

## EXPERIENCE WITH PLASTIC PATELLAR-TENDON-BEARING ORTHOSES

James T. Demopoulos, M.D.,<sup>1</sup> and  
John E. Eschen, C.P.O.<sup>2</sup>

The management of patients with lower-limb deficiencies that produce gait abnormalities has undergone considerable evolution during the last decade. Current concepts in lower-limb orthotics include the development and use of plastics, creation of a new functional nomenclature, introduction of the multidisciplinary approach proven so valid in prosthetics, and the use of instrumentation and data systems to monitor results.

The application of the above concepts to the field of "lower-limb bracing" is a rather recent development, demonstrating new trends as reviewed by Lehman and his colleagues (8, 9). Other investigators, including Corcoran (1), Jebesen (5), Simons (15), Lehneis (10, 11), and Sarno (14), have utilized plastic materials and technol-

ogy in prescribing lower-limb orthoses. Additionally, the authors have prescribed and fabricated over 200 lower-limb plastic orthoses for a wide range of musculoskeletal defects found in adults and children (2, 3, 4).

The principle of using the patellar-tendon and condylar areas of the tibia for weight-bearing in the below-knee amputee was successfully transferred to the discipline of orthotics by McIlmurray and Greenbaum (6, 7, 12, 13, 16), resulting in the development of the VACP patellar-tendon-bearing "brace." The early design combined a pretibial plastic shell and conventional metal uprights to "unload" the tibia and the foot-ankle complex. In an effort to achieve reduction of weight, to improve cosmesis and comfort, and to provide more physiological motion, the authors have developed an all-plastic patellar-tendon-bearing orthosis.

This paper relates our experience with the plastic patellar-tendon-bearing orthosis and describes the details of fabrication.

<sup>1</sup>Director, Rehabilitation Medicine, Hospital for Joint Diseases and Medical Center, 1919 Madison Ave., New York, N.Y. 10035.

<sup>2</sup>Eschen Prosthetic and Orthotic Laboratories Inc., 156-158 East 116th St., New York, N.Y. 10029.

TABLE 1. DIAGNOSIS AND AGE OF REVIEWED POPULATION

Patient	Age (Yrs)	Diagnosis
F.G.	9	Congenital intra-articular denervation of knees and ankles
A.S.	58	Charcot's arthropathy of ankles
H.S.	61	Spontaneous subluxation, ankle
M.R.	48	Severe burns of hindfoot
A.M.	39	Primary tumor of tibia
G.R.	27	Failed arthrodesis of ankle
L.H.	54	Delayed union of distal tibia fracture
M.M.	7	Osteogenesis imperfecta, tibia
L.P.	68	Neurofibromatosis, fracture of tibia
G.D.	59	Severe osteoarthritis of ankle

### CLINICAL MATERIAL

The patient-study population consisted of ten patients who were evaluated and provided with plastic patellar-tendon-bearing orthoses.

Our initial experience dates to July 1972 and our follow-up extends over an 18-month period.

Chronologically, our youngest patient was 7 years old; the oldest, 72. The study group included three females and seven males. The diagnoses of the population are listed in Table 1.

### METHOD

Eight of the ten patients who received a plastic patellar-tendon-bearing orthosis were referred to us by the staff of the Department of Orthopaedics, and therefore had the benefit of complete orthopaedic evaluations, including radiographic determinations, prior to prescription.

The members of the Orthotic Clinic Team of the Department of Rehabilitation Medicine, including the physicians and allied health professionals, measured and recorded data relating to muscle strength, joint motion, presence of contractures, gait, elevation ability, spasticity, sensation, joint stability, and the degree of edema if present. The unit's orthotist provided the technical expertise needed to formulate the final prescription. As required, pre-orthotic and post-orthotic physical therapy was prescribed. In addition, the patients' psychosocial and vocational characteristics were measured.

The completed orthosis was delivered and both patient and device were subjected to a final analysis, with attention focused on relief of pain, comfort, fit, appearance, alignment, degree of deformity correction, and total overall functional improvement. Both static and loading conditions were used in our determinations. Finally, serial reexaminations were conducted over a period of months, our longest follow-up being 18 months.

### RESULTS

Our experience with the plastic patellar-tendon-bearing orthosis in ten patients indicates that many musculoskeletal defects of the lower limb can be managed with this device, offering many advantages over conventional designs. The advantages are:

- Superior cosmesis
- Lighter weight
- Improved comfort
- Superior alignment
- Improved biomechanics
- Favorable strength-weight ratio
- Ease and constancy of application
- Minimal maintenance

However, not all advantageous features were present in each case. Disadvantages included the considerably higher cost of the plastic orthosis. Problems were encountered with growing children who required frequent replacement. It was most important to observe carefully those patients with vascular and sensory problems since

the plastic orthosis is applied snugly. Edema of the foot-ankle area had to be carefully controlled also.

The various disabilities that are amenable to orthotics management utilizing the plastic patellar-tendon-bearing orthosis are listed below:

- Congenital denervation of ankle joint
- Acquired denervation of ankle joint
- Delayed or nonunion of fractured tibia
- Imminent fracture of tibia, secondary to tumor, bone atrophy and development defects
- Degenerative disease of ankle joint
- Inflammatory disease of ankle joint
- Trauma of foot-ankle joint
- Failed foot-ankle surgery
- Infectious disease of foot
- Disease of trauma of sole of foot



Fig. 1. Conventional ischial weight-bearing orthosis is heavy and bulky.

