damp
32	804	38	Hot/surface damp
36	799	5	Hot
40	796	3	Suitable for lamination
44	792	4	Crack developing
48	783	9	Crack larger
52	782	1	Crack larger
56	781	1	Test discontinued

end of the fifth interval, or a total exposure of twenty minutes in the microwave oven, but not enough to allow for lamination. We were impressed with the results shown in the table on page 27.

LITTON INDUSTRIES MICROWAVE OVEN

At this point we were able to obtain a demonstrator oven manufactured by Litton Industries. This larger oven, designed for restaurant use, featured a half-power switching arrangement found to be quite convenient. The Litton oven measured about 35 cm. x 61 cm. x 25 cm., sufficient for all except our largest lower-limb and body casts.

The results of the power of the Litton oven were soon apparent. Two test models exploded, but without injury to personnel or equipment

FIG. 6 Higher-powered Litton oven generated steam of water in center of cast causing same to explode as shown. Time was less than five minutes. There was no damage to personnel or equipment.

(Fig. 6). On inspection of the broken pieces of the case it appeared that water vapor deep within the cast was being converted to steam, and that the water was being forced from deep inside the cast to the outside surfaces. We repeated several of the earlier experiments using test models of differing plasters ordinarily used in orthopaedic, prosthetic, and orthotic practices. The additional power and size of the Litton oven represented an advantage.

Sufficient dryness for use in forming orthotic and prosthetic devices, is of course, reached well before all the water is extracted from the cast, and therefore it was desirable that simple tests be developed that would allow us to determine when the cast was sufficiently dry for use. We used an open mesh abrasive (Sand Screen 8 M7555, No. 180 mesh, made by Carborundum) with which we rubbed the test surface. When the plaster was too wet to work, the interstices of the screen filled with the wet material thus destroying its abrasive effectiveness. When dry, the plaster tends to fall away from the screen.

The larger size of the Litton oven allowed us to study its drying capabilities with a full-size cast. These duplicated a below-knee amputation stump. To assure their standardization they were made from a common wrap cast and with identical amounts of plaster and water. We also used wood dowels rather than the usual sections of metal pipe for handling the casts, since metal acts as a heat sink in microwave ovens.

The freshly mixed plaster cast was placed in the center of the Litton oven, resting in a quantity of ceramic beads in a glass baking dish. Neither the beads nor the glass dish are affected by microwave energy. Full power was applied at intervals of two mintues, and between intervals the cast was weighed quickly in order

not ot interfere with the drying process to any practical extent. Time and weight losses were recorded. Loss in weight was, of course, due to water loss, and therefore represented the drying rate of the system. The plaster duplicate of the BK stump was subjected to microwave energy in intervals of two minutes. At the end of the second interval—a total of four minutes—the cast was warm to the touch and water vapor was arising from its surface. At eight minutes the entire cast was dripping wet with water collecting in large droplets. Some droplets ran off onto the floor as the cast was removed for weighing.

Both the Sears and Litton ovens were equipped with air fans to discharge the warm, moist air through their perforated front panels. It occurred to us that for our selective use we could use a higher heat and higher volume of air flow, sufficient, perhaps, to prevent the coalescence of water vapor into droplets, and therefore further reduce the drying time.

Shrinkage of plaster was the subject of a comparative investigation of the accelerated drying of plaster by microwave energy and the conventional hot air drying technique.

Two identical plaster duplicates of the same amputation stump were produced and their measurements were checked at some eight points in addition to circumferential measurements at identical levels (Fig. 7). One cast was dried in the conventional way, in a 150 degree F. oven, overnight, and the other in the Sears oven. No significant differences were found in the comparative measurements of the two casts following the drying procedures.

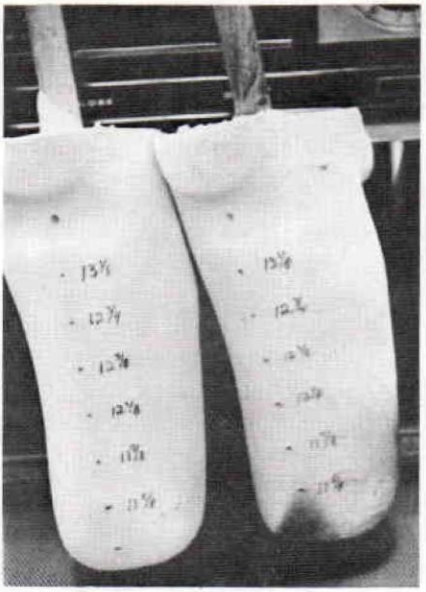

FIG. 7 Identical plaster stump reproductions were dried, one in a 150 degree F. heated oven overnight, the other in the microwave oven for 50 minutes. There comparable dimensions demonstrated no measurable difference.

BECHTEL CORPORATION STUDY

As a result of our experiments we contracted for independent feasibility studies with the Bechtel Corporation, a commercial firm having the capability of designing a microwave drying system for our particular use. We supplied Bechtel with plaster of Paris for our own supplies, molding equipment, and associated materials for making their test casts. In addition, to assure identical tests values in the beginning, we also provided a staff member who actually made all plaster casts. These duplicated those made in our own laboratory, ranging in size from the small, bowl-shaped casts to large torso casts weighing ten to eleven kilograms.

Bechtel used thicknesses ranging

from 5 to 30 cm. They felt that an oven with a rectangular cavity of 43 x 61 x 41 cm. would be sufficient and should include a mode stirrer and turntable to achieve uniform power density. For testing, power at 2450 MHz was provided with adjustable power output up to 2.5 kw.

In the laboratory oven configuration used, the casts received only 75% to 90% of the 1.5 to 2.5 kw. microwave energy available. A plot of energy versus weight reduction for heavy and light samples is shown in Figure 8. In a production unit designed specifically for this application, Bechtel feels that these percentages can be increased.

Qualitative judgment of the samples indicated that workability (sufficient dryness) was achieved at 72% of initial weight (Fig. 9).

When the sample reached this weight loss, the exterior surface of the cast was hot and slightly damp. The surface temperature ranged from 120 to 140 deg. F. Higher interior temperatures, in the order of 220 deg. F., still forced small quantities of moisture to the surface. Allowing the sample to cool for several minutes produced a dry, completely workable, surface.

Exhausting the mositure laden air from the oven at a rate of 2.24 cubic meters per minute (80 cfm) greatly reduced the accumulation of water on the bottom of the cavity. The concurrent introduction of a 160 deg. F. hot air supply afforded a small additional improvement. A hot air supply alone had little effect in reducing accumulated condensate. The air system reduced the length of time that the surface of the cast remained wet, but the weight loss versus total incident microwave energy curve remained essentially unaffected. The most notable effect was that when the air system was not used the plaster usually spalled and cracked.

In addition, measurements made on 3 kg. knee casts at 27% weight

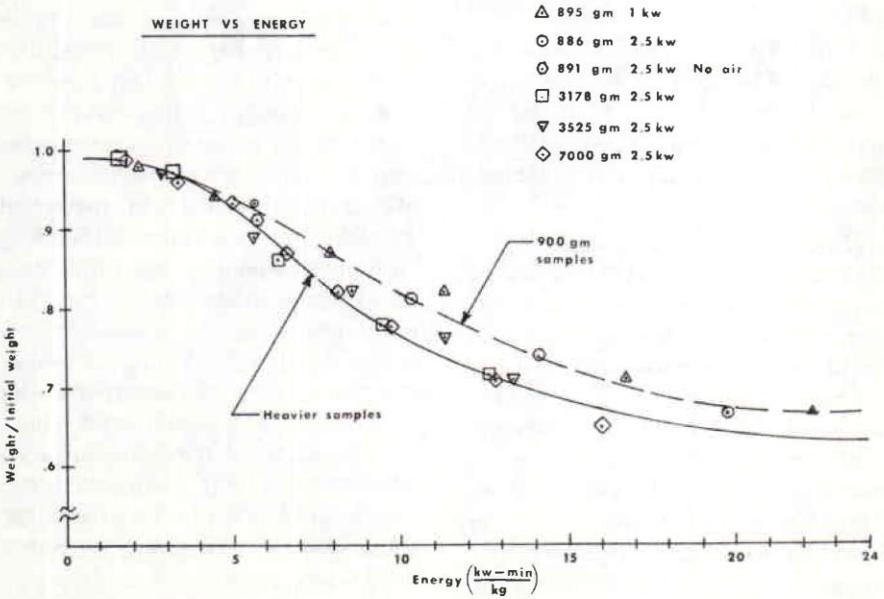

FIG. 8 Rate of drying vs. energy required for microwave/air drying.

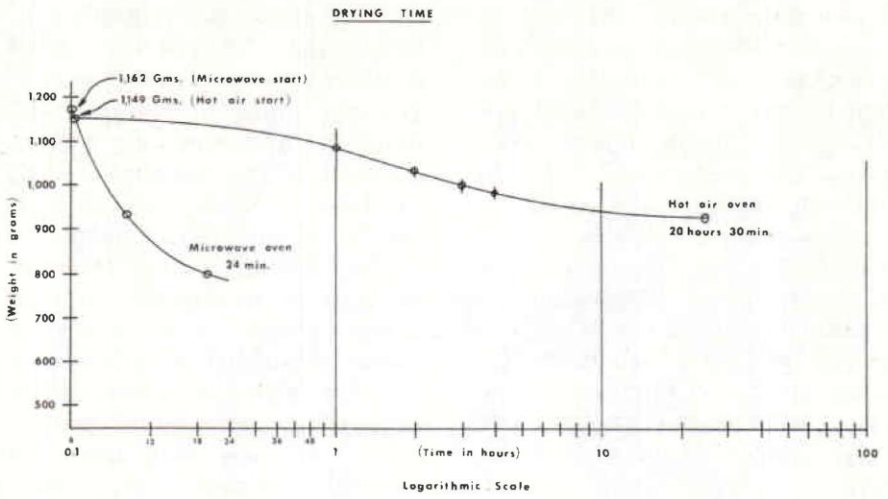

FIG. 9 Loss in weight vs. time for hot air oven and for microwave oven.

loss showed that the air system affected the interior temperature, as measured 3.81 cm. below the surface. With both the hot air supply and exhaust operating, the internal temperature was 217 degrees F. With only the exhaust system operating, this temperature rose to 224 degrees F. With neither system operating, the interior temperature was 228 degrees F. This data indicated that if the water was not removed from the surface of the plaster by the air system, a higher internal temperature or driving force is generated to bring the remaining interior water to the surface, and the temperature moderating effect of evaporative cooling at the surface was not as pronounced. This effect is likely responsible for the higher incidence of spalling and cracking experienced without the air system.

