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Volume 33
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Orthotics and Prosthetics

Journal of the American Orthotic and Prosthetic Association

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Orthotics and Prosthetics

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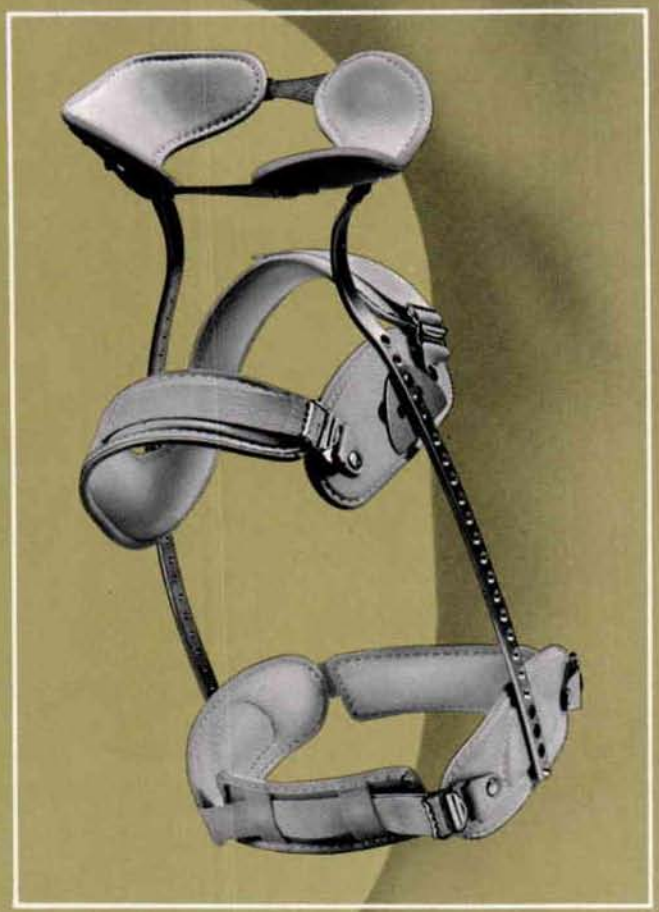

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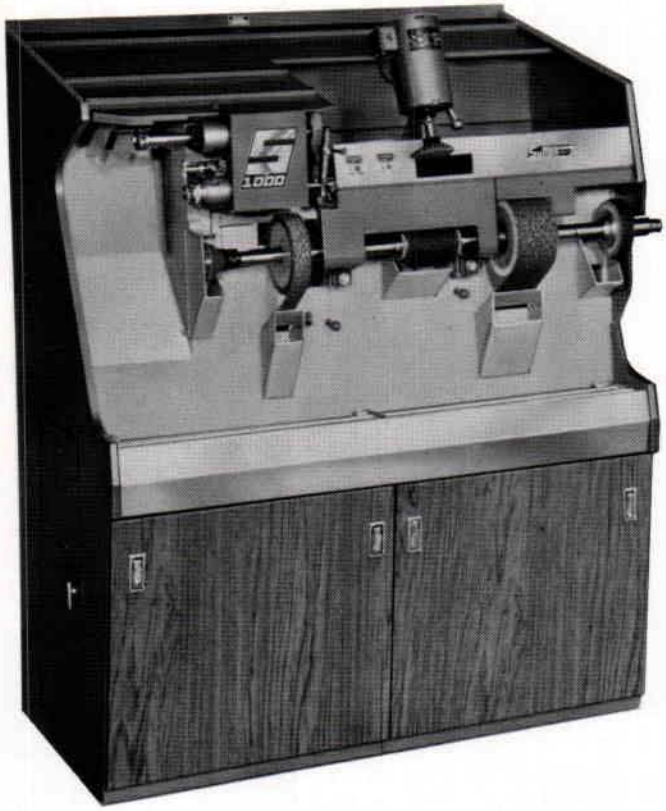

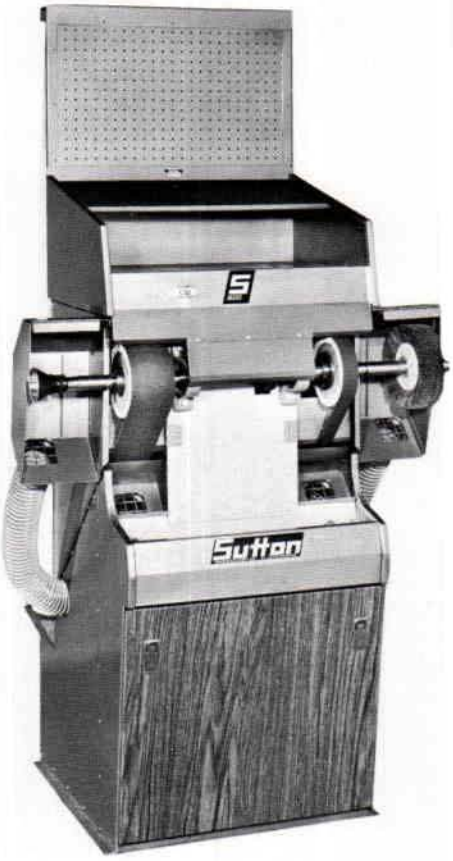

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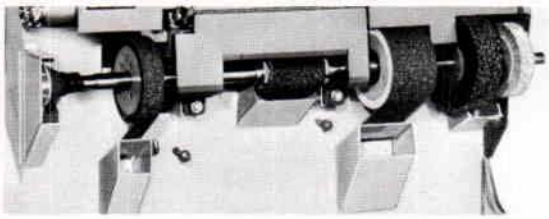

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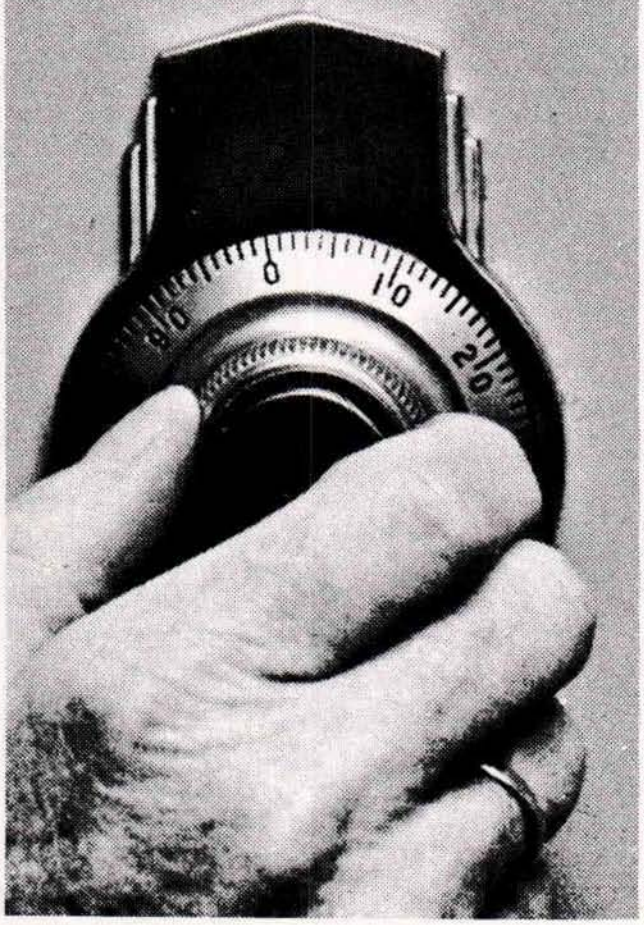

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Kingsley Mfg. Co. has the jump on Spring fashion with a sneak preview of the stylish new Ladies 3½" Hi Style Foot.

Hi Style unlocks the intriguing world of fashion shoes and allows ladies to step forward with a refreshing flair.

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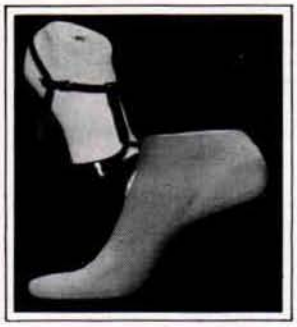

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Commentary

I want to take this opportunity to thank my fellow editorial board members in electing me as chairman for this term and Alvin Miulenburg, my predecessor, for doing such a fine job over the past several years. Evidence of this can be found in the Dec. 78 journal, An Assessment. At our national meeting in San Diego I met with the other board members for the first time and it was encouraging because until then all our correspondence has been by mail or phone. I have found that my responsibilities are quite general because as you know the cohesive force behind our journal has been our editor, A. Bennett Wilson Jr. Being in the east along with our editor, national office and other board members I hope to be seeing more of the energies that go into the publication of *Orthotics and Prosthetics*.

The Journal is our vehicle for growth as a profession and only by continued input can we channel your efforts towards this goal. In the future I will be inviting individuals to make their contribution in the form of the editorial. Input can also be increased by more letters to the editor, Ben Wilson has assured me he would very much like to hear more response in this area.

A section dedicated to facility techniques can also lend itself to increased input by dealing with short articles not requiring the scientific research that go into the feature articles. There is abundant knowledge out there just waiting to be tapped.

Writing an article or report takes time, effort and dedication and this is exactly what we are here for to help you in this endeavor. Commitment to professionalism is the goal of our Journal and only by your energies can this be realized.

Micheal N. Pecorella


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Orthotics and Prosthetics, Vol. 33, No. 1, PP 3-10, March 1979

A New Ankle-Foot Orthosis Combining the Advantages of Metal and Plastics

ALAN S. BENSMAN, M.D.[1]
WALLACE W. LOSSING, C.O.[2]

Jointed Plastic Bracing (JPB), a new orthotic concept in the treatment of lower-limb paralysis or paresis, which combines the attributes of metal and plastic, using the preferred characteristics of both in a single orthosis has been developed.

The necessity of applying a lower-limb orthosis is determined by a number of factors and treated by use of a variety of orthotic designs. For the sake of brevity, this discussion will be limited to those diagnoses concerning the ankle. Historically and typically, problems about the ankle would have been treated by the application of an orthosis constructed of metal and leather. The bulk and weight of such an appliance stimulated a search for a better method. With the advent of thermoplastic materials new designs have been developed. Plastics, however, have not yielded a satisfactory joint, thus limiting mobility of the anatomical joint involved. In order to retain the flexibility of a metal joint, and also retain the light, cosmetic attributes of plastic, a wedding of the materials has been carried out. The union has resulted in a new and versatile approach for lower-limb orthotics. Jointed Plastic Bracing has now been applied to more than 50 patients during the past year with excellent results.

HISTORY

Orthoses, until recent years, used metal joints placed in a position to approximate the anatomical joints. These orthoses generally did permit improvement in mobility of the patient and, thereby, resulted in an increase of his activity level. However, in too many cases, to stabilize meant to immobilize and to mask incomplete correction. The metal orthosis provided a measure of security to the patient, and had a long life due to the types of materials used, and there are still some situations which can best be treated with the application of a metal orthosis. The obvious shortcomings of metal are poor cosmetic appearance and the weight involved, not to mention the difficulties in keeping that type of appliance clean.

The advent of plastics produced a much more acceptable orthosis. Plastics are far more adaptable for conforming to body shapes, and produce an orthosis more acceptable to the eye. Another exciting feature of plastics is the dramatic reduction in weight of an orthosis, since the amount of weight involved in treating a particular diagnosis can be cut from pounds to ounces in many cases. The result of this weight difference was frequently an equally dramatic increase in

the activity level of a patient. Frequently, the control of a paretic or paralyzed limb was considerably more refined by the application of a plastic orthosis. An added advantage realized in this area was the reduction of pressure problems caused by the application of a standard metal orthosis due to incomplete correction. Plastics, furthermore, are readily cleaned with mild soap and water.

Experience with plastics has happily proven that plastic orthoses can readily compete with metal in durability and life expectancy. There are actually fewer repairs due to breakage on a plastic orthosis in comparison to metal orthoses, and the replacement time appears to be about the same. The primary drawback to an orthosis constructed exclusively of plastic is the inability to allow mobility, i.e., joint function. Reduction in the amount of plastic applied around a particular joint is essentially the only means of increasing the mobility of that joint. Many "plastic joints" have been developed, but to date none has been proven adequate when incorporated into an actual orthosis.

METHODOLOGY

The inadequacies of the previously described orthoses led to a design that used "the best of both." The result is an orthosis fabricated primarily of plastic, but uses metal to provide the joint motions needed. In this way, light weight was sacrificed to obtain the desired joint function.

To illustrate the use of the new concept, consider the application of this type of orthosis to the diagnoses concerning the ankle joint. The more frequently encountered forms of paralysis or paresis for the ankle joint are generally categorized into:

1. foot drop—lack or loss of dorsiflexion only
2. lack or loss of plantarflexion
3. pes planus, valgus or varus.

Any or all of these specific problems can be controlled by an orthosis constructed solely of either metal or plastic. Selection of an orthosis that will not only provide the best control, but will also take into consideration individual factors unique to a particular patient will require a close analysis. Consideration in this analysis should include:

1. diagnosis
2. muscle(s) involved
3. patient's age, weight, functional, and activity level
4. cosmesis, and
5. contributing physical factors; for example, other non-functioning extremities.

The goal of this analysis is to determine the exact orthosis for this particular patient, and how to accomplish this goal with the least amount of "bracing" without sacrificing any possible functional gain.

In order to analyze the success or value of a given orthosis, the desired criteria of an orthosis must be examined:

1. improved mobility for increased independence
2. fit and control
3. safety
4. cosmesis
5. life span of the orthosis.

Normally, foot drop alone can be controlled with a posterior leaf ankle-foot orthosis (AFO) of plastic. However, if foot drop is complicated with pes planus, valgus or varus, a custom molded foot piece with medial-lateral ankle joints is beneficial. Either a spring dorsiflexion assist or a limited motion ankle joint with a posterior stop (Fig. 1) may be used here. The combination of a well-molded plastic foot cup, metal ankle joints and plastic calf cuff obtain a good correction, and the anatomical joint is controlled or free to function as desired.

In the instance of lack of plantarflexion, a reverse-spring loaded assist would

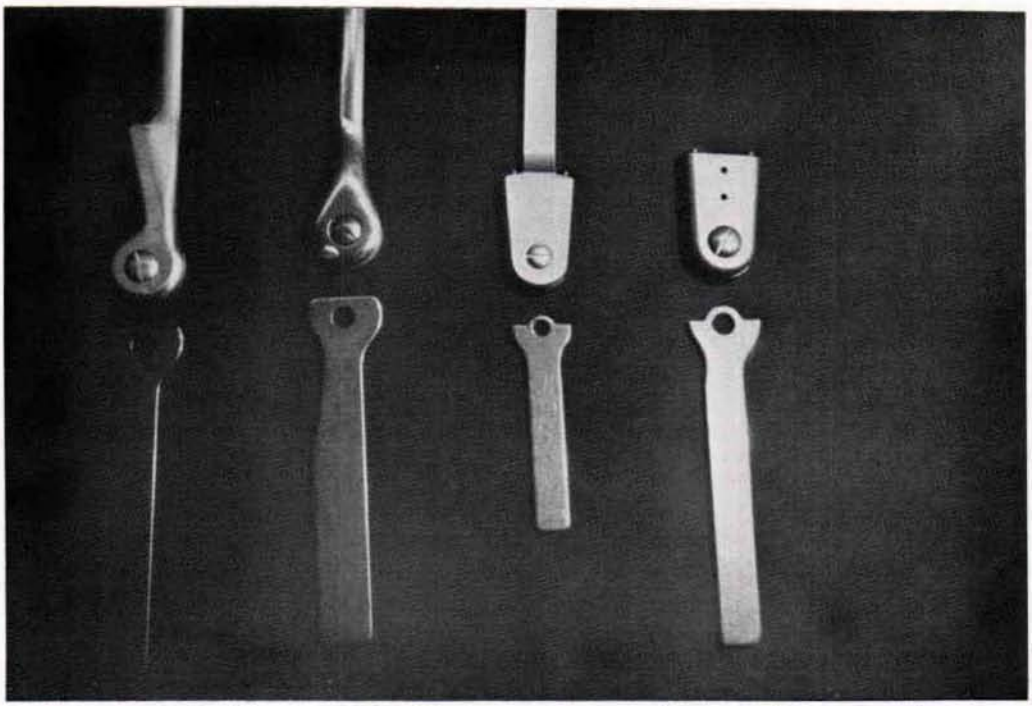

Fig. 1. Types of ankle joints. L to R: Dorsiflexion assist or reverse for plantarflexion assist; limited motion or free motion; bical; and another bical.

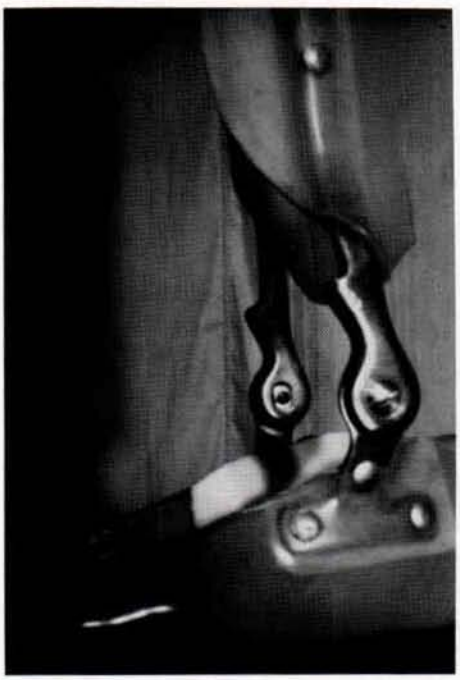

Fig. 2. Extension of calf piece.

be required in the ankle joint (Fig. 1). Again, custom molded plastic foot and calf pieces complete the orthosis.

In cases of either medial or lateral instability, an extension of the calf piece is made to come to a point just above the malleolus on the weaker side (Fig. 2).

FABRICATION PROCEDURES

The procedure for fabricating a Jointed Plastic Brace (JPB) combination orthosis is essentially the same as for an all plastic orthosis. A plaster cast is made of the patient's limb in the corrected position; from this is made a plaster model of the limb which is used in the actual fabrication of the orthosis (Figs. 3 and 4). The joints are applied to the plaster model, and positioned correctly before the plastic is drawn over the mold (Fig. 5).

Note that the joints and metal components are lined with ¼-in. thick Plastazote (Fig. 6) before the plastic is drawn

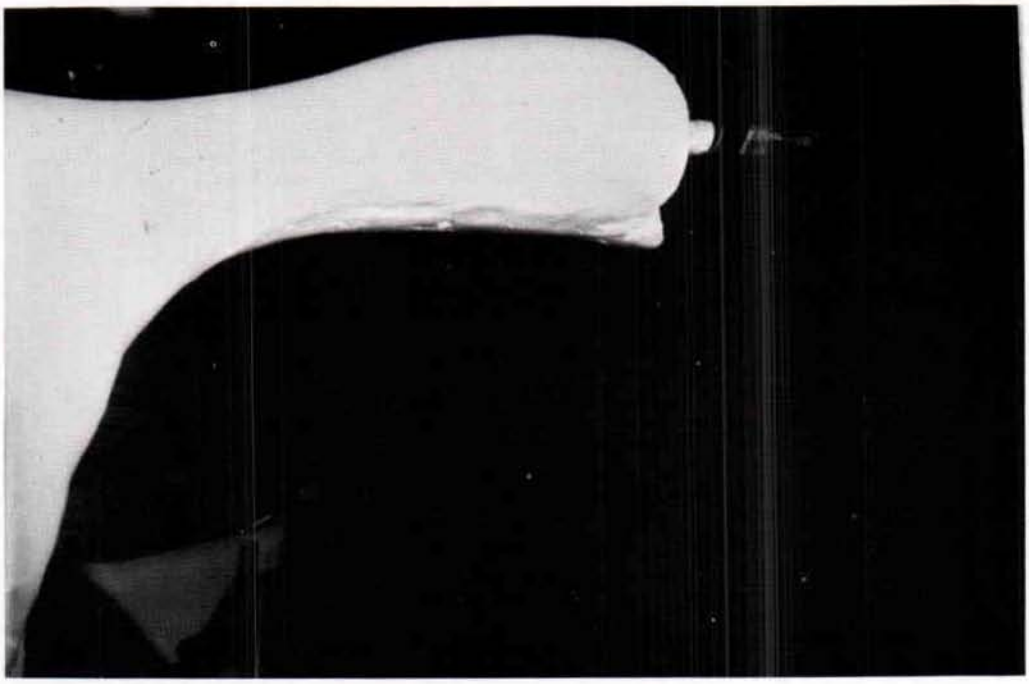

Fig. 3. Plaster model.

over the mold and vacuum applied (Fig. 7).

The application of the joints before forming by vacuum allows for a smooth union of the elements of the orthosis. The trimming of the plastic, and refining of the original product is again essentially the same as for an all-plastic orthosis. Two examples of completed Jointed Plastic Braces are shown in Figure 8.

ACCEPTANCE

To determine the impact of the new combination orthosis, a study was conducted to determine parental reaction to Jointed Plastic Bracing.

Questionnaires were prepared and sent to parents of twenty-seven children who had been fitted with a JPB since November, 1975. The two-page questionnaire consisted of demographic information, forced choice questions, and open ended queries; data on bracing and adjustments

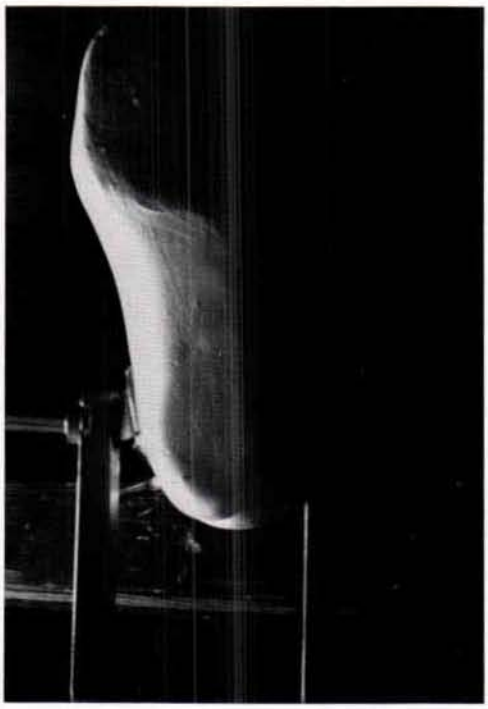

Fig. 4. Corrected alignment.

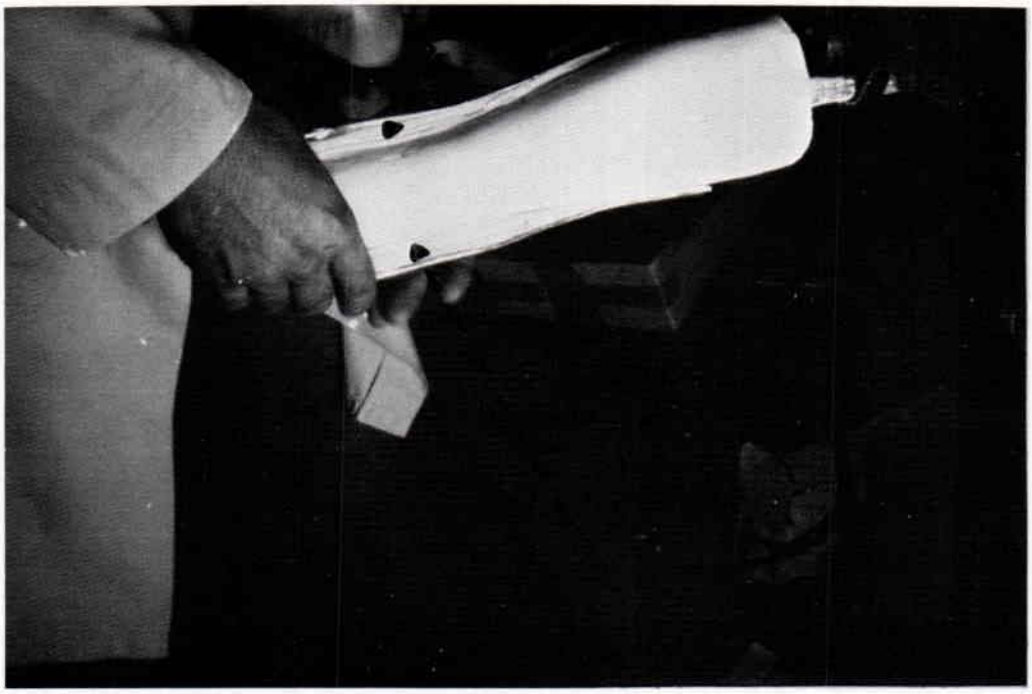

Fig. 5. Application of ankle joints to plaster model of patient's foot and shank.

