

Clinical Applications of the Veterans Administration Prosthetics Center Patellar-Tendon-Bearing Brace

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AN CERTAIN pathological conditions of the lower extremity, the stress of weight-bearing cannot be tolerated because of pain or the possibility of actual tissue damage. Pathologies encountered in such situations fall into three broad categories: (1) those affecting bone—delayed unions or non-unions of fractures; (2) those involving the ankle or foot joints, such as traumatic arthritis or similar conditions; and (3) those involving the soft tissue, such as ulcers and traumatic loss of the heel pad or other soft tissues.

In these circumstances, bracing is frequently used as an aid to management, the brace serving as a weight-bearing device to relieve the skin-muscle-bone complex of intolerable stresses.

Historically, the application of a brace to unweight the lower extremity has involved provision for support of the body weight at the level of the pelvis, typically some form of ischial weight-bearing. A variable proportion of body weight is then transmitted to the ground through side bars and a locked knee. This type of brace is inherently disadvantageous because of its bulk and because the locked knee imposes a stiff-legged gait which increases energy costs. In situations where the pathology is located above the knee, avoidance of these

disadvantages may be impossible. However, in selected below-knee lesions, a brace which bears weight about the knee (like the patellar-tendon-bearing prosthesis) appears not only desirable but pos-

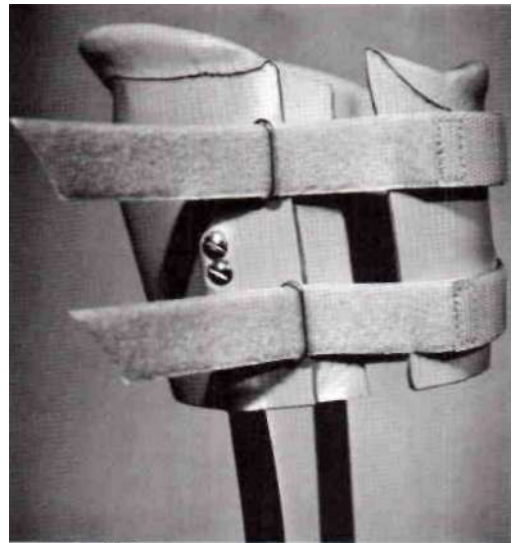


Fig. 1. Proximal weight-bearing portion of the PTB brace.

sible. A brace of this type would not only allow unrestricted knee motion, and hence a more natural gait, but it would have the advantages of reduced bulk and the absence of equipment above the knee.

In 1958, VAPC designed such a below-knee weight-bearing brace (3). The VAPC design was based on the then current below-knee patellar-tendon-bearing (PTB) prosthetic techniques. The primary weight-bearing component is a partial socket of

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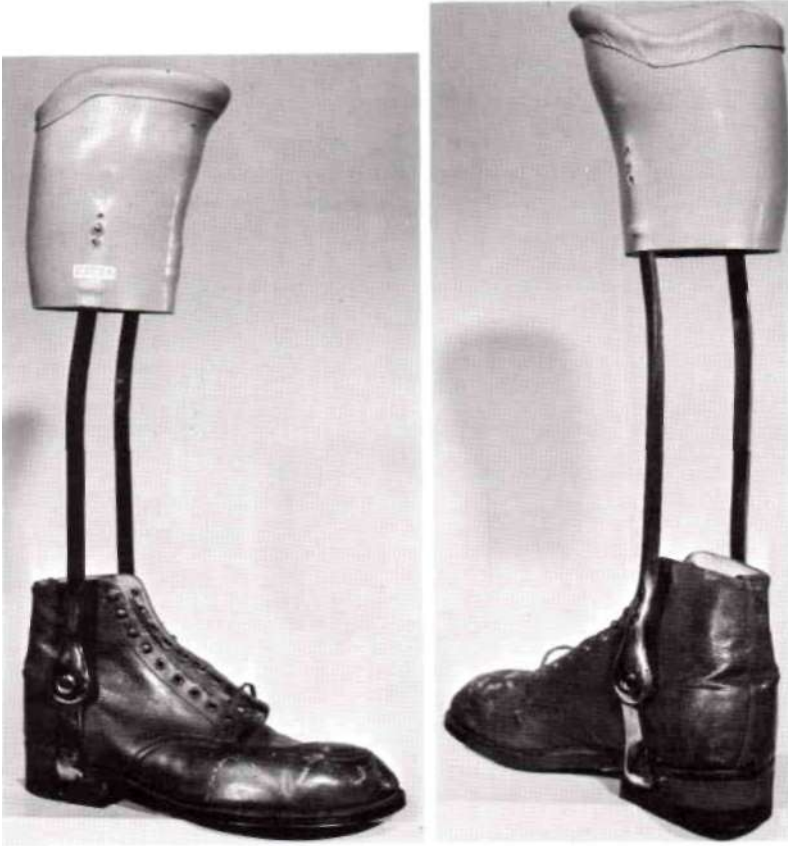


Fig. 2. Completed brace of initial design.

laminated plastic with a soft (Kemblo [TM]) liner similar to the proximal portion of a PTB prosthesis (fig. 1). Stainless-steel uprights were used with a stainless-steel limited-motion stirrup (fig. 2). The ankle joints were modified to permit 10° of plantar flexion and to limit dorsiflexion at 90° . The stirrup and uprights were fitted and aligned as in a conventional ankle brace. In wearing the brace, an open-end wool stump sock was used as with a below-knee prosthesis.

As experience with the PTB-type brace accumulated at VAPC, a number of modifications were introduced (fig. 3). A compressible heel, similar to that of the solid-ankle cushion-heel (SACH) prosthetic foot, and a rocker bar attached to the sole of the shoe became incorporated as standard components of the device. The SACH heel

wedge and rocker bar were incorporated in the shoe to simulate plantar flexion and provide a more natural roll from heel to toe, thus minimizing gait deviations imposed by limited ankle motion (4). The SACH heel wedge is also considered to function as a shock absorber, contributing to a smoother gait. Some patients with painful ankles were unable to tolerate motion in the ankle joint at the brace and were fitted with rigid joints.

