Clinical Prosthetics & Orthotics

Volume 10, Number 1 **Winter, 1986**

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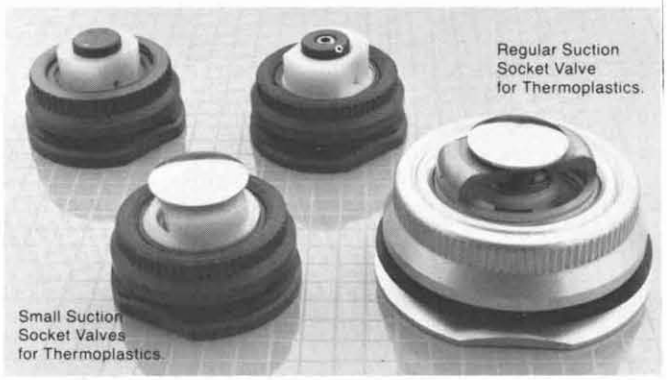

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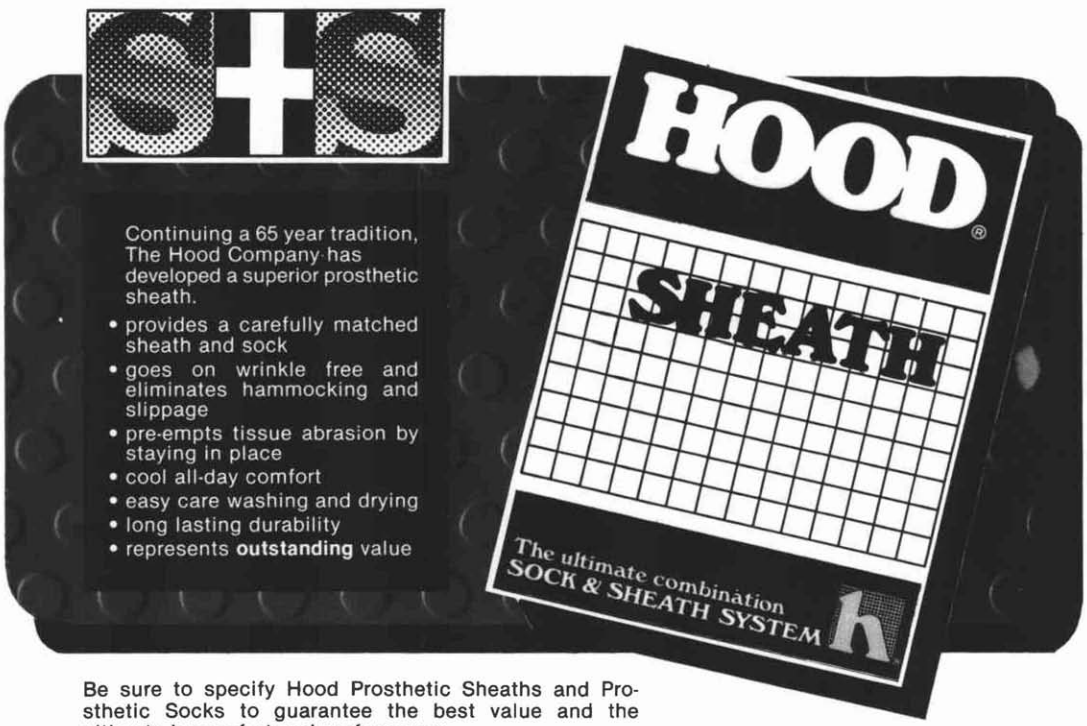

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CORRECTION

The Officers of the American Academy of Orthotists and Prosthetists were inadvertently not included with the Directors who made contributions towards *Clinical Prosthetics and Orthotics,* Volume 9, Number 4.

With apologies for the omittance, the Academy would like to gratefully acknowledge the contributions of the Officers and Directors listed below whose generosity helped make possible the publication of *Clinical Prosthetics and Orthotics,* Volume 9, Number 4.

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EDITOR'S NOTE:

Clinical Prosthetics and Orthotics has undergone many changes since 1984—a new format, an expanded subscriptions base, and a greater number of the superior scientific, clinical, and philosophical articles that you've come to expect.

With this issue, as we begin our second decade, we continue the evolution of *C.P.O.* with the inclusion of paid display advertising. Some readers may fear that display ads will somehow compromise our editorial integrity, or will infringe on the "purity" of the Academy and *C.P.O.* I personally find these statements bewildering, as they imply that our focus has been diverted from publishing a lively, educational quarterly to chasing profits. By accepting advertising, we are admitting only that *C.P.O.* has outgrown its annual budget allocation from the American Academy of Orthotists and Prosthetists, and that precisely because the publication is making an impact in the field, we must now find other sources for funding. There is no better way for a publication to carry its own weight—and justify its place in the literature—than by publishing advertising from the suppliers within its profession.

The officers of the Academy and the Editorial Board of *C.P.O.* are not entering into this venture without research and a good deal of planning. Advertising will not be blindly accepted. The Academy reserves the right to refuse to publish any advertising for any reason, and that information is stated up front to our advertisers.

On a production note, some of our sharper readers may have noticed a change in our paper stock, from a matte finish to a high gloss. This will allow us to do more work with color in the future, without affecting the readability of *C.P.O.*

I am glad you are joining us for our second decade of publishing, and I look forward to another year of stimulating articles and commentary.

Charles H. Pritham, CPO
Editor
Clinical Prosthetics and Orthotics

CONTENTS

Volume 10, Number 1 **Winter, 1986**

FEATURES

ADVERTISERS' INDEX

From the Editor:

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Clinical Prosthetics and Orthotics, Vol. 10, No. 1, pp. 8–14

The Biomechanics of the Foot

by André Bähler

"The human foot is one of nature's works of art and as such, it has not yet been fully recognized and explained. It will require a deal of scientific investigation before this structure is fully understood."

These words of the old master of orthopaedics, Georg Hohmann, from his book "Fuss und Bein" are still applicable today. Thirty years later, the biomechanics of the foot have still not been completely explained, and there are many questions yet unanswered.

The many, more or less articulated connections of the foot allow a variety of changes which make it difficult to understand the movement as a homogeneous process. Too many factors can only be qualified, but not quantified.

Nor may we forget the reciprocal influence of the position of the foot, knee, and hip joints. Each change in the position of one of these joints automatically involves a change in the position of the other two joints.

For example, in the upright position, the neck of the femur forms a posteriorly open angle of approximately 20 degrees. This is determined by the anatomical factors in relation to the frontal plane of the body. The direction of the axis of the hip joint corresponds fairly accurately to the connection inner-malleolus/outer-malleolus, which have an exterior rotation of approximately 20 to 30 degrees in relation to the frontal plane. Consequently, there is a conformity between the ankle axis and the hip axis.

In the upright position, the knee is practically locked due to the automatic rotation and so the position of this axis is of minor importance. When walking, the pelvis rotates approximately 20 degrees forward. As the lower leg also rotates inwardly in relation to the upper leg during flexion, the ankle axis rotates inwardly and the foot takes up a straight position in the swing phase.

CHARACTERISTICS OF THE FOOT

The foot has the characteristics of a triple axial joint which allows it to assume any position. The three main axes of movement converge in the talus area (Figure 1). Particularly during rotational movements to adapt the foot to an uneven surface, all the joints are involved to some extent; nevertheless, the ankle joint,

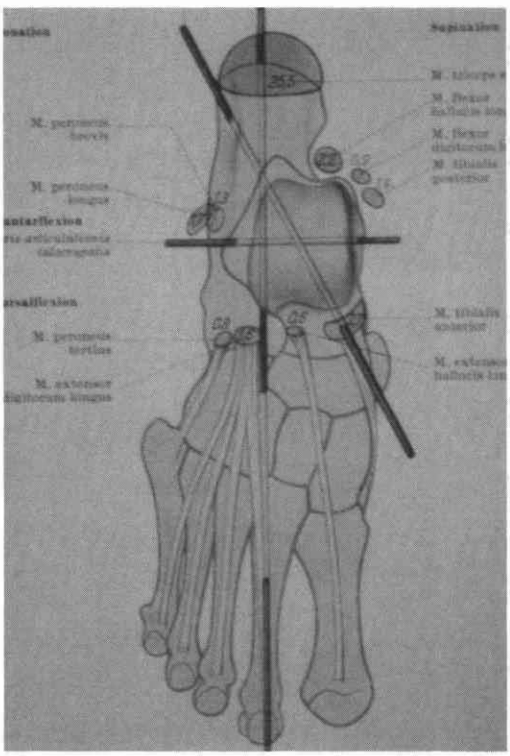

Figure 1.

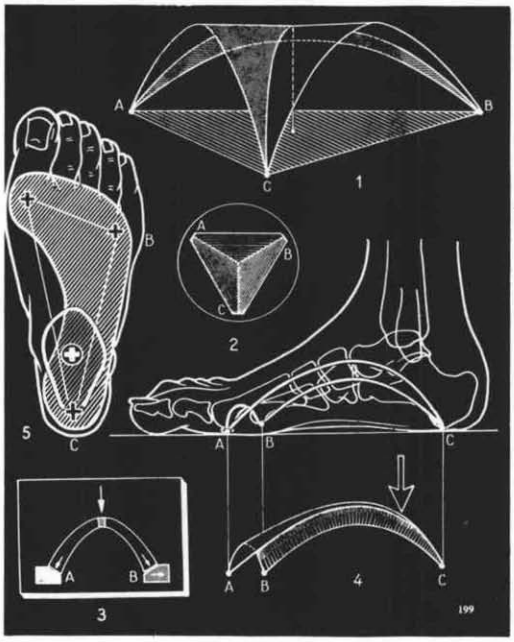

Figure 2.

although formed as a hinge joint, forms the main joint for locomotion.

According to Kapandji, the foot can be compared architectonically to a vault, which is supported by three arches. Other authors criticize this vault-concept on the basis that it is too static. However, the vault-structure is very meaningful as an aid to analyzing the foot in general (Figure 2). The arrow shows the direction and position of the main weight, which is first taken by the calcaneus (A) and then transferred to the forefoot: inside on metatarsal I (B) and outside on metatarsal V (C). The front transversal vault can also be understood as a supporting construction: on the one side the two corner stones (metatarsal I and metatarsal V) and on the other side, the transverse vault (metatarsal II, III, and IV). This construction enables the forefoot to take a great amount of weight and at the same time allows the foot to adapt to uneven surfaces.

Furthermore, it can be seen that when the feet are put together, the position of both calcanei can be regarded as a vault structure. The position of the calcaneus together with a slight valgus position serves to stabilize the body, particularly during the walking motion of the leg (Figure 3).

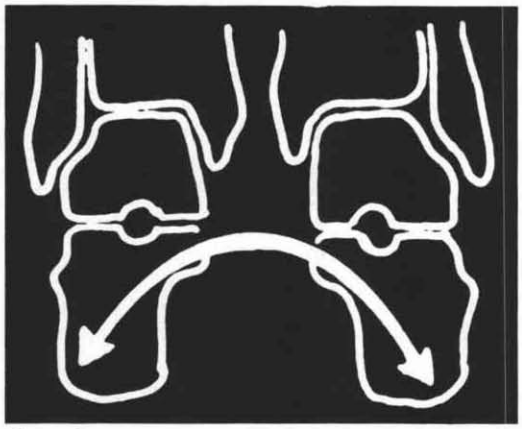

Figure 3.

THE JOINTS

The joints themselves pose some problems. Let us take for example the development of the inclination of the trochlea of the talus, and the distal tibial epiphyseal cartilage to the longitudinal axis of the lower leg in the frontal plane as described by Lanz Wachsmuth.

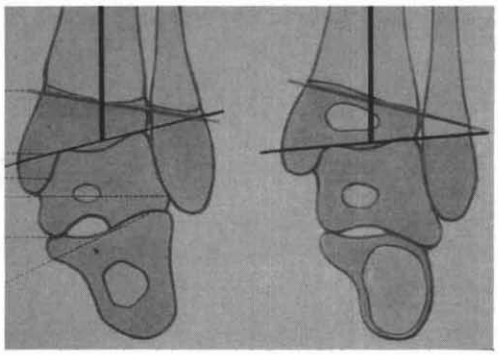

Figure 4.

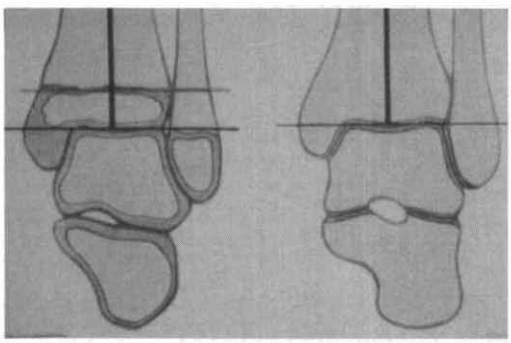

Figure 5.

Left in the infant and right in a two year old (Figure 4), it can be seen that the axes of the ankle joint and the talo-calcaneonavicular joint and that of the epiphyseal cartilage are developing. In the 12 year old, left, and in the adult, right, the axis becomes horizontal during normal growth process, stabilizing the support system of the foot (Figure 5). The changes in the various process-, movement-, and development-axes of the ankle during the development of the child are probably one reason for the controversial views over the biomechanics of the foot.

Biomechanically we are interested in the joints, and in particular, those used when walking.

The Ankle Joint

The ankle joint (Figure 6) is of particular importance, because in at least one direction it secures a movement without which it would be impossible to walk. This joint could also be described as a hinge joint with a diagonal axis of rotation, which allows a movement of about 20 degrees up and down. This inclination of the ankle joint certainly contributes to stability when carrying weight and can only be fully understood when considered in connection with the talo-calcaneonavicular joint.

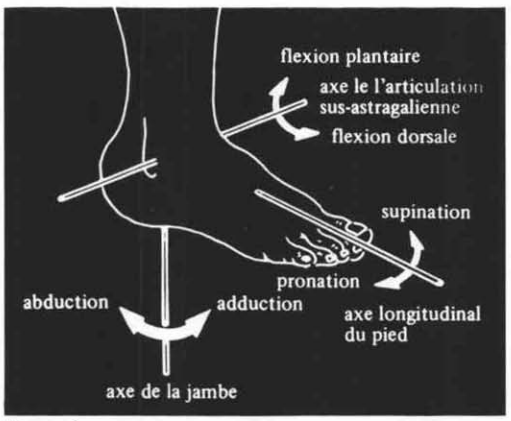

Figure 6.

The Talo-Calcaneonavicular Joint

The movement of the talo-calcaneonavicular joint is decidedly more difficult to understand. Whereas the axis of the ankle joint can easily be defined, the axis of the talo-calcaneonavicular joint is drawn obliquely from lateral posterior to medial anterior. It is surprising that both articular surfaces of the talo-calcaneonavicular joint are congruent only in the mid-position. An incongruence develops between the two articular surfaces by both eversion and inversion. This incongruence cannot be maintained for long periods when carrying weight.

The ankle joint and the talo-calcaneonavicular joint must be regarded as a functional unit. The possible movements of these two joints can be compared to a spheroid joint which can be moved freely within its range of motion: flexion, supination, pronation, abduction and adduction which in some respects corresponds to a rotation.

Chopart's Joint

The talo-calcaneonavicular joint, comprising the talus and the navicular, and the joint which is formed from the calcaneus and the cuboid, together all form a sort of working unit. These two joints comprise Chopart's joint which allows a rotational movement of the fore-foot.

Lisfranc's Joint

The Lisfranc joint is a collective joint where the three cuneiform bones and the cuboid bone on the one side, and the five metatarsal bones on the other side, are united to form an articular connection. The small deflectionary movement can be described as in an obliquely situated hinge exhibiting dorsal and plantarflexion.

The Chopart and the Lisfranc joints are connected by taut ligaments so that there is hardly any friction between them. They serve primarily to give elasticity to the foot during pressure and allow it to adapt better to uneven surfaces.

The Transversal Anterior Vault of the Foot

From metatarsal I to metatarsal V, the metatarsal bones form an oblique arch (Figure 7). This arch tends to drop due to excessive pressure, which can partly be attributed to walking on level ground. This "even" walking, which

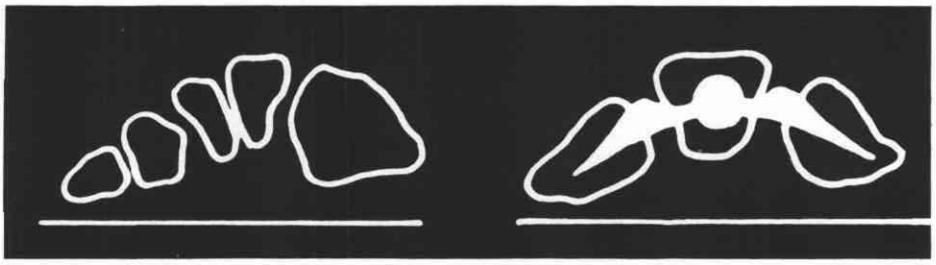

Figure 7.

always puts pressure on the same points of the foot, leads to over-exertion of the individual metatarsal heads.