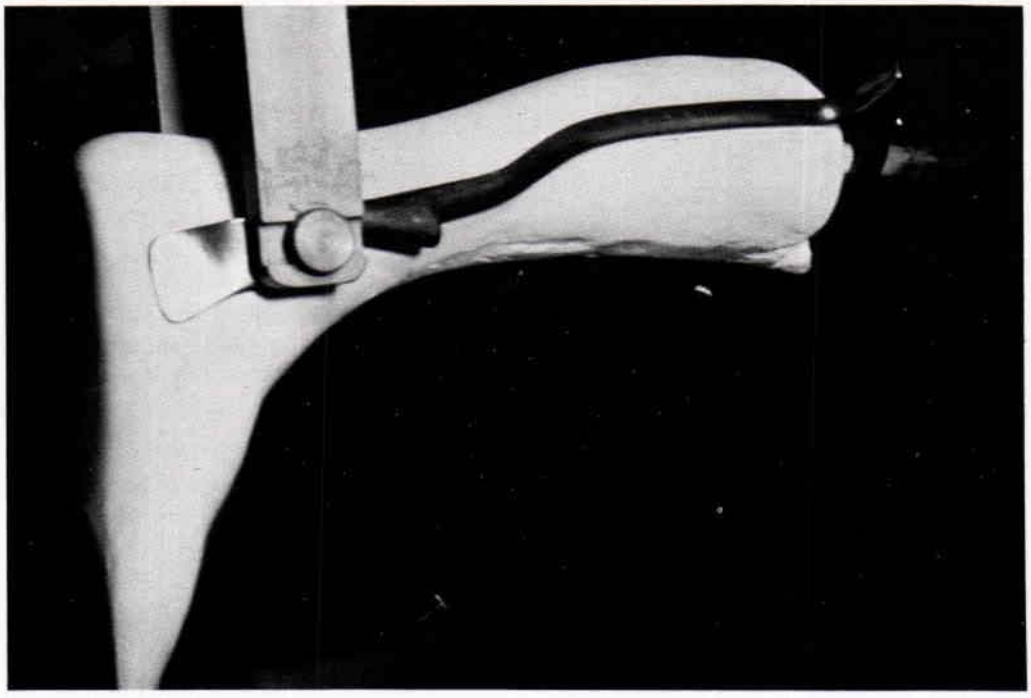

Fig. 6. Plastazote is used to fill space at joint.

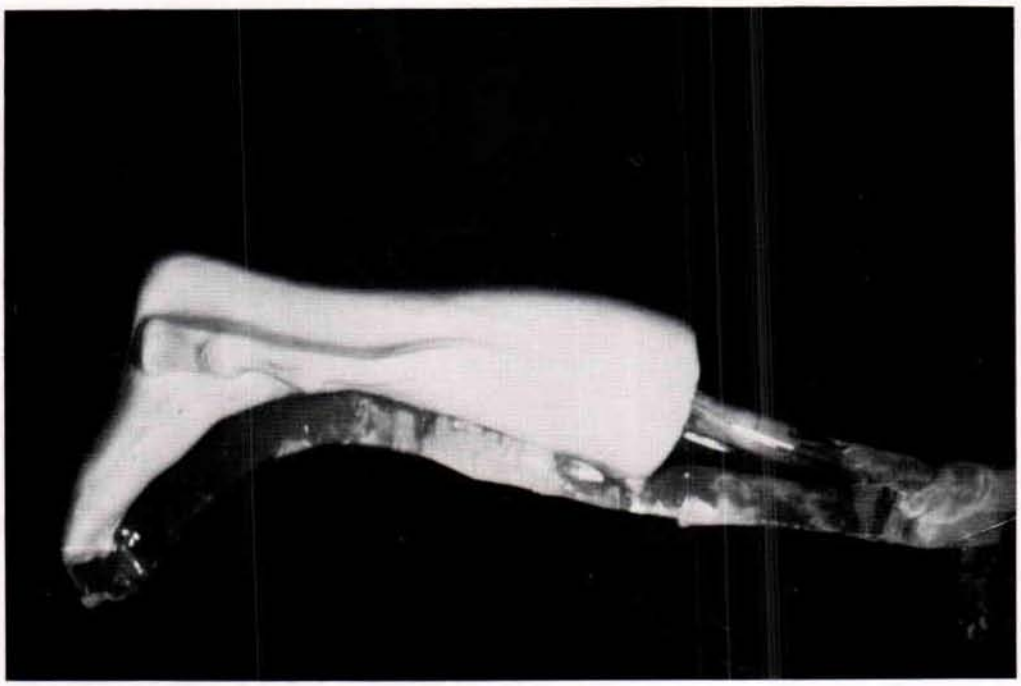

Fig. 7. Vacuum is used to form shape of plastic components.

were also gathered from patient files.

Nineteen completed questionnaires were returned for a 70 percent response rate; those nineteen served as a basis for the following analysis.

Demographically, by sex, the parents responding represented nine girls and ten boys. By age on last birthday the children in JPB in this study, the range spanned age one to thirteen with the average age at 5.94 years, the mean at 5.66 years, and the mode at 4 years.

By diagnosis the greatest percentage of children's handicaps resulted from cerebral palsy; the next greatest resulted from spina bifida (Table 1).

Diagnosis	*Percent*
Cerebral Palsy	37
Spina Bifida	26
Hemiparesis/spastic leg/ foot drop	21
No answer	16

Table 1.

Over half of the children had been fitted with bilateral Jointed Plastic Braces (58 percent). Three children wore Jointed Plastic Braces on their right lower limbs and five on the left only.

When parents were asked to compare Jointed Plastic Bracing to previous bracing, an overwhelming response was received preferring JPB over other bracing. Eighty-nine percent of the respondents felt JPB to be the best; one respondent only thought the previous braces to be better. On a comparison basis, 63 percent of the respondents perceive the JPB to be somewhat better to much better than previous bracing.

In terms of gait evaluation and in evaluating the child's walking with the Jointed Plastic Braces, 89 percent of the parents rated it fair or above. By comparison, in evaluating the child's walking without the JPB found 84 percent of the respondents listing it fair to very poor. An evaluation of rating the child's walking

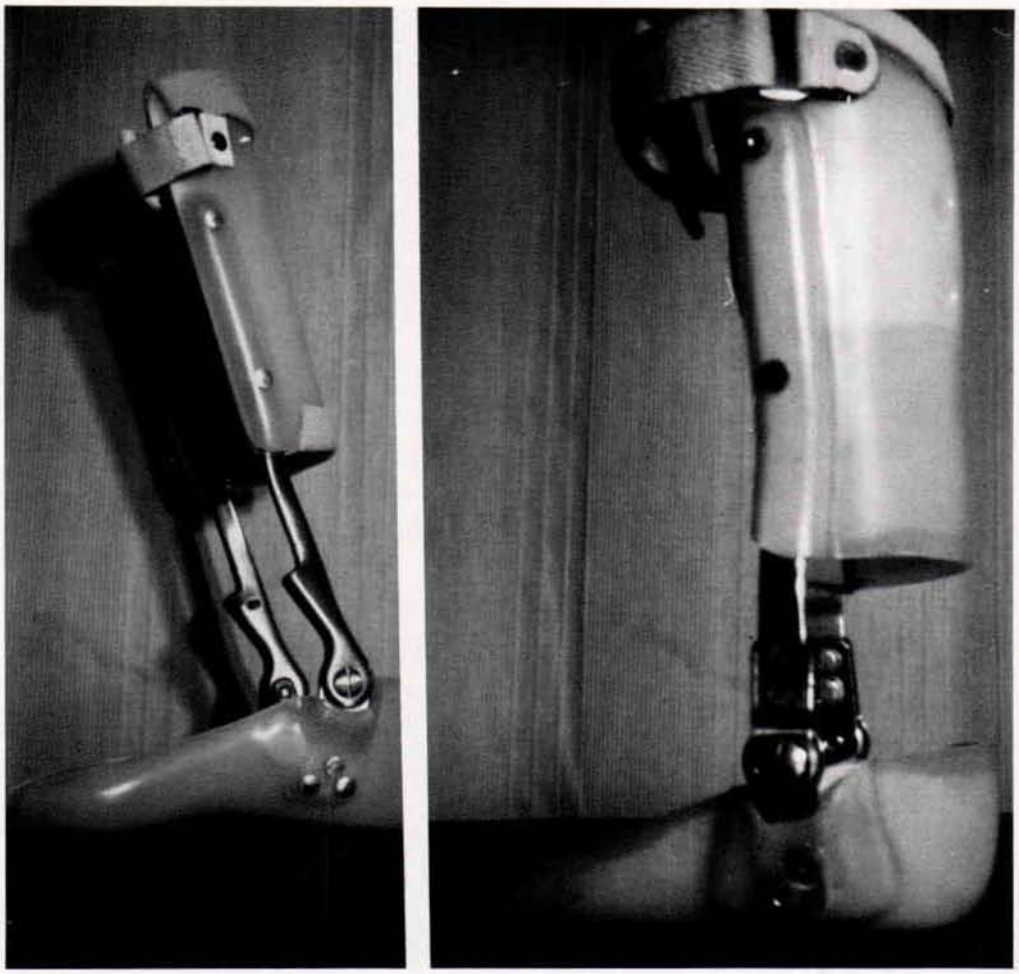

Fig. 8. Two views of the completed jointed plastic orthosis that uses dorsiflexion assist ankle joints.

with previous bracing produced a 74 percent fair or above ranking. In conclusion in rating gait, 89 percent of the parents gave the best appraisal to the child's walking with the Jointed Plastic Braces.

The parents were also given a listing of potential problem areas encountered with Jointed Plastic Braces by frequency of occurrence. The results are presented in Table 2.

Pressure areas	*Frequently*	*Occasionally*	*Never*
	Frequency of Occurrence		
Problem	*Frequently*	*Occasionally*	*Never*
Pressure areas	4	12	2
Breakage	1	5	11
Adjustments	4	11	1
Fit with shoes	—	9	6
Clothing	2	2	12
Other	—	1	—
Totals	11	40	32

Table 2.

It appears that the most problems occurred with excessive pressure and with adjustments; however, both of these problems occurred occasionally rather than frequently. Actually, the respondents do not perceive as many problem areas nor as frequently as had been anticipated.

Two open-ended questions related to advantages and disadvantages of Jointed Plastic Bracing were also provided. The advantages listed here were reported by at least three parents and are presented in order by most frequent mention:

1. more natural means of balance/walking
2. lighter
3. wear with any shoe
4. stronger
5. more cosmetic

The disadvantages using the same criteria of inclusion are:

1. shoe damage/shoe fit
2. cost
3. heavier
4. stiff joints/oiling required
5. need for precise fit

CONCLUSION

This orthotic concept does not replace either plastic or metal, but combines the two, thereby offering another alternative for treatment when an orthosis is required. If, by applying this analysis, a combination orthosis is utilized, it clearly meets the criteria established for a satisfactory orthotic result. Parental evaluation and perception of Jointed Plastic Bracing found it to be a much better alternative to previous types of bracing for their children.

SUMMARY

A new orthotic concept in the treatment of lower extremity paralysis or paresis which combines the attributes of metal and plastic, using the preferred characteristics of both in a single orthosis has been implemented. In order to retain the flexibility of a metal joint and also retain the light, cosmetic attributes of plastic, a wedding of the two materials has been effected. By combining the use of a well-molded plastic foot cup, metal ankle joints, and a plastic calf cuff, a good correction is obtained and the anatomical joint is controlled or free to function as desired. This has resulted in a new, more versatile concept for lower-limb orthotics. Jointed Plastic Bracing (JPB) has been applied to more than 50 patients during the past year with excellent results. Indications, specifics of construction, clinical application, and results in some of these fifty (50) patients has been discussed.

Footnotes

[1]Department of Rehabilitation Medicine, Methodist Hospital, 6500 Excelsior Boulevard, Minneapolis, Minnesota 55426

[2]Lossing Orthopedic Brace Company, 2217 Nicollet Avenue south, Minneapolis, Minnesota 55404. (612) 871-7250

Orthotics and Prosthetics, Vol. 33, No. 1, PP 11-15, March 1979

The ROL[1] Rotator

GERALD A. TINDALL, C.P.O.[1]
ROBERT O. NITSCHKE, C.P.[1]

The staff at Rochester Orthopedic Laboratories has long believed in the concept of controlled rotation about the long axis of an artificial leg, often referred to as "transverse rotation." We have used all available rotation units as they have been developed, and found them functionally satisfactory, but for our purposes lacking certain qualities necessary for our continued use. First, the available units are not easily repaired; in fact, failure of the unit requires complete replacement. Second, all units placed in the prostheses of active patients needed replacement in a short period of time—two to twelve months. Third, it was expressed to us by some patients that they required adjustable torque resistances, and to date there is no readily available unit that allows for adjustment. Other problems are, the lighter units are not as strong as heavier ones, and when either was used the patient complained about replacement or weight respectively. We set out to see if some of these problems could be solved and make rotation as practical as it is beneficial for the patient.

On February 27, 1976 the first ROL Rotator was delivered to a very active male mechanic with a knee disarticulation who was 74 in. in height and weighed 205 lbs. After three months of use, no appreciable wear could be detected and no failure of any components had occurred. Therefore, we proceeded with other installations. Since 1976 we have installed approximately 80 rotators. The design has not been modified except for minor changes in materials. It remains as seen in Figure 1.

MATERIALS

The ROL Rotator consists of:

1. An ankle block with a ½ - 24 bolt receiver of 1-¼ in. long steel.
2. A medial set screw to lock bolt down (¼ - 28).
3. Two ¼-in. thick phenolic plates (one proximal, one distal) to act as rubber retainers, and to provide strength.
4. Two Teflon bearing surfaces to reduce friction.
5. A rubber sheet, 1/16-in. thick, under distal Teflon surface to promote even wear.
6. Rubber block, 1-in. O.D., posteriorly to provide torque resistance.
7. Compression bearing with ½-in. dia. hole to eliminate resistance of the bolt on the foot.
8. Foot bolt, ½ - 24, 3 in. long.

Fig. 1. A PTB prosthesis that uses a ROL rotator.

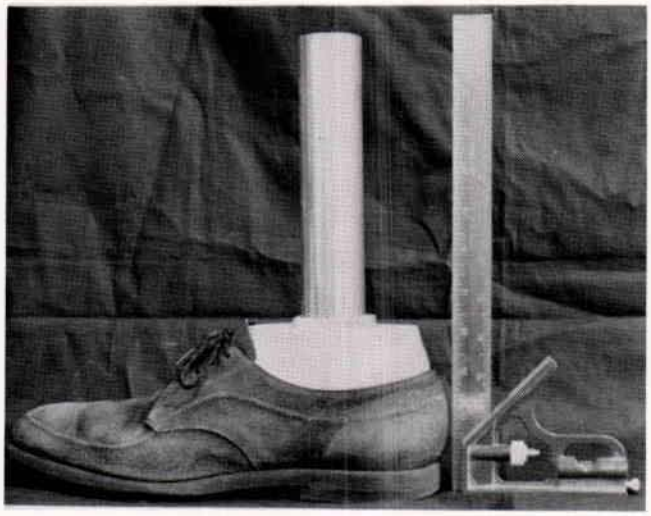

Fig. 2. The proximal surface of the SACH foot is sanded to provide 2 deg. of anterior tilt of the pylon of the adjustable leg.

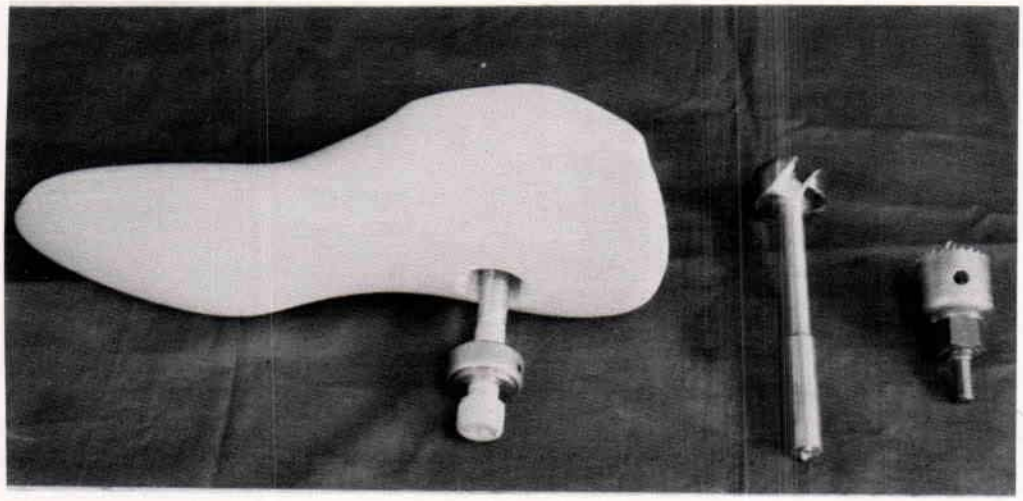

Fig. 3. The hole in the bottom of the SACH foot is enlarged to accept the bearing of the rotator.

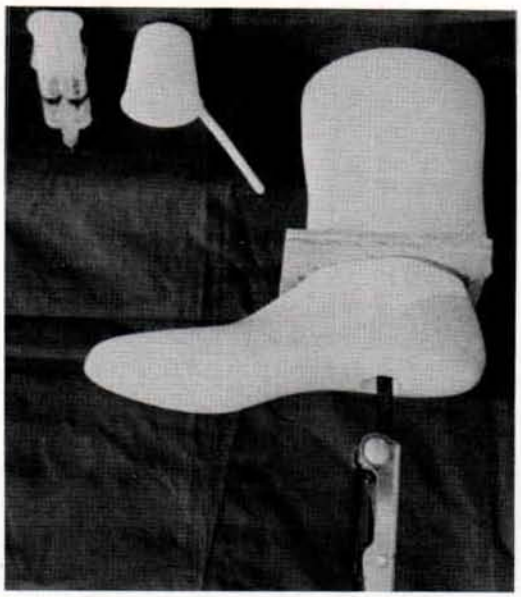

Fig. 4. A phenolic plate is attached to the proximal surface of the foot with epoxy.

INSTALLATION

The Sach foot to be used is placed in the shoe. The proximal surface is sanded to provide 2 deg. of anterior tilt of the pylon of the adjustable leg (Fig. 2). The hole in the bottom of the foot is then enlarged to accept the bearing (Fig. 3). A 1-¼-in. dia. hole saw is used, and the base of the hole is squared with a Forstner bit. The base of the hole must be parallel to the proximal surface of the foot and the hole for the bolt should be at the center to eliminate any possible binding of the unit. (We now have in use a bearing with a smaller outside diameter which eliminates most of this step, but at this time we are not ready to recommend it for use as it has not been tested thoroughly. The large bearing is shown in Fig. 3.)

The phenolic plate is glued to the proximal surface of the foot with a reliable epoxy (Fig. 4), taking care to center the rubber over the keel posteriorly. The

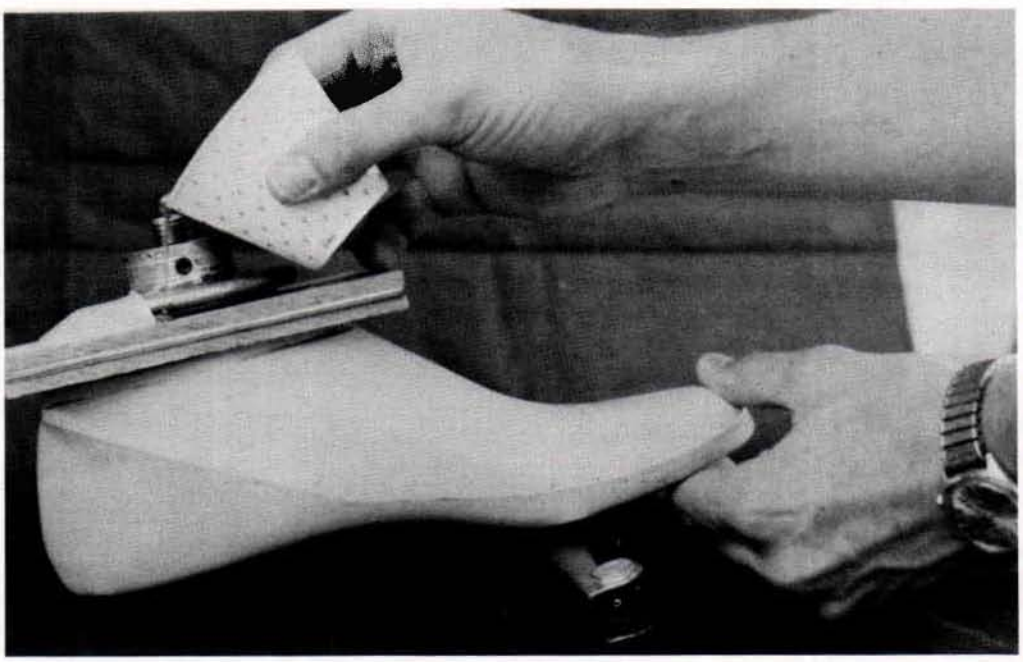

Fig. 5. Epoxy or polyester resin is poured around the posterior aspect of the foot plug to keep it from rotating with respect to the proximal plate.

plate with the rubber layer is used under the Teflon atop the foot to simplify finishing.

A foot plug, tapped for ½ - 24 bolt, and with a set screw in either side is attached to the subassembly. Epoxy or polyester resin is poured around the posterior aspect to keep it from rotating on the proximal plate (Fig. 5). It is now ready to fit (Figs. 6 and 7). After fitting, the complete rotator and foot are removed and transferred in the usual manner (Figs. 8 and 9). The medial set screw in the foot plug must be loosened before the bolt is removed. Toe-out is retained in the same manner as a normal transfer. The toe-out is set and the proximal plate is fastened with epoxy after the plastic is removed from the posterior proximal area. The rotation area obviously must be free of plastic.

Torque resistance is reduced simply by enlarging the hole in the posterior rubber and is increased by installing solid rubber.

When the rotator is being assembled for delivery, there are several points to remember. First, the Teflon around the rubber retainer hole should be checked to make sure that all sharp edges have been removed. Shearing of the rubber can be nearly eliminated if this simple procedure is followed. Second, the bolt should be tightened completely and then backed off until complete return of the foot is effected on rotation, but no pronounced gapping occurs under stress. Tightening the bolt first ensures that the bearing is well seated on the keel. Third, to adjust the resistance, several different courses may be taken. Rubber of different durometers may be used or, even simpler, a hole may be punched in the center of the rubber and enlarged until the desired resistance is attained. Small amounts of Silicone or Vaseline may be applied to the Teflon, though need for this has not been proven.

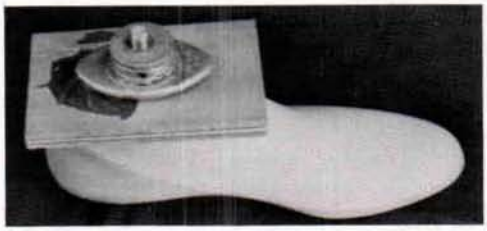

Fig. 6. Foot and rotator ready for fitting.

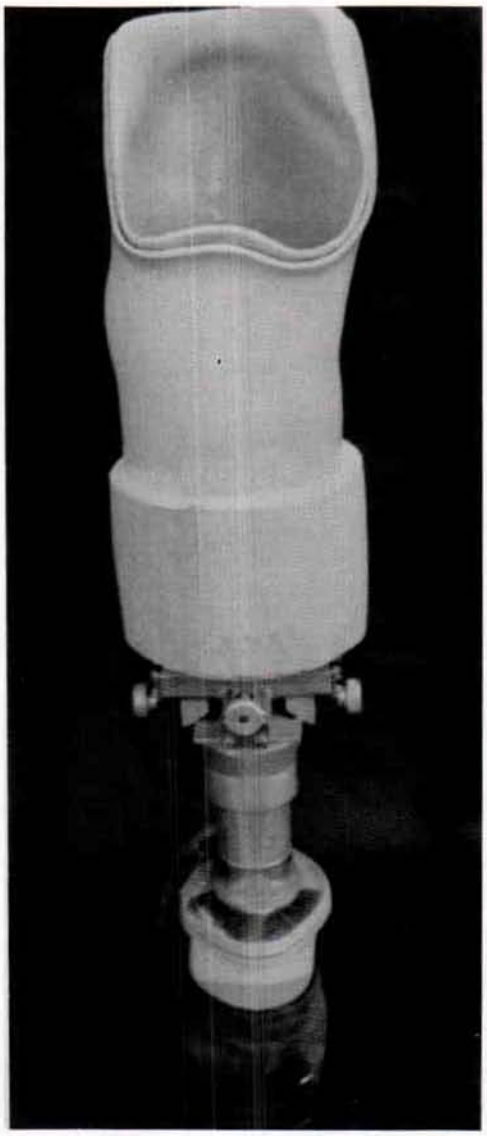

Fig. 7. The rotator installed in adjustable leg for amputee trial.

