Clinical Prosthetics & Orthotics

Orthotic Management of the Foot

Volume 12, Number 2 Spring, 1988

We're ready willing and able!

We're a roll-up-your-sleeves-and-get-the-job-done company. Sure, we have on suits and ties at the meetings, but back at the warehouse, the sleeves are rolled up and the job gets done. We are there to answer the phones, take your orders and solve your supply problems. We'll check stock and guarantee you that your order will be sent out on time. We're not afraid of hard work. We'll provide service that is so good, you'll call us again, and again and again ...

For Orthotic & Prosthetic Parts and Supplies, call PEL TOLL FREE ---

Nationwide 1-800-321-1264
In Ohio 1-800-345-5105
FAX # 216-267-6176

PEL SUPPLY CO.

4666 Manufacturing Rd.
Cleveland, Ohio 44135

Paul E. Leimkuehler, C.P. president

CONTENTS

Volume 12, Number 2 **Spring, 1988**

Orthotic Management of the Foot

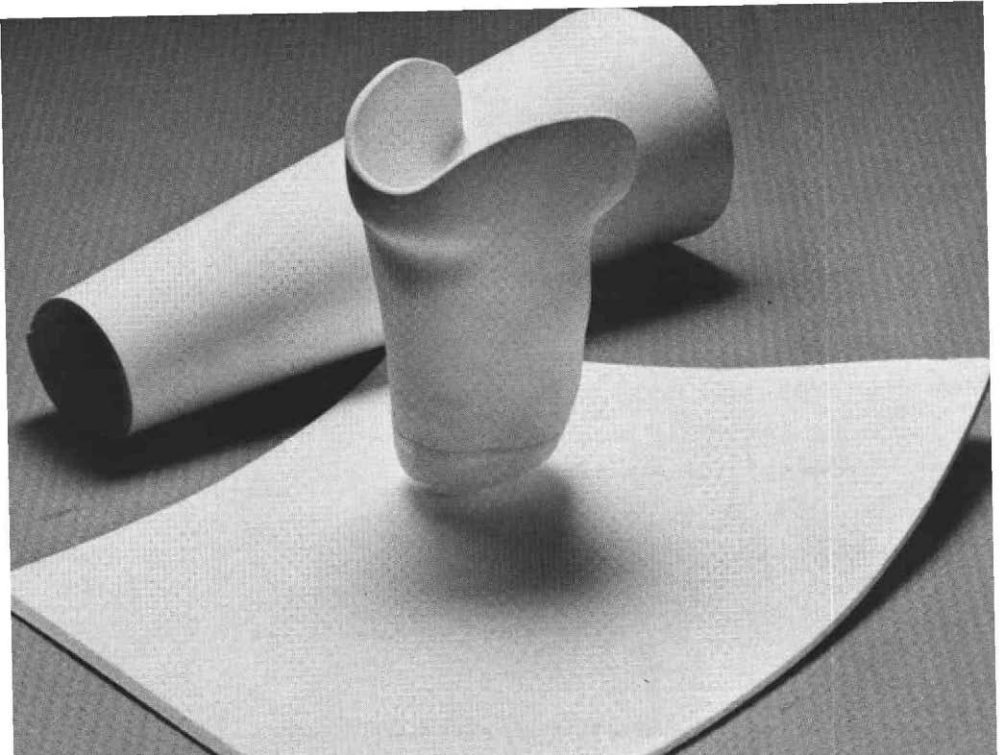
From the Editor:

Opinions expressed in *Clinical Prosthetics and Orthotics* are solely those of the authors. No endorsement implied or explicit is made by the editorial staff, or by the American Academy of Orthotists and Prosthetists.

FEATURES

AD INDEX

Clinical Prosthetics and Orthotics (ISSN 0735-0090) is published quarterly by the American Academy of Orthotists and Prosthetists, 717 Pendleton St., Alexandria, VA 22314. Subscriptions: $25.00 domestic, $30.00 foreign, $40.00 air mail. Second-class postage paid at Alexandria, Virginia and additional mailing offices. POSTMASTER: Send address changes to *Clinical Prosthetics and Orthotics*, 717 Pendleton St., Alexandria, VA 22314.



Prefabricated Pelite Cones for P.T.B. liners

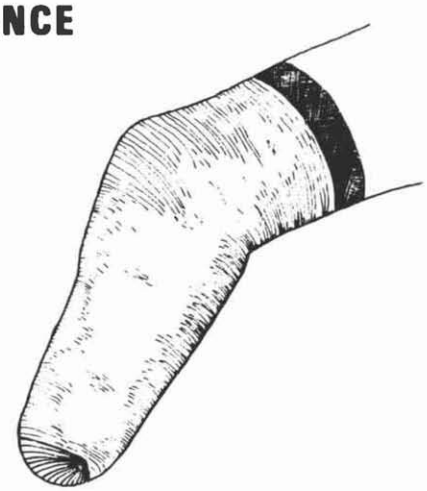
Since its introduction in 1982 the Durr-Fillauer Prefabricated Pe-Lite Cone has proven to be a real favorite in the prosthetic profession. As it is available as a prepackaged kit it saves the busy professional time and the mess and inconvenience of having to skive and glue the vertical seam. It comes either singly or in boxes of three and in two lengths, 12" and 14". The width of the skived seam has been narrowed for a neater appearance without sacrifice in strength.

Pro-Com
INCORPORATED

P.O. BOX 325 • MILLINGTON, NEW JERSEY 07946
Out of State: 800-524-0215
In New Jersey: 800-221-6936

THE B/K SHRINKER FOR MAINTENANCE

PRO-COM's lightweight **B/K Shrinker** is fabricated with a circular knit. This construction provides a two-way stretch to the material resulting in a more even compression to the effected limb. It is constructed of nylon covered rubber. The proximal aspect is 100% nylon, without rubber, for greater patient comfort. The distal aspect has a flat posterior seam which eliminates pressure across the tibia.



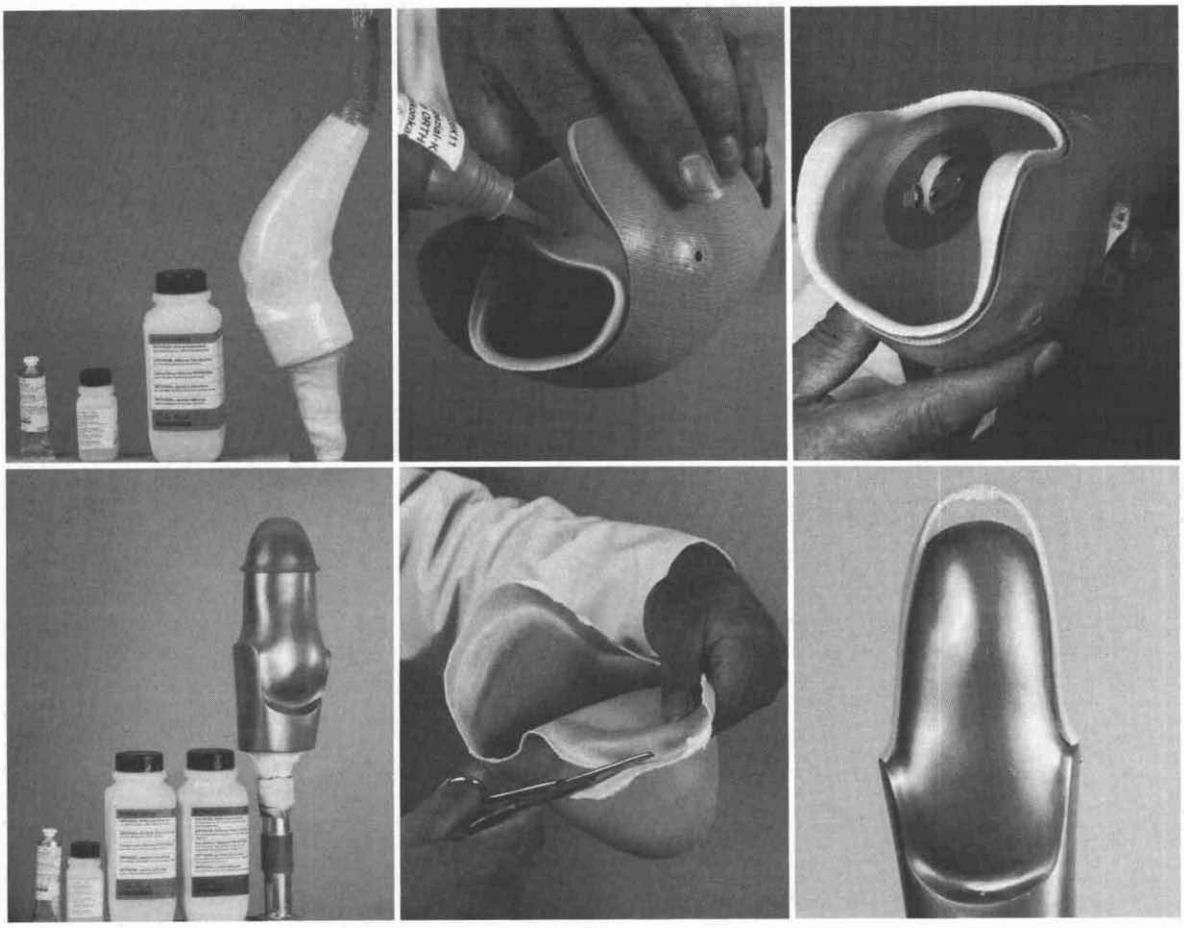
PRO-COM's lightweight **B/K Shrinker** is available in three sizes:

652001 – SMALL – Fits 8 to 12 inches in circumference – 12 Inch Length
652002 – MEDIUM – Fits 12 to 16 inches in circumference – 14 Inch Length
652003 – LARGE – Fits 16 to 20 inches in circumference – 16 Inch Length

DISTRIBUTED BY:

Pro-Com
INCORPORATED

WASHINGTON PROSTHETIC SUPPLIES
40 PATTERSON STREET, N. E.
WASHINGTON DC 20002
(202) 789-0052
Toll Free: (800) 424-5453



ORTHOSIL Silicone Gel – OTTO BOCK Application Technique

OTTO BOCK has improved the fabrication technique for socket liners using ORTHOSIL Silicone Gel:

- Higher viscosity allows easier processing and more thorough saturation.
- High tear strength; increased durability.
- Mixing of the two ORTHOSIL types allows individual determination of the density.

The ORTHOSIL product line includes:

617H43 ORTHOSIL Silicone Gel for the fabrication of soft insert liners.
617H44 ORTHOSIL Silicone Gel for the fabrication of pads and distal end-bearing cushions; available in 900-gram and 4600-gram containers.
617H45 ORTHOSIL Catalyst for 617H43 and 617H44; available in 100-gram and 1000-gram containers.
617Z19 ORTHOSIL Pigment Paste (Caucasian); available in 90-gram tubes.
623T13 Elastic Stockinette, specialized for use with the ORTHOSIL Silicone Gel; available in 10 cm and 15 cm widths.
519L5 ORTHOSIL Parting Agent; available in 400-gram spray cans.
617H46 ORTHOSIL Bonding Agent; available in 90 ml tubes.
617H47 ORTHOSIL Stabilizing Agent for the fabrication of ORTHOSIL paste; available in 100-gram containers.
636K11 ORTHOSIL Adhesive; available in 25-gram bottles.

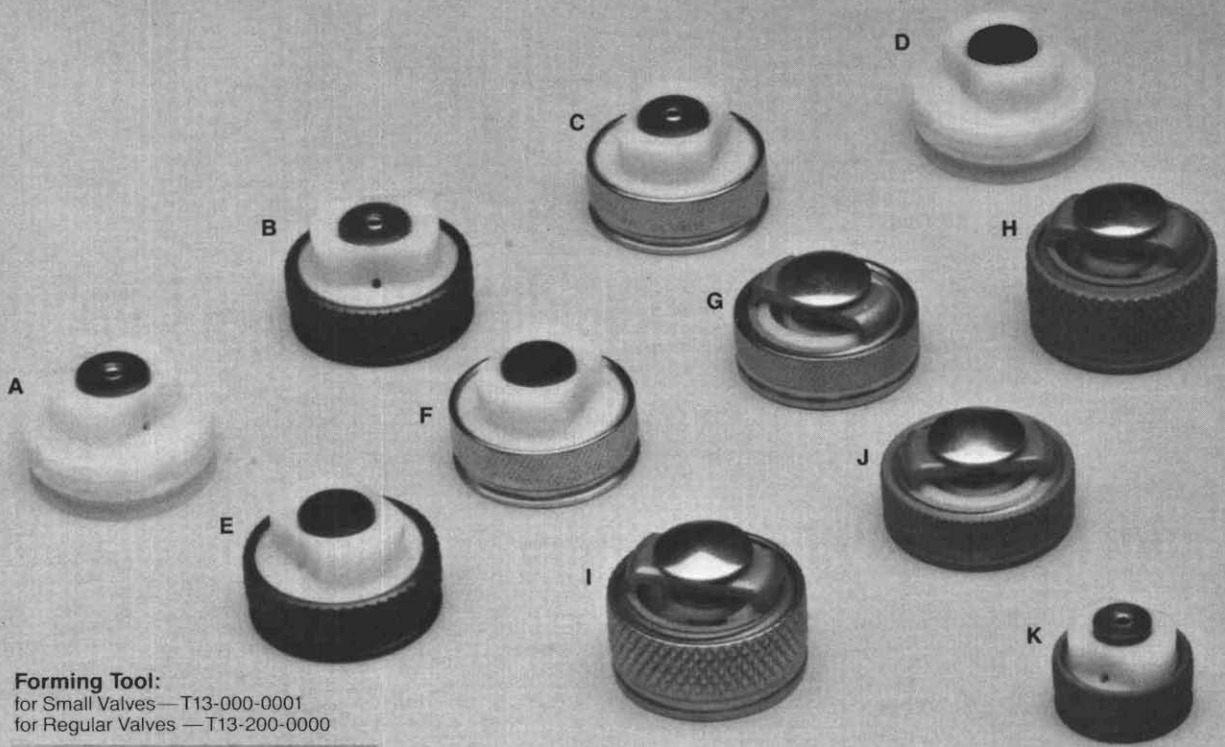
Otto Bock
ORTHOPEDIC INDUSTRY INC.
UNITED STATES OF AMERICA

4130 Highway 55
MINNEAPOLIS/Minnesota 55422
Telephone (612) 521-3634
Telex 2 90 999

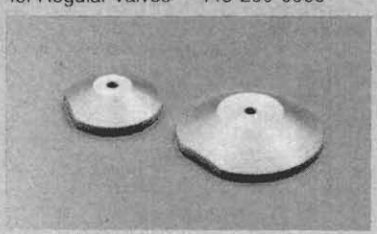
The line of choice ir

for Laminating Applications

	Adjustable Leak Rate	Non-adjustable
Green Dot Total Contact Suction Socket Valves (dia. x thickness)	**A**—1¼"x ⅜" Plastic Housing—P12-310-2000 **B**—1¼"x ⅜" Aluminum Housing—P12-350-2000 **C**—1¼"x ⅜" Stainless Steel Housing—P12-320-2000	**D**—1¼"x ⅜" Plastic Housing—P12-310-1000 **E**—1¼"x ⅜" Aluminum Housing—P12-350-1000 **F**—1¼"x ⅜" Stainless Steel Housing—P12-320-1000
Laurence Total Contact Suction Socket Valves (dia. x thickness)		**G**—1¼"x ⅜" Stainless Steel Housing—P13-010-0200 **H**—1¼"x ⅝" Aluminum Housing—P13-020-0100 **I**—1¼"x ⅝" Stainless Steel Housing—P13-010-0100 **J**—1¼"x ⅜" Aluminum Housing—P13-020-0200
Small Suction Socket Valves (dia. x thickness)	**K**—⅞"x ⅜" Push Type—P19-000-0005	**L**—⅞"x ⅜" Pull Type—P19-000-0004 **M**—⅞"x ⅜" Push Type—P19-000-0006



Forming Tool:
for Small Valves—T13-000-0001
for Regular Valves —T13-200-0000



Now you can choose from 22 different Suction Socket Valves for laminating and thermoplastic applications.

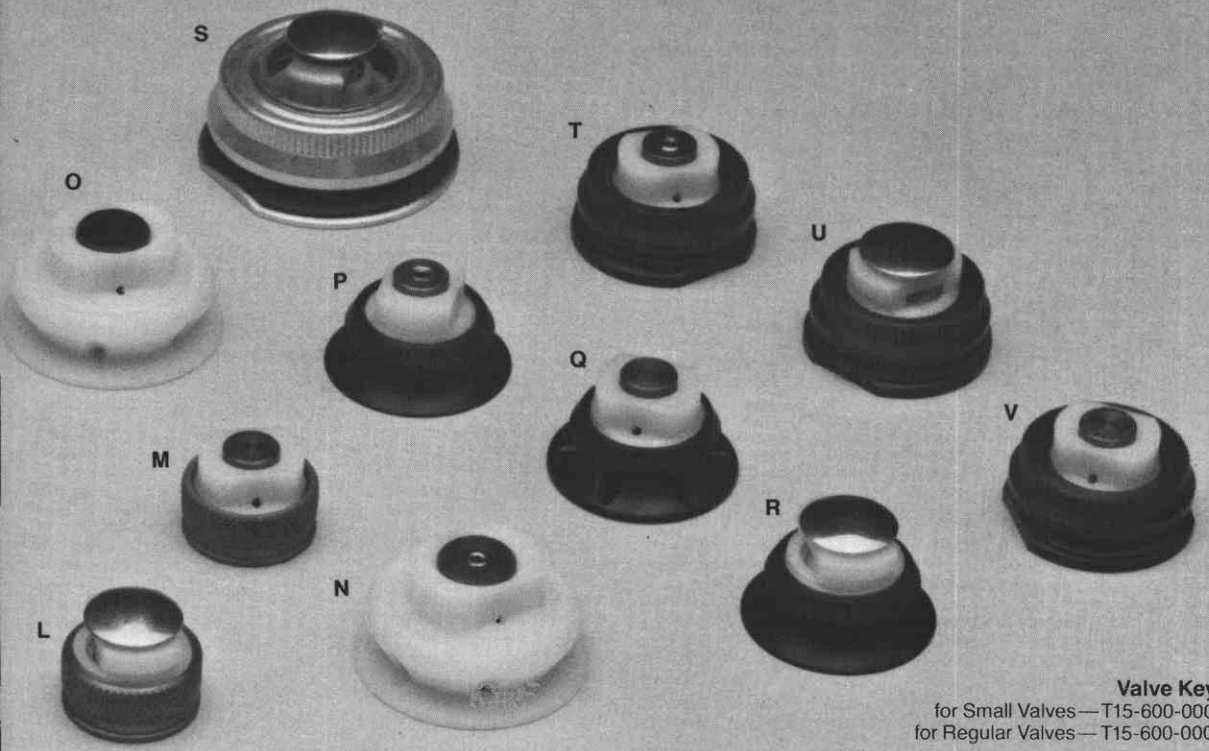
It's the widest variety of Suction Socket Valves ever.

To make the right decision for your patient's needs, go with the company that offers the widest variety in Suction Socket Valves—United States Manufacturing Company.

Suction Socket Valves...

for Thermoplastic Applications

	Adjustable Leak Rate	Non-adjustable
SFS Valves (dia. x thickness)	**N**—1½" x ½" Push Type—P12-340-2000	**O**—1½" x ½" Push Type—P12-340-1000
Small SFS Valves (dia. x thickness)	**P**—1¼" x ½" Push Type—P19-000-0008	**Q**—1¼" x ½" Push Type—P19-000-0009 **R**—1¼" x ½" Pull Type—P19-000-0007
Large Laurence Suction Socket Valve (dia. x thickness)		**S**—1¾" x ⅞" Pull Type—P13-030-0100
Small Suction Socket Valves (dia. x thickness)	**T**—1¼" x ½" Push Type—P19-000-0002	**U**—1¼" x ½" Pull Type—P19-000-0001 **V**—1¼" x ½" Push Type—P19-000-0003



Valve Key:
for Small Valves—T15-600-0001
for Regular Valves—T15-600-0000

USMC™

United States Manufacturing Company
180 N. San Gabriel Blvd., Pasadena, CA 91107-3488 U.S.A.
P.O. Box 5030, Pasadena, CA 91107-0030 U.S.A.
Telephone: (818) 796-0477, Cable: LIMBRACE, TWX: 910-588-1973
Telex: 466-302, FAX: (818) 440-9533

Clinical Prosthetics and Orthotics, Vol. 12, No. 2, pp. 44–50

Clinical Analysis of Foot Problems

by Karen S. Seale, M.D.

Introduction

Orthotists are vital members of the foot care team. Their expertise and special interests in materials and biomechanics add a unique dimension to the management of foot problems.

It is hoped that the principles of clinical assessment of foot problems set forth in this article will foster even greater interest in and understanding of the pathophysiology of foot problems. The purposes of this article are threefold:

- To familiarize the orthotist with the general concepts of clinical analysis of the foot.
- To assist the orthotist in designing the most appropriate orthosis based on clinical assessment of the problem.
- To give examples of clinical analysis of the following common foot problems for which an orthotic treatment may be prescribed:
  1. Heel pain
  2. Pes planus
  3. Metatarsalgia
  4. Ankle instability

Discussion

Clinical analysis of the foot consists of obtaining a pertinent history and performing a physical examination of the lower extremity. The medical history is an opportunity to gather as much information as possible by asking the patient to describe the pain, problem, or deformity. Specific information is sought by asking about the type of pain, its duration, onset (whether insidious or abrupt), location of the pain, and activities that help or aggravate the pain (such as rest, walking, or wearing or removing certain shoes).

Physical examination involves inspection, palpation, and manipulation. Observe the patient, first with and then without his typical footwear, both standing and walking, with arms hanging freely at the sides. The patient should be observed from the front and from the back. With the patient seated at a height comfortable for the examiner and the shoes removed, palpation and manipulation can be performed. Palpation is not intended to inflict pain, but rather to identify areas of discomfort. For example, applying direct pressure in the center of the heel pad may cause discomfort in a patient with "heel spur" syndrome.

In addition to palpation, manipulation is used to assess range of motion of the various joints and to determine the biomechanical relationships of the component parts of the lower extremity. Although a description of a comprehensive foot examination is beyond the scope of this paper, clinical analysis of four common foot problems is included in the next section.

Heel Pain

A very common clinical problem for which shoe modifications may be prescribed is heel pain. Although many causes of heel pain exist, common etiologies include, (1) fat pad atrophy, (2) plantar fascitis or "heel spur" syndrome, and (3) neuritis of the medial calcaneal or lateral plantar nerves.

Atrophy of the fat pad is particularly common among older individuals who will

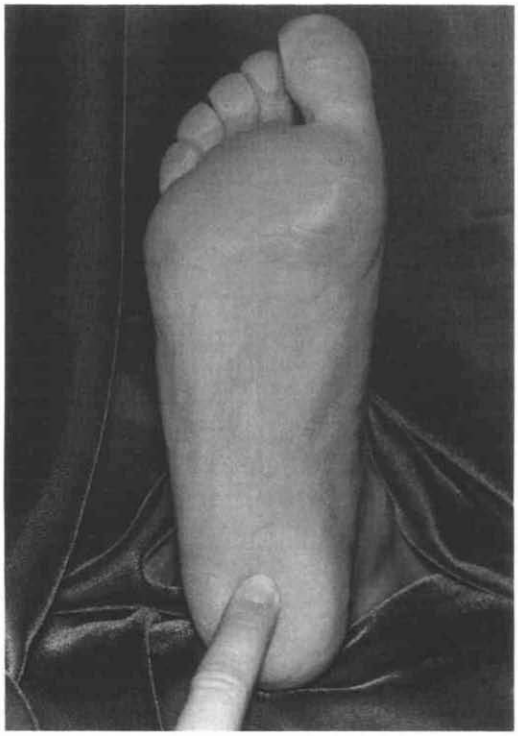


Figure 1A. Point of tenderness in patient with plantar fascitis.

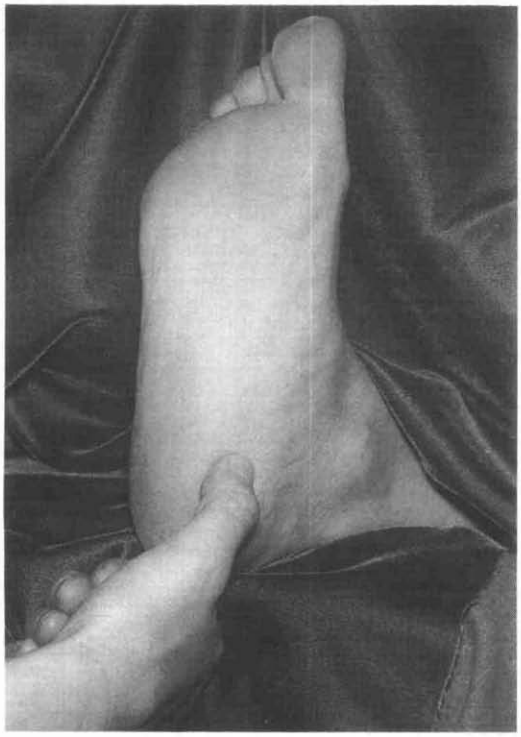


Figure 1B. Point of tenderness in patient with neuritis of medial calcaneal and/or lateral plantar nerve.

complain of localized pain about the heel brought on by walking, especially in hard soled shoes. Varying degrees of fat atrophy of the metatarsal area as well as the heel pad are observed on physical examination and the underlying tubercle of the calcaneous can be readily palpated. The key to successful shoe modification in treating this condition is to increase the padding beneath the heel.

The onset of chronic heel pain due to plantar fascitis or "heel spur" syndrome may be either acute or insidious. It is often most severe upon arising in the morning, but improves after a period of "warming up." However, it may worsen if the patient remains on his feet during the day or with intermittent periods of rest and activity. The patient is usually tender to palpation at the origin of the plantar fascia on the plantar tubercle of the calcaneus and about one centimeter distally (Figure 1A). The principles of shoe modification management are soft soles, relief in the center of the heel, and a soft arch support to better distribute the weight and relieve the painful heel area.

Neurologic causes of heel pain include neuritis and/or compression of the medial calcaneal nerve, the lateral plantar nerve, or the nerve to the abductor digiti quinti, which is a branch of the lateral plantar nerve.[2] The pain is usually not well localized as with plantar fascitis, but tends to be diffuse. On physical examination tenderness may be found on the medial aspect of the heel over the origin of the abductor hallucis (Figure 1B). Occasionally, the examiner can elicit pain or tingling along the medial aspect of the heel with light tapping or pressure in this area. For these patients, an orthosis which limits excessive pronation, and thereby decreases the pull of the abductor hallucis across the nerves, is useful.

Pes Planus

Pes planus, or flat foot, is a descriptive term indicating the loss of height of the medial arch, but is a more complex entity than the name im-

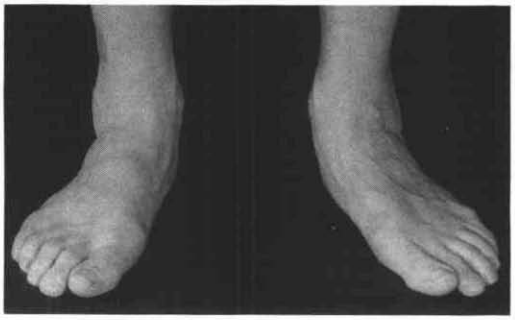


Figure 2A. Note loss of longitudinal arch, with the excessive forefoot abduction and external rotation.