To reduce the number of unknown factors, most of the experiments were conducted without the insertion of a handle into the cast. In separate, controlled, experiments, several types of rods were evaluated for use as handles. Both fiberglass and polypropylene caused the plaster to crack. Because polypropylene is relatively transparent to microwave energy, it is likely that conduction heating of this material by the hot interior of the plaster caused thermal expansion sufficient to produce the cracking. A section of teflon tubing provided the only successful handle. Because the microwave transparency of teflon is similar to that of polypropylene, it can be postulated only that the success was due to the hollow cross-section. This configuration is assisted by some degree of cooling due to the interior air column. Also it is less rigid and more able to absorb thermally generated stresses. It appears that a metal rod inserted in and secured to a teflon or polypropylene tube will provide a satisfactory handle.

CHEMISTRY

Based on the assumption that the "as received" plaster powder was 100% calcium sulfate hemihydrate ($CaSO_4 \cdot 1/2H_2O$), the weight losses measured for samples dried by microwaves to workability exceeded the weight loss expected in drying to the normal dihydrate ($CaSO_4$ -

2H2O) state. For the hemihydrate, mixed in a 2:1 ratio, by weight, with water, curing to the dihydrate would have resulted in a 20.9% weight loss. Returning to the hemihydrate state would have produced a 33½% weight loss and curing to the anhydrous state would have yielded a product with a 39% loss. Optimum microwave drying, as determined by workability, required a 28 to 30% weight loss. To determine the hydration state of the plaster in all phases of processing, samples were weighed and dehydrated in an air oven.

Samples of the "as received" plaster powder were placed in an air oven at 150 deg. F. for 72 hours. There was no noticeable weight loss that would indicate the presence of free water. These samples were then heated to 425 deg. F. and held there for two hours. The measured weight loss after this period indicated that the "as received" powder had been mainly CaSO4 - 1/2H20. Exposure to higher temperature (1400 deg. F.) failed to produce a further weight reduction. Several of the air-oven dried 900 gram samples were weighed and dehydrated at 425 deg. F. The resulting weight loss indicated that these samples were in the dihydrate state. Similar measurements showed the microwave-dried samples to be primarily hemihydrate.

Information from the United States Gypsum Corporation confirmed that most plaster of Paris is shipped in the hemihydrate state and subsequently cured to the dihydrate. The majority of the chemical action occurs in 10 to 20 minutes with the removal of excess water comprising the remainder of the process. Normal cure tempature is 120 deg. F. Above 200 deg. F. the plaster goes to the hemihydrate state and reaches the anhydrous state above 350 deg. F. The hemihydrate is weaker and subject to greater shrinkage than the dihydrate. This shrinkage likely refers to tolerances of few thousandth of an inch acceptable in precision metal casting. Measurements made on laboratory samples failed to show a difference in shrinkage between air and microwave dried plaster. Also there was no obvious qualitative difference in strength or workability noted between the air-oven cured control samples and the microwave dried samples.

From weight loss date and temperature measurements, it appears that the microwave drying produces a cast with a hemihydrate core and dihydrate exterior.

CONCLUSIONS

Experimental results appear to justify the following conclusions:

1. Microwave drying of "set" orthopaedic plaster is a feasible process.

2. The drying time of a 3 kg. knee cast to a level of mechanical workability can, for example, be reduced from the twelve hours required by a hot air oven to 30 minutes with the air-assisted microwave oven.

3. The use of air in conjunction with microwave energy is beneficial in achieving high drying rates and a good quality product.

4. Microwave/air drying appeared to yield a product having a hemihydrate core and a dihydrate exterior.

5. No observable differences in strength, shrinkage and mechanical capability were noted in the micro-

wave/air dried samples compared to control samples dried in a hot air oven.

6. Sufficient knowledge of the microwave drying parameters of plaster molds in the size range of interest was obtained to permit establishing design specifications for a prototype oven.

Constructive Lay-up Technique for Lower-limb Orthoses[1]

RALF UHLIG, O.M.[2]

It is probably because Engineer Scallas and Prosthetist Passerini reported their lower-limb orthotic techniques at the INTERBOR meeting held in Karlsruhe, Germany, 1969, that new emphasis has been placed on orthotics. Their techniques, which have been published, led professional discussions somewhat away from prosthetics, which had overshadowed orthotics for some time. This, of course, resulted in extensive discussions, bringing forth agreement, indifference, or controversy. This paper is intended to document an approach developed by me, and to state opinions different in part from the Karlsruhe discussions.

Fabrication of lower-limb orthoses intended for fixation, correction, weight-bearing, or extension, relates considerably more to the etiology or therapy to be applied than, for example, the principles involved in limb prosthetics. Therefore, frequently the fabrication of leg orthoses is considered a task for a hospital-owned or affiliated orthotics facility. However, manufacturing of lower-limb prostheses is much more frequently the responsibility of independent facilities.

A tuberculosis treatment center cannot be compared with an outpatient department of a general hospital since hospital days per patient, overall costs, and economizing of treatment vary greatly. Nor could one compare orthotic and prosthetic rehabilitation tasks.

Both tasks of rehabilitation differentiate for the Orthotist-Prosthetist economically and structurally during the fabrication process. However, they also vary as to the cause of impairment, course of treatment, and dynamic-static principles.

I hope that my interpretation of the Karlsruhe discussions is correct in reviewing the most interesting topics covered.

Mr. Scallas (Italy) compared prosthetic advances with those of orthotics and

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[1] This paper is published under the auspices of INTERBOR's Publication Committee. (Translation by Siegfried W. Paul, C.P.O.)

[2] Director, Professional School for Technical Orthopaedics, Frankfurt/ Main, Germany

concluded that impressive progress was made in prosthetics but only little or none in orthotics. At present, orthotists are inclined to use time-consuming and much too complicated methods in fabricating lower limb orthoses. Present systems (1969) can be considered empiric and results of doubtful congruity. Supine positioning of the patient during tracing complicates the design of an orthosis intended for an upright position. The numerous modifications at time of, or after fitting the device, can, according to Scallas, be avoided and are most debatable.

Conclusions of the Karlsruhe meeting resulted in the introduction of a new system and I quote Mr. Scallas:

> "Our new development provides for a rational obtaining of body measurements resulting in most accurate fabrication data. These measurements truly correspond with any given anatomical circumstances representing a cost cutting factor which will permit a lowering of the 'sale price.' Another important advantage is elimination of any fitting. This alone saves time and travel expense in particular for patients coming from some distance."

I would like to express my own thoughts on the same subject:

(1) Comparison of technical advances made in prosthetics with those of orthotics cannot be made. Today's lower limb amputation can be managed with principles and components which are of such different magnitude that they could not be related to the impaired but, in general, preserved lower limb considered for an orthosis.

(2) There exist distinct biomechanical differences between a body supporting device and a limb-replacing prosthesis. One utilizes the stump as a functional part of the body created by the surgeon; and the other a body or joint function directing stabilization of the impaired, but still present, extremity. Combining the orthosis with this extremity will result in the desired function. Today's orthotic technology is frequently forced to make use of complicated and time-consuming principles based on many facts considering the medical circumstances. Construction of an orthosis is often ruled by the function anticipated, and therefore, dependent on existing conditions.

(3) All of the currently applied orthotic systems or working procedures are and will always be empiric in principles of their technology and precision. Body outlines remain within doubtful congruity in relation to anatomical and mechanical joint functions. In fact, they frequently must be fashioned incongruent in order to correct functions as desired by the prescribing physician.

(4) Measuring and casting techniques of extremities in effective positions will always create pro's and con's regardless of whether a vertical or horizontal approach is utilized. Personally, I believe that in most cases the vertical system is more difficult than the horizontal approach. After all, it will be the final product, the leg orthosis, which is supposed to control positioning and support of the extremity. I do not consider shifting of soft tissue during horizontal projecting as decisive, nor does this shifting have any bearing on function, statics, or the mechanics to be established. This cannot be said about the

vertical system mentioned earlier which rather tends to invite pelvic tilt and malalignment of the pelvic portion created by forces of the support brackets.

(5) Time consuming fitting procedures are not always the result of fab rication processes, but may be due to a relatively congruent agreement about older functional and fitting prfinciples of an orthosis by physician and technician.

(6) Of course, I do agree with Engineer Scallas that we have to make use of more rational methods of fabrication.

I have pointed out the deviation of opinions with the interest of our subject, the patient, in mind, and shall now discuss technical details of the various manufacturing techniques.

A. Fabrication of orthoses with the aid of plaster-of-Paris molds.

B. Fabrication of orthoses making use of a mounting jig as used in the Pope-Klenzak or the Scallas/Passerini system.

C. The Uhlig Modular system of constructive orthotic fabrication.

ORTHOTIC FABRICATION METHODS UTILIZING A PLASTER-OF-PARIS MOLD

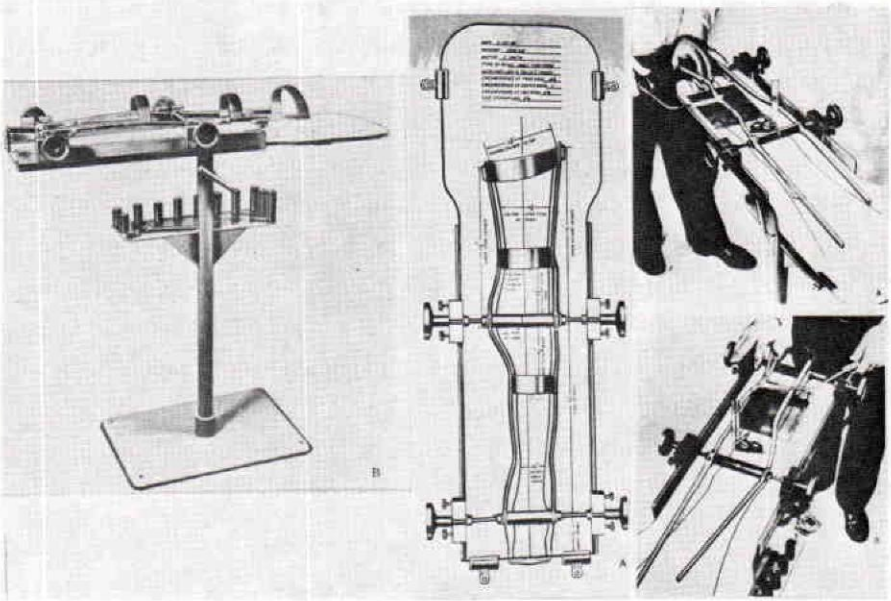
This technique is based on a plaster-of-Paris negative of the impaired extremity and the positive to be evaluated later on. Construction is based on body landmarks to be checked on the plaster positive. Difficult cases with pathological components are left up to the subjective judgment of the orthotist. It is his evaluation and ability to modify the positive which determines correct alignment or malalignment of the orthosis. Dependence on the experience of the individual handling the case is obvious.