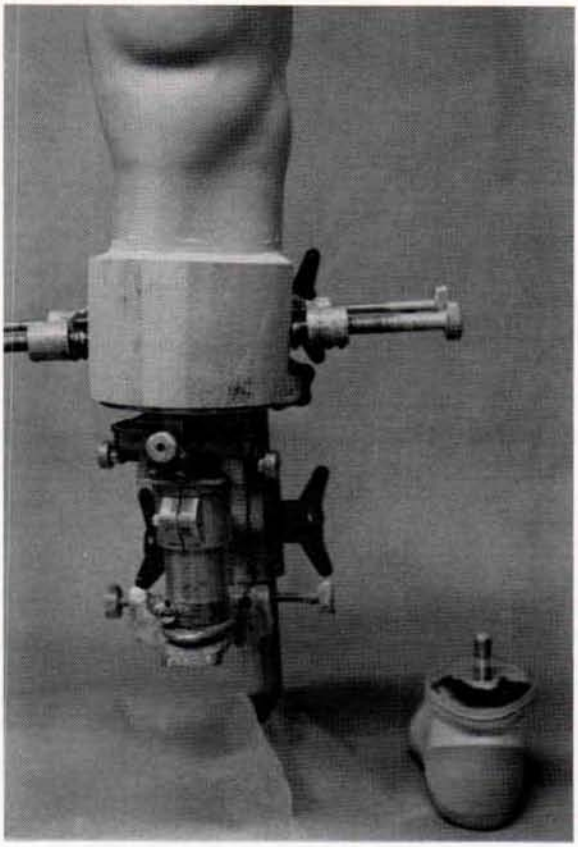

Fig. 8. The rotator-and-foot assembly is removed from the adjustable leg.

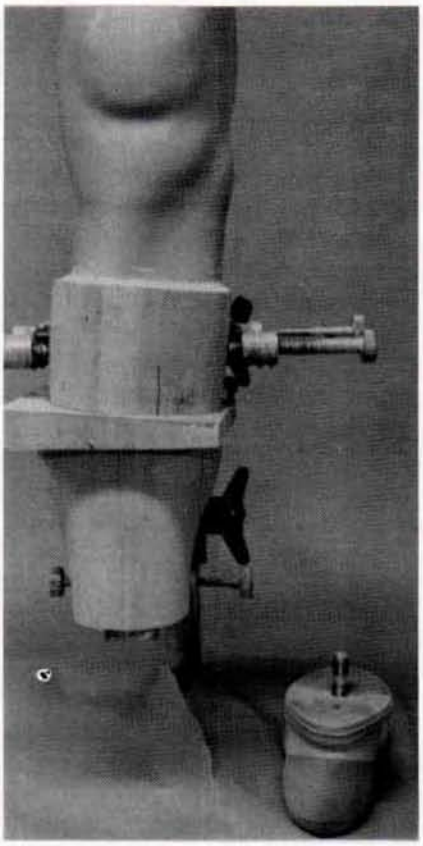

Fig. 9. Fabrication of the PTB is carried out in the usual manner.

SUMMARY

When properly installed, the ROL Rotator is virtually trouble free. Worn components can be quickly, easily, and economically replaced. Torque adjustments are quick and simple. The six-ounce weight the rotator adds to the prosthesis is well accepted. The rotator is very cosmetically acceptable. Repairs have consisted of rubber replacement on several occasions and in two instances with very active patients the Teflon wore out and was replaced. In short, all the rotators we have installed since February 1976, to the best of our knowledge, are still in operation and none have failed or been removed for any reason.

Footnote

[1]Rochester Orthopedic Laboratories, 1654 Monroe Avenue, Rochester, N.Y. 14618.

Orthotics and Prosthetics, Vol. 33, No. 1, PP 16-21, March 1979

Ice-Water Quenching Technique for Polypropylene[1]

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T.J. SUPAN, C.P.O.[3]
D. BELTON, M.S.[4]

The use of polypropylene as a material in orthotics and prosthetics has gained widespread acceptance over the last several years. However, our basic knowledge of this material has not kept pace with its use in the design of orthoses and prostheses. This report is an attempt to make the practitioner aware of possible variations in the properties of polypropylene as a function of processing conditions. Specifically, the processing variable investigated in this report has been a rapid rate of cooling for polypropylene devices during fabrication. A description of the fabrication procedure is preceded by a brief summary of some principles of polymer science relevant to polypropylene processing.

Polypropylene belongs to a class of polymeric materials known as the semicrystalline thermoplastics. The classification of polypropylene as a material of this type implies a rather complex microscopic structure as well as extreme sensitivity of physical properties to processing conditions (1). Processing conditions involve primarily the thermal history, pressure, and the extent to which the molten material is mechanically deformed prior to its solidification. Thermal history is especially significant. At temperatures above the melting point (170 deg C for polypropylene), the long polymer molecules entangle randomly to form a network lacking structural order (amorphous network). Upon cooling, however, a certain portion of the material solidifies in the form of ordered molecular arrays known as crystallites[5], while the remaining portion retains the structure characteristic of the amorphous network. In this context, the significance of thermal history to physical properties of polypropylene lies in the possibility of controlling through temperature the relative amounts of crystalline and amorphous material present in the final product. This control is crucial in processing of semicrystalline thermoplastics since the mechanical properties of crystalline and amorphous material differ substantially. For example, crystalline material is generally stronger, yet less flexible than amorphous material (2). One possible way of controlling crystalline vs. amorphous content in the final

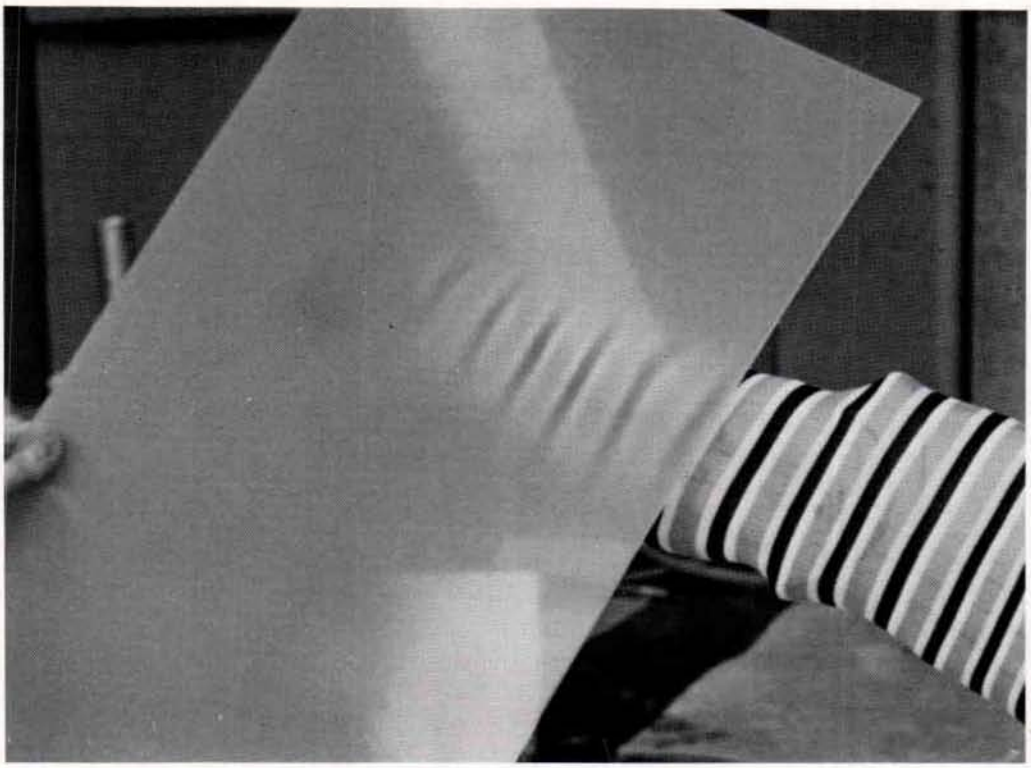
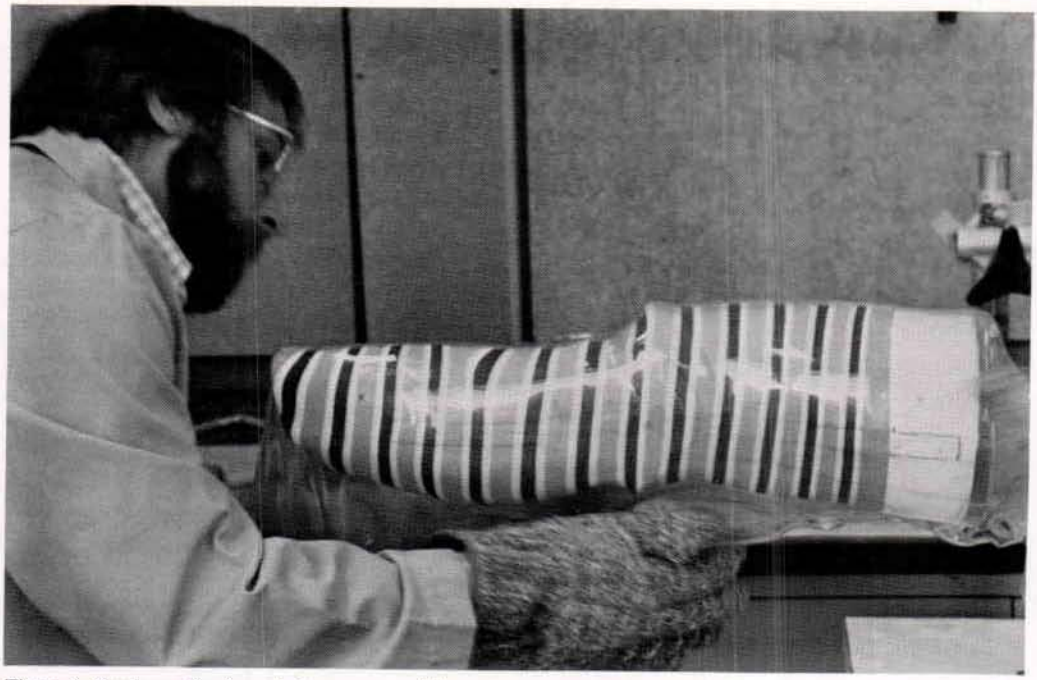


Figure 1. Polypropylene sheet (1/8 in., 0.32 cm) to be formed over a cast for a knee orthosis.

product is by manipulation of the cooling rate used to solidify the molten polymer. This possibility is based on the fact that substantial growth of crystallites requires finite periods of time at temperatures 20-100 deg lower than the melting point, depending on the material (3). As a consequence, some semicrystalline polymers, when solidified by rapid cooling of the melt to ambient temperatures or below, tend to contain a considerable volume fraction of amorhpous flexible material.

Another characteristic feature in the structure of semicrystalline themoplastics is the formation of rather large spherical aggregates upon the solidification of molten material. These aggregates can be considered as the basic 'grains' of the material and are known as spherulites. Depending partly on processing conditions, spherulites can range in size from microscopic dimensions to a few millimeters in diameter (4). These spheroidal grains consist of both crystallites and amorphous material, and their size can greatly affect both the mechanical and optical properties of the final product. For example, solidified materials consisting of small sized spherulites tend to be more transparent than those in which spherulites are of considerable dimensions (1). This difference is based on the

Figure 2. Softened polypropylene sheet being placed over the cast.



Figue 3. Sealing of softened sheet to provide vacuum contouring. This procedure is to be followed by removal of excess material.

fact that spherulites tend to scatter light when their size is comparable to visible wavelengths. Furthermore, in polypropylene and other semicrystalline thermoplastics, it is often found that small spherulites increase impact strength in the final product (5). Spherulite size is, therefore, important in determining physical properties and, again, this variable can be controlled by processing conditions such as cooling rate. Generally speaking, fast cooling rates to temperatures well below the melting point of the material lead to the formation of small spherulites in semicrystalline thermoplastics.

ICE-WATER QUENCHING PROCEDURE

The relations between microstructure and properties discussed here have provided the basic rationale for the newly developed processing technique for polypropylene devices. Orthotic and prosthetic devices quenched in ice water immediately after forming exhibit greater transparency than those exposed to slower cooling rates through the use of compressed air. Furthermore, in agreement with the discussion above, these devices have also been found to possess greater

Figure 4. Vacuum-formed cast immersed in ice-water bath.

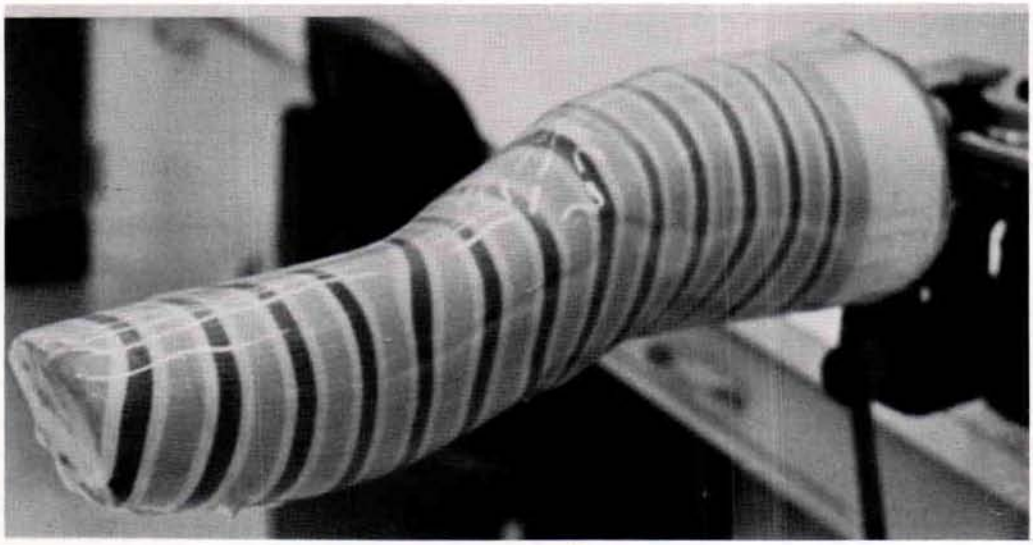


Figure 5. Vacuum-formed knee orthosis prior to removal from cast.

mechanical flexibility. The handling of the polypropylene is the same as with other vacuum forming methods with the exception that the model must be removable from the vise. Figures 1 through 5 illustrate the technique on a knee orthosis (K.O.). The cast is covered with a multicolored nylon to illustrate the transparency of the ice-water quenched orthosis. Specifically, a comparison of Figure 1 with Figure 5 illustrates the difference in transparency between the original sheet and the ice-water quenched material. One important property of ice-water-quenched polypropylene is the fact that it tends to contract upon cooling. This is evidenced by the observed overlapping of seams in devices which have been removed from the models.

RECOMMENDATIONS AND CONCLUSIONS

The use of ice-water-quenched polypropylene is recommended when increased transparency, increased impact strength, and increased flexibility are desired. Although the properties of the original material may vary according to its source, those of the processed material are expected to be similar from device to device. Increased transparency improves the acceptability of orthoses from the standpoint of appearance. It also facilitates visual examination of underlying skin in both orthoses and in sockets for artificial limbs. Increased impact strength, conversely, would be recommended for prostheses and lower-limb orthoses. It should be pointed out that even though increased flexibility is not always desired, the resulting toughtness, and thus a decreased tendency to crack or tear, are always advantageous properties. In cases where an increased flexibility in the material presents a problem, changes in geometric design can be used to overcome this disadvantage. An example of such changes is the introduction of corrugations in the device.

Some of the advantages of ice water-quenched polypropylene have been pointed out above. Currently, solidified

materials obtained using various cooling rates are being quantitatively characterized in terms of both mechanical and optical properties. It is hoped that these measurements will allow optimization of properties in polypropylene orthotic and prosthetic devices through the control of processing conditions.

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(1) F.W. Billmeyer, Jr., *Textbook of polymer science*, Ch. 7, Interscience Publishers, New York, 1970.

(2) H.P. Frank, *Polypropylene*, Ch. 4, Polymer Monographs, H. Morawetz, ed., Gordon and Breach Science Publishers, New York, 1968.

(3) B. Wunderlich, *Macromolecular physics*, Vol. 2, Ch. 5, Academic Press, Inc., 1976.

(4) F.W. Billmeyer, Jr., *Textbook of polymer science*, pg. 148, Interscience Publishers, New York, 1970.

(5) P.W.O. Wijga, *The physical properties of polymers*, pp. 35-45, S.C.I. Monograph No. 5, The MacMillan Co., New York, 1959.

Footnotes

[1]This work supported by RSA Grant No. 23-P-55898 and V.A. Contract No. V101 (134)-P326

[2]Department of Biological Materials and Rehabilitation Program, Northwestern University, Chicago, Illinois 60611

[3]Rehabilitation Engineering Program, Northwestern University, Chicago, Illinois 60611

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[5]Crystallites usually consist of very thin layers of material with thicknesses in the range of 10^{-6} cms.

Orthotics and Prosthetics, Vol. 33, No. 1, PP 22-24, March 1979

"H"-Shaped Wrist-Hand Orthosis

GERALD A. SOLIE, O.T.R.[1]

Many patterns of wrist-hand orthoses available today are bulky, warm to wear because of the excessive amount of splinting material used to partially enclose the forearm, wrist, and hand.

The need for a simple wrist-hand orthosis that will fit properly with a minimum amount of time and skill has been sought for a good many years. Such a design is now available with use of an "H"-shaped pattern (Fig. 1) and a low-temperature splinting material known as Polyform.[2] The "H" pattern when properly used is applicable to either hand. It may be used as a dorsal, volar, or ulnar orthosis depending upon the patient's needs. Furthermore, the "H" pattern is simple in design, cosmetically acceptable to the patient, economical, lightweight, easy to fabricate, and maintains the normal arch of the hand. Since the orthosis is molded directly to the patient it makes a proper and comfortable fit easier to achieve.

PROCEDURE

Water is heated in an electric fry pan to 71.2 Celsius (160 Fahrenheit).

Each end of the longest section of the pre-cut splint blank is dipped into Polyform Solvent Cleaner[2] to a depth of approximately 2.54 cm (1-inch), and wiped off with a cloth to remove a coating from the Polyform so it will adhere to itself when heated and molded to the hand.

The widest end of the orthosis blank is inserted into the heated water for approximately 40 seconds, or when the right pliability has been reached.

Heating one section of the orthosis blank at a time permits easier fabrication and will also improve the fit. The Polyform should be soft enough so it does not spring back when being formed, but not so hot that it will stretch easily and destroy its molding properties. If this should occur the Polyform should be allowed to cool before attempting to mold it around the hand. Water adhering to the Polyform should be removed by blotting it with a towel.

The orthosis blank when used for dorsal splinting should follow the midline of

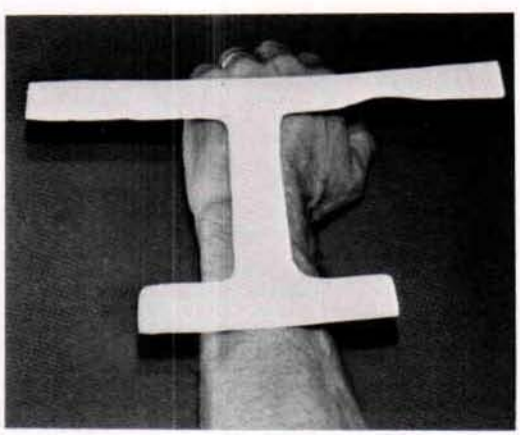

Fig. 1. Pre-cut "H" blank in position for fabrication of left dorsal wrist-hand orthosis

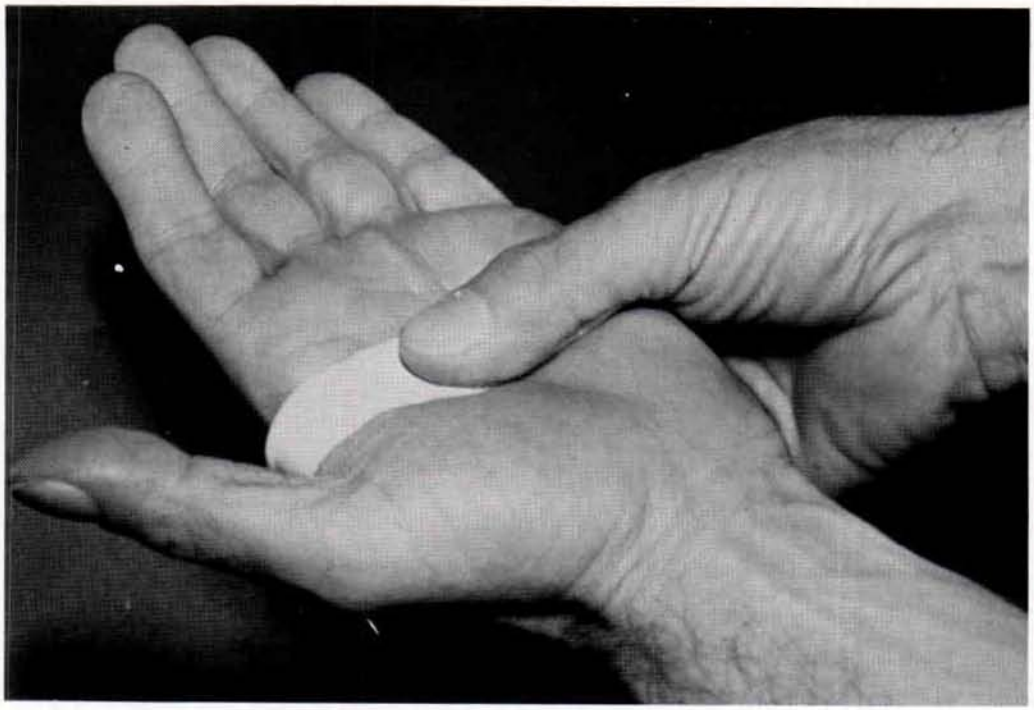

Fig. 2. Forming distal transverse arch

the forearm and be placed proximal to the metacarpophalangeal (MCP) joints of the hand (Fig. 1). Both ends are brought around to encircle the hand and are overlapped by about 2.54 cm (1 in.). When the overlap is more than 2.54 cm (1 in.) any excess material is cut off. Both ends are pressed together using the index finger and thumb so the ends will adhere to each other securely and to reduce the depth of the double thickness. The thumb is pressed and gently slid over the volar area of the cuff to maintain the distal transverse arch of the hand (Fig. 2). The Polyform is removed from the hand after a few minutes when it is cool enough so that it will not lose its new shape. The opposite end is inserted into the water. The middle section is not heated.

When the proximal end is heated sufficiently, the enclosed cuff is slid over the MCP joints, the splint is aligned on the forearm and the ends are molded around the forearm. The orthosis should be formed while the wrist is held in a neutral position. Upon cooling the device is removed, Velcro fasteners are attached, and the device is reapplied to the patient. Excess material is determined and trimmed away. The patient should be able to flex and extend fully without any interference at the MCP joints. The thumb web space should be checked for comfort and to insure that no pressure point areas are present. The wrist area needs additional support provided by an aluminum reinforcement bar attached with two-part rivets (Fig. 3). Desired wrist

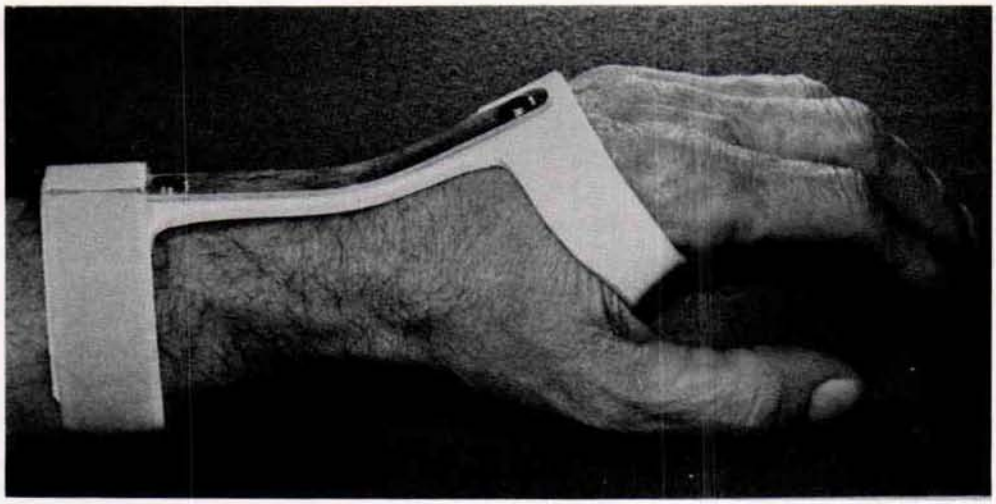

Fig. 3. Completed wrist-hand dorsal orthosis

extension may be changed at this time without heating the Polyform by bending the orthosis in your hands to provide the amount of extension needed at the wrist joint.

SUMMARY

Wrist-hand orthoses are used for many different purposes and for a variety of diagnoses. The main purpose is to support or rest the wrist joint, maintaining the wrist in a slight extension position, permitting finger and thumb movement. This type of orthosis will also serve as a base for adaptations for activities-of-daily-living.

Footnotes

[1]Coordinator, Rehabilitation Medicine Service and Spinal Cord Injury Service, Veterans Administration Center, Wood, Wisconsin 53193.