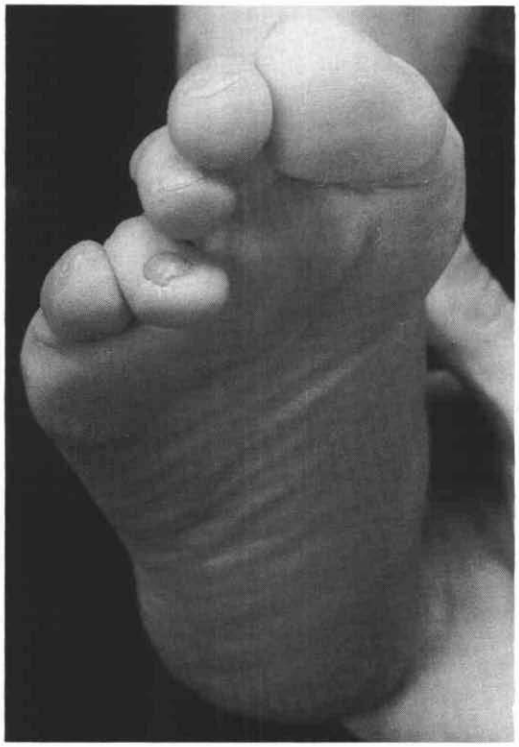


Figure 2B. Forefoot varus—plantar aspect of foot facing medially.

plies. There are many causes of symptomatic flat feet, including posterior tibial tendon rupture, Charcot joint degeneration secondary to neuropathy, rheumatoid arthritis, and generalized ligamentous laxity.[4] The specific complaints vary depending on the etiology, but in general, pes planus leads to diffuse aching of the foot and early fatigue. Patients with inflammation or early rupture of the posterior tibial tendon will note pain on the medial aspect of the foot and ankle early on, but as significant deformity develops, pain occurs on the lateral aspect of the hindfoot due to impingement of the fibula against the valgus-tilted calcaneus.[3] The rheumatoid patient may have a great deal of diffuse pain, whereas the patient with Charcot joint degeneration secondary to neuropathy may have little or no pain in the presence of very severe deformity.

Pes planus is best observed seen while the patient is standing. One notes the decrease in the medial arch height, the increase in forefoot abduction and external rotation as well as the presence of heel valgus (Figure 2A). Observations, made from behind as the patient walks, are (1) the excessive external rotation of the foot relative to the line of progression, and (2) the lack of significant heel inversion motion from foot flat to heel lift.

Further biomechanical evaluation is performed by sitting in front of the seated patient to observe the relationships of the hindfoot to the leg and of the forefoot to the hindfoot. The subtalar joint motion is assessed by grasping the heel and tilting it laterally (into valgus or eversion) and then medially (into varus or inversion). Not infrequently, the patient with pes planus will demonstrate excessive eversion, greater than the normal excursion of 10°.

The foot is then placed in its "neutral position," which is the point at which the calcaneus is centered under the tibia and the talar head is adequately covered by the tarsal navicular. This is done by the examiner's holding the heel in alignment with the long axis of the tibia or in a few degrees of valgus and then adducting the forefoot approximately halfway between maximum forefoot abduction and maximum adduction. The position of the plantar aspect of the forefoot relative to the perpendicular axis of the tibia is noted. There is usually a component of forefoot varus which means the plantar aspect of the foot is facing medially (Figure 2B).

The principles of orthotic management of pes planus include correcting the valgus tilt of the calcaneous, providing a medial arch support, and posting of the first ray to control the hyperpronation.

Metatarsalgia

Metatarsalgia is pain in the forefoot area for which a wide variety of etiologies have been identified. For the purposes of this article, which is aimed at the practicing orthotist dealing with foot problems, the discussion will be limited to the following:

- Fat pad atrophy
- Sesamoiditis
- Disorders of the lesser metatarsophalangeal joints
- Interdigital neuroma
- Rheumatoid arthritis
- Pes cavus

Fat Pad Atrophy

As in heel pad atrophy, the soft tissue padding under the metatarsal heads may become atrophied with age, causing diffuse pain under the metatarsal heads due to the lack of sufficient padding for shock attentuation. The patient may complain of pain especially when walking on a hard floor without shoes. The atrophy is apparent on general inspection; palpation reveals the prominence of the metatarsal heads plantarly. The patient may be tender to palpation directly under the metatarsal heads. Soft soled shoes and soft inner soles with metatarsal pads proximal to the metatarsal heads are beneficial modalities.

Sesamoiditis

Patients with inflammation of the sesamoids of the first metatarsophalangeal joint will complain of well localized pain on the medial aspect of the foot just proximal to the first metatarsal head upon weight bearing. There may be a history of repeated jumping or running on the balls of the feet or of a crush injury due to a heavy object falling on the foot. The patient may walk by rolling his foot into supination and inversion, thus bearing the majority of the weight on the lateral border of the foot. Palpation directly over the involved sesamoid will cause localized tenderness beneath either the tibial or the fibular sesamoid (Figure 3A). Look for associated edema and swelling under and around the first metatarsal head. Passive extension of the first metatarsophalangeal joint will aggravate the pain. Placing the patient in low heeled shoes with padding devices which relieve weight bearing under the first metatarsal head are indicated.

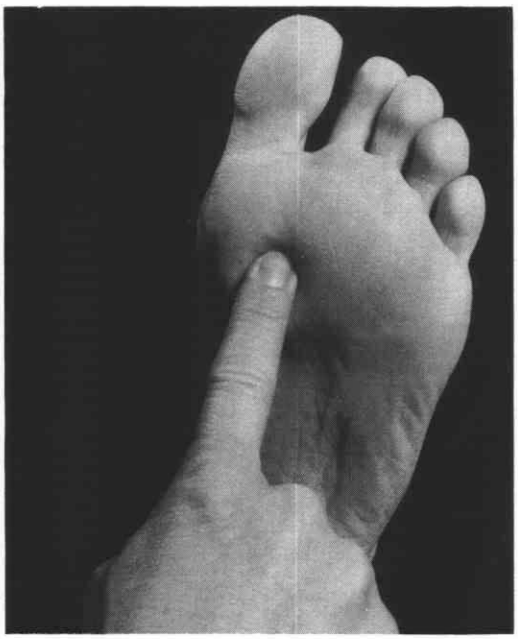


Figure 3A. Area of point tenderness of fibular sesamoiditis.

Disorders of the Lesser Metatarsal Joints

Disorders such as subluxation or dislocation, isolated synovitis, or Freiberg's disease can cause pain limited to a single metatarsophalangeal joint.[5] The onset of pain may be insidious and there may or may not be a history of trauma associated with the onset of pain. The patient is usually able to point to the involved area. Pain can be elicited upon palpation of the involved joint and with passive manipulation. Synovial thickening may be appreciated when comparing the thickness of the involved joint to the normal joint of the opposite foot.

Interdigital Neuroma

The well localized pain associated with an interdigital, or Morton's, neuroma is caused by a thickening of the soft tissues surrounding the common digital nerves on the plantar aspect of the foot and occurs most frequently between the third and fourth metatarsal heads. This entity occurs frequently in women and probably

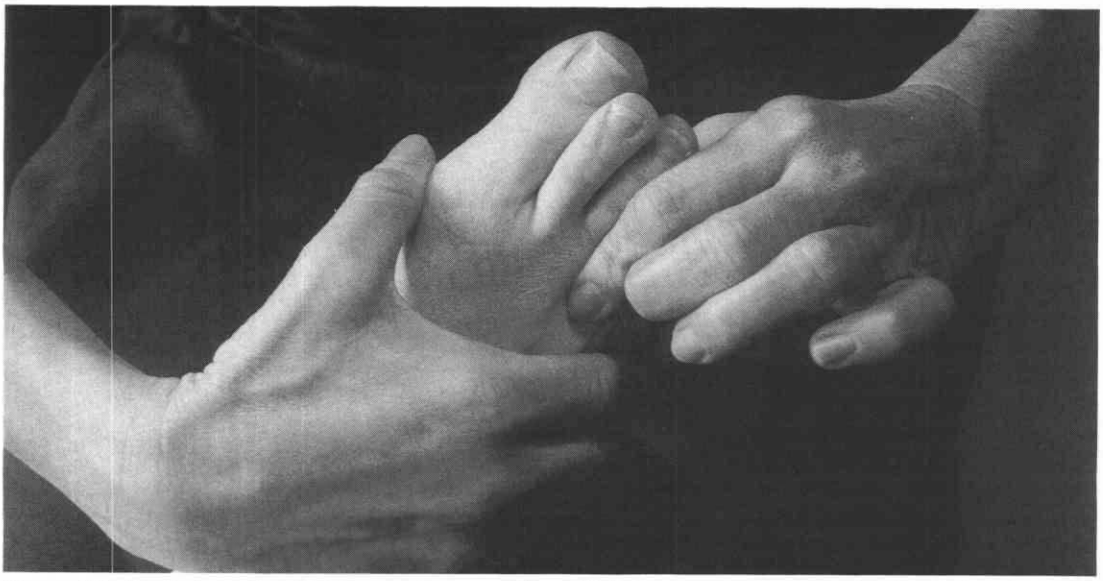


Figure 3B. Technique for eliciting tenderness of interdigital neuroma between third and fourth metatarsal heads.

results from the repeated trauma to the metatarsal region caused by the wearing of high heeled shoes. The patient is usually able to point out the area of maximum pain on the plantar aspect of the foot, pain which occasionally radiates to the toes, and which is worse with weight bearing when wearing snug, thin soled shoes. Removing the shoes and massaging the foot usually affords some temporary relief.

The physical examination will be normal to inspection, but upon palpation pain can be elicited by squeezing the soft tissues between the involved metatarsal heads. This is done by using the thumb and forefinger of one hand to simultaneously press from dorsal and plantar while compressing all the metatarsal heads medially and laterally with the opposite hand (Figure 3B). Occasionally, the enlarged nerve tissue can actually be felt to roll between the finger and the thumb.

Keeping the pressure off the involved area with a metatarsal support proximal to the metatarsal heads and eliminating snug, high heeled shoes can be helpful in decreasing the pain.

Rheumatoid Arthritis

The typical advanced deformities of rheumatoid arthritis causing metatarsalgia are hallux valgus with lateral deviation and dorsal dislocation of the lesser metatarsophalangeal joints. This results in the distal displacement of the plantar fat pad, thus leaving the metatarsal heads displaced plantarly with insufficient fat pad coverage (Figures 3C and 3D). Broad, soft soled shoes with an adequate height of the toe box to accommodate the deformities are necessary. Providing a soft, total contact insert with metatarsal padding proximal to the prominent metatarsal heads is helpful in decreasing the weight born by the metatarsal heads and more evenly distributing the weight across the sole of the foot.

Pes Cavus

A common complaint of the person with pes cavus, or a high arch, foot deformity is metatarsalgia. The elevated arch results in greater weight being borne on the metatarsal heads. The cavus foot is more rigid and, thus, has less shock attentuation capability than the normal, more supple foot. Metatarsalgia can be worsened in the presence of clawing of the toes, which involves hyperextension of the metatarsophalangeal joints, thus making the metatarsal heads even more prominent plantarly.

The deformity can best be appreciated on

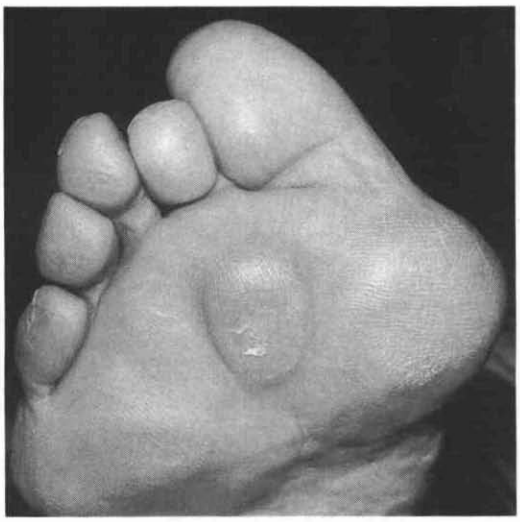


Figure 3C. Typical forefoot deformities of rheumatoid arthritis—hallux valgus and dorsal dislocation of metatarsalphalangeal joints (plantar view).

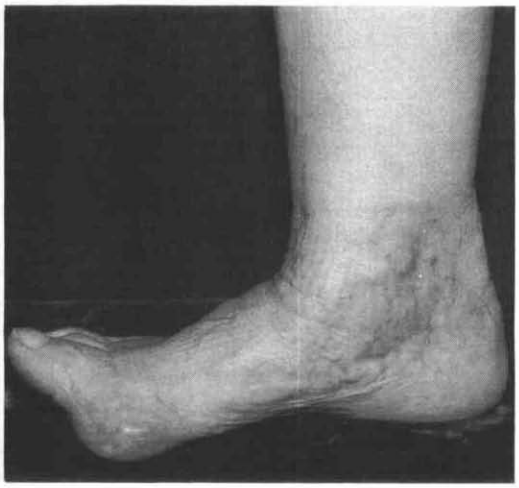


Figure 3D. Typical forefoot deformities of rheumatoid arthritis—hallux valgus and dorsal dislocation of metatarsalphalangeal joints (lateral view).

physical exam by watching the patient in a standing position. In addition to the elevated longitudinal arch, heel varus may be noted. Plantar flexion of the first ray may be present and can be seen by viewing the foot anteriorly with the patient seated. Stabilize the calcaneus in alignment with the tibia and note the level of the plantar aspect of the first metatarsal head relative to the others. The patient with metatarsalgia secondary to pes cavus may benefit from a soft arch support to increase the weight bearing surface of the foot and to improve shock attenuation.

Ankle Instability

Ankle instability may be the result of lateral ligamentous laxity, a varus heel, or a varus angulated tibia.[4] A patient with lateral ligamentous laxity of the ankle may give a history of having initially sustained an ankle sprain secondary to significant ankle trauma followed by recurrent sprains with minimal or no trauma. The wearing of high heeled shoes worsens the tendency of recurrent ankle sprains as this further throws the foot into supination.

Ligamentous laxity causing ankle instability can usually be demonstrated by the "lateral talar tilt" test. The ankle is stress tested both in dorsiflexion, to test the calcaneofibular ligament, and in plantarflexion, to test the anterior talofibular ligament. The tibia is held stationary as the examiner applies pressure on the lateral aspect of the hindfoot in a medial direction (Figure 4). The ankle, which lacks adequate ligamentous support, will tilt medially indicating instability.

The presence of heel varus can be appreciated by viewing the patient from behind as he stands with shoes removed. It will be noted that the calcaneous is medial to the longitudinal axis of the tibia. Upon manipulation of subtalar joint motion, there may be decreased eversion of the calcaneous relative to inversion.

A person who had a varus angulated tibia, either from a congenital deformity or secondary to a tibia fracture which has united in varus, may also experience ankle instability. With such malalignment, the biomechanical forces pass lateral to the center of the calcaneous. Observing the standing patient from the front, the examiner will note that an imaginary plumb line dropped from the center of the patella will fall lateral to the center of the ankle on the affected side.

A lateral heel and sole wedge tilts the hindfoot into slight valgus to help prevent recurrent ankle instability.

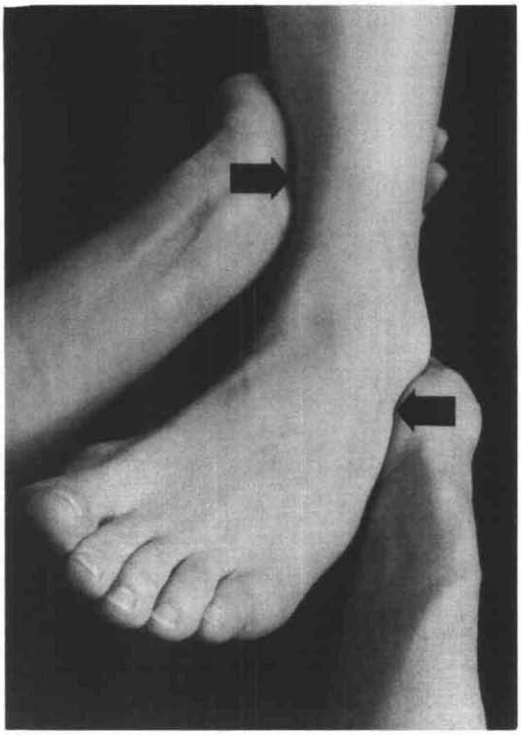


Figure 4. "Lateral talar tilt" test for ankle instability.

Summary

The principles of clinical assessment of four common clinical problems for which orthotic treatments are prescribed have been discussed. The information gained from the medical history and physical examination used in clinical assessment of foot problems can aid the orthotist in improving his or her effectiveness as a vital member of the foot care team.

References

[1] Baxter, Donald E., "The Evaluation and Treatment of Forefoot Problems in the Athlete" (Unpublished manuscript).

[2] Baxter, Donald E. and C. Mark Thigpen, "Heel Pain-Operative Results," *Foot & Ankle,* 5:1, 1984, pp. 16–25.

[3] Johnson, Kenneth, "Tibialis Posterior Tendon Rupture," *Clinical Orthopaedics & Related Research,* 166, 1983, pp. 143–150.

[4] Mann, Roger A., "Biomechanical Approach to the Treatment of Foot Problems," *Foot & Ankle,* 2:4, 1982, pp. 205–212.

[5] Mann, Roger A., "Metatarsalgia," *Postgraduate Medicine,* 75:5, 1984, pp. 150–167.

[6] Mann, Roger A. *Surgery of the Foot,* The C.V. Mosby Co., 1986.

Author

Karen S. Seale, M.D. is assistant professor in the Department of Orthopedics, University of Arkansas Medical School Center.

Clinical Prosthetics and Orthotics, Vol. 12, No. 2, pp. 51–60

Orthotic Management of the Arthritic Foot

by C. Michael Schuch, C.P.O.

With ever increasing public exposure, orthotists are being requested more frequently to confront new challenges caused by physical disability. In the spectrum of orthotic protocols, management of the arthritic foot and ankle is a relatively new challenge. During the past five years, the Department of Orthopaedics and Rehabilitation, the Division of Rheumatology, and the Division of Prosthetics and Orthotics, all of the University of Virginia Medical Center, have comprised an Arthritis Rehabilitation Research and Training Center, providing a regional referral center for arthritis patients. Orthotic services for these patients have concentrated on the foot and the ankle, and this population of patients has been substantial enough to permit the development of a consistently successful protocol of management. The intent of this paper is to review the skeletal anatomy of the ankle and foot, discuss the types of arthritis and their relative pathophysiology and clinical manifestations, and finally to present our protocol for management of the various problems presented by the arthritic foot and ankle.

Review of Ankle-Foot Anatomy

The skeleton of the foot consists of three groups of bones: tarsal bones, metatarsal bones, and phalanges. The tarsal bones are further divided into two groups, the first group consisting of the talus and the calcaneus, together forming the hindfoot. The talus, which is the only bone to articulate with the tibia and the fibula, acts as a rocker by which the foot as a unit can be dorsiflexed and plantarflexed at the hinge of the ankle joint. In stance, the talus receives the entire weight of the lower limb; half this weight is transmitted forward to the bones forming the arch of the foot, and half of the weight is transmitted downward to the heel or calcaneous. The calcaneus, or os calcis, is the bone of the heel. It supports the talus, withstands shock as the heel strikes the ground, and transfers forward the portion of body weight it receives from the talus.

The second group of tarsals consists of the five bones anterior to the talus and the calcaneus. The navicular, cuboid, and three cuneiforms increase flexibility of the foot, particularly in its twisting movements. These bones form the longitudinal arch of the foot, and are referred to collectively as the midfoot.

The five metatarsal bones lie anterior to and articulate with the second group of tarsal bones described above. Each metatarsal consists of a base, a shaft, and a head, in respective order from proximal to distal. The distal-most bones of the foot are the five phalanges, which extend from the five metatarsals and form the bones of the toes. The metatarsals and the phalanges form the forefoot.

The foot has three arches: the medial, lateral, and transverse. The normal medial arch rises through the calcaneous to the head of the talus, and from this high point it descends forward through the navicular, cuneiforms, and first three metatarsal heads. The lateral arch, which is lower than the medial, extends from the cal-

caneus to its high point at the cuboid, and down through the fourth and fifth metatarsals. The transverse arch rises across the width of the foot between the medial and lateral borders, primarily under the metatarsal shafts.

The junctions of these various groups of bones form the joints that allow the functional motions of the ankle and foot to occur. The talocrural (ankle) joint consists of the medial and lateral malleoli and the trochlear surface of the talus. This joint permits the motion of plantarflexion and dorsiflexion. The subtalar (talocalcaneal) joint is formed by the articulation of the talus and the calcaneus, and permits the heel to share in inversion and eversion. The transverse tarsal (midtarsal) joint is not an anatomic entity, but an important functional grouping of two joints which occur anterior to the talus. These two joints, the talocalcaneonavicular and the calcaneocuboid, permit much of the inversion-eversion of the foot. The other tarsal joints, tarsometatarsal joints, and distal joints aid in flexibility of the foot from heel strike through mid-stance, and help the foot form a rigid lever during toe-off, or the propulsion part of the gait cycle.

Each of the joints of the ankle and foot, including the joints between the sesamoids and the first metatarsal are lined with synovium so that when inflammatory conditions that affect the synovium are present, the foot and ankle may show dramatic changes clinically, radiographically, and pathologically.

Types and Pathophysiology of Arthritis

While there are a half dozen or more differing types of arthritis,[3] we will limit our discussion to the types that have a tendency to involve the foot and ankle. The most commonly seen and most debilitating form of arthritis is rheumatoid arthritis.

Rheumatoid Arthritis

Rheumatoid arthritis is an inflammatory condition of unknown etiology that primarily affects the synovial lining of joints, tendons, and bursae. Secondarily, it may cause destruction to cartilage, bone, ligaments, and other soft tissue. Most people with rheumatoid arthritis have some degree of foot and/or ankle involvement.[3] The joints of the feet are initially involved more often than the joints of the hands.[4] Vaino showed that more than 88% of adults and 69% of children with rheumatoid arthritis have involvement of the feet during some phase of the disease.[6]

Guerra states that the earliest sign of rheumatoid arthritis is congestion of the synovial membranes with edema.[2] As the synovial inflammatory tissue and fluid within the joint ac-

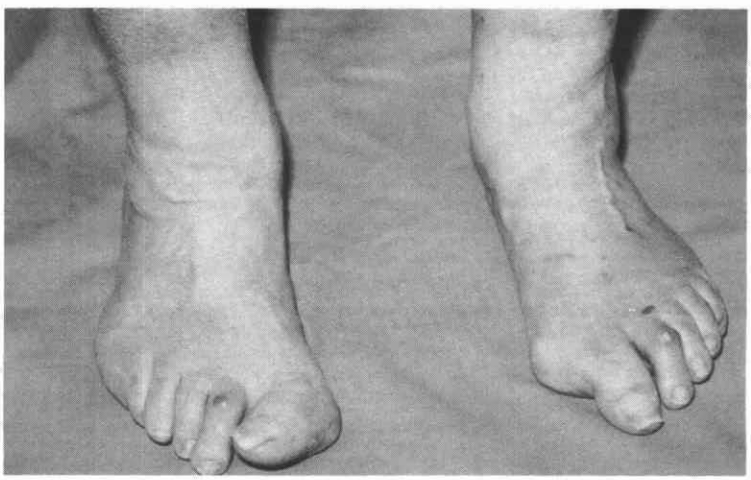


Figure 1. View of patient's feet afflicted with rheumatoid arthritis. Note, hallux valgus, claw toes, depressed longitudinal arch, and pronation or eversion at the subtalar joint.

cumulate, there is swelling of the soft tissue, and decreased range of motion of the joint. The inflamed synovium adjacent to the marginal bare areas causes destruction of bone, resulting in bony erosion at the margins. Because the inflamed synovium, known as the pannus, also proliferates, expansion occurs over the cartilage and destroys the cartilage through enzymatic action, producing symmetrical joint space narrowing. The pannus may also penetrate the unprotected bare bone and cause destruction of the cartilage from the marrow side. The reactive hyperemia, part of the inflammatory process, is implicated in the periarticular osteoporosis and the discontinuity of the subchondral bony plate.[2] Joint destruction and deformities occur and become fixed as the weakened support structure of the ankle and foot gives way to the normal mechanical stresses placed upon it; changes in alignment of joints allow muscles, tendons, and ligaments that cross the joints to exert different forces, and stiffness and pain in the joints prevent mobility.[3]

Clinical manifestations can include all joints of the ankle-foot, collectively or individually. Ankle involvement in rheumatoid arthritis is not as common as involvement of other joints of the foot.[5] The clinical picture of ankle involvement is less dramatic than with the other joints, with swelling, stiffness, decreased range of motion, and pain being the indicators. Unlike the ankle, the hindfoot is often affected early in rheumatoid arthritis. The most common deformity of the hindfoot is pes planovalgus, or more simply, valgus of the hindfoot and flattening of the longitudinal arches.[5] The midfoot-tarsal joints develop inflammatory changes that contribute to the pes planovalgus deformity of the hindfoot and midfoot.[5] In time, each of the tarsal bones seem to be equally involved, causing loss of pronation-supination and malleability of the foot in general. The forefoot shows marked abnormalities on clinical and radiologic examination. The altered forces created by hindfoot and midfoot deformities act with the inflammatory process, affecting the metatarsal-phalangeal (MTP) joints and proximal interphalangeal (PIP) joints to give the typical findings of hallux valgus, claw toes, subluxation and depression of the metatarsal-phalangeal joints, abduction of the forefoot, and splay foot. Involvement here as in other parts of the foot is symmetric and increases with disease duration.[5]

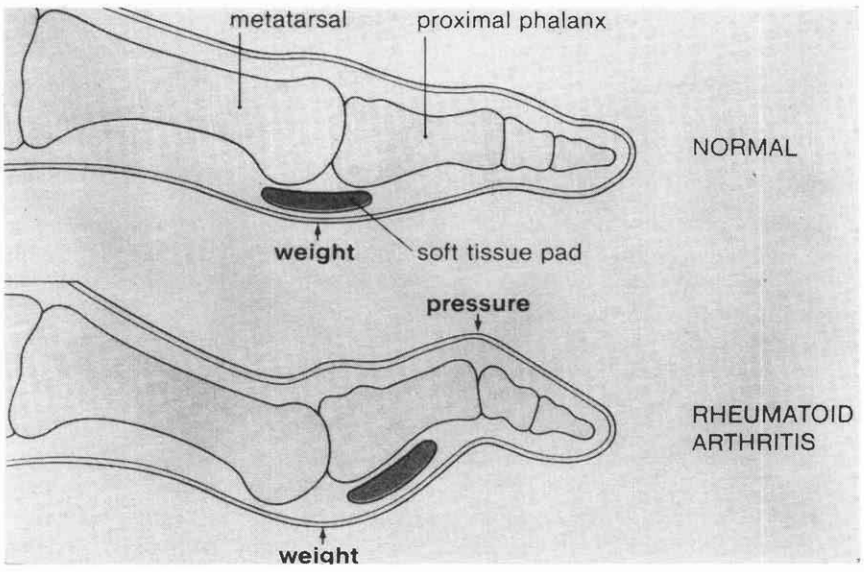


Figure 2. Schematic view showing the effects of claw toes with subluxed MTP joints, resulting in metatarsal head prominences on the plantar surfaces of the foot.