In view of the principles involved, it is frequently necessary to cut the cast into individual segments which need to be modified and reassembled in a corrected position. Any malalignment needs to be corrected prior to actual fabrication and fitting of the orthosis. This type of fabrication process is primarily necessary for ischial weight-bearing components and lacers made of plastic or molded leather.

FABRICATION OF ORTHOSIS WITH THE AID OF MECHANICAL JIGS

Such a method is used after evaluation of the impaired limb and projection of a horizontal, traced outline.

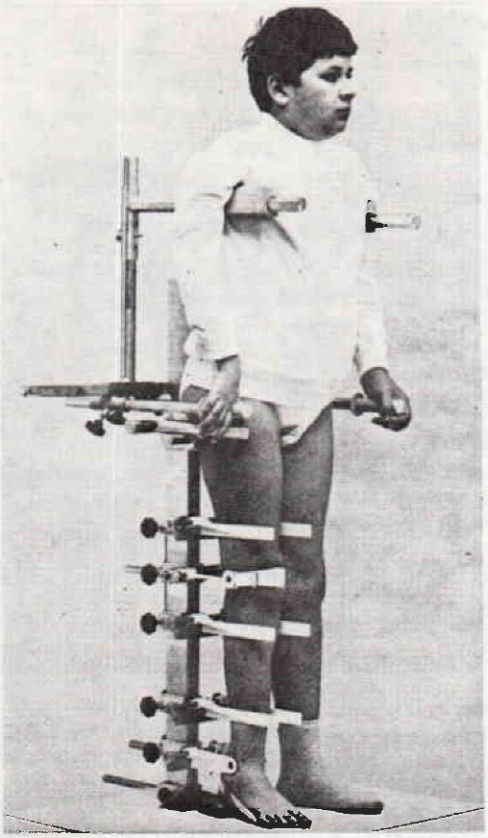
KLENZAK SYSTEM



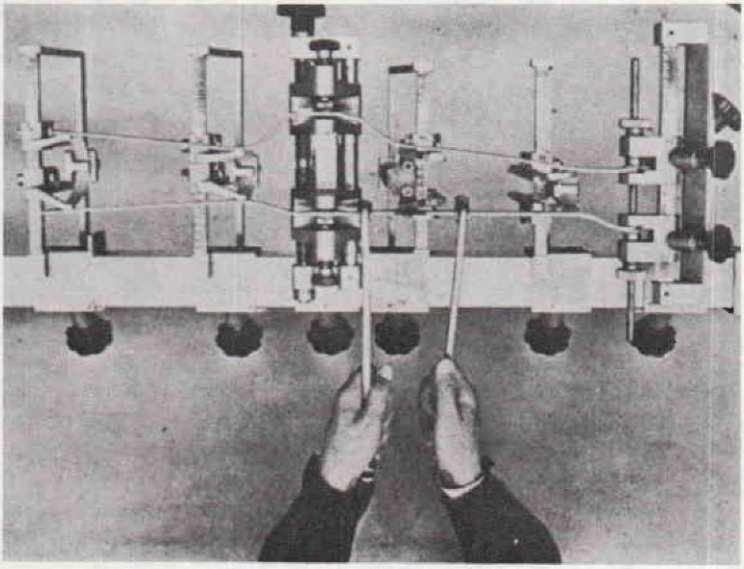
We learned about this technique in Europe in 1952 after publication of Volume I of the Orthopedic Appliance Atlas. This excellent book illustrates an American method of the Pope Foundation system, Klenzak, on Pages 406-414. A frontal tracing of a lower limb is placed on a working table, that can be adjusted in the frontal and horizontal planes. The parallel sides of the steel work table are attached solidly and function as a base for adjustable knee and ankle joint brackets. Fixation of knee and ankle joints make contouring of tubular bar stock possible by simply using an oxy-acetylene torch and bending irons. This method was used for central fabrication type of production according to measurements and corrected tracings taken at a clinic or office.

METHOD OF SCALLAS AND PASSERINI

Another method based on vertical projection utilizing a measuring and horizontal work jig which can be pivoted was developed by Scallas and Passerini in 1968. This Italian system has been published repeatedly.



The vertical jig is used for obtaining measurements. The horizontal assemb-



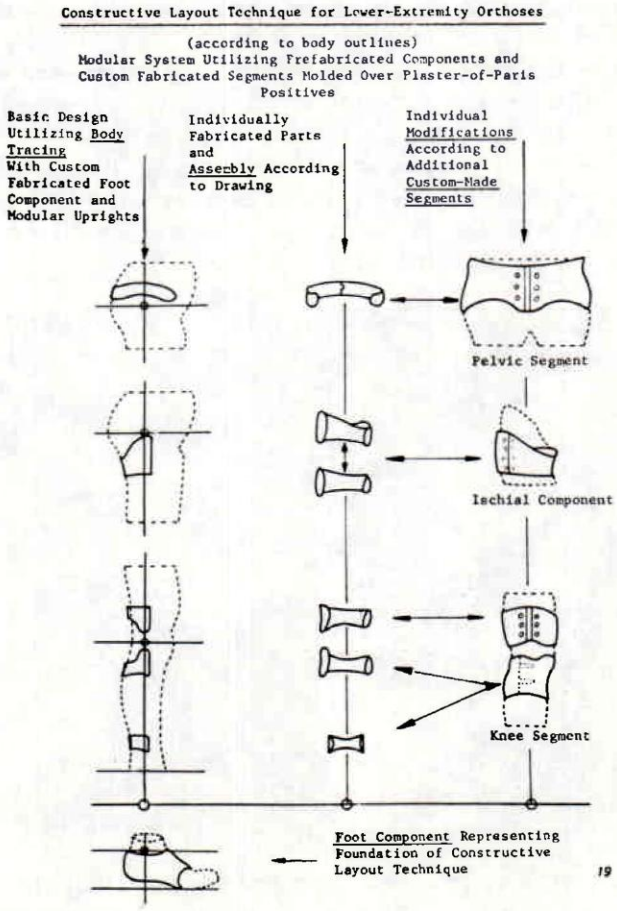
ly jig is provided with a turning fixture. The measuring device permits record-

ing of longitudinal measurements such as the level of the ischium and ankle. The exact placement of foot control and the various bands can also be registered. Each measurement is recorded on a special chart.

Longitudinal and M-L measurements are fundamental data required for the alignment of the orthosis, and are transferred to the assembly jig. This assembly unit consists of a rectangular frame with adjustable brackets for fixation of the AK and BK uprights was well as depth and width indicators for correct location of the bands. Bending irons are used to make bars and bands conform to the established measurements. After completion of alignment, the bands and bars are welded while in the jig.

THE CONSTRUCTIVE ORTHOTIC FABRICATION TECHNIQUE

This method was developed by me in 1952 and 1953, and is based on earlier experience established in Germany. Constructive orthotic fabrication is based on technical drawings, evaluations of x-rays, bony landmarks, contours, and "body measurement tables" of the proportional sciences.



Plaster-of-Paris molds are utilized in conjunction with the before-mentioned

information obtained. However, it is only necessary to case "extremity sections" that require special attention.

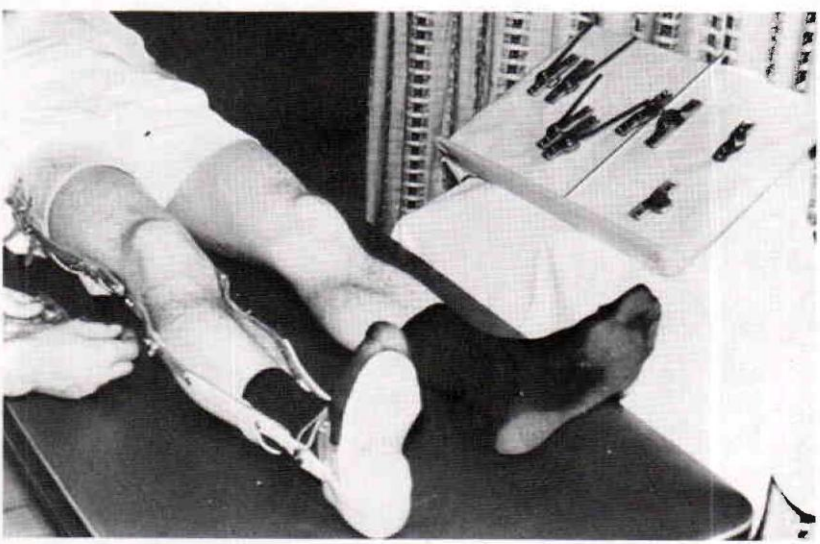
Why such segmentation? Malignment or malfit always results in malfunction. Therefore, prior to reaching a conclusion, it should be mandatory to first evaluate the overall condition, then to examine carefully each body segment individually.

The "constructive" lay up and fabrication method for lower-limb orthoses is a method utilizing the modular system, with application of prefabricated components such as uprights and only some segments which need custom fabrication.

The need to obtain a plaster mold for the entire extremity, which at times is most difficult, is no longer required in most cases. All that is needed usually are tracings projecting frontal, sagittal, and horizontal views. Foundation of the constructive orthotic lay up technique is the foot control component which needs to be fashioned over a plaster mold in every case. Additional plaster molds are required if corrections are desired, or anatomical pathologic circumstances need to be met.

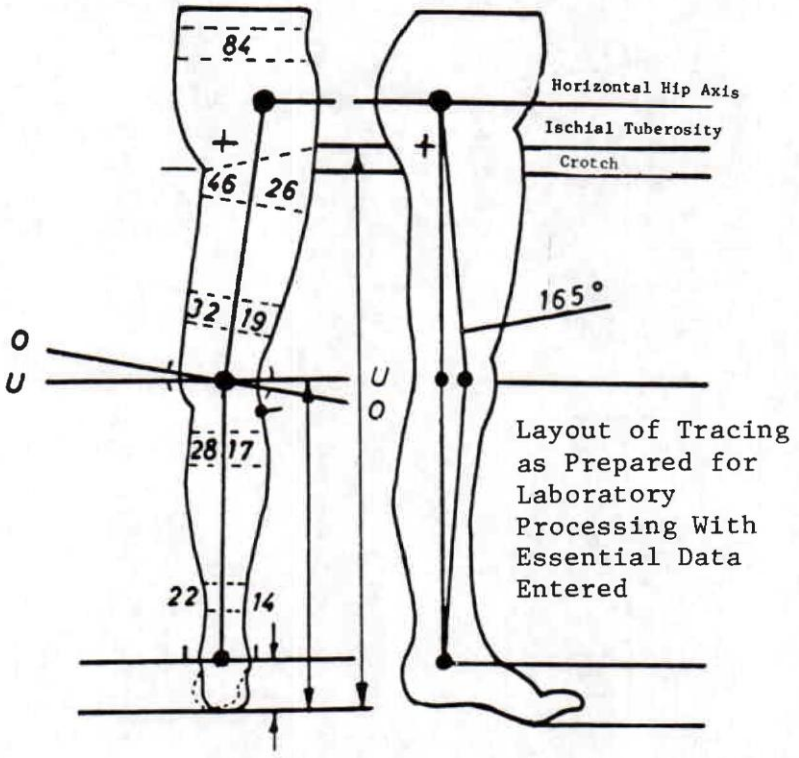
An additional advantage for my system came about with introduction of interchangeable joints, such as the one developed by Mr. John in Hanover and manufactured by Otto Bock. These joints are standardized, and offer great variety of technical variations such as free motion, polycentric alignment, drop lock, Swiss lock, etc.