[2]"H" shaped wrist-hand orthosis kit and Polyform solvent cleaner may be purchased from: Rolyan Medical Products, 14635 Commerce Drive, P.O. Box 555, Menomonee Falls, Wisconsin 53051.

Orthotics and Prosthetics, Vol. 33, No. 1, PP 25-38, March 1979

An Evaluation of the C.A.R.S.-U.B.C.[1] Knee Orthosis[2]

BRIAN REED[3]

More than 20 million Americans suffer from some form of arthritis. About 5 million have rheumatoid arthritis, and another 12 million have some type of osteoarthritis (1).

The knee, which is the largest joint in the body, is a common site of involvement for patients with osteo or rheumatoid arthritis (2). In either case, the patient characteristically has pain and ligamentous instability when bearing weight, and therefore decreased mobility. Thus, an unstable arthritic knee is a common clinical problem.

If the disease process goes unchecked, a permanent deformity of flexion with genu varum or valgum may result (3, 4). Such a deformity makes ambulation much more difficult, if not impossible (5). The treatment goals for an unstable knee are the relief of pain, maintenance of stability and mobility, and the prevention of further deformity.

The use of orthoses is an important non-surgical method of helping to attain these goals. However, a review of the literature shows an absence of any on-going clinical evaluation that documents the efficacy of the various knee orthoses currently in use. Consequently, the clinician is forced to choose an orthosis on the basis of trial-and-error experience.

The purpose of this study was to describe the over-all usefulness of the C.A.R.S.-U.B.C. orthosis (6, 7) in a sample of 10 arthritic patients with medial-lateral knee instability as a major complaint.

While recognizing that 10 is a small number for an evaluation program of this type, it was still felt that certain laboratory measurements should be made in an effort to determine if they could lead to better prescription guidelines.

The C.A.R.S.-U.B.C. orthosis (Fig. 1) is designed to stabilize a varus or valgus moment at the knee. It is a dynamic orthosis, providing maximum support when the knee is extended, as in the stance phase of gait. The orthosis consists of two plastic cuffs—one about the thigh and one about the shank, which are connected by a telescoping rod to provide complete freedom in the flexed condition but provides a force that tends to straighten the knee joint in the parasagittal plane upon full extension. When the knee is extended, the system becomes taut. When relief on the medial side is desired, the cuffs and rod are fitted to the lateral side of the leg, and the leather pad supports the medial side of the knee. The opposite scheme is used to obtain relief on the lateral side.

The units of the CARS-UBC knee orthosis were made available for evaluation by the University of British Columbia and the United States Manufacturing Company at the request of the Rehabilitation Engineering Center since the device fell

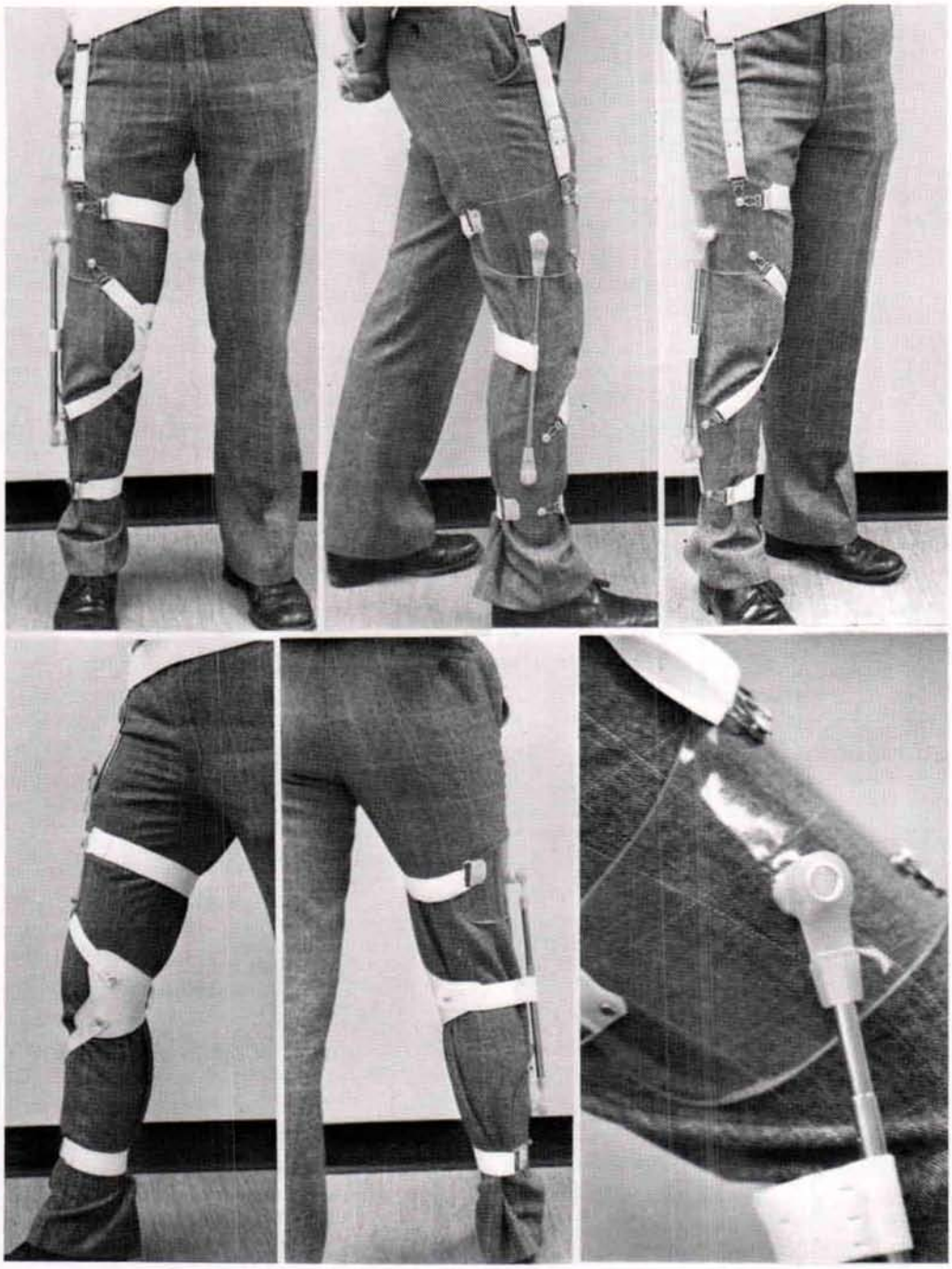

Fig. 1 Various views of the CARS-UBC knee orthosis for arthritis. These views show the orthosis fitted to provide for lateral instability. It can be fitted just as easily with the telescoping bar on the medial side of the knew to provide for medical instability. Although shown here being worn on the outside of trousers the orthosis may be worn next to the skin or simply with a stockinet over the knee.

well within the scope of its charge from its primary sponsor, the Rehabilitation Services Administration.

METHOD

The sample used in the evaluation consisted of ten patients referred from the Arthritis Center of Albert Einstein Medical Center. The subjects were diagnosed as having rheumatoid or osteo arthritis with knee instability. All of the subjects were female, ranging in age from 47 to 81. The mean age was 64.4. Patients were selected on the basis of the following general requirements:

1. Medial or lateral knee instability
2. The ability or potential ability to ambulate independently on stairs, ramp and level surface
3. Absence of complicating medical conditions which might contraindicate participation in the study
4. The mental and physical ability to don and doff the orthosis, or a family member who could do it
5. Informed consent of the patient and physician

The severity of involvement of each patient was assessed by using two knee-scoring scales, Slocum (8) and Kettlekamp (9). Each of these forms allows a score to be tabulated based on the knee range of motion, joint stability, functional capabilities of the patients, etc. The two scores were averaged. Patients were classified as minimally, moderately, or severely involved according to this score.

The subjects were tested in the laboratory initially and again two to four weeks later when the patient had become accustomed to the orthosis. The subject was fitted with instrumentation and then was asked to ascend and descend a set of stairs, a ramp, and to walk on a level surface. The three different surfaces were chosen to provide an overview of functional performance. Patients ascended and descended the stairs (6 steps) and ramp (8 percent grade) twice, and they made four steady-state passes across force plates (1.5 m long) on the level surface. The instrumentation used on the stairs and ramp included adjustable force sensing transducers strapped to each shoe, and two knee electrogonoimeters. The electrogoniometer used for the involved limb was a parallelogram type so that the orthosis would not interfere with range of motion measurements during the second test session. Analog data from these instruments were collected on a six-channel Gould pen recorder. For the level surface walking, the outsole force transducers were not used. Instead, the subject walked across strain-gage force plates in the locomotion laboratory. In addition, during level walking, a tachometer string was attached to a belt over the patient's lumbar area to record velocity. Level surface data were collected by means of a general sampling program on a PDP-11 computer at a rate of 40 samples per second. The parameters that were either measured directly, or derived from the data, are:

1. peak-to-peak range of motion (involved knee)
2. vertical load
3. rate of loading
4. swing/stance ratio
5. task time (stairs and ramp only)
6. velocity (level surface only)
7. Symmetry:
   a. range of motion symmetry
   b. loading rate symmetry
   c. step length symmetry (level surface only)

In addition to the above parameters, static alignment photographs were taken of each patient before and after bracing (Fig. 2). This was done using the technique developed by Cook et al (10, 11). In this procedure, the floor-reaction force vector through the patient's limb is super-

imposed on the patient's image by means of an optical beam splitter while the patient stands on one of the force plates. In this manner, the force vector indicates changes in torque or alignment at the knee.

The parameters that were used were selected on the basis that if the orthosis stabilizes the involved knee, the patient should experience less pain on weight-bearing, and should feel more secure. Consequently, one would expect the patient to be able to walk faster and more vigorously. The parameters, except for task time and the measures of symmetry, would be expected to increase from pre-bracing to post-bracing. The assumption is made that if greater symmetry is an improvement (that it is more "normal") one would expect the symmetry values to decrease because the values used were the differences between right and left limb performance (ROM, loading rates, etc.).

At the time of the second testing, the subjects were asked to complete a questionnaire about the orthosis (Fig. 3). The questionnaire was based on the criteria established by Cousins and Foort (12). Each question was weighted numerically so that a score could be tabulated for the entire questionnaire. A perfect score was 10 points.

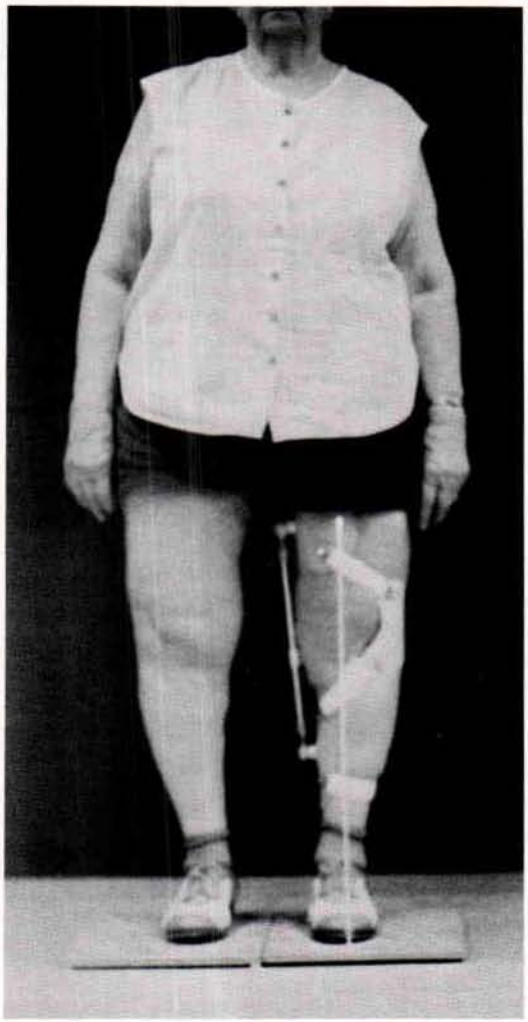

Fig. 2. Patient standing on forceplate so that position of weight line can be recorded. The length of the weight line is proportional to the force exerted.

RESULTS

Severity of Involvement

Nine out of the ten patients were classified as moderately involved. The other patient (No. 8) was classified as severely involved.

Laboratory Results

In an effort to stay as "close" to the data as possible in describing the results, the patient's performances are presented

BRACE EVALUATION FORM

(ADOPTED FROM CARS-UBC)

Patient's Name: _____

Date: _____

1. Do you wear your brace: ☐ all the time ☐ only when going outside ☐ only around the house ☐ not at all
2. Has your brace been: ☐ a great help ☐ no help ☐ a moderate help ☐ a hinderance
3. Do you function better: ☐ all the time ☐ occasionally ☐ most of the time ☐ not at all

Please answer Yes or No:

1.	Is your brace comfortable?	Yes	No
2.	Is the fit of your brace good?	Yes	No
3.	Is the weight of the brace noticeable?	Yes	No
4.	Does the brace catch your clothes?	Yes	No
5.	Does the brace soil your clothes?	Yes	No
6.	Does the brace make you perspire?	Yes	No
7.	Does the brace rub your skin?	Yes	No
8.	Is cleaning the brace a problem?	Yes	No
9.	Do you like the appearance of the brace?	Yes	No

REMARKS:

Fig. 3. Questionnaire administered to patients in study.

in the displays shown in Figures 4. Along the abscissa in each display, the patients are listed in decreasing order of their acceptance of the orthosis according to the questionnaire scores. The ordinate represents the mean value of each parameter for the patient during the pre-bracing and the post-bracing test. Heavy lines represent an improvement from pre-bracing to post-bracing. Conversely, narrow lines represent a decrease in performance from pre-bracing to post-bracing. Symbols (circles, squares and triangles) indicate the pre-bracing value on each of the various walking surfaces: up or down the stairs or ramp, and level walking. Finally, the average performance of the group ($\bar{X}$) *is represented at the extreme right-hand side of each display.*

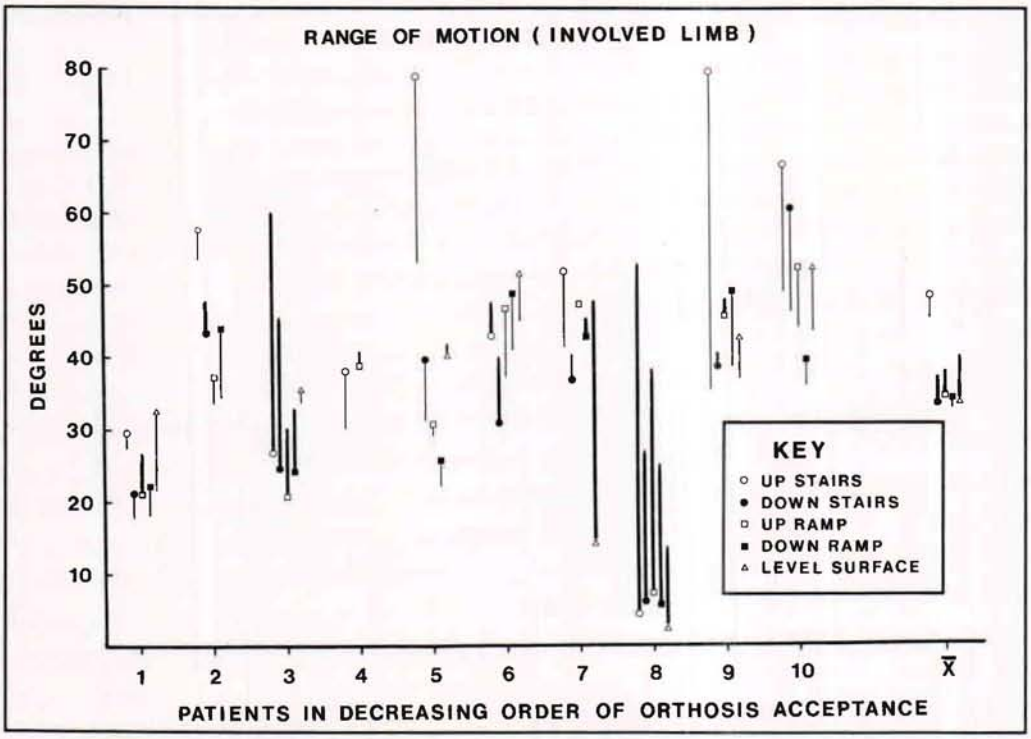

Fig. 4. Range of Motion (Involved Limb).