Osteoarthritis

The next most commonly seen type of arthritis to cause foot problems is osteoarthritis, or degenerative joint disease. This form of arthritis is not a systemic inflammatory disease; rather it is a disease that is secondary to the wear and tear phenomena on joints. Disruption of the cartilagenous matrix occurs as a result of enzymatic action. Large weight-bearing joints of the body are particularly prone to dysfunction. The ankle joint and the first MTP joint seem most susceptible, with weight bearing, trauma, and footwear having all been implicated as causative agents. Radiologic examination reveals asymmetric narrowing of the joint space, the areas of stress demonstrating less interosseous space.[2]

Other Arthritis Types

The arthritis patient population requiring foot orthotic management primarily falls into one of the above two categories of diagnosis. However, occasions will arise necessitating foot and or ankle management for patients with other arthritic diagnoses. The seronegative arthridities are ankylosing spondylitis, Reiter's syndrome and its variants, and psoriatic arthritis. Two additional types of arthritis that may affect the foot and/or ankle are gout and systemic lupus erythematosis. While differing in pathophysiology from rheumatoid arthritis and osteoarthritis enough to warrant separate diagnostic classification, the clinical manifestations of the ankle and foot are similar.

Orthotic Designs and Indications

As in all orthotic management, the scope of the problem dictates the complexity of the orthosis. We have been pleased with the simplicity of the decision making process that has been developed at the University of Virginia. Sophisticated evaluation processes are not necessary; patient communication concerning location of pain and routine physical examination of ankle-foot abnormalities are sufficient. Observation of gait irregularities usually reinforce communication/physical examination findings. Orthotic management conveniently falls into two levels of complexity: foot orthoses (FO's) and ankle-foot orthoses (AFO's).

Foot Orthoses

The objectives of foot orthoses for arthritic patients include, (1) maintainence and support of existing arches of the foot; (2) re-establishment of fallen arches when flexibility permits; (3) provision of inversion-eversion balance or stability; (4) distribution of weight bearing pressures; and (5) provision of soft tissue supplement.

The clinical picture requiring this level of orthotic management can range from mild longitudinal arch depression with callous formation under the metatarsal heads to severe loss of the longitudinal arches, medial drift of the talocalcaneonavicular joint complex, subluxation of MTP joints with depressed and protruding metatarsal heads, hallux valgus, and claw deformities of the phalanges. Traditional foot orthoses for this type of clinical picture have been Plastizote® inserts, molded directly to the patient's foot. However, Plastizote® is not durable; it packs down quickly with wear. The more severe the deformity, the quicker the material loses its integrity and ability to meet the objectives of foot orthoses as described above. Occasionally, arthritic patients have presented or reported being fit with rigid foot orthoses, fabricated of Nyloplex (Rohadur), usually provided by podiatrists. While this material selection and orthotic design are ideal for many cases, we have found it to be highly unsuccessful with arthritic patients to the point that we consider rigid foot orthotics contraindicated for this patient population. Our experience has shown that this type of orthosis lacks the flexibility and soft tissue supplement necessary to promote acceptance by patients with arthritis. The choice of materials and design for arthritic foot orthoses at the University of Virginia has been PVC-Pelite™ foot orthoses, molded over positive models of the patient's foot or feet.

Description of Technique

Negative impressions of the patient's feet are obtained using any of the commercially available foam impression blocks. This impression is taken with the patient seated, to capture the shape of the existing arches at their maximum height, free of weight-bearing loads. Care should be taken to balance inversion-eversion as the foot is pressed into the foam. Positive models are obtained in the conventional manner

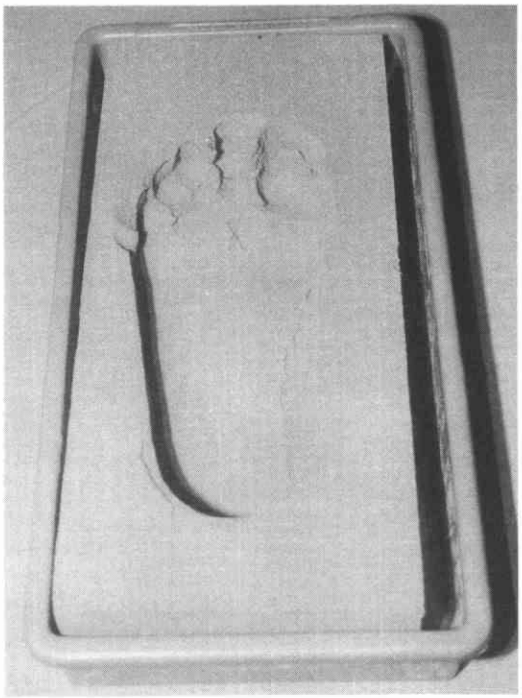


Figure 3. View showing left foot impression taken in foam foot impression block. Note "X" identifying metatarsal head prominence.

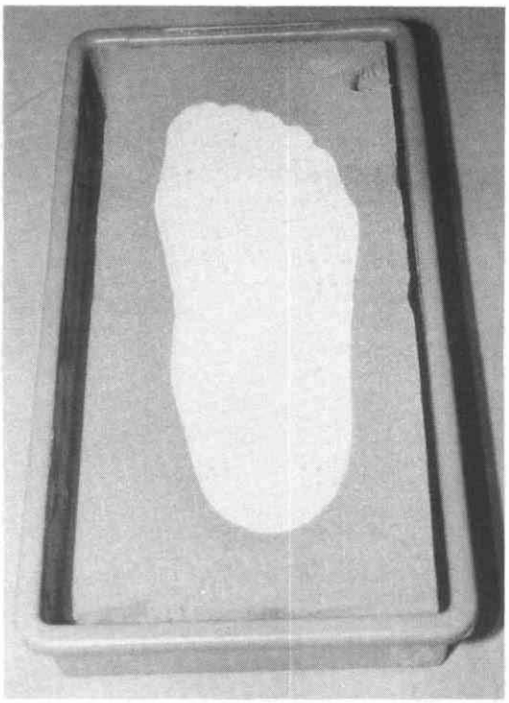


Figure 4. Foot impression filled with molding plaster forming a positive model of the patient's foot.

by pouring molding plaster into the impression forms. Modification of the positive model is necessary to meet the objectives of foot orthoses for arthritic patients as discussed above. The longitudinal arch is increased mildly, especially posteriorly, as proposed by Carlson, et al., in their technique for modification of the UCB foot orthosis.[1] This modification meets the objectives of maintenance and support of existing arches, provision of eversion or valgus stability, and distribution of weight bearing forces. The metatarsal or transverse arch modification is perhaps most important, and the degree of this modification in terms of size and depth parallels the severity of MTP subluxation and metatarsal head depression. It is frequently greater than ½″ in depth. The shape of this modification should simulate that of prefabricated rubber metatarsal pads, which are commercially available in varying sizes and depths. Proper placement of this modification is critical; when an existing transverse arch can be identified, it should be exaggerated. If there is no identifiable transverse arch, the modification for this arch in the positive model falls under the metatarsal shafts, with the dome or apex of the plaster removal just posterior to the metatarsal heads, and the proximal edges blending gradually into the longitudinal arches. This modification provides support to uplift the depressed metatarsal heads and reduce trauma at the push-off phase of the gait cycle. It also meets the objectives of maintenance and support of existing arches in some cases, re-establishment of fallen arches in other cases, and better distribution of weight-bearing loads. The final modification to the positive model includes adding plaster to the plantar aspect of the PIP joints of the phalanges, which aids in providing a smooth transition from the MTP to the phalangeal area of the foot orthosis.

The positive model is now complete and ready for molding of the base material, PVC Pelite™, which is available in 4′ square sheets,

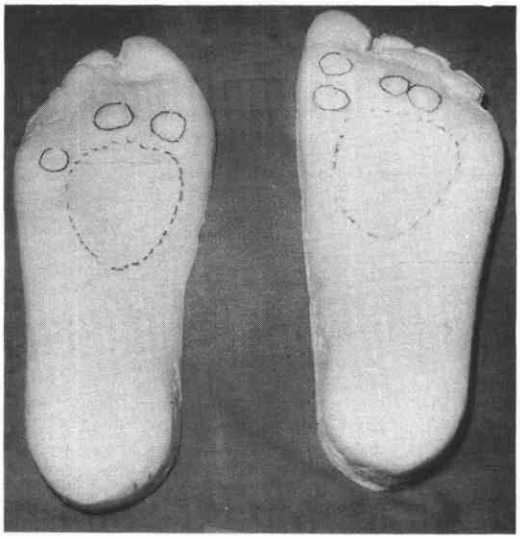


Figure 5. Positive models of patient's feet, plantar surface facing up. Note identification of transverse (metatarsal) arch and prominent metatarsal heads.

⅛″ thick. PVC Pelite™ is ideal for foot orthoses because: (1) the PVC laminate (vinyl covering) assists the Pelite™ in maintaining its desired shape after heat molding; (2) the PVC laminate provides strength and durability, decreasing and even eliminating incidences of the Pelite™ packing down, and (3) the PVC laminate consists of closed cells and is waterproof, which makes it easy to clean and discourages the growth of bacteria and fungus. The size of the PVC Pelite™ sheet to be molded over the positive model is determined by closely tracing the positive model onto the PVC Pelite™ and allowing extra material to cover the longitudinal arch and extra material beyond the phalanges. Care should be taken to closely trace the lateral and posterior aspects of the positive model, because excess material here makes molding or vacuum forming more difficult, frequently resulting in bunching or folding of the material and, thus, an unacceptable orthosis. Heating the PVC Pelite™ sheet can take place in an oven, an electric skillet, or with a heat gun. The vinyl covering of PVC Pelite™ should not be subjected to high heat or heated directly since it can delaminate under these conditions and develop bubbles or blisters. When sufficiently pliable and moldable from the heat, the PVC Pelite™ sheet is molded in place over the plantar surface of the positive model using any of the following techniques:

1. Wrapping the PVC Pelite™ in place around the positive model with an elastic bandage.
2. Vacuum formed in place using a vacuum hose placed inside a small airtight plastic bag.
3. Vacuum formed in place using a commercially available foot orthosis vacuum-forming machine.

Once the PVC Pelite™ is molded in place and cooled sufficiently for the molded shape to be maintained, a sheet of ½″ thick medium density Pelite™ is cut to fill the transverse and longitudinal arch areas as a single piece. (To save time we have these precut in large numbers to a single large size that can be trimmed to fit a given positive mold.) This piece of ½″ medium density Pelite™ is heated to a moldable state using oven, skillet, or heat gun, and is then molded or vacuum formed in place as was the

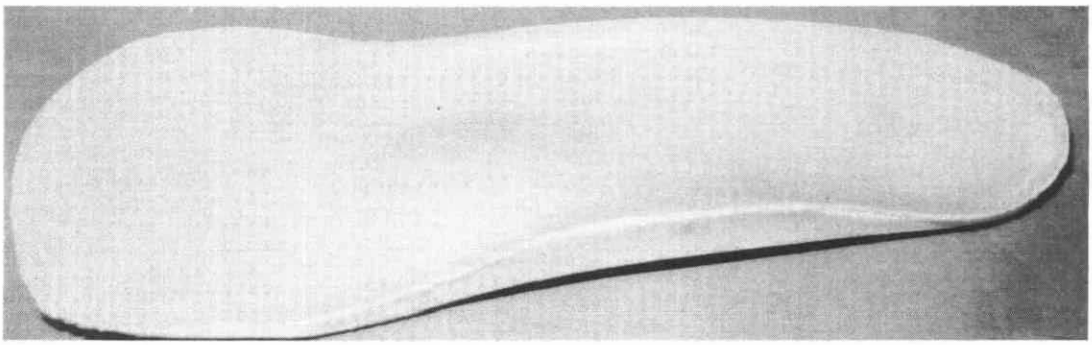


Figure 6. Molded PVC-Pelite™ foot orthosis, with longitudinal and metatarsal arch support.

PVC Pelite™. When sufficiently cooled, it is glued in place using Polyadhesive and sanded to a feather edge so that it will blend with the PVC Pelite™. Additional modifications to this PVC Pelite™ foot orthosis design may include either of the following:

1. For increased soft tissue supplement and shock absorption, ⅛" PPT can be glued to the bottom surface of the PVC Pelite™ foot orthosis.
2. For maximum soft tissue supplement in cases of severe metatarsal head protrusion, nylon lined ⅛" PPT may be glued on top of PVC Pelite™ foot orthosis.

Either modification will require greater depth within the patient's shoes. With or without the above modifications, final shaping and fitting are done to the patient and his shoes.

An additional point worthy of mention: soft tissue supplement, weight bearing pressure distribution, metatarsal head pain relief, and other plantar surface objectives can be attained with this foot orthosis system regardless of shoe integrity. However, when the objective is control of the inversion-eversion (varus-valgus) balance in the foot, or maintenance, support, or re-establishment of the longitudinal arch, the shoes become an adjunct to the foot orthosis and thus must have a firm heel counter with good integrity along the medial aspect of the longitudinal arch.

Ankle Foot Orthoses

Although somewhat rare compared to the numbers of patients we have encountered requiring foot orthotic management, there are those arthritics with severe enough involvement to warrant a higher level orthosis. The typical picture requiring AFO management is pain, swelling, and decreased range of motion located in the ankle (talocrural) joint, with frequent moderate to severe pes planus and subtalar (talocalcaneal) erosion. Although rheumatoid arthritis patients dominate this type of patient population, it is not unusual for patients with osteoarthritis to present at this level. Again, severity of involvement dictates the complexity of the orthosis. We have used two types or designs of AFO's in our management of these kinds of problems: rigid, molded plastic AFO's and bivalved, weight bearing,

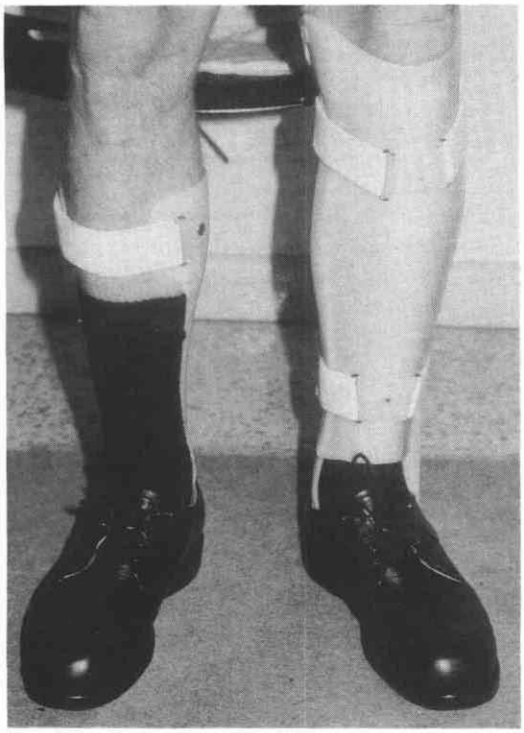


Figure 7. Rheumatoid arthritis patient wearing right molded, rigid copolymer AFO and left molded, weight-bearing, bivalve, rigid AFO.

rigid, molded plastic AFO's (also known as PTB AFO's or axial load resist AFO's.) The distinction between the two is quite simple. When pain in the ankle or subtalar joint is due to the forces of walking or movement, i.e. if the normal movements of the ankle-subtalar complex in the course of walking causes or increases pain, yet standing stationary is comfortable and pain-free, the only need is elimination of motion which can be provided by a rigid, molded AFO. When pain is experienced in both standing and ambulation, the goals are to redistribute weight-bearing loads by reducing the amount of weight to be borne through the diseased ankle-foot complex and to eliminate range of motion. These objectives can be met with a bivalved, weight-bearing, rigid, molded AFO.

As standard AFO's are commonplace items in any orthotic practice, detailed discussion in this context serves no purpose. However, the need for rigidity should be emphasized. The

lower vertical trimlines need to be anterior to the malleoli, and carbon composite inserts can be used if necessary.

Our chosen design for bivalved, weight bearing, rigid, molded AFO's is that described by Wilson, Stills, and Pritham[7] with the addition of a higher posterior trimline in the popliteal area, similar to that in a below-knee prosthesis. The reduction in the range of knee flexion as a result of this higher posterior trim is a minor sacrifice for a major gain in reduction in pain. We purposely try to avoid the use of the term PTB orthosis because of its erroneous weight-bearing implications. The patella tendon is identified by mild modification of the positive model in this anatomical region, similar to but much less aggressive than in a so called "PTB" prothesis. However, there is little concentrated weight-bearing in this area; the goal of weight-bearing is equal distribution throughout the entire part of the lower leg contained within the orthosis. Perhaps the most accurate prosthetic acronym describing the weight-bearing goals of the bivalved, weight-bearing, rigid, molded AFO, is the "total surface bearing" concept. In the case of an intact lower limb as is encountered in orthotics, modification of the term "to maximum surface bearing" seems appropriate.

None of our patients requiring rigid AFO's has required SACH (solid-ankle cushion-heel) and rocker sole shoe modifications. We do recommend the use of shoes with soft soles constructed of Vibram® or crepe.

Shoes for Arthritic Patients

Proper shoes are a vital component of orthotic management of the arthritic foot. As was stated earlier, some foot orthotic objectives can be attained with shoes of poor quality or integrity. However, properly designed and fitted shoes can only enhance the best designed and fabricated foot or ankle-foot orthoses.

Our large arthritic patient population at the University of Virginia has allowed us to recommend and fit a wide variety of accommodative shoes. As we gained experience, it became apparent that we could rely on a minimum inventory of shoe types or designs. I refrain from the use of the descriptor "style" because there may be several "styles" available within a shoe design category. The categories of "design" that I refer to could be listed and described as follows:

1. Thermo adjustable shoes
2. Extra depth shoes
3. Running shoes.

Thermo Adjustable Shoes

This shoe type or design is made primarily of Dermaplast®, which is a heat shrinkable Plastizote®. Known as Apex Ambulators®, there are two styles available: #1201, the simplest and most accommodative, and #1273, a more cosmetic version of the first style.

Style #1201 is of black Dermaplast™ with a thin outer fabric covering, crepe wedge soles, Velcro® lap closure (eases donning for those

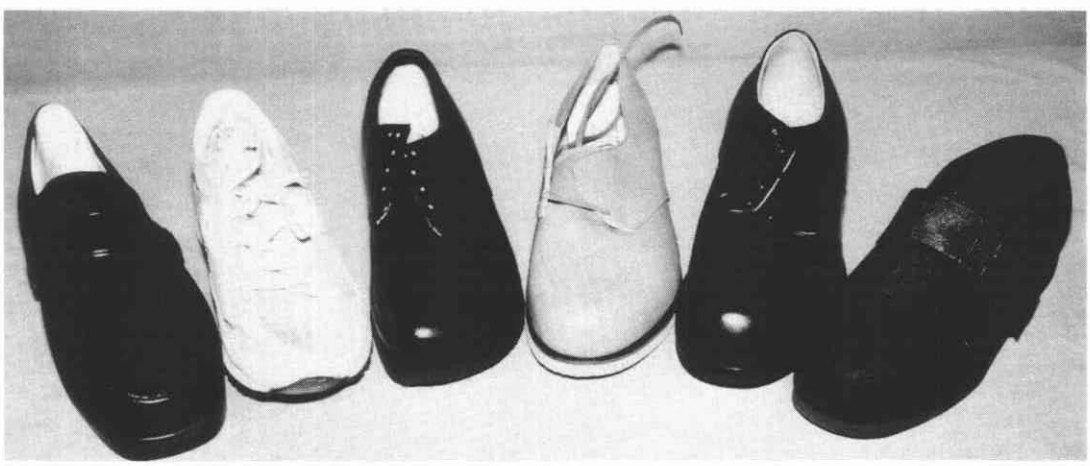


Figure 8. View of various shoes useful in the management of patients with arthritis affecting the feet and ankles.

arthritics with hand involvement), and removable Plastizote® insole. There is no heel counter reinforcement. The indications for this type of shoe is last resort, severe deformities, especially in the dorsal aspect of the foot, that are difficult or impossible to accommodate in shoes of firmer and less adjustable materials. Examples of such deformities are severe hammer toes, severe hallux valgus, and/or nodules on the dorsum of the feet or toes. This shoe is fitted slightly large and then heated while on the patient's foot (with protection by socks, of course). The application of heat causes the Dermaplast® to shrink and mold to the patient's foot shape, thus accommodating the severe deformity. The shoe upper material of Plastizote® and fabric is very soft and forgiving to such deformities. In all cases, we replace the removable Plastizote® insoles with molded PVC-Pelite™ foot orthoses.

The other style of Apex Ambulators® thermo adjustable shoes, #1273, is very similar to that described above. The major difference is the outer covering of the uppers, which in this second style is thin, pliable leather. This shoe is more cosmetically appealing to most patients because the leather uppers allow the choice of four colors, (the catalogue number varies with color variations). It has slightly more integrity than the #1201 style, including a moderately reinforced heel counter. It also has a removable tongue, which is secured in place with Velcro®, a feature that enhances its adjustability. It is available with either lace or Velcro® loop back closure. Accommodation of deformities can be accomplished either by heating and shrinking a loose fit as with the #1201's above or by fitting the shoes to the proper size and then stretching the uppers with shoe stretching tools over areas of deformity.

Extra Depth Shoes

Extra Depth® shoes are offered by several manufacturers and provide greater depth throughout the entire shoe. This depth is ideal for accommodating molded foot or ankle foot orthoses designed for arthritic foot deformities. Extra depth shoes, like molded AFO's, are a familiar item in any orthotic practice, and therefore do not necessitate detailed discussion. However, there are two important considerations regarding their application to arthritic patients: (1) the shoe style selected should be made of very soft leather, preferably calfskin or deerskin, as these leathers are most easily spot stretched to accommodate deformities, and are the most forgiving to areas of inflammation; (2) adequate width in the forefoot or toebox of the shoe cannot be overemphasized.

The extra depth shoes that we recommend for our arthritic patients are manufactured and distributed by Alden Shoe Company and P.W. Minor. The designs and styles vary in leather utilized, closure (lace or Velcro®), and amount of heel counter reinforcement. All have soft crepe soles and uppers that can be modified for deformities with relative ease using shoe stretching tools and equipment.

Running Shoes

Running or jogging shoes should be familiar to orthotists and patients alike. Their application to patients with arthritic foot problems stem from three of their characteristics: (1) they are acceptable to many patients who do not accept the "lack of style" of other appropriate shoes; (2) most utilize separate, removable insoles, which when removed, allow adequate room for use of molded foot or ankle foot orthoses; and (3) most are very light in weight. Problems we have encountered with running shoes include seams in the dorsal aspect of the toe box, making spot stretching difficult or impossible, and construction of vinyl or other synthetic materials which also make stretching difficult or less successful.

Conclusion and Results

An experience based protocol for orthotic management of the arthritic foot has been described. This experience is based on over 300 arthritic patients who required orthotic management by our service since 1985. Seven patients have been fit with eight bivalve, weight-bearing rigid, molded AFO's (one bilateral). One of these seven patients benefitted from a rigid, molded AFO on his lesser involved lower extremity. The remaining patients have been managed with custom molded PVC Pelite™ foot orthoses. Many of the patients fit with PVC Pelite™ foot orthoses were successfully converted from direct molded Plastizote® shoe inserts. Through routine follow up and chart re-

views, we have found less than a three percent rejection rate; more important, we have found more active patients who enjoy a better quality of life.

References

[1] Carlson, J. Martin, and Gene Berglund, "An Effective Orthotic Design for Controlling the Unstable Subtalar Joint," *Orthotics and Prosthetics,* 33:1, March, 1979, pp. 39–49.

[2] Guerra, J. and D. Resnick, "Arthridities Affecting the Foot and Ankle-Pathology and Treatment. The Relationship Between Foot and Ankle Deformity and Disease Duration in Fifty Patients," *Foot and Ankle,* 2:6, 1982, pp. 325–331.

[3] Portwood, Margaret M., "The Foot and Ankle in Rheumatic Disorders," *Principles of Physical Medicine and Rehabilitation in the Musculoskeletal Diseases,* Grune and Stratton, 1986, Chapter 19, pp. 489–513.

[4] Short, C.L., W. Bauer, W.E. Reynolds, *In Rheumatic Arthritis,* Harvard University Press, Cambridge, 1957, pp. 194–195.

[5] Tillman, K., *The Rheumatic Foot: Diagnosis, Pathomechanics, and Treatment,* Stuttgart, Georg Thieme Publishers, Boston, PSG Publishing Co., 1979, pp. 3–61.

[6] Vaino, K., "The Rheumatoid Foot: A Clinical Study With Pathologic and Roentgenological Comments," *Ann. Chir. Gynaecol. 45 (Suppl),* 1956, pp. 1–107.

[7] Wilson, A. Bennett, Jr., David Condie, Charles Pritham, and Melvin Stills, *Lower-Limb Orthotics, A Manual,* First Edition, Rehabilitation Engineering Center, Moss Rehabilitation Hospital, Temple University, Drexel University.

Appendix

Alden Shoe Company, Taunton Street, P.O. Box 617, Middleborough, Massachusetts 02346.

Apex Ambulators, Apex Foot Products, 330 Phillips Avenue, S. Hackensack, New Jersey 07606.

PPT, The Langer Biomechanics Group, 21 East Industry Court, Deer Park, New York 11729.

PVC Pelite™, Durr-Fillauer Medical, Inc., Orthopedic Division, P.O. Box 5189, Chattanooga, Tennessee 37406.

P.W. Minor Extra Depth Shoe Co., 3 Treadeasy Avenue, Batavia, New York 14020.

Author

C. Michael Schuch, C.P.O., is an Assistant Professor in Orthopaedics and Rehabilitation and Associate Director of Prosthetics, Orthotics, and Rehabilitation Engineering Services at the University of Virginia Medical Center, Box 467, Charlottesville, Virginia 22908.

Clinical Prosthetics and Orthotics, Vol. 12, No. 2, pp. 61–66

The Susceptible Insensate Foot

by Mitchell E. Kalter, M.D.
Richard L. Jacobs, M.D.

Introduction

Patients with limbs which are both insensate and functionless often are best treated with amputation to improve hygiene, functional potential with prosthetics, and often cosmesis. There exists, however, a large population of patients whose lower extremities are insensate, but remain functional. Because of continued functional demands, and the loss of important protective mechanisms, breakdown of the delicate articulations occurs resulting in neuropathic arthropathy.

While there are a multiplicity of disease states associated with neuropathic arthropathy, there are certain general principles and characteristics inherent in the final common pathway of the Charcot joint. In years past, neurosyphillis was the major cause. Nowadays, diabetes mellitus is by far the most common cause.

This article will explore some of the historical aspects, causes, pathophysiology, clinical manifestations, and principles of treatment as they relate to neuropathic arthropathy of the susceptible insensate foot.

Historical Aspects

Jean Martin Charcot, at La Salpetriere in 1868, first called attention to "ataxic" forms of arthropathy associated with neurological diseases, the most commonly recognized cause being tabes dorsalis.[1,2,4] Charcot attributed the acute and destructive arthropathy to the loss of certain "neurotrophic influences" ncessary to support the normal joints.[6]

Charcot's contemporaries, Volkmann and Virchow, disagreed with this "trophic," or what was known as the "French" theory.[2] They argued that the arthropathy was due to continued mechanical stress and trauma on an insensitive biological structure.[2] These stresses continued in the absence of normal protective reflexes, which inevitably lead to a cycle of injury, inflammation, further injury, and finally instability and joint destruction. The end result, now the "Charcot joint."

This basic process was gradually recognized in an ever broadening horizon of disease entities. Myelitis and syringomyelia were recognized as causes in 1875 and 1892 respectively.[1] It was not until 1936 that Jordan described neuropathic arthropathy in the diabetic,[5] now the most common cause of Charcot joints.[4]

Etiologic Factors

The myriad of conditions which can produce Charcot joints is well outlined elsewhere.[2,6] The three most common causes are diabetes mellitus, tabes dorsalis, and syringomyelia.[4] The prevalence of neuropathic arthropathy in diabetes is only 0.1% to 0.5%, as compared to tabes dorsalis and syringomyelia which are 5% to 10% and 25%, respectively.[4] The almost epidemic numbers of diabetics makes them the largest group seen clinically, however.