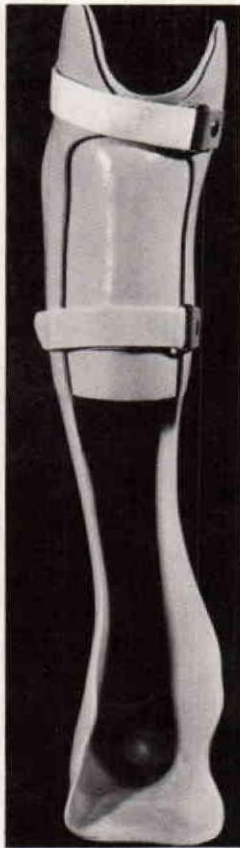


Fig. 2. Front view of the plastic patellar-tendon-bearing orthosis.

The alternative orthosis required for most of the disabilities listed would be a heavy, bulky, ischial weight-bearing orthosis (Fig. 1).

The lighter, more cosmetic, plastic patellar-tendon-bearing orthosis is shown in Figures 2 and 3. The orthosis is donned properly with ease; the separate patellar-tendon-bearing panel is inserted when the knee is flexed at 90 deg. The orthotic foot-ankle section is molded so that it is highly congruous with the patient's foot and ankle; and the position of the patient's ankle can be fixed in the desired attitude. A special shoe heel is used (comparable to a prosthetic SACH heel), together with a rocker assembly when "unloading" of the posterior aspect of the foot is desirable. In other instances, an ordinary shoe suffices.

A number of case discussions will illustrate the criteria used in prescribing the patellar-tendon-bearing orthosis; fabrication details appear at the end of the paper.

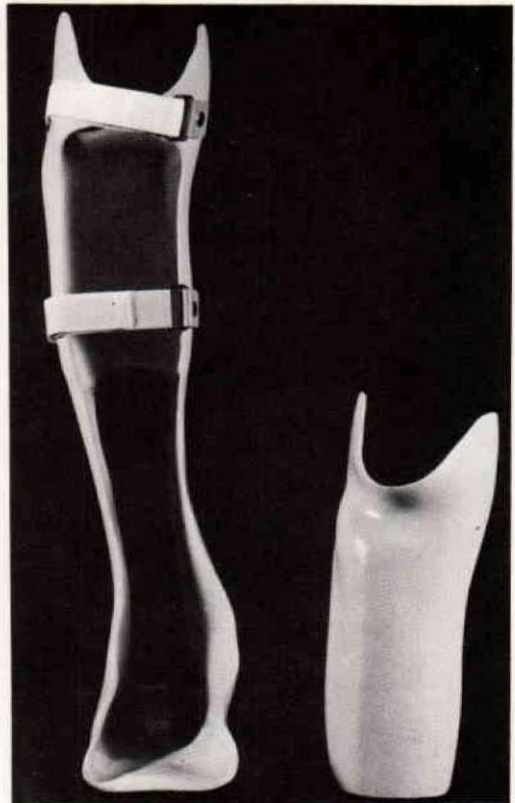


Fig. 3. The removable PTB section is easily donned.

### CASE PRESENTATIONS

Case No. 1. F.G. is a 9-year-old boy with congenital absence of intra-articular innervation of his knees and ankles (Fig. 4). Functionally, the left knee and right ankle created considerable difficulties in ambulation and elevation activities. In our initial experience with patellar-tendon-bearing orthoses, we adhered to the original concept of using plastic materials for patellar and

tibial condylar weight support and conventional metal uprights attached to a molded leather-covered footplate; the uprights were extensible and the ankle-joint position was adjustable (Fig. 5). A plastic quadrilateral socket, attached to conventional uprights, was used to reduce weight-bearing forces at the left knee and ankle (Fig. 6). Clearly, the right patellar-tendon-



Fig. 4. Congenital absence of intra-articular innervation produced severe deformities of left knee and right ankle. Case No. 1.

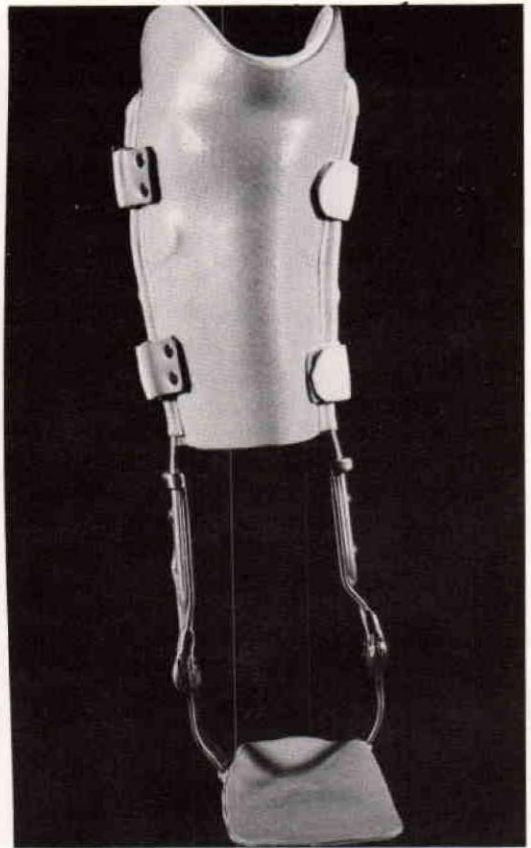


Fig. 5. The early design combined plastic and metal components.

bearing orthosis was more acceptable to the patient. As we evolved the all-plastic PTB orthosis, we substituted this device for the original orthosis. A 65 percent weight reduction was accomplished, with more efficient alignment of the foot and ankle, with resultant reduction of the abnormally high intra-articular forces at the ankle.

Case No. 2. L.H. is a 54-year-old woman with severe deformity of the tibia following malunion of pathological fractures. Figure 7 illustrates the original PTB orthosis; the newer plastic PTB orthosis prevented recurrence of fractures for an 11-month period, until the patient succumbed to metastatic disease.



Fig. 6. An "early" PTB orthosis is used to reduce trauma to the right ankle. Case No. 1.