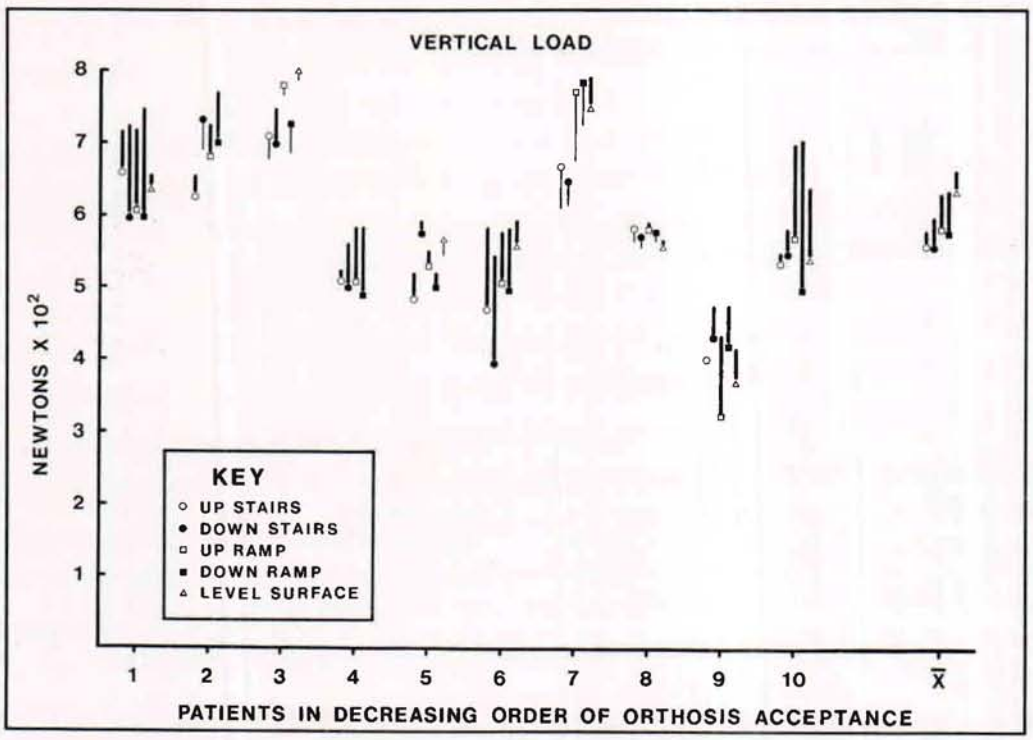

Fig. 5. Vertical Load

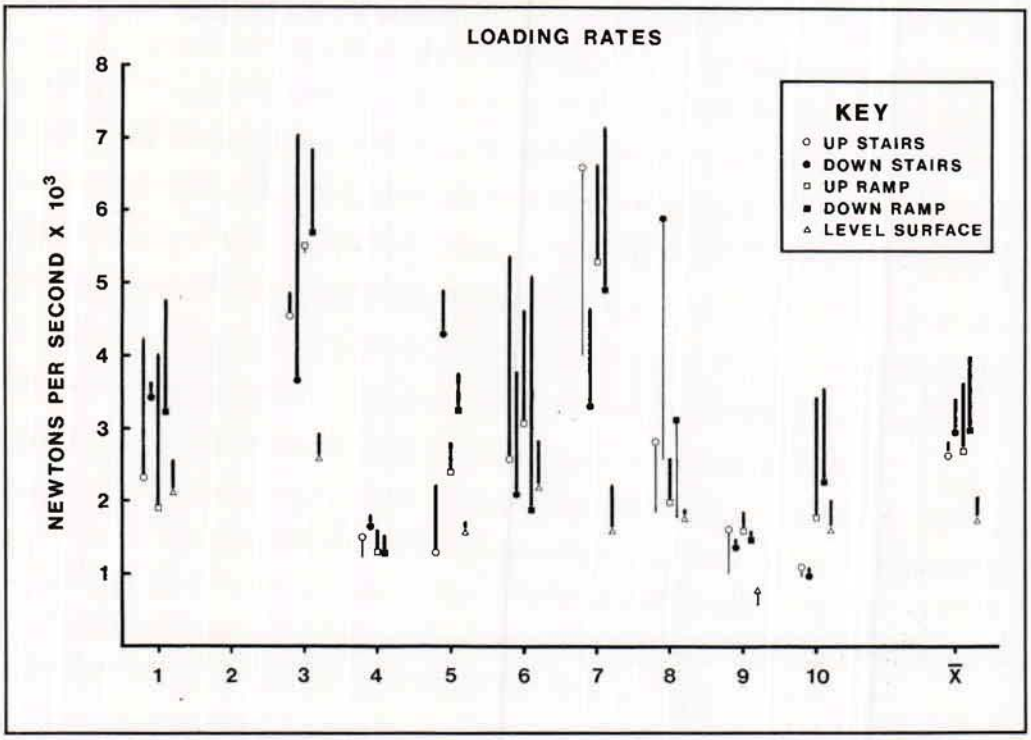

Fig. 6. Loading Rates

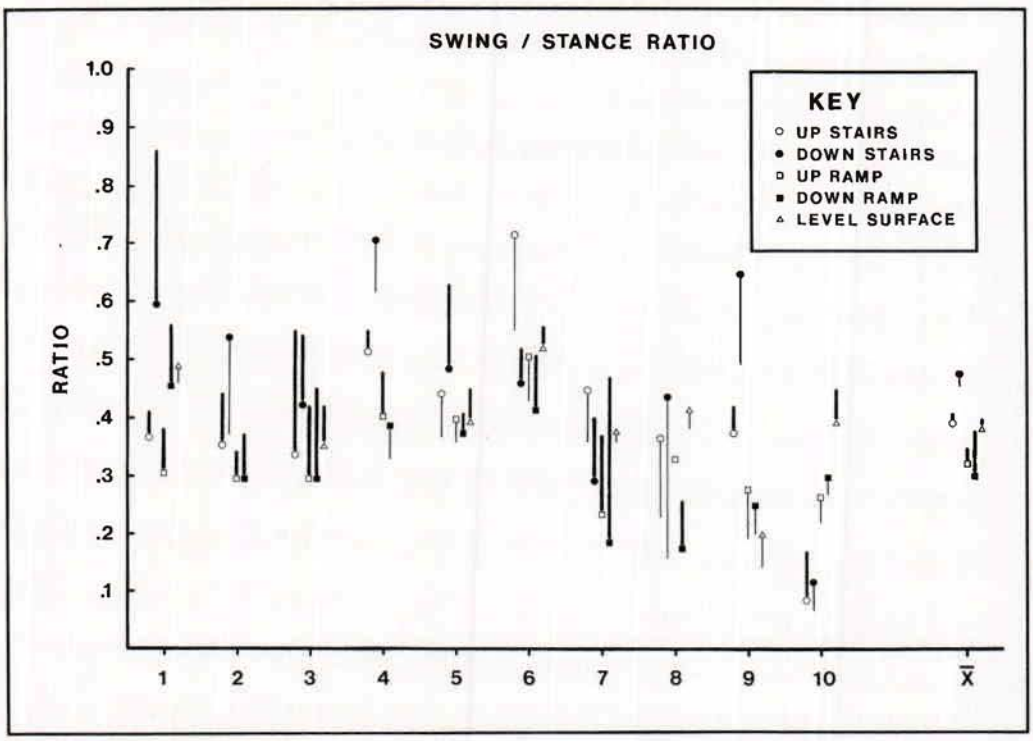

Fig. 7. Swing/Stance Ratio

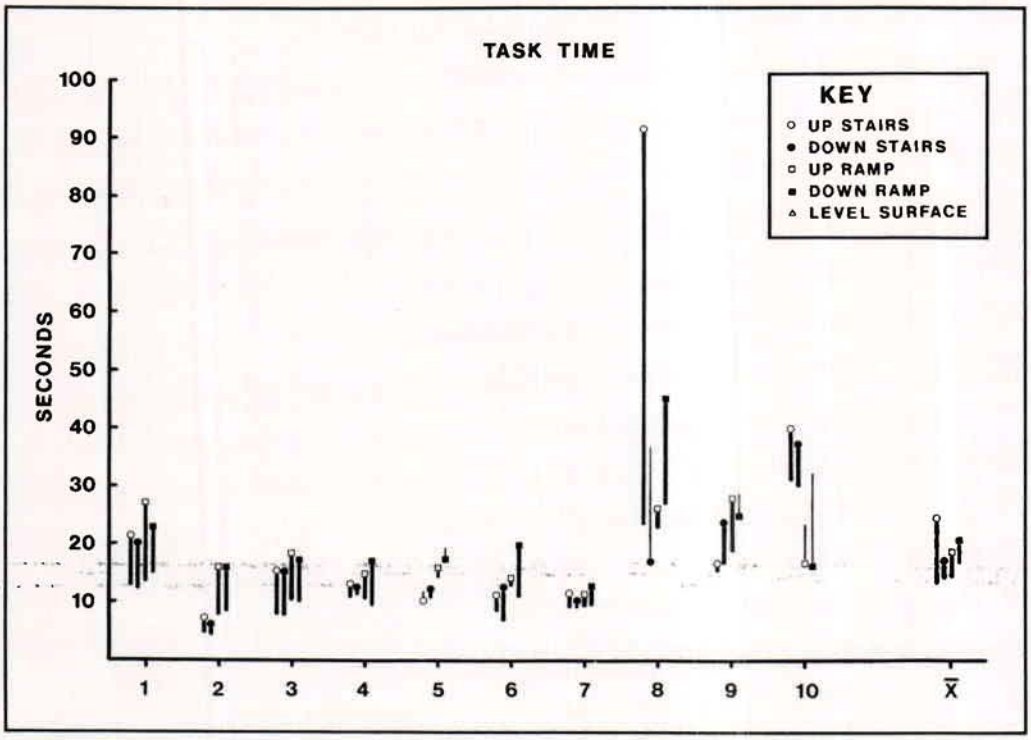

Fig. 8. Task Time

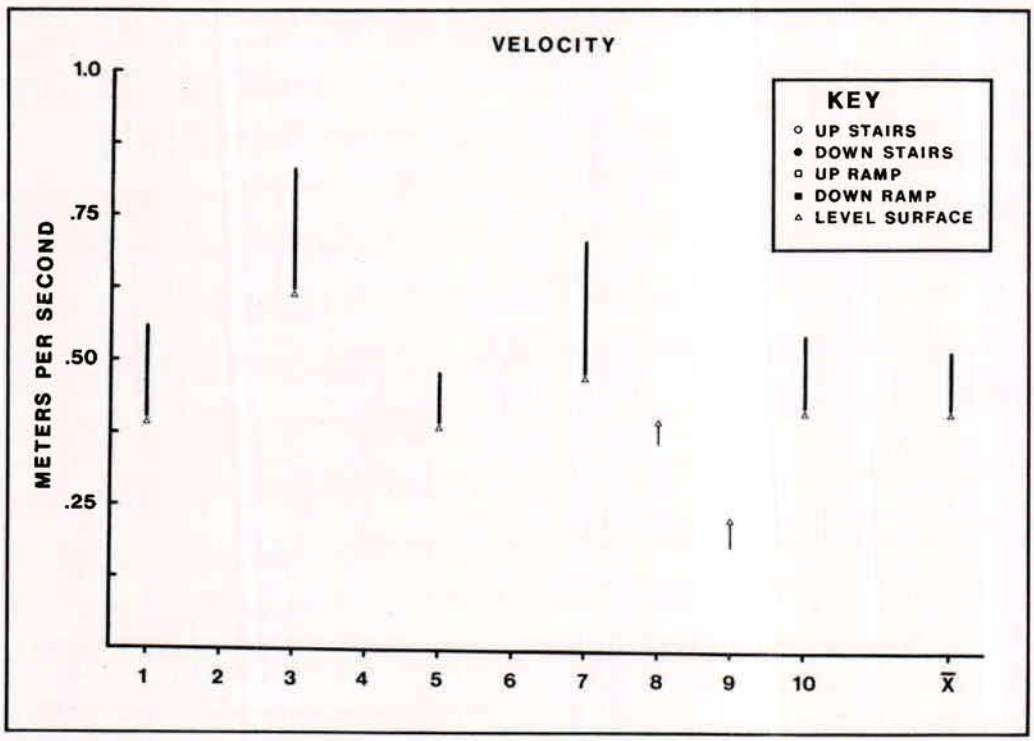

Fig. 9. Velocity of Walking

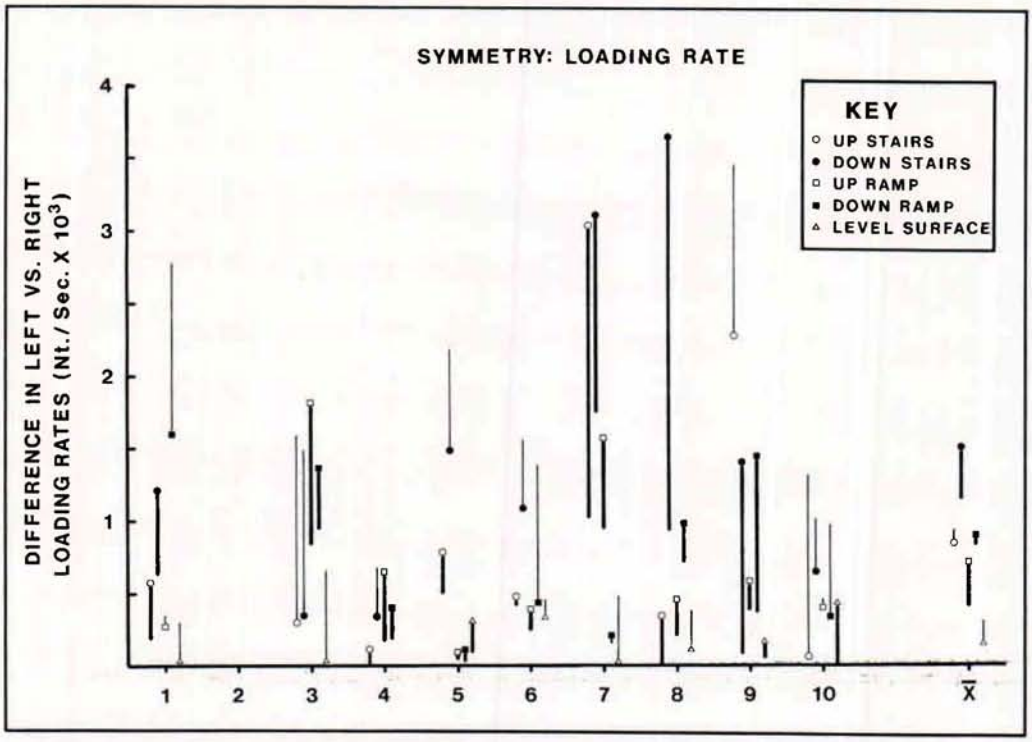

Fig. 10. Symmetry: Loading Rate

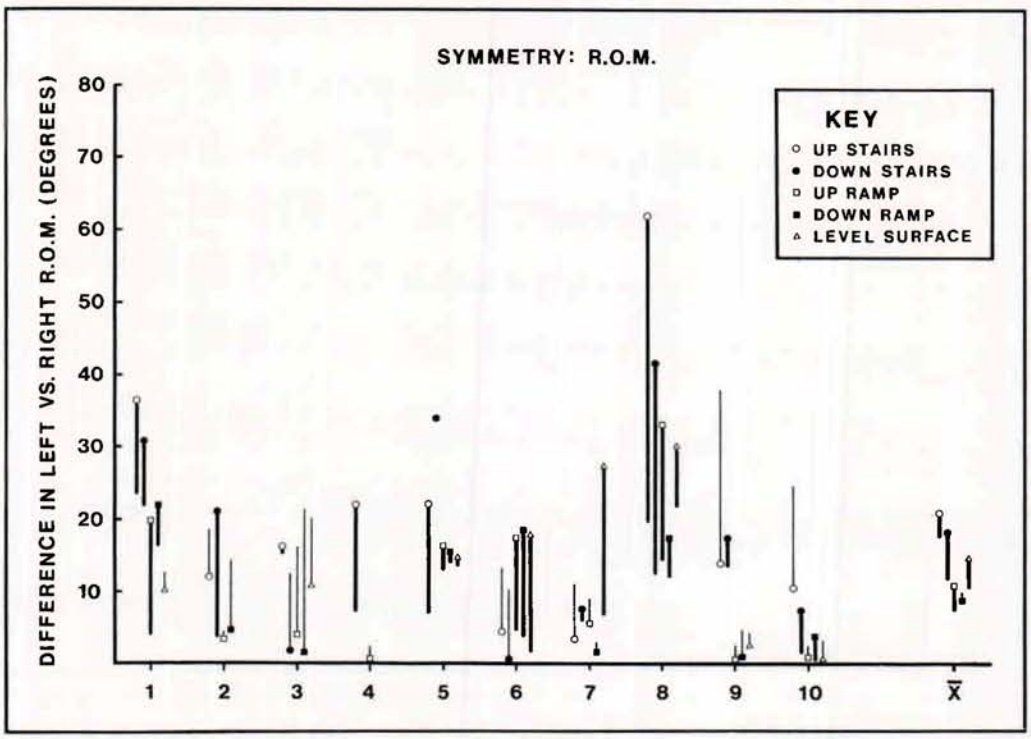

Fig. 11. Symmetry: Range of Motion

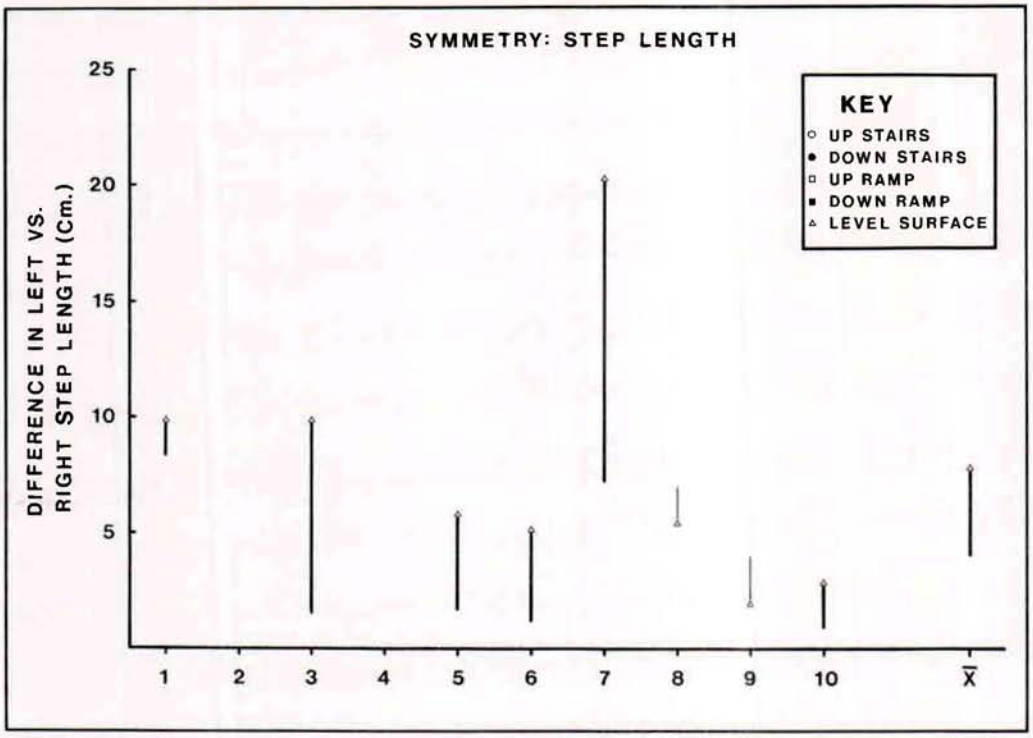

Fig. 12. Symmetry: Step Length

It appears that the group has no particular pattern of positive or negative change for the parameters of ROM, Swing/Stance Ratio, and Loading Rate Symmetry. This is true even though certain patients showed dramatic positive or negative changes on some or all of the surfaces. The group showed general improvement in the other parameters, although certain subjects showed negative changes on some or all of the surfaces. How significant the various changes are is a debatable question especially when variability is considered. As described in the methodology, all of the pre- and postbracing values are mean values. This means that there is some variability about all of the plotted values. In some cases, when the prebracing to postbracing change was very small, it was less than one standard deviation from the pre- or postbracing value. In other cases, where a pre- to postbracing change is very large, the change would certainly seem to be "clinically significant."

In an attempt to look at the data without attaching some critical level of significance to the size of the pre/postbracing changes, another type of plot was used (Fig. 13). Each parameter is plotted against the proportion of patients who exhibited any positive changes, no matter how small. The heavy bars indicate the proportion of positive changes for the group across all surfaces. The narrow bars indicate the proportion of positive change for an individual surface. The heavy bars are the most important since

they represent the proportion of positive changes in fifty pre/postbracing changes (10 patients x 5 surfaces). If the orthosis neither helped or hindered the patients as a group and no other factors affected their gait, a proportion of about 0.5 could be expected for all of the parameters, since according to the laws of probability, the pre/post changes would be positive as often as they were negative. It can be seen that all of the parameters, except for range of motion are above the 0.5 level. Two parameters, ROM symmetry and swing/stance ratio, are only slightly above the 0.5 level. Loading Rate Symmetry is somewhat higher. Three parameters, Vertical Load, Loading Rates and Task Time, are well above the 0.5 level. In fact, the number of positive changes in these parameters is significant at the 1 percent level when subjected to the Sign Test for Significance. The parameters of Velocity and Step Length Symmetry are also well above the 0.5 level, but they must be considered with caution since they represent a smaller number of pre/post bracing changes (level surface only).

The results of the weight line photographs were that five of the eight pictures obtained showed a measurable change in weightline location. (A measurable change means a medial or lateral displacement of the line from prebracing to postbracing of 1 mm or more as measured at mid-patella on 3 in. x 5 in. glossy prints). All of the displacements were appropriate; i.e., for a valgus knee, the line was moved laterally and for a varus knee, the line was moved medially.

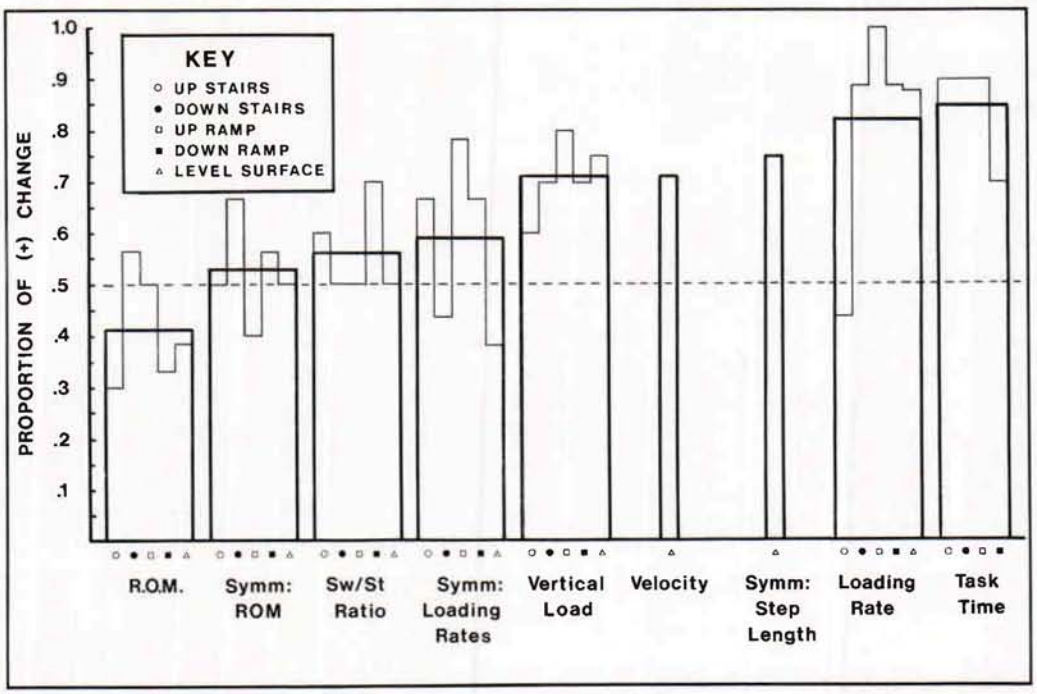

Fig. 13. Proportion of Positive Changes

	Wearing Time				Helpfulness				Better Function				Comfortable?		Good Fit?		Weight Noticeable?		Catch on Clothing?		Soil Clothing?		Cause of Perspiration?		Rub Skin?		Cleaning a Problem?		Do you like its Appearance?		
	All the time	Only inside	Only outside	Not at all	A great help	A moderate help	No help	A hindrance	All the time	Most of the time	Occasionally	Not at all	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Score
1. 78 yrs., DJD Left Valgus	X				X				X				X		X			X		X		X		X		X		X		9.5
2. 53 yrs., DJD Right Valgus		X			X				X				X		X			X	X			X		X		X		X		9.25
3. 47 yrs., RA Right Varus	X				X					X			X		X			X		X		X		X		X			X	8.25
4. 56 yrs., RA Left Valgus	X				X				X				X		X			X		X		X	X		X		X		X		8.0
5. 74 yrs., DJD Right Varus			X		X				X				X		X			X		X		X	X			X		X		X	7.75
6. 61 yrs., DJD Left Valgus	X				X				X				X		X			X		X	X			X		X	X			X	7.5
7. 74 yrs., DJD Left Varus		X			X				X				X		X			X	X			X		X		X	X			X	7.25
8. 53 yrs., RA Left Valgus		X				X					X			X		X		X		X		X		X		X		X			7.25
9. 81 yrs., DJD Left Valgus	X						X					X	X		X		X			X		X		X		X			X		7.0
10. 68 yrs., RA Left Varus			X		X				X					X		X		X	X			X	X		X			X		X	3.75

Fig. 14. Results of the Questionnaire

Questionnaire Results—The data from the questionnaire is presented in Figure 14.

It appears that the patients at the time of the follow-up wore their orthoses at least some of the time, a few wore it all the time. All but one thought it was a great or moderate help and that they functioned better with it. The other patient felt that it was no help. The greatest problems seem to be cosmesis, interference with clothing, and excessive perspiration. There are no obvious correlations between patient responses and age, type of arthritis, or type of instability.

DISCUSSION

The laboratory data indicate that except for range of motion, the overall functional performance of the patients showed general improvement with bracing. How clinically significant the magnitude of these changes are an open question, but there were consistently more positive changes than negative. This was especially true for Vertical Load, Loading Rate and Task Time. These three parameters may be more critical indicators of change than the other parameters. Velocity, being the level surface counterpart to task time may also be a parameter worthy of further study. Although the average performance of the group in Range of Motion showed gains on three out of five surfaces, the pre/post bracing changes were negative more often than positive. This implies that overall, the orthosis does not promote an improved range of motion in the saggital plan. It may in

fact hinder knee movement slightly in some patients. The group gains in range of motion can be attributed to dramatic improvements by patients 3 and 8.

The data from the questionnaire indicate that a majority of the patients tested throught that the C.A.R.S.-U.B.C. orthosis was a reasonably good solution to their knee problem. It must be pointed out, however, that the sample consisted mostly of moderately involved arthritics. An additional twenty candidates refused to participate in the study. Although the severity of involvement of those patients was not documented by the knee scoring scales, it seems probable that most of them would have fallen into the minimally involved or severely involved categories. The patients who were "minimally" involved seemed to reject the orthosis because of its size and cosmesis. They preferred the idea of a knee corset. The "severely" involved patients, particularly those with rheumatoid arthritis, seemed to reject the orthosis because of problems in donning and doffing. Many had hand deformities and difficulty bending forward, which prevented them from doing these tasks independently. Reconstructive surgery was a more palatable option for many of these patients. The moderately involved patient's pain seemed severe enough to outweigh the cosmesis considerations, yet they were capable of donning and doffing the orthosis independently.

Although it was difficult to observe clinically reduced varus or valgus moments when the patients walked, the weight line photographs showed definite alignment changes in some cases. This, along with the generally favorable acceptance of the brace by the patients, leads one to the hypothesis that the orthosis reduces the end-range of a medial-lateral movement. This could be enough to relieve pain. The result is a symptomatic relief but not a dramatic realignment of the limb.

This study should be considered in light of the fact that the patient sample is small, and that there could have been extraneous variables affecting gait in the two to four weeks between tests. Examples of such variables are weather conditions, a temporary remission of symptoms, or a placebo effect from the orthosis.

CONCLUSION

In summary, the study found that the C.A.R.S.-U.B.C. orthosis can exert corrective forces to an unstable knee in the medial-lateral plane. Our sample of moderately involved arthritics generally liked the orthosis, and they showed general improvement in the gait parameters measured.

ACKNOWLEDGEMENT

Grateful appreciation is expressed to the staff of the Arthritis Center at Moss Rehabilitation Hospital for their cooperation in this work.

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Footnotes

[1]Canadian Arthritis and Rheumatism Society—University of British Columbia.

[2]This work was supported in part by Rehabilitation Service Administration, Department of Health, Education, and Welfare under Grant #23P-5551B.

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An Effective Orthotic Design for Controlling the Unstable Subtalar Joint

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GENE BERGLUND[2]

Some 14 years ago, Messrs. W.H. Henderson, J.W. Campbell, and others at the University of California Biomechanics Laboratory gave us the UC-BL shoe insert type of foot orthosis. The concept envisioned in the UC-BL design was excellent. It embodies a design concept that lends itself well to solving a whole range of malalignment and pressure distribution problems of the foot. In the years since 1964, several materials have come to be commonly used in the construction of this orthosis as it has gained wide usage.

Since the advent of the application of the plastic shell design in AFO's and KAFO's, the principles involved in the proper stabilization and support of the pathological foot have gained new and greater recognition as being important. The plastic shell AFO and KAFO give us a "built-in" opportunity to do a superior job of supporting the patient's foot. This cannot be overemphasized. Nowhere is it as true as it is in the field of children's orthotics.

Children with a whole range of neuromuscular disorders demonstrate a large potential and propensity for the development of serious foot deformities. After pes equinus, the most common deformity is valgus instability of the subtalar joint. The diagram in Figure 1 shows how, in the coronal plane, a simple loss of foot inverter strength is sufficient to precipitate a very unstable and progressive condition. Fortunately, in children, this deformity is often flexible, and proper alignment can be achieved passively.

Unfortunately, the foot support configurations we commonly see in contemporary foot orthoses and ankle-foot orthoses

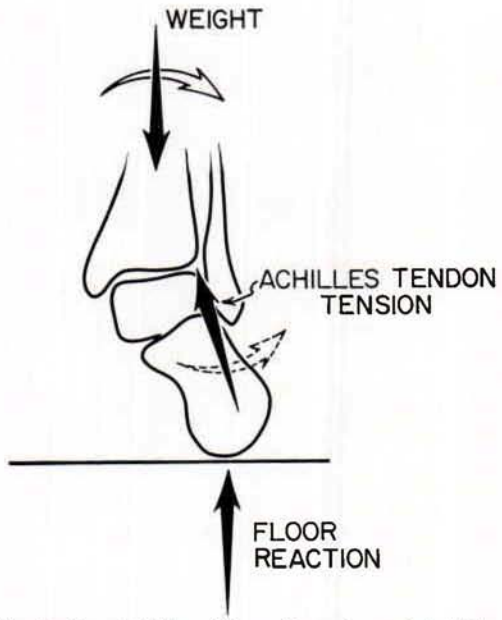


Fig. 1. Destabilizing effects of gravity and Achilles-tendon tension.

for children are not capable of holding the calcaneus in alignment necessary to stabilize the subtalar joint. In fact, it has come to be the opinion of many physicians, after experience with the shoe insert foot orthosis, that the contemporary orthosis is not effective in stabilizing flexible pes valgus when the instability is greater than moderate. This is indeed unfortunate.

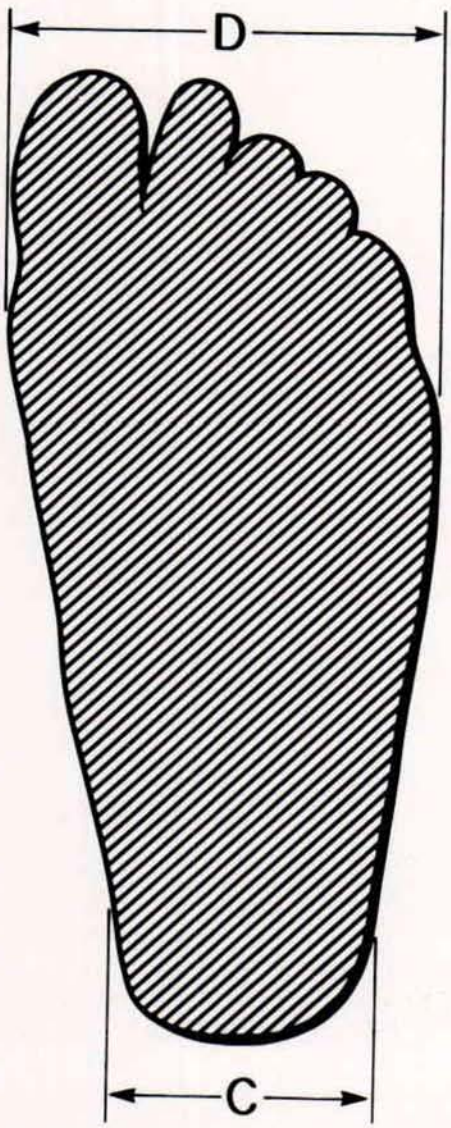


Fig. 2. Medio-lateral measurements of the foot necessary for correction of the plaster positive model.

We doubt that the problem is the use of inappropriate materials, but rather that the problem usually results from a combination of failure to understand the procedures set forth by UC-BL and failure to develop the design beyond what was originally set forth.