The Toe Joints

The toe joints are limited spheroid joints. That is, they are capable of sideways movement within certain limits, but are primarily intended as hinge joints with movement upwards and downwards.

THE LIGAMENTS

It is known that the structure of the foot is held together with muscles and ligaments. These ligaments are so constructed as to be able to withstand the extreme pressures exerted on the foot (long jump and high jump).

THE MUSCLES

Long and short muscles hold and move the foot. If one of the muscles gives way, it is immediately visible from the gait how important the interaction of each muscle group is for locomotion. However, descriptive anatomy is not the theme here and so a further discussion of this aspect must be omitted.

THE MECHANICS OF DEPRESSION OF THE FOOT

Experience has shown that not every valgus of the calcaneus results in an equivalent drop of the longitudinal vault.

The talipes valgoplanus is a collective term for different inadequacies which arise when the foot is under pressure. These can be classified according to different characteristics: (Figure 8)

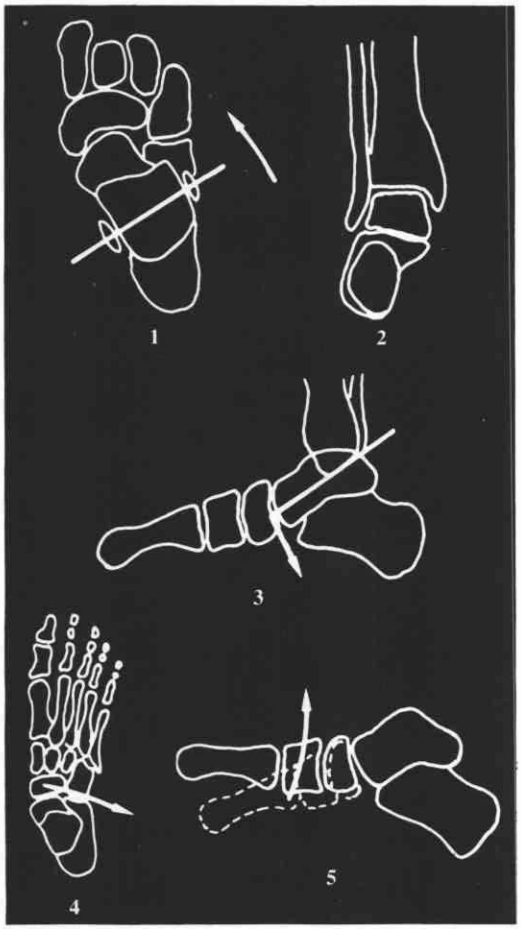

Figure 8.

1. The pronation position of the calcaneus;
2. Inward rotation of the ankle joint;
3. A forward and inward drop of the talus;
4. Abduction of the fore-foot; and
5. Supination, i.e., a turning upwards of the first metatarsal.

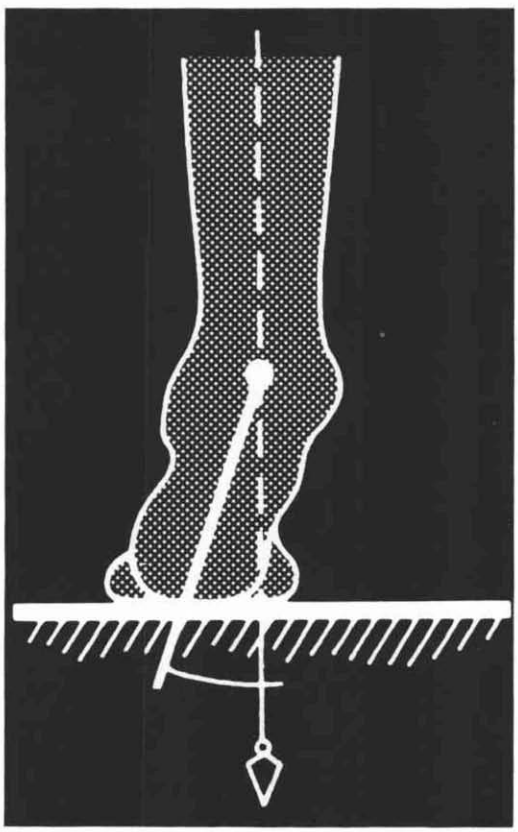

Figure 9.

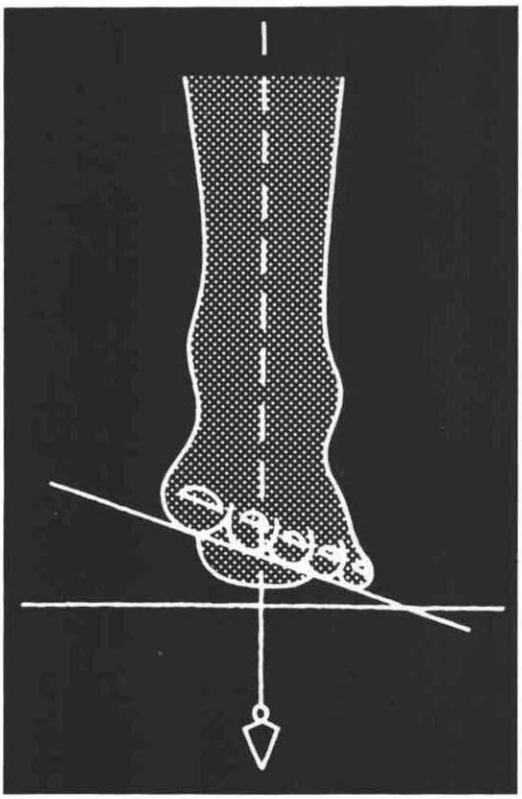

Figure 10.

These five basic characteristics of the talipes valgoplanus lead to a variety of outward manifestations, which must be taken into consideration when deciding on a course of action. This wide variety is one reason why the kinematics of the foot eludes an exact biomechanical and mathematical analysis.

When pressure is applied in valgoplanus, the calcaneum gives way but the fore-foot remains flat on the ground, regardless of the extent of the flexion. Congenital and ischaemic valgoplanus are exceptions to this but they are not included in the discussion here (Figure 9).

Between the calcaneus, rear-, and fore-foot there is a distortion or rotation. If pressure is removed from the foot, the calcaneus falls into a vertical position, but the fore-foot then rotates to the same degree. Consequently the position of the rear-foot relative to the fore-foot remains a constant deformity (Figure 10).

What then is the role of the shoe in the standing position and swing-phase? In the standing position, more pressure is exerted medially on the rear part of the shoe (the counter and the heel), depending on the extent of the valgoplanus. However, the front of the shoe remains flat on the ground regardless of the extent of the deformity.

In the swing-phase, the distortion between the fore- and rear-foot influences the alignment of the shoe. If the heel is too big or badly fitting, the fore-foot dictates the position of the shoe and as a result there is an unwanted deflection of the heel of the shoe from the heel of the foot.

This means that the heel-strike is lateral and as pressure is exerted, it then turns inwards and adapts to the surface whereby it has returned to the original standing position. The distortion between the fore- and rear-foot, combined with an inadequate heel counter, produces a potential risk of injury. A stone on an inclined surface can easily lead to a strained joint (Figure 11). This phenomenon is particularly signifi-

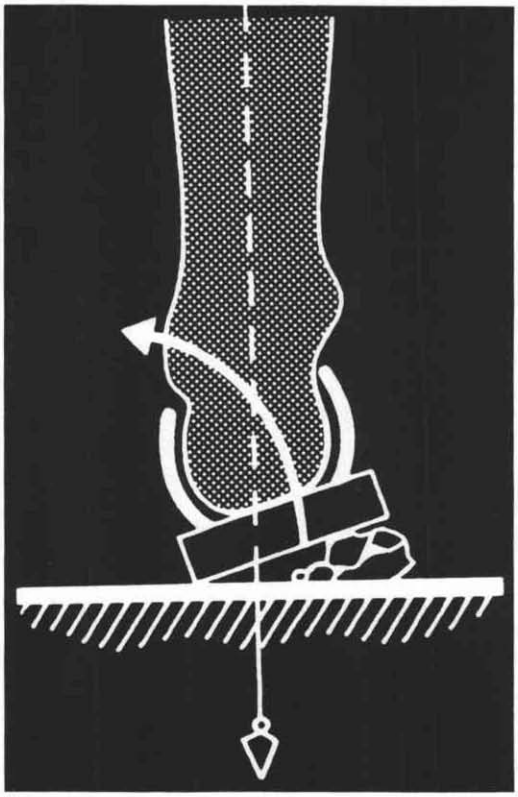

Figure 11.

cant for sportsmen and joggers who train in open country. After suffering such strains, the fear of further injury can hinder training.

DEFORMITY OF THE FORE-FOOT (TALIPES TRANSVERSOPLANUS)

During growth, there is a slight biomechanical change in the lateral metatarsal arch. The first metatarsal rotates pronatorally and this leads to a greater arching in adults.

Congenital ligament or tissue weakness can cause this lateral arch to flatten under pressure and so result in a broadening of the fore-foot. Here, the length of the various metatarsal bones compared to the different patterns of pressure exerted on the fore-foot is of significant importance. Depending on the type of foot, the first or second metatarsal will be under greater pressure depending on which is the longer of the two. Instability between the fore- and rear-foot can also result if the inclination between metatarsal one and metatarsal five is too great. This type of foot tends to tilt sideways during the propulsion process of walking.

In the case of the high-arched foot, the angle between the metatarsal and the ground increases, resulting in a greater load to the individual metatarsal heads.

THE SHOE

From a biomechanical point of view, the shoe plays a significant part in the process of walking and standing. The height of the heel as well as the thickness of the sole greatly influence the conveyance of the weight and consequently influence locomotion itself. This sphere of influence must be duly considered, particularly in cases of static deformity. A build-up of the shoe, i.e., constructing a rocker bottom must be compensated for at the heel, otherwise the relationship between the heel-height and sole-thickness in the front of the shoe will be disturbed, thus having a negative effect on the roll-over process (Figure 12).

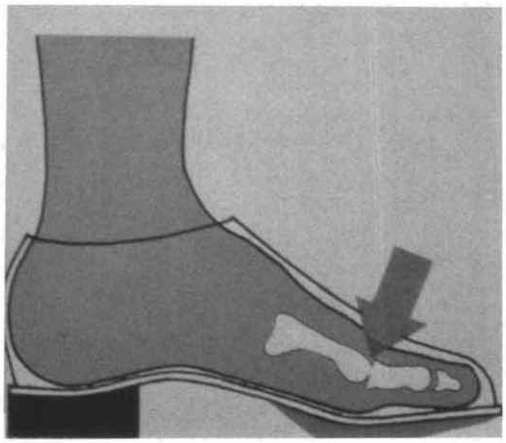

Figure 12.

CUSHION-HEEL

The attachment of a cushion-heel also changes the roll-over process in that it acts as a shock absorber at heel strike and at the same time increases the roll-over (Figure 13).

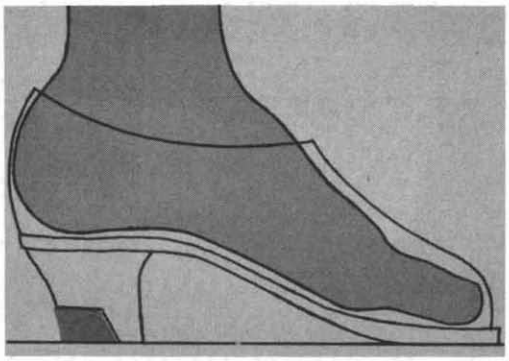

Figure 13.

HEEL-TO-TOE-ROLL FOR THE WHOLE SOLE

A heel-to-toe roll sole can be attached to the shoe to protect the ankle joint and Chopart's joint. Measured radially from the knee, this allows a complete roll of the foot (Figure 14).

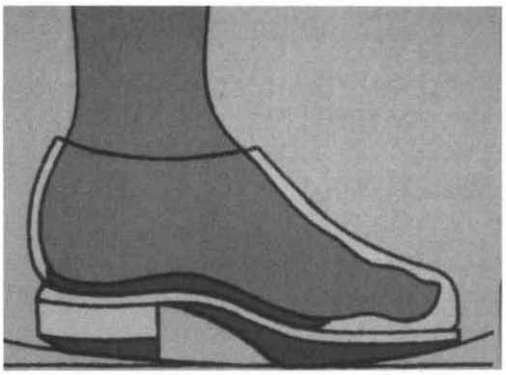

Figure 14.

THE USE OF INSOLES

The insole and the shoe must form a unit with the level ground. Whether the foot is neutral, in pronation or supination, is of no significance.

When insoles are made of solid material, their length and shape are important. It is of particular importance with handicapped patients that the insoles are kept somewhat longer in order to reduce the risk of tilting sideways. This pronatory support, especially in the fore-foot region, gives the patient a feeling of security.

The correction of the talipes valgus should be differentiated from the correction of the talipes varus. With talipes valgus, the rear of the foot should be supinated and the fore-foot pronated in order to achieve a rotation of the foot. With talipes varus, this is not possible. Here, the whole foot must be pronated, i.e., the rear- and fore-foot must be included in an homogenous correction.

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Clinical Prosthetics and Orthotics, Vol. 10, No. 1, pp. 15–23

The Neurophysiological Ankle-Foot Orthosis

by Cyndi Ford, P.T.
Robert C. Grotz, M.D.
Joanne Klope Shamp, C.P.O.

Since the late 1960's when Yates[1] and Lehneis[2] wrote the first articles pertaining to the use of plastics, orthotic practice has been revolutionized by the design possibilities afforded by total contact devices. However, prescription of lower extremity orthoses for neurologically involved patients has traditionally depended solely upon biomechanical principles even as neurophysiological approaches to treatment gained recognition and acceptance. Neurodevelopmental Techniques (NDT) were developed as a theory of Karl and Berta Bobath and evolved to "a sensorimotor approach to control motor output and in doing so change sensory input."[3] Handling techniques which counteract patterns of abnormal tonic reflex activity reduce spasticity and allow facilitation (activation) of normal postural reactions through stimulation of key points of control, which include points on the foot and ankle. Recent advances incorporating neurophysiological principles of inhibition and facilitation into the design of ankle-foot orthoses make possible tone-reducing devices with specific areas of pressure or contact to inhibit abnormal hypertonicity.

Eberle, Jeffries, and Zachazewski[4] recently reported success with an inhibitive AFO, a concept that was not feasible with metal orthotics. Their report stated that "the technique of fabrication used for the construction of a molded polypropylene AFO allows for all of the tone-inhibiting characteristics of casting . . . to be built into the AFO."

Although tone-reducing AFO's inhibit abnormal hypertonicity in the affected lower extremity, the disadvantages inherent in traditional AFO's persist. Limited ankle dorsiflexion and plantar flexion, create a negative influence upon independent knee and hip function. Floor reaction forces intended to prevent the typical hemiplegic knee recurvatum during stance phase also contribute to increased effort and decreased smoothness in gait. Tonic foot reflexes elicited by contact on the plantar surface of the foot as a means to facilitate normal movement are disregarded.

In an effort to address these gait concerns, an orthosis was designed based upon the neurodevelopmental concepts as described by Bobath[5] and Utley[6], and the foot reflexes as described by Duncan and Mott[7] with the following considerations in mind:

1. A design configuration intended to utilize both biomechanical principles to limit calcaneal varus and neurophysiological principles (of facilitation and inhibition) to obtain dynamic ankle dorsiflexion and plantar flexion.
2. Selection of a material with adequate flexibility, durability, and shape retention under conditions of continual deformation during ambulation.
3. Ease of donning for the one-handed patient.

