Improvement and Innovation:
Some Case Studies in Orthotics

Much has been published in this and other Journals on prosthetics and artificial limb design and on cases using prostheses. Therefore, it was thought desirable to use this opportunity to provide some experiences had by the VA Prosthetics Center in orthotics, an area which deserves much more attention generally.

The cases described here represent orthotic disabilities commonly referred to the VA Prosthetics Center. All of the orthopedic shoe cases were never seen in the Center; all assistance and the appliances themselves were provided on the basis of detailed correspondence from VA field stations.

Some of the appliances used in bracing represent new developments, of devices and techniques not covered in the previous article.

Case #1. This 46-year-old baker fractured his right tibia in the distal third as a result of a fall in May 1962. After 17 weeks in a plaster cast, he was discharged and returned to work. Ten days afterward he fell and fractured the tibia at the old fracture site.

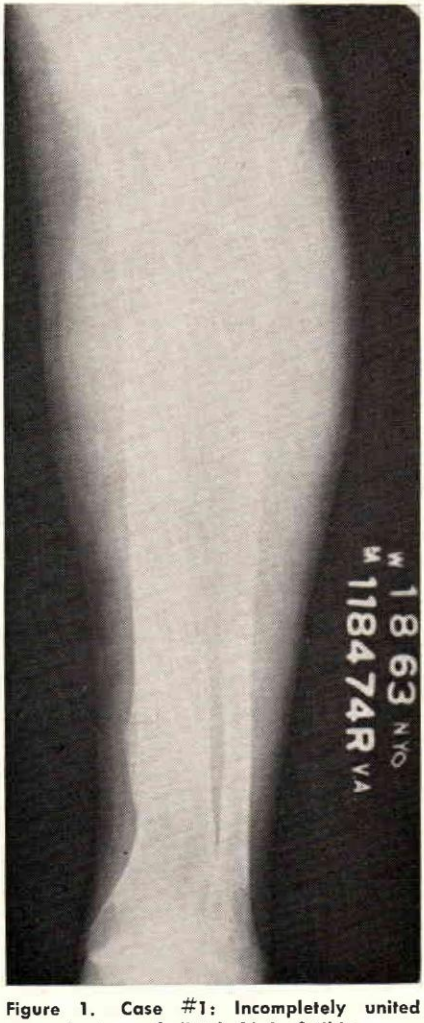

Figure 1. Case #1: Incompletely united fracture of distal third of tibia.

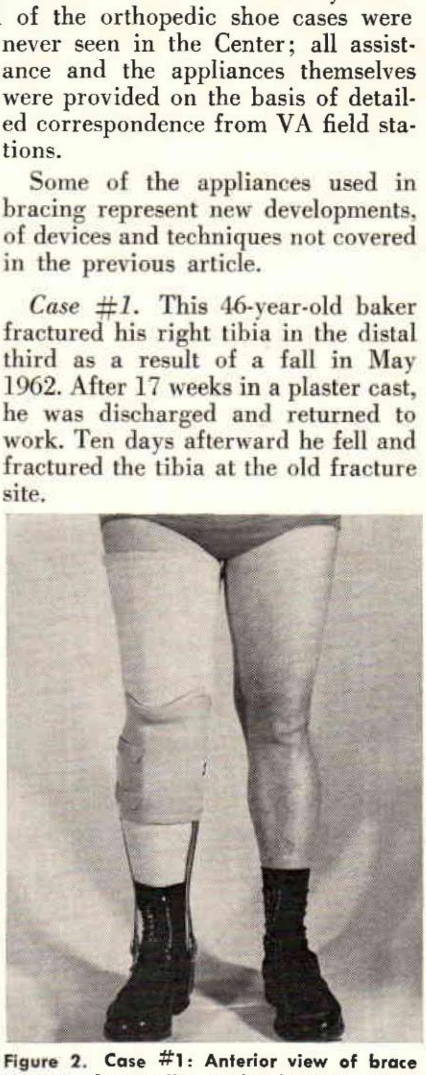

Figure 2. Case #1: Anterior view of brace showing the patellar tendon bearing socket.