Considering all of the components to be utilized has its beginning at the time of measuring the patient. This constructive method, which has proved most effective in hundreds of cases, can be considered rational if one interprets the term "ratio" with "sensible."

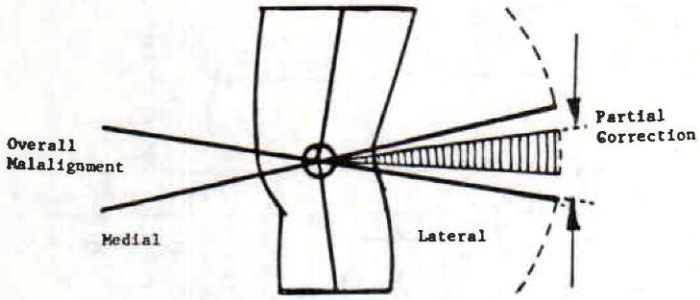


A horizontal examining table is used in drawing frontal sagittal, and horizontal view of the extremity. Accuracy in the vertical projection is assured by using a scriber holding the pencil. Anatomical landmarks and individual

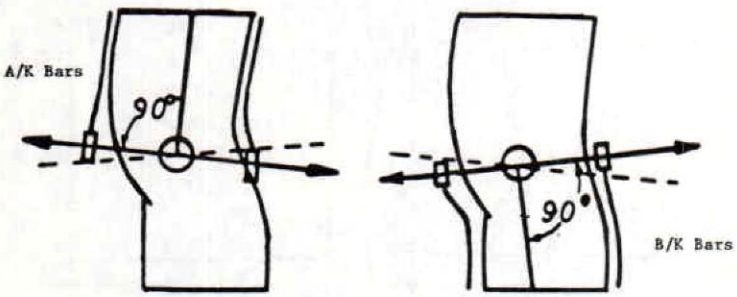
measurements such as circumferences and positional angles are entered on the drawing. Special attention is given to heel height and the forefoot section.



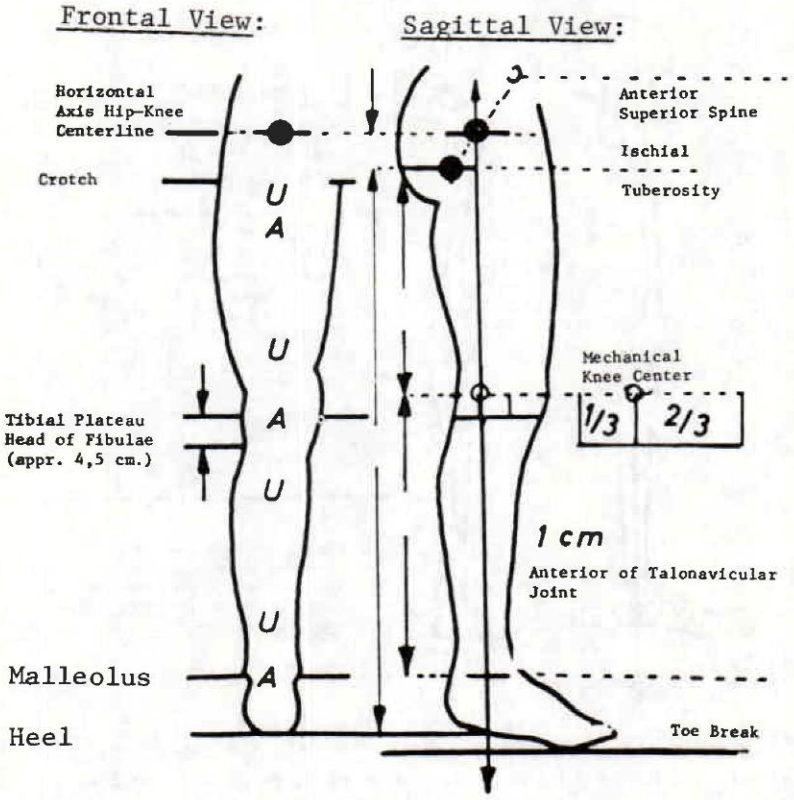
The body outline will next be transformed into a technical drawing. The skeletal alignment, or better, the pathological deviations, can be corrected or improved through therapeutic and precise mechanical exercises providing that no secondary findings such as contractures or other complications are present.



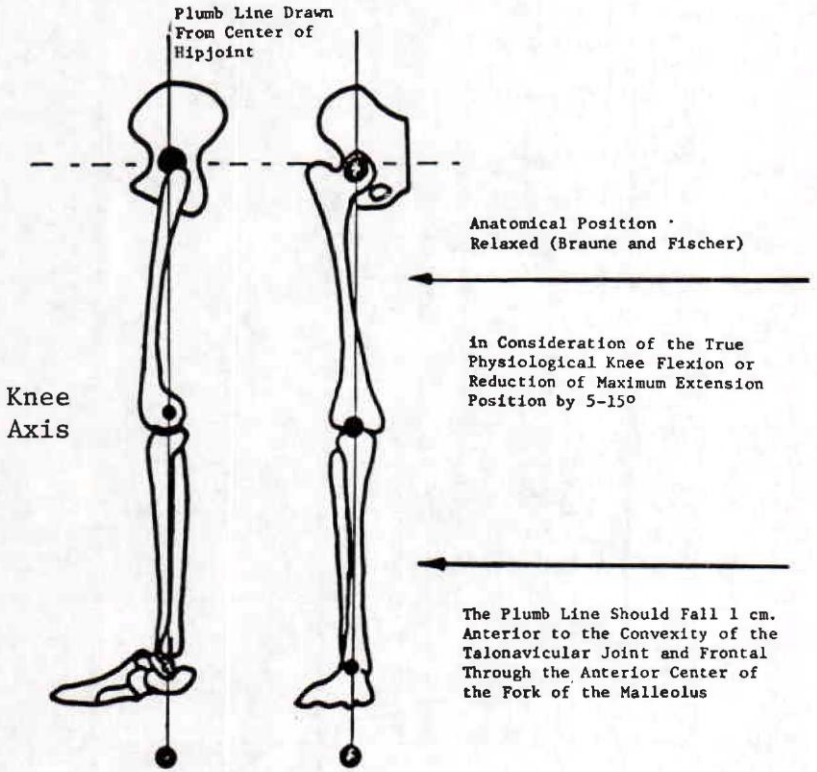
Example: Knock-Knee Angle



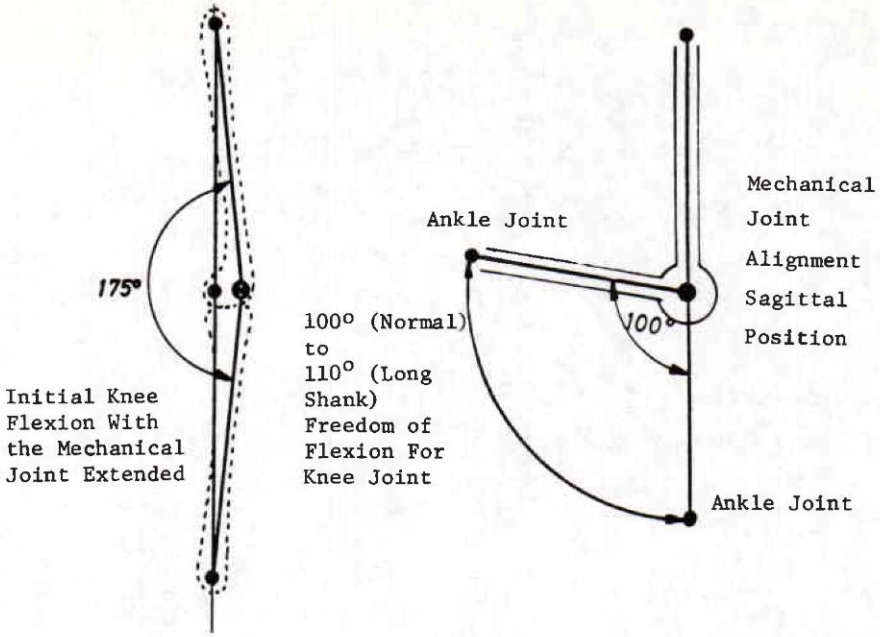
Most orthotists do not have radiological equipment at their disposal and are forced to depend on clinical examination in an attempt to reconstruct normal anatomical conditions. For that reason, it is that only exact technical drawings along with plaster molds, selected joints, and uprights will be processed in the laboratory. All of this information is controlled by a technical evaluation.



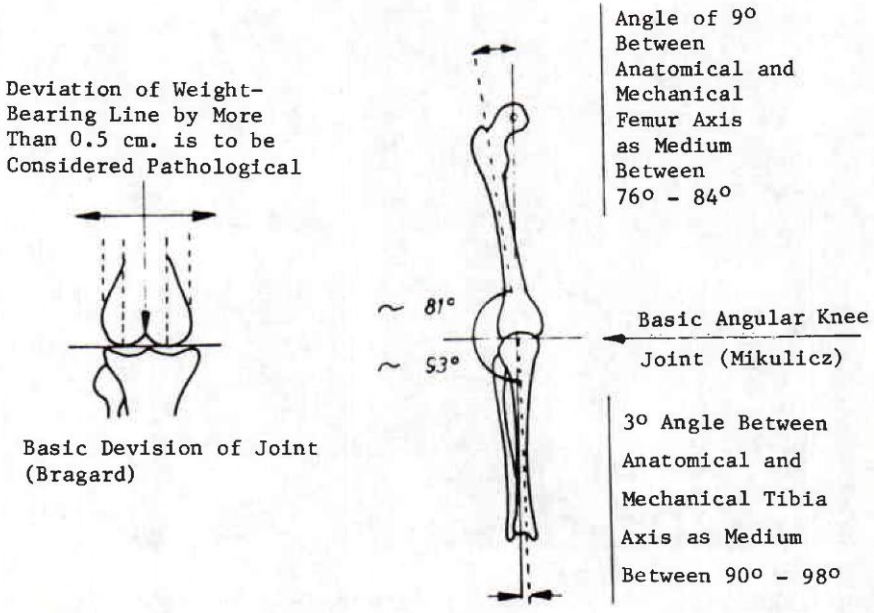
Anatomical reference points of importance are the horizontal hip axis, exact location of the ischial tuberosity, the knee and ankle joint, and location of the fibula. Additional points of reference are circumferences, longitudinal measurements, and M-L dimensions.