DESIGN RATIONALE

The Neurophysiological Ankle-Foot Orthosis (NP-AFO) is a custom polypropylene device, vacuum-formed over a plaster model of the patient's affected lower extremity (Figure 1). Within the total contact design are incorporated the following forces:

1. A three-point pressure system to biomechanically control calcaneal varus (Figure 2).
2. A biomechanical force medial to the achilles tendon to counterbalance and prevent excessive pronation and rotation of the orthosis in the shoe (Figure 3).
3. A neurophysiological force on the medial aspect of the calcaneus, extending to the plantar surface of the longitudinal arch without creating pressure under the navicular itself (Figure 3). This facilitates straight plane dorsiflexion.
4. A neurophysiological force on the lateral aspect of the plantar surface of the foot (Figures 4 and 5) to facilitate the eversion reflex (peroneals) and recruit more proximal controls (vastus lateralis and gluteus medius) for knee and hip stability as discussed by Duncan[8]. The amount of dorsiflexion assist may be graded by adjusting the width of the segment joining the heelcup and the metatarsal arch (Figure 5).
5. A neurophysiological force to inhibit the toe grasp reflex (toe flexors and gastrocnemius-soleus) by unweighting of the metatarsal heads through use of a metatarsal arch (Figure 6).
6. Biomechanical function through flexibility of the foot and ankle due to the trimlines and configuration of the plastic NP-AFO (Figures 7 and 8).

PRESCRIPTION RATIONALE

The NP-AFO is designed for use in the treatment of the patient with a central nervous system disorder, such as a cerebral vascular accident or closed head injury. Assessment should include analysis of the individual's tone or spasticity, range of motion, and the availability of follow-up by members of the clinic team familiar with a neurophysiological approach to care. Spasticity has been classified as minimal, moderate, or severe in terms of function of the foot and ankle during gait.[9] Minimal spasticity allows the patient to land on a stable calcaneus without excessive supination of the forefoot and then shift the body weight over the heads of the metatarsals, although during swing phase the foot assumes a varus or supinated posture. Moderate spasticity causes the calcaneus to assume a position of varus with ex-

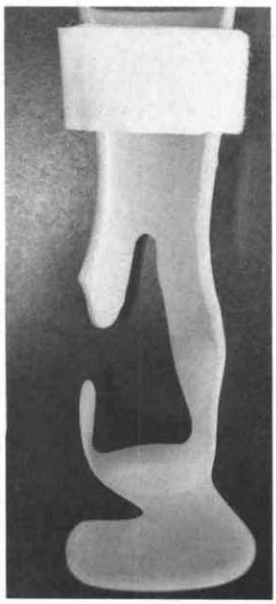


Figure 1.

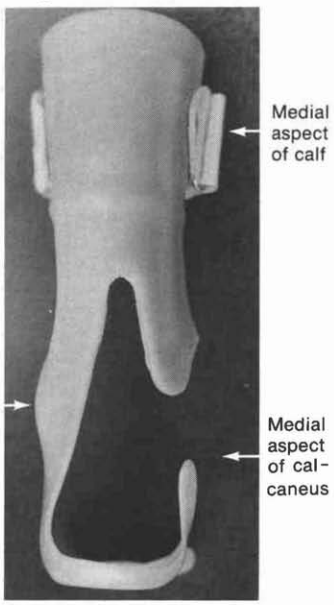


Figure 2.

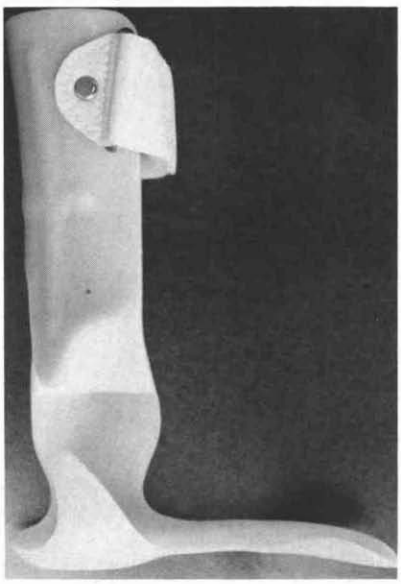
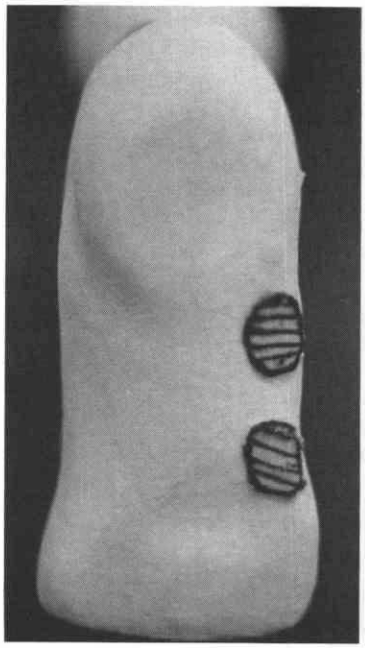


Figure 3.



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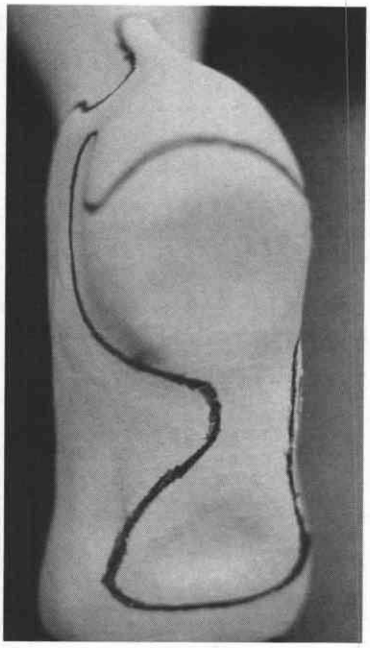


Figure 5.

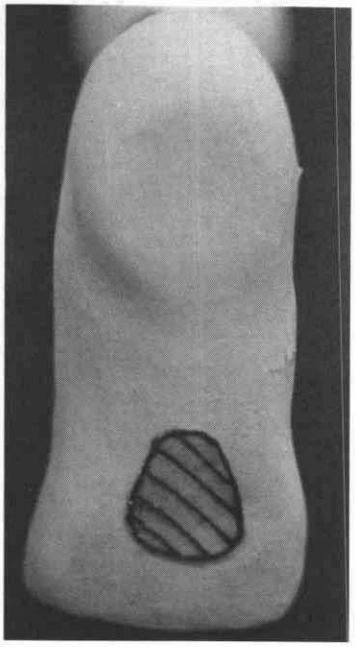


Figure 6.

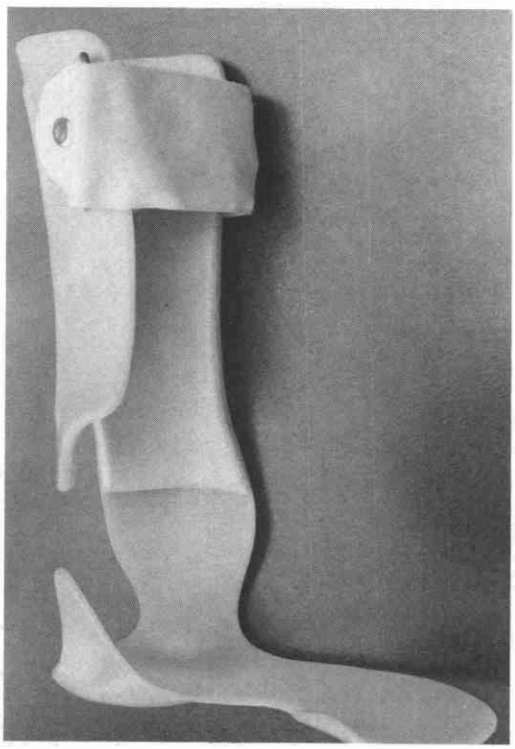


Figure 7. Medial view, left foot.

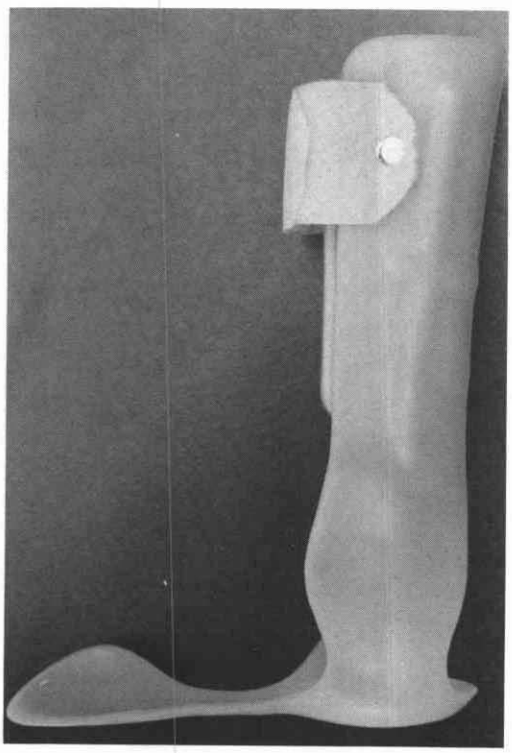


Figure 8. Lateral view, left foot.

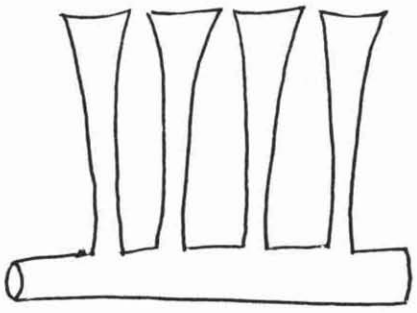


Figure 9. Toe separators fabricated from Plastazote® with a Moleskin® cover and toe extension.

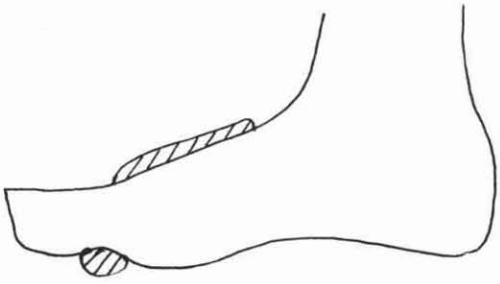


Figure 10. Toe separators in place under the toes.

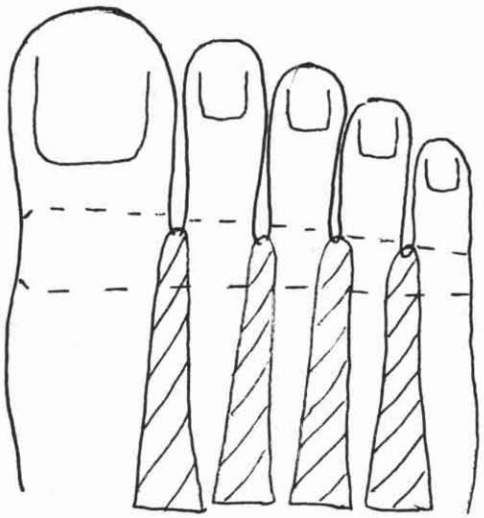


Figure 11. Superior view showing tabs to hold in place under sock.

cessive supination at initial contact; however, during midstance some pronation occurs and the body weight can again be transferred normally across the forefoot. Severe spasticity is characterized by the foot and ankle being held rigidly in a position of equinovarus throughout stance so that the body weight remains on the lateral aspect of the forefoot with little or no weightbearing through the heel or medial metatarsal heads. This varus position persists throughout swing phase also.

Patients exhibiting minimal or moderate spasticity are excellent candidates for the NP-AFO. Patients with severe spasticity are candidates only if their tone can be modified through handling techniques and/or inhibitive casting. The use of toe separators (Figures 9,10,11) as an adjunct treatment is also effective in patients with a separate toe grasp reflex to inhibit excess tone and reduce pain.[6] In order for the NP-AFO to function appropriately, the patient must have at least 15 degrees of passive dorsiflexion with the knee in flexion.

Follow-up by a clinic team familiar with the device is important to monitor the continued fit and function. With most AFO's the major concern may be skin breakdown. However, with the NP-AFO the change in fit due to edema, weight loss, or tone variations may require modifications to maintain the critical areas of contact.

Contraindications for this device are severe spasticity which cannot be modified through inhibitive casting or handling techniques, and early excessive pronation or calcaneal valgus with the foot pronated at initial contact of stance.

CLINICAL EXPERIENCE

The NP-AFO has been prescribed for 35 patients with the following diagnoses: 29 Cerebral Vascular Accidents (CVA), 4 Closed Head Injuries (CHI), 1 Cauda Equina Injury, and 1 undiagnosed Demyelinating Disease. Although three patients were lost to follow-up, the NP-AFO has continued to be worn by the remaining 32 with overwhelming acceptance which seems to be attributed to the comfort and function of the device. Of the four patients converted from traditionally designed orthoses (2 metal, 2 plastic AFO's), three have im-

proved gait patterns and prefer the NP-AFO to their previous device. The fourth has rejected orthotic care due to refusal to adapt footwear from inappropriate styles with 2½" heels. Four patients became independent ambulators without the use of any orthotic device.

FABRICATION

Polypropylene was chosen as the thermoplastic currently exhibiting the best conformance to the desired qualities, when used in the fabrication process described.

CASTING PROCEDURE

The casting technique is similar to that described in *Lower Limb Orthotics, A Manual*[10] and is a procedure commonly used by certified orthotists. The cast must be taken in a position of maximal dorsiflexion, preferably 20 degrees. The calcaneus, midfoot, and forefoot should be in a neutral position. It has been our experience that tone-reducing handling activities performed by a physical therapist just prior to casting will help assure an optimal position. These activities include forefoot, midfoot, and hindfoot mobilizations as taught by Jan Utley.[6]

The cast is removed upon hardening and filled with plaster to create a positive model for use in vacuum-forming of the orthosis. The positive model is now ready for modifications to create the necessary biomechanical and neurophysiological forces.

MODIFICATION OF THE POSITIVE MODEL

As the key to function of the orthosis is selective inhibitive and facilitative forces, accurate cast modification is essential. Plaster removal is performed in the following areas to a depth of 0.5 to 1 cm. depending upon the compressibility of the patient's extremity. These modifications must be sufficient to provide a very firm force to the skin as designated.

1. Medial and lateral to the achilles tendon using a Scarpa's knife to deeply groove the modification (Figure 12).
2. Medial aspect of the calcaneus extending to the plantar surface of the longitudinal arch *without* creating pressure under the navicular itself that would stimulate mid and forefoot supination (Figure 13).
3. Along the lateral plantar surface of the mid- and forefoot, excluding the base and head of the fifth metatarsal (Figure 14).

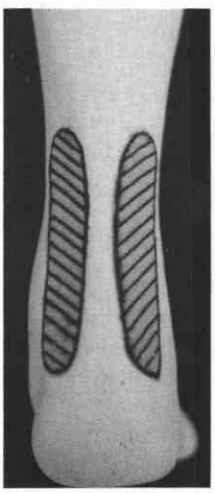
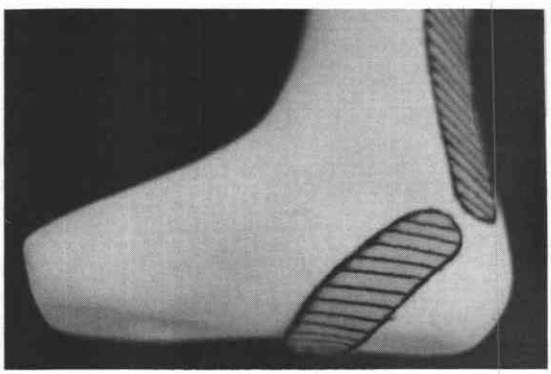


Figure 12.



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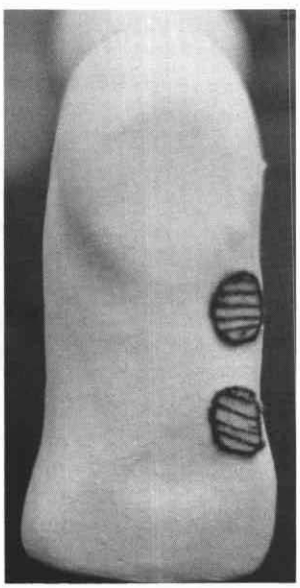

Figure 14.

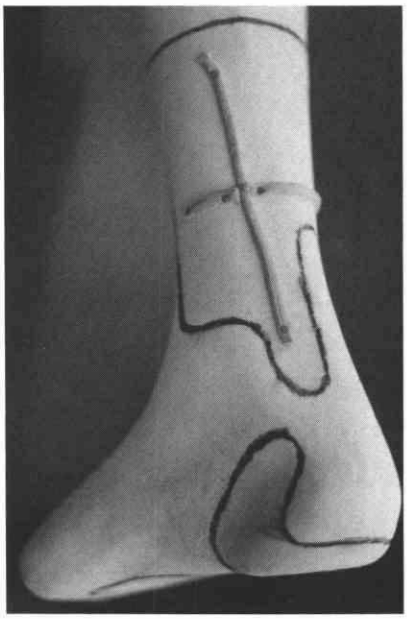

Figure 15.