Various theories have been espoused, such as Charcot's "neurotrophic" theory, Volkmann's "mechanistic" theory, and "neurovascular" theories.[4] Each stresses some aspect of the observations made in the neuropathic ar-

thropathy process. Certainly, "trophic" nerves have never been proven.[2] Mechanical trauma most certainly has a major role in the process, as is noted by many authors.[1,2,3,6,7,8]

The basic concept of the mechanical theory is the blunting or eliminating of pain and proprioceptive information received from the involved body part. This dampens the afferent input for both conscious and nociflexive response patterns which have evolved to protect the extremity from intolerable mechanical stresses, and thus avoid injury.[8] The loss of proprioceptive and fine sensory input leads to ataxic gait patterns which further increase mechanical stresses.

The spectrum of sensory deficit can be from an apparently normal sensory examination, to complete anesthesia.[4] Patients can experience pain, but it is invariably much less than expected for the degree of trauma and distortion of bone and soft tissues.[2,4,5,7] When pain does occur, it is usually secondary to severe posttraumatic inflammation of richly innervated synovial and pericapsular structures.[4,6] Joint proprioception, which normally inhibits hypermobility, is diminished, or absent, allowing instability to develop and progress.[8]

Attempts to explain the rapidity of the process and bony reabsorption, seen especially in the diabetic patient,[6,10] have been made with the "neurovascular" theory.[4] This theory states that an abnormal "neurovascular reflex"[4] increases blood flow, resulting in bony washout, and hyperemic distensible soft tissue supports, all of which predispose the joint to a destructive process with normal stresses. The high incidence of objective autonomic dysfunction in diabetics lends some support to this theory.[4]

As stated by Hurzwurm and Barja,[4] ". . . a more plausible explanation is that all of the above theories play a role . . . ," but to different degrees in each patient.

Simply, relatively minor fractures in an otherwise normal foot or ankle can lead to rapid Charcot arthropathy if neuropathy is present.[7]

One can think about the insensate foot like the insensate mouth after our friendly dentist mercifully relieves pain. If we insist on eating before the anesthetic wears off, despite his instructions, we can induce a "Charcot mouth." We will have pain for our indiscretion within several hours. The patient with neuropathy will continue to "chew away," oblivious of the damage he creates.

Clinical Features

The foot is the most commonly affected part of the appendicular skeleton.[4] However, it should be noted that different distributions of skeletal involvement can be seen, such as primarily upper extremity involvement with syringomyelia. The spine, knee, and hip may also be involved.[11] Why one joint in an insensate extremity is involved, while other joints remain normal, has remained unanswered.[1]

Patients commonly present with the chief complaint of swelling, deformity, or mal perforant ulcers.[4,5] Pain may or may not be present, but is usually dependent upon presence of acute inflammation.[4,5]

As described by Charcot and Volkmann,[2] the process of joint disruption begins with a period of swelling, erythema, local hyperemia, and effusion. This acute phase presentation is a manifestation of a normal acute inflammatory response to injury. If the injury is not perceived, the already edematous and hyperemic tissues receive continued trauma, recurrent inflammation, and poor, inadequate healing occurs. This eventually, if unchecked, leads to progressive soft tissue and bony deformity,[5,6] more characteristic of the chronic phase. An important distinction must be made between acute inflammation and infection, as both can present with the same local findings of swelling, erythema, and increased skin temperature. In the Charcot joint, however, laboratory studies, such as the white blood and differential counts and sedimentation rate, are normal; and importantly, there are no systemic manifestations such as fever or signs of sepsis.[5]

Usual deformities include increasing flat foot to complete arch collapse, ankle and hindfoot valgus (or varus), and forefoot external rotation and eversion.[5,6,8] Mal perforans ulcers are formed intradermally, under heavy callous, caused by abnormal weight bearing.[3,5] A 50% association of diabetic mal perforans with neuroarthropathy has been described,[5] usually occurring at the metatarsophylangeal joint level.

Patterns of joint involvement have been described in the diabetic. Primary ankle and subtalar joint patterns are frequent, with mid-tarsal

joints most frequently involved.[6] Tarsometatarsal and metatarsophylangeal involvement have each been described in up to 30% of cases[4] (Figures 1 and 2).

Radiological characteristics of neuropathic arthropathy progress from debris at the articular margins and periarticular calcifications, to diffuse bony fragmentation which can coalesce to larger fragments and large osteophytes.[1] Later changes include bony marginal sclerosis in attempts to reform articulations[1] (Figure 2).

Pathologic examination reveals bone and cartilage fragments in the synovial tissues, and fibroblastic reaction with some round cell infiltrates in ligamentous and capsular soft tissues.[4,6]

Circulatory status may be good in the Charcot foot,[4] but it is crucial to establish the diagnosis of vascular compromise on first evaluation as this can drastically affect treatment and outcome, especially in the diabetic.[5]

Neuropathic arthropathy can be the presenting problem with previously undiagnosed diabetics.[7]

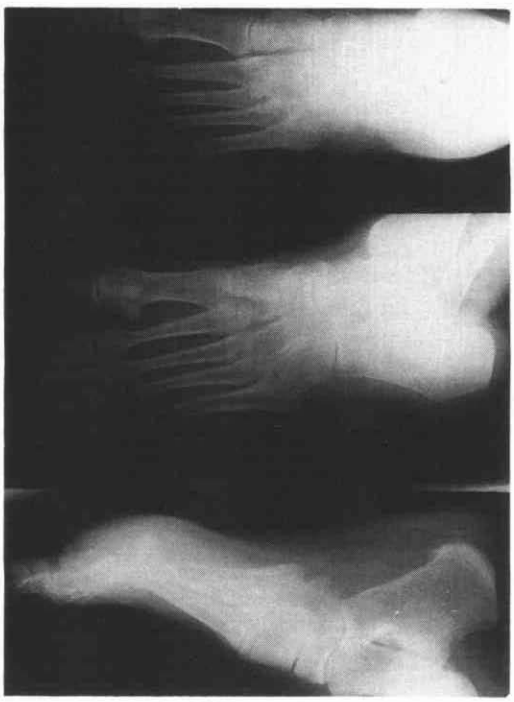


Figure 1A. Initial evaluation of a 54 year old female diabetic. Normal AP, lateral, and oblique views of the left foot.

Complicating factors in the clinical course are spontaneous fractures, which can hasten the degenerative process; deformity, which can be quite rapid in syringomyelia, tabes dorsalis, and with varus deformities; and soft tissue injury, predominantly neurotrophic plantar ulcers.[6]

Treatment

Treatment follows from the recognition that the extremity is injured; and is likely to have continued trauma because of the neuropathy. Early recognition should allow curtailment of the progression, but because of the 'nature of the beast', there is often significant arthropathy at presentation.

Control of neuropathy, if this is possible, should be a primary consideration. This should be followed by attention to soft tissue injuries, or skin ulcerations which may require local debridement.[6] Evaluation of circulation is also part of the initial evaluation,[6,9] with necessary vascular intervention performed if this is a concomitant problem.

Cast immobilization to decrease edema, allow bony and soft tissue healing, and avoid or correct deformity, has been advocated by many authors.[1,4,6,7,9,10] Prolonged immobilization is essential to allow healing and stabilization.[4,6,9] Casting should continue until the local temperature has returned to that of the uninvolved or inactive side. It can then be assumed that the acute repair process has abated, and progression to supportive and protective orthoses is possible.[4,6,9]

Because of the potential for rapid progression, periodic x-rays must be obtained to assess progression which may alter therapy[5] (Compare Figures 1B and 1C).

The indications for orthopaedic surgical intervention include unacceptable deformity, making shoeing difficult; bony prominences, causing ulceration; concomitant infection, requiring debridement and drainage; and deformities with a high likelihood of progression (i.e. varus).[6] ''Bumpectomies,'' decompressive fusions of digits, Keller bunionectomies, and subtalar or ankle debridements and fusions are some of the more commonly indicated procedures.[5,6] Total joint arthroplasty has no place in the neuropathic patient as it will inevitably

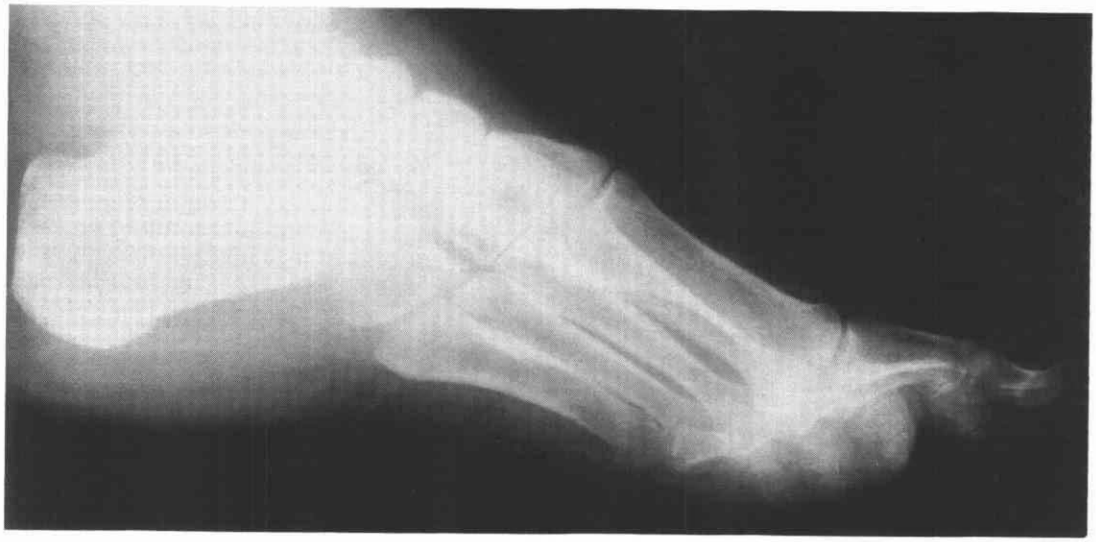


Figure 1B. At age 59 years, the lateral view is still normal.

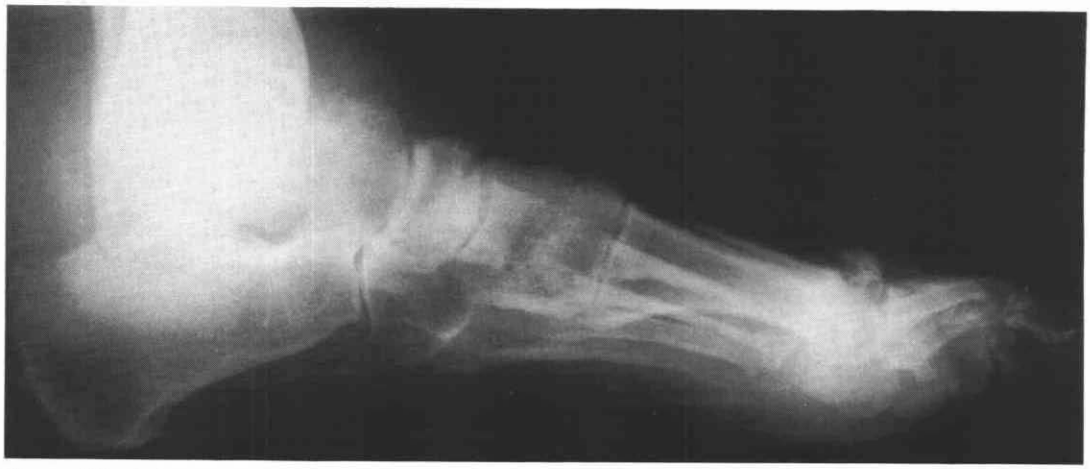


Figure 1C. Only ten months later, lateral view of same foot shows advanced Charcot changes of the ankle, subtalar, and metatarsalphylangeal joints.

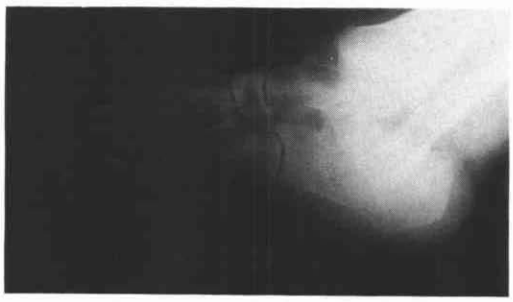


Figure 1D. AP view.

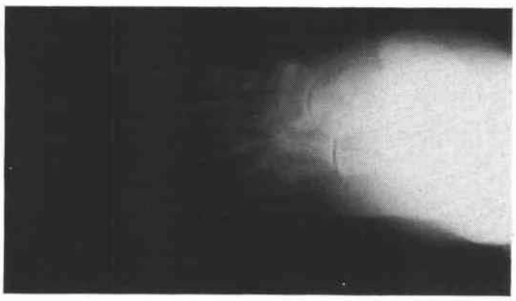


Figure 1D. Oblique view.

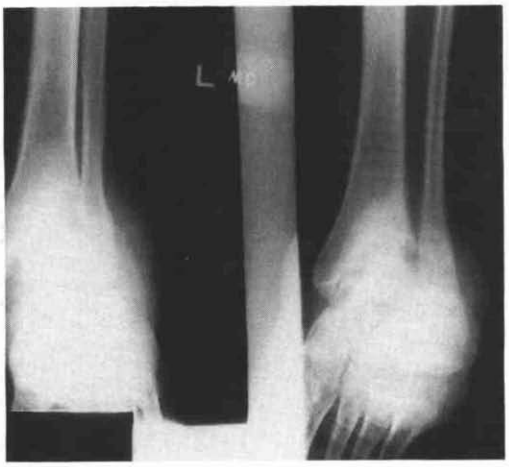


Figure 1E. AP and mortise views of the ankle at the same time as 1C and 1D.

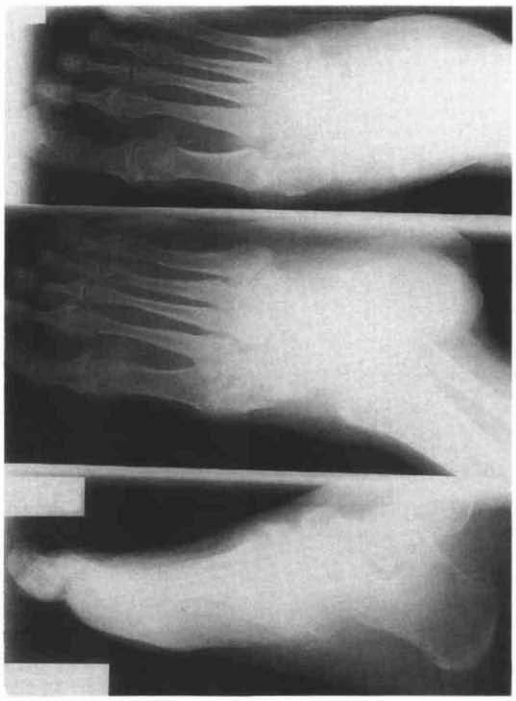


Figure 2. The right foot of same patient in Figure 1. Lateral, oblique, and AP views show midtarsal, tarsal-metatarsal, as well as interphylangeal Charcot joint changes—a different pattern of joint involvement in the same patient. Elements of bone fragmentation, joint subluxation and dislocation and bone formation are represented.

be disrupted by the same process that destroyed the natural joint.[6]

Conclusions

The major problem of the insensate foot is its susceptibility. Ataxia, secondary to neuropathy, imparts abnormal stresses and trauma to an extremity no longer able to detect injury. The neuropathy is usually irreversible, so defensive measures must be taken to control the process of joint destruction. Well fit ankle and foot orthoses to support unstable joints and redistribute weight bearing forces more evenly are the next line of defense once cast immobilization has controlled the injury reaction and allowed healing. Surgery is useful to correct unacceptable or unstable deformities and relieve skin pressures.

By understanding the patient's perceptions, and the pathophysiology of the Charcot foot, we can provide treatment to prolong the functional life and avoid the complications of the insensate foot.

References

[1] Curtiss, P.H., "Neurologic Diseases of the Foot," *Foot Disorders: Medical and Surgical Management,* Editor N.J. Giannestras, Lea & Febiger, Philadelphia, 1973, pp. 500–503.

[2] Delano, P.J., "The Pathogenesis of Charcot's Joint," *American Journal of Radiology,* 2:56, August, 1946, pp. 189–200.

[3] Donovan, J.C. and J.L. Rowbotham, "Foot Lesions in Diabetic Patients: Cause, Prevention, and Treatment," *Joslins's Diabetes Mellitus,* 12th Edition, Editors A. Marble, et al., Lea & Febiger, Philadelphia, 1985, pp. 732–736.

[4] Herzwurm, P.J. and R.H. Barja, "Charcot Joints of the Foot," *Contemporary Orthopaedics,* 3:14, March, 1987, pp. 17–22.

[5] Jacobs, R.L., "Neuropathic Foot in the Diabetic Patient," *Foot Science,* Editor M.E. Bateman, W.B. Saunders Co., 1976, pp. 235–253.

[6] Jacobs, R.L. and A.M. Karmody, "The Charcot Foot," *The Foot,* Editor M. Jahss, W.B. Saunders Co., 1982, pp. 1248–1265.

[7] Kristiansen, B., "Ankle and Foot Fractures in Diabetics Provoking Neuropathic Joint Changes," *Acta Orthopaedics Scandanavia,* 51, 1980, pp. 975–979.

[8] Locke, S. and D. Tarsy, "The Nervous System and Diabetes," *Joslin's Diabetes Mellitus,* 12th Edition, Editors A. Marble, et al., Lea & Febiger, Philadelphia, 1985, pp. 665–685.

[9] Mooney, V. and W. Wagoner, "Neurocirculatory Disorders of the Foot," *Clinical Orthopaedics,* 122, January–February, 1977, pp. 53–61.

[10] Podolsky, S. and A. Marble, "Diverse Abnormalities Associated with Diabetes," *Joslin's Diabetes Mellitus*, 12th Edition, Editors A. Marble, et al., Lea & Febiger, Philadelphia, 1985, pp. 843–866.

[11] Salter, R.B., "Degenerative Disorders of Joints and Related Structures," *Textbook of Disorders and Injuries of the Musculoskeletal System*, Williams & Wilkins Co., Baltimore, 1970, pp. 219–220.

Authors

Mitchell E. Kalter, M.D., and Richard L. Jacobs, M.D., are with the Division of Orthopedic Surgery at Albany Medical College, Albany, New York

Clinical Prosthetics and Orthotics, Vol. 12, No. 2, pp. 67–73

Soft Molded Sandals for Insensitive Foot Care

by William C. Coleman, D.P.M.
Arthur Plaia, M.A.

In the United States, the most common cause of sensory loss on the foot is diabetes. Fifty to seventy percent of all non-traumatic amputations in this country are performed on diabetics.[10] In Atlanta, Georgia, the amputation rate was lower by half after a program of foot inspection, footcare, and shoe-fitting was instituted.

A person with loss of sense of touch and pain in the feet should never walk barefoot. A single step on a sharp object or hot surface with bare feet often results in permanent loss of foot function or eventual amputation of the foot.

A comprehensive program of medically-prescribed, therapeutic footware should address the patient's need for appropriate shoes at all times. Once the need for prescribed footwear has been identified, there is a period between the time the prescription is written and time when the definitive shoes are dispensed to the patient. During that period, the feet still need protection. A form of protective, temporary footwear, needs to be worn by the patient until those shoes are ready. There are a wide variety of devices used for this purpose around the country. The form of these devices is largely dependent on the available facilities and footwear expertise.

A person with a plantar ulcer on an insensitive foot should never walk in shoes or sandals. The most important therapeutic consideration for a person with no sense of pain is to control the mechanical stresses during the healing of these wounds.[9] Shoes and sandals do not provide enough control over these forces.

After a wound has been covered completely by skin, the healing and repair of the injury is not complete. A person with sensory loss needs very careful monitoring during this period immediately after closure, because they are at very high risk of reulcerating the area. [7] Temporary footwear, which provides a high level of protection, should be worn during this time.

Usually, unmodified Plastazote®† shoes or postoperative wooden soled shoes are used as the temporary protection. Once they have served this temporary function, the shoes are discarded and only the definitive shoes are worn from then on. There are many other times, however, when protection of the insensitive foot is needed and custom molded footwear would be the best form of protection.

Other times when protective footwear is needed are listed here.

1. Many people do not want to wear their street shoes around the house until bedtime. Since a person with insensitive feet should never walk barefoot, protective footwear, for use in the house, should be worn. Most commercial house slippers have thin soles which are not intended for walking on rough surfaces and do not provide any significant protection from

† Plastazote® is a trademark of BXL Plastics Limited, 675 Mitcham Road, Croydon CR9 3AL England.

sharp objects on the floor.
2. Plantar foot deformity is often present when prescribed footwear is a necessity. With bony prominences or loss of plantar fat-pads, a person should never walk or stand barefoot on hard surfaces. This is a problem, particularly when this person showers and they stand on porcelain, concrete, or tile.
3. A person who needs prescribed footwear should always have at least two pairs. Most people, who need them, do not. This is important during periods of time when these shoes are being repaired or the prescription is changed.

Plastazote® was first used for orthopedic purposes by William Tuck, in England, in 1967.[11] He notified Dr. Paul Brand in Carville, Louisiana and the first Plastazote® sandals were constructed soon after. Plastazote® provided a material which was easily molded directly on the foot so protective, interim footware could be quickly constructed.

Prior to the introduction of Plastazote®, sandals at Carville were constructed of ⅝" thick microcellular rubber. Microcellular rubber is not a moldable material and foot conformity had to be accommodated by constructing microcellular pads and wedges.[4] This was imprecise and time consuming.

Over the years, several people have contributed modifications to the design and construction techniques of the "Carville" sandal.[8] It has become an integral part of the total foot program.

Materials and Equipment Used to Construct the Sandal

The following is a list of the materials used to build the sandal.

Materials for the Plastazote® Foot Bed

2 pieces of ½" × 6" × 12" Plastazote® #1 (medium)‡
2 pieces of ½" × 6" × 12" Plastazote® #2 (firm)‡
2 pieces of ¼" × 5" × 12" Plastazote® #3 (rigid)‡
2 pieces of Plastazote® #2, 5" × 10" × ½" thick to provide heel lift
2 pieces of ¼" × 3" × 33" Plastazote® #3 for wrapping the sides of the sandals

Additional Materials

Neoprene crepe soling (12 iron = ¼") (24 iron = ½") (1" × 9") Spring steel cut to the full length of the sandal's length.

Webbing for Straps

2 pieces of cotton webbing 1" × 9"
2 pieces of cotton webbing 1" × 8½"
2 pieces of cotton webbing 1½" × 9"
2 pieces of cotton webbing 1½" × 8½"
2 pieces of cotton webbing 1" × 12"

Velcro® to be sewn to webbing

2 pieces of 1" × 2½" Velcro® hook
2 pieces of 1½" × 2½" Velcro® hook
2 pieces of 1" × 2½" Velcro® pile
2 pieces of 1½" × 2½" Velcro® pile

Glue

Contact Cement or other adhesive

Tools

- Skiving knife
- Ruler
- Scissors
- Polyfoam block (size 8" high × 12" wide × 18" long) cut at approximately 45° from the top to the base at the front of the block.

Equipment

- Sewing machine or Patcher machine
- Finishing sander or grinding wheel
- Oven

Pieces of the Sandal Prepared in Advance

Most of the materials used in the construction of a sandal are pre-cut and pre-sewn in the

‡The numerical identifications of the different densities of Plastazote® correspond with the designations assigned for these densities by Alimed Inc., 297 High Street, Dedham, Massachusetts 02026.

shop to speed the construction process.

All pieces of Plastazote® are cut from large sheets into the rectangular sizes listed above. The cotton webbing and Velcro® are purchased on large rolls and cut to the sizes above in advance.

A 1½″ × 2½″ patch of hook Velcro® is sewn to one end of a 1½″ × 9″ piece of webbing. Approximately ½″ of cotton webbing is left exposed on the very end so the end can be grasped by the patient to release the strap. A 1½″ × 2½″ piece of pile Velcro® is sewn to the end of a 1½″ × 8½″ piece of webbing. This procedure is repeated on the 1″ × 8½″ and 1″ × 9″ pieces of cotton webbing.

The oven should be preheated to a temperature of 140° Celsius (285° Fahrenheit). This is the temperature at which all polyethylene materials should be heated.

Plastazote® is a closed-cell polyethylene foam material. If polyethylene foam materials are overheated, the cell structure is weakened and the material shrinks in all directions. To determine the amount of time a polyethylene foam should be heated, measure the thickness of the material in millimeters and multiply the thickness by twelve (10 mm × 12 = 120 seconds). The answer will be the time of heating in seconds.

To mold the Plastazote® directly on the foot, the heated Plastazote® is placed between the foot and a thick foam rubber block. The foot is pressed into the foam and Plastazote®. The foam presses the polyethylene foam up around the sides of the foot and into every plantar hollow and the material cools and remains in this shape.

The top/front of the foam a block is cut at a 45° angle to prevent obtaining a deep mold of the toes (Figure 1). A deep mold would create a ridge distal to the ends of the toes. During gait, the medial foot enlongates with pronation. This elongation could result in distal toe damage on an insensitive foot if this ridge were present.

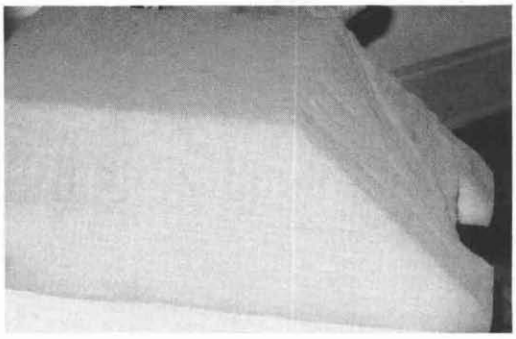


Figure 1. The open-celled foam block used to mold the Plastazote® footbed is cut on the top/front to prevent deep-molding the toes into the Plastazote®.

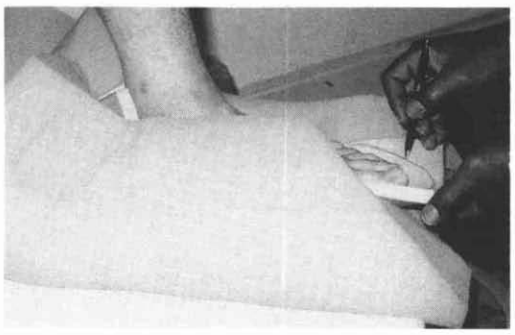


Figure 2. As the first Plastazote® layer is cooling, a line is drawn to mark the outer edge of the sandal.

Construction of the Sandal

Patients are seated in an adjustable chair to insure the knee and ankle can be maintained at right angles as the Plastazote® is molded to their foot. Patients with insensitive feet are asked to wear socks for heat insulation from the warm polyethylene foam.

To begin the sandal, a piece of 6″ × 12″ × ½″ thick, medium, Plastazote® #1 is heated according to the above formula. After the Plastazote® has been heated, it is placed on the foam block with the toe region hanging over the 45° cut of the foam block. The foot is aligned over the Plastazote® with the metatarsal heads positioned over the top edge of the cut-off section of the foam block. The patient's foot is then pressed into the Plastazote®.

After the Plastazote® foot bed has cooled, but before the patient is asked to lift their foot, an outline is drawn to mark a reference for what will become the outer sides of the sandal

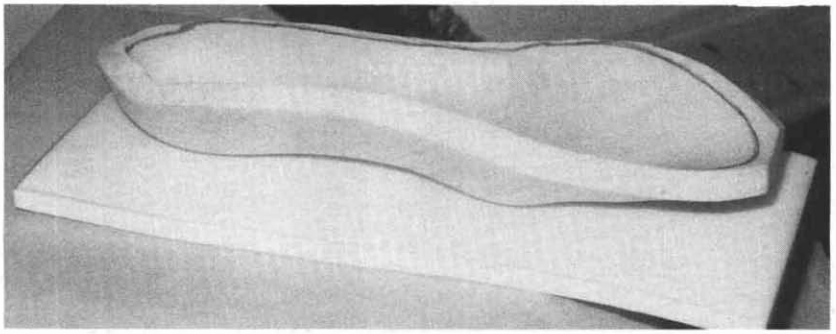


Figure 3. The molded #1 Plastazote® is set on the glued surface of the heated #2 prior to molding the two together.