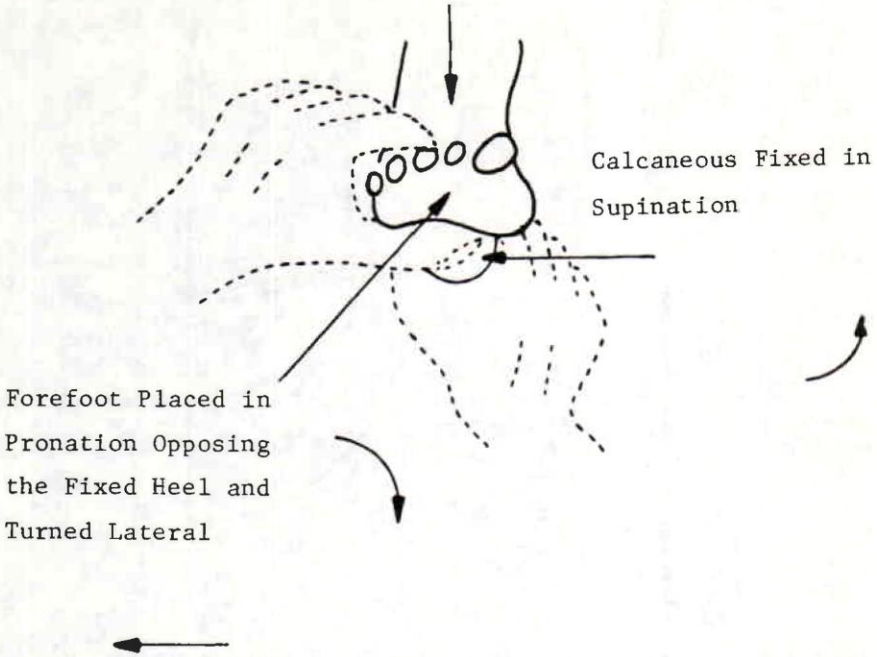


The orientation line in the sagittal view for a +/- deviation is projected from anterior to the femoral head to the mechanical point of knee rotation and a position 1 cm anterior to the convexity of the talonavicular joint. Anteriorly this line extends through the knee joint to the center of the malleolal fork. This is accompolished under consideration of the true physiological knee flexion. (Reducing 15° from complete knee extension under tension to a relaxed anatomical position according to "Braune and Fisher."(This individual physiological knee flexion also provides a comparison to the assumed skeletal position when a tracing is being projected.

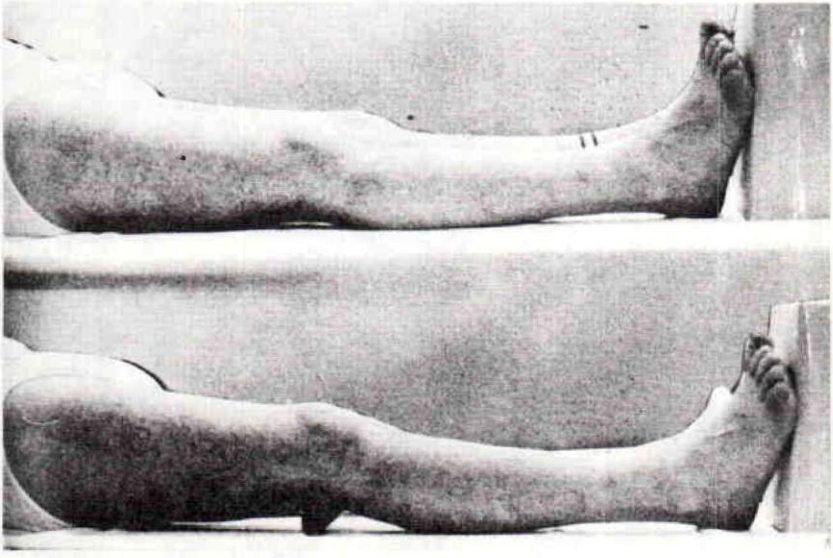


Founded on this physiological knee flexion, one can observe that the flexion angle of the orthosis consisting of 165° will actually result in an extended position. In addition, the orthosis will provide for a range of flexion and extension of 100°-110° accommodating the need for sitting comfort (average BK legth). Determination of the knee axis horizontally is based on the tibial plateau as well as the anatomical and mechanical function of the knee joint.



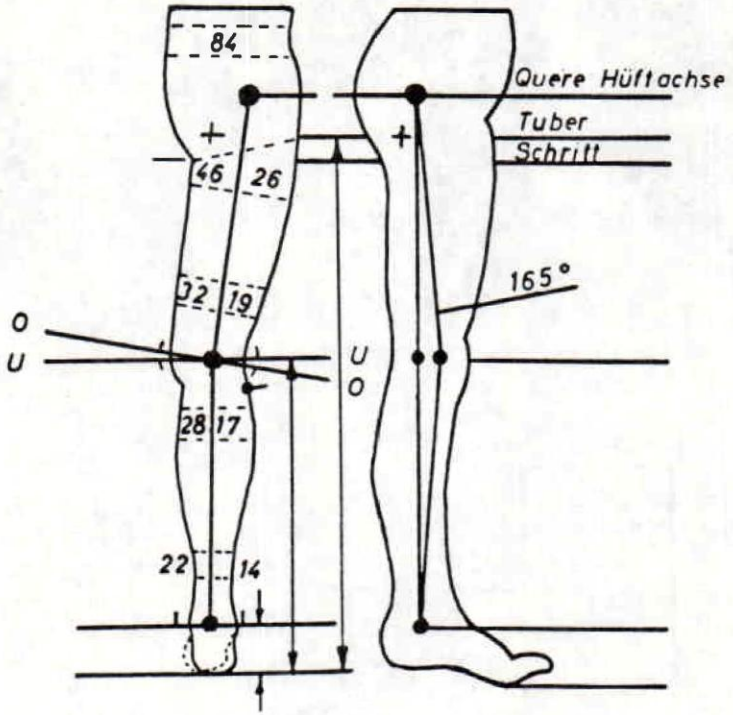


Thorough examination of the foot is required in order to achieve a functional and, if desired, correcting position. One must check the range of motion (pronation, supination, abduction, adduction, and rotation) prior to taking a mold or tracing of the foot portion. Deviations of importance need to be recorded. A foot support for the side not involved should be considered as essential if no leg length discrepancy is present.



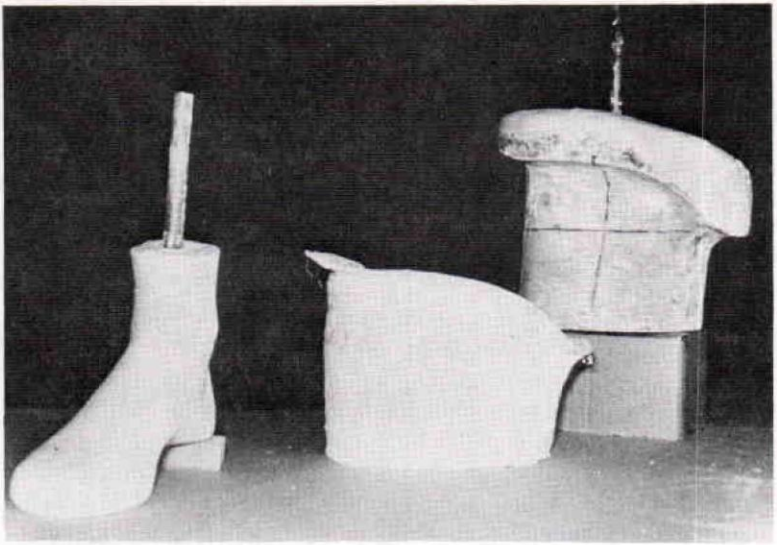
Particular attention should be given to atrophied soft portions of the extremity while taking the tracing. Soft tissue displacement can easily cover

recurvatum of flexion contractures present. Considerable experience and knowledge is required in order to recognize and correct such problems.

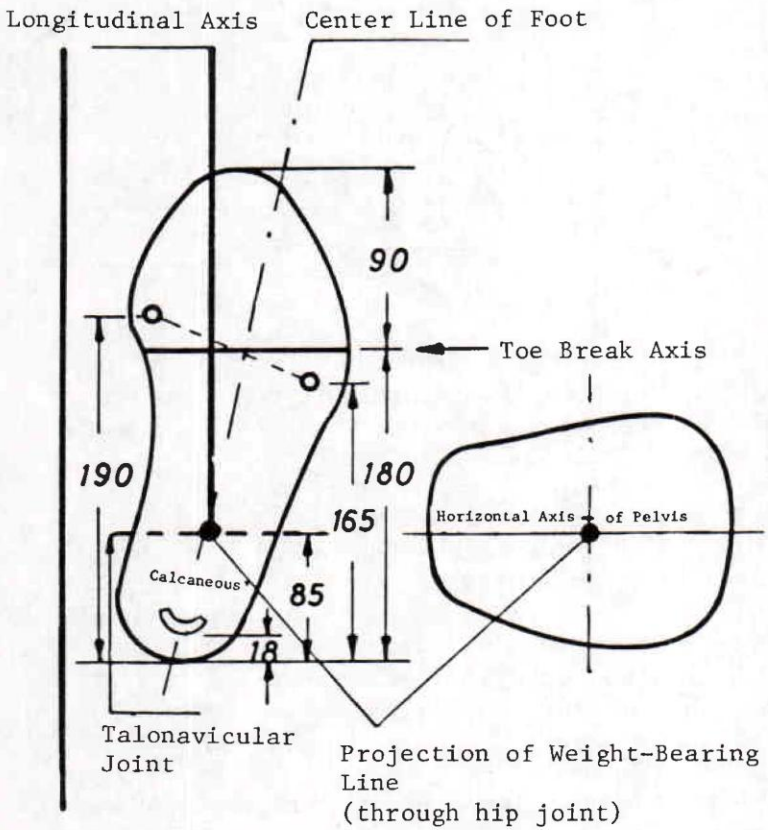


Essential information which should be listed on the tracing:

(1) Extremity outline for contouring of upright.
(2) Tibial plateau (exact position).
(3) Head of Fibula (center of head).
(4) Location of knee axis (compromising location).
(5) Distance of floor to knee axis (inclusive heel).
(6) Angular evaluation of Genu Varum, valgum, flexion angle, etc., as projected in anterior and lateral views.
(7) Intended corrections according to radiographic studies.
(8) Distance from floor to crotch.
(9) Distance from floor to ischial tuberosity.
(10) Position of ischial tuberosity (sagittal and frontal).
(11) Circumferences.
(12) M-L dimensions.
(13) Other information as obtained from body proportion analysis charts.