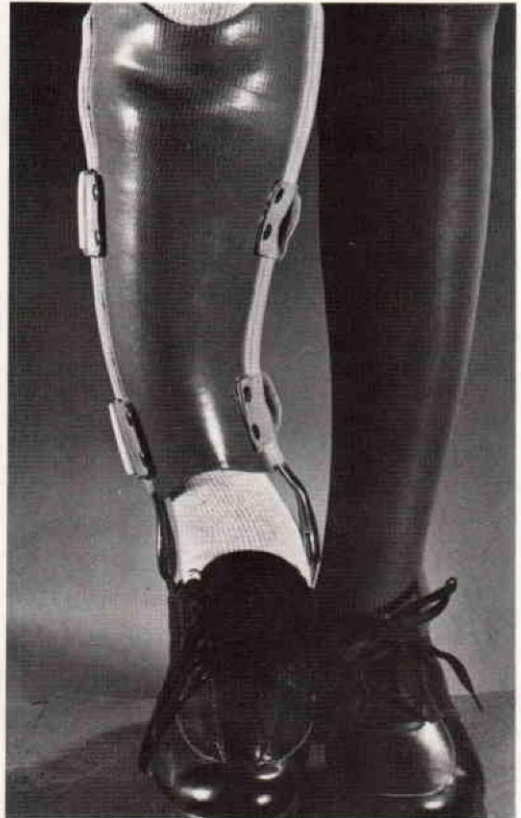


Fig. 7. Use of a PTB orthosis prevented recurrence of pathological fractures of the tibia. Case No. 2.

Case No. 3. A.S., a 58-year-old mechanical engineer, was admitted to our hospital with a history over several years of progressive Charcot's arthropathy of both ankles. The right foot required a below-knee amputation secondary to intractable osteomyelitis. In an effort to prevent a similar process in the aneural left ankle,

we prescribed a plastic patellar-tendon-bearing orthosis. The patient was able to return to work as an engineer, with a below-knee prosthesis and a PTB orthosis (Fig 8). Figures 9 and 10 are, respectively, front and lateral views of the patient wearing the PTB orthosis. Note the removable panel in Figure 10.



Fig. 8. The patient's functional level was significantly improved with provision of a PTB orthosis. Case No. 3.



Fig. 9. The PTB orthosis reduced ankle intra-articular forces and provided mediolateral knee stability. Case No. 3.



Fig. 10. The PTB panel is inserted with the knee flexed to 90 deg. Case No. 3.

Case No. 4. H.S., a 61-year-old individual employed as a truck driver, sustained a chronic subluxation of his subtalar joint with increasing pain and inability to walk more than a few steps. The abnormalities are shown on the radiograph in Figure 11. A plastic patellar-tendon-bearing orthosis prevented further malalignment, reduced the pain considerably, and permitted resumption of relatively unlimited ambulation.



Fig. 11. Subtalar subluxation produced considerable pain and limited ambulation. Case No. 4.

Case No. 5. M.R., a 48-year-old woman, sustained severe burns of the plantar surface of her foot, with multiple grafting that repeatedly failed because of inadequate orthotic management. Figure 12 depicts the pathology, while Figure 13 demonstrates use of the plastic PTB orthosis.

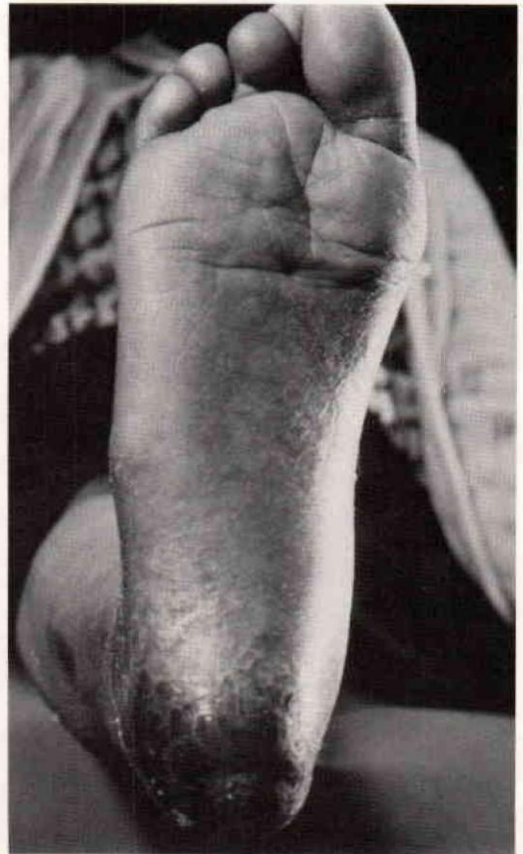


Fig. 12. Multiple grafting of the plantar surface was required prior to prescription of a PTB orthosis. Case No. 5.

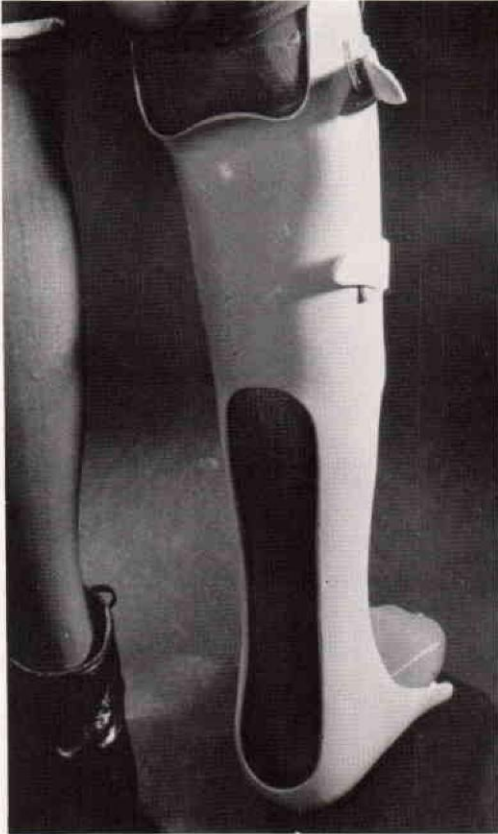


Fig. 13. The plastic PTB orthosis effectively eliminated contact between the orthosis-shoe unit and the ground. Case No. 5.