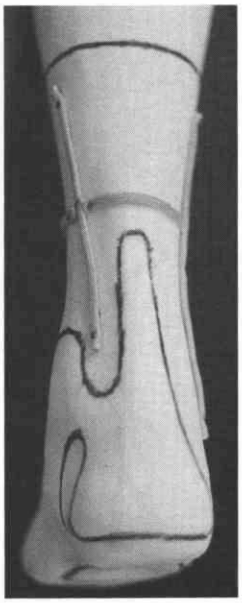

Figure 16.

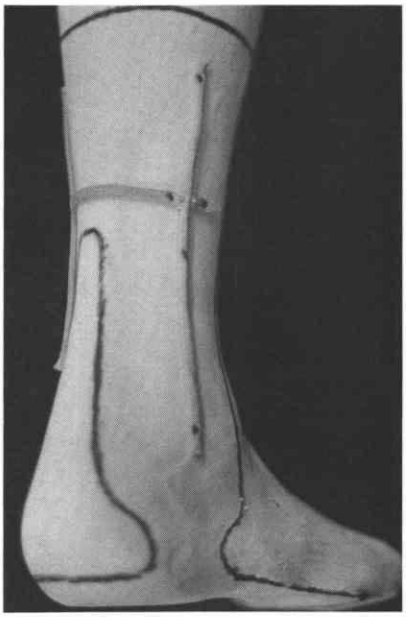

Figure 17.

4. Create a metatarsal arch 6mm. proximal of the metatarsal heads for the inhibitive function of unweighting the metatarsal heads and thereby reduce tone (Figure 6).
5. Smooth entire cast.

If an accurate negative cast and positive model were created, no further modifications are necessary.

VACUUM-FORMING PROCESS

Leather, nylon, or rope cording is applied to the cast (Figures 15,16,17) to create strengthening corrugations in the orthosis after molding.

A separating agent or material is used between the positive model and the hot plastic to create adequate vacuum and to leave a smooth inner surface. For our drape-forming process one layer of perlon with one layer of ladies' nylon knee-high stockings are applied and smoothed with talc. Stress-relieved 3/16" polypropylene is then drape-formed under vacuum to the positive model and allowed to cool for 24 hours.

TRIMLINES

The orthosis is removed from the positive model using a cast cutter and is sanded to finish according to the following trimlines:

1. Overall height of the orthosis is equal to the distance from the plantar surface of the calcaneus to the flare of the achilles tendon as it meets the gastrocnemius-soleus group, multiplied by 2. An average overall length for a 175cm. (5'9") adult is 25.5cm. (10").
2. Length of the plantar extension is terminated 6mm. proximal to the metatarsal heads for comfort.
3. The lateral trimlines (Figure 18) come as far anterior as possible and still allow passage of the leg into the orthosis. The posterior trimline (Figures 18 and 19) approaches the lateral margin of the achilles tendon, but may require modification to prevent a bowstring effect by the heel counter of the shoe against the NP-AFO.

   Note that flexibility is enhanced by the narrowing anteriorly and posteriorly as the lateral side meets the heelcup.
4. The achilles tendon is left exposed to the point of flare with the gastronemius-soleus (Figure 19).

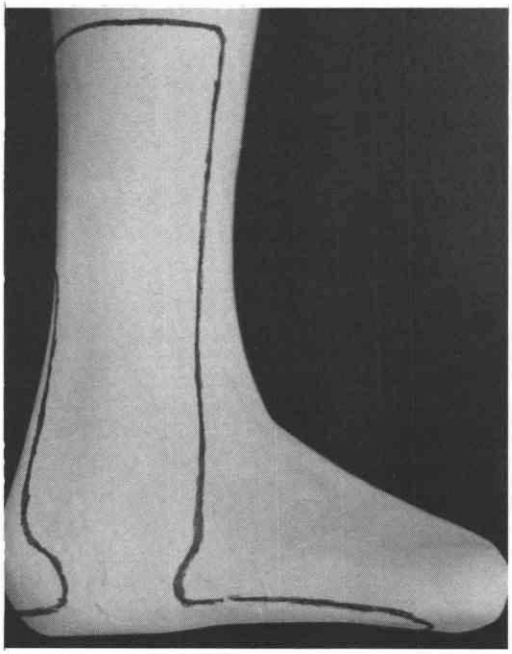

Figure 18.

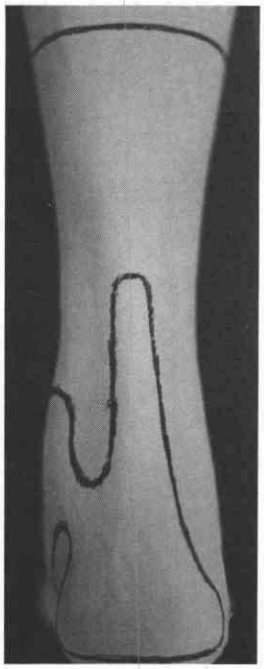

Figure 19.

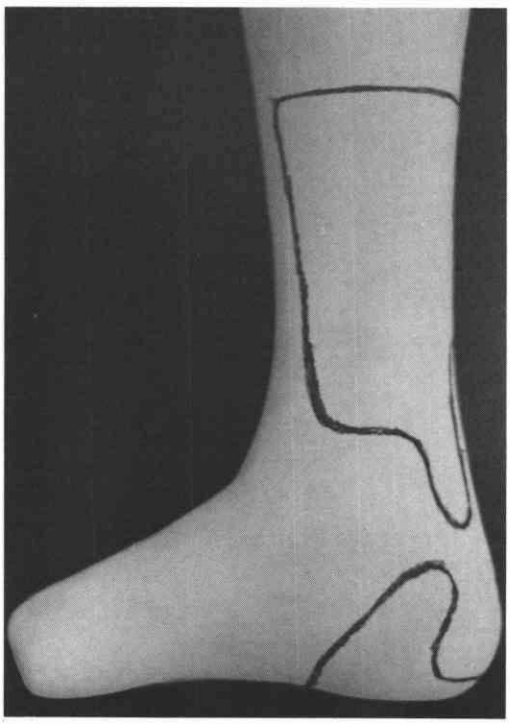

Figure 20.

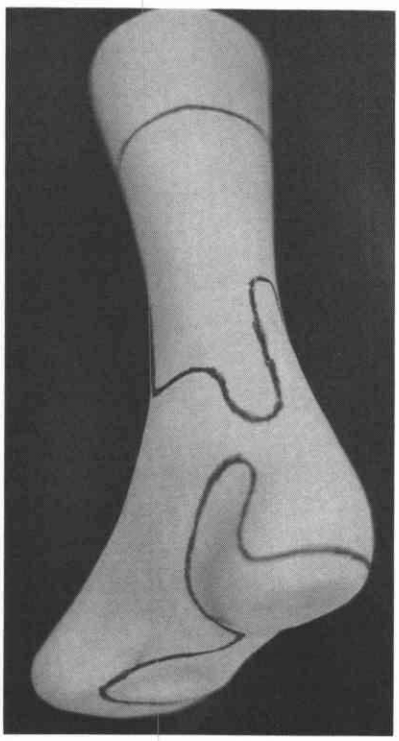

Figure 21.

5. The medial margin is trimmed so as to provide the appropriate forces and yet avoid contact on the medial malleolus and under the navicular. The open area provides for lack of resistance to dorsiflexion and plantar flexion (Figures 20 and 21).
6. The plantar extension (Figure 21) may be varied in width depending upon the size of the patient and flexibility desired, but as it serves only to join the metatarsal arch to the heelcup, it should remain as flexible as possible. The distal aspect, including the metatarsal pad, should span the distance between the shaft of the first metatarsal and the extreme lateral margin of the foot to allow maximum facilitation of the eversion reflex.

A full ⅛″ Plastazote® liner is glued to the inner surface of the orthosis, with the exception of the areas contained by the patient's shoe to allow ease of donning the same size shoe previously worn by the patient. A Velcro® strap of 2″ width is applied to the proximal anterior calf. A lace-tied or Velcro®-closed shoe is recommended to maintain the critical fit of the NP-AFO.

DISCUSSION

The movement allowed by the NP-AFO encourages dynamic control of the entire lower extremity. When sitting, normal weight-bearing attitude can occur with the foot remaining in full contact with the floor throughout a full range of knee flexion. Analysis of the normal movements of the ankle during elevation from a chair has revealed to us that the ankle begins in dorsiflexion and continues to dorsiflex during the initial phase of the elevation before plantar flexing to a relatively neutral position. Devices which eliminate this normal range of dorsiflexion necessarily require a patient to work over an abnormal base and make difficult active weight-bearing during elevation. The ability to assume a normal weight-bearing surface in a position of power as allowed by the NP-AFO encourages weight-bearing on the affected extremity throughout all activities of daily living.

Further, dynamic control of the pelvis and knees are encouraged during ambulation by eliminating floor reaction forces inherent in other AFO's. Without these abnormal forces, the patient experiences the normal movement of the pelvis and knee over the foot, allowing development of a propulsive toe-off with the NP-AFO.

Progressing from use of the NP-AFO to being independent of assistive devices is more feasible, as the patient has the opportunity to gain control of muscles through the normal range of movement.

SUMMARY

The adequacy of traditional AFO's to provide a safe, functional gait pattern is irrefutable. However, experience with patients who sustained a CVA five to fifteen years ago and received a traditional metal or plastic AFO reveals they now present problems related to overuse of the sound side: the pathomechanics resulting from a rigid ankle and/or increasing hypertonicity from abnormal weightbearing patterns. As more patients have increased lifespans following a CVA, treatments and orthotic care which assure prolonged quality of life become increasingly important. Neurophysiological treatment attempts to do this through emphasis upon normal movement patterns and integration of the affected and unaffected sides.

The NP-AFO is a biomechanically and neurophysiologically effective ankle-foot orthosis that is appropriate for creating a functional gait in the patient with a central nervous system disorder. The design allows for independent motion at the ankle, knee, and hip joints in a lightweight and cosmetic custom-made orthosis. The NP-AFO joins the inhibitive cast and other neurophysiological armamentarium in new approaches to the rehabilitation of the spastic or hypertonic patient.

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The Use of the AFO and PTB Orthoses for Severe Pes Planus

by Gustav Rubin, M.D., F.A.C.S.
Malcolm Dixon, M.A., R.P.T.

When the severely deformed pes planus foot is rigid, the deformity fixed, and the arch totally dropped, to provide the patient with a conventional molded arch "support" is an exercise in futility. Placement of a shoe insert under the non-existent long arch cannot prevent further dropping on weight-bearing if the talar head is already in contact with the floor and the intertarsal joints are immobile.

It is the purpose of this paper to report the use of the Ankle Foot Orthosis and Patellar Tendon Bearing Orthosis for such a situation.

Because it would not be feasible to attempt to raise the arch of a rigid foot with an orthosis, the authors decided to employ an orthosis to decrease stresses on the foot and ankle by transferring push-off forces to an AFO.[1] This was to be accomplished by fabricating the orthosis with a solid ankle and modifying the shoe to incorporate a long steel spring and a rocker bar. Since it was anticipated that this approach might not provide adequate relief, it was considered that the next procedure would be to introduce partial unweighting with a Patellar Tendon Bearing Orthosis.[2] This would also be fabricated with a solid ankle and include a shoe with a long steel spring and a rocker bar.

CASE REPORT

B.L., age 62, was initially referred to the VA Prosthetic Center on June 14, 1982, with a history of painful feet since World War II, which had become worse in recent years. The patient stated that "my feet are going to collapse and I can hardly walk and barely make it when I stand and walk." He had a cerebral vascular accident on January 18, 1982, but had made an almost complete recovery. There was also a history of aortic valve insufficiency and gout. The patient was receiving coumadin, inderal, digoxin, and allopurinal for his medical problems. He had not had relief of his foot pain from arch supports in the past.

On examination there was noted medial downward dislocation of the talar heads, abduction of the forefeet, absence of the long arches, marked restriction of joint motion, marked splaying of the forefeet and severe hallux valgus, bilaterally (Figure 1). The dorsalis pedis and posterior tibial arteries were palpable.

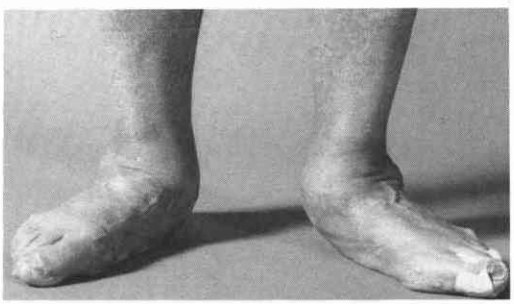

Figure 1. The severe bilateral pes planus noted when patient was first seen at VAPC.

X-Rays confirmed the clinical findings of severe pes planus and hallux valgus bilaterally. The patient's private orthopedic surgeon had fit

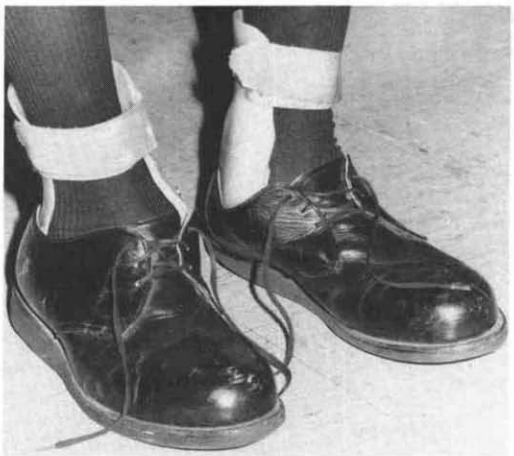

Figure 2. Orthosis prescribed by patient's private orthopedic surgeon.

Figure 3. Bilateral AFO's and shoe corrections prescribed at the VAPC.

him with short AFO's (Figure 2). These were a significant improvement over previous arch supports, but were bio-mechanically inefficient. Bilateral solid ankle AFO's and shoes with long steel springs and rocker bars were prescribed (Figure 3).

On July 16, 1982 the patient reported that he was much more comfortable.

When re-evaluated on October 21, 1982 it was indicated that the left side was subjectively worse than the right. He was experiencing very painful weight-bearing directly on the talar head. The "comfort" that he had reported in the previous note was relative. A PTB orthosis was prescribed for the left side (Figure 4), in accordance with the originally outlined plan of procedure.

On April 19, 1983 the patient stated that the PTB was an improvement over the AFO.

On August 7, 1984 he returned for a new orthosis because of loss of fit. The patient had lost weight following cardiac surgery for aortic valve replacement and triple bypass in March, 1984.

On October 4, 1984 he reported that the new orthoses were "comfortable, that he feels much better with them, and is able to ambulate." He and his wife both stated that he "would not be able to walk" without these orthoses.

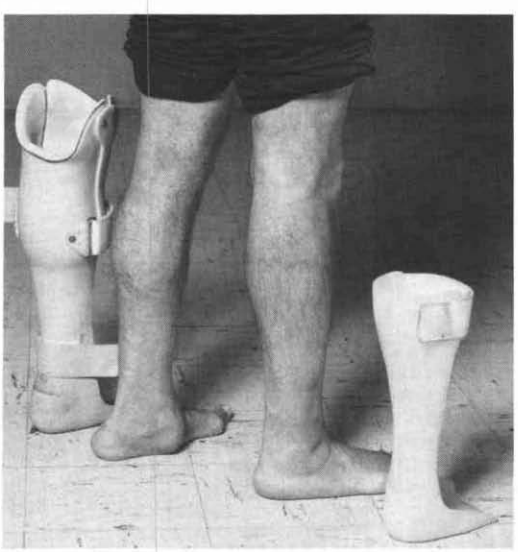

Figure 4. The final prescription included an AFO on the less symptomatic right side and a PTB orthosis for the left side.

DISCUSSION

Severe pes planus of the type described in this report can only be helped to a limited degree by orthoses. However, if a maximally efficient approach is employed, the limited degree of relief can be significant and allow an almost non-ambulatory patient to achieve a useful degree of ambulation.

A solid ankle AFO not only functions to stabilize the ankle and foot, but when combined with shoe corrections (rocker bar and long steel spring), it acts to diminish the stresses on the foot and ankle. The PTB provides, in addition, partial unweighting, while retaining the features that permit transfer of forces to the orthosis.