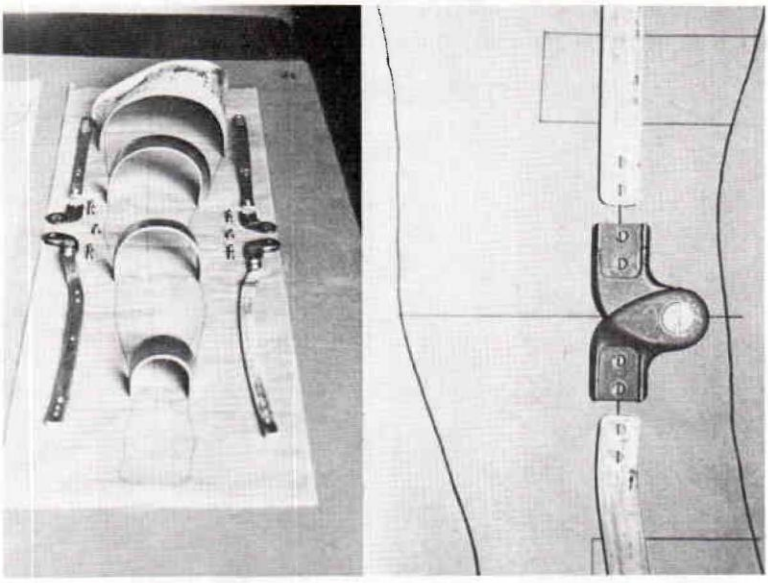
Plaster-of-Paris molds are utilized only when custom contouring is essential.



Of greatest importance is the position of the foot which requires correction in most cases.

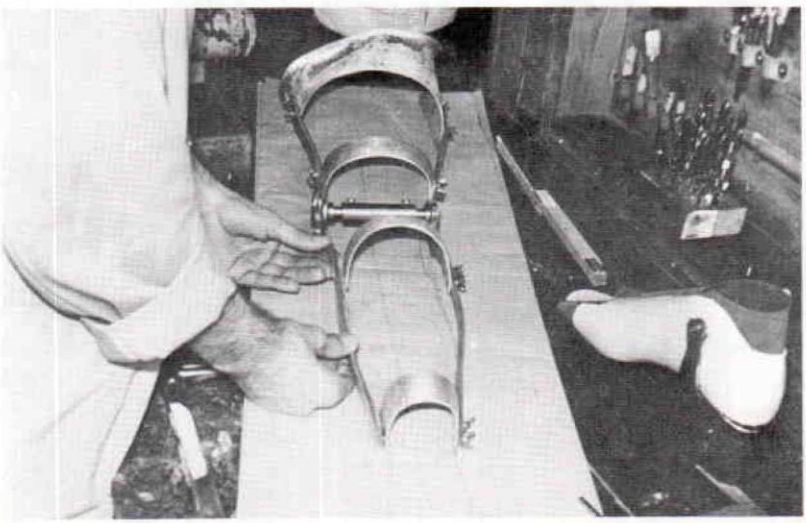
Birds' eye view are used for projection of the foot component which will also aid in identifying the congruity of axial mechanic joint alignment.

The longitudinal axis of the foot control component should always remain parallel to the mid-sagittal line and the mechanical toe break line which is located in an angle of 90° to this reference line.



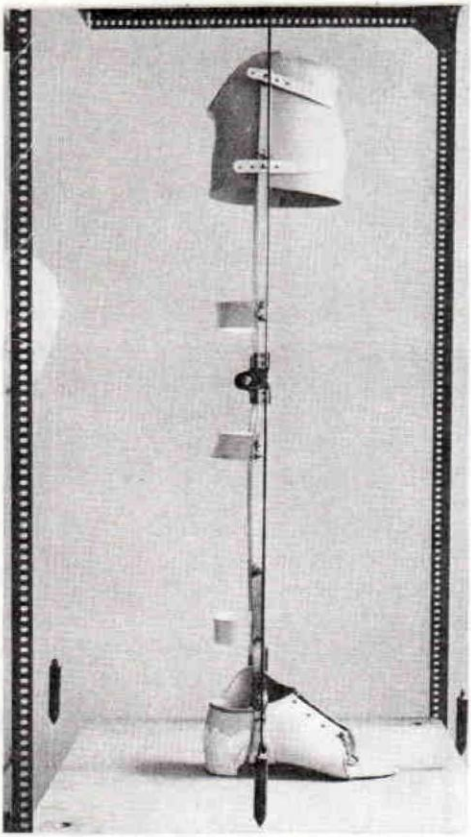
The orthotist can now select the mechanical components for fabrication of the orthosis.

Particular attention should once again be given to the mechanical joint alignment since it is easy to be misled by the cosmetic contouring of prefabricated bars and misinterpret the true, functional location of the polycentric joint.

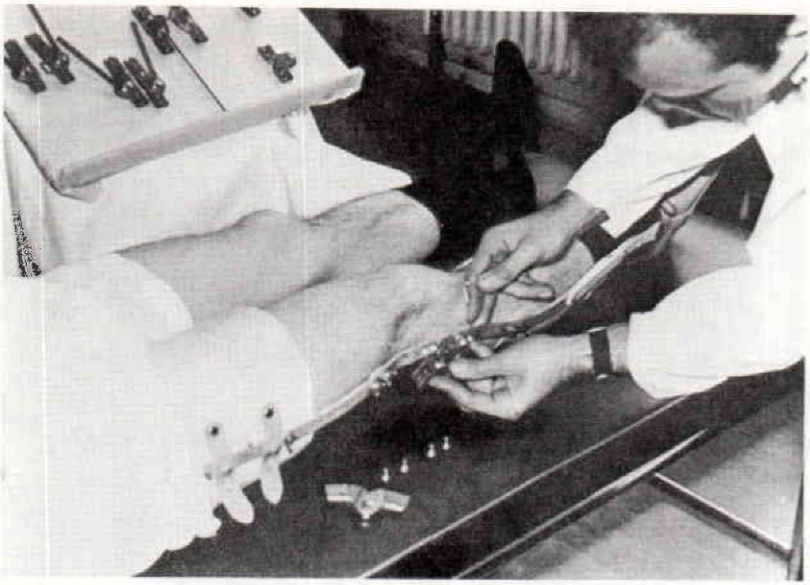


Assembly of the component is done with the aid of spacers at the knee and

ankle joint. The bars are contoured with bending irons. All parts are temporarily fastened with wing-nut screws permitting easy adjustment at the time of fitting. Permanent fastening and finishing are carried out later.



The orthosis undergoes a thorough check-out by the orthotist comparing the technical data with the actual laboratory product. Deviations will result in return of the device for correction prior to any fitting attempts. Patients are not to be used as guinea pigs and an orthosis has to be as precise as the information provided to the laboratory. Application of such a rigid system provides us with information leading directly to possible mistakes making the constructive layout procedure a most precise time-saving and, with it, rational approach.



Fitting of the orthosis to the patient should in essence consist of no more than minor alignment adjustments and possibly the exchange of joint segments. Functional fittings with weight-bearing should never be performed without having the exact heel height established.

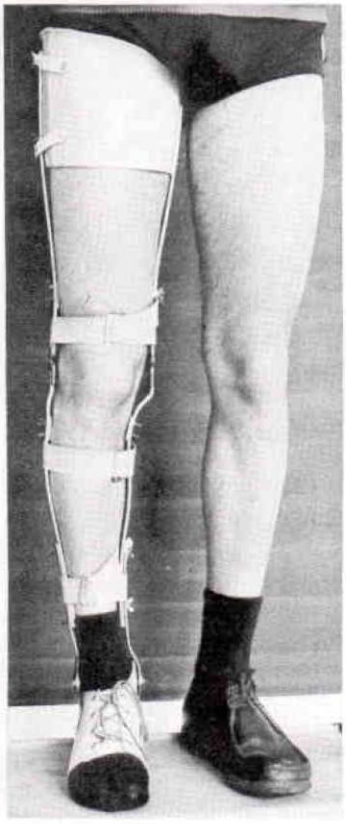
The contour and position of the foot component are greatest in importance since an ignoring of this principle results in considerable changes at higher locations. Attempts to correct those problems above the foot component are utopian experiments. It would also have no meaning to speak about millimeter precision of polycentric joint alignment at the knee or the individual influence on joint function at ankle or hip joint. Finally, one should postpone subjective thoughts and concentrate on technical principles easily recognized. Sufficient time is always left to meet individual requirements.

CONCLUSION

Taking into consideration all of the currently known orthotic systems and their easily identified pro's and con's—if one bothers to make a scientific evaluation—speaking for myself, I must state that one should rather utilize a system as discussed and not a "measuring machine." Utilization of tracings, technical and anatomical evaluations, plus selected bony impressions for preparation of the layout make it possible to engage shop supportive personnel of various qualifications for any given detail to be performed.

The final outcome of an orthosis will no longer be influenced by the work force available. Function of an orthosis (fixation, correction, and support) is depending on its exact alignment. The design must guarantee individual influences on skeletal conditions (the bony structure) as well as muscular and ligamental functions. The use of proper incorporation of mechanical joints is in relation to anatomical function of greatest importance. Alignment and joint evaluation should not be guided by the empiric feeling of a patient but based on accurate preliminary planning.

It is for this reason that I am speaking of a "constructive design" technique. After all, I think it to be better to use one of the four techniques mentioned or at least a system rather than to be an individualist without any formal approach. We, as orthotists, are also human and should attempt to eliminate outdated guess work through technical perfection.



Guide to Understanding Medical Terminology

Understanding medical terminology is as difficult as understanding Greek for many people. This comparison is quite valid because many of the basic medical terms stem from the Greek or Latin language. Added to these basic terms are one or more letters before the word (prefixes) or after the word (suffixes) which either alter or enhance the meaning. The following pages are organized into sections of suffixes, prefixes and then stem or root words. Lengthy medical terms can often be understood by breaking them down into their roots and affixes, as is shown in the article. This will help your reading understanding of the words, but proper pronunciation can come only through conversational use. The majority of these terms can be found in a standard dictionary, which will provide the syllabic breakdowns, inflections, and pronunciations when needed.

The following is from the Northwestern University Prosthetic-Orthotic Center's instructional material prepared by Mr. Charles Fryer for prosthetists, orthotists, and rehabilitation personnel. The compilation is based on the premise that the technical vocabulary of the prosthetist-orthotist deals most frequently with the neuromusculoskeletal and articular systems of the human body.

Michael Quigley, C.P.O.