This paper will outline the design principles and procedures used at Gillette Children's Hospital, and present a few examples of short range results.

DESIGN PRINCIPLES

To create an effective foot orthosis, we must achieve the following:

- Creation of an inner contour for the orthosis which is capable of giving the foot architecture maximum passive support.
- Positive stabilization of the orthosis in the shoe so that it cannot be rolled into a valgus orientation.
- Stabilization of the shoe on the walking surface.

Although the list progresses obviously from most difficult to easiest, all three elements are essential to success, and none can be ignored.

INNER CONTOUR

Creation of a proper inner configuration begins with an accurate model of the foot. The calcaneus should be well defined in a position of good alignment. The model should possess a longitudinal arch, which needs not to be emphasized anterior to the navicular, since this may cause discomfort while contributing little to the stability of the calcaneus.

There are a variety of procedures and tricks which may be used to obtain a good model. We position the patient supine on a fitting table. The borders of the malleo-

li and the navicular are marked with indelible pencil directly on the skin. We also mark the anterior border of the medial aspect of the calcaneal tuberosity. A piece of surgical tubing is taped longitudinally to the dorsal surface of the foot, and petroleum jelly is applied to the skin avoiding the indelible marks. After applying an elastic plaster bandage, a casting board is pressed against the plantar surface of the plaster covered foot. With one hand, the orthotist grasps the forefoot against the casting board, while the other hand holds the calcaneus in proper alignment. Inward rotation of the foot may also be helpful as outlined in the original UC-BL paper (1). Partial weightbearing is simulated by the orthotist exerting pressure against the base of the casting board.

After obtaining the model, the width of the bare foot is measured at the metatarsal heads and at mid-heel point (Fig. 2). These measurements are taken with the stick pressed against the plantar surface so that a measurement approximating the weightbearing configuration is obtained.

The positive model is smoothed, and the M-L dimension at the metatarsal heads is brought to measurement. The plantar surface at and just proximal to the metatarsal heads and at the heel is flattened precisely perpendicular to the vertical (Fig. 3). In cases where the deformity is severe, it is advisable to flatten the heel at a slight angle (4 deg to 7 deg. depending on severity), by removing more plaster from the medial side. The forefoot is left alone at this point. (It will be shown later how this wedge effect is supported.) Figure 4 illustrates the alignment of the metatarsal and heel flats in the severe case. The M-L dimension of the base of the heel is brought to 0.3 cm. under measurement by removing plaster from the lateral tissue bulge at the base of the heel.

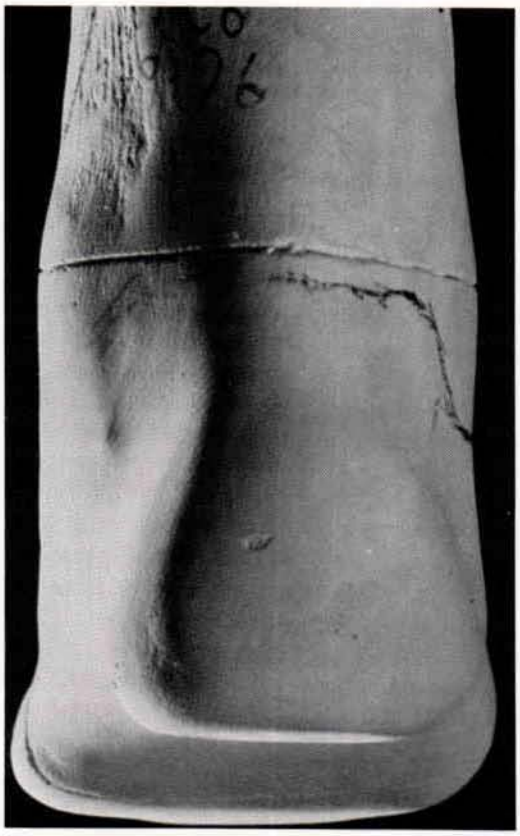


Fig. 3. Posterior view of the positive model showing the orientation of metatarsal head and heel flats.

Perhaps the most important step in cast modification is exaggeration of the posterior aspect of the longitudinal arch (Fig. 5) and blending this in with the medial support area above the calcaneal tuberosity (Fig. 6). At this state, the markings locating the navicular and the calcaneal tuberosity become very important. It is between these two features that it is necessary to remove plaster aggressively in order to create the pressure needed to support directly the calcaneus in the area of the sustentaculum tali (Fig. 7). The amount of plaster removed depends on the size of the foot and the thickness of

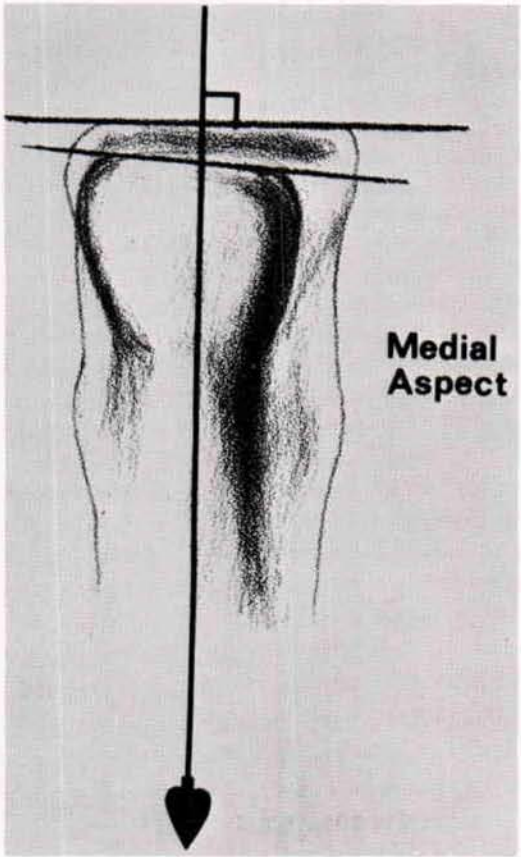


Fig. 4. Diagram illustrating the orientation of the flattened areas in the more severe case. The diagram shows the foot upside down as it would be during modification.

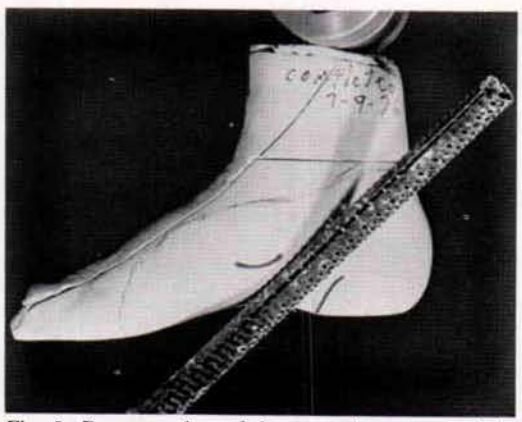


Fig. 5. Exaggeration of the posterior aspect of the longitudinal arch is very important.

subcutaneous tissue. It is not uncommon for us to remove plaster to a maximum depth of 0.8 cm. (¼ inch) on the model of a juvenile foot. To do this without causing tissue damage requires respect of the borders of the calcaneal tuberosity and, especially, the navicular.

The effectiveness of a good supporting inner contour should never be compromised by an improper trim line. Trim lines on the medial aspect should be as high as is comfortable and practical. On the lateral aspect, they can be considerably lower.

Richard Lehneis (2) pointed out several years ago the disadvantages of supporting the midfoot primarily and relying on medial ligaments such as the spring ligament to transmit this support back to the calcaneus (Fig. 8). It is likely that this (latter) approach will merely result in greater hypermobility of the subtalar joint.

STABILIZING THE ORTHOSIS

Positive stabilization of the orthosis in the shoe is accomplished by means of a medial heel extension lump. When the model is covered with hot polypropylene, 0.3-cm. thick, a small piece of hot polypropylene, 0.6-cm. thick, is pressed onto the medio-plantar aspect of the heel portion of the first layer. The result is an extra lump of material fusion-bonded to the outside of the shell. Later, when the assembly has cooled and frozen, the lump is ground down to square it off as shown in Figure 9.

Figure 10 is a cross-section of the foot orthosis without the medial heel extension. As the foot tends to roll the orthosis into valgus, the orthosis will tend to tip up and roll over the point of most medial contact. A resisting moment (W times r, the distance of that point from the weight line) will tend to prevent this from happening. As can be seen from the diagram

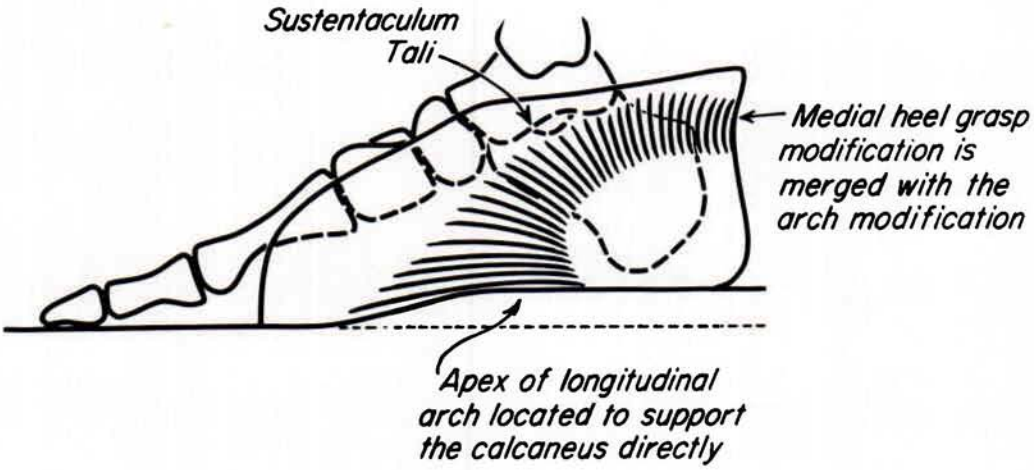


Fig. 6. Diagram of medial support areas.

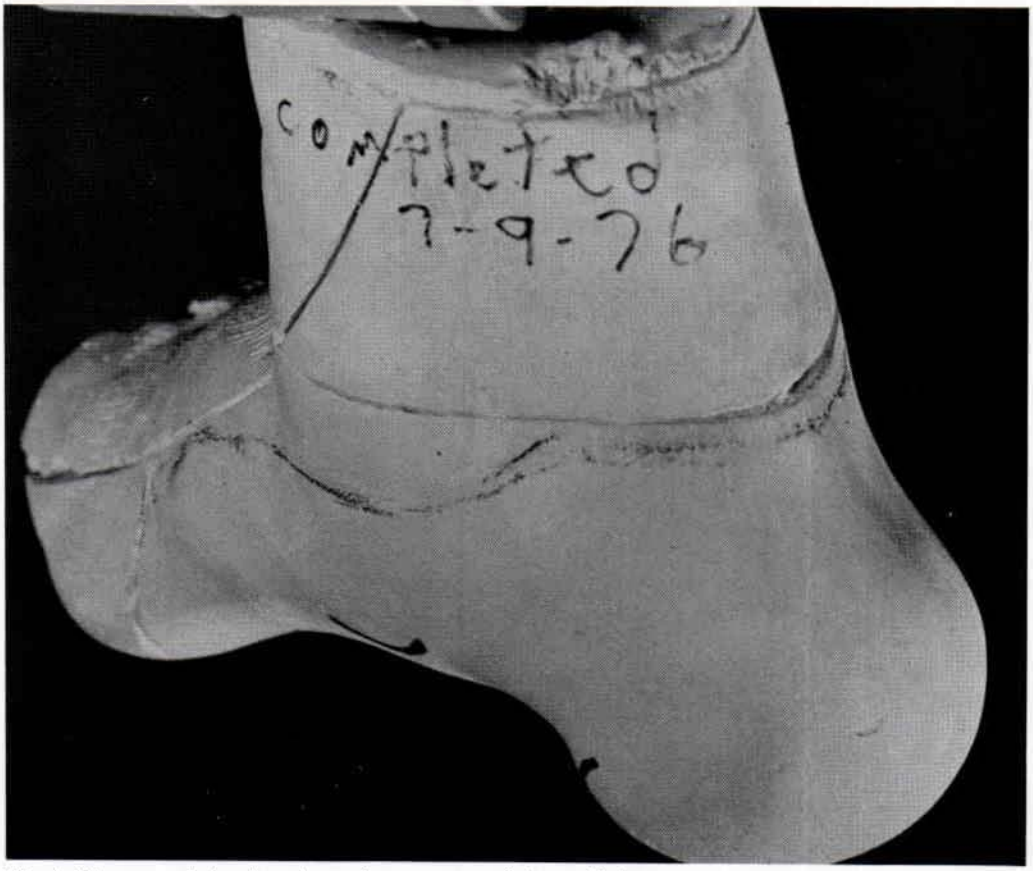


Fig. 7. Photograph showing the surface contour of the medial support area.

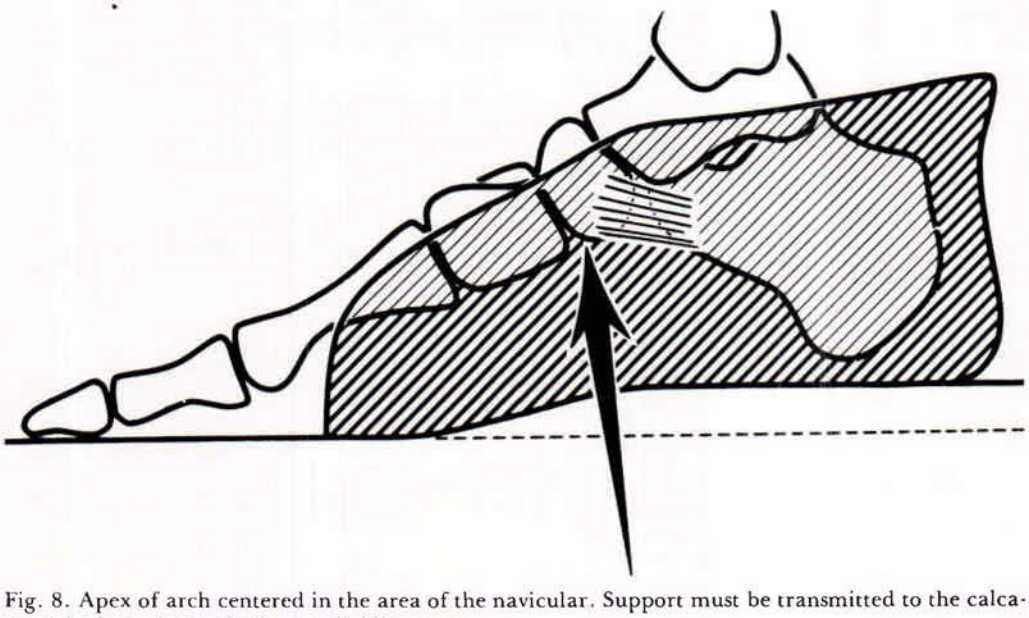


Fig. 8. Apex of arch centered in the area of the navicular. Support must be transmitted to the calcaneus via the spring and other medial ligaments.

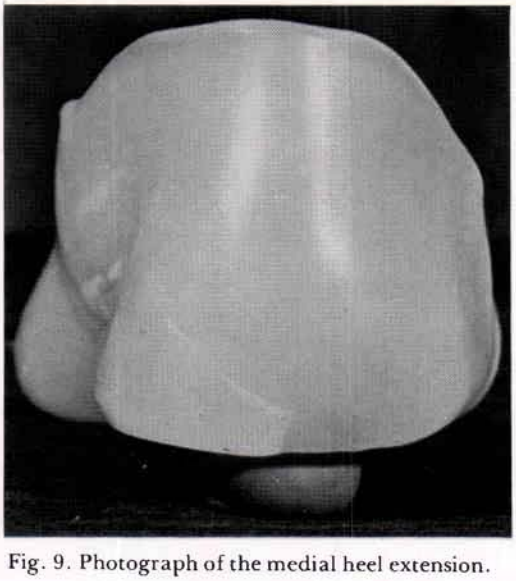


Fig. 9. Photograph of the medial heel extension.

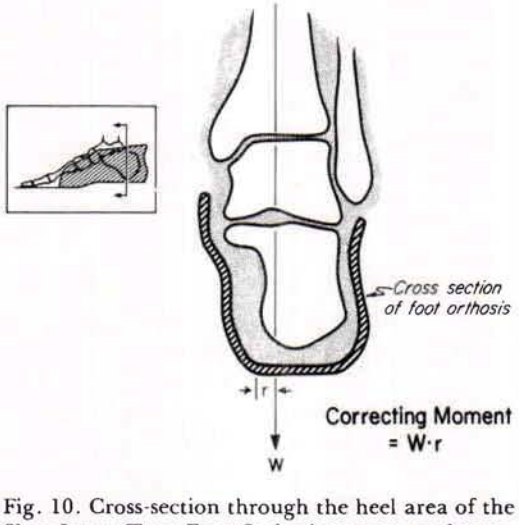


Fig. 10. Cross-section through the heel area of the Shoe Insert Type Foot Orthosis as commonly provided.

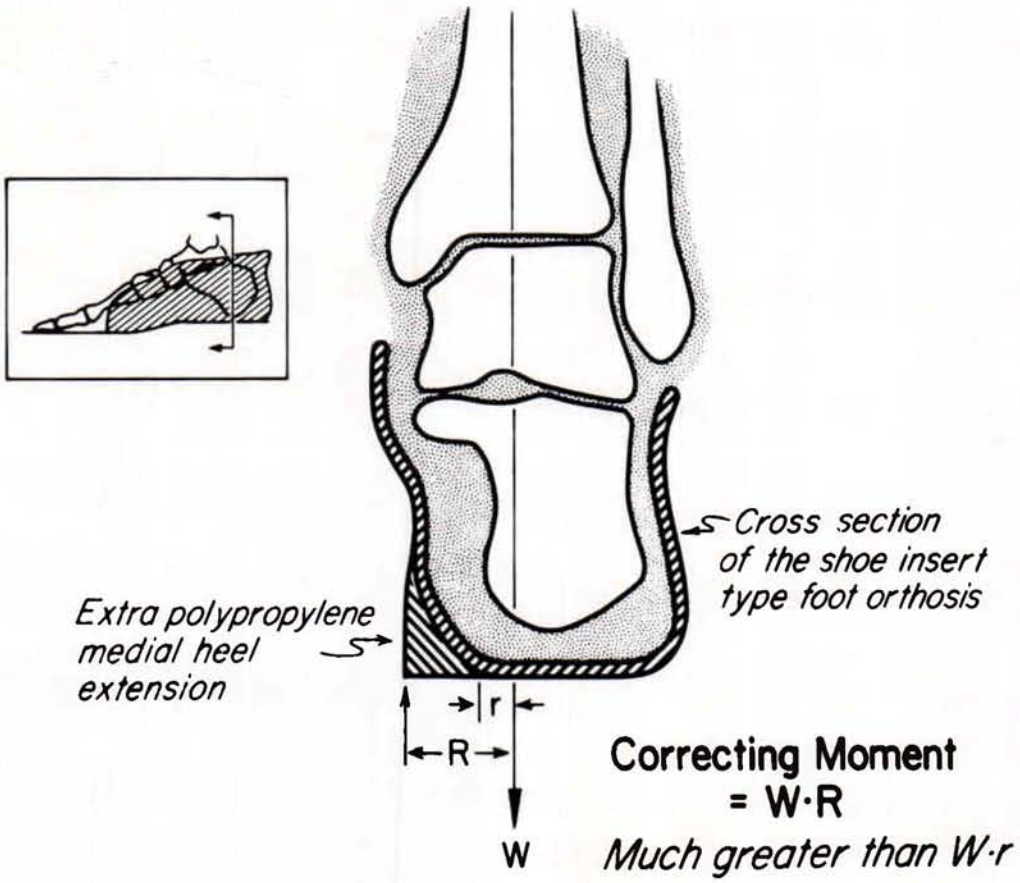


Fig. 11. Stabilizing effect of the extension on the medial aspect of the heel of the Foot Orthosis.

of Figure 11, the addition of the medial heel extension significantly increases the moment arm, R, and it has much greater resistance to being rolled into valgus.

In those more severe cases where we have angled the heel medially, the polypropylene which we added to create a medial extension is utilized also as a wedge (Fig. 12). This wedge should be equivalent to the amount of plaster removed from the medial plantar aspect of the heel during model modification. It extends part way under the heel supporting the orthosis in the correct alignment.

When treating a varus instability, the inner contour of the orthosis will not contain the medial calcaneal support feature, and the extension will be placed on the lateral side of the heel instead of the medial side.

Robert Nitschke (3) has also been using a medial heel extension, but his have been on a design using Orthoplast.

STABILIZING THE SHOE

Stabilizing the shoe on the walking surface is usually not a problem if everything

else has been done correctly. The children seen here wear a wide variety of shoes with their foot orthoses including tennis shoes. We do tell our patients to avoid shoes with narrow heels, especially those made of the softer materials, because such heels may allow the entire foot-orthosis-shoe complex to roll quickly into valgus.

RESULTS

We at Gillette Children's Hospital are pleased about the results we have been getting with this design during the past two years. Most of the children we treat have long range orthopedic problems, and preventing or at least minimizing foot deformities in these children is also a long range endeavor. It should begin certainly while the deformity is still flexible and bone deformities are still minimal. Treatment probably should continue until the deforming forces have been alleviated in the bare foot or through the end of growth, whichever comes first. Perhaps this is a good time to point out that although this foot orthosis does find some application in club foot and other congenital foot deformities, this paper discusses application in the more flexible deformities generally acquired after birth.

Figure 13 is the photograph of the foot of a six-year-old child with myelomeningocele. Although her deformity is serious, the calcaneus can still be brought into good alignment (Fig. 14). The photos of Figures 15A and 15B show her moments later in her orthosis. Although her shoe and orthosis obscure the view of her foot, there seems little doubt about the improvement.

Figure 16 is a photograph of the feet of a ten-year-old child with a glycogen storage disease. Again the deformity is quite severe, but flexible. Figure 17 shows two views of him standing in his orthoses.

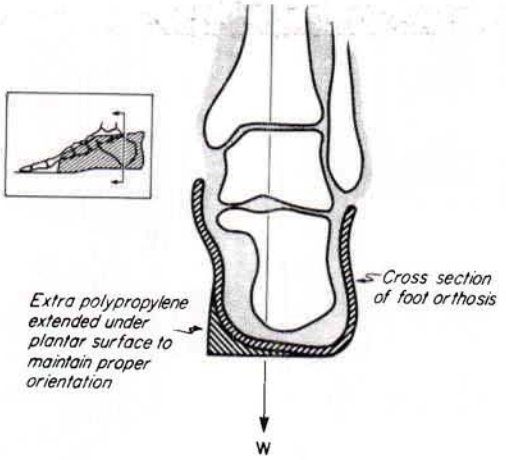


Fig. 12. The polypropylene medial heel extension is ground flat on a horizontal plane to create a wedge supporting the orthosis in proper alignment.

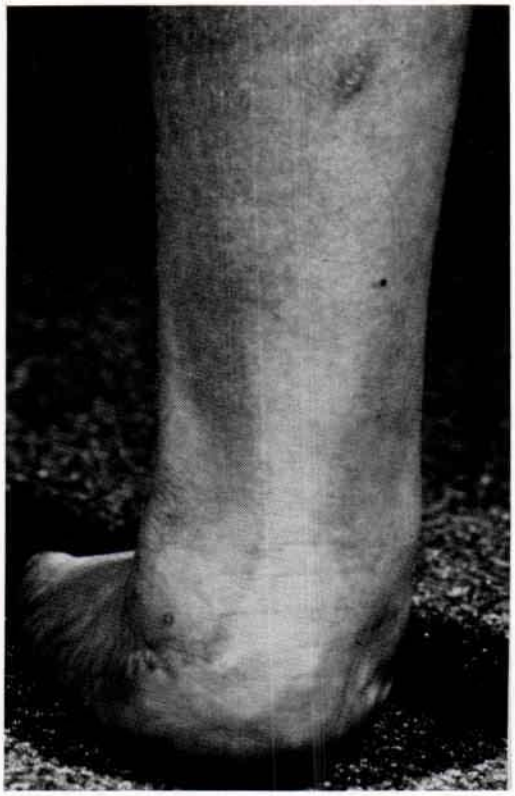


Fig. 13. Photograph of the weightbearing foot of a six-year-old child with myelomeningocele.

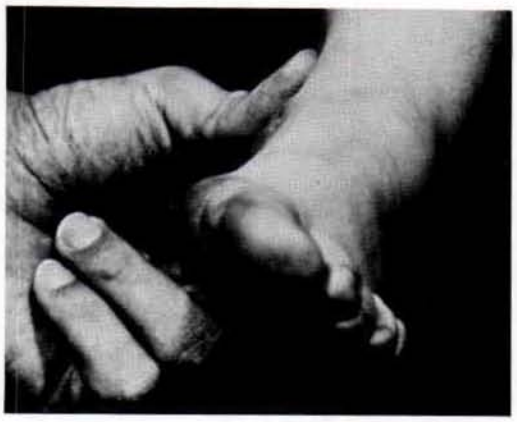


Fig. 14. Illustration of the flexibility of the foot deformity in the six-year-old child.