We have employed the AFO in other similar instances, but this was the first occasion in which we employed the PTB for severe pes planus.

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Clinical Prosthetics and Orthotics, Vol. 10, No. 1, pp. 27–32

Functional Variations in Thoracic Suspension Orthosis Design†

by Carrie L. Beets, C.O.
Gretchen Hecht, C.O.

The thoracic suspension orthosis (TSO), developed at Newington Children's Hospital in Newington, Connecticut, is an alternative total contact thoraco-lumbo-sacral orthosis (TLSO) used for control of progressive spinal deformities in patients who are poor candidates for traditional spinal orthoses and/or surgery. Based on experience accumulated at Newington Children's Hospital and other facilities, indications and contraindications for the device's use have been clearly outlined and the biomechanical mechanisms have been validated.[1,2,3] Along with the prescription criteria, the fabrication process has been specifically delineated in the literature and is stringently adhered to in practice.

Contraindications leading to failure of the TSO are uncooperative patient or family, hip joint stiffness with inability to sit, severe athetoid cerebral palsy, gross obesity, and cachexia. Failure to control the initial break-in schedule has also been shown to be a reason for failure. Based on the success or failure of early trials with the thoracic suspension orthosis, the criteria for usage as well as the steps for achieving success with a thoracic suspension patient have been well established. Unfortunately, the presupposition that the orthosis can only achieve success if the fabrication and application of the device conform precisely to the established guidelines, has given rise to a pattern of stereotypical usage.

The thoracic suspension orthosis was developed for use primarily with patients with spina bifida or neuromuscular diseases. These patients often have secondary deformities or environmental circumstances which would benefit from modification of the original TSO design. In the prescription and application of any orthosis, it is the responsibility of the orthotist to recognize the need for modification of the orthotic design and to provide that modification within the framework of the established biomechanical principles so that it will better suit the needs of the patient. The application of the thoracic suspension orthosis appears to be the one exception of this practice, with practitioners dogmatically adhering to the prescribed design of a single anterior opening and indentation of the upper abdominal region on plaster modification.

The variety of secondary complications seen in myelodysplasia and neuromuscular patients (bony defects, gibbouses, paradoxical breathing patterns, older patients difficult for caretakers to handle due to their size and weight, etc.) can and often do affect the final outcome of the use of a thoracic suspension orthosis. In application of traditional spinal orthoses, these complications are taken into consideration when determining the functional design of the orthosis to be used. When a patient is being evaluated for a thoracic suspension orthosis these same complications must be considered and the thoracic suspension orthosis should likewise be modified as needed within the framework of the biomechanical principles to accommodate the individual needs of the patient.

Using the above mentioned hypothesis, as patients are evaluated for candidacy for thoracic suspension orthoses, a careful look is

† Cases presented in this article include patients from the Rehabilitation Engineering Center at Children's Hospital at Stanford in Palo Alto, California and Duke University Medical Center, Durham, North Carolina. A companion article following this one describes the treatment of a child at Duke University in a similar fashion, page 38.

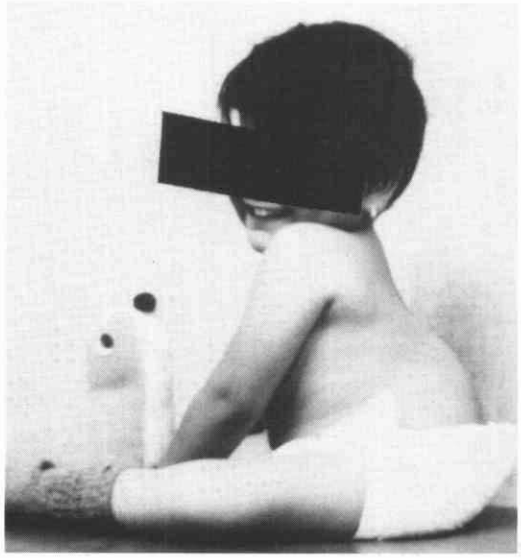

Figure 1. Three and one-half year old with a thoracolumbar kyphosis uses her hands to maintain sitting balance.

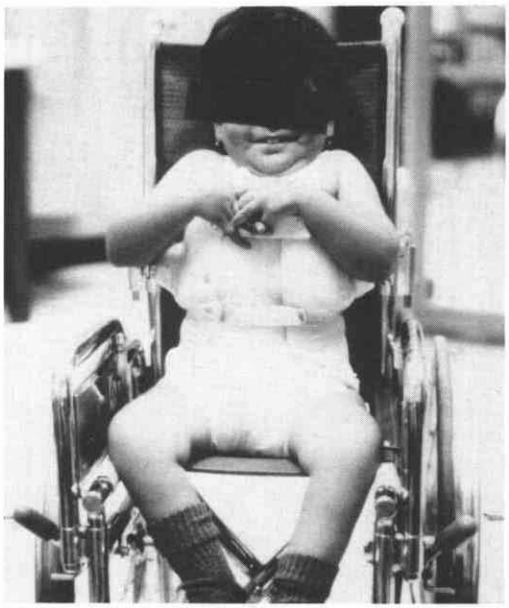

Figure 2. Child wearing traditional anterior opening TSO now has use of upper extremities for daily activities.

taken to determine the most functional design for the individual patient and whether the optimal design is compatible with the principles of thoracic suspension. The following examples illustrate the evaluation process and the resulting design choice in each case.

CASE 1

This patient is a 3½ year old girl with an L-2 level myelomeningocele, multiple hemi-vertebrae at T10,11,12, slight scoliosis and a thoracolumbar kyphosis of 60 degrees. On observation, the girl sat in a kyphotic posture and used both upper extremities to maintain sitting balance. She was evaluated in clinic for a spinal orthosis to limit progression of her spinal deformity so surgical intervention could be delayed due to her age. The child appeared to be an excellent candidate for a thoracic suspension orthosis. A TSO was considered appropriate rather than a more conventional spinal orthosis due to the severe collapsing nature of her spinal deformity and the fact that she had to use her hands to maintain sitting balance. On examination she had no secondary deformities affecting the design of the TSO. Skin integrity at the level of the spinal bifida defect was excellent (Figure 1).

A single anterior opening TSO was fabricated for this child. The initial break-in period went well and the child subsequently wore the TSO at home and school. By the school's request, an extra set of suspension brackets were provided for attachment to the school commode (Figure 2).

CASE 2

This patient is a nine year old female with myelodysplasia, complete paraplegia with lumbar kyphosis (Figure 3). X-rays revealed a hemivertebrae at L-2 and a spinal angulation of 90 degrees at the L-3 level. The patient has had chronic skin decubiti over her lower back. Modified wheelchair trunk cushions had proven inadequate to prevent recurrent breakdowns. The patient was flexible and the kyphosis reduced partially with distraction. She was chosen as a candidate for a thoracic suspension jacket. At the time of evaluation, the open areas on her back were too many to permit casting. She was sent home for three weeks for

Figure 3. Nine year old child with a 90 degree lumbar kyphosis, large boney defect and repeated decubit over lumbar area.

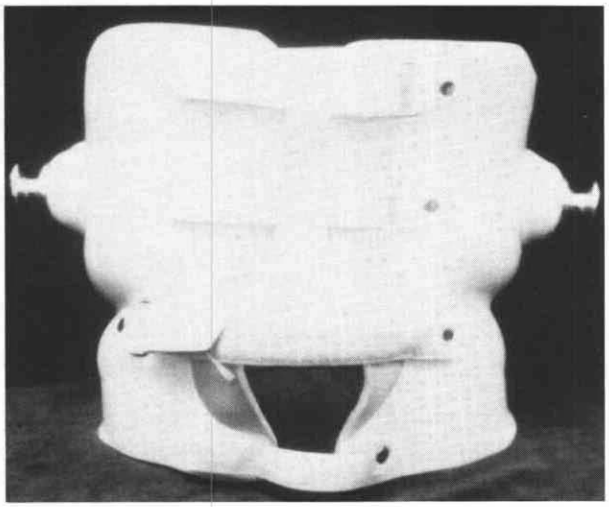

Figure 4. Posterior view of single posterior opening TSO modified to provide pressure relief over boney prominences.

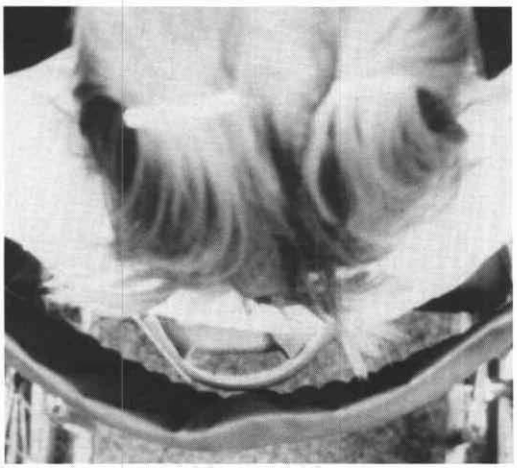

Figure 5. Superior view of modified posterior opening TSO with patient in suspension in wheelchair.

prone positioning to allow the skin over her lower back to heal.

The involved area of the bony defect and kyphosis covered the majority of her lower back. Because skin integrity was so poor, it was felt the entire area would require relief build-ups on the positive plaster model. There was concern that the necessary reliefs would compromise the overall fit of the body jacket. To avoid compromising fit in order to provide sufficient pressure relief, we chose to use a posterior opening orthosis instead of the standard anterior opening design. The width of the posterior opening was increased in the area of the kyphosis, with the plastic shell being trimmed wider and the soft plastazote lining being left in place to prevent any edge pressure (Figure 4).

CASE 3

Optimal placement of closure straps included a strap crossing the area of the kyphosis. To ensure adequate circumferential containment, while still avoiding any pressure contact to the bony defect from the closure strap, an aluminum bar was contoured and placed inside the strap (Figure 5).

This patient is a twenty year old male with Duchennes Muscular Dystrophy who presented a 70 degree progressing C-curve scoliosis and accompanying loss of sitting balance and head control (Figure 6). This patient was still able to operate his electric wheelchair, however, he had sufficient upper extremity weakness to prevent activities of daily living. On evaluation for a thoracic suspension orthosis, he exhibited no precluding medical complications. In spite of his age and degree of involvement, and though he had a reduced vital capacity, he was still a chest breather and had some flexibility in his spine. It was felt that rejection of the standard style orthosis would occur due to his sheer mass and the difficulty attendants would have in applying and removing the orthosis. It was decided that a single attendant would be unable to satisfactorily apply an anterior opening orthosis. A bivalved design was felt to be the only realistic method of donning the orthosis, much less ensuring accurate positioning of the costal margin undercut (Figure 7).

During the initial in-hospital break-in period, it became apparent that though the patient

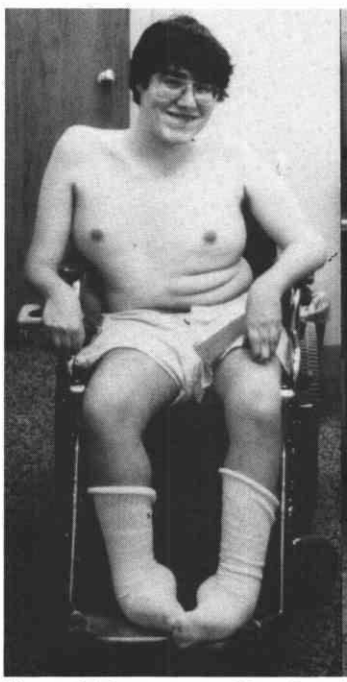

Figure 6. Twenty year old male with Duchennes Muscular Dystrophy and a 70 degree C curve. Patient has problems with sitting balance and loss of head control.

Figure 7. Patient in TSO with regained sitting tolerance and voluntary but weak head control.

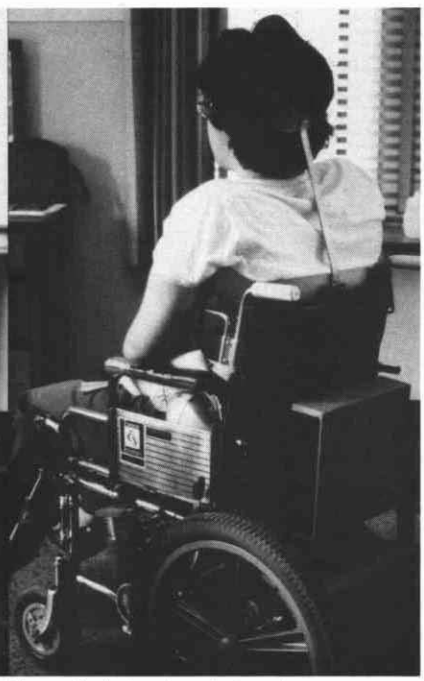

Figure 8. Lateral posterior view of patient in suspension showing simple head rest.

could achieve head control when in the orthosis, he readily fatigued, losing his head balance and was unable to regain it. A simple, removable head support was attached to the posterior shell of the jacket. The support was held in place by a screw in the aluminum upright which rested in a groove in the bracket attached to the posterior half-shell when the upright was slipped through the bracket. This arrangement permitted consistent height placement of the head support, but allowed a small amount of pivoting to take place (Figure 8) so that the head support would move with the patient.

While in the hospital, the patient was evaluated by an occupational therapist and was provided with a balanced forearm orthosis which enabled him to feed himself. At discharge, the patient was tolerating two hours of uninterrupted suspension.

At his three week follow-up clinic appointment, the patient reported tolerating suspension for five hours in the morning, then coming out of suspension for the afternoon and returning to the suspended position for the evening meal. Due to his size, his mother was unable to place him back in suspension in the afternoon, so he remained in the orthosis unsuspended until his father returned home from work. X-rays in the orthosis revealed a reduction in his curve at 48 degrees.

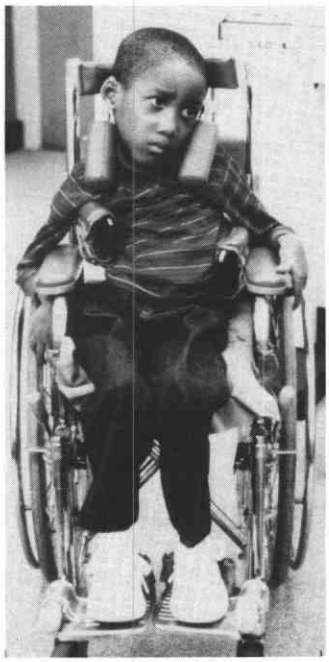

Figure 9. Five year old child with spinal muscle atrophy and a 72 degree scoliosis seated in a Mulholland chair with scoliosis pads.

CASE 4

This patient is a five year old male with Werding-Hoffmann Type II spinal muscle atrophy. The child was presented in clinic with a Mulholland chair with scoliosis pads, shoulder supports and head support (Figure 9). The patient had a rapidly progressing C-curve scoliosis which had progressed 51 degrees over a ten month period. X-rays showed a curve of 72 degrees while sitting in the Mulholland chair. Since it was felt that the Mulholland scoliosis pads had not been useful on deterring the progression of his curve, he was evaluated for a thoracic suspension orthosis.

On evaluation, the patient was noted to be emaciated and exhibited a typical christmas tree deformity of the thorax. He was a complete paradoxical breather. He lacked head control while sitting in his chair. His hypotonia was advanced and included total body involvement and he had elbow and knee flexion contractures. It was felt that a bivalved orthosis would offer the easiest donning and would provide quick visual assessment of the skin for this fragile appearing child. A large abdominal opening was made in the anterior shell to allow for his paradoxical breathing.

The child tolerated the initial break-in period quite well. Parents found the bivalved jacket design easy to handle. X-rays taken in suspension revealed reduction of his 72 degree curve to 25 degrees. He no longer used the head support, but the head rest was left in place to provide him with the option of using it to rest and to prevent excessive hyperextension of the neck during transportation and wheelchair use over uneven terrain (Figures 10, 11, and 12).

CONCLUSION

The TSO provides an alternative to traditional spinal orthoses for the management of difficult spinal deformities. Variation of the

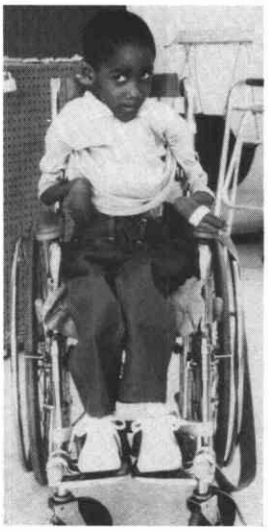

Figure 10. Anterior view of child in TSO suspension. Scoliosis reduced to 25 degrees in suspension.