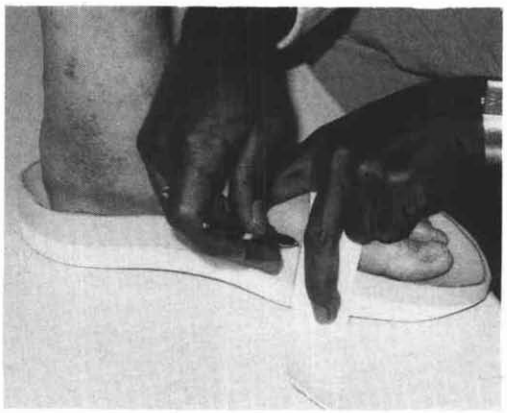


Figure 4. The cotton-webbing straps are held in place while the sandal and straps are marked for later gluing.

(Figure 2). Hold the pen marking this line in a vertical position. Purposely draw the toe area distal to the foot further distal to the toes than needed. Mark the toe of the sandal about 1″ distal than the toes of the foot. Material used to wrap the sides of the sandal will pull the distal end of the sandal back.

Cut the molded piece of Plastazote® around the outside of the molded portion to remove excess material. Make this cut approximately ½″ outside the drawn line. This will allow for better control of shaping the sandal during a later grinding process.

Apply adhesive to the bottom (convex side) of the molded material and to one side of a 6″ × 12″ × ½″ firm, #2 Plastazote® piece. Then heat the #2 Plastazote®. Set the heated #2 piece on the foam block and the molded #1 Plastazote® piece on top of it (Figure 3). Place the foot back into the molded #1 piece and then press down to mold the #2 Plastazote® piece to the bottom of the #1 piece. Plastazote® #1 and #2 are autoadhesive, but this

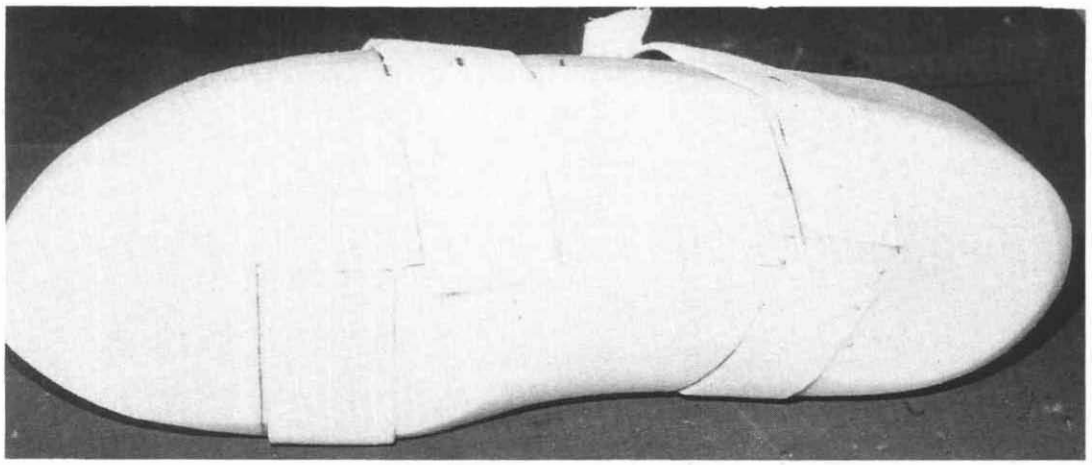


Figure 5. The straps are cut so they do not overlap under the footbed.

characteristic of the material has not proven to form a dependable bond in these sandals.

Then cut the #2 piece to the edge of the #1 piece and ground both pieces vertically to meet the line drawn earlier. At this time, ground flat some of the roundness on the plantar surface of the molded #2 piece and flatten by grinding the area under the metatarsal heads and toes.

Use the 1½″ wide webbing to build the strap which will cross over the midfoot region just in front of the ankle. Use the 1″ webbing for the strap which will cross over the top of the metatarsals just proximal to the metatarsal heads. Also use 1″ strapping behind the heel.

Place the patient's foot in the foot bed and "velcro'' the straps together and hold them in place over the foot. Align the straps over the foot and mark the Plastazote® and straps (Figure 4). Glue together the Plastazote® footbed and straps, using the marks as a reference. Cut the straps under the sandal so they don't overlap (Figure 5).

Coat with glue the 5″ × 10″ × ½″ scrap piece of #2 Plastazote® and the bottom of the molded footbed and heat the #2 piece. Glue the #2 piece under the heel arch and metatarsal heads. Ground down the bottom to form a ½″ high wedge heel which tapers down to the metatarsal heads (Figure 6). This heel lift also serves to fill any remaining arch and curvature under the sides of the molded footbed.

The sole of these sandals should be absolutely rigid. On smaller patients the rigid Plastazote®, which will be added later, will be sufficient to accomplish this. But in larger, heavier patients, it may be necessary to include a rigid steel shank from the heel to the toe. For those patients, glue a piece of leather to the bottom of the footbed to prevent penetration of the steel through the footbed. Bend up the steel from the metatarsal heads to the end of the toe of the sandal in the form of a rocker. Glue the steel shank to the bottom of the leather, and shape and grind flat a filler material around the shank so bumps will not form in the outer sole of the sandal.

If the steel shank is not used, coat with glue a piece of 5″ × 12″ × ¼″ rigid #3 Plastazote® and the bottom of the footbed. Heat the #3 piece and then attach it to the bottom of the footbed. This is done by adhering the heel of the sandal to the #3 piece first and then, in a rolling motion, elevate the heel of the sandal as the toe is pressed down onto the material piece (Figure 7). This creates a rocker sole with increased toe spring under the toes.

Skive back one end of a piece of rigid Plastazote® 3″ wide by 33″ long and ¼″ thick to a distance of 2″ and at a shallow angle. Then apply glue over the 2″ skived portion and the entire other side of the rigid Plastazote® piece. Coat the sides of the footbed with glue. Heat the rigid Plastazote® and glue it vertically around the perimeter of the sandal (Figure 8). Glue the skived end to the medial arch area of the footbed first. This leaves the glue coated skived area facing out from the sandal. Completely wrap the #3 strip around it, overlapping onto the skived area, and cut off the excess. Trim the bottom flat and round the upper edge

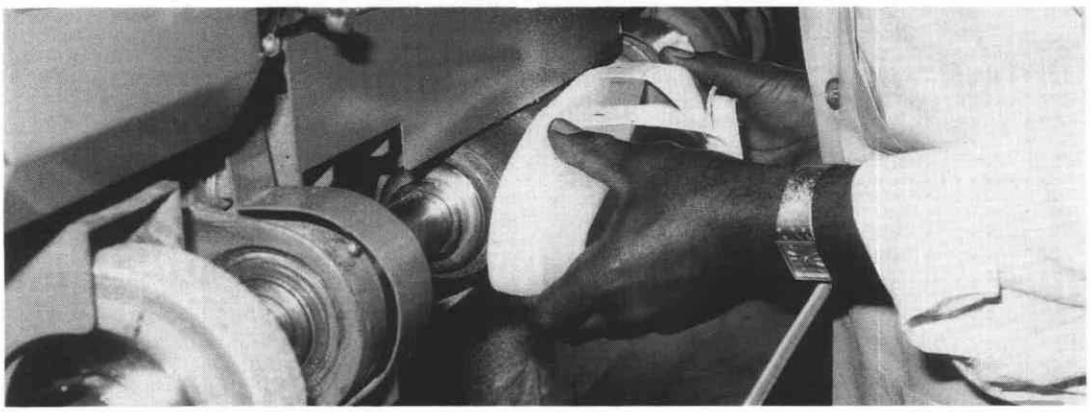


Figure 6. The bottom of the sandal is ground flat under heel, arch, and metatarsal heads after the heel wedge is glued on. The area under the toe is ground up to form the rocker.

Figure 7. The heel of the sandal is lifted before the front of the heated #3 Plastazote® is glued to the footbed to help form the rocker sole.

Figure 8. The sandal is made more rigid by gluing ¼" #3 Plastazote® vertically around the footbed.

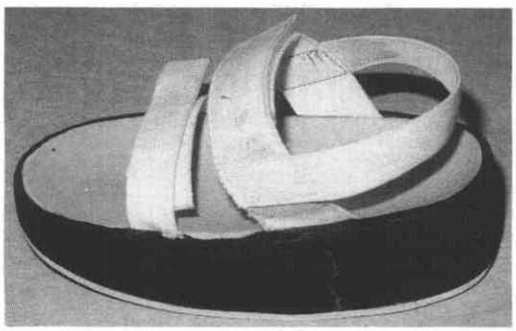


Figure 9. The completed sandal with neoprene crepe soling and heel strap attached.

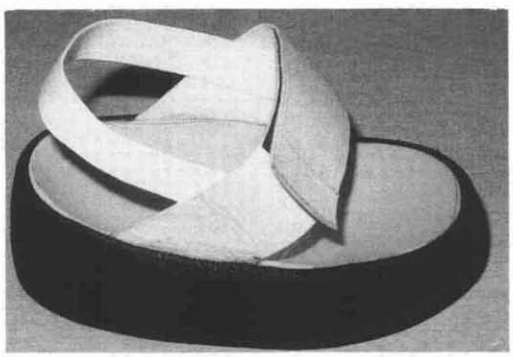


Figure 10. For shortened feet a single, broad strap can be used across the instep.

level with the top of the footbed by grinding. Then glue neoprene crepe soling to the bottom.

Place the patient's foot into the sandal to fit a heel strap. The strap is 1" cotton webbing. Mark the location of the strap. Remove the sandal and sew the strap into place (Figure 9). Rivets can also be used to attach the strap.

For shortened feet, use only a single vertical, instep strap of 1½" to 2" width and attach the heel strap to this single strap (Figure 10). For more long-term use, construct the straps and sides of leather (Figure 11). If the patient's skin

Figure 11. Leather can be used for sandals intended for long-term or outdoor wear.

is thin and atrophied, softer materials such as beta-pile can be used as straps.

Considerations for Insensitive Feet

In a series of 41 diabetic patients with sensory neuropathy in their feet, when measured with pedobarograph, 51% had abnormally high pressure under their metatarsal heads.[2] This is compared to only 7% of non-diabetic patients displaying higher pressures. The skin under the metatarsal heads has been shown in many studies to be the most frequently ulcerated part of the insensitive foot.[3,6] The forefoot region of insensitive feet needs a higher level of protection than the rest of the foot. This can be accomplished in the Plastazote® sandal by making the sole rigid and creating a rocker effect in the sole design.[7] A rigid sole minimizes shear between the sandal and skin. It also eliminates flexion and extension at the metatarsal-phalangeal joints.[7] If the toes of the foot are rigid, a flexible soled shoe will press up into the toes during gait.

Rocker soles have been shown to greatly reduce foot pressure during gait. The point on the sole where rocking begins should always be posterior to the metatarsal heads, but ideally would be placed near the middle of the sandal. These rocker styles of sole are also helpful in the rehabilitation of patients with fused ankles.[5]

Conclusion

For 20 years at the Gillis W. Long Hansen's Disease Center in Carville, Louisiana, Plastazote® sandals have proven to be an effective form of interim footwear for insensitive patients. The technique is simple and highly adaptable to many types of foot therapy.

References

[1] "A Report of the National Diabetes Advisory Board," *NIH Publication No. 81-2284*, Bethesda, Maryland, November, 1980, p. 25.

[2] Boulton, A.J.M., M.D., C.A. Hardisty, M.D., R.P. Betts, Ph.D., C.I. Franks, Ph.D., R.C. Worth, M.D., J.D. Ward, M.D., and T. Duckworth, M.D., "Dynamic Foot Pressure and Other Studies as Diagnostic and Management Aids in Diabetic Neuropathy," *Diabetes Care*, 6, June, 1983, pp. 26–33.

[3] Duckworth, T., M.D., A.J. Boulton, M.D., R.P. Betts, Ph.D., C.I. Franks, M.D. and J.E. Ward, M.D., "Plantar Pressure Measurements and the Prevention of Ulceration in the Diabetic Foot," *The Journal of Bone and Joint Surgery*, 67, January, 1985, pp. 79–85.

[4] Karat, S., M.D., "The Role of Microcellular Rubber in the Preservation of Anaesthetic Feet in Leprosy," *Leprosy Review*, 40, July, 1969, pp. 165–170.

[5] Milgram, J.E., M.D., "Office Measures for Relief of the Painful Foot," *Journal of Bone and Joint Surgery*, 46, July, 1964, pp. 1095–1116.

[6] Pati, L., M.D. and F. Behera, M.D., "Metatarsal Head Pressure (M.H.P.) Sores in Leprosy Patients," *Leprosy in India*, 53, October, 1981, pp. 588–593.

[7] Price, E.W., M.D., "Studies on Plantar Ulceration In Leprosy VI, The Management of Plantar Ulcers," *Leprosy Review*, 31:3, July, 1960, pp. 159–171.

[8] Reed, J.K., RPT, "Plastazote® Insoles, Sandals, and Shoes for Insensitive Feet," *Surgical Rehabilitation in Leprosy*, Editors F. McDowell and C.D. Enna, Williams and Wilkins, 1974, pp. 323–329.

[9] Ross, W.F., M.D., "Footwear and the Prevention of Ulcers in Leprosy," *Leprosy Review*, 33, February, 1962, pp. 202–206.

[10] "Selected Statistics on Health and Medical Care of Diabetics," The National Diabetes Data Group, 1980, pp. A–3.

[11] Tuck, W.H., C.P.O., "The Use of Plastazote® to Accommodate Deformities in Hansen's Disease," *Leprosy Review*, 40, July, 1969, pp. 171–173.

Authors

William C. Coleman, D.P.M., is Chief of the Podiatry Department at the Gillis W. Long Hansen's Disease Center, Carville, Louisiana 70721.

Arthur Plaia, M.S., is Chief of the Orthotic Department, Gillis W. Long Hansen's Disease Center.

Clinical Prosthetics and Orthotics, Vol. 12, No. 2, pp. 74–80

Orthopedic Walkers: Effect on Plantar Pressures

by James A. Birke, P.T., M.S.
Deborah A. Nawoczenski, P.T., M.Ed.

Introduction

Short leg (SLW) and patellar tendon bearing walkers (PTBW) are orthotic appliances† which have been recently designed as alternative devices to traditional plaster cast immobilization. The indications for use of lower leg walkers include severe ankle sprains, and ankle and foot fractures. Orthopedic walkers are convenient to use, lightweight, and removable to perform joint range of motion or inspect the extremity. Short leg walkers have been shown to be as effective as walking casts in healing stable ankle fractures, and patients treated with short leg walkers have shown significantly less edema, tenderness, and joint stiffness after six weeks of immobilization.[13] The authors feel that orthopedic walkers may also prove to be a beneficial alternative to traditional management of neuropathic fractures and plantar ulcerations, which are commonly seen in diabetes mellitus and Hansen's disease.

Neuropathic foot lesions are the result of abnormal or repetitive stress.[3,4,8,10,16] Treatment techniques for neuropathic foot conditions should be effective in reducing pressure and shear stress. Traditional methods of treating neuropathic foot lesions include walking casts, fixed ankle braces, and PTB braces.[1,5,6,7,14,17] Plaster walking casts and PTB braces have been shown to significantly reduce pressure on the plantar surface of the foot during walking.[2,9,11,15] The total contact walking cast is considered effective in reducing pressure on the foot by redistributing forces on the plantar surface of the foot and lower leg. Several features of PTB orthoses shown to be important in achieving maximal weight bearing reduction on the foot include a rigid closure PTB shell, a heel-shoe clearance of ⅜″ to 1″, a fixed ankle joint, and a rocker sole.[11] Orthopedic walkers incorporate these same design features to varying degrees which has generated our interest in studying their effectiveness in reducing pressure on the foot.

The SLW has a fixed ankle joint, rocker sole, and a polyurethane liner which is snugly secured to the leg with Velcro® closures (Figure 1). The PTBW incorporates all the features of the SLW, as well as a non-custom molded, semi-rigid polyethylene PTB shell (Figure 2).

The effectiveness of the SLW or PTBW in reducing pressure or shear stress on the foot has not previously been studied. The potential value of these devices in managing the neuropathic foot may be evaluated by their effectiveness in reducing pressure and shear stress. Currently, there are unreliable methods for measuring shear stress. However, shear is directly related to the perpendicular forces acting on the foot. Pressure equals the perpendicular forces per unit area. Pressure transducers provide a repeatable measurement of relative pressure inside footwear when the material interfacing with the transducers is controlled.[12]

† 3D Orthopedics, Inc., 10520 Olympic Drive, Dallas, Texas 75220.

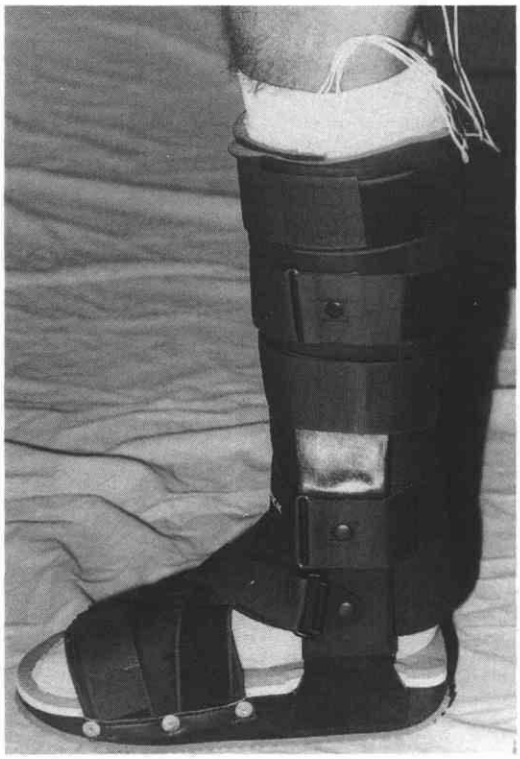


Figure 1. Short Leg Walker.

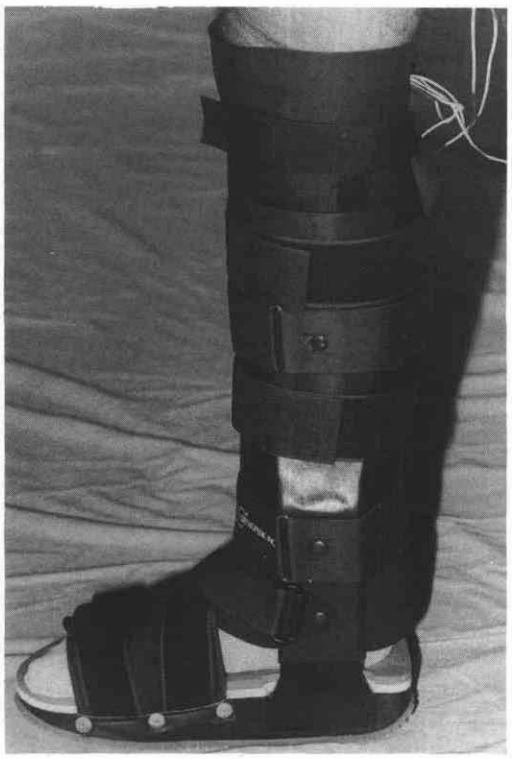


Figure 2. Patellar Tendon Bearing Walker.

Purpose

The purpose of this study was to determine the effectiveness of SLW and PTBW in reducing the pressure distribution on the normal foot during walking.

Method

Ten subjects (6 male and 4 female) without a history of foot pathology participated in this study. Capacitive pressure transducers‡ 2mm thick and 1.5cm in diameter were taped to the first metatarsal head (MTH), third MTH, fifth MTH, and plantar heel of the right foot of each subject (Figure 3). The foot was covered with a thin cotton stockinette which remained undisturbed during the study. Transducers were calibrated according to the manufacturer's instructions prior to testing each subject. Pressure recordings were made using a four-channel capacitive impedance bridge amplifier‡ and oscillographic recorder††† while subjects walked in a cast shoe (CS-1) (Figure 4), short leg walker (SLW), patella tendon bearing walker (PTBW), and again in a cast shoe (CS-2). All the walking devices were fabricated by the same manufacturer.† The cast shoe was identical to the foot component of both the SLW and PTBW, utilizing identical rocker outersoles and 2.4mm polyurethane material insoles. SLW and PTBW were applied to the leg with a ⅜" heel-shoe clearance. Subjects walked a distance of 100 meters for each treatment condition. The testing order of treatments SLW, PTBW, and CS-2 was randomly assigned to eliminate systematic error.

Relative pressure was measured in millimeters of peak to peak chart deflection for 24 steps for each treatment condition. The middle distance of each run was used for analysis in order to eliminate pressure variations due to the acceleration and deceleration phases of each trial. Percent pressure change relative to CS-1

‡ Hercules Orthoflex Data System, Allegany Ballistics Lab, Cumberland, Maryland.

††† Gulton TR-400a, Gulton Industries, Inc., East Greenwich, Rhode Island.

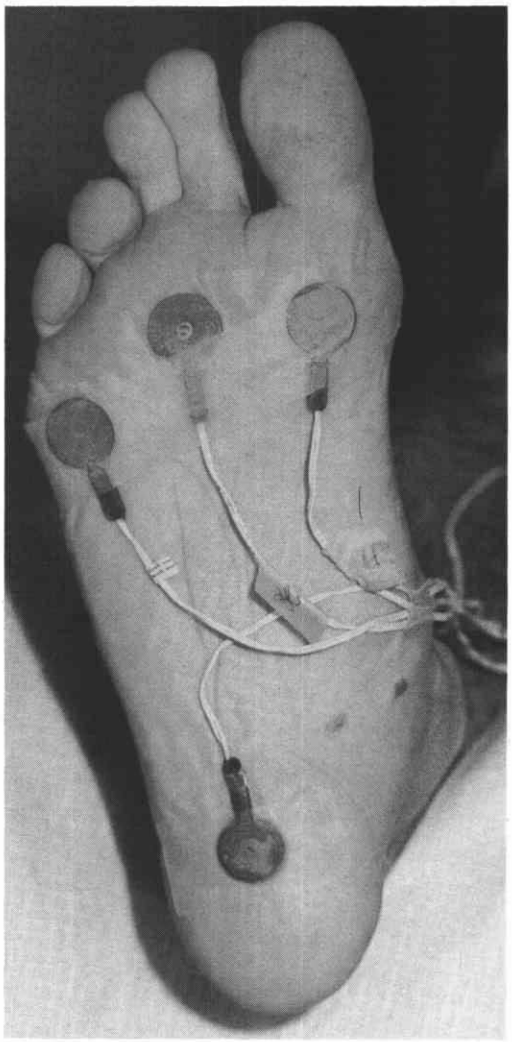


Figure 3. Pressure transducer placement on selected areas of the foot.

was calculated for treatments SLW, PTBW, and CS-2. Means and standard deviations were computed for treatments at each transducer site. An analysis of variance for repeated measures was used to determine whether treatment differences were significant within each site. Duncan's test was used for post-hoc analysis of means. A significance level of 0.05 was used for comparisons.

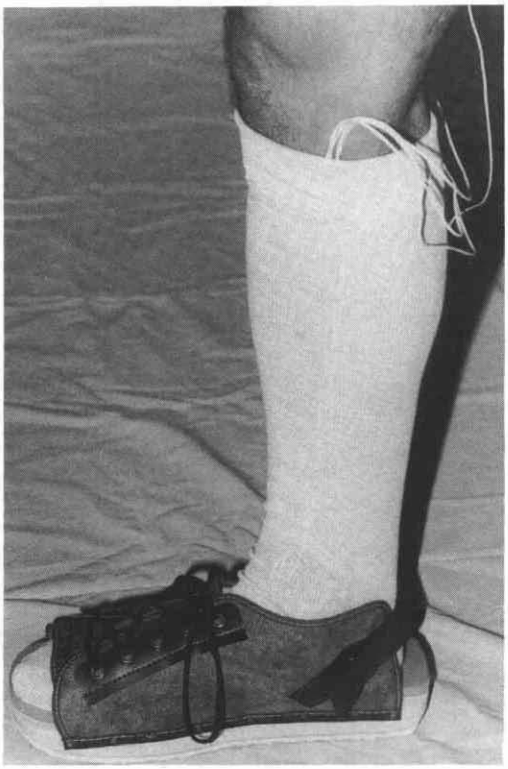


Figure 4. Cast Shoe.

Results and Discussion

An analysis of variance (Table 1) for mean percent reduction in pressure was highly significant at all sites tested (Figures 5, 6, 7, and 8). Duncan's test was performed to establish which treatments differed. Significant differences were found between the percent reduction in pressure walking in SLW and PTBW as compared to the CS-2 at all sites. No difference was found between SLW and PTBW at any site. The percent pressure reduction using the walker devices was comparable at all the sites tested.

This study demonstrated the effectiveness of the short leg and patellar tendon bearing walkers as compared to the cast shoe in reducing plantar pressure on the foot. Since all the devices in this study had the same sole design and insole materials, treatment differences must be attributable to proximal orthotic components including the polyurethane liner, fixed ankle uprights, and Velcro® closures. The SLW and PTBW differed only by the polyeth-

Analysis of Variance of Percent Pressure Reduction

SITE	SOURCE	DF	SS	MS	F
1ST MTH	Treatments	2	1.378	0.689	187.08*
	Subjects	9	0.5468	0.0608	
	Error	18	0.0663	0.0037	
	Total	29	1.9912		
3RD MTH	Treatments	2	2.4045	1.2022	433.8666*
	Subjects	9	0.2841	0.0316	
	Error	18	0.0499	0.0028	
	Total	29	2.7385		
5TH MTH	Treatments	2	1.0142	0.5071	400.0744*
	Subjects	9	0.5052	0.0561	
	Error	18	0.0228	0.0013	
	Total	29	1.5422		
HEEL	Treatments	2	1.2276	0.6138	828.9806*
	Subjects	9	0.1868	0.0208	
	Error	18	0.0133	0.0007	
	Total	29	1.4278		

* $P < .001$.

Table I. Analysis of Variance of Percent Pressure Reduction.

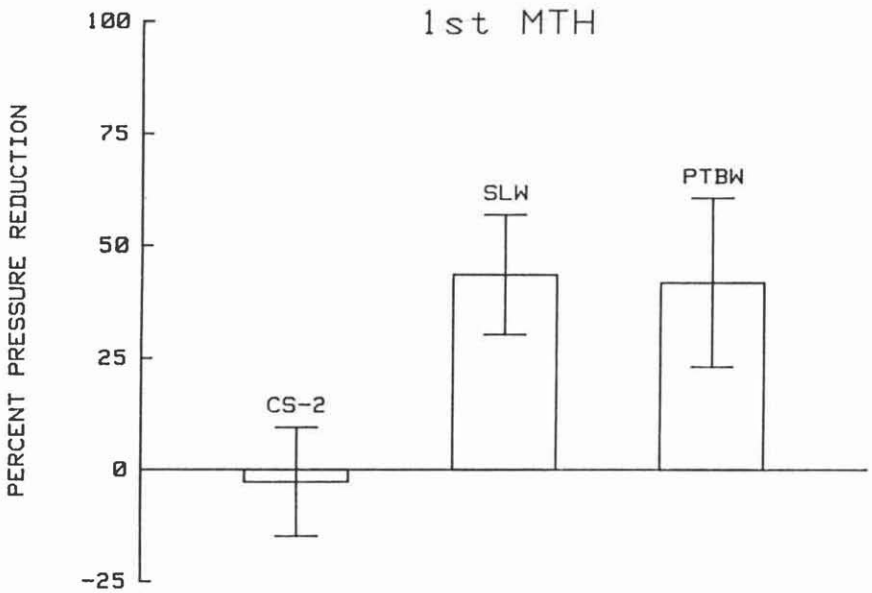


Figure 5. Percent pressure reduction at the first metatarsal head (1 MTH) walking in cast shoe-2 (CS-2), short leg walker (SLW) and patellar tendon bearing walker (PTBW) compared to walking in cast shoe-1.