Probably better than 80 percent of our patients who require orthotic treatment across the ankle or across the knee and ankle possess a potentially serious valgus instability of the subtalar joint. The techniques outlined for generating a supporting inner contour are used to equally good advantage in our plastic AFOs and KAFOs. Proper alignment and support below the subtalar joint reduces or eliminates the need for valgus corrective straps and padding above the ankle.

The purpose which the outrigger lump serves on the FO is generally, of course, not appropriate on the AFO or KAFO.

Finally, the subtalar joint also exhibits some plantar and dorsiflexion motion

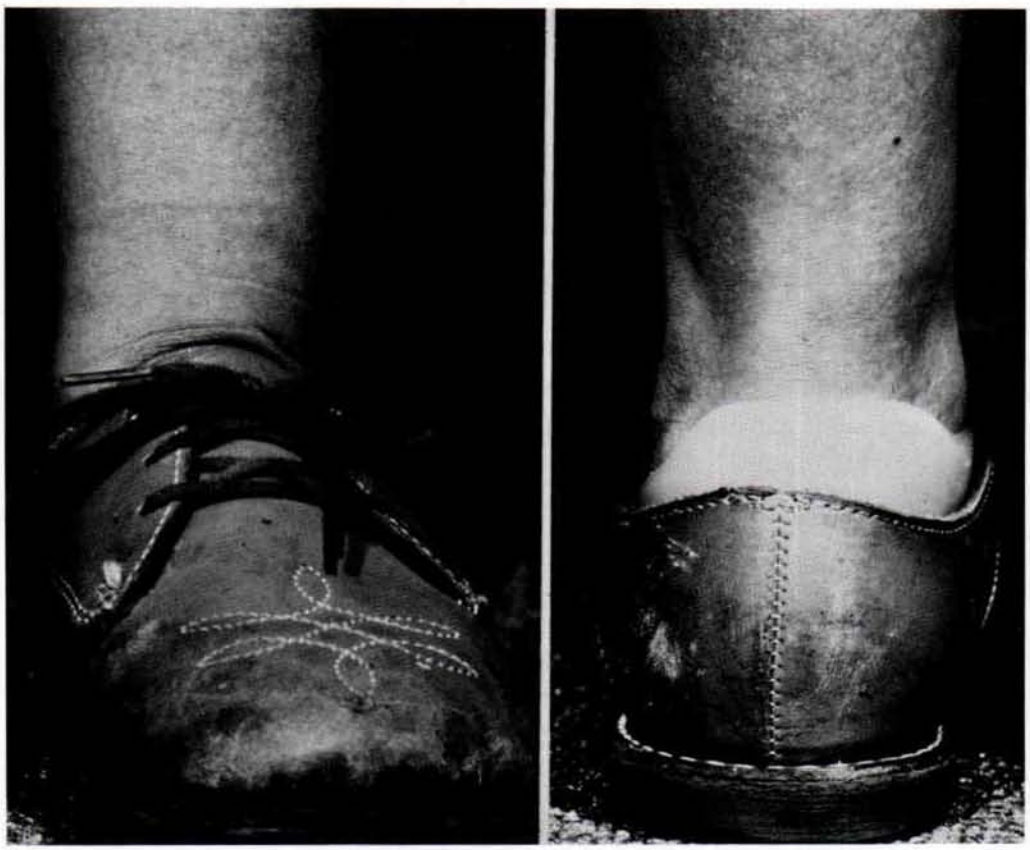


Fig. 15. Photographs of the same six-year-old in her Foot Orthosis and shoe.

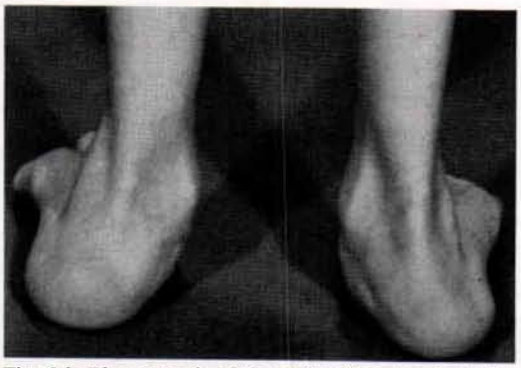
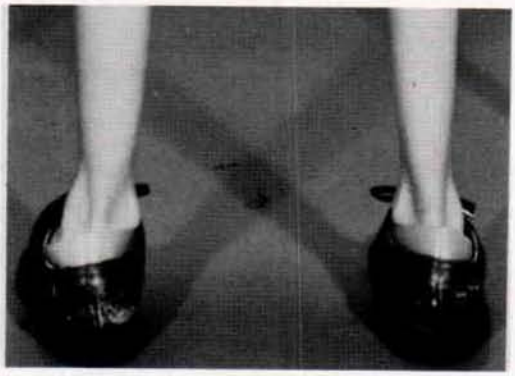


Fig. 16. Photograph of the weightbearing feet of a ten-year-old child with a glycogen storage disease.



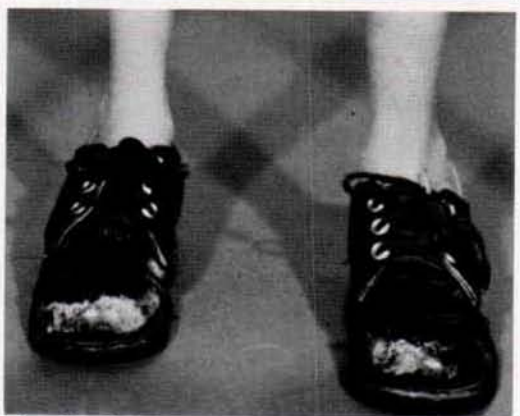


Fig. 17. Photographs of the child of Figure 15 wearing his Foot Orthoses and shoes.

and transverse rotation. We do not want to leave this subject without commenting briefly on what happens in the sagittal plane.

The top view in Figure 18 is the lateral weightbearing X-ray of the bare foot of the girl in Figures 13, 14, and 15. The navicular is in very close proximity to the floor, and it can be seen easily that the calcaneus and talus are in a relatively plantar-flexed position.

The bottom view of Figure 18 is an X-ray moments later of her foot in the orthosis and bearing weight. Weight-bearing forces have obviously been shifted forward and medially off the tuberosity of the calcaneus. The distance from the navicular to the insole has been almost doubled. The flesh pad under the calcaneal tuberosity is now almost twice as thick, proving decompression, but the calcaneus and talus are still relatively plantarflexed. Obviously, this aspect of the deformity is not as flexible as the valgus instability.

When plantarflexion of the calcaneus is due to spastic plantar-flexor muscles, it is pretty clear that both surgical and orthotic treatment are required for correction. This child does not have this problem, and tight ligaments are probably preventing the hind foot from assuming a more dorsiflexed position with respect to the forefoot. It will be interesting to see if these ligaments loosen with time, allowing the talus and calcaneus to assume a more normal dorsiflexion angle.

ACKNOWLEDGMENTS

The authors wish to acknowledge the contributions made by the other members of the Orthotic and Prosthetic Laboratory at Gillette Children's Hospital. The sketches and diagrams were by Carol Novak. The photography was by Ken Jandl and Gordon Dunn.

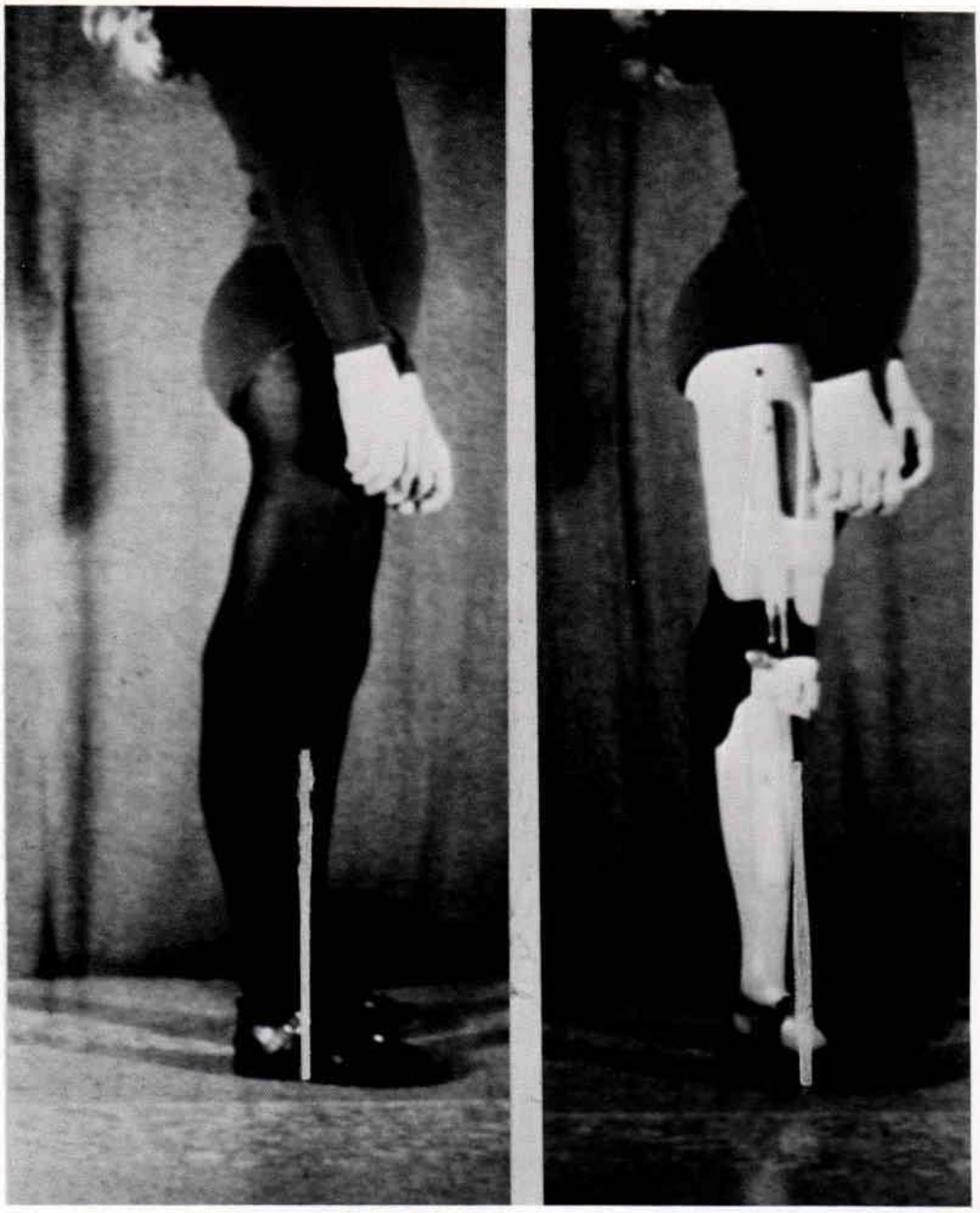


Fig. 18. Lateral weightbearing X-rays of six-year-old patient shown in Figures 12, 13, and 14 in lateral weight-bearing without orthosis (top) and with the orthosis (bottom)

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Orthotic Management of the Late Postpolio Patient[1]

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REBECCA CRAIK[3]
THOMAS M. COOK[3]

Since the introduction of a vaccine in 1954 by Dr. Jonas Salk, poliomyelitis has ceased to be the scourge that it once was in the western nations. This is not to say that polio is not still with us, for it is a very real presence in many parts of the world, and in the developed countries sizable populations affected in youth remain. It is this latter group that is the concern of this paper for it has been noted by a number of practitioners that an increasing number of older post-polio patients are seeking orthopedic solutions for their problems. The challenge presented by such a patient is a formidable one, and, while we can certainly not claim to have all the answers, we have garnered some experience and attempted to formulate guidelines which we herein offer for consideration.

Infantile Poliomyelitis is a viral infection that affects the anterior horn cells of the spinal cord resulting in flaccid paralysis but leaving the sensory system intact. It affects primarily the lower limbs. The two features, flaccidity and sensation, result in the common pathological picture regardless of the level of involvement. Good early management and the absence of spasticity has produced patients that are typically free of severely deforming flexion contractures and are able to adopt such compensatory movements as genu recurvatum and to otherwise make the best use of the remaining musculature.

Conversely, the lack of supporting muscles with their resilience and shock absorbing capacity implies that joints are prey to arthritic deterioration and the gradual stretching of ligaments, both of which may result in disabling pain. In a similar fashion sensation offers definite advantages and potential long term disadvantages. Unlike patients with injury to the spinal cord, the individual with polio is able to make optimum use of remaining muscles and thus a knowledge of joint positions to substitute for missing function. However, increasing deformity about the joints can result in pain and a decrease in function.

THE CLINICAL PICTURE

In general, postpolio patients are referred for one of two basic problems, although both as well as others are often present in the same patient. The first and possibly the easiest to cope with is pain. Pain can result not just from wear and tear, but also from angular deformity that unduly stresses supporting elements of the involved joint. It must be borne in

mind that these angular deformities are often of a functional nature. The goal in treatment is not to restore correct alignment, but to block the extreme of motion and reduce the pain to a tolerable level. Genu recurvatum is the best example of this principle.

The other broad category encountered is debility and an ensuing inability to cope as well as before. Frequently the increase in debility has been gradual and undramatic, and the patient complains of an increase in fatigue, unsteadiness, and experiences more falls than was the case formerly. In other instances the patient is seen under more dramatic circumstances in the aftermath of some recent illness or surgery (itself often times a result of increasing age) or after healing of a fracture (possibly a side effect of the unsteadiness cited above). In these instances, the loss in strength can be pronounced and is a considerable source of concern to the patient. In any event, this broad category of increasing debility is a difficult one to cope with and the goals must often be of a limited nature. It may well be that the only recourse is to stop motion at a joint so as to further compensate for a failing compensatory motion in order to increase safety and enable the patient to use available resources to a better effect elsewhere. In either category the problem for which help is sought is not necessarily in the most severely involved extremity, but in the so-called "sound side." The limb may be failing as a result of the high loads put on it over the years and the best treatment may well be to restore the more severely involved leg to a more functional state, thus relieving the "sound side" of its unequal share of the load.

As a result of their intact sensory system and capability for compensatory motions, when first seen patients may well relate a history of having discarded whatever orthosis had been provided previously or of retaining only a portion of it. This abandonment is generally described with pride as an example of recovery (as well as a benefit of tendon transfers and bone blocks) and of the patient's ability to find a satisfactory solution to his own problems despite the somewhat ineffectual, but well intentioned help of a clinical team years ago. When this attitude is coupled with the normal aversion to wearing an orthosis that is not strictly necessary, it is not hard to understand the anxiety and even outright hostility with which any suggestion that an orthosis may be needed is greeted. It is difficult to convince them that with age their stamina and strength have decreased, adversely affecting their ability to compensate. It is equally hard to convince them that whatever measure of deformity and pain they are experiencing is quite likely to progress with debilitating results unless some measure of prophylatic treatment is instituted and maintained. Winning their confidence and cooperation is a formidible obstacle that must be accomplished by the clinic team.

This discussion of the clinical picture is of a general nature and is compiled not just from our own somewhat limited clinical experience, but also from discussions with other professionals seeing similar numbers of patients. It is put forth, not as a totally accurate and all inclusive description, but as an orientation to a problem that is uniquely difficult and infrequently encountered by most clinical teams.

PRESCRIPTION PRINCIPLES

Orthotic prescription for the postpolio patient is a formidable problem, not only owing to the physical condition of the patient, but also because of the individual's past experience with orthotic devices.

The patient may have rejected all orthoses at some point in the past and may be unwilling to consider an orthosis now. In another instance, the patient may have worn one particular orthosis for years and be completely opposed to any change. This hesitancy is best overcome by citing the advances in materials and fabrication techniques that have been made and the potential benefits these changes offer. Orthoses fabricated from polypropylene, polyethelene, and aluminum joints around an individual mold taken from the patient's limb offer not just greater comfort, cosmesis, and improved control, but also lighter weight, an important consideration for those individuals with full sensation and decreased strength. In addition, that the shoe need not be an integral part of the orthosis is a telling point for it means that the patient will have a wider range of footwear available and will be able to change shoes with almost total freedom.

During the formulation of the prescription and the actual fitting process, the need for compromise and "tailoring" of the orthosis must be kept in mind. It is often difficult to determine the real needs of the patient and the practitioner may find himself imposing his misconception of the problem on the patient, to their mutual frustration. At all times the clinic team must be willing to sacrifice secondary goals in order to retain primary ones. Wearing of an orthosis implies not only acceptance of its advantages, but also its disadvantages and to win acceptance it is necessary to "maximize" the one and "minimize" the other. Some portion of the orthosis may not only be uncomfortable or cumbersome, but actually interfere with compensatory motions with disastrous implications. The need is to decide whether or not the offending portion can be sacrificed without adverse effects. This is nothing more than a reiteration of the principle that an orthosis should perform only the intended function and nothing more, but it cannot be emphasized enough when dealing with the postpolio patient.

The fitting process is likely to be a long and arduous one demanding much patience and tact from all concerned. A decision to fit the postpolio patient should not be taken lightly and the prescribing physician will spare both the orthotist and the patient needless frustration, expense, and inconvenience if he will first determine not just a real pressing need for an orthosis, but also a sincere willingness on the patient's part to accept such a solution. Moreover, everyone should know beforehand that success is not assured and when it is abundantly clear that a successful solution is impossible, they should be willing to face the facts squarely and call it "quits" on good terms.

CASE HISTORIES

The following case histories have been chosen to illustrate one or more points made in the previous discussion.

CASE NO. 1 (Fig. 1)

C.H. is a 24-year-old speech therapist with an onset of polio at age four. Despite general weakness, hip flexion contractures, and a lower-limb length discrepancy, she has walked with crutches and led an independent life. In the summer of 1977 she was seen by the prescribing physician, complaining of difficulty with gait, increased fatigue, discomfort in stance, and occasional buckling of the right knee. Examination revealed that her more involved side, the right, demonstrated shortening, subtalar inversion, and genu valgum and recurvatum. In

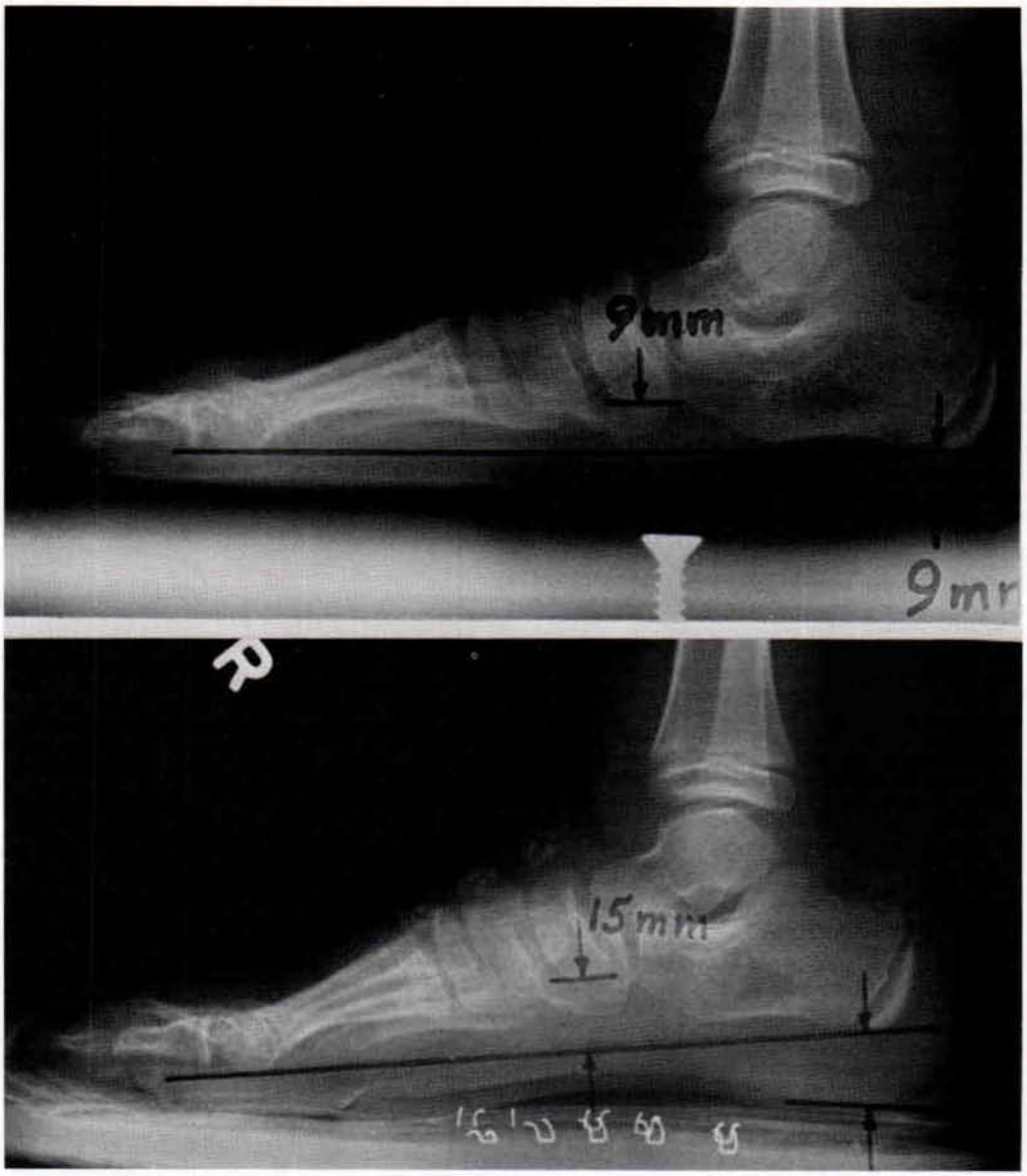

Fig. 1. C.H. with and without KAFO. Weightline visualization techniques demonstrate the improvement in alignment with a decrease of Genu Recurvatum. For an explanation of weightline visualization consult reference 7.

addition, it was determined that the left knee demonstrated recurvatum. Following examination in the Gait Clinic it was decided to fit the more severely involved, right, leg with a KAFO with offset knee joints and optional drop lock to support the ankle and limit the painful genu valgum and recurvatum. Following ini-

tial delivery of the orthosis the patient was seen a number of time for minor adjustments. At the last consultation, she was walking with a free knee and reported a cessation of pain in both knees. As a result, plans to apply an orthosis to the "sound" left knee were abandoned.

CASE NO. 2 (Fig. 2)

L.S., a 64-year-old male, was seen on referral to be fitted with a new orthosis lighter than the one he had been wearing for some 20 years. A printer by trade, L.S. had been fitted originally with an orthosis after a fall at work in an attempt to prevent reoccurrences and potential damage to the knee. Examination revealed that the residual effects of polio were essentially confined to the one limb and that the orthosis was forged of carbon-steel with partial ischial gluteal weightbearing, bail lock, and a sandal that fitted inside of the shoe. The patient's only real complaints with this orthosis were the bail lock which interfered with his pants and the need for shoe modifications to accommodate the sandal. A previous attempt had been made to fit him with a polypropylene orthosis without success. The patient stated that he felt insecure in this orthosis and objected to the drop locks. It turned out that his orthosis had been fabricated without ischial gluteal weightbearing and that the knee sagged into flexion on weightbearing. An impression was taken and a new polypropylene orthosis was fabricated, in which ischial

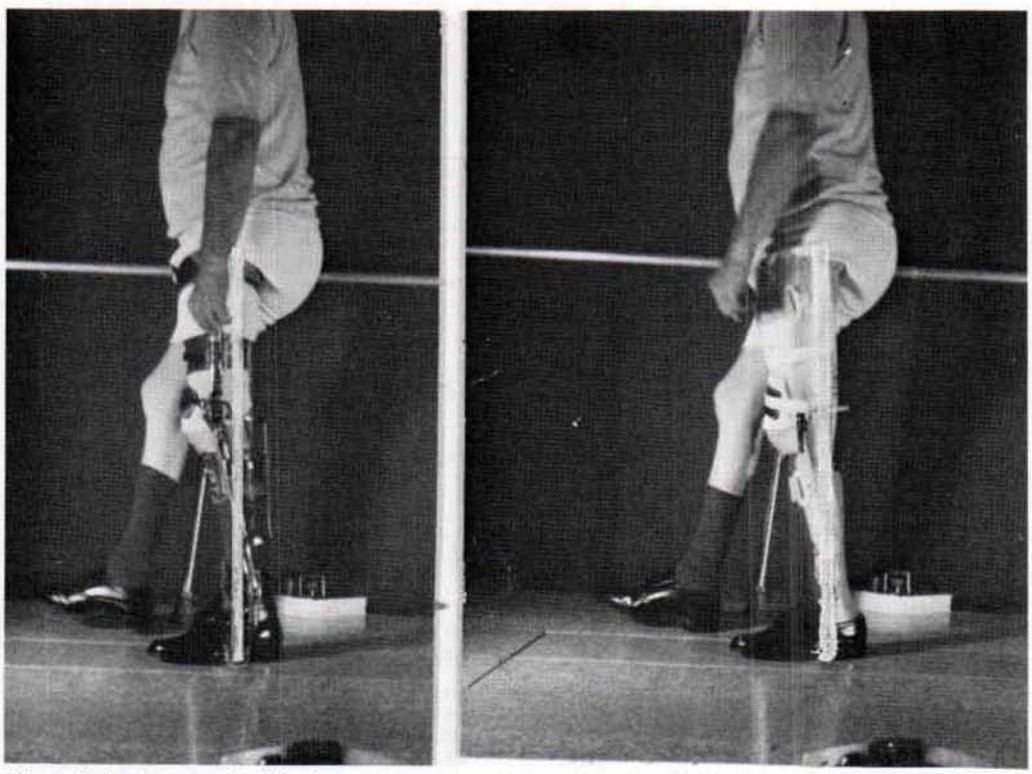

Fig. 2. L.S. photographed in the same instance of the gait cycle with his old steel orthosis and the new one fabricated of lightweight materials. Alignment is essentially unchanged as demonstrated by the position of the weight line relative to the limb.

gluteal weightbearing and a bail lock were incorporated. Considerable effort and several fitting sessions were necessary to adjust the KAFO to the patient's satisfaction. While he appreciated a decrease in weight, it was only after the new orthosis fitted as well as the old one that he preferred it to his original.