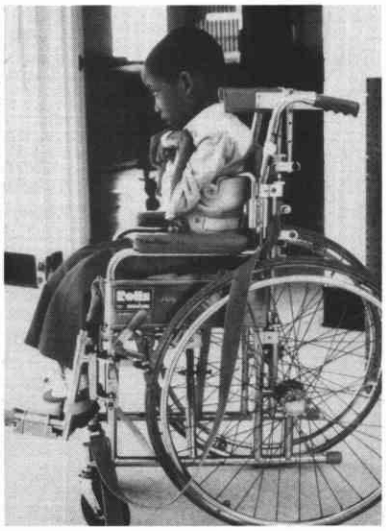

Figure 11. Lateral view of child with TSO in suspension.

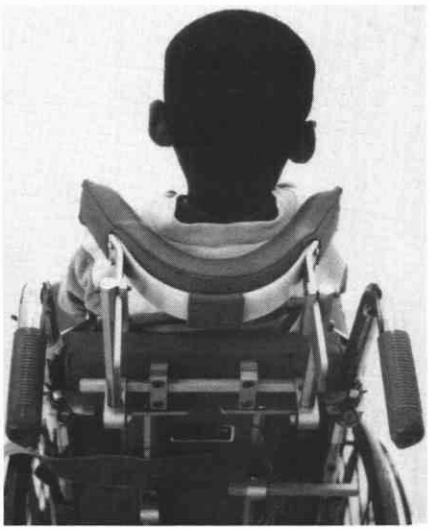

Figure 12. With improved sitting balance, patient regained head control. The head support was readjusted and left in place to limit possible neck hyper-extension during transportation.

orthosis design can be successfully accomplished within the frame work of the biomechanical principles of thoracic suspension. Thorough evaluation of the patient for appropriateness as a candidate is mandatory. Once the candidacy has been established, the orthotist can build upon this foundation with his knowledge of orthosis design principles to provide the optimum TSO design for the patient.

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Clinical Prosthetics and Orthotics, Vol. 10, No. 1, pp. 33–37

Immediate Post-Operative Orthotic Impression Technique for Thermoplastic Spinal Orthoses Following Spinal Surgery

by James T. Lehner, M.D.
Wilbur A. Haines, C.P.O.
Mark E. Horwitz, C.O.
Cynthia J. King, C.O.

Spinal surgery has been revolutionized in recent years by advances in surgical approaches, surgical techniques, and forms of internal fixation. Post-operative management has progressed from bed rest with log rolling, to mobilization in plaster casts, to modern technology orthoses. Co-polymer plastic composite orthoses have been used by the authors during the last few years. The orthoses have been easy to apply and have been comfortable for our patients. There have been no associated complications which would jeopardize the outcome of the operative procedure.

PATIENT SELECTION

The original patient the authors selected for management using a thermo-plastic orthosis was a retarded child with cerebral palsy who had previously been intolerant of casting, developing pressure sores within the cast. Molding for the co-polymer orthosis had to be done while the patient was anesthetized, since this patient was combative and otherwise difficult to work with. While the impression for this patient was being made, it became apparent that this molding technique would be easy to do in the operating room at the conclusion of operative spinal procedures. Initially, this post-operative molding technique was used for "special cases." These included patients with cerebral palsy, myelomeningocele, severe osteoporosis, and patients with severe respiratory problems. Eventually the older adult idiopathic population which seemed very intolerant of rigid metallic orthoses or casting was included. Things have gradually evolved to a point where most patients, other than teenage idiopathics, are candidates for this type of orthosis. The authors still prefer using a Kosair metallic axillary crutch style orthosis post-operatively for adolescent idiopathic scoliosis patients, since they seem to tolerate the rigidity of this system well.[1]

The first 80 patients fitted with the co-polymer postoperative spinal orthotic system are reviewed in this study.

Diagnoses include all the aforementioned, plus other types of muscular dystrophy, congenital scoliosis, tumors, post-menopausal deformities, and degenerative spinal deformities. All orthoses were applied after long (minimum of six vertebral levels) spinal fusions. All surgical cases, except those of congenital scoliosis, were routinely done with instrumentation.

ORTHOSIS IMPRESSION TECHNIQUE

The orthotic impression is taken immediately after the spinal surgery while the patient is still asleep. The technique is:

1. After the skin incision is closed, a light layer of Adaptic® and one layer of sterile four-by-fours are placed over the wound.
2. The skin is bilaterally marked longitudinally along the mid-axilla (mid-coronal line) using a wet indelible pencil. Perpendicular hash marks are randomly made across the mid-axillary line to be used as "key" reference marks later.
3. Sterile Vidrape® is placed across the patient's back to establish an impermeable membrane.
4. The Vidrape® is marked by superimposing onto it the marks made previously on the patient's skin.
5. Plaster splints are draped across the required area of the patient's torso, making sure that the plaster crosses the mid-axillary lines on both sides of the patient. The first layer is applied using two or three thicknesses of plaster. Subsequent reinforcing layers are applied, using about six layers of plaster. Finally, a few strips are applied to help prevent distortion of the mold. These are placed across the mold at two or three locations in the shape of an inverted "V."
6. At this point, the posterior section of the impression is removed from the patient when hard (Figure 1).
7. The Vidrape® is then removed in a manner which keeps plaster or water from touching the wound.
8. Sterile dressings are applied by the scrub nurse, who has remained sterile to this point.
9. The patient is placed on the post-operative bed that has been prepared using one extra sheet.
10. Vidrape® is then applied to the patient anteriorly in preparation for the anterior section molding. (Cover breast and groin areas with four-by-fours or diapers.)

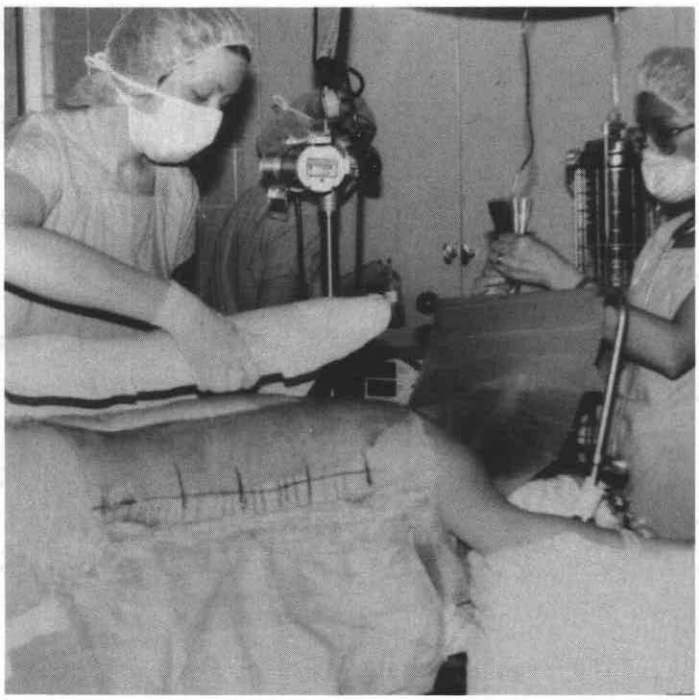

Figure 1. Orthotist removing posterior mold. Note Vidrape® and markings in mid-axillary line.

11. The indelible pencil marks are again superimposed onto the Vidrape® along the mid-axillary lines, and appropriate relief markings are made on the rib cage and iliac crests.
12. The anterior mold is made using the technique described in step five. When set, the plaster is removed.
13. Finally, the Vidrape® is carefully removed and the patient is ready to go to the post-operative recovery room.

After the impression has hardened sufficiently, a cast cutter may be used to cut along the mid-axillary indelible lines, visible on the inner surfaces of each half of the impression. Using the "key" hash marks established previously, the two impression halves are joined together with plaster strips. The impression is now ready for orthotic fabrication using the method of choice.

Since the impression has been made with the patient in the prone and supine positions, the orthotist must take this into account when fabricating the orthosis. The medial-lateral dimension of the patient is distorted normally about one inch due to the flattening effect created by the patient's weight against the operating and post-operative bed.

The time required for the impression procedure adds 15 to 20 minutes of extra anesthesia and operating room time. There have been no infections in any of these cases.

RESULTS

The orthosis described has been applied to 80 post-spinal surgery patients between January, 1980 and October, 1984. There were no cases of rod dislodgement or pseudoarthrosis. Fifty-eight patients had instrumentation done using segmental spinal wiring with either L-Rod or Harrington Rod fixation. One Mongoloid boy broke a wire in his L-Rod fixation, but over a subsequent 24 month follow-up, has shown no further wire or rod breakage. No other incident of internal fixation failure, while wearing the orthosis, has been encountered to date. Early in the series, one orthosis had to be remade due to pressure problems. No other orthosis has required anything except routine minimal corrections of trim lines. In the beginning, the average time of orthotic application was the eighth post-operative day. Later in the series, this dropped to the fifth post-operative day. Orthotic application varied from the second to the thirteenth day post-op and was determined by the patient's medical condition in all but one case. The patients were placed upright immediately upon application of the orthosis (Figure 2). They were dismissed from the hospital an average of four days after the orthosis was applied.

Orthoses were worn about six and one half months post-operatively (the first 25 patients wore theirs for eight months post-op; all subsequent patients have worn theirs for six months post-operatively).

Compliance has been monitored by the parents or guardians of the patients. They have reported 100 percent compliance. The parents are instructed that the orthosis may be removed when the patients are supine, for bathing, skin care, and pulmonary toilet as needed. Patients

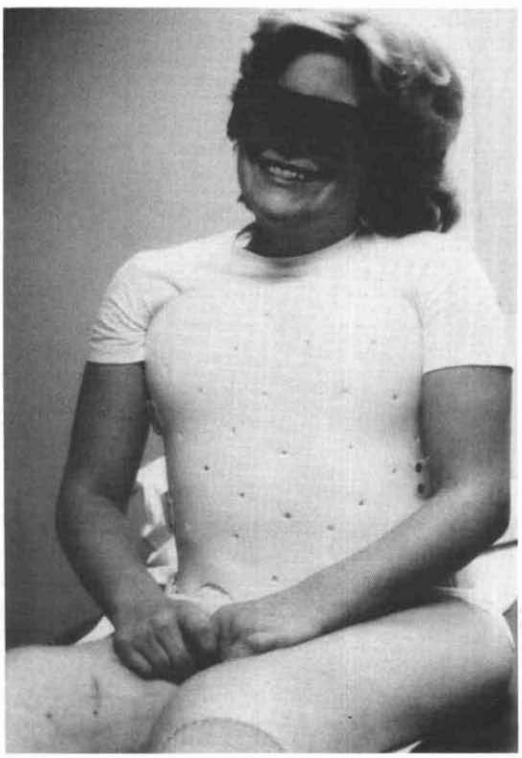

Figure 2. Post-op Spina Bifida child two days after brace application and four days post-operatively. Note colostomy site on right lower quadrant.

are never allowed up in the sitting position without wearing the orthosis during the six month post-operative period. One-half of the patients were non-ambulatory.

DISCUSSION

This is an easy, quick, and accurate way to measure and apply post-operative thermoplastic orthoses after spinal surgery. It has been possible to eliminate patient discomfort during the molding process and no manipulation of the patient was required during the procedure.

While this technique requires a close working relationship between physician, hospital personnel, and orthotist, it has virtually eliminated time delays in orthotic delivery. Historically, orthotic impressions were taken "when the patient was ready post-operatively." This left the impression making process in a nebulous time frame. Typically, patients were delayed in the application of their orthosis by a few days. This added additional patient time in the hospital with little benefit. Also, the orthotist had to schedule the impression making process at a time convenient to appropriate hospital personnel.

The technique described gives the orthotist and his/her staff adequate time to properly design and fabricate the orthosis. Although none of the patients were felt to be ready to ambulate or sit on the first post-operative day, it would be possible to apply the orthosis, if necessary, within 24 hours. Many of the severe respiratory cases (spinal muscular atrophy) are fitted with their orthoses, and sit up, while still on a respirator in intensive care. There was only one case where orthotic application delayed patient mobility (orthosis revision was necessary). Usually, comfort was the deciding factor in getting patients up. Later in this study group, when indications were broadened to include healthier patients, the time frame post-op of ambulation decreased significantly.

It is believed that molding for a spinal orthosis while the patient is awake, several days after surgery, is unnecessarily painful. It also places the patient in some jeopardy of dislodging the instrumentation while having the impression made. It is also considered irrational to mold patients for an orthosis at a time when they are actually ready to be up and around. The authors do not trust segmental spinal instrumentation without external bracing, and reports now indicate this conservative approach, including the use of an orthosis, in this group of patients is warranted.[2,3] Retarded children and patients with anesthetic skin easily get into trouble with body casts and non-removable orthoses. The orthotic system described certainly helps to alleviate many of the problems previously encountered with post-operative spinal orthoses. This technique is still not used for the standard adolescent idiopathic patient, who in our judgment currently does well with Harrington Instrumentation fixation and post-operative bracing using a rigid metallic Kosair type orthotic system.

ADVANTAGES

The co-polymer post-operative orthotic spinal system has many advantages:

1. Minimal patient discomfort;
2. Expedient spinal orthosis application;
3. Maximum utility for patient care (skin cleansing, checking anesthetic skin, respiratory therapy, etc.);
4. Taking an accurate impression with minimal post-operative movement of the patient; and
5. Excellent wearing compliance by patients.

DISADVANTAGES

While there are disadvantages to most anything, the negative points of this technique and system are few. They would include:

1. Increased anesthesia and operating room time (15–20 min.);
2. Tight post-op scheduling of the orthotist's time (Requires a close working relationship with physician, hospital personnel, and orthotist).

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Clinical Prosthetics and Orthotics, Vol. 10, No. 1, pp. 38–41

Use of a Bivalved Thoracic Suspension Jacket in the Orthotic Seating Management of Severe Arthrogryposis Multiplex Congenita

by Carrie L. Beets, C.O.
Louis Whitfield, R.T. (O)
Jan Minnich, L.P.T.
J. Leonard Goldner, M.D.

INTRODUCTION

The thoracic suspension orthosis[1,2,3] was developed to aid in the management of patients with neuromuscular disease and has been used primarily in individuals with myelodysplasia. The principle of the device is to use the rib cage as a weight bearing structure and thus provide improved seating posture for the patient while attempting to limit spinal deformity and relieve excess ischial pressure. Additional benefits include improvement of balance and mobility, freeing of the hands and arms for feeding and other activities of daily living. The body image of the patient is improved while seated in a wheelchair and the patient may interact better with the environment.

The thoracic suspension orthosis should be considered for those patients who cannot tolerate surgery, or when surgery should be delayed until they reach maturity.

The patient presented in this paper does not fit the usual criteria for use of a thoracic suspension orthosis. The needs of this patient went beyond those provided by usual orthotic seating devices and led to the adaptation of established techniques and development of a different design to provide a functional seating arrangement for a severely involved child who had failed with other custom seating devices.

This seven year old girl with severe generalized arthrogryposis multiplex congenita had functional limitation in the upper extremities and no voluntary action in the lower extremities. Surgical releases of soft tissue contractures and proximal and distal femoral osteotomies had been performed to adapt the patient to a sitting position. Past attempts to provide molded seating inserts to allow a comfortable sitting position had failed. She was most functional supine in a custom designed portable bed-like seating insert which permitted feeding.

Examination of the child revealed severe muscle atrophy of both upper extremities. There was active elbow extension but no active flexion. She was able to get her left hand to within several inches of her mouth by abducting and forward flexing her shoulder and then allowing gravity to bring her hand to the mouth.

The spine revealed right thoraco-lumbar scoliosis, thoracic kyphosis, fixed lumbar lordosis, and a fixed pelvic obliquity in which the left pelvic brim was higher than the right.

The left hip had a range of motion from 30 degrees flexion to about 90 degrees for a total of 60 degrees of flexion, with an external rotation deformity. The right hip was fixed in +20 degrees flexion. Both knees had flexion contractures of 70 degrees with 10 degrees motion.

In order to flex the right femur for sitting, a subtrochanteric osteotomy had been performed with creation of a silicone capped pseudoarthrosis. While this was relatively successful, pain occurred when the patient was placed in a sitting position with any weight bearing occurring on the right ischium. For this reason, she was evaluated for use of a thoracic suspension orthosis.