### FABRICATION DETAILS

#### MATERIALS AND EQUIPMENT NEEDED FOR CASTING

- Two rolls of elastic plaster bandages
- Cotton stockinette 3 in. wide, to place over knee down to and including the foot
- Indelible pencil
- Water in basin 6 in. deep
- Surgical tubing or webbing strip
- Cast cutter
- Bandage shears
- Yardstick
- Tape measure
- Ritz stick
- Measurement chart
- Casting lasts for matching heel height of shoe to orthosis

### CASTING

The cast is taken in two sections. The first section includes the foot-ankle to the mid-calf areas. The second section includes the mid-calf area to a point above the femoral condyles.

#### *First Section (Fig. 14)*

1. Patient is seated on a plinth or chair with the foot held in 5 deg. of dorsiflexion on the properly selected last.
2. Stockinette, sewn at the toes, is placed on the leg and brought above the knee.
3. The leg is brought into 5 deg. of dorsiflexion relative to the floor.
4. With the indelible pencil the patella is located and its borders marked; tibial tubercle, crest of tibia, head of fibula, lateral flare of tibia, medial condyle flare, both medial and lateral malleoli, first and fifth metatarsal heads, and any

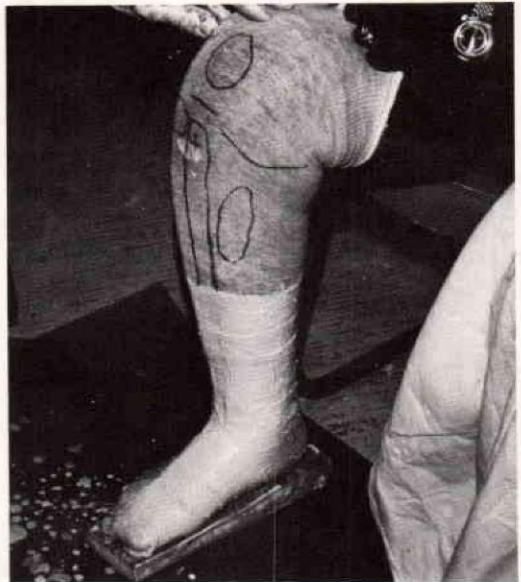


Fig. 14. The major bony landmarks are outlined on the cotton stockinette; elastic plaster-of-Paris bandage is used to wrap the foot while it is positioned on a last.



other pertinent bony prominences. The midpoint of the patellar tendon is also marked (Fig. 14).

5. A strip of surgical tubing is placed along the medial side of the knee and down the anterior midline of the leg, extending to the toes, to permit removal of the cast later (Fig. 15).

6. Elevate the foot and wrap with elastic plaster bandage going to the mid-calf level.

7. Replace the foot on the last and hold in the correct position until plaster has hardened (Fig. 14).

#### *Second Section*

1. After the foot-ankle cast has hardened sufficiently, extend the knee to 30 deg. of flexion.

2. Wrap from the mid-calf area to a point above the femoral condyles with the second plaster-of-Paris bandage.

3. Locate the patellar tendon and popliteal fossa, and compress as is done regularly for any PTB casting procedure.

4. After the plaster has hardened, several horizontal orientation lines are placed along the outline of the surgical tubing. Removal of the cast is now accomplished by cutting down the outline of the surgical tubing with a cast cutter (Fig. 15). The hash lines are used to reestablish the cast, which is then filled with plaster of Paris (Fig. 15). The plaster bandage is stripped off in the conventional manner.

#### MEASUREMENTS

The measurements required are:

- Calf circumference
- Ankle circumference
- Femoral condyles width
- Malleoli width
- Height from floor to mid-patellar-tendon level
- Anteroposterior width of knee at mid-patellar-tendon level



Fig. 15. The negative wrap has been removed. Note the patellar-tendon indentions and cast reference lines.

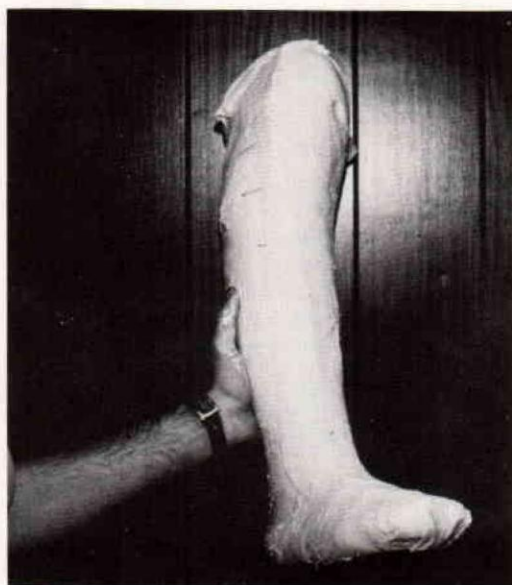


Fig. 16. The completed negative wrap is ready for filling with plaster of Paris.

### CAST MODIFICATION

1. The proximal section of the cast is modified in the same manner recommended for the conventional PTB down to the mid-leg level (Figs. 17, 18, and 19).

2. Extra relief is given to the medial and lateral malleoli and any other prominences as appropriate.

3. A metatarsal arch is cut into the sole of the

foot—located  $\frac{1}{2}$  in. behind the apices of the metatarsals, the high point being under the second metatarsal and extending into a triangular shape under the shaft of the metatarsals (Fig. 20).