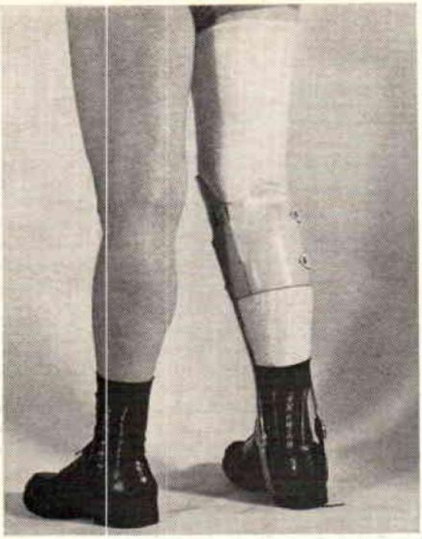

Figure 3. Case #1: Medial posterior view showing hinge for posterior opening.

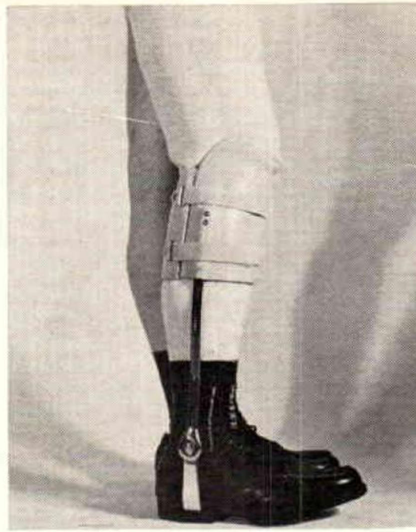

Figure 4. Case #1: Lateral view illustrating Velcro closures.

He was referred to the VAPC in January 1963 for brace prescription. X-rays taken at that time (Fig. 1) showed an old incompletely united fracture of the distal third of the tibia with the fracture line still visible. There was no impairment of the knee-joint.

Brace prescription was as follows: below-knee weight-bearing brace with patellar-tendon-bearing type plastic socket (Fig. 2) with medial hinge (Fig. 3) and Velcro closures (Fig. 4); stainless steel uprights and a stirrup with ankle motion limited to 0° in dorsiflexion and about 10° in plantar flexion; a Sach-type heel and a rocker bar to partially compensate for the limitation of ankle motion.

Patient was fitted with an open-end stump sock and after a short amount of gait training did exceedingly well. The cast was discarded and he was discharged.

He was seen again on a 30-day follow-up. He reported that he was back at work, and the brace socket felt comfortable. Examination of the leg showed weight-bearing to be similar to that of a patellar tendon-bearing prosthesis. His gait was good, with the restriction of ankle motion hardly noticeable.

Case #2. This 43-year-old farmer's case was submitted by the VA Hospital, Wichita, Kansas.

The physician's diagnosis was as follows: patient suffered a compound, comminuted fracture of the left lower extremity from gunshot wounds. Chronic osteomyelitis and deformity

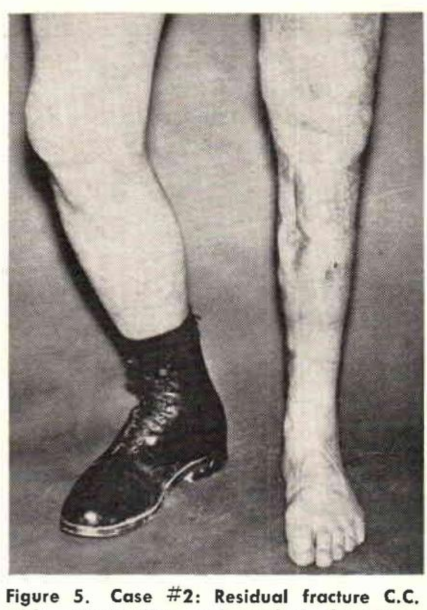

Figure 5. Case #2: Residual fracture C.C. with osteomyelitis and marked shortening.

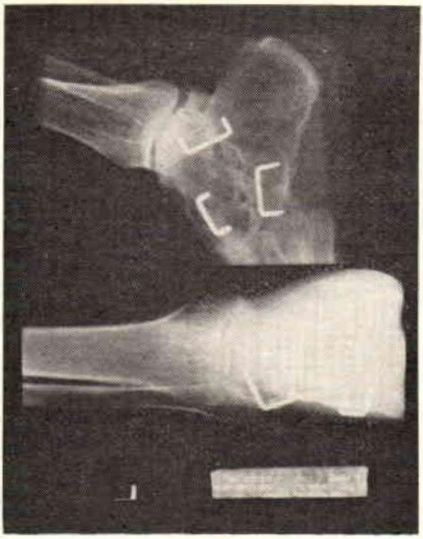

Figure 6. Case #2: Ankylosis, subastragalar: staples in situ.