PREFIXES

PREFIXES: One or more letters or syllables combined at the beginning of a word to further explain or add to meaning. An example of a true prefix is "INTER." As the forepart of a word it expresses the meaning "between." INTERnational means "BETWEEN"nations. The prefix "INTRA" means "WITHIN." Consequently, the word INTRAmuscular means "WITHIN" a muscle.

Listed below are some of the more commonly used prefixes as related to the musculo-skeletal and articular systems of the body.

PREFIXES OF NEGATIVE MEANING

PREFIX	MEANING	EXAMPLE	
A-	WITHOUT	Atrophy	WITHOUT nutrition
AN-	WITHOUT	ANesthesia	WITHOUT sensation
IM-	NOT	IMobility	NOT movable
IN-	NOT	INfirm	NOT strong

PREFIXES INDICATING LOCATION AND DIRECTION

PREFIX	MEANING	EXAMPLE	
AB-	FROM, AWAY FROM	ABduction	To lead AWAY FROM
AD-	TO, NEAR, TOWARD	ADduction	To lead TOWARD
CIRCUM-	AROUND	CIRCUMduction	To lead AROUND
PERI-	AROUND	PERIosteum	AROUND a bone
SYM-	WITH, TOGETHER	SYMphysis	A growing TOGETHER
SYN-	WITH, TOGETHER	SYNostosis	A FUSION of two bones
DIA-, DI-	APART FROM	DIAstasis	SEPARATION of two bones
DIS-	APART FROM	DISarticulation	SEPARATION of a joint
EX-	OUT FROM	EXostosis	OUT FROM a bone
EXO-	OUTSIDE	EXOskeleton	OUTSIDE skeleton
EXTRA-	OUTSIDE	EXTRAarticular	OUTSIDE a joint
IM-	IN	IMpacted	Packed IN
IN-	IN	INjection	Thrown IN
INTRA-	WITHIN	INTRAmedullary	WITHIN the medullary cavity
ENDO-	WITHIN	ENDOskeleton	INNER skeleton
EPI-	UPON	EPIcondyle	An eminence UPON a Condyle
INFRA-	UNDER	INFRApatellar	UNDER the knee cap
SUB-	UNDER	SUBalar	UNDER the ankle
INTER-	BETWEEN	INTERtrochanteric	BETWEEN the trochanters
PARA-	BESIDE	PARAvertebral	BESIDE the spine
RE-	BACKWARD	REcurvatum	Curved BACKWARD
SUPRA-	ABOVE	SUPRAspinous	ABOVE the spine

PREFIXES INDICATING NUMBERS AND MAGNITUDES

PREFIX	MEANING	EXAMPLE	
UNI-	ONE	UNIarticular	Pertaining to ONE joint
MONO-	ONE	MONOplegia	Paralysis of but ONE part
BI-	TWO	BIceps	TWO heads
TRI-	THREE	TRIceps	THREE heads
QUADRI-	FOUR	QUADRIceps	FOUR heads
HEMI-	HALF	HEMIplegia	HALF paralyzed
HYPER-	TOO MANY, EXCESSIVE	HYPERactivity	EXCESSIVE activity
HYPO-	LESS (DEFICIENT)	HYPOplastic	DEFICIENT development

MISCELLANEOUS PREFIXES

PREFIX	MEANING	EXAMPLE	
IDIO-	ONE'S OWN	IDIOpathic	SELF originated disease
ISO-	EQUAL	ISOmetric	EQUAL distance
MACRO-	GREAT	MACROcephalic	LARGE head
HYDRO-	WATER	HYDROcephalic	WATER head
MICRO-	SMALL	MICROcephalic	SMALL head
MORPHO-	FORM	MORPHOlogy	The study of biological FORMS
NEO-	NEW	NEOplasm	NEW formation (growth)
ORTHO-	STRAIGHT	ORTHOpaedist	Originally one who STRAIGHTENED the deformities of children
PAN-	ALL	PANtalar fusion	Afusion of ALL the joints to which the talus contributes
PSEUDO-	FALSE	PSEUDOarthrosis	FALSE joint

SUFFIXES

SUFFIXES: A suffix consists of one or more letters or syllables combined at the end of a word to further explain or add to meaning. For example, in the word "FLEXIBLE" the suffix "IBLE" indicates "ABILITY or CAPACITY." Therefore, "FLEXIBLE" MEANS "CAPABLE" of being bent or flexed. In the word "ORTHOPAEDIST" the ending, or suffix, "IST" means "ONE WHO PRACTICES." So an "ORTHOPAEDIST" "ONE WHO PRACTICES ORTHOPAEDICS."

Listed below are some commonly used suffixes and their meanings.

SUFFIXES

SUFFIX	EXAMPLE	MEANING
ABILITY and CAPACITY		
-ABLE	viABLE	CAPABLE of life
-IBLE	irreversIBLE	Not CAPABLE of recovery
RELATED TO		
-AL	crurAL	RELATED to the leg or thigh
-AC	CardiAC	RELATED to the heart
-IC	osteopathIC	PERTAINING to any disease of bone
OF THAT KIND		
-EAL	ostEAL	OF THE NATURE or quality of bone: bony
-EOUS	ossEOUS	OF THE NATURE or quality of bone: bony
-OSE	adipOSE	Of a fat-like QUALITY
-OUS	cartilaginOUS	OF THE NATURE of cartilage
CONDITION (usually morbid)		
-IA	malacIA	the CONDITION of being pathologically soft
-ID	flaccID	The CONDITION of being flail
-ISM	mitISM	The CONDITION of being mute
-OSIS	necrOSIS	The CONDITION of dying
-Y	apoplexY	The CONDITION of having suffered a stroke
ONE WHO PRACTICES OR AGENT		
-IST	orthopaedIST	ONE WHO PRACTICES orthopaedics
-OR	donOR	ONE WHO DONATES
-ER	examinER	ONE WHO EXAMINES
QUALITY		
-ITY	porosITY	The QUALITY of being porous
DIMINUTIVE		
-CLE	tuberCLE	A LITTLE knot or knob
-CULE	moleCULE	A SMALL mass
ACT IN A CERTAIN WAY		
-IZE	osteotomIZE	To PERFORM an osteotomy
TUMOR (NEW GROWTH)		
-OMA	osteOMA	A bone TUMOR

MISCELLANEOUS SUFFIXES

SUFFIX	MEANING	EXAMPLE	
-ALGIA	PAIN	near ALGIA	Nerve PAIN
-DYNIA	PAIN	coccygoDYNIA	Coccygeal PAIN
-ITIS	INFLAMMATION	arthrITIS	inflammation of a joint

-LOGY	STUDY OF	pathoLOGY	The STUDY OF disease
-PATHY	DISEASE	neuroPATHY	A DISEASE of the nervous system
-PLASIA	FORMATION	achondroPLASIA	Without FORMATION of cartilage
-PTOSIS	A FALLING	gastroPTOSIS	A FALLING of the stomach
-STASIS	POSITION	metaSTASIS	Change of POSITION
-THERAPY	TREATMENT	radioTHERAPY	TREATMENT by radium
-OTOMY	TO CUT INTO	osteOTOMY	TO CUT INTO a bone
-ECTOMY	TO CUT OUT	patellECTOMY	TO CUT OUT the patella

STEMS OR ROOTS

STEMS OR ROOTS: A stem is the basic component of any medical word. The prime requirement for understanding medical terminology is to be able to recognize stems. A stem or root has been defined as The part of a word which remain after the prefixes and suffixes have been removed."

The stem in the word "INTEROSSEOUS" is "OSSE," which means "BONE." If we modify the stem "OSSE" by recalling the meaning of the prefix "INTER" and the suffix "ous" we can interpret the word "INTEROSSEOUS" to mean: "OF THE KIND WHICH IS BETWEEN BONES." The "INTEROSSEOUS MEMBRANE," then, is "THE KIND OF MEMBRANE WHICH IS BETWEEN BONES." Some of the stems or roots which are used fairly commonly in the

BONES

1. OS, OSSIS	=	Bone	13. CNEMIS	=	Shin
2. OSTEON	=	Bone	14. PES, PED	=	Fott
3. CHONDROS	=	Cartilage	15. POUS, POD	=	Foot
4. SPONDYLOS	=	Vertebra	16. POLLEX	=	Thumb
5. COSTA	=	Rib	17. HALLUX	=	Great toe
6. CONDYLOS	=	Knuckle	18. DIGITUS	=	Finger
7.THOCHANTER	=	Pulley	19. DACTYLOS	=	Finger
8. PATELLA	=	Small Dish	20. BRACHIUM	=	Arm
9. FIBULA	=	Brace	21. CUBITUS	=	Forearm
10. TIBIA	=	Shin	22. FEMUR	=	Thigh
11. ILIUM	=	Flank, hip	23. CRUS, CRUR	=	Leg
12. ISCHION	=	Hip	24. CHEIR, CHIR, CHIRO	=	Hand

ROOTS

OS, OSSIS, OSTEON, OSTEO, OSTE, OST, OSSE = Bone
CARTILAGO, CHONDROS = Cartilage

WORD		ANALYSIS
OSTEO/LOGY	-	Bone + the science or study of
OSTEO/TOMY	-	Bone + to cut
OSTEO/POR/OSIS	-	Bone+ passage + the morbid condition of
OSTEO/MALACIA	-	Bone + a softening
OSTEO/GEN/ESIS	-	Bone + to produce
OSTEO/CLASIS	-	Bone + breaking
OSTEO/MYEL/ITIS	-	Bone + marrow + inflammation
OSTE/OMA	-	Bone + tumor
PERI/OST/EUM	-	Around + bone
PERI/OST/ITIS	-	Around + bone + inflammation
OSTEO/NECROSIS	-	Bone + death + condition of being
EPI/PHY/SIS	-	Upon + growth + condition of being
EPI/PHYSIO/DESIS	-	Epiphysis + a binding
EPI/PHYSIO/LYSIS	-	Epiphysis + loosening
EPI/PHYS/ITIS	-	Epiphysis + imflammation
EX/OST/OSIS	-	Out of + bone + morbid condition
EXO/SKELETAL	-	Outside + skeleton (crustacean)
ENDO/SKELETAL	-	Inside + skeleton (vertebrate)

OSTE/AL	-	Bony: osseous
OSSI/CLE	-	Any small bone
OSTE/ITIS	-	Bone + inflammation
OSTEO/CHONDR/ITIS	-	Bone + cartilage + inflammation
OSTEO/CHARTILAGIN/OUS	-	Bone + cartilage + of that kind
OSTEO/DYS/TROPHY	-	Bone + bad + nutrition
OSTEO/CHONDR/OMA	-	Bone + cartilage + tumor

JOINTS (ROOTS)

1. ARTHRON	=	Joint
2. ARTICULUS	=	Joint
3. GLENE	=	Socket
4. ACETABULUM	=	Vinegar saucer
5. COXAL JOINT	=	Hip joint
6. GENU	=	Knee
7. TALUS	=	Ankle
8. ASTRAGALOS	=	Ankle
9. CARPUS	=	Wrist