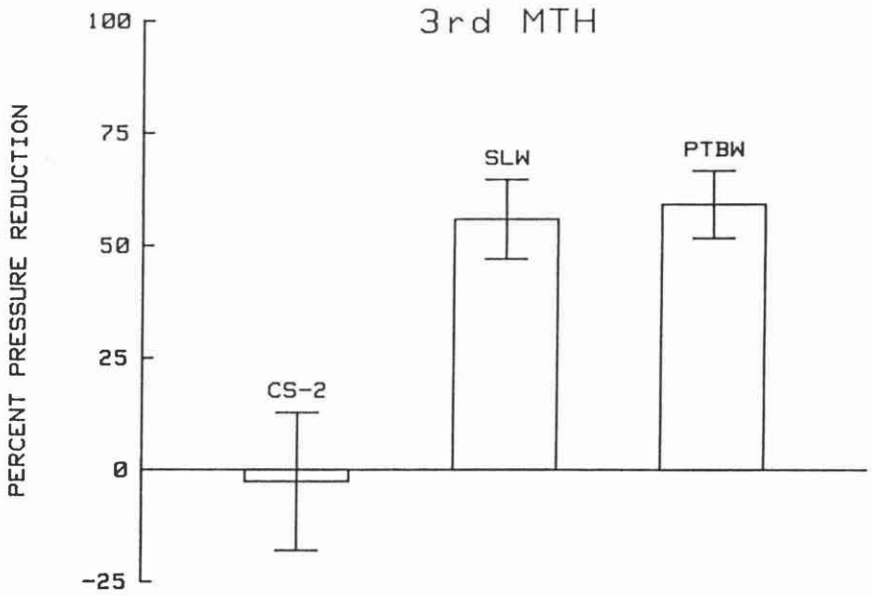


Figure 6. Percent pressure reduction at the third metatarsal head (3 MTH) walking in cast shoe-2 (CS-2), short leg walker (SLW) and patellar tendon bearing walker (PTBW) compared to walking to in cast shoe-1.

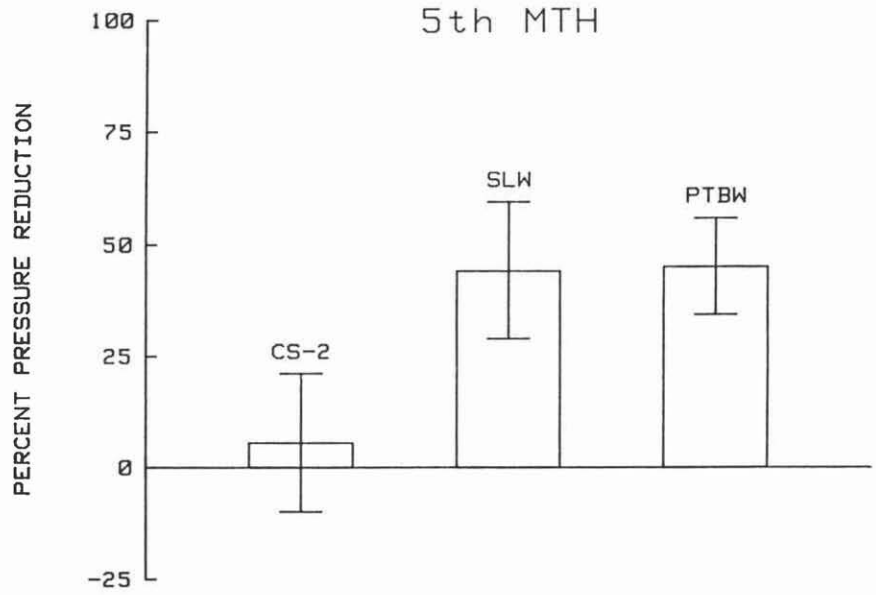


Figure 7. Percent pressure reduction at the fifth metatarsal head (5 MTH) walking in cast shoe-2 (CS-2), short leg walker (SLW) and patellar tendon bearing walker (PTBW) compared to walking in cast shoe-1.

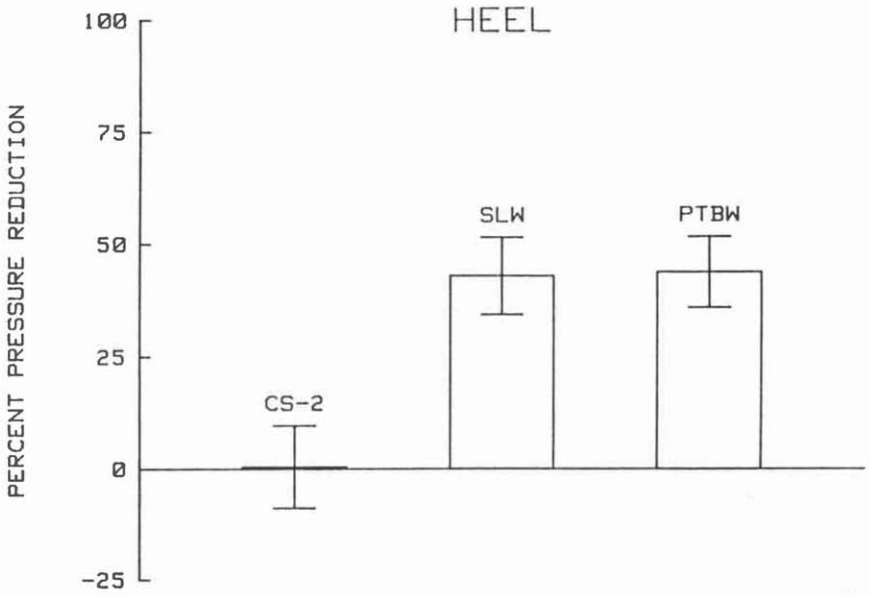


Figure 8. Percent pressure reduction at the heel walking in cast shoe-2 (CS-2), short leg walker (SLW) and patellar tendon bearing walker (PTBW) compared to walking in cast shoe-1.

ylene, non-custom molded patellar tendon cuff. Since no treatment difference was seen between these devices, the PTBW cuff design must not have been effective. However, in follow-up, single subject trials, we were not able to change walking pressures by redesigning the PTBW cuff using polyethylene or plaster custom molded PTB cuffs. An alternative conclusion is that the SLW design alone optimally reduced plantar pressure by the fixed ankle joint and uprights snugly supporting the lower leg and calf.

In this study, orthopedic walkers were equally effective in reducing pressure at all sites tested on the foot. In previous studies, casts were shown to reduce pressure more effectively in the forefoot than the heel, and PTB orthotics reduced pressure more effectively in the heel than the forefoot.[2,11,15]

Based on the results of this study, othopedic walkers may be effective devices in the reduction of plantar foot pressure in patients with neuropathic conditions of the foot. There is no evidence to show that the PTBW will be more effective than the SLW. Further study utilizing a patient population is recommended.

Conclusions

Within the scope of this study, it is possible to conclude the following: (1) SLW and PTBW orthopaedic walkers are effective in reducing pressure at the first MTH, third MTH, fifth MTH and heel in normal subjects during walking, and (2) there is no difference in pressure distribution between the SLW and PTBW during walking.

References

[1] Anderson, J.G., "Treatment and Prevention of Plantar Ulcers," *Leprosy Review*, 35, 1964, pp. 251–258.

[2] Birke, J.A. and D.S. Sims, "Walking Casts: Effect on Plantar Foot Pressures," *Journal of Rehabilitation Research and Developement*, 22:3, July, 1985, pp. 18–22.

[3] Brand, P.W., "The Insensitive Foot," Editor M.H. Jahss, *Disorders of the Foot*, Vol. II, W.B. Saunders, 1982, p. 1266.

[4] Cterctecko, G.C., M. Dhanendran, W.S. Hutton, and L.P. LeQuesne, "Vertical Forces Acting on the Foot of Diabetic Patients with Neuropathic Ulceration," *British Journal of Surgery*, 68, 1981, pp. 609–614.

[5] Coleman, W.S., P.W. Brand, and J.A. Birke, "The Total Contact Cast: A Therapy for Plantar Ulceration of the Insensitive Foot," *Journal of the American Podiatric Medical Association*, 74:11, November, 1984, pp. 548–552.

[6] Enna, C.D., P.W. Brand, J.K. Reed, and D. Welch, "The Orthotic Care of the Denervated Foot in Hansen's Disease," *Orthotics and Prosthetics,* 30:1, March, 1976, pp. 33–39.

[7] Gristina, A.G., A.L.W. Thompson, N. Kester, W. Walsh, and J.A. Gristina, "Treatment of Neuropathic Conditions of the Foot and Ankle with a Patellar-Tendon-Bearing Brace," *Archives of Physical Medicine and Rehabilitation,* 54, December, 1973, pp. 562–564.

[8] Hall, O.C. and P.W. Brand, "The Etiology of the Neuropathic Plantar Ulcer," *Journal of the American Podiatric Medical Association,* 69:3, March, 1979, pp. 173–177.

[9] Helm, P.A., S.C. Walker, and G. Pullium, "Total Contact Casting in Diabetic Patients with Neuropathic Foot Ulcerations," *Archives of Physical Medicine and Rehabilitation,* 65, 1984, pp. 691–693.

[10] Lang-Stevenson, A.I., W. Sharrard, R.P. Betts, and T. Duckworth, "Neuropathic Ulcers of the Foot," *Journal of Bone and Joint Surgery,* (British) 67B, 1985, pp. 438–442.

[11] Lehmann, J.F., C.G. Warren, D.R. Pemberton, B.C. Simons, and B.J. DeLateur, "Load-bearing Function of Patellar Tendon Bearing Braces of Various Designs," *Archives of Physical and Medical Rehabilitation,* 52, August, 1971, pp. 366–370.

[12] Patterson, R.P., and S.V. Fisher, "The Accuracy of Electrical Transducers for the Measurement of Pressure Applied to the Skin," *IEEE Transactions on Biomedical Engineering,* 26:8, August, 1979, pp. 450–456.

[13] Polakoff, D.R., S.M. Pearce, D.P. Grogan, and W.Z. Burkhead, "The Orthotic Treatment of Stable Ankle Fractures," *Orthopedics,* 7, 1984, pp. 1712–1715.

[14] Pollard, J.P., and L.P. LeQuesne, "Method of Healing Diabetic Forefoot Ulcers," *British Medical Journal,* 286, February, 1983, pp. 436–437.

[15] Pollard, J.P., L.P. LeQuesne, and J.W. Tappin, "Forces Under the Foot," *Journal of Biomedical Engineering,* 5, 1983, pp. 37–40.

[16] Sabato, S., Z. Yosipovitch, A. Simkin, and J. Sheskin, "Plantar Trophic Ulcers in Patients with Leprosy," *International Orthopedics,* 6, 1982, pp. 203–208.

[17] Soderberg, G., "Follow-up of Application of Plaster-of-Paris Casts for Noninfected Plantar Ulcers in Field Conditions," *Leprosy Review,* 41, 1970, pp. 184–190.

Authors

James A. Birke, P.T., M.S., is Chief of the Physical Therapy Department at G.W. Long Hansen's Disease Center, Carville, Louisiana 70721.

Deborah A. Nawoczenski, P.T., M.Ed., is Assistant Professor at the Department of Physical Therapy for the College of Allied Health Professions at Temple University, Philadelphia, Pennsylvania 19140.

Clinical Prosthetics and Orthotics, Vol. 12, No. 2, pp. 81–98

Report From: International Workshop on Above-Knee Fitting and Alignment Techniques

by C. Michael Schuch, C.P.O.

An "International Workshop on Above-Knee Fitting and Alignment Techniques" was held in Miami, Florida, May 15–19, 1987. Conceived and organized by A. Bennett Wilson, Jr. and Melvin L. Stills, C.O., the workshop was supported and sponsored jointly by the International Society for Prosthetics and Orthotics and the Rehabilitation Research and Development Service of the Veteran's Administration. Hosting the workshop was the Prosthetics and Orthotics Education Program of the School of Health Sciences, Florida International University, and more specifically, Dr. Reba Anderson, Dean of Health Sciences and Ron Spiers, Director of Prosthetic Orthotic Education. Approximately 50 invited professionals attended the workshop, representing the United States, England, Scotland, Denmark, Sweden, Israel, the Netherlands, and Germany. Invited professionals included physicians, engineers, educators, and researchers, as well as prosthetic practitioners, all known to be active in the field of prosthetics.

The intent of the workshop was an organized sharing and discussion of information and experiences relative to the management of above-knee amputees. Above-knee socket design variables, specifically the accepted and established quadrilateral design and the newer ischial-containment designs known by various acronyms (CAT-CAM, NSNA, Narrow M-L), were discussed in great detail. Goals were to determine differences/similarities, advantages/disadvantages, indications/contraindications, as well as to develop recommendations for future action with respect to the various socket designs. While many prosthetists and/or clinics may have considerable experience with the newer above-knee socket designs within the United States, it is true that there are still many questions and concerns on the part of consumers, prescribing physicians, third party paying agencies, and educators in the U.S., as well as a great curiosity on the part of our international colleagues abroad.

After introductory remarks from Dr. Anderson, Dean of Health Sciences at Florida International University, Mr. John Hughes, President of ISPO, and Dr. Margaret Gianninni, Director of the Rehabilitation Research and Development Service of the Veteran's Administration, the program began with a presentation by A. Bennett Wilson entitled, "Recent Brief History of AK Fitting and Alignment Techniques." This paper began with the advent of the suction socket in the U.S. shortly after World War II and proceeded with the development of the total contact quadrilateral socket in the early 1960's. The audience was reminded that the total-contact quadrilateral socket, with

or without suction suspension, was the socket design of choice from 1964 until very recently, when ischial-containment socket designs emerged. It was noted that, at present, the three senior prosthetic education programs in the U.S. (UCLA, Northwestern University, and New York University), in addition to teaching the application of the standard total contact quadrilateral socket, are offering special courses in what at first glance appear to be radical departures from the quadrilateral design. The technique at UCLA is known as CAT-CAM (Contoured Adducted Trochanteric-Controlled Alignment Method), based on work by John Sabolich, C.P.O., and inspired by Ivan A. Long, C.P. The technique being presented at Northwestern University is said to be based more directly on the Ivan Long technique and is known as NSNA (Normal Shape-Normal Alignment). The technique taught at New York University is usually referred to as the narrow ML socket design based on a special tool designed by Daniel Shamp to facilitate casting. Mr. Wilson concluded his remarks by saying "unfortunately, none of these techniques has been subjected to an evaluation program independent of the development group, and a great deal of confusion exists among clinicians responsible for amputee care. I hope that this workshop can be helpful in clearing away some of the confusion, and point the way for action that will bring order to the present day practice of above-knee prosthetics."

The next speaker on the agenda was Charles Radcliffe, Professor of Mechanical Engineering at the University of California, Berkeley. Professor Radcliff's presentation was entitled, "Review of UCB Quadrilateral Socket and Alignment Theory." Having been a member of the Prosthetic Devices Research Project of UC Berkeley in the 50's and 60's, Professor Radcliff is still a strong proponent of the quadrilateral socket. He presented a detailed review of the history and development of the quadrilateral socket and summarized this section of his presentation with the following comments. "The net result of all of this work in the 1950–1963 period was a better understanding of the complex interrelationships between the functional capability of the amputee, the rehabilitation goals, the prosthetic components required in the prescription, the gait of the amputee, the biomechanical forces generated, the socket shape, and the alignment. The socket was no longer described as a cross-section shape at the ischial level, but rather a three-dimensional receptacle for the stump with contours at every level which could be justified on a sound biomechanical basis. . . . It should be emphasized again that the quadrilateral type of fitting is not just a socket, it is a complete system which includes the amputee as a most important component. The socket is the interface between stump and prosthesis, and its primary functions are to provide for weight-bearing in the stance phase, allow the use of the stump and hip musculature to control motion and posture of the upper body in the stance phase (Figure 1), and to provide for control of the prosthesis in the swing phase of walking."

The next section of Professor Radcliffe's presentation focused on biomechanical and alignment principles of a prosthesis with a quadrilateral socket. Here he related his feelings that many of the biomechanically related claims made by proponents of the newer non-quadrilateral socket designs are equally attainable in the quadrilateral socket if the original biomechanical principles are followed. "Regardless of the fitting method employed, the socket for any patient must provide the same overall functional characteristics, including comfortable weight-bearing, a narrow base gait, and as normal a swing phase as possible consistent with the residual function available to the amputee after amputation. It is possible to provide this with a quadrilateral socket and it is being done routinely in many facilities." Professor Radcliffe went on to say, "In most of the recent articles that I have read, statements have been made which indicate clearly that the author is comparing very poorly fitted quadrilateral sockets to the results obtained using the new technique. They show diagrams of typical fittings and gait deviations which can only be described as a complete list of horror stories describing what not to do in fitting a quadrilateral socket. Any prosthesis with the problems listed in these articles should never have been delivered. If the average prosthetist in the United States is having the problems described by Long, Shamp, and Sabolich, then I must suggest that something is wrong with the methods being taught and used

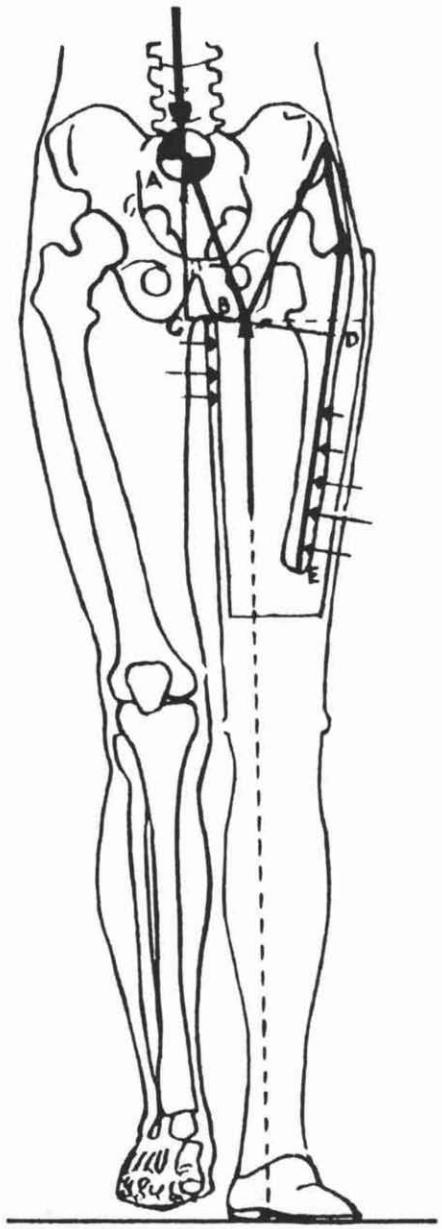


Figure 1. Biomechanical forces diagram, Above-knee amputee weight-bearing in the stance phase.[1]

in daily practice. I am aware that the schools have made significant changes in the way that the principles are taught, with each school emphasizing different aspects of the problem. I suspect that there may have been a shift away from the fundamentals of teaching of overall objectives, including the interrelationships of amputee evaluation, components prescribed, biomechanics, and why sockets are fitted with particular contours."

Following Professor Radcliffe was Tim Staats, Director of the UCLA Prosthetics Education Program. Mr. Staats' presentation was on the "UCLA CAT-CAM." UCLA began teaching CAT-CAM above-knee prosthetics with a pilot course in March 1985, which included both John Sabolich and Tom Guth as course instructors. Mr. Staats made it clear that the UCLA CAT-CAM philosophy of 1987 has departed from that of Sabolich, Guth, et al. and that the UCLA philosophy has now evolved to the point where a third edition of a teaching manual was published in March, 1987. To quote Mr. Staats as he spoke about this new manual, "the third edition of the UCLA CAT-CAM Above-Knee Prosthesis teaching manual integrates much additional material, covering the anatomy/socket relationship and how this is best achieved—material not yet fully understood and synthesized at the time of preparation of the previous edition. The UCLA CAT-CAM above-knee socket is a variation of the CAT-CAM design developed by John Sabolich, C.P.O., and Tom Guth, C.P., and the NSNA AK prosthesis of Ivan Long, C.P. Through countless hours of literature search, discussion, and intensive training given in this and nine foreign countries, and through the results of over 200 students who have fabricated and fit over 1,000 sockets under the guidance of our staff, a new insight has been developed. Our staff has refined the techniques of measurement, casting, and model modification to the point where it is a clearly teachable and viable above-knee fitting method. It is with great respect that we continue to recognize the published contributions of John Sabolich, C.P.O., Tom Guth, C.P., and Ivan Long, C.P., to the development and evolution of the UCLA technique. We would hope that this manual captures, blends, and enhances their philosophies. We recognize that our technique and CAT-CAM evolved from NSNA and we hope that these professionals can appreciate our efforts to refine and further evolve their clinical approach into a methodical step-by-step teaching manual."

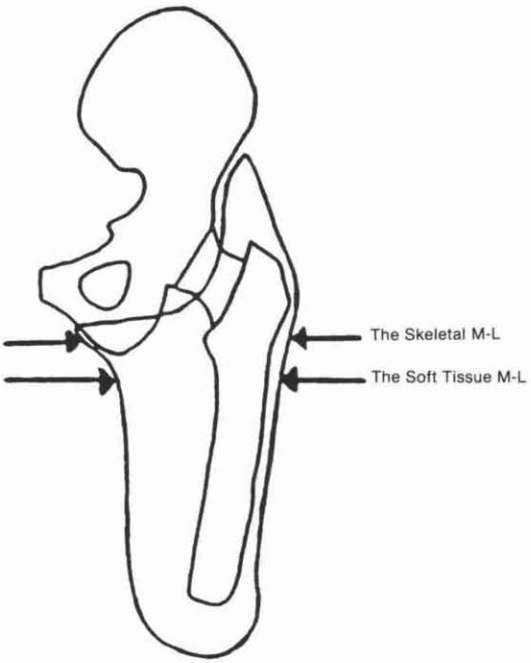


Figure 2. UCLA CAT-CAM medial-lateral diameter measurements.[2]

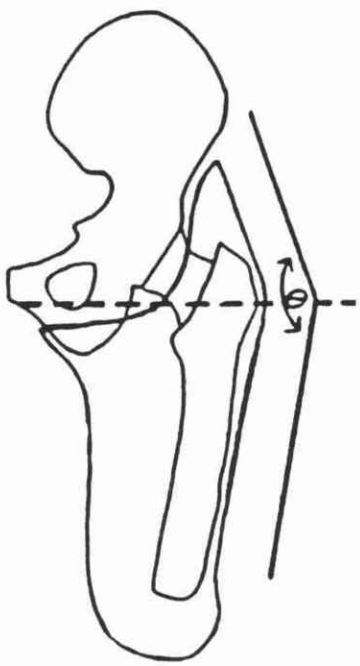


Figure 3. Ilio-femoral angle, as measured for UCLA CAT-CAM.[2]

At this point I will briefly review the highlights of the UCLA CAT-CAM sequence, beginning with patient evaluation and measurement and proceeding through model modification and bench alignment. For the details, I suggest referencing the third edition of the UCLA manual.

The recommended evaluation/measurement protocol is very complete and detailed, covering many of the procedures with which we should all be familiar. Adduction and flexion analysis of the residual limb are emphasized. Some new measurements and/or evaluations are introduced and illustrated:

- Skeletal ML dimension, actually measured on patient (Figure 2)
- Soft tissue ML dimension, taken from Ivan Long's chart of circumferences and related ML values (Figure 2)
- Ilio-femoral angle, actually measured on the patient (Figure 3)
- Public arch angle, evaluated by palpation and captured in the wrap cast (Figure 4)
- Ischial inclination, evaluated by palpation and captured in the wrap cast (Figure 5)

The wrap cast is taken with the patient in a standing position, and all shaping of the cast is accomplished by hand molding. The goal is good definition and containment of the medial and posterior aspects of the ischial tuberosity and ischial ramus within the wrap cast and subsequent socket, as well as allowance for the pubic ramus to exit the socket near the midline of the medial wall (Figure 6).

The initial trimlines for the resultant socket are as follows:

1. Anteriorly, just proximal to the inguinal crease. The anterolateral brim must clear the superior iliac spine when the patient is sitting.
2. Laterally, the brim extends approximately 3″ above the trochanter. The final height of this wall will be determined during fitting.
3. Posteriorly, the trim line should begin at least 1″ above the level of the inferior border of the ischial tuberosity. The curve that defines the posterior to lateral trim line normally begins at a point between the lateral third and the midline of the socket ML dimension at ischial level.

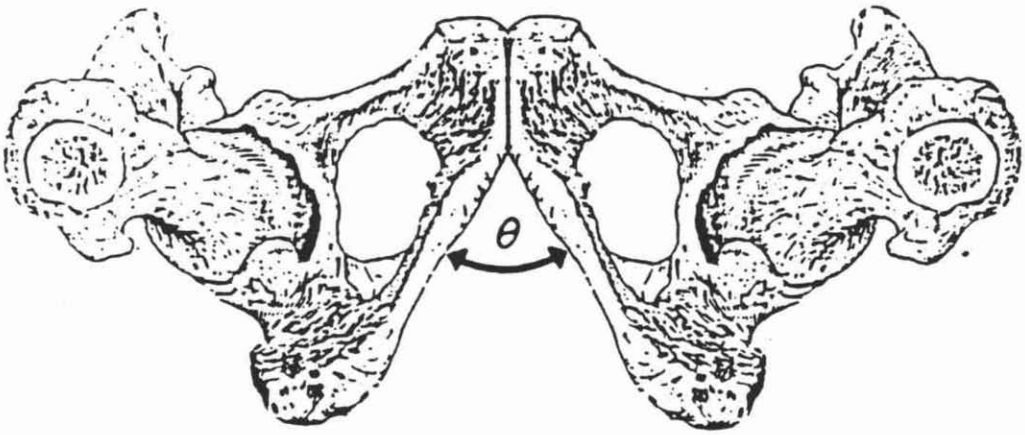


Figure 4. The pubic arch angle, as evaluated for UCLA CAT-CAM.[2]

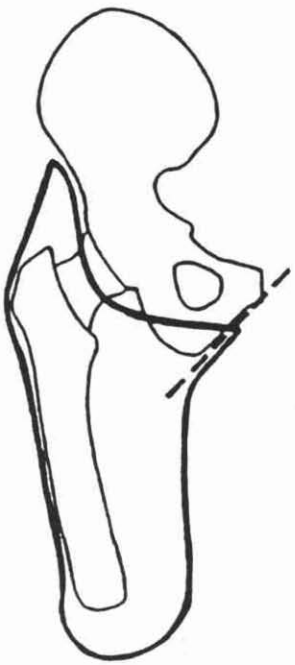


Figure 5. The ischial inclination angle, as evaluated for UCLA CAT-CAM.[2]

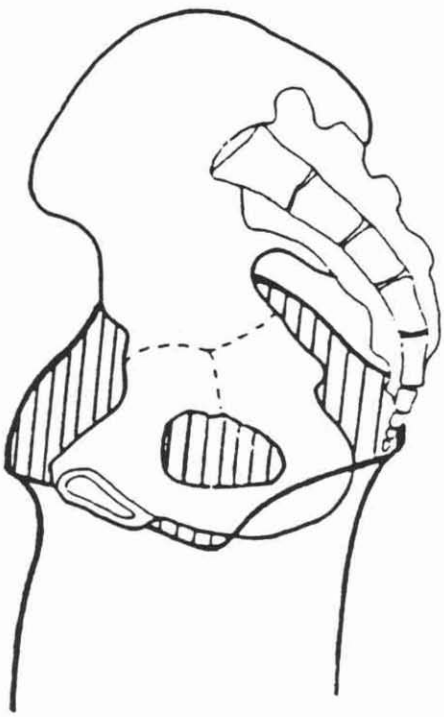


Figure 6. Medial view of pelvis-socket relationship, UCLA CAT-CAM.[2]

4. The medial proximal brim will be "V" shaped, with the vortex of the "V" located at the point where the pubic ramus crosses the medial wall. This trim line projects upward from the vortex, posteriorly to encapsulate the medial aspect of the ischial ramus and tuberosity. (Figure 6) A circumference reduction chart is used to attain suction suspension. The values used in this chart are slightly less than those normally used in quadrilateral suction sockets.