Figure 7. Case #2: High quarter custom orthopedic shoes with inside cork extension left shoe—attached to leg brace.

of the foot with a $3\frac{1}{2}''$ shortening of the extremity resulted. (Figs. 5 and 6).

Prescription called for high quarter, custom orthopedic shoes with left inside cork extension $3\frac{1}{2}''$ at the heel, $2\frac{5}{8}''$ at the ball and $1\frac{1}{2}''$ at the toe, with leg brace. (Figure 7). Results were gratifying and lasting inasmuch as the patient returned to his farming duties without interruption.

Case #3. This 38-year-old patient fractured his right patella and tibia in a fall from a telephone pole during World War II. In 1949 he developed a popliteal cyst, and an arthrotomy for chrondromalacia was performed. In 1957, he injured his right knee. A debridement was performed which was followed by aseptic arthritis of the knee. He was fitted with an ischial-bearing brace, and the knee became ankylosed. In 1960 he again injured his knee and developed severe pain with a high fever. He had an incision and drainage of an abscess and two decortations of the tibia with packing of the wound.

In 1962 he was referred to the VAPC with a prescription for a weight-bearing leg-thigh brace with a diagnosis of chronic osteomylitis of the right leg. There was a deep wound just below the knee with a scar extending about 10° down the leg (Fig. 8). There had not been any drainage for almost a year with ambulation aided by cast and crutches. He was fitted with a leg-thigh brace with a free motion stirrup at the ankle, stiff knee, plastic quadrilateral socket with medial hinge and Velcro closures (Figs. 9, 10, 11).

During the cast-taking on the casting stand, it was found that the patient could not tolerate complete ischial bearing. And his dissatisfaction with his old ischial ring made it necessary to include an extensive amount of gluteal bearing into the socket. The major portion of his weight is now being borne by the socket, and his gait is satisfactory despite the stiff knee.

There has been no flare-up of the osteomylitis nor any other complications.

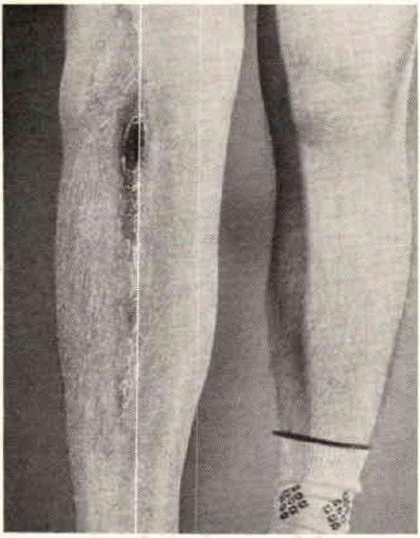

Figure 8. Case #3: Chronic osteomyelitis, post-operative.

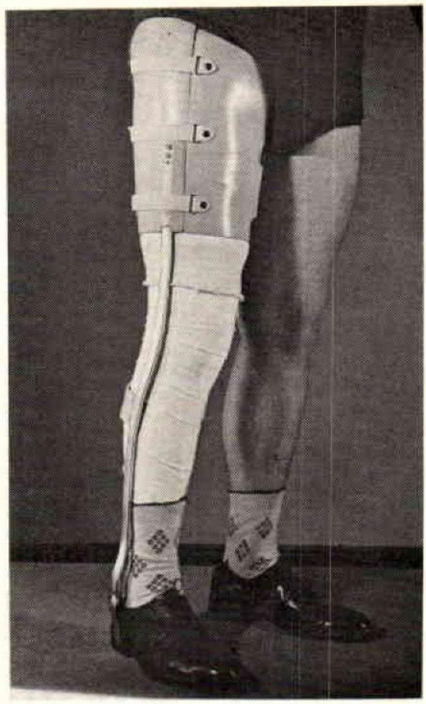

Figure 9. Case #3: Weight-bearing leg-thigh brace with free motion stirrup, stiff knee and plastic quadrilateral socket.