4. The longitudinal arch is defined further (Fig. 21).

5. The cast is then smoothed and prepared for lamination in the conventional manner (Fig. 22).

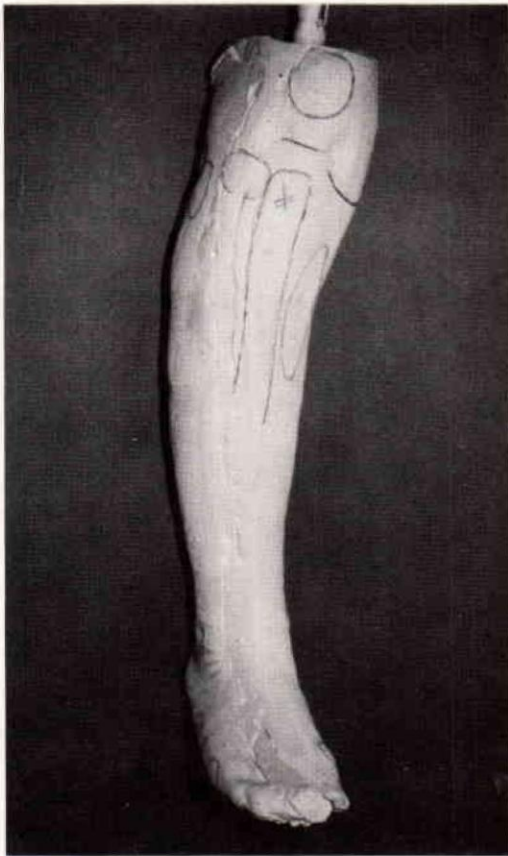


Fig. 17. The negative wrap has been stripped away, and reference lines outlining bony prominences have been reinforced on the crude positive model.

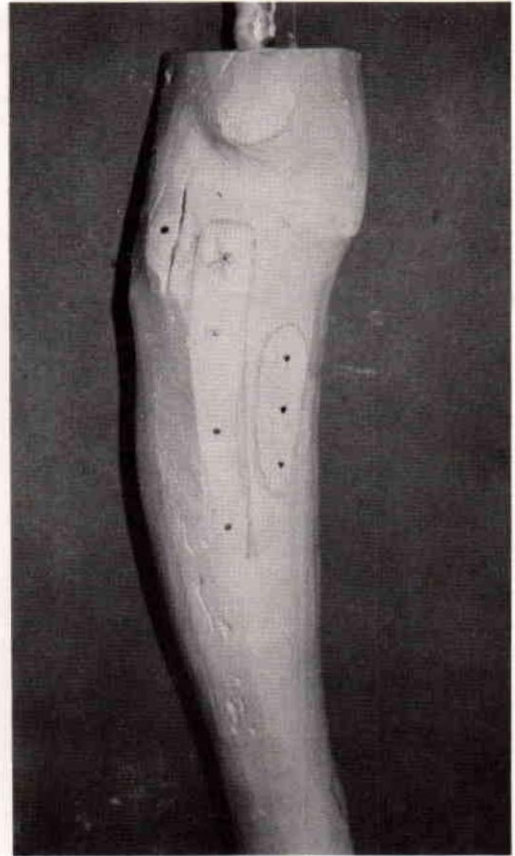


Fig. 18. Plaster has been removed in the area of the patellar tendon, under the medial condyle, and along the proximal part of the tibia and fibula.

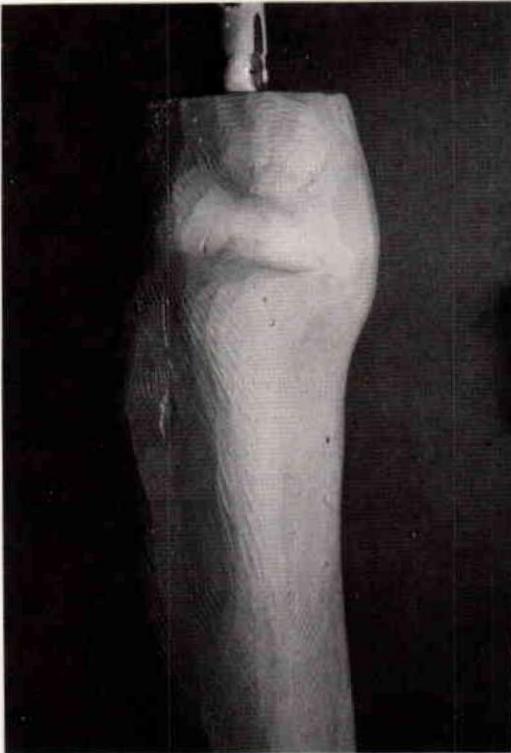


Fig. 19. Plaster of Paris has been added over the head of the fibula, lateral tibial condyle, proximal tibial shaft, and the tibial tubercle. Posteriorly, the popliteal area is built up and flared for the hamstring tendons.

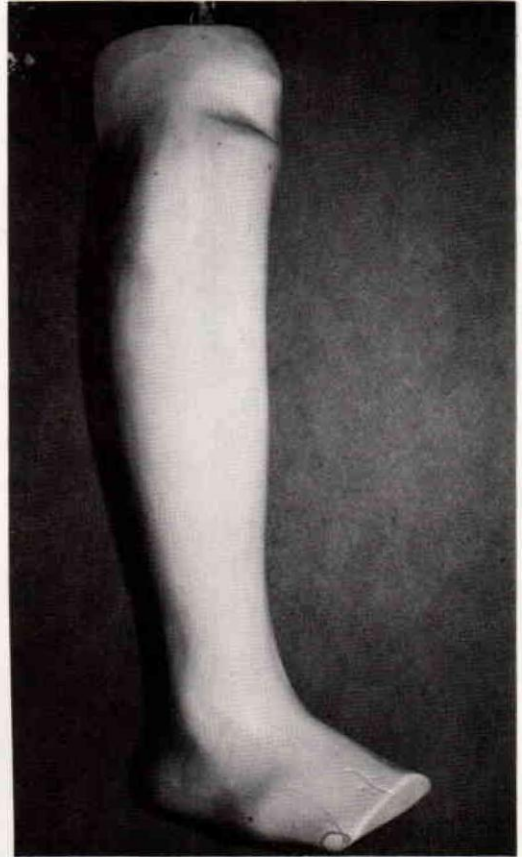


Fig. 20. Finished plantar surface of positive mold; note formation of metatarsal and longitudinal arches and relief for base of fifth metatarsal.