The Veterans Administration Prosthetics Center submitted the PTB weight-bearing brace to the Committee on Prosthetics Research and Development for evaluation. Unfortunately, at that time procedures for the testing of orthotic devices were not available. However, in December 1963 an orthotic evaluation program was inaugurated by New York University, and the

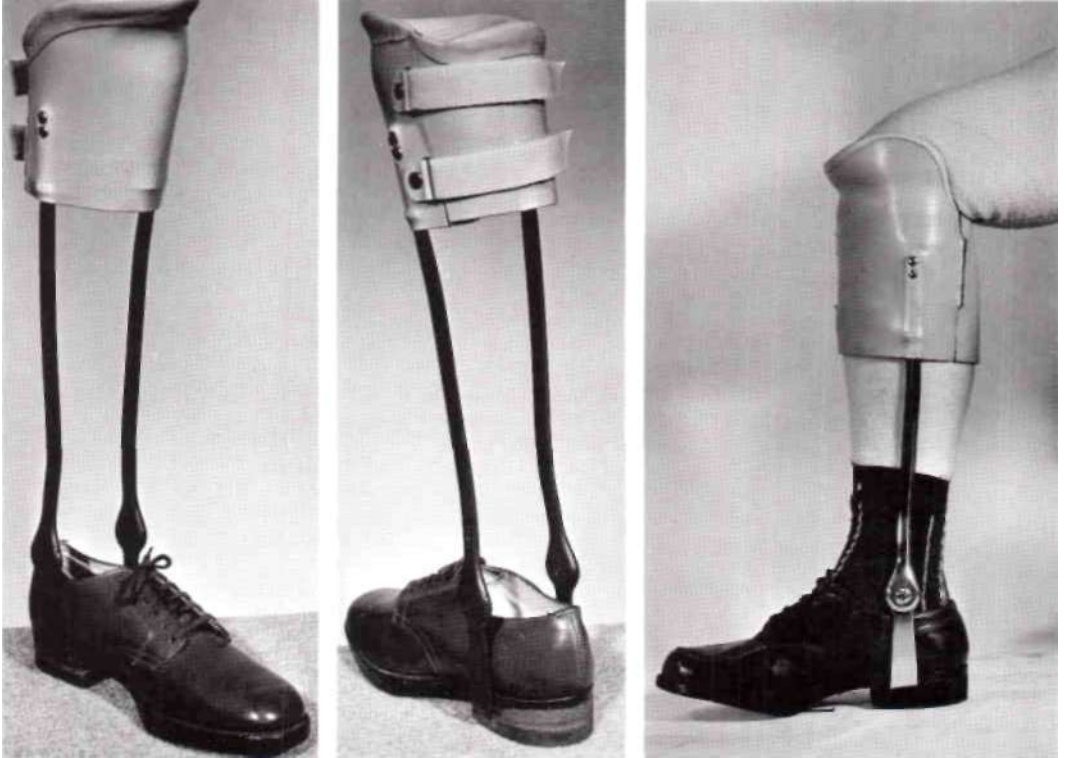


Fig. 3. Views of the modified brace showing application of SACH heel and rocker bar.

VAPC device was selected by CPRD as a suitable item for this program.

The initial phase of the NYU evaluation involved the review and examination of patients fitted by VAPC. Of the 22 patients who had been fitted by VAPC between 1958 and November 1963, 8 accepted the invitation to appear for interview and examination. The findings of this review study indicated that the VAPC patellar-tendon-bearing brace was an effective device from the medical, orthotic, functional, and wearer-reaction points of view (1).

CLINICAL FITTINGS

On September 1, 1966, the National Academy of Sciences—National Research Council entered into Contract SAV-1053-67 with the Vocational Rehabilitation Administration (now the Social and Rehabilitation Service) to establish a pilot program for the clinical evaluation of pros-

thetic and orthotic devices under the jurisdiction of the Committee on Prosthetics Research and Development. Two orthotic items were selected to initiate this program: the Baylor (Engen) hand orthosis and the University of California dual-ankle control system. The Engen study was undertaken (2) but, for various reasons, the UC study could not be undertaken, and evaluation of the VAPC PTB brace was substituted for the UC item.

Since the earlier favorable NYU review, an instructional manual has been prepared by the developer (5). Accordingly, five treatment centers were recruited as participants in a clinical application study of the VAPC PTB brace: the University of Alabama Medical Center, Birmingham, Ala.; Goldwater Memorial Hospital, New York, N.Y.; Jackson Memorial Hospital, Miami, Fla.; Rancho Los Amigos Hospital, Downey, Calif.; and the Rehabilitation Institute of Chicago, Chicago, Ill.

A course of instruction in the fabrication and application of the VAPC PTB brace was conducted at the Veterans Administration Prosthetics Center, New York, by the developers. Orthotists from the participating clinics undertook training for five days (May 8-12, 1967), while physicians had a one-day orientation (May 12, 1967).

A protocol for the study, together with appropriate data-recording forms, was prepared by the CPRD staff.

Following the instructional course, several fittings were accomplished at each of the participating centers. Subsequently, a number of factors arose to militate against the completion of the planned course of study. Two of the clinics suffered the loss of the physician member of the participating team, and two other centers became engaged in studies of cast braces for fractures of the lower extremity. These fracture-cast braces had some of the same characteristics and performed similar functions as the test item. The physician member of the fifth participating team suffered a prolonged illness, which disrupted the progress of the study at his center.

The clinical study of the VAPC PTB brace was reactivated early in 1970 when the physician who had been ailing recovered his health and it was discovered that the orthotics clinical group at the Duke University Hospital had been fitting the test item since 1962 and had accumulated a sizable series of patients. Arrangements were made, therefore, to review patients fitted in Birmingham and Durham. The data obtained in these reviews form the basis for this report. The experience of these two centers is presented in the following sections of this report.

BIRMINGHAM, ALABAMA

Following the return of the physician—orthotist team from the instructional course at VAPC, seven patients were fitted in the study. Two of these patients were civilians (one woman and one boy) and five were veterans. The injuries of three of the veterans were non-service-connected.

Review of the data available on these seven patients fitted in Birmingham indi-

cates that in four instances the experimental brace was used satisfactorily and successfully. In two cases, the results were inconclusive in that the follow-up data are not available. The seventh patient must be considered a probable failure, although again follow-up data are not available. Condensed case histories on these patients follow.

SUCCESSFUL OUTCOMES

Case No. 1

P.S. was born on February 28, 1953. He suffered from congenital pseudarthrosis of the right tibia and fibula, essentially constituting a defect similar to an ununited fracture. Prior to referral to the Crippled



Fig. 4. X-ray of *P.S.*'s leg at time of fitting the VAPC PTB brace.

Children's Service Clinic in Birmingham, he had undergone surgery at an early age. This surgery, involving the use of metallic screws and sutures, was unsuccessful. Further surgical procedures were attempted subsequently, an onlay bone graft being done on July 20, 1965. This surgery was followed by infection and was unsuccessful. A sliding bone graft was attempted on June 6, 1967, but this also was unsuccessful.