WORD		ANALYSIS
ARTHRO/LOGY	-	Joint + the science or study of
ARTHRO/PATHY	-	Joint + disease
ARTHRO/DESIS	-	Joint + binding
ARTHR/ALGIA	-	Joint + pain
ARTHRO/GRYPOSIS	-	Joint + curved + morbid condition
ARTHR/ITIS	-	Joint + inflammation (traumatic pyogenic)
ARTHRO/CHONDR/ITIS	-	Joint + cartilage + inflammation
ARTHRO/PLASTY	-	Joint + to form
HYPER/TROPHIC ARTHRITIS	-	Over + nutrition + arthritis
OSTEO/ARTHR/ITIS	-	Bone + joint + inflammation
PERI/ARTHR/ITIS	-	Around + joint + inflammation
POLY/ARTICUL/AR	-	Many + joints
MONO/ARTICUL/AR	-	One + joint
INTRA/ARTICUL/AR	-	Within + a joint
BI/ARTICUL/AR	-	Two + joint
INTER/ARTICUL/AR	-	Between + joints
BI/AXIAL JOINT	-	Two + axes + joint
POLY/AXIAL JOINT	-	Many + axes + joint
UNI/AXIAL JOINT	-	One + axis + joint
SYN/ARTHR/OSIS	-	Together + joint + the condition of being
AMPHI/ARTHR/OSIS	-	On both sides + joint + the condition of being
DI/ARTHR/OSIS	-	Apart from + joint + the condition of being
TALO/CRURAL JOINT	-	Ankle + leg + joint
SUB/TALAR JOINT	-	Below + ankle + joint
SUB/ASTRAGALAR JOINT	-	Below + ankle + joint
GENU/RECURVATUM	-	Knee + a backward bending or curvature
TALI/PES EQUINUS	-	Ankle + foot + horse's hoof
TALI/PES CALCANEUS	-	Ankle + foot + heel
TALI/PES EQUINO/VARUS	-	Ankle + foot + horse's hoof + bent inward
TALI/PES CALCANEO/VALGUS	-	Ankle + foot + heel + bent outward
GENU VARUS	-	Knee + bent ourward (bow leg)
GENUVALGUS	-	Knee + bent inward (knock knee)
COXA VARA	-	Angle between neck and shaft of femur (less than 125°-130°)
COXA VALGA	-	Angle between neck and shaft of femur (greater than 125°-130°)
PSEUD/ARTHR/OSIS	-	False + joint + condition of being

MUSCLES (ROOTS)

1. MYO, MY	=	Muscle			
2. MUSCULUS	=	Muscle	13. LONGUS	=	Long
3. TENO, TENONTO	=	Tendon	14. MAGNUS	=	Great
4. Bi, TRI, QUADRICEPS	=	2, 3, 4 Headed	15. MAJOR	=	Greater
5. COMMUNIS	=	Common	16. MAXIMUS	=	Greatest
6. EXTRENUS	=	Outer	17. MEDIUS	=	Middle
7. GRACILIS	=	Slender	18. MINIMUS	=	Smallest
8. OBLIQUUS	=	Oblique	19. MINOR	=	Smaller
9. PROFUNDUS	=	Deep	20. VASTUS	=	Huge
10. QUADRATUS	=	Square	21. RHOMBOIDEUS	=	Diamond Shaped
11. RECTUS	=	Straight	22.SUBLIMIS	=	Topmost
12. BREVIS	=	Short	23.TERES	=	Round (cylindrical)
			24. TRANSVERSUS	=	Crosswise

WORD		ANALYSIS
MYO/LOGY	-	Muscle + the science or study of
MY/ALGIA	-	Muscle + pain
MY/ASTHENIA	-	Muscle + weakness
MY/A/TONIA	-	Muscle + loss of + tone
MYOS/ITIS	-	Muscle + inflammation
MYO/CARDIUM	-	Muscle + heart
MYO/HYPER/TROPHIA	-	Muslce + over + nutrition
MY/OMA	-	Muscle + tumor
MYO/NECRO/SIS	-	Muscle + death
MY/OPATHY	-	Muscle + disease
MY/A/TROPHY	-	Muscle + without + nutrition
MYO/PLASTIC	-	Muscle + to form
MYO/SCLEROSIS	-	Muscle + hardening
MYO/TONIA	-	Muscle + tone
A/MYO/TONIA	-	Without + muscle + tone
PSEUDO/HYPER/TROPHIC	-	False + over + nutrition of a muscle caused by
MUSCULAR DYSTROPHY	-	Faulty + nutrition
MYO/CARD/ITIS	-	Muscle + softening
MYO/MALACIA	-	MuscleMuscle + heart + inflammation
TENO/DESIS	-	Tendoln + binding
TENO/SYNOV/ITIS	-	Tendon + synovia + inflammation
TENO/DYNIA	-	Tendon + pain
TEN/OTOMY	-	Tendon + to cut
TENO/MY/OTOMY	-	Tendon + muscle + to cut
TEN/ECTOMY	-	Tendon + to cut out

NERVES (ROOTS)

1. NEURON	=	Nerve
2. NEURO, NEUR	=	Relationship to a nerve or nerves, or to the nervous system
3. MYEL	=	The spinal cord (the marrow" of the spinal cord)
4. MYELO	=	Relationship to the spinal cord or marrow
5. PLEGIA	=	Paralysis
6. PARESIS	=	Weakness
7. CEREBRUM	=	Brain
8. ENCEPHALON	=	Brain
9. MENINGES	=	The three membranes which envelop the brain and spinal cord (arachnoid, pia, dura mater)

WORDS		ANALYSIS
POLIO/MYEL/ITIS	-	Gray (matter) + spinal cord + inflammation
QUADRI/PLEGIA	-	Four + paralysis
HEMI/PARESIS	-	Half + weakness
TRANSVERSE MYEL/ITIS	-	Across + spinal cord + inflammation
SYRINGO/MYELIA	-	Pipe or cavity + spinal cord

MENING/ITIS	-	Inflammation + meninges
ENCEPHAL/ITIS	-	Brain + inflammation
NEURO/LOGY	-	Nerve + the study of
NEURO/PATHY	-	Any nervous disease
MYELO/GRAPHY	-	Spinal cord + to write
NEUR/OMA	-	Nerve + tumor
INTRA/CEREBRAL HEMAT/OMA	-	Blood + tumor + within + brain
EXTRA/DURAL HEMAT/OMA	-	Blood + tumor + outside + dural membrane
MENINGI/OMA	-	Meninges + tumor
INTRA/MEDULLARY	-	Within + marrow (spinal cord or bone)
SPONDYL/ITIS	-	Vertebra + inflammation
SPONDYLO/LISTHESIS	-	Vertebra + to slip

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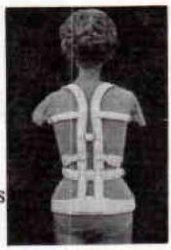

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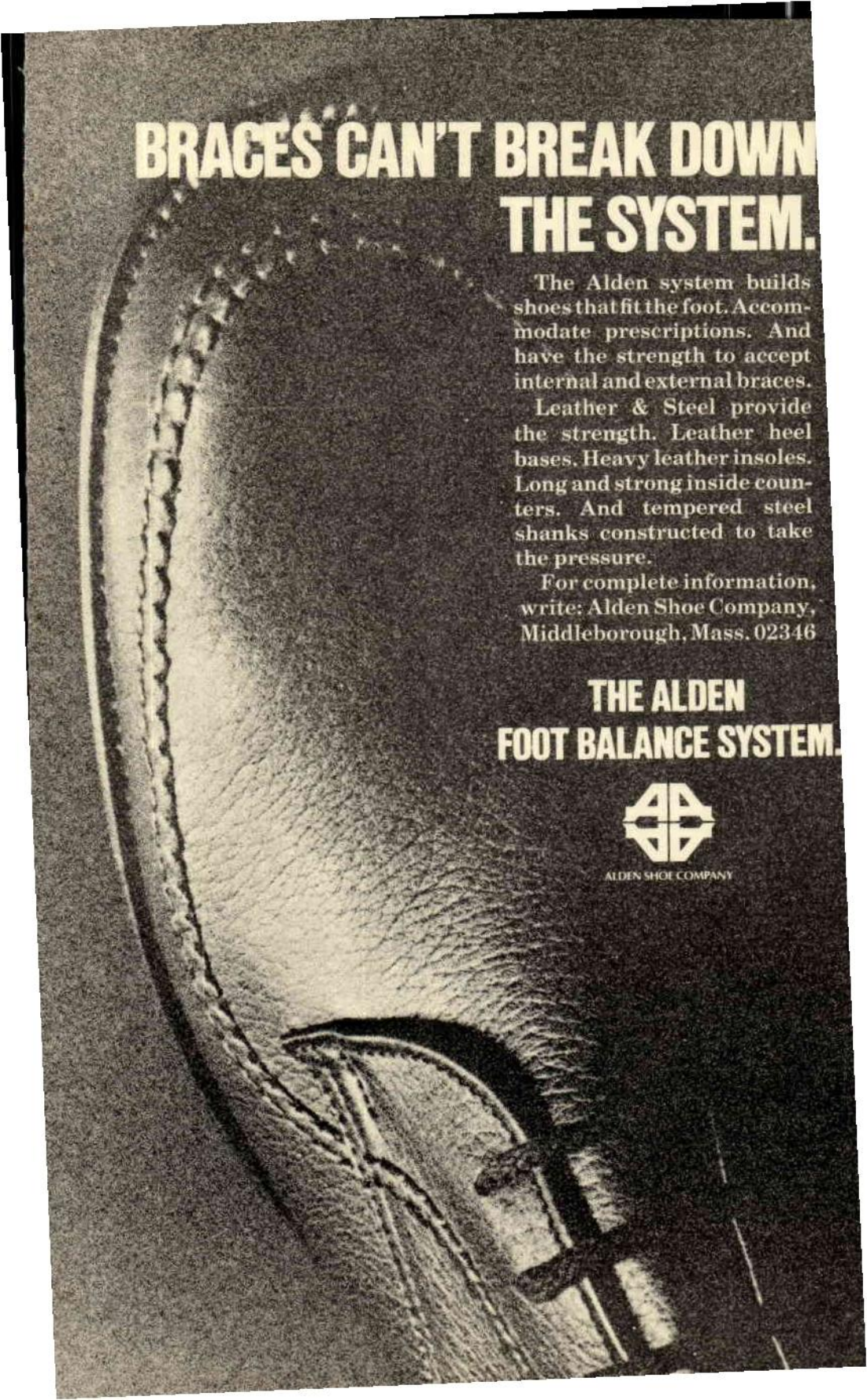
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