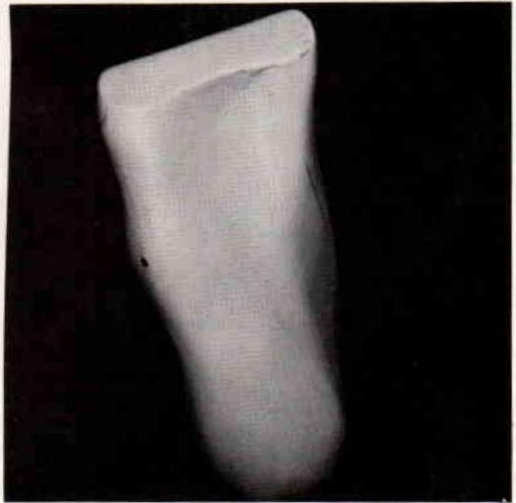


Fig. 21. The finished positive mold is ready for the first lamination process; note relief for malleoli.

## PLASTIC LAMINATION

The lamination process is carried out in two steps.

*Anterior-Proximal Section* (Figs. 22, 23, and 24).

1. A layer of PVA foil is placed over the modified cast.
2. Four layers of Perlon stockinette are applied to the distal section.
3. Four layers of fiberglass stockinette are applied.
4. One layer of reinforced fiberglass matting is added.

5. Four additional layers of Perlon stockinette are applied.

6. The second PVA bag is then applied.

7. A mixture of 80% Laminar Harz<sup>3</sup> and 20% Degaplast<sup>3</sup> with 4% color and 3% catalyst is laminated under suction (Fig. 25). A batch of 300g is usually a sufficient quantity.

8. The lamination is removed taking care not to damage the anterior section of the cast.

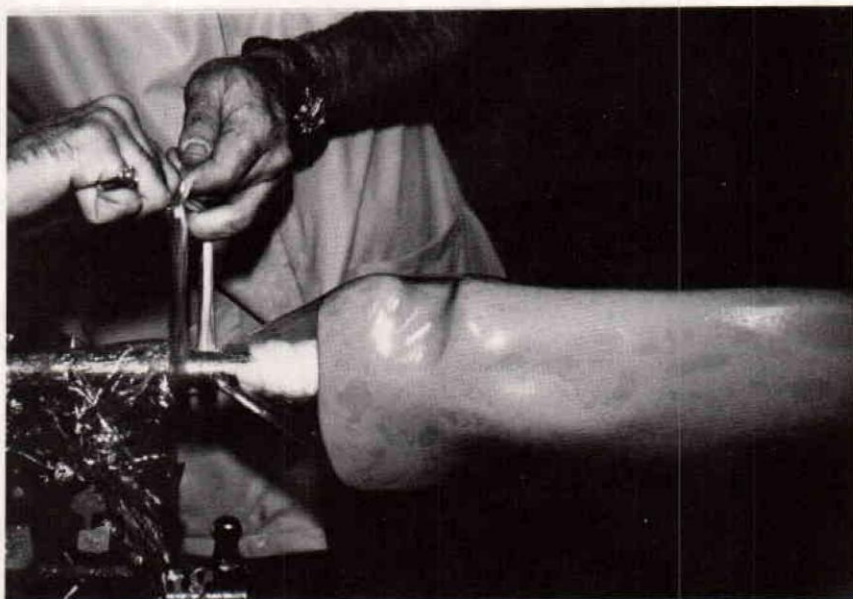


Fig. 22. The completed positive mold has been lacquered and sprayed with silicone; the first PVA foil has been applied and the pipe cast drilled for the suction attachment.

<sup>3</sup>Otto Bock Industries, Duderstadt, West Germany

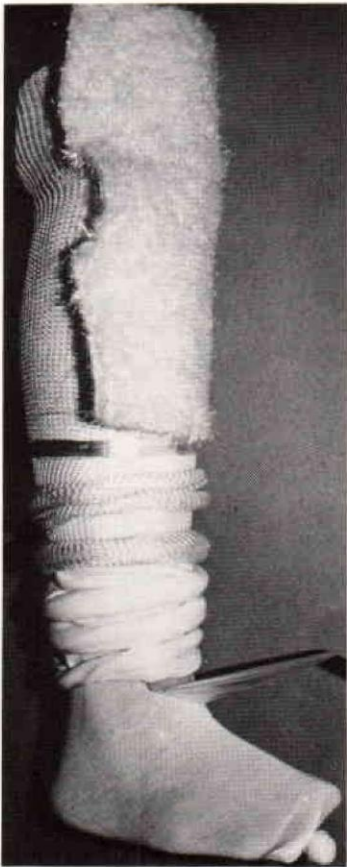


Fig. 23. The positive mold has been wrapped with 4 layers of Perlon and 3 layers of fiberglass stockinette; a single layer of fiberglass stockinette has been applied to the anterior mold surface.



Fig. 24. The prepared positive mold, covered by a second PVA foil, is ready for lamination.