The VAPC PTB brace was fitted in April 1968. The condition of the right tibial and fibular defects at that time is shown in figure 4. The brace prescription included a SACH heel and a rocker bar incorporated into the shoe build-up (the right leg being shorter than the left). Initially, no motion was provided at the ankle joint.

Following application of the brace, the leg shrank rapidly, and a new socket was required in approximately one month.



Fig. 5. P.S.'s leg after wearing the experimental brace approximately 14 months.



Fig. 6. C.S.'s X-rays after wearing the experimental brace for 9 months. Good bone union is evident at the fracture site.

Because of this loss of fit, the amount of weight borne on the defective limb was increased. This boy was a very active user; he played basketball and reported that he went hunting almost every day. As a result of this active use, numerous breakages occurred at the junction of the brace upright and shoe plate. The upright was eventually strutted for extra strength, and after about a year and a half of wear a few degrees of motion were introduced at the ankle joint. This limited motion resulted in reduction of the breakage problems.

Although the patient was well pleased with the brace and wore it satisfactorily, the tibial and fibular defects failed to unite (fig. 5).

The physician, orthotist, and patient all considered this brace to be superior to any previously worn.

Case No. 2

C.S. was born on April 17, 1915. He was injured on March 2, 1967, when he slipped

on the ice and fell, sustaining fractures of the left tibia and fibula. He was treated with plaster casts, but union of the tibial fracture was delayed.

He was fitted with the VAPC PTB brace in September 1968. The prescription was standard, and included a SACH heel, a rocker bar, and a rigid ankle. A full leather cuff was applied over the fracture site.

This patient's treatment program proceeded uneventfully, and by June 1969 a good bone union was evident clinically and confirmed by X-ray (fig. 6). This patient was discharged from the doctor's care.

Case No. 3

H.E. was born on October 25, 1933. He was hit by a car on October 12, 1966, sustaining a fracture of the right tibia, which failed to unite. Draining osteomyelitis also was present.



Fig. 7. *H.E.*'s X-rays show indications of healing of fracture after the brace was worn for 10 months.



Fig. 8. X-ray of *J.C.*'s right ankle 5 months after injury.

He was fitted with the experimental brace on October 25, 1968. The prescription included a SACH heel, a rocker bar, a fixed ankle, a short leather cuff, and a high shoe. He initially walked with crutches or canes but later discontinued these aids.

This patient is a large, heavy man and very active. Many repairs were required at the shoe-plate junction, and eventually a strut had to be added for additional strength.

This patient's treatment program proceeded relatively uneventfully. In August 1969, the brace was reported as working well, and no drainage had been experienced since October 1968. Although the fracture had not healed, X-rays revealed some indications of healing (fig. 7). In March 1970, apparent ankylosis of the ankle joint was noted, and progressive ossification within the fracture area was evident. The patient continues to wear the brace and tolerates it well. He still wears

an elastic below-knee stocking, but this is apparently more for insurance than because of actual need.

Case No. 4

J.C. was born on October 27, 1948. He was injured by shrapnel on May 14, 1967, sustaining a fracture of the neck of the talus on the right leg and loss of soft tissue on the right heel. Figure 8 shows the condition of his right ankle approximately five months after the injury.

The experimental brace was prescribed for this patient on November 21, 1967, and it was delivered on December 13. The prescription incorporated a SACH heel, a rocker bar, a reinforced foot plate, and no ankle motion. This patient experienced no particular problems other than the need for shoe changes. He found the brace useful

and comfortable. X-rays taken on April 9, 1968, showed marked improvement (fig. 9). His injuries proceeded to complete healing, and he is no longer wearing the VAPC brace.

Case No. 5

S.D. was born on May 18, 1927. She was injured on August 30, 1967, sustaining a comminuted fracture of the right tibia and fibula. The tibial fracture failed to unite.

She was treated with long and short leg casts and fitted with the PTB brace on May 29, 1968. The prescription was standard, and included a SACH heel, a rocker bar, and no ankle motion. The patient tolerated the brace well, and X-rays taken on July 1, 1968, indicated satisfactory progress (fig. 10).



Fig. 9. Marked improvement is evident in *J.C.*'s ankle after wearing the experimental brace approximately 5 months.



Fig. 10.S.D. shows satisfactory progress one month after fitting with a PTB brace.

Few maintenance requirements were found, except that the shoes had to be changed and one upright and one foot plate broke.

The patient was seen in August 1969, at which time she was using the brace with crutches. She has not been seen since, so the end result is unknown.

Case No. 6

D.E. was run over by a truck in May 1966, and he sustained fractures of both legs and the left foot. The left tibia failed to unite, as indicated in X-ray films taken six months after the injury (fig. 11). He was fitted for the VAPC PTB brace in December 1968, but left the hospital before the brace was delivered. The brace was delivered at home just before Christmas 1968, and he apparently has not been seen since except for a casual encounter with the orthotist on the street, when it was reported that the fracture had healed and that the patient no longer needed the brace. Again,

because of the loss of this patient to active follow-up, the full story is not known.

ASSUMED UNSUCCESSFUL OUTCOME

Case No. 7

R. McK. was born on May 21, 1908. His injury occurred as a result of a land-mine explosion on February 27, 1942. He sustained the loss of the os calcis and the heel pad bilaterally.

He was fitted with the VAPC PTB brace on the right side only, the device having a fixed ankle, SACH heel, and rocker bar.

This patient was apparently dubious about the brace from the outset, and expressed lack of confidence in the doctors and the course of treatment. He wore the experimental brace for a very limited pe-



Fig. 11. Condition of D.E.'s leg prior to fitting with a PTB brace.

riod (approximately five days) and claimed that it limited his freedom, particularly when driving. This patient subsequently became lost to follow-up, and all indications were that the application of the brace in this case was unsuccessful as well as perhaps ill-advised.

DISCUSSION AND CONCLUSIONS

The evidence in the Birmingham fittings of the VAPC PTB brace was strongly positive with respect to its value as a means of patient management. In some instances, this value was in providing partial unweighting so that the damaged part could heal. In other instances, the unweighting provided by the brace permitted the patients to engage in vigorous programs of activity despite a lack of union in the tibia.

In addition to these general findings, some specific findings of interest emerged.

1. Following application of the VAPC PTB brace, shrinkage of the limb enclosed

by the plastic cuff was encountered. Close control of the fitting during this period is essential in order to avoid the development of loose fit and a reduction in the amount of weight borne by the brace.