The patient was initially placed in a plaster cast thoracic suspension jacket for a three week trial. During this time, the periods of suspension were gradually increased. Her skin was not accessible for monitoring; however, since she had normal sensation and was cooperative, we depended on her complaints of pain to assess the support. She tolerated the three week trial period and experienced no skin breakdown or abrasion. At that time, a cast impression was taken for the fabrication and fitting of a thoracic suspension orthosis.

FABRICATION AND FITTING

Due to the lack of spinal flexibility, the need for easy and accurate application of the orthosis, as well as the need to make the device as simple as possible for the parents, a bivalved design was chosen rather than the traditional single anterior opening. The bivalved design (Figure 1) necessitated fabrication of two plastazote™ linings complete with conventional additional plastazote™ layers over the inferior costal margins. Special attention was needed to insure that the anterior and posterior halves of the two linings matched up accurately during the vacuum forming process (Figure 2).

The suspension spools were incorporated into the posterior shell, which was fabricated of low density polyethylene. High density polyethylene was chosen for the anterior shell, as it was felt that the additional rigidity provided by this material would be needed to maintain the integrity of the circumferential containment of the jacket under weight bearing. A large abdominal opening was provided in the anterior shell because the patient had experienced some distress in the plaster jacket, especially following meals, which had been relieved by the addition of an opening in the plaster cast

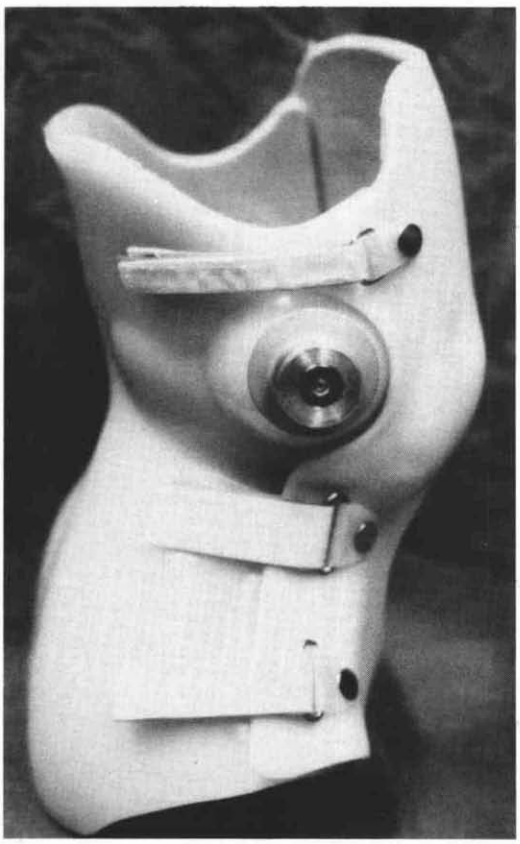

Figure 1. Lateral view of bivalved thoracic suspension orthosis showing anterior shell trimlines.

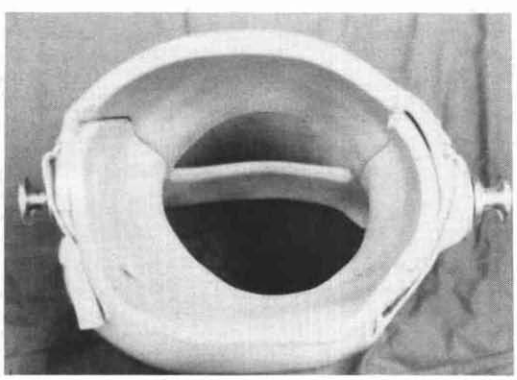

Figure 2. View from above, the anterior and posterior linings match up to provide an even pressure just distal to the lateral and anterolateral inferior costal margins.

Figure 3. Anterior view of bivalved thoracic orthosis showing abdominal opening.

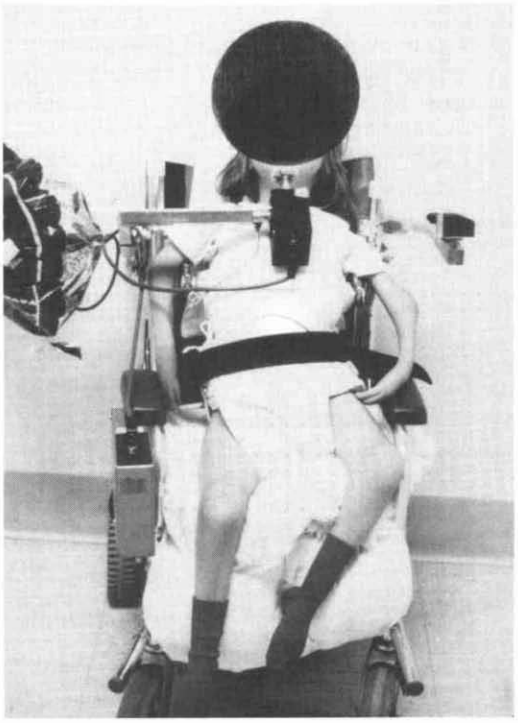

Figure 4. Patient sitting in suspension in wheelchair.

(Figure 3). The two half shells were held in place as a unit with Velcro® closures.

Fitting of the orthosis was followed by an in-hospital program of gradually increasing wearing time both in the nonsuspended and suspended states. Her original supine positioning device was modified to permit her to lie in this with the thoracic suspension jacket on, eliminating the need to take off the jacket between periods of suspension. Since she could not tolerate any weight bearing on her right hip, the suspension brackets on the wheelchair were positioned for full weight bearing suspension. She tolerated the conditioning program well, and at the time of discharge was wearing the jacket all day long and was tolerating uninterrupted suspension for periods of two and one-half hours. Her electric wheelchair was outfitted with a chin operated joy stick control (Figure 4). While suspended, she could operate the wheelchair well, but at the end of two and one-half hours in suspension, the patient would begin to complain of discomfort and, at that time, would be transferred to her supine positioning device.

CONCLUSION

The application of a thoracic suspension jacket is a way of successfully providing a functional sitting position for a patient with severe arthrogryposis. In conjunction with a modified electric wheelchair, the patient was given an opportunity to interact actively with her environment, including a vertical position for eating.

The bivalved design not only affords easy application and removal, but also permits visual monitoring of the skin. The crucial circumferential containment in the area of and just distal to the inferior costal margin was maintained satisfactorily with a bivalved design.

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AUTHORS

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J. Leonard Goldner, M.D., was former Chief of Orthopedics, Division of Orthopedic Surgery, Duke University Medical Center.

Analysis of Questionnaire—Improved Fitting Techniques

There were 25 respondents to this questionnaire. In replying to the first question 12 (25%) said that they used check sockets routinely and 12 (48%) said that they used them occasionally. Eight respondents (32%) said that they used alginate routinely and 12 (48%) reported using it occasionally. Only 5 (20%) said that they never used it. In stark contrast, only 4 (16%) reported using x-ray or xeroradiography routinely. Ten (40%) used it occasionally and 11 (44%) stated that they never used it. As regards the use of video tape during dynamic alignment, seven (28%) used it occasionally and 18 (72%) said they never used it. No one reported using it routinely. Interestingly enough several respondents specifically mentioned that they did not have video equipment available.

The sharp distinction between the two group of questions is interesting. It may be hypothesized that prosthetists have readily implemented the techniques, check sockets and alginate, that can be put in place at minimal expense and with minimal involvement of outside personnel. However, it may also be that people just do not know enough about either technique to adopt them or the two techniques have not proven themselves to be beneficial.

Calendar

1986

January 27–February 2, Academy Annual Meeting and Scientific Seminar, MGM Grand, Las Vegas, Nevada. Contact: Academy National Headquarters: (703) 836-7118.

February 20–25, American Academy of Orthopedic Surgeons Annual Meeting, New Orleans, Louisiana.

March 2–5, 3rd Israel-Scandinavian Rehabilitation Seminar, "ISRASCAN: Work for Disabled Adults," Eilat, Israel. Contact: Israel Rehabilitation Society, 18 David Elazar Street, Tel Aviv 61901, Israel.

March 14–15, American Academy of Orthotists and Prosthetists Continuing Education Conference 1-86, "Spinal and Seating Orthotics," Birmingham, Alabama.

March 17–21, Fitting Procedures for the Utah Artificial Arm, UCLA Post-Graduate Medical School, Department of Prosthetics and Orthotics, Los Angeles, California. Contact: Harold Sears, Ph.D., Motion Control, Inc., 95 South Elliott Road, #105, Chapel Hill, North Carolina 27514; tel. 919-968-8492.

March 21–22, Combined meeting of the Texas Chapter of the Academy and the Texas Association of Orthotists and Prosthetists. La Mansion Del Rio Hotel, San Antonio, Texas. For further information contact: Dean Raymond, 512-224-0726 or 512-224-5433.

April 8–11, Pacific Rim Conference, Intercontinental Hotel, Maui, Hawaii.

April 9–12, Ambulatory Surgery in 1986—What's Happening Now. Freestanding Ambulatory Surgery Association, Boston Marriott Copley Place, Boston, Massachusetts. Contact: 703-836-8808.

April 10–12, New England Chapter of the Academy Spring Seminar and AOPA Region I Combined Meeting, Dunfey Hotel, Hyannis, Massachusetts. Contact: E. Janulaitis, CPO, tel. 617-586-7700.

April 12, Midwest Chapter of the Academy Spring Continuing Education Seminar/Social Event.

April 18–19, NY State Chapter of the Academy, Rochester, New York.

May 7–10, Annual Meeting of the Association of Children's Prosthetic-Orthotic Clinics, Milwaukee, Wisconsin. Contact: Francis J. Trost, M.D., Program Chairman, 2545 Chicago Avenue South, Minneapolis, Minnesota 55404.

May 16–17, American Academy of Orthotists and Prosthetists Continuing Education Conference 2-86, "Lower Limb Prosthetics," Kansas City, Missouri.

May 28–30, S. M. Dinsdale International Conference on Rehabilitation, "Towards the 21st Century," hosted by the Royal Ottawa Regional Rehabilitation Centre, 505 Smyth Road, Ottawa, Ontario K1H 8M2. Contact: Education Dept. tel. 613-737-7350, ext. 602.

June 2–6, Fitting Procedures for the Utah Artificial Arm, Northwestern University Post Graduate Medical School, Department of Prosthetics and Orthotics, Chicago, Illinois. Contact: Harold Sears, Ph.D., Motion Control, Inc., 95 South Elliott Road, #105, Chapel Hill, North Carolina 27514; tel. 919-968-8492.

June 6–8, AOPA Region IX, COPA, and the California Chapters of the Academy Combined Annual Meeting, Newport Beach Marriot, Newport Beach, California.

June 19–22, AOPA Region VI and Academy Midwest Chapter Combined Annual Meeting, Lakelawn Lodge, Delavan, Wisconsin.

June 23–27, RESNA 9th Annual Conference on Rehabilitation Technology, "Employing Technology," Radisson South Hotel, Minneapolis, Minnesota. Contact: RESNA, Suite 700, 1101 Connecticut Avenue, NW, Washington, D.C. 20036; tel. 202-857-1199.

July 18—19, American Academy of Orthotists and Prosthetists Continuing Education Conference 3-86. "Disarticulation Prosthetics," Milwaukee, Wisconsin. Contact: Academy National Headquarters, 703-836-7118.

August 5–7, Canadian Association of Prosthetists and Orthotists Bi-Annual National Convention, World Trade Center, Halifax, Nova Scotia, Canada. Contact: Nova Scotia Rehabilitation Centre, Orthotics/Prosthetics Unit, 1341 Summer Street, Halifax, Nova Scotia B3H 4H4, Canada.

September 19–20, American Academy of Orthotists and Prosthetists Continuing Education Conference 4-86, "Powered Limb Prosthetics," Albany, New York. Contact: Academy National Headquarters, 703-836-7118.

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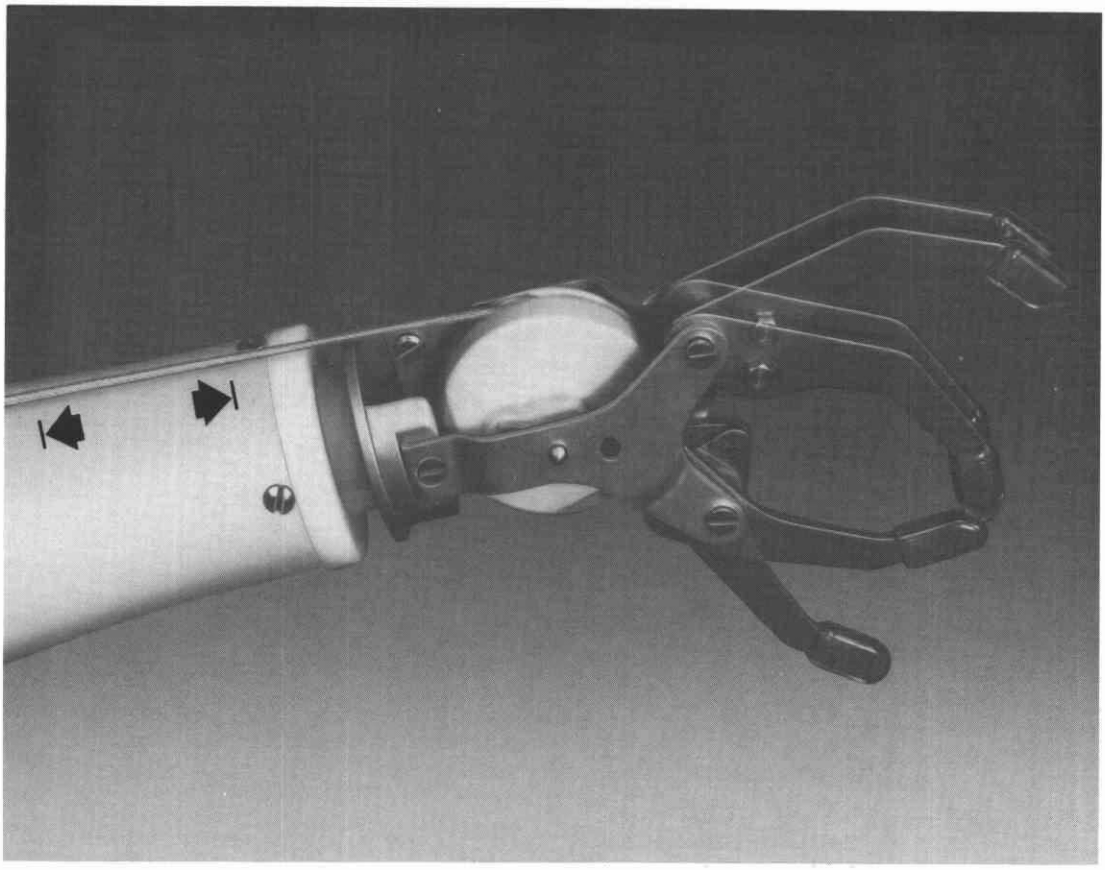
Christopher R. Colligan
Managing Editor
September 27, 1985