For bench alignment, the following references are used:

1. Posteriorly, bisect the socket at the level of the soft tissue ML, this reference line should fall as a plumb line to the center of the heel.
2. Laterally, bisect the socket AP dimension at ischial level, this reference line should fall as a plumb line between 0″ and 1″ anterior to the foot bolt.
3. Socket is set in measured adduction, and measured flexion plus 5°.
4. The distal aspect of the medial wall should be on the line of progression.
5. The knee bolt is externally rotated 5°.
6. The top of the foot, as well as the prosthetic shank should lean medially 4°, or alternatively, the socket is hyper-adducted 4° beyond measured adduction with the foot parallel to the floor and the shank perpendicular to the floor.

The UCLA CAT-CAM can be fabricated using rigid socket or flexible socket techniques. If a flexible socket or brim system is desired, the proximal medial trimline in the ischial area must be more aggressive during casting to allow for the linear shrinkage factor known in most thermoplastics.

A final comment: the manual reflects the accumulated experience of the UCLA staff and includes a section on problem solving the difficulties that might be experienced in the CAT-CAM socket.

Next to speak was Gunther Gehl, C.P., Director of Prosthetic Education at Northwestern University in Chicago. Northwestern has been teaching the NSNA AK techniques of Ivan Long for several years now, and it was Mr. Gehl's task to report to the workshop on NSNA and Long's Line. He said that he and his staff taught NSNA as presented by Ivan Long with no changes. Ivan has been fitting Long's Line, now known as NSNA, for more than 12 years, and his approach has been consistent, with few changes. Perhaps changing the name from Long's Line to NSNA in July, 1985 is the most significant change. Mr. Long has published three technical papers describing his technique: ''Allowing Normal Adduction of the Femur in Above Knee Amputees,'' (*Orthotics and Prosthetics,* December, 1975); ''Fabricating the Long's Line Above Knee Prosthesis,'' (1981); and as a reprint of the Long's Line article with new title, ''Normal Shape-Normal Alignment (NSNA) Above Knee Prosthesis,'' (*Clinical Prosthetics and Orthotics,* Fall, 1985). These articles were the basis for Gunther Gehl's presentation to the International Workshop.

I will attempt to review and highlight the NSNA philosophy as I did the UCLA CAT-CAM. Again, within the limitations of this report, this will only be an overview. With the widespread availability of Ivan's publications, it does not seem necessary to go into details.

NSNA is less detailed regarding evaluation and measurements, placing great emphasis on the wrap cast, subsequent model modification, and alignment, all based on Long's Line, which is defined as a straight line, starting approximately at the center of a narrow socket, passing through the distal femur, and on down to the center of the heel (Figure 7). Long's Line is not always vertical because it shifts constantly when the amputee goes from a standing position to a walking position.

The wrap cast is taken with the patient in a standing position. The important points about the wrap cast procedure are identification of the ischium and proper alignment. The hand will be held to indicate the medial and posterior surface of the ischium, but not forward of the ischium. The amputee then adducts as tightly as possible and extends his thigh to tighten the hamstrings. At this point a lateral reference line is established.

The resultant cast model is oversized and will require considerable modification. Practically all modification will take place on the lateral wall. Following is a brief description of modification goals and resultant trimlines, taken from Mr. Gehl's presentation and from Mr. Long's publications.

1. The lateral wall is to be shaped to give support over a wide area, and particularly the lateral-posterior aspect of the socket.
2. The medial wall will be lower than seat level, and the wrap cast will be the guideline as to how low.
3. Depth of the socket will be the same as the measured length of the thigh.
4. The seat will be at a right angle to Long's Line.
5. Long's Line is drawn from the center of

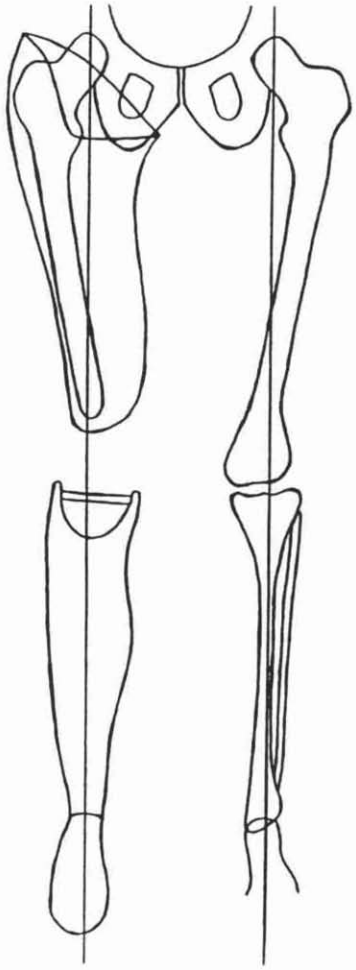


Figure 7. Long's Line.[3]

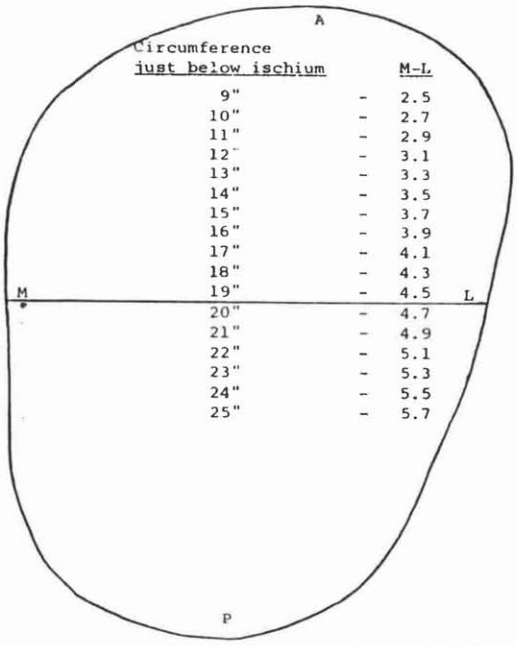


Figure 8. Table of M-L values determined from circumference just below ischium, used in NSNA.[3]

the seat level ML to the center of the distal femur. The distal femur will be very close to the lateral surface, probably only covered by skin.

6. The top 1″ of the medial wall will flare outward at 45°.
7. The lateral wall extends above the trochanter.
8. The ischium will bear on the flare of the socket, both medially and posteriorly.
9. The cast is taken down in the ML as though the trochanter does not exist. In order to achieve the desired ML, many casts will be reduced 2″ or more. The desired ML dimension is taken from Ivan's chart of ML values related to the thigh circumference just below the ischium (Figure 8).

Circumference reductions for suction suspension begin at 1″ of tension proximally, reducing to ¾″, then ½″, with the remaining tensions at ¼″.

Mr. Long does not advocate use of an alignment device. Bench alignment is critical and is based on Long's Line. The center of the lateral wall is marked at seat level for TKA and the vertical reference line established during casting should parallel the TKA line. Long's Line is marked on the posterior of the socket. For the male, the socket is mounted with the inner aspect of the medial wall (which follows the pubic ramus angle) in 30° internal rotation to the line of progression (the outer edge of the medial trimline is on the line of progression), and with the knee bolt axis 4° higher on the lateral side. This is the same as adding 4° additional adduction to Long's Line. For the female, the socket is mounted with the inner aspect of the medial wall in 40–45° internal ro-

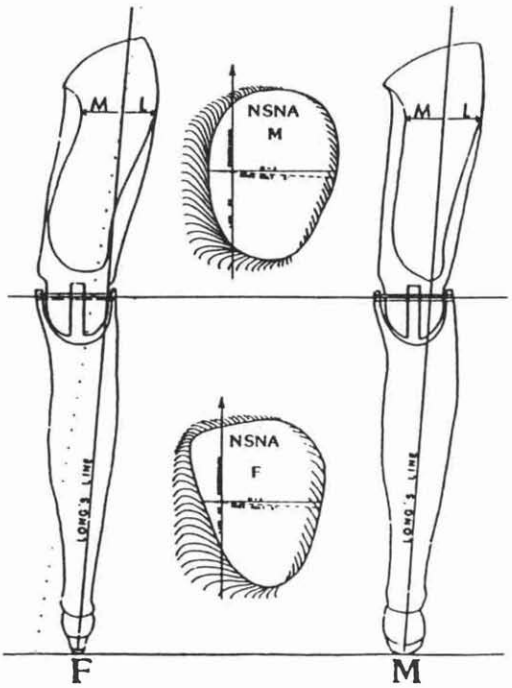


Figure 9. NSNA socket shape and alignment diagram, male and female.[4]

Figure 10. Centralization of the femur, as proposed by Dan Shamp for Narrow ML Socket.[5]

tation to the line of progression (again, the outer edge of the medial trimline is on the line of progression), and with the knee bolt axis 7° higher on the lateral side (Figure 9). Mr. Long emphasizes that it is not necessary to change the alignment. When the amputee is allowed time to adjust to the new prosthesis, then alignment changes will not be necessary.

Following Gunther Gehl was Daniel Shamp, C.P.O., presenting, "The Shamp Brim, For the Narrow ML Above-Knee Prosthetic Socket." Mr. Shamp's system of brim casting and evaluation is currently the content of a special short course offered by New York University's Prosthetic and Orthotic Education Program.

Long and Sabolich, as well as UCLA, advocate that the hand casting technique is the most successful in their experience with the narrow ML, wide AP, or ischial-containment socket for above-knee amputees. In response, Mr. Shamp stated, "Experience with the Shamp Brim system has proven to make the procedure more uniformly successful and more easily learned and applied by the practitioner who has spent years working with the brim method for quadrilateral socket casting and modification." Mr. Shamp went on to present detailed biomechanical rationale for the narrow ML socket. Biomechanical descriptions such as bony lock on the ischium, ischial containment within the socket, retention of normal adduction, etc., are consistently relevant to Mr. Shamp's socket system, as well as all of the latest ischial-containment socket designs. Two noticeably different aspects of Mr. Shamp's technique are (1) the brim forming system itself, which allows for evaluation of brim design under weight bearing conditions before proceeding with the wrap cast, and (2) what Mr. Shamp refers to as centralization of the femur. To accomplish centralization of the femur, during the casting pro-

cedure, the prosthetist pulls the distal medial tissue in a lateral direction while stabilizing the femur with the other hand by means of a 45° force against the lateral shaft of the femur (Figure 10). Mr. Shamp stated that this centralization procedure is essential to prevent a large medial-distal bulge with resultant cosmetic problems when the femur is maintained in a position of maximum adduction in the AK prosthesis.

Again, I will present an overview of the Shamp Narrow ML technique, summarizing from Mr. Shamp's presentation and from the "Manual for use of The Shamp Brim," which was provided for the workshop attendees. This manual was produced by Prosthetic Consultants, Incorporated of Akron, Ohio in cooperation with the Department of Prosthetics and Orthotics, New York University Post-Graduate Medical School, and is published by the Ohio Willow Wood Company.

The measurement and evaluation procedure includes a careful observation and recording of the characteristics, lengths, and circumferences requested on the Narrow ML AK Information Chart. Review of this information chart will show the practitioner who is familiar with the technique for the quadrilateral socket that only a small number of measurements are different for the Narrow ML socket. It is important to note that three ML measurements must be taken precisely as follows:

1) Distal Ischial Tuberosity (DIT): firm ML measurement of the anatomy taken 1″ to 2″ distal to the ischial tuberosity (Figure 11).
2) Oblique ML (OB): firm ML measurement taken from the medial side of the ramus of the tuberosity to a point just superior to the greater trochanter of the femur (Figure 12).
3) Ischial Tuberosity ML (IT): firm ML measurement taken from the medial border of the ramus of the ischial tuberosity to the subtrochanteric area of the femur (Figure 13).

The Shamp Brim, which is compatible with the Berkley brim stand, is now set up and adjusted to the patient's measurements. As stated earlier, the brim allows for weight-bearing evaluation of the patient with regard to socket design before the actual wrap cast is taken.

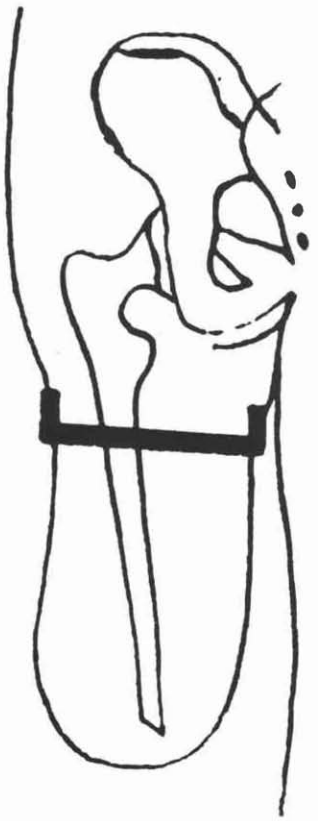


Figure 11. Distal Ischial Tuberosity (DIT), medial-lateral diameter measurement for Narrow ML Socket.[5]

As with all of the ischial-containment socket designs discussed at the Workshop, the location of the ischial tuberosity in the socket is essential to both a comfortable fit and a stable femur in maximum adduction. For the Shamp technique, the ideal location is ½″ inside the medial-proximal wall of the prosthesis and indicates the area referred to as the IT ML measurement. The medial wall has a 45° angle that assists the wedge effect in stabilizing the femur and so the location of the tuberosity on this slope is important. The trimlines are similar to both NSNA and the UCLA CAT-CAM, including the low anterior wall with clearance for the ASIS, the relatively horizontal posterior wall, and the high lateral wall, which extends

Figure 12. Oblique ML (OB), medial-lateral diameter measurement for Narrow ML Socket.[5]

Figure 13. Ischial Tuberosity ML (IT), medial-lateral diameter measurement for Narrow ML Socket.[5]

generously above the trochanter. Although, not as exaggerated as the UCLA CAT-CAM, the medial wall is lowered as it approaches the anterior wall, allowing for the pubic ramus to pass from within the socket.

Alignment follows generally accepted quadrilateral alignment principles for TKA and knee bolt external rotation. For alignment in the frontal plane (posterior view, ML plane), Mr. Shamp advocates the principles of Long's Line.

Dr. Hans Lehneis, C.P.O., of the Rusk Institute of Rehabilitation Medicine was the next speaker and his presentation covered work done at the Rusk Institute and the New York Veterans Administration. Dr. Lehneis and associates are investigating anatomical, physiological, and biomechanical characteristics of geriatric above-knee amputees in an attempt to develop a set of design criteria for geriatric above-knee sockets. As this project is still in the developmental stages, I will not elaborate on this subject.

Following Dr. Lehneis was Ossür Kristinsson of Iceland. As the developer of the flexible socket-rigid frame system, he was the first to speak on flexible sockets. Mr. Kristinsson reported that he was continuing development of flexible sockets, including walls and brims. He is conducting an extensive materials search in hopes of finding the materials that will make possible the ultimate flexible socket design.

Mr. Kristinsson went on to say that we need some simple definition of flexible socket characteristics. "To label a socket as flexible, I would say that you should be able to deform it

by your hands, and the material should not be elastic enough to stretch under the loads it will be subjected to." Concerning flexible socket design, Mr. Kristinsson stated, "When designing a flexible socket system, the most critical aspect for the comfort of the wearer is how the frame is designed. It has to be capable of supporting the flexible socket, preventing permanent deformation, and the socket-frame combination has to be structurally strong and stable enough to counteract the reaction forces." Mr. Kristinsson made a final, important point: "There may be doubt among professionals and users about the value of the flexible wall. I am, however, totally convinced that the flexible socket is here to stay. If anything, I think it will get more flexible as we gain access to more suitable materials than we are using today, and some obstacles on the way to proper understanding of the socket-stump interaction are overcome."

Continuing the flexible socket presentations was Norman Berger of New York University's Prosthetic Orthotic Program. Mr. Berger's presentation was the ISNY (Icelandic-Swedish-New York) flexible socket design as taught by NYU. Mr. Berger described the socket and frame fabrication technique used in the ISNY. Three interesting points are worthy of mention:

1. The flexible socket is fabricated with polyethylene, which has a known shrinkage factor.
2. The desired wall thickness of the flexible socket is 60/1000".
3. Lateral distal support for the femur is not provided for by the frame.

The final presentor on the topic of flexible sockets was Charles Pritham, C.P.O. of Durr Fillauer Medical Company. A co-author and co-developer of Durr-Fillauer's flexible socket technique, Mr. Pritham described the biomechanical function of the flexible walled ischial-gluteal bearing quadrilateral socket as follows:

1. Ischial/gluteal weight bearing;
2. Stabilization of the distal femur laterally;
3. Total contact; and
4. Flexible walls.

Note the mention of stabilization of the distal femur laterally; this is provided for by the frame design of the Scandinavian Flexible Socket. Mr. Pritham went on to say, "It will be appreciated that the design is actually not fundamentally different, flexible walls aside, from a similarly designed socket in the rigid walls. Indeed one of the factors that undoubtedly hastened its acceptance was the fact that previously learned methods of casting and fitting quadrilateral sockets were fully acceptable when fitting a flexible walled socket. While the advantages cited are formulated with the quadrilateral socket in mind, there is no reason to suspect that they are significantly different from non-quadrilateral above-knee sockets. Indeed, flexibility is often considered by the designers of one another of the various designs as an integral factor in their success."

Mr. Pritham listed advantages of flexible walled sockets as:

1. Flexible walls;
2. Improved proprioception;
3. Conventional fitting techniques;
4. Minor volume changes readily accommodated;
5. Temperature reduction; and
6. Enhanced suspension.

Indications for use of the flexible wall socket are:

1. Mature stumps (where frequent socket changes are not anticipated);
2. Medium to long stump (where a significant portion of the wall will be left exposed and flexible); and
3. Suspension is not a factor.

While the use of flexible wall sockets has been well accepted, Mr. Pritham pointed out that questions have arisen in at least three areas.

Material

Both Surlyn® and low density polyethylene (in a variety of types and name brands) have been used successfully and each has its advocates. Mr. Pritham and colleagues at Durr Fillauer prefer Surlyn® for three reasons: clarity, no shrinkage, and ease of rolling the edge.

Thickness

Originally socket walls of 30/1000" thickness were specified, however, this proved to

lack durability. Subsequently, thickness in the neighborhood of 80–90/1000″ were specified and are preferred. (Note: NYU prefers 60/1000″.)

Frame configuration

At least three different configurations have been described for quadrilateral sockets. The differences center on the lateral wall and the amount of support considered necessary for the femur.

A variety of designs have been put forth in order to achieve specific features in non-quadrilateral sockets, including the well known total flexible brim.

Mr. Pritham concluded his presentation by saying, "the crucial point would seem to be that flexibility is independent of socket shape and can be modified to provide specific design features in a socket-frame system. The specific configuration depends upon the prosthetist's experience and fitting philosophy and the needs of the individual patient."

Rounding out the first day of presentations was Dr. Robin Redhead, Senior Medical Officer at the Roehampton Limb Fitting Centre in London. Dr. Redhead's paper was entitled "Experience With Total Surface Bearing Sockets." This presentation centered more on weight-bearing distribution and biomechanics than on socket design or shapes. Dr. Redhead and associates maintain that regardless of socket shape or design, well distributed weight-bearing can eliminate the need for single point, bony weight bearing (such as ischial weight-bearing). This system of well distributed weight-bearing was referred to as a total-surface-bearing socket. It infers a hydrostatic type of socket fit utilizing the incompressibility of the fluids in an above-knee residual limb.

This presentation brought a reaction from of Professor Radcliffe, who doesn't agree with the hydrostatic concept of weight-bearing in prosthetics. He stated that "you need a closed system for hydrostatics and the AK residual limb is not a closed fluid system. With an open fluid system, the fluids are pushed out."

There was considerable discussion on this topic, both pro and con, and it was never resolved.

Beginning the morning of the second day, John Sabolich, C.P.O., from Oklahoma City, and Glenn Hutnick, C.P., from New York, presented another view of CAT-CAM. As stated earlier, Tim Staats, C.P.O. reported that the UCLA CAT-CAM is evolving independently of the CAT-CAM technique of the original developers.

Sabolich and Hutnick report that the original CAT-CAM is continuing to evolve and develop. Sabolich stated that, "it took five to six years to develop the current medial wall design, which has become increasingly more aggressive in enclosing and capturing the ischial ramus." They advocate use of the total flexible brim. "The key is the flexible brim system—it is totally flexible in the proximal area, where most patients complain." Aside from 100% use of the total flexible brim, the Sabolich/Guth CAT-CAM differs from NSNA and the UCLA CAT-CAM by not advocating the 4° to 7° medial lean of the foot, pylon, and knee bolt in bench alignment as proposed by Long and UCLA. John Sabolich went on to say "this additional adduction or tilting of the knee bolt is a cover-up for lost stability due to inadequate ischial containment." Mr. Long's response was that this was incorrect. Probably the most noticeable aspect of design that separates the Sabolich/Guth CAT-CAM apart from the other recent ischial-containment designs is the earlier mentioned aggressive capture of the ischial tuberosity and ramus. Sabolich claimed that they are enclosing more and more of the ischial ramus, as much as possible and still allow pubic ramus comfort. This ramus enclosure provides two biomechanical functions: (1) a medial bony stop for ML stability, and (2) rotational control, especially on soft fleshy residual limbs. Other than these departures, the Sabolich/Guth CAT-CAM differs very little from the UCLA CAT-CAM, especially in terms of brim shape, trimlines, and biomechanics. Sabolich, unlike Long, does advocate the use of dynamic alignment devices.

At this point in the Workshop, Professor Radcliffe returned to the podium in an attempt to present and clarify the comparative biomechanical principles of both quadrilateral and ischial-containment sockets. The following biomechanical analyses are taken from Professor Radcliffe's discussion and from the paper he

later submitted reviewing his presentations.

"It has been demonstrated that pressure against the medial aspect of the pubic ramus can be used to supplement the weight-bearing on the tuberosity of the ischium and contribute to medial stabilization in the upper one-third of the above-knee socket. In taking advantage of the weight-bearing potential on the medial aspect of the ramus, the prosthetist is creating a situation much like weight-bearing on the seat of a racing bicycle. To prevent the ramus from sliding laterally and downward into the socket, the prosthetist must exaggerate the counterpressure from the lateral side. This has been done by a reduction in the M-L dimension particularly in the area just distal to the head of the trochanter. The soft tissue must be accommodated. Therefore, the A-P dimension is correspondingly increased as compared to the quadrilateral socket. As compared to the quadrilateral fitting, the height of the anterior brim is typically lowered and flared and the gluteal area is filled in and fitted higher as a result of the ischium being encased deeper into the socket."

"The medial brim of the socket must slope forward and downward to the point where the pubic ramus crosses the medial brim and emerges from the socket. The ischial ramus clearly is capable of providing medial counterpressure which supplements the medial pressure on the adductor musculature. Since the socket slopes downward and inward along the entire medial brim, this contour is flared into the medial wall of the socket, which gives the impression of exaggeration of the medial counterpressure in the upper one-third of the socket."

"The adduction of the socket and the use of lateral stabilization should not differ from that achieved by a properly fitted quadrilateral socket. There is an apparent exaggeration of the modification of the lateral wall, but this is primarily limited to the area just below the trochanter where the M-L dimension has been reduced to insure that the encased pubic ramus and ischium are maintained in the desired position on the medial brim. The exaggeration of the medial flare and reduction of the M-L dimension in the upper third of the socket leads to the impression of a greater angle of femur adduction, but the actual angle of the femur should be similar in both types of fittings if the quadrilateral socket is properly fitted and aligned."

"Long's Line as proposed by Ivan Long is the anatomical axis of the lower extremity as described in anatomy textbooks. Placing the femural stump in an advantageous position for normal use of the hip musculature by adduction and flexion of the socket has been a part of good prosthetic practice for at least 40 years in the United States and perhaps longer in certain European centers. Mr. Long's Line appears to be most useful in the cast taking procedure and subsequent modifications of the model rather than have any fundamental bearing on the alignment of the prosthesis. It appears to offer no new concepts useful in the bench or dynamic alignment of the prosthesis."

Professor Radcliffe told the Workshop attendees that the use of "catchy names" should be avoided, and he therefore proposed the terminology of Ischial-Ramal weight-bearing socket, as well as Ischial-Gluteal weight-bearing socket.

Professor Radcliffe continued his biomechanical analysis by saying "The biomechanics of the ischial-ramal weight-bearing socket are similar to the ischial-gluteal weight-bearing quadrilateral socket. The major differences are in the manner in which the ischium is maintained in position within or on the brim of the socket. In each case, there must be vertical support with a combination of lateral and anterior counterpressure to maintain the ischium in position" . . . "Some of the socket shape diagrams I have seen published are so crude and inaccurate as to be almost meaningless. The level of the cross section shown is often not indicated and a section at ischial level is sometimes compared to a section which is obviously higher or lower." Professor Radcliffe then sketched on the blackboard what he believed to be a more accurate comparison with emphasis on the three-dimensional shape both above and below the level of the tuberosity of the ischium. In each case, he showed a cross section of the socket at, (1) ischial level with the medial wall projected upward to this level; and (2) the outline of the highest points on the brim (Figures 14 and 15).