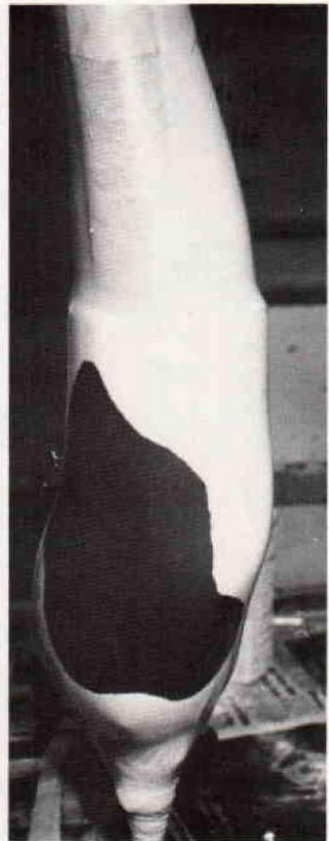
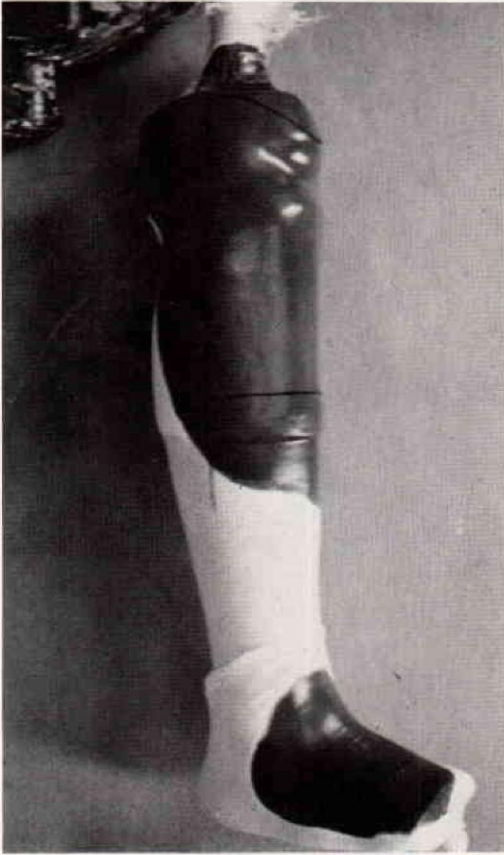


Fig. 25. Laminar Harz (dark area) is flowing through a PVC tube, impregnating the stockinette and fiberglass areas of the proximal knee section.



9. The anterior section is marked and trimmed (Fig. 26) according to the following criteria:

- a. mid patella anteriorly;
- b. going proximally at least 2-2½ in. above the mid-patellar tendon medially and laterally;
- c. at mid A-P of the leg, two vertical lines are dropped and the lamination trimmed to this line;
- d. the distal edge is a horizontal line anywhere between the proximal third to proximal half of the leg.

10. The anterior section is reapplied to the cast after all edges have been smoothed.

#### *Shank Section*

1. A strip of Dacron webbing is placed down the center of the anterior section (Fig. 27).

2. The hindfoot section is built up to a thickness between ¾ and ½ in. with a material such as SACH foot rubber to allow relief during weight-bearing (Fig. 28).

Fig. 26. The first lamination has been completed; the anterior insert (shell) has been marked prior to its removal from the cast.

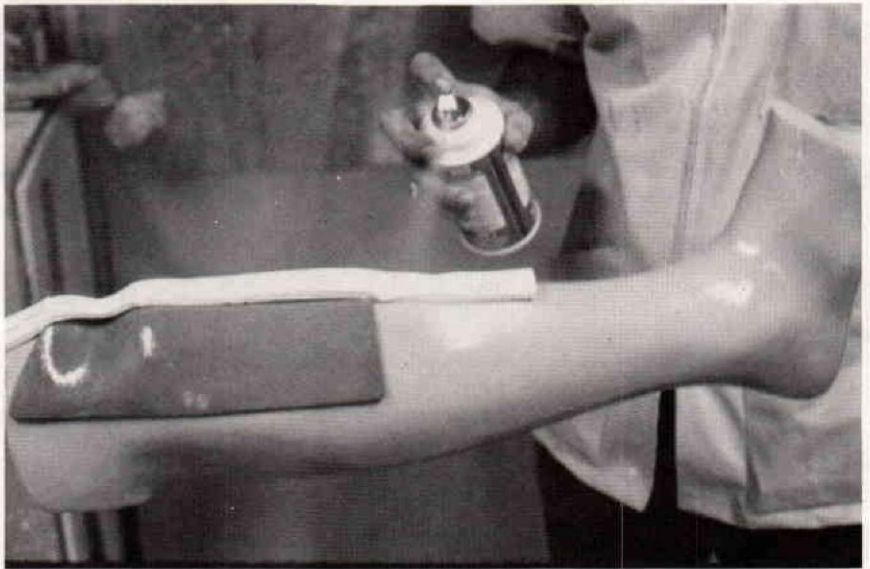


Fig 27. The anterior PTB shell is placed on the cast. A strip of 1 in. Pelite is placed on the shell prior to the second lamination process.

3. A PVA bag is placed over the cast and the anterior section.

4. When patient weighs less than 175 lb, four layers of Perlon stockinette are applied to cast. For heavier patients, two layers of fiberglass are used.

5. One piece of fiberglass mat about 2 in. wide is placed under the medial flare of the tibia running distally along the medial side under the sole of the foot, going proximal along the lateral side of foot and ending under head of the fibula.

6. A T-shaped fiberglass mat is placed under the sole of the foot cupping the heel and going proximally halfway up the medial and lateral sides.

7. Two layers of fiberglass stockinette are applied.

8. Four additional layers of Perlon stockinette are applied.

9. The second PVA bag is applied.

10. Lamination is then accomplished with 700g of resin - 80% Laminar Harz - 20% Degaplast (Fig. 29). When the patient weighs more than 175 lb., an additional fiberglass mat is placed under the medial flare and under the sole of the foot to neck of the fibula.

11. Lamination is carried out under a vacuum of 20 kg/sq cm.

12. Lamination is removed by cutting through the anterior part of the shank section, taking care not to cut through the first section.