CASE NO. 3 (Fig. 3)

L.B., a 35-year-old female with a history of polio at age 12, was referred to us with a prescription for bilateral KAFO's to support her painful knees. She was ambulatory despite a pattern of such diffuse weakness that she was unable to rise from a normal height chair without assistance. Essentially, the only muscles better than trace or poor in the lower limbs were her toe flexors, and to walk she found it essential to wear shoes with high heels. The functional genu recurvatum that enabled her to walk had been causing an increase in pain just prior to her appearance at the clinic, and she was using a wheelchair more than before. Due to the unique nature of her gait pattern and the role played in it by the compensatory motions and her musculature, it was decided that it was vital to address only the specific complaint with as few side effects as possible. After gaining the physician's approval to a change in prescription, she was cast for bilateral supracondylar knee orthoses (S.K.O.'s) as described by Hans R. Lehneis. The intention was to block only the extreme of genu recurvatum and thus the pain without interfering with the vital function this compensatory motion played in her life. As a result of the high loads generated in the soft tissues and the shrinkage that resulted it was necessary to see the patient persistently over a period of six months for adjustments before a stable state that was both comfortable and functional was achieved. Follow up after a year and a half reveals that she is still wearing the orthosis.

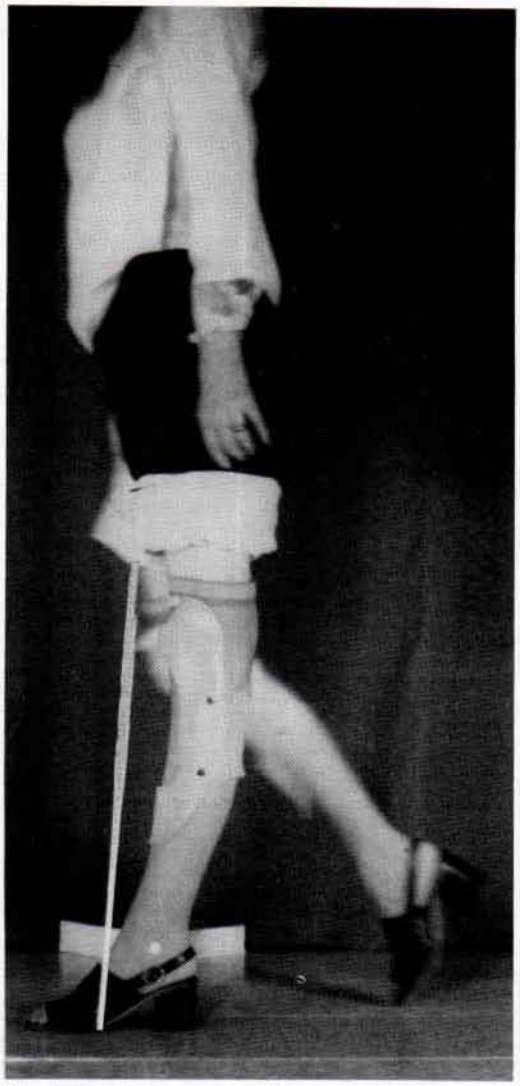

Fig. 3. L.B. photographed with weightline visualization techniques and ambulating with bilateral supracondylar knee orthoses. Recurvatum and the torque generated by the force line in the right knee are readily appreciated.

CASE NO. 4 (Figs. 4 and 5)

M.R., a 59-year-old male who had polio at age three, was seen for treatment of progressive genu valgum and recurvatum in the right leg. He has worn a Swedish knee cage unsatisfactorily for this condition, and has walked for many years with crutches. The condition has worsened since he fractured his left hip two years before presenting. In addition there is marked involvement of both feet. After discussion with the patient and the clinic team a plastic impression was made and a KAFO with single axis free flexion knee joints was fitted. During the initial fitting it was necessary to extend the trimlines about the knee and add a broad leather band to win patient acceptance. Subsequently he was seen because the orthosis felt heavy (2½ pounds), cumbersome, and interfered with driving and stair climbing. To meet these objections all function about the ankle was sacrificed, rendering the ankle portion flexible and purely a suspensory component. Material was removed where possible in other areas, and the broad leather strap posterior of the knee was replaced by a one-inch-wide Dacron strap that passed in an oblique fashion from one side over to and about the joint on the opposite side of the knee and back again (Fig. 5). This idea for knee control was borrowed from Robert Nitschke's design for a single upright KAFO, and the patient found it

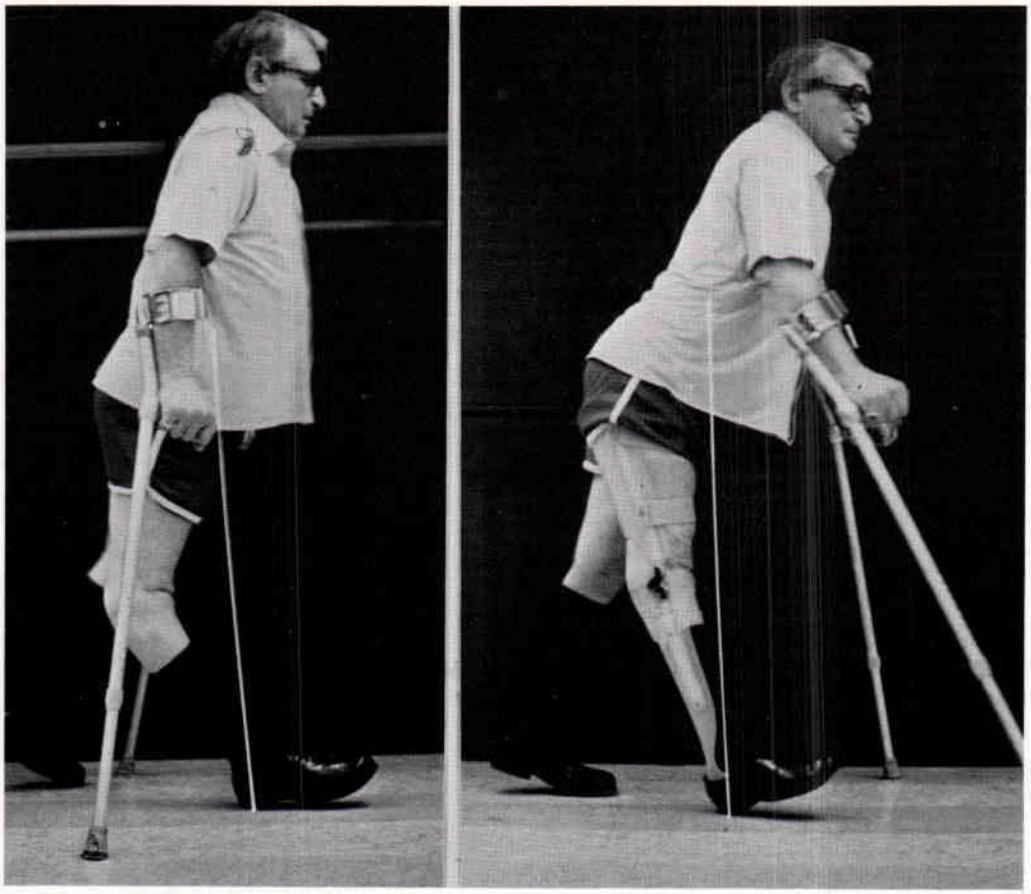

Fig. 4. M.R. ambulating in walkway without and with the orthosis.

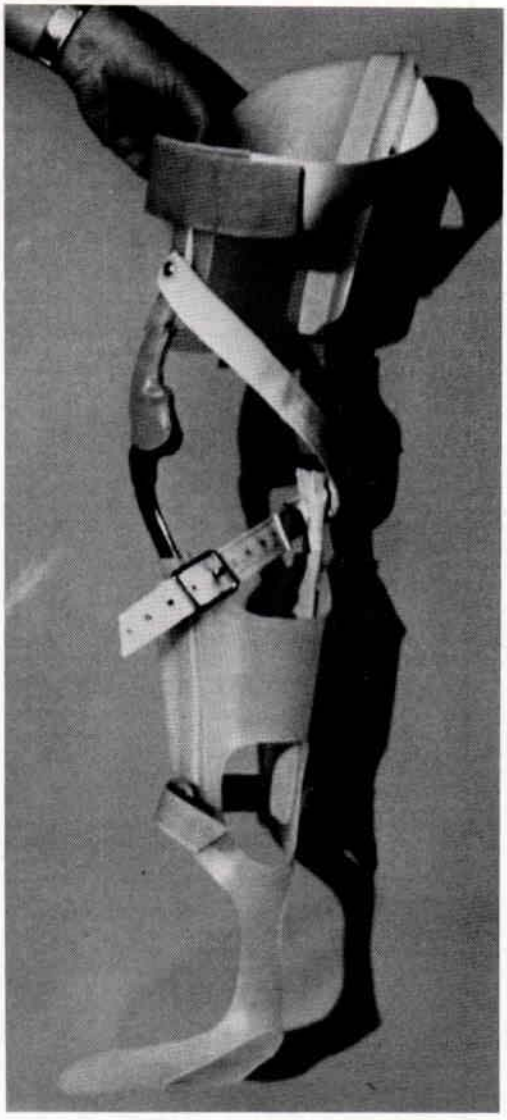

Fig. 5. Ultimate configuration of M.R.'s orthosis. Proximal thigh section covers the anterior portion of the limb and at the patient's request the heel portion of the foot plate has been eliminated, without deleterious effects. The ankle portion has been reduced to a very flexible leaf spring and serves only for suspension of the more proximal portions of the orthosis.

more comfortable than the previous arrangement. He has been seen since for adjustment to the ankle and addition of a strap over the distal tibia for proper control of the genu recurvatum which the patient found to be comfortable and tolerable. The net result after some effort is an orthosis that specifically controls the undesired motion at the knee and sacrifices any other function in order to win the patient's acceptance. Subsequent to the original fitting period the patient was seen for replacement of the distal lateral upright which had broken from the stress applied to it by the oblique strap. While he had formerly been reluctant to wear an orthosis the patient now stated that he was unable to do without one and found the present KAFO of considerable benefit.

DISCUSSION

That postpolio patients are currently presenting with increased muscle weakness, skeletal deformity, and joint pain which is interfering with a previously achieved level of independence is corroborated in several other documented case studies (1,2,3). A common explanation for this functional deterioration has been that paretic or flail musculature cannot provide adequate joint and long-bone protection and thus leads to ligamentous laxity, articular damage, deformity and pain. This rationale has been applied regardless of the etiology for these clinical symptoms, e.g., inadequate surgical or orthotic intervention in early management, lack of appropriate follow-up, and chronic stress on inadequate tissues. However, a review of the literature yields very few attempts to correlate these or any other etiological factors to the clinical manifestations. Moreover, the studies cited seriously question the validity of this common clinical assumption (4,5,6).

The additional muscle weakness with which these patients present has been attributed to chronic stress on inadequate tissue which leads to trauma and fatigue. In an attempt to relate this etiology to the latent weakness, Campbell, Williams, and Pearce presented five case studies and reviewed 83 similar cases presented in the literature (4). The only conclusion drawn from this study was that the latent weakness followed a benign course. Examination of the sites of the involved muscles did not justify the selection of stress as the sole causative factor. Additional explanations for this muscle weakness included reoccurrence of the original disorder, persistence of a latent virus or a secondary biochemical disorder.

An explanation used to explain the presenting symptoms of deformity and pain is that prior surgical intervention is no longer adequate leading to unwanted joint motion and degenerative joint changes. Robins examined the late results of triple arthrodesis, a standard operation used to stabilize the foot in patients with poliomyelitis (5). Sixty feet of poliomyelitis patients who had undergone surgery ten to twenty-four years previously (mean = 19 years) were examined. Robins reported only a low incidence of lateral ankle instability indicating the long-term success of this intervention and a striking absence of osteoarthritis of the ankle joint.

Glynn, et al (6) examined the presence of osteoarthritis in the lower limbs of patients with poliomyelitis. The hip and knee joints were examined in 100 patients who had been diagnosed as having poliomyelitis at least ten years previously. Patients selected had primary involvement in one lower limb, wore a "long-leg" orthosis, and ambulated regularly. Both lower limbs of each patient were examined and a similar number of age and sex-matched healthy subjects were used as controls. The results indicated that the osteoarthritis demonstrated radiographically in the joints of the more involved limb was considerably less than that found in the stronger limb. This could be explained by assuming that the stronger limb was absorbing most of the weight, thereby sparing the more involved limb. However, the incidence of osteoarthritis was similar when comparing the radiographic findings of this limb to the lower-limb joints of the control sample. The explanation that the polio patients generally ambulate less than healthy subjects and therefore require longer to develop degenerative problems was also examined. There was no indication that the patients who were more active had any increased incidence of osteoarthritis when compared to those patients who walked less frequently; furthermore, these patients were presenting with the symptoms generally ascribed to degenerative joint disease, e.g., pain and deformity. These data refute the common assumption that chronic stress on a muscularly inadequate limb leads to osteoarthritis. In fact, the incidence of osteoarthritis was significantly lower than that found in the age and sex-matched healthy control sample. These findings led the authors to suggest that the residual paralysis following poliomyelitis in some way hinders rather than promotes the development of osteoarthritis.

This cursory review of the literature raises questions of a fundamental as well as a clinical nature. It appears that the underlying mechanisms responsible for the clinical symptoms merit further investigation and should include the following: 1) the etiology of the latent muscle weakness; 2) the physiological mechanisms responsible for the apparent prevention of osteoarthritis in this population; 3) the source of the persistent complaint of joint pain in the absence of any degenerative disease; 4) the implications of these findings to other disease cate-

gories which produce chronic disability, e.g., cerebral vascular accident, cerebral palsy, spina bifida. Furthermore, although an increasing number of postpolio patients are returning for clinical treatment, there is a surprising dearth of literature to which the clinician can refer. No literature was found which presented a comprehensive clinical picture of these patients nor were there articles to suggest a management regime. Perhaps an investigation into the long term effects of orthotic or surgical intervention for this patient population would provide insight into the early management of other disease categories which produce chronic disability.

Footnotes

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December, p. 3

Title Index

RESOLUTION CONCERNING THE METRIC SYSTEM

The following resolution was adopted by the Board of Directors of the American Orthotic and Prosthetic Association at its meeting in San Diego October 3, 1973:

WHEREAS by Act of Congress it has been determined that the United States should proceed towards adoption of the metric system as used almost universally throughout the rest of the world, and

WHEREAS the technological professions and many segments of the health professions have commonly used the metric system over an extended period of time, and

WHEREAS it is important for members of the orthotic/prosthetic professions to interact with their colleagues in the medical and technological communities for optimum patient service be it hereby

RESOLVED that the American Orthotic and Prosthetic Association endorses the use of the metric system by its members and other orthotic and prosthetic practitioners in the United States, and in witness of this endorsement and Association urges the editors of its journal *Orthotics and Prosthetics* to commence the dual reporting of weights and measurements in both the English and metric systems at the earliest possible date with the objective of employing the metric system solely by the time of the 29th Volume in 1975.

METRIC SYSTEM
Conversion Factors

LENGTH

Equivalencies

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

To Convert from	To	Multiply by
inches	meters	0.0254‡
feet	meters	0.30480‡
yards	meters	0.91440‡
miles	kilometers	1.6093

AREA

To convert from		
square inches	square meters	0.00063616‡
square feet	square meters	.092903

VOLUME

Definition

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

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

MASS

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

FORCE

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

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

STRESS (OR PRESSURE)

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

TORQUE (OR MOMENT)

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

ENERGY (OR WORK)

Definition

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

1 cal (gm) = 4.1840 joules

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

TEMPERATURE CONVERSION TABLE

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

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

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

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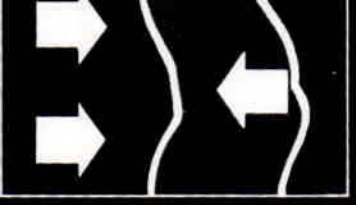

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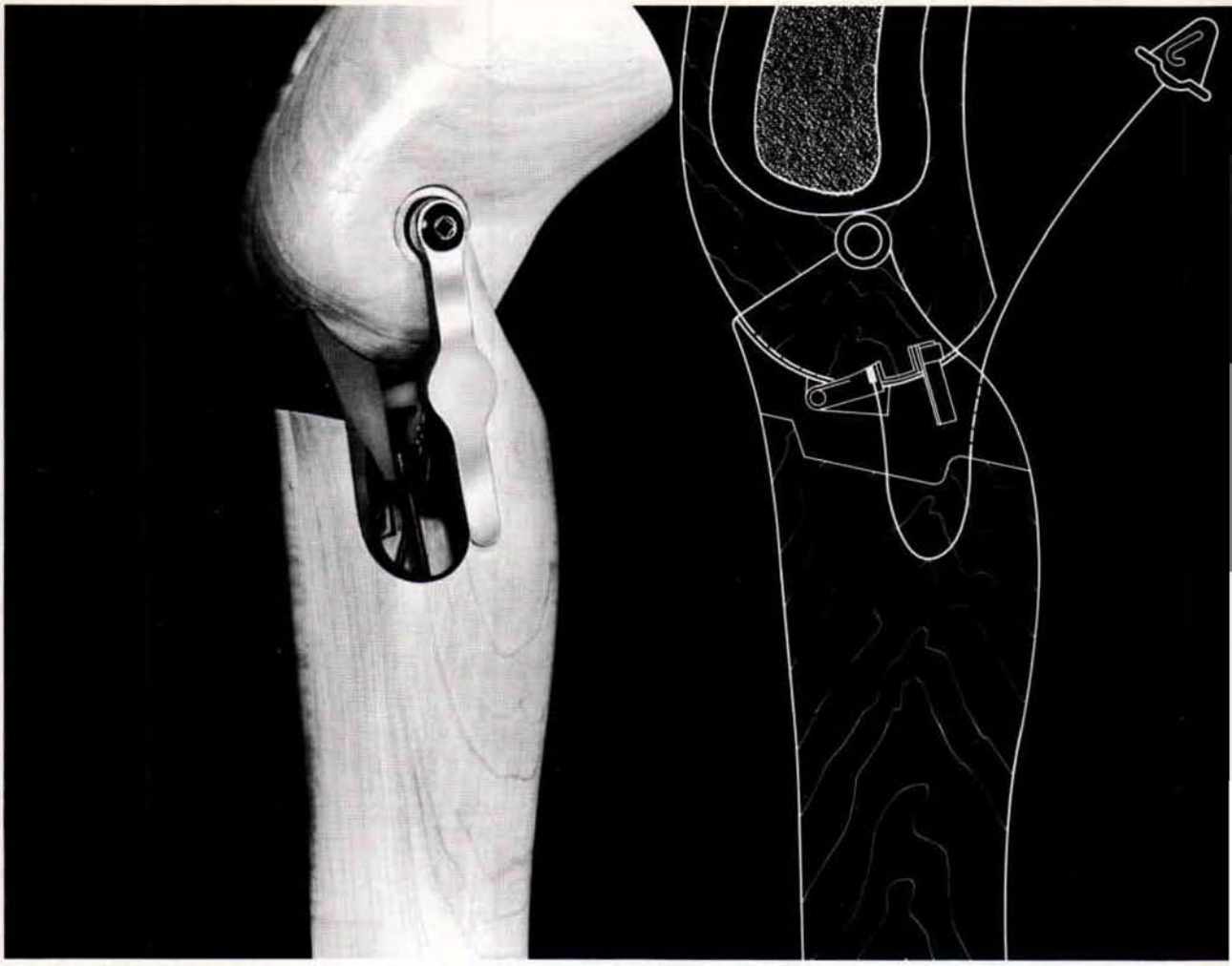

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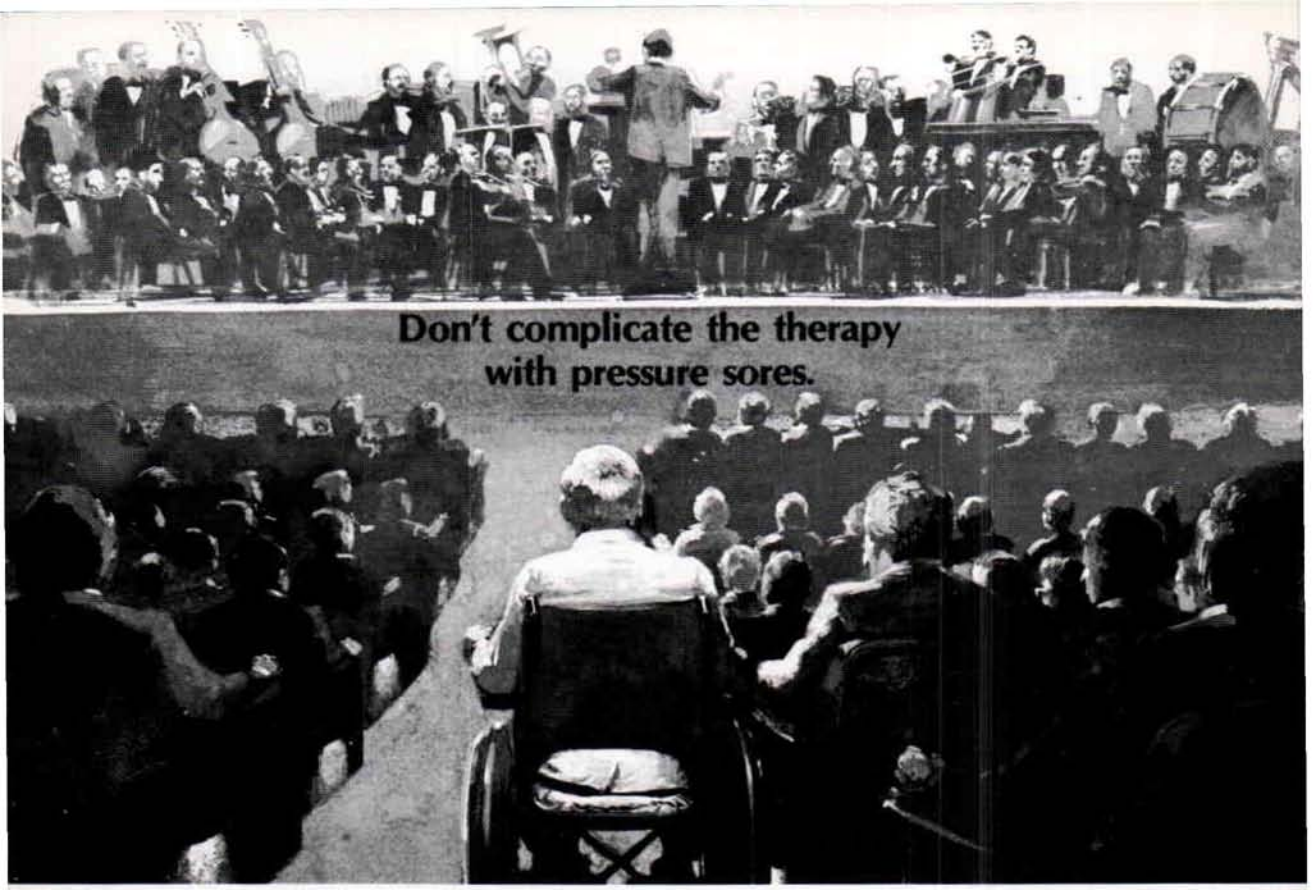

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1. Archives of Physical Medicine & Rehabilitation, Vol. 59, pp. 68-72, January 1978, Wheelchair Cushion Effect on Skin Temperature.
2. Archives of Physical Medicine & Rehabilitation, Vol. 55, pp. 460-464, October 1974, Wheelchair Cushions to Reduce Pressure Under Bony Prominences.

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