This concluded all presentations of current fitting techniques. The remaining presentations were concerned with evaluation techniques. Bo Klasson of Een-Holmgren Company in Sweden

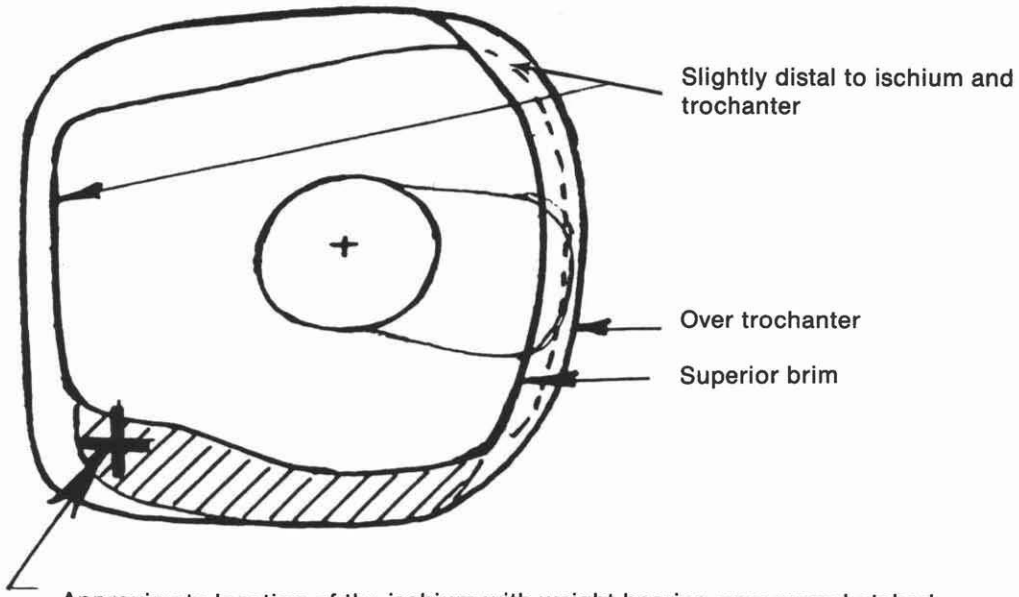


Figure 14. Socket contours for an Ischial-Gluteal weight-bearing socket using the UC Berkeley Brims.[6]

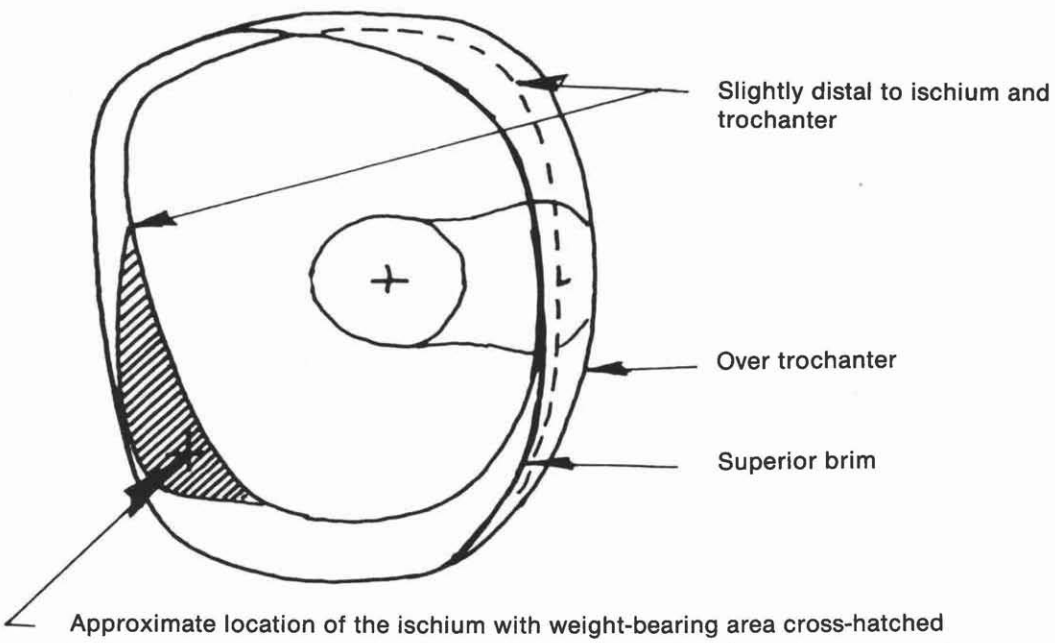


Figure 15. Socket contours for an Ischial-Ramal weight-bearing socket of the NSNA type provided by Ivan Long.[6]

presented on "Socket Fit With Reference to Soft Tissue Force Transmission." Briefly, Mr. Klasson's theory is that we should attempt to design sockets with physical characteristics that match the physical characteristics of the residual limb. In other words, where the tissues of the residual limb are firm, so should the matching area of the socket material be; where the tissues are soft and flexible, so should the socket be. Mr. Klasson refers to this as "surface matching."

The next speaker was Professor George Murdoch of Dundee, Scotland, presenting "A Method for the Description of the Amputation Stump." Professor Murdoch's paper was based on his premise that there is a need for an international classification system for residual limbs to be developed in order to compare one publication with another, one patient with another, one fitting technique with another.

The final presentation was made by A. Bennett Wilson on "Physiological Monitoring Equipment in Evaluation of Lower Limb Prosthetic Components and Techniques." He reported on a system of physiological monitoring originally developed by MacGregor of the University of Strathclyde in the 1970's. Recently modified for use by the University of Virginia Division of Prosthetics and Orthotics, this system consists of a compact tape recording component worn on a waist belt that records electronically, step count, walking velocity, standing versus sitting, and heart rate, plotted against time up to 24 hours. The tapes are then analyzed by a special micro-computer program, which subsequently prints the information in digital and graphic format.

Under some circumstances the heart rate data can be useful in providing an energy index, but probably more importantly, the step count, standing versus sitting, and velocity data provide specific information about the activity of the subject. Mr. Wilson and colleagues have recently developed a solid state device which is less costly and more reliable. The new system has 17 information gathering channels. Mr. Wilson concluded by saying, "At this point, we do not have sufficient experience to know how many subjects have to be monitored and how much data is needed to show significant differences, but it certainly appears that at last we have a breakthrough in instrumentation for evaluation of prosthetic devices and other treatments involving the function of the musculoskeletal system.

With all presentations complete, the plenary group was divided into six panels of six to nine members with the following charges:

1. Determine similarities
2. Determine differences
3. What is the role of flexible walls?
4. Indications and contraindications
5. Recommendations for future action
   a. Evaluation
   b. Education
   c. Application

This first group of panels reported back on Sunday morning. The reports were quite consistent among the different panels. A synopsis of these reports will be presented in concluding this report.

On Monday, new panels were formed to restudy the rationale for and possibly develop protocol for evaluation. The reports from this second group of panels was heard in plenary session on Tuesday morning.

The meeting was adjourned Tuesday, May 19, 1987 at noon.

What follows here is a synopsis of the conclusions and recommendations of the panel reports.

I. Similarities & Differences

A. *Biomechanics*

1. Ischial Containment:
   a. similarities:
      –all ischial containment sockets advocate and utilize varying degrees of ischial containment
   b. differences:
      –quads do not utilize ischial containment
      –ischial containment sockets, amount of ischial containment
2. Weight Bearing Distribution:
   a. similarities:
      –ischial containment sockets, combination of ischial tuberosity and ramus, and peripheral (soft tissue)

b. differences:
–quads, ischial-gluteal weight bearing

3. ML Stability—maintenance of adduction
   a. similarities:
      –goal of all AK socket systems
      –greater success and maintenance in ischial containment sockets due to ischium acting as bony stop or lock
   b. differences:
      –quad, soft tissue lock only, no bony lock
      –less successful maintenance of adduction, thus less ML stability
4. Socket Shape—ischial level cross section
   a. similarities:
      –ischial containment sockets, narrow ML, wider AP, concave post-trochanteric shape
   b. differences
      –quad, wider ML, narrower AP
5. Trimlines:
   a. similarities:
      –ischial containment sockets, generally; especially anterior, posterior, and lateral wall trimlines
   b. differences:
      –quads, especially higher anterior, lower posterior and lateral wall trimlines
      –medial wall of CAT-CAM
6. Suspension:
   a. similarities:
      –all compatible with suction
   b. differences:
      –ischial containment sockets, unclear about auxiliary suspension
7. Alignment:
   a. similarities:
      –all but NSNA utilize alignment devices
      –ischial containment sockets, medial wall not on line of progression
      –NSNA & UCLA CAT-CAM, tilting of knee bolt in bench alignment
      –Shamp Narrow ML & NSNA, use of Long's Line
      –ischial containment sockets, TKA bench alignment, socket midline
   b. differences:
      –NSNA does not use dynamic alignment device
      –quad medial wall on LOP
      –not all tilt knee bolt
      –NSNA, varying degrees of knee bolt tilt, 7°, female, 4°, male
      –quad, bench alignment, more stable TKA, T reference point is located at posterior ⅓ of socket
8. Rotational Control:
   a. similarities:
      –ischial containment sockets, bony lock of Ischium and post-trochanteric concavity
   b. differences:
      –quad, muscular-soft tissue cross-section

B. *Method of Obtaining Cast*
   a. similarities:
      –quad and Shamp Narrow ML utilize a casting brim
      –UCLA CAT-CAM & Sabolich/Guth CAT-CAM, hand molding technique
      –NSNA & UCLA CAT-CAM, standing
   b. differences:
      –CAT-CAM & NSNA, hand molding technique
      –Sabolich/Guth CAT-CAM, sometimes cast lying down

C. *Anatomical Considerations*
   1. UCLA CAT-CAM detail about pelvic differences:
      – ischial inclination
      – pubic arch angle
      – ilio-femoral angle
   2. NSNA male, female alignment differences:
      – bolt tilt

II. Role of Flexible Walls
- not linked to any one philosophy of designing an AK socket
- vital to the success of the Sabolich/Guth CAT-CAM

- improved sitting comfort
- improved proprioception
- better heat dissipation
- improved muscle activity
- reduced weight
- ease of socket change within frame, no loss of alignment
- enhanced suspension, if suction suspension

All participants agreed there is great need for improved flexible materials.

III. Indications and Contraindications

- there were no specific contraindications noted for any socket design
- some advocated not changing successful quad wearers
- quads are most successful on long, firm residual limbs with firm adductor musculature
- ischial containment sockets are more successful than quads on short, fleshy residual limbs
- ischial containment sockets are the better recommendation for high activity/sports participation/running
- lack of agreement on best recommendation for bilateral above-knee

IV. Recommendations

The panels' conclusions and recommendations were remarkably consistent. Most consistent was the recommendation for improved terminology, lumping what I have referred to as ischial containment into a single, workable term. Suggestions ranged from "Narrow ML" to Ischial/Ramus Containment (IRC) and Non-Ischial Containment (Non-IRC). Due to time constraints, arguments about this recommendation were never resolved. It is hoped that all recommendations can be addressed in a future workshop or through some other form of action.

A. *Evaluation*

There was unanimous agreement for formal evaluation of the newer above-knee techniques (NSNA, CAT-CAM, Shamp Narrow ML) as well as evaluation of implications of the inferiority of the quadrilateral technique.

1. A program for scientific/laboratory evaluation should be set up at a center or multiple centers, depending upon resources. This study might include: cinematography, force plate, motion analysis, gait mat and other "gait lab" studies as well as radiographical data on alignment and containment, physiological data, residual limb/socket force analysis, and/or any other relevant laboratory studies.
2. A program of clinical evaluation, based on previous fittings and continuing fittings in clinics already utilizing new fitting techniques. This would be a more subjective study, and would require a greater effort for coordination and pooling of data.
3. Complete manuals should be developed for each individual technique, unless the developers can find it mutually agreeable to work together and blend the new techniques. The panels found the latter option to be most desirable.
4. Evaluation should be independent of the developers.
5. Any evaluation needs to be coordinated by an authoritative group. ISPO and/or the U.S. Veterans Administration were recommended. The American Academy of Orthotists and Prosthetists should also be involved.
6. Possible funding sources within the states include the Veterans Administration and the National Institute on Disability and Rehabilitation Research (NIDRR).

B. *Education*

The post-graduate, specialized courses for experienced practitioners appear to be most appropriate for teaching these newer techniques at this time. Incorporation into entry level education programs should follow as well written, experience based manuals are developed. Any teaching course should include "hands-on", patient contact, fitting, and management as part of the curriculum.

C. *Application*

The application of these new techniques, while certainly not as widespread and accepted as the quadrilat-

eral technique, or even the flexible socket technique, is occurring at this time. Growing acceptance and application will most certainly follow. It is hoped that this workshop, as well as future workshops, will aid in safe and proper application of these and future advances and developments in prosthetics.

References

[1] UCLA AK Teaching Manual, 1977–1978.

[2] *UCLA CAT-CAM Above Knee Prosthesis,* Teaching Manual, Third Edition, March 1987.

[3] *Fabricating The Long's Line Above-Knee Prosthesis,* by Ivan long, 1981.

[4] Ivan Long's business card.

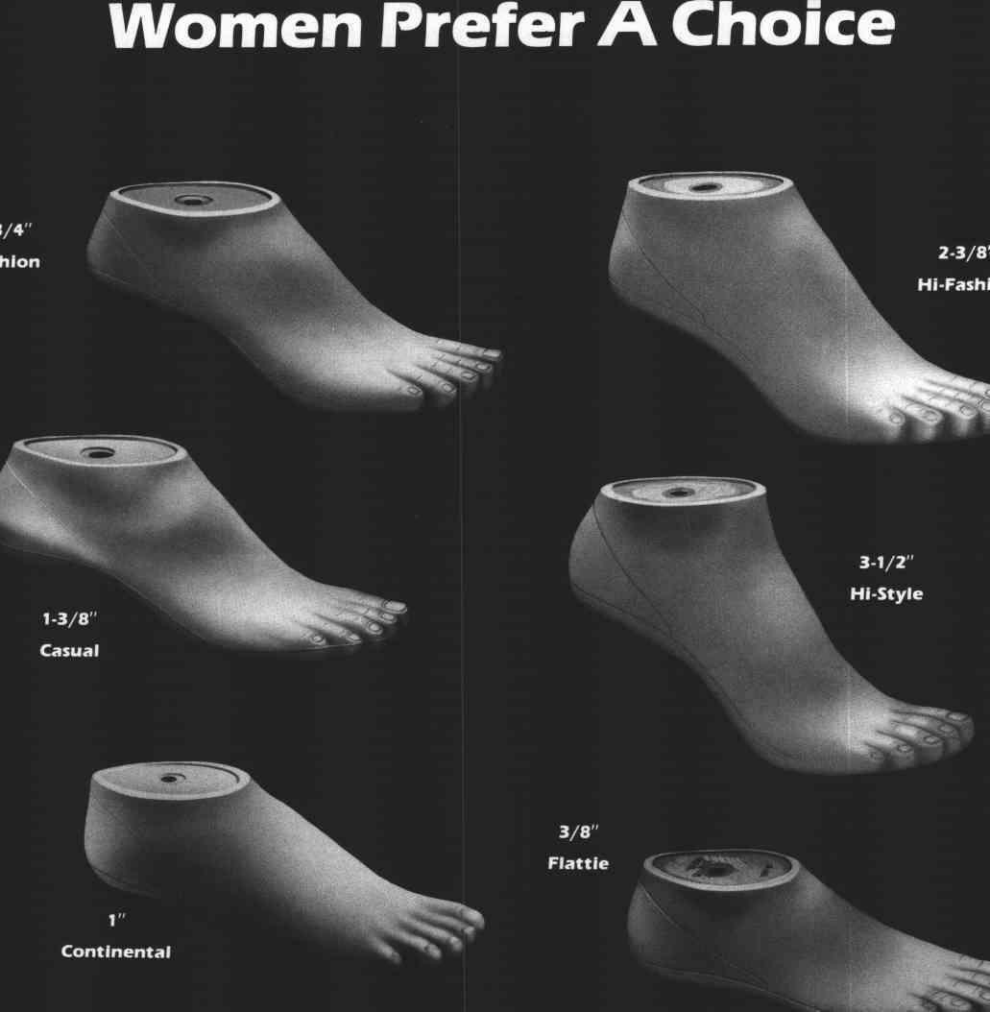
[5] *Manual for use of THE SHAMP BRIM for the Narrow ML Above-Knee Prosthetic Socket,* The Ohio Willowwood Co., 1987.

[6] By Charles Radcliffe. Re-drawn by A. Bennett Wilson, Jr.

Author

C. Michael Schuch, C.P.O., is Assistant Professor of Orthopaedics and Rehabilitation and Associate Director of the Department of Prosthetics and Orthotics at the University of Virginia Medical Center, Box 467, Charlottesville, Virginia 22908.

Women Prefer A Choice



Calendar

Please notify the National Office immediately concerning all meeting dates. It is important to submit meeting notices as early as possible. In the case of Regional Meetings, check with the National Office prior to confirming date to avoid conflicts in scheduling.

1988

April 20–22, Hosmer Electric Systems Workshop, VoTech Institute 916, Minneapolis, Minnesota. Contact: Catherine Wooten, Hosmer Dorrance Corporation, 561 Division Street, Campbell, California 95008; (408) 379-5151 or (800) 538-7748.

April 11–12, AOPA Cost Accounting Seminar, San Francisco Airport Hilton, San Francisco, California. For more information, contact: Bill Fancher, (703) 836-7116.

April 13, 14, 15, "Anatomical Design Socket and Advanced Prosthetic Techniques," Certificate CEC Course. Flexible AK/BK & Narrow ML (CAT-CAM/NSNA equivalent). Contact: DAW Industries, 5360 A Eastgate Mall, San Diego, California 92121; 800-824-7192.

April 27, 28, 29, "Anatomical Design Socket and Advanced Prosthetic Techniques," Certificate CEC Course. Flexible AK/BK & Narrow ML (CAT-CAM/NSNA equivalent). Contact: DAW Industries, 5360 A Eastgate Mall, San Diego, California 92121; 800-824-7192.

May 2–3, AOPA Cost Accounting Seminar, Airport Marriott Hotel, Kansas City, Missouri. For more information, contact: Bill Fancer, (703) 836-7116.

May 4, 5, 6, AFI-ENDOLITE Prosthetic Certificate Course, "Endolite High Technology Prosthesis," Miami Lakes Inn & Country Club, Miami, Florida. Contact: Karen Hewitt, Registrar, AFI-ENDOLITE, 2480 West 82 Street, Hialeah, Florida 33016; (305) 823-8300.

May 4, 5, 6, "Anatomical Design Socket and Advanced Prosthetics Techniques," Certificate CEC Course. Flexible AK/BK & Narrow ML (CAT-CAM/NSNA equivalent). Contact: DAW Industries, 5360 A Eastgate Mall, San Diego, California 92121; 800-824-7192.

May 6–7, 6th Annual Prosthetics-Orthotics Course, Clarion Hotel, Sacramento, California. Sponsored by the Office of Continuing Medical Education, School of Medicine, University of California, Davis. For more information, contact: Office of Continuing Medical Education, UC Davis, School of Medicine, 2701 Stockton Blvd., Sacramento, California 95817; (916) 453-5390.

May 13–14, Academy Continuing Education Conference 2-88 and New York State Chapter Combined Meeting, "Current Clinical and Technical Concepts in Lower Limb Prosthetics," Albany Marriott Hotel, Albany, New York. Contact: Academy National Headquarters, (703) 836-7118.

May 13–14, Charleston Bending Brace Seminar, Park Suite Hotel. Contact: Melissa Wetherell, P.O. Box 1070, Apopka, Florida 32704-1070; (800) 327-0073.

May 13–15, AOPA Region IX, COPA, and the California Chapters of the Academy Combined Annual Meeting, Mission Hills Resort, Rancho Mirage, California. Contact: Lynn F. Crotto, (415) 621-4244.

May 16–20, "Fitting Procedures for Utah Artificial Arm and Hand System," 916 VoTech, White Bear Lake, Minnesota. Contact: Harold Sears, Ph.D., 95 South Eliot, #105, Chapel Hill, North Carolina 27514; (919) 968-8492, or 1-800-621-3347.

May 18, "Graph-Lite Orthotics," Daw Industries Advanced Continuing Education Seminar, Certificate CEC course. Contact: Daw Industries, 5360 A Eastgate Mall, San Diego, CA 92121; 1-800-824-7192.

May 18, 19, 20, AFI-ENDOLITE Prosthetic Certificate Course, "Endolite High Technology Prosthesis," Miami Lakes Inn & Country Club, Miami, Florida. Contact: Karen Hewitt, Registrar, AFI-ENDOLITE, 2480 West 82 Street, Hialeah, Florida 33016; (305) 823-8300.

May 19, 20, 21, "Anatomical Design Socket and Advanced Prosthetics Techniques," Certificate CEC Course. Flexible AK/BK & Narrow ML (CAT-CAM/NSNA equivalent). Contact: DAW Industries, 5360 A Eastgate Mall, San Diego, California 92121; 800-824-7192.

May 19, 20, 21, "Anatomical Design Socket and Advanced Prosthetic Techniques," Certificate CEC course. Flexible AK/BK & Narrow ML (CAT-CAM/NSNA equivalent). Contact: Daw Industries, 5360 A Eastgate Mall, San Diego, CA 92121; 1-800-824-7192.

May 20–21 Freeman Orthotic Fitters Training Workshop, Daytona Beach, Florida. For more information, write: Freeman, Drawer J. Sturgis, Michigan, or call Cameron Brown, 800-253-2091.

May 23–24, AOPA Cost Accounting Seminar, Logan Airport Hotel, Boston, Massachusetts. For more information, contact: Bill Fancher, (703) 836-7116.

May 24–26, HIBCC '88: The Health Industry Electronic Communications Conference, Hyatt Regency Chicago, 151 East Wacker Drive, Chicago, Illinois 60611. Contact: Health Industry Business Communications Council, 70 West Hubbard, Suite 202, Chicago, Illinois 60610; (312) 644-2623.

June 1, 2, 3, AFI-ENDOLITE Prosthetic Certificate Course, "Endolite High Technology Prosthesis," Miami Lakes Inn & Country Club, Miami, Florida. Contact: Karen Hewitt, Registrar, AFI-ENDOLITE, 2480 West 82 Street, Hialeah, Florida 33016; (305) 823-8300.

June 8–11, AOPA Regions II and III Combined Annual Meeting, Trump Plaza Hotel and Casino on the Boardwalk, Atlantic City, New Jersey.

June 12–17, "Matchmaker" Trade Delegation to Belgium and the Netherlands. Sponsored by the Commerce Department and co-sponsored by the Small Business Administration. For more information, contact: Denis Csizmadia, Project Manager, US&FCS, Room 2118, Washington, DC 20230; (202) 377-8433/34.

June 14–18, AOPA Regions VII, VIII, X, and XI Combined Annual Meeting, Westin Hotel, Seattle, Washington. Contact: Steve Colwell, (206) 526-7944.

June 15, 16, 17, AFI-ENDOLITE Prosthetic Certificate Course, "Endolite High Technology Prosthesis," Miami Lakes Inn & Country Club, Miami, Florida. Contact: Karen Hewitt, Registrar, AFI-ENDOLITE, 2480 West 82 Street, Hialeah, Florida 33016; (305) 823-8300.

June 22–25, Convention of the Canadian Association of Prosthetists and Orthotists (CAPO), Queen Elizabeth Hotel, Montreal, Quebec, Canada. Contact: C.A.P.O. Convention '88, 5713 Cote des Neiges, Montreal, Quebec H3S 1Y7, Canada; (514) 731-3378.

June 23–27, AOPA Regions V and VI and the Academy Midwest Chapter Joint Education Seminar, Pheasant Run, St. Charles, Illinois. Contact: Cathy Ensweiler, CO, (219) 836-2251.

June 25–30, International Conference of the Association for the Advancement of Rehabilitation Technology, Palais des Congres, Montreal, Quebec, Canada. Contact: International Conference, 3631 Rue St. Denis, Montreal, Quebec H2X 3L6, Canada; (514) 849-9847.

July 13, 14, 15, AFI-ENDOLITE Prosthetic Certificate Course, "Endolite High Technology Prosthesis," Miami Lakes Inn & Country Club, Miami, Florida. Contact: Karen Hewitt, Registrar, AFI-ENDOLITE, 2480 West 82 Street, Hialeah, Florida 33016; (305) 823-8300.

July 15–16, Academy Continuing Education Conference 3–88, "Clinical Practice Management—Ethical and Legal Considerations," Vanderbilt Plaza Hotel, Nashville, Tennessee. Contact: Academy National Headquarters, (703) 836-7118.

July 16–17, ABC Board of Director's Meeting, Washington, D.C. Contact: ABC National Office, (703) 836-7114.

The following statement of Ownership, Management, and Circulation is required by USPS reg. 39 U.S.C. 3685:

September 30, 1987

Clinical Prosthetics and Orthotics (publication no. 07350090) is published quarterly by the American Academy of Orthotists and Prosthetists, 717 Pendleton Street, Alexandria, Virginia 22314, for annual subscription rates of $25 domestic, $30 foreign surface, and $40 foreign airmail. The complete mailing address of the headquarters of the publisher is the American Academy of Orthotists and Prosthetists, 717 Pendleton Street, Alexandria, Virginia 22314. The publisher is the American Academy of Orthotists and Prosthetists at the address above. The editor is Charles H. Pritham, C.P.O., % Durr- Fillauer Medical, Inc., 2710 Amnicola Highway, Chattanooga, Tennessee 37406. The managing editor is Sharada Gilkey, % American Academy of Orthotists and Prosthetists, 717 Pendleton Street, Alexandria, Virginia 22314. The full name and address of the owner is the American Academy of Orthotists and Prosthetists, 717 Pendleton Street, Alexandria, Virginia 22314.

For the issues published in the last 12 months, an average of 3,416 copies of *Clinical Prosthetics and Orthotics* were published. Of these, 3,115 were distributed through mail subscription—for a total paid and/or requested circulation of 3,115. And 291 were disseminated as promotional or otherwise free samples, to equal a total average of 3,406 copies of each issue distributed. An average of 10 copies per issue were used as office copies or otherwise not distributed. For the issue nearest the filing date, 3,382 copies were printed. A total of 3,080 were sent through the mail. There were 285 distributed free as promotional copies and for other uses, for a total distribution of 3,365. There were 17 office copies, spoiled copies, or otherwise unaccounted copies.

I certify that the statements made by me above are correct and complete.

Sharada Gilkey
Managing Editor

TRADITION

A HISTORY OF SERVICE

THE KNIT-RITE Company

KNIT-RITE STUMP SOCK

MEMBER O.A.L.M.A.

History

In **1906** Willaim Edgar Isle became manager of the Kansas City branch of the J.F. Rowley Company, which became the W.E. Isle Company in **1920**.

In **1923**, with the purchase of the first knitting machine, Knit-Rite came into being. By the **1930s**, departments had been established to manufacture prosthetic and orthotic components. In **1938**, a 24-page catalog, offering a wide variety of supplies, was published. Through the **1950s** and **'60s**, Knit-Rite developed as a major broad-line distributor. Through the **1970s**, textile production was automated, expanded and diversified and distribution continued to expand. The **1980s** have brought even more rapid changes in technology to our field and our way of doing business.

THE KNIT-RITE Company
PHONE BA 1-0206
1121 GRAND AVENUE • KANSAS CITY 6, MO.
KNIT-RITE STUMP SOCK

KNIT-RITE

We continue today, following the principles established by our founder. That is to do the best we can for the orthotically and prosthetically disabled; to operate efficiently, but not sacrifice or compromise our level of service or quality; to provide products and services to others which we would want to receive.

Specialists in Orthotic-Prosthetic Textile Technology

Knit-Rite can meet almost any Orthotic/Prosthetic sock requirement. Our expertise has been built through years of experience working with a wide variety of materials & weights, production techniques, and problem solving. By staying abreast of technology we are able to provide the best textile interface components available. When it comes to special fabrics and special construction for special needs we know a lot and through research will learn more.

KNIT-RITE®

Distributor/Supplier

Knit-Rite is a broad-line distributor of items of its own and other manufacture to the Orthotic/Prosthetic profession. More than 13,000 products and nearly 2,500,000 units are carried in stock and represented in our 500 plus page product/reference catalog. We continually review our line and examine new products in order to offer the most technologically advanced products available to the O&P field.

KNIT-RITE®

Call Us Toll Free Today—You'll Be Glad You Did

Missouri 800-892-7180 ***USA 800-821-3094*** ***Canada 800-626-6069***

TRADITION & TECHNOLOGY — REQUEST THE BEST

KNIT-RITE™ INC.

2020 GRAND AVENUE • P.O. BOX 410208 • KANSAS CITY, MISSOURI 64141-0208
(816) 221-5200 • TWX#9107710513 • CABLE CODE: KNIT-RITE • FAX (816) 221-2896

The American Academy of Orthotists and Prosthetists

American Academy of Orthotists and Prosthetists
717 Pendleton Street
Alexandria, Virginia 22314