13. The trimlines of the shank section are then drawn (Fig. 30).

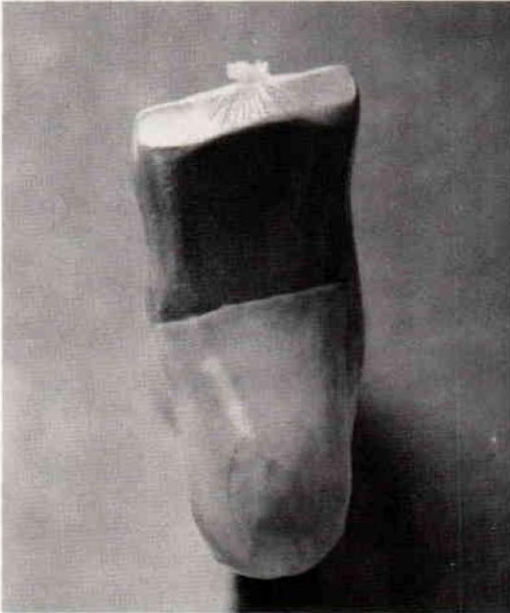


Fig. 28. The hindfoot section of the cast has been built up with hard SACH-foot rubber to allow relief of the hindfoot during weight-bearing.

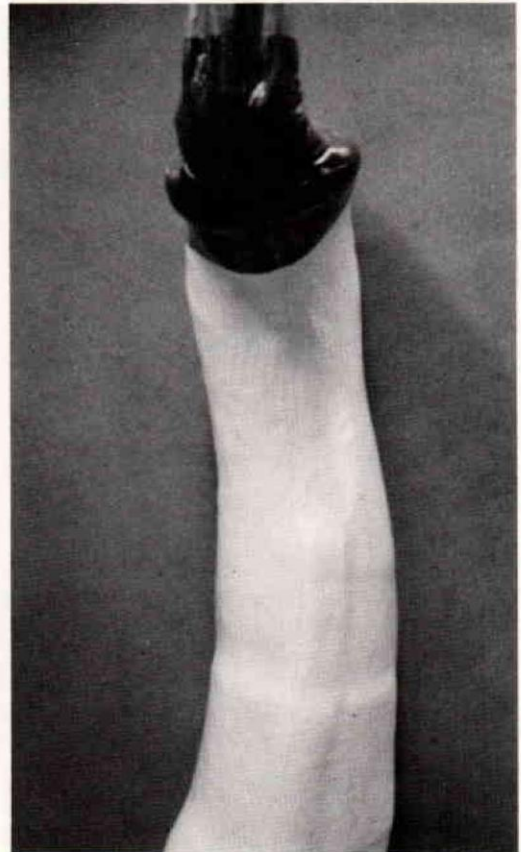


Fig. 29. The second lamination process is begun following the addition of layers of Perlon, fiberglass stockinette, fiberglass matting, and a PVA foil.

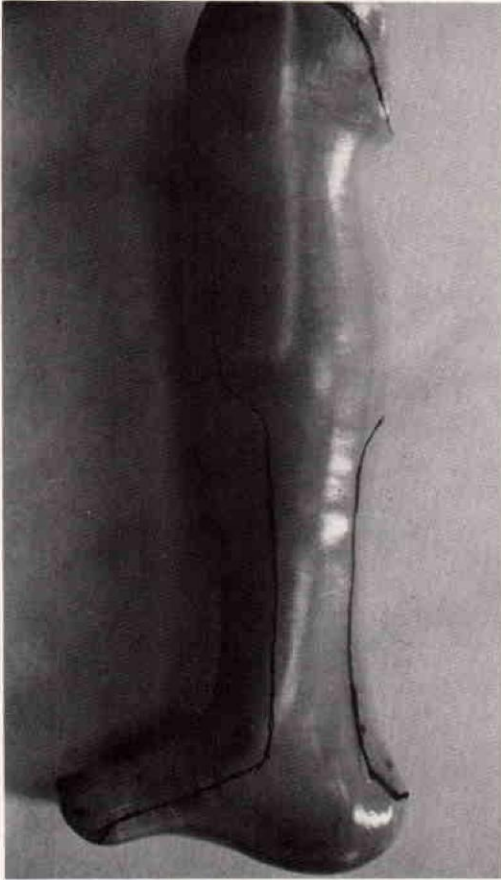


Fig. 30. Following completion of the second lamination, the orthosis is marked for cutting away from the cast.

#### FITTING

1. A length of stockinette is applied to the patient's leg.
2. The shank section is donned by spreading apart the patellar-tendon groove and sliding the foot through (Fig. 31).
3. The section is applied by sliding in from the anterior section until the section keys into the shank section.
4. Velcro is placed around the patellar-tendon area and the mid-point of the anterior section.
5. The patient's shoe is placed on the orthosis and the patient is asked to stand.
6. Normal checkout for the PTB is performed making sure weight-bearing is on the patellar ten-



Fig. 31. During donning of the orthosis, the patient inserts the anterior PTB shell; final fitting and "check-out" complete the process.

don and medial flare of tibia. If the orthosis is fitted correctly, the patient should experience a contact of the sole on the footplate of the orthosis but no weight-bearing.

#### SUMMARY

Our experience with plastic patellar-tendon-bearing orthoses in ten individuals with varying musculoskeletal defects of their lower limbs has been presented. We concluded that several disabilities of the lower limb can be successfully managed with this device, affording superior cosmesis, reduced orthotic weight, more comfort, and improved physiological and anatomical alignment. Disadvantages included increased cost, frequent replacement in children, and potential skin problems in those individuals with impaired vascular and sensory areas.

Our preliminary 18-month experience led us to the conclusion that the plastic patellar-tendon orthosis is a valuable tool in the care of disabled adults and children; we are continuing our clinical trials and will publish a subsequent paper outlining our experiences with neuromuscular disabilities.



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