2. As in all prosthetic-orthotic applications, judicious selection of patients is essential. In the Birmingham group, one fitting was apparently doomed to failure from the outset because of the patient's attitude, while another patient was a chronic alcoholic, so that the possibility of securing follow-up data was negated from the outset.

It should be emphasized that the Birmingham fittings closely followed the technique practiced and taught by the Veterans Administration Prosthetics Center. Review by one of the co-developers of the device on a number of the cases fitted early in the study indicated good workmanship and generally excellent fit and alignment.

Some observations by the orthotist member of the fitting team were:

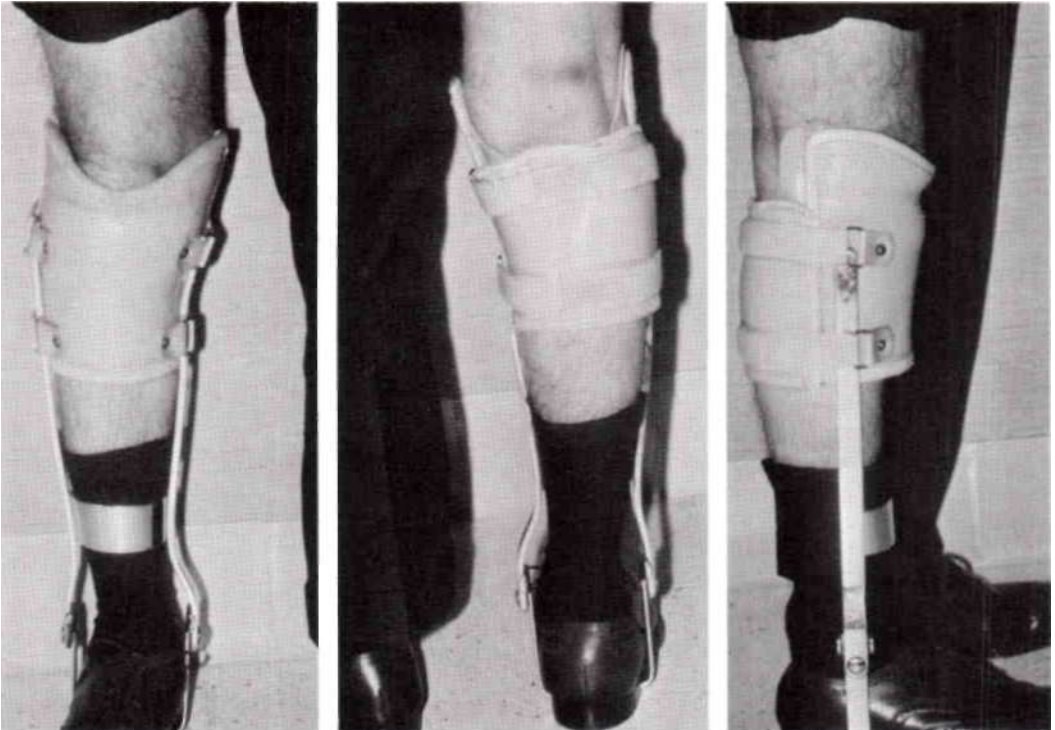


Fig. 12. Front, rear, and side views of PTB brace with earlier Durham bivalve socket lined with horsehide,

1. Fabrication of the VAPC PTB brace requires experience in both prosthetics and orthotics, since elements of both specialties are involved.

2. A course of instruction in the technique during which the braces are actually fabricated under competent instructors is a most desirable means of transmitting fitting knowledge and skill.

3. The selection of patients for the device is most important and should include not only considerations of psychological factors such as those described above but also of physical factors which may increase the difficulty of fitting. (The presence of loose tissue around the knee which could become a flesh roll above the brace cuff was cited as an example of this type of difficulty.)

4. All patients fitted in the Birmingham group were initially provided with braces with no provision for motion at the ankle joint. In active and/or heavy patients, this resulted in numerous brace-upright and shoe-plate breakages. Later, some patients were provided with a small amount of ankle motion, and this had the effect of reducing incidence of breakage. Criteria for the prescription of fixed or limited motion in ankle joints should therefore be defined more carefully.

DURHAM, NORTH CAROLINA

Mr. Bert Titus, director of the Department of Prosthetics and Orthotics, Duke University, began fitting the VAPC-PTB-type brace in 1962. The initial braces were fabricated in accordance with the VAPC manual of January 3, 1961 (5). Over the years, however, the original VAPC procedures were modified at Duke in a number of ways. Although the original concept of patellar-tendon weight-bearing for reduction in the amount of weight borne by the affected part of the limb was maintained, the changes are significant enough to be worthy of note.

1. The socket, which in the VAPC version was hinged on the medial side, was first changed to a bivalve construction involving anteroposterior sections joined by adhesive tape (fig. 12). The type of socket now fitted in Durham involves a plastic laminate without liner which is flexible on the posterior aspect and the posteromedial corner (fig. 13). The socket is split along the posterolateral corner and closure is effected by two or more Velcro (TM) straps (figs. 14 and 15). The fabrication of this socket is described in a report being prepared by Titus. An abbreviated description of the Duke procedures appears as a supplement to this article.

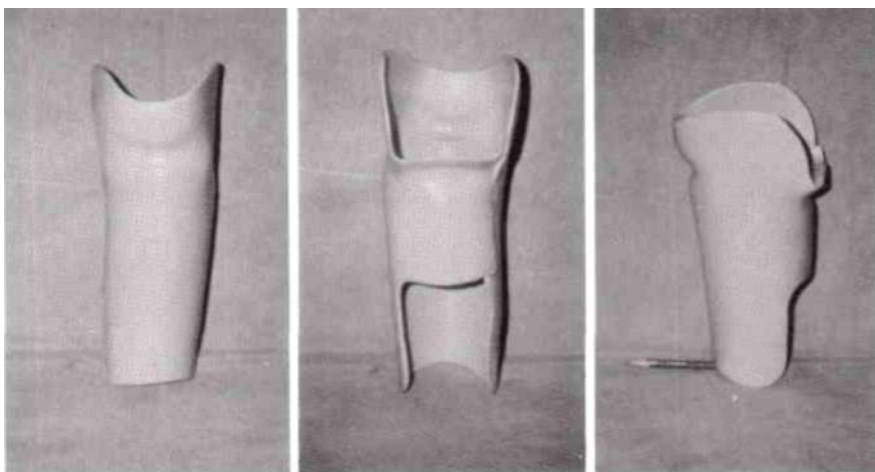


Fig. 13. Front, rear, and side views of current Durham socket.

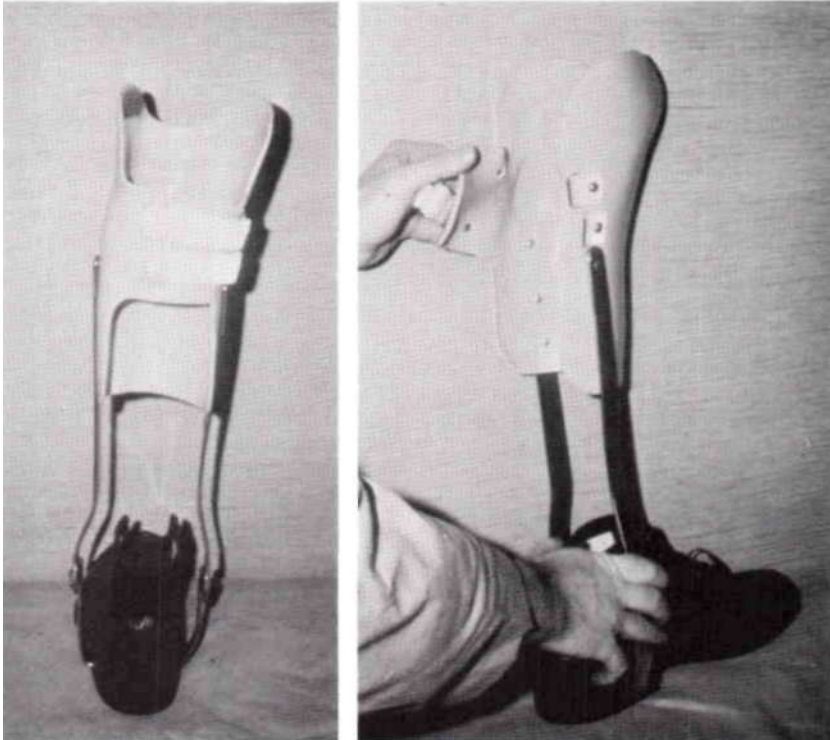
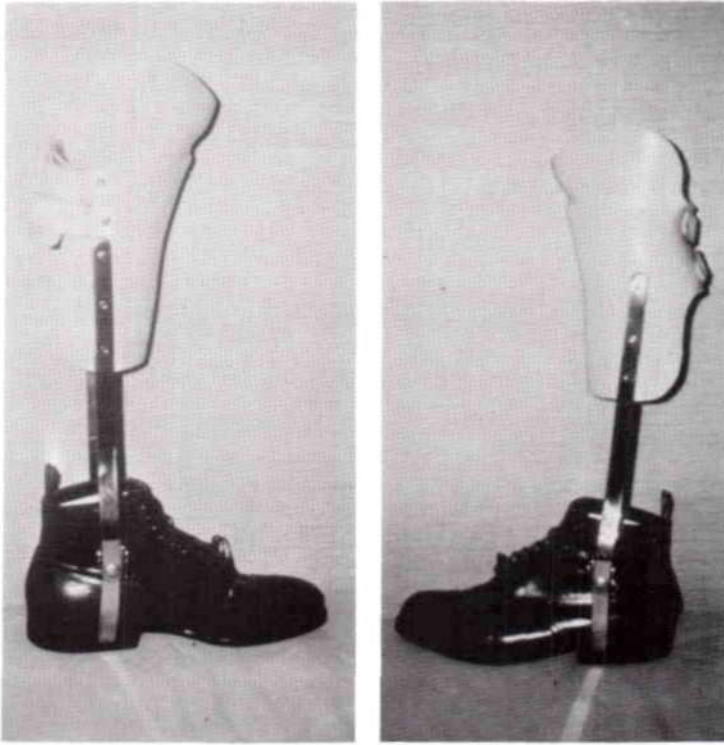


Fig. 14. Medial, lateral, rear, and oblique views of socket with sidebars and shoe attached.

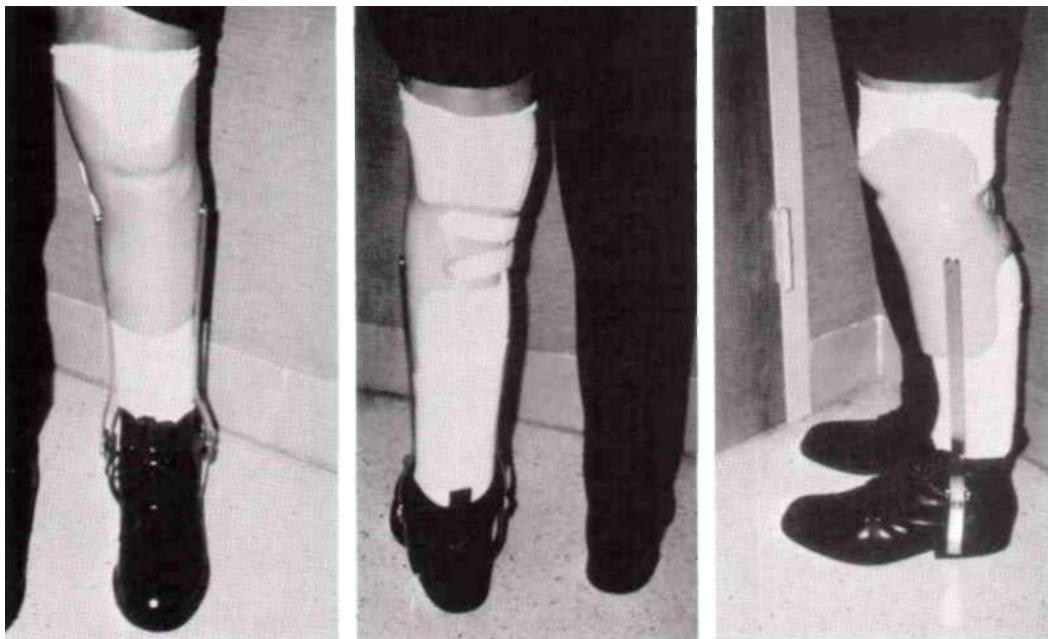


Fig. 15. Current version of Durham modification fitted to patient.

2. The sidebars in the Durham version of the weight-bearing brace are of either stainless steel or aluminum, and most recently have been attached to the outside of the socket with rivets. This procedure is in contradistinction to the VAPC method, which involves insertion of the proximal ends of the sidebars into prepared channels. Distally, the bars are detachable from the shoe.

3. All the VAPC-type braces fitted at Durham incorporated some degree of ankle motion. Typically, this was 20° to 25° of dorsiflexion with a 90° stop. However, some of the ankle joints were completely free. This feature again contrasts with the VA practice in which the brace ankles are frequently of the rigid type. It was reported that none of the braces fitted at Durham had completely rigid ankles.

4. Typically, the Durham version of the weight-bearing brace does not include either a SACH heel or a rocker bar. Doubtless, the need for such aids to roll-over is

reduced or eliminated by the provision of ankle motion.

Between the initial fittings in 1962 and June 15, 1970, the Duke Limb and Brace Shop fitted approximately 27 PTB-type braces. Of these patients, 20 were civilians seen through the Orthopaedic Department of Duke University Hospital and 7 were veterans who were treated through the Veterans Administration Hospital at Durham. Three additional braces were being fabricated at the time of this review.

On June 22-23, 1970, the author, accompanied by William McIlmurray from the VAPC, reviewed 8 patients who had been fitted through the Duke University Department of Prosthetics and Orthotics. The group of patients reviewed included 5 civilians and 3 veterans. The case-history files of 12 additional patients were also reviewed. The data obtained in these reviews are presented below in three sections—one indicating the types of disabilities for which the brace was used, the second containing

illustrative case histories of patients treated, and the third containing comments on fit and alignment. In general, the outcomes of the fittings appeared to be very positive.

TYPES OF DISABILITIES

Chronic osteomyelitis with secondary deformity of distal tibia and fibula and partial ankle fusion.

Slow-healing spiral fracture of the tibia and fibula.

Compound fracture of the tibia and fibula and fracture of the left foot followed by infection and numerous operative procedures culminating in ankle fusion.

Fracture of the tibia and fibula.

Nonunion of the tibia and fibula with compression-plate fixation.

Nonunion of a tibial fracture with draining osteomyelitis.

Comminuted fractures of the distal right tibia and proximal right fibula and fracture dislocation of the right ankle. A painful ankle led to the performance of a triple arthrodesis.

Comminuted fractures of the ankle mortice bilaterally (right medial malleolus and tibia, left spiral fracture of tibia and fibula; both ankles stabilized with pins). Six pins were subsequently removed.

Traumatic arthrosis of the right ankle following fracture of the distal right tibia and fibula.

Compound trimalleolar fractures of the left ankle with dislocation.

Nonunion of a left tibial fracture with osteoporosis.

Calcaneal valgus deformity of the right foot treated with a triple arthrodesis of the right foot and ankle; delayed healing of subtalar, talonavicular, and calcaneocuboid joints with severe osteoporosis.

Pain on plantar aspect of heel following fracture of the os calcis.

Foot pain following football injury; triple arthrodesis performed.

Degenerative changes in left knee secondary to old fracture of the tibial plateau.

Nonunion of medial malleolus following trimalleolar fracture sequelae of traumatic arthrosis and arthrodesis.

Comminuted fracture of os calcis leading to a crushed heel pad, osteoporosis, and triple arthrodesis subsequently.

Right heel pain, characteristic of traumatic or degenerative arthritis.

Fracture of the right os calcis with painful right foot and ankle.

CASE HISTORIES

Case No. 1

W.J. was born on April 3, 1927. From early childhood, he had suffered from a defect in his left leg which had been attributed to an aftermath of diphtheria. His condition was reported as being chronic osteomyelitis with a secondary deformity of the distal tibia and fibula combined with partial ankle union.

The patient was fitted with a PTB brace in August 1962, and thus had worn the device for almost eight years. The brace worn had an ankle with a positive 90 deg. stop and approximately 30 deg. of dorsiflexion motion. He wore a low shoe with a 2 1/2-in. build-up. Otherwise, the brace was of the Durham type as described previously. He reported that he wore the brace for more than nine hours daily, and that it was generally quite comfortable and satisfactory. His condition was reported to have stabi-



Fig. 16. *J.G.*, with nonunion of fractures and draining osteomyelitis.



Fig. 17. J.G., with Durham bivalve-type brace.



Fig. 18. Views of T.L.'s fractures before fitting with PTB brace.

brace. From his remarks, it would appear that the brace was a definite aid to his mobility.

Case No. 2

J.G. is a 30-year-old male garbage collector who was jammed between the garbage truck and a brick wall, sustaining a fracture of his left tibia and fibula on March 22, 1967. A nonunion of the fractures with a draining osteomyelitis ensued (fig.16).

The patient was fitted with a PTB brace in September 1969. He reported that he was feeling fine, the osteomyelitis had stopped draining, and he had returned to work driving a garbage truck.

The brace worn was the Durham bivalve device with the ankle completely free (fig. 17). He wore the brace all day every day and reported absolutely no problems with it.

From the patient's remarks, his return to work, and his comments concerning the brace, it would appear that this fitting was quite successful.

lized, although his ankle and shin sometimes ached after prolonged standing or walking. He stated that he felt that he was bearing more than 50% of his weight on the

Case No. 3

T.L., a physician, sustained a spiral fracture of the tibia and fibula on February 5, 1969. He wore a long leg cast for six months following the injury, and on August 8, 1969, he was fitted with the PTB brace. The condition of his fractures just prior to fitting is shown in figure 18. With the device, he was able to return to his medical

practice. The fracture was pronounced healed in November 1969, and the PTB brace was discarded. His brace was of the standard Durham type with a completely free ankle joint.

When interviewed, the patient's comments concerning the brace were very positive. So much so, in fact, that when the interviewer remarked that he seemed like a happy customer, he retorted that he was

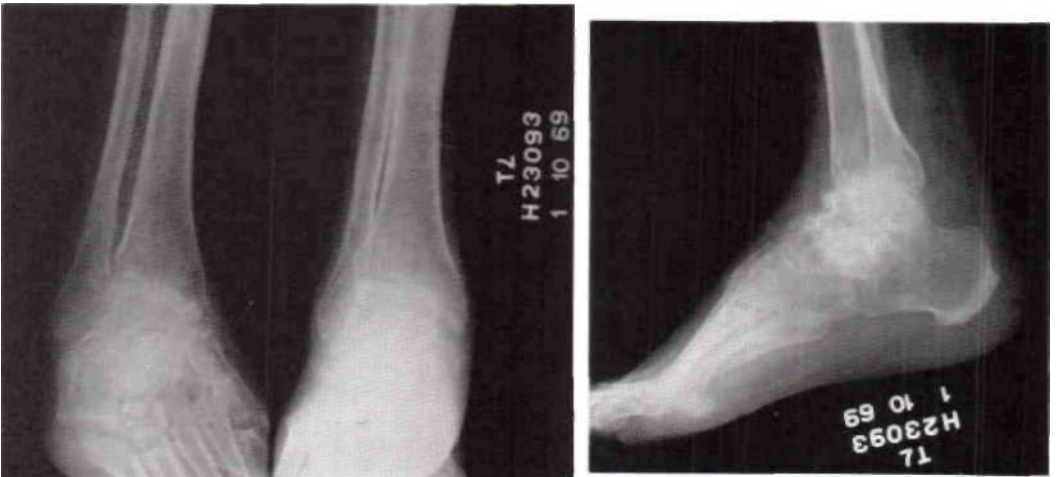


Fig. 19. X-rays of F.E.'s distal leg, ankle, and foot.



Fig. 20. Condition of F.E.'s limb 9 months later.



Fig. 21. Condition of H.H.'s fractures 8 months after injury (2 months' wear of PTB brace).

more than happy—he was delighted—and in fact had sent two patients with fractures to be fitted with the same type of brace.

Case No. 4

F.E., a 43-year-old male, was buried under eight to ten tons of chemical in March 1966, sustaining compound fractures of the left tibia and fibula, a fracture of the left foot, and fractures of the pelvis and of the right upper femur. Following open reduction and internal fixation, the injury became infected and the fixation was removed. The patient had a number of operative procedures on his right hip, and on October 3, 1967, underwent multiple fusions of the ankle bones.

He was fitted with a PTB brace on March 27, 1968, and thus had worn it for slightly more than two years. The device is of a standard Durham type with a 90° ankle stop and with approximately 5° of dorsiflexion. The sidebars were of aluminum with an anterior aluminum calf

band. A low shoe was worn with a build-up on the opposite side because of a shortening of the right leg related to the pelvic and femoral fractures. The brace was of the bivalve type. Figures 19 and 20 show the condition of the foot and distal tibia and



Fig. 22. Persisting nonunion of fibula approximately 4 1/2 years after injury.

fibula over the period from January to October 1969. The patient reported that without the brace he experienced discomfort at the fracture sites, but that with the device he was reasonably comfortable and could wear the brace all day. He claimed that he took about 30% of his weight on the brace. Again, it appeared that this brace is a highly acceptable aid to the mobility of the patient.

Case No. 5

H.H., 40 years of age, sustained multiple fractures of the lower extremities on August 4, 1969. His injuries included fractures of the left femur, tibia, and fibula, and right tibia and fibula. He was fitted with a PTB-type brace in February 1970. His condition two months after fitting (eight



Fig. 23. Nonunion of tibial fracture 10 months after accident.



Fig. 24. Nonunion persisting 3 years after accident. PTB brace worn 3 months.

months after injury) is shown in figure 21. His device was of the single-lamination type and incorporated a free ankle and a high shoe. The fit of the socket was somewhat loose, and the patient expressed the opinion that no weight was being taken on

the socket. He used Canadian-type crutches bilaterally. The clinical notes on his condition indicated good alignment of the bony fragments and no pain. He was wearing the brace all day and had no problems with it.

Case No. 6

J.H., born in 1927, suffered his injury in December 1966. Nonunion of the left tibia and fibula ensued, with compression-plate fixation.

The patient had been fitted initially with the bivalve-type socket (separate anterior and posterior sections), but was currently wearing the one-piece laminated socket with a flexible posterior section. The brace incorporated a free ankle, and a low shoe was worn.

Recent clinical notes on this case indicated that on March 25, 1970, there was good alignment of the bony fragments,

and early bridging of bone had begun in the tibia and fibula. On May 27, 1970, the patient was reported to be feeling well, but there was still nonunion of the fibula (fig. 22). The patient reported no problems with the brace.

Case No. 7

R.C.M., 39 years old, sustained a comminuted fracture of the left tibia and fibula when a tree fell on his leg in March 1967. Nonunion of the left tibial fracture ensued, with chronic osteomyelitis and drainage (fig. 23). A bone graft to the tibia was attempted in March 1968.

The patient wore a long leg cast, followed by an initial weight-bearing brace. He was fitted with the PTB device in December 1969. His clinical record indicated that there was intermittent drainage in December and January but no drainage in February or March 1970 (fig. 24). On April



Fig. 25. *Left*, R.McC.'s initial injury, Nov. 15, 1969. *Right*, after open reduction and internal fixation, Jan. 2, 1970.

1, 1970, it was reported that no active osteomyelitis was evident. However, at the time of the review (June 24, 1970), the patient reported that drainage had restarted.

His brace included a 90° posterior stop with about 10° of dorsiflexion motion evident. The patient wore a built-up low shoe to accommodate a 2 1/2-in. shortness of the affected limb. His socket was of the two-part (bivalve) type. He used a cane as an aid in ambulation.

The patient reported that the brace felt comfortable most of the time, although he had occasional swelling of the leg after long use and some discomfort at the site of the fracture after prolonged sitting.

Case No. 8

R.McC., 69 years old, was injured in an automobile accident on November 15, 1969. He sustained fractures of the head of the tibia, the head of the fibula, and the proximal third of the fibula (fig. 25). He was fitted with the PTB brace on April 6,



Fig. 26. *Left*, R.McC.'s fractures at time of fitting the PTB brace, 4 1/2 months after injury, April 1970. *Right*, after 1 month's wear of PTB brace, May 1970.

1970 (fig. 26). Thus, at the time of the review, he had been wearing the device for approximately two and one-half months. He reported that the brace was generally comfortable, but that he had had some problems with swelling and stiffness in the ankle. He estimated that the brace was taking approximately 25% of his body weight. His brace was a standard Durham type with a 90° posterior stop and dorsiflexion motion of approximately 30°. When first fitted with the PTB brace, he had used two crutches, but now was only using one.

Although in this instance the period of brace wear was too short for definite conclusions to be drawn, the brace was being tolerated well by the patient and was of assistance to him in ambulation.

Case No. 9

J.B., 67 years old, was admitted to Duke University Hospital on March 12, 1969, with a closed comminuted fracture of the left distal tibia, fibula, and ankle joint, and an open trimalleolar fracture of the right ankle. Operative procedures were carried out the same night, and the patient was discharged from the hospital on April 11, 1969, with the wounds healed and the feet in apparently satisfactory condition, with the right foot in a better state than the left.

X-rays taken on January 12, 1970, showed an old fracture of the right ankle with fixation by metallic pins and screws and good external bony bridging and normal alignment (fig. 27). On the left side, internal-external bridging of the fibula with marked angulation, as well as poor healing of the tibial fragments, was evident.

He was fitted with the PTB brace in February 1970. Four weeks later, the clinic notes reported that the fibula had healed, and that the tibia was nontender.

No significant further changes were noted at examination on May 26, 1970. However, that patient reported that since wearing the PTB brace he had experienced practically no pain in the ankle or foot. He was to continue wearing the brace.



Fig. 27. *Left*, J.B.'s left ankle 10 months after reduction, Jan. 1970. *Right*, views of ankle 12 months after reduction (1 month after fitting with PTB brace) March 1970.

CRITIQUE OF FABRICATION AND ALIGNMENT

William McIlmurray of the Veterans Administration Prosthetics Center, one of the co-developers of the PTB brace, participated in the review of patients at the Durham facilities. Mr. McIlmurray described the fitting and alignment of the braces seen as generally good. He noted some of the characteristics of the Durham devices previously mentioned: the one-piece socket lamination, the ankle motion provided in all prostheses in contrast to the need that VA found to fit some braces with rigid ankles, the external attachment of the sidebars, the use of detachable stirrups, and the absence of SACH heels and rocker bars on the shoes of the patients. The absence of a liner in the sockets fitted and the fact that some patients did not wear stump socks was also noted.

Mr. McIlmurray subsequently discussed these features of the Duke fittings with Werner Greenbaum, the other co-devel-

oper of the VAPC technique. Their joint comments follow.

No objection is raised to the use of hard, unlined sockets which have a flexible medioposterior corner. However, it should be emphasized that, if this portion of the socket is too flexible, it will not offer support and the weight-bearing effectiveness of the brace will be reduced.

In courses of instruction on the PTB brace, it would be desirable to teach fabrication methods for both lined and unlined sockets. Clinics would then have the choice of using either method, thus creating a situation similar to current practice in the prescription of PTB prostheses.

VAPC also employs a one-piece socket fabrication procedure, and the use of this method is endorsed by the Duke experimentation.

The channels which are prepared in the socket for insertion of the sidebars result in a product which is cosmetically more acceptable than one with bars externally attached. Moreover, these channels are very necessary for alignment adjustability during the fitting procedures. They permit us to make minute height adjustments and to tilt the socket either medially or laterally. This adjustability is a most important feature, and we would not agree to its elimination.

We think that, in general, detachable stirrups are contraindicated, although they might possibly be used on lightweight, inactive patients.

Usually we do allow some ankle motion if warranted by the pathology. However, the weight-bearing characteristics of the brace are better maintained if only plantar flexion is allowed. When mechanical ankle-joint motion is not provided, SACH-heel and rocker-bar principles are applied.

DISCUSSION AND CONCLUSIONS

The clinical records of 27 patients fitted with the patellar-tendon-bearing brace through the Department of Prosthetics and Orthotics at Duke University were reviewed. A number of the patients in this series were interviewed and examined. From the data gathered, it appears incontrovertible that this type of brace has useful applications for a variety of below-knee problems.

Two broad areas of application were noted:

1. In instances where fractures or operative procedures were slow to heal, the brace was used as a means of mobilizing the patients more rapidly than might otherwise have been the case.

2. In cases of chronic pain in the leg, ankle, or foot arising from fractures, traumatic arthritis, and the like, the weight-bearing relief provided by the brace permitted patients to be ambulatory with considerably less pain and discomfort than was the case without the brace.

The review data indicated that the outcomes of the application of the brace were viewed very positively by the orthopedists, the orthotists, and the patients.

The variations in fabrication and fitting procedures used at Durham as compared with those originally promulgated by VAPC are noteworthy:

1. One-piece fabrication of the PTB-type socket or cuff without a liner appears to be a possible improvement over the original VA procedure.

2. The external attachment of sidebars appears somewhat less cosmetic than the original technique, but is probably somewhat simpler and faster to do.

3. Detachable stirrup-type upright applications showed some loosening tendencies.

In some cases, the provision of ankle motion in the brace undoubtedly eliminated the need for a SACH heel and a rocker bar, and resulted in less breakage of sidebars at the shoe attachment. However, the question as to whether some of these patients should have had rigid ankles with a SACH heel and/or rocker bar is unclear. The rule of thumb used at Duke appeared to be that, the closer the disability was to the ankle joint, the less motion had to be provided. However, as reported, all patients were given some degree of ankle motion.

In conclusion, it would appear that the Duke application of the PTB brace was in general highly successful. Some of the changes made in the original VAPC procedures appeared to have definite merit.

RECOMMENDATIONS

Since the results of this study indicate that the VAPC PTB brace can be successfully and beneficially applied by unaffiliated treatment centers, thus corroborating the developer, it is recommended that: (1) the results of the study be broadly disseminated by publication in *Artificial Limbs* and by other means, (2) the prosthetics—orthotics schools be encouraged to include instruction in the PTB brace as part of the lower-extremity orthotics curriculum, and (3) the fabrication modifications introduced by the Duke University Department of Prosthetics and Orthotics be tried at VAPC, and that following these trials the two institutions collaborate on the production of a fabrication manual for the PTB brace which will incorporate the best procedures currently known.

SUMMARY

In the late 1950s, a brace to unweight the leg was designed at the Veterans Administration Prosthetics Center (VAPC), New York, N.Y. This brace incorporated a lined plastic cuff essentially similar to the prox-

imal portion of the patellar-tendon-bearing (PTB) prosthesis. By varying the tightness of this cuff and the lengths of the uprights connecting it to the shoe, the amount of body weight borne on the proximal shank could also be varied. By these mechanisms, the distal portions of the limb could be unweighted to the desired degree.

The VAPC PTB brace was reported by the developer as having beneficial applications in cases of delayed or ununited fractures (tibia and fibula), painful ankles, and soft-tissue damage to the heel and the plantar aspect of the foot. It appeared potentially useful in any leg condition which produced pain on weight-bearing. Patients fitted by VAPC were reviewed by an independent agency (New York University) in 1963, and the developer's claims for the device were essentially substantiated.

The present report presents the results of VAPC PTB brace fittings performed by two groups other than the developer. The clinical records of 36 patients were reviewed, and approximately one-third of the patients were examined and interviewed.

The studies generally corroborated the positive findings previously reported by the developer. Wide dissemination of information concerning the VAPC item and its incorporation in orthotics instructional courses is recommended.

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