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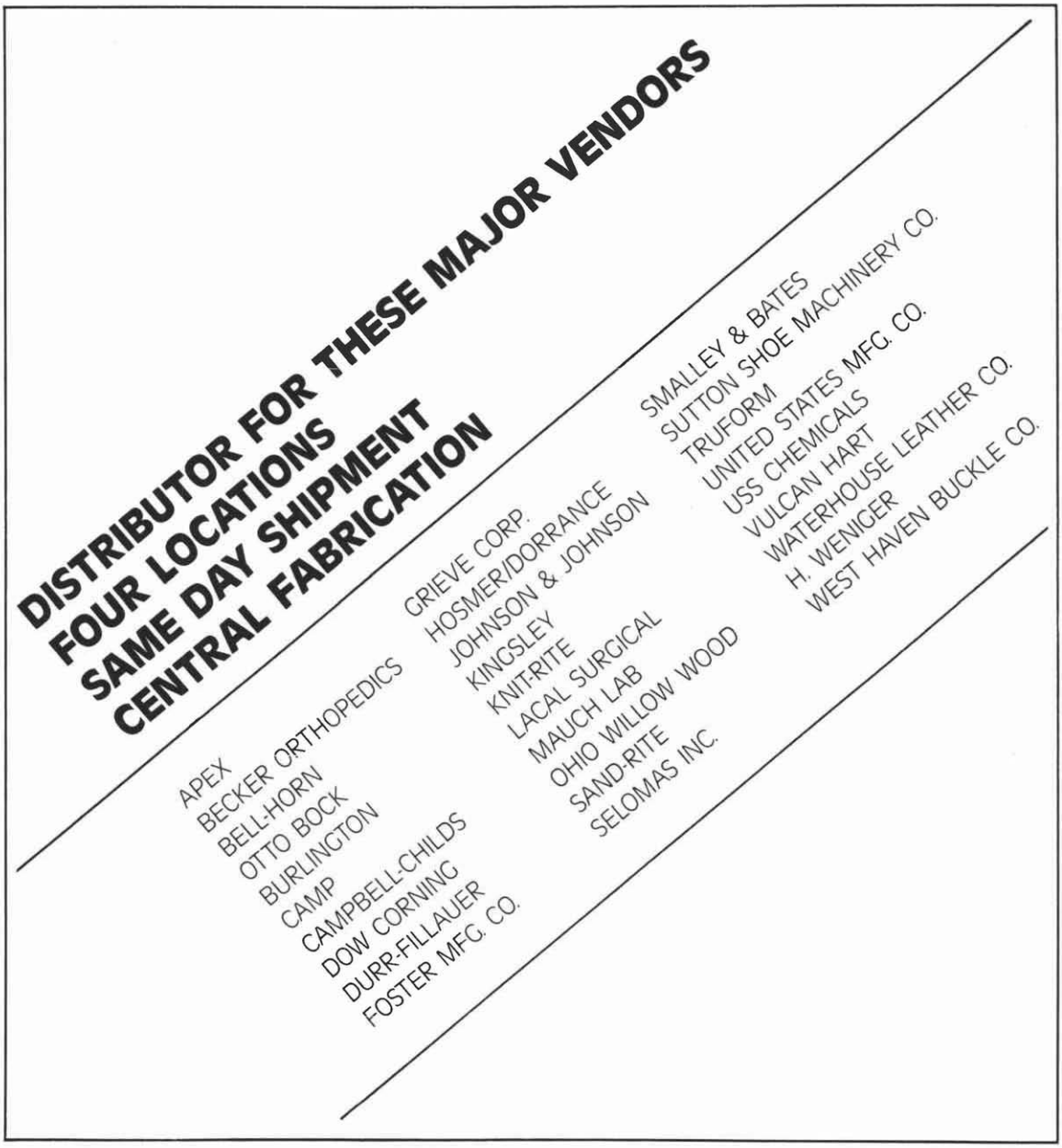

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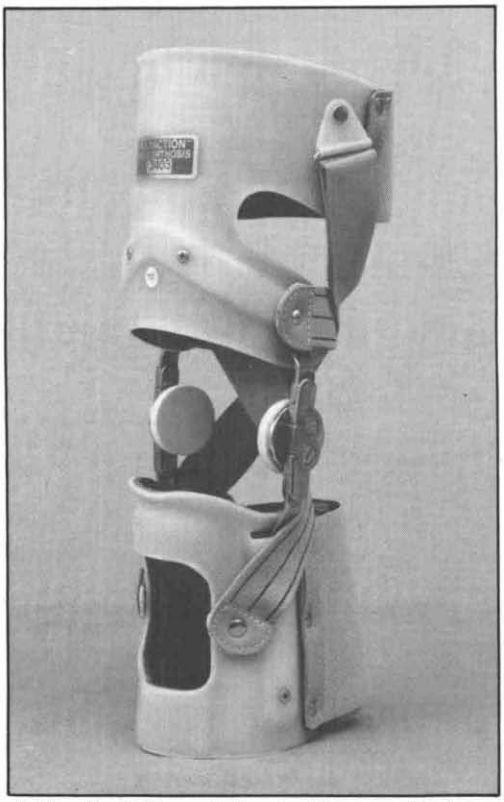

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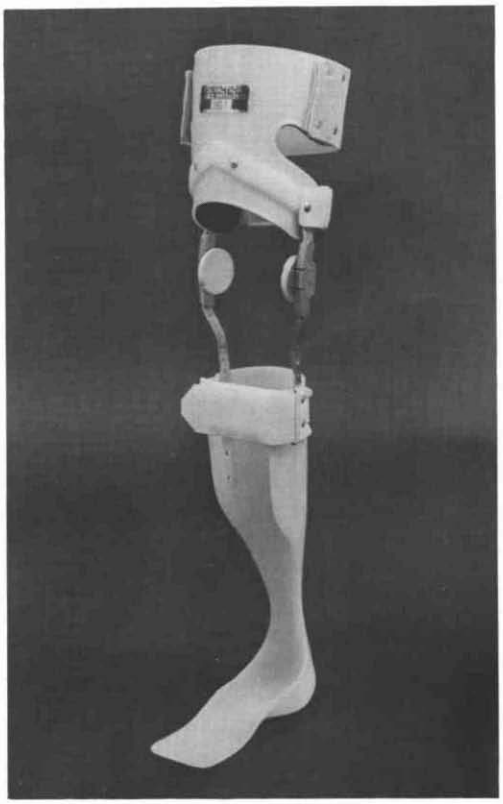

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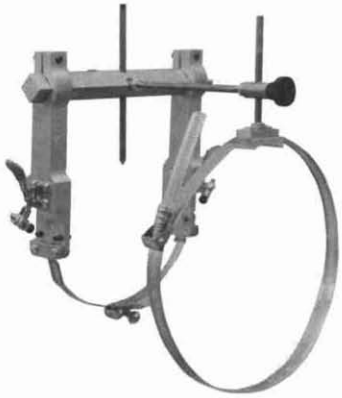

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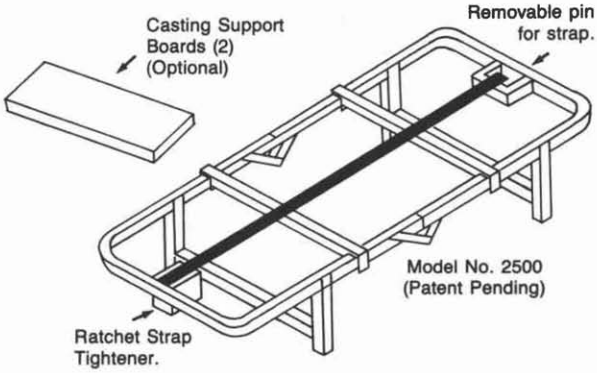

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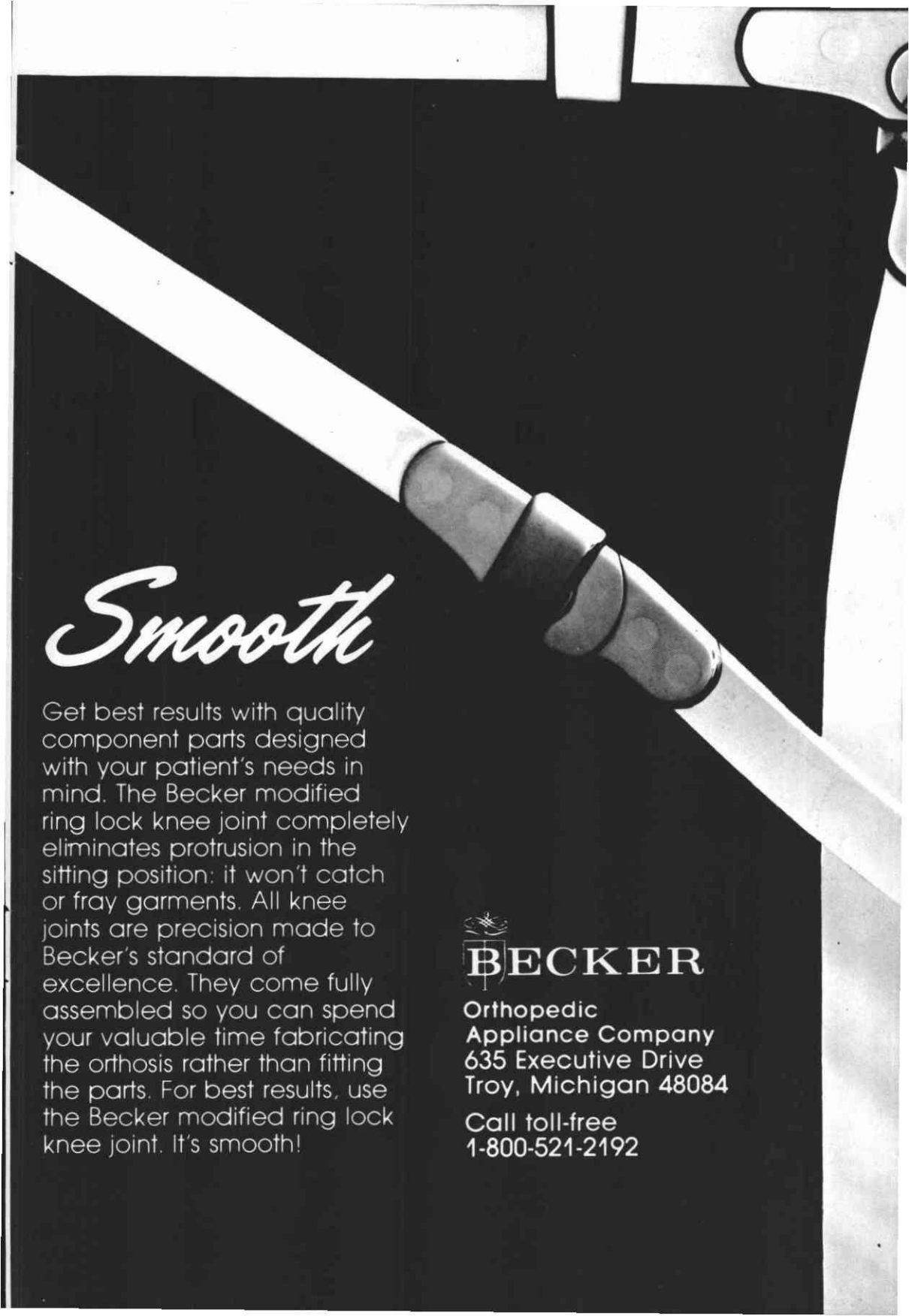

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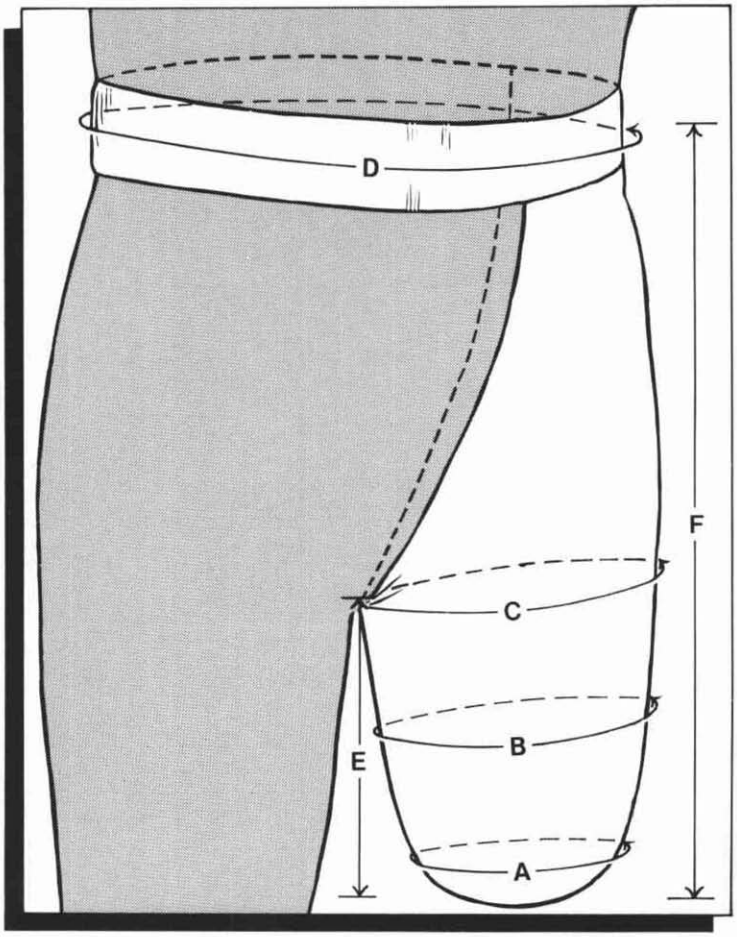

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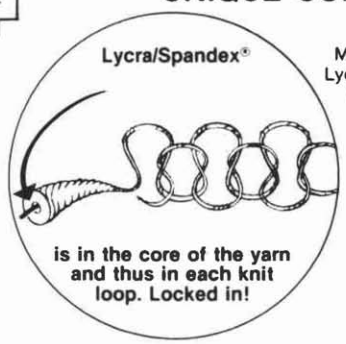

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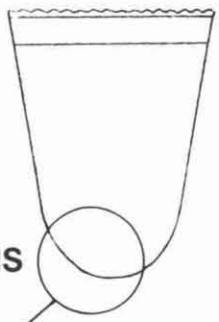

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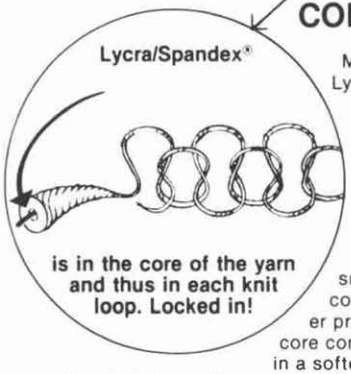

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2HP-MRM-10 12 14	Medium	Medium	4"	6"	12-14"	15-17"	10" 12" 14"
2HP-MRW-10 12 14	Medium	Wide	5"	7"	15-17"	18-20"	10" 12" 14"

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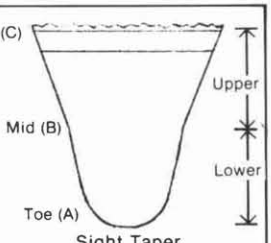
2HP-HDN-10 12 14	Heavy	Narrow	3	3.5	6"	9-11"	15-17"	10" 12" 14"
2HP-HDM-10 12 14	Heavy	Medium	4	4.5	7"	12-14"	18-20"	10" 12" 14"
2HP-HDW-10 12 14	Heavy	Wide	5	5.5	8"	15-17"	21-24"	10" 12" 14"
2HP-MDN-10 12 14	Medium	Narrow	3	3.5	6"	9-11"	15-17"	10" 12" 14"
2HP-MDM-10 12 14	Medium	Medium	4	4.5	7"	12-14"	18-20"	10" 12" 14"
2HP-MDW-10 12 14	Medium	Wide	5	5.5	8"	15-17"	21-24"	10" 12" 14"

Select proper size according to distal circumference of stump; then select proper taper (Regular or Double) of Stump Shrinker, according to proximal circumference.

**DOUBLE TAPER

Fashion knit, with gradual taper distally, flaring to a wide top. Flat widths are expressed as toe/mid/top in the size chart. The mid-point flat width of the "Double Taper" model is slightly less than the corresponding mid-point flat width of the regular taper model.

The length of the upper portion of all lengths of "Double Taper" socks is 7 ". The length of the lower portion is 3", 5" or 7" on the 10", 12" and 14" length socks respectively.



Sight Taper Distally (Lower Portion)

CAUTION: Compression proximally should not be greater than compression distally.

TWO PRESSURES—

Heavy compression (green top) exerts 25-30 mm Hg pressure at 50% stretch for reduction of edema and shaping of stump.

Medium compression (gray top) exerts 10-15 mm Hg pressure at 50% stretch for tender stumps, nighttime wear and stump size maintenance.

50% Stretch is Required to render the desired compression of 25-30 mm Hg for the heavy weight Green Top or 10-15 mm Hg for the medium weight Gray Top. 50% stretch is calculated as follows for 3" Toe (flat) Width: 3" x 2 = 6" (Relaxed Circumference). The 6" x 50% = 3" of stretch. In this example the distal circumference of the stump should be in the range of 9" to 11" to insure proper compression by the stump shrinker. Top (proximal) circumference should fall within the 30% to 50% stretch range. Top stretch percentage should not exceed the toe stretch percentage. The sizing chart sets out the toe and top "fit range".

FOR SPECIAL SOCKS: Send Measurements:

BK: 1 inch from distal end_____; 3 inch from distal end_____; 6 inch from distal end_____; top_____ length of stump_____ Length of sock_____

AK: 1 inch from distal_____; 3 inch from distal_____; 6 inch from distal_____; waist_____; length distal to groin_____; length distal to waist_____

2HP-HBK-SP BK Stump Shrinker, Heavy Pressure, Special
2HP-MBK-SP BK Stump Shrinker, Medium Pressure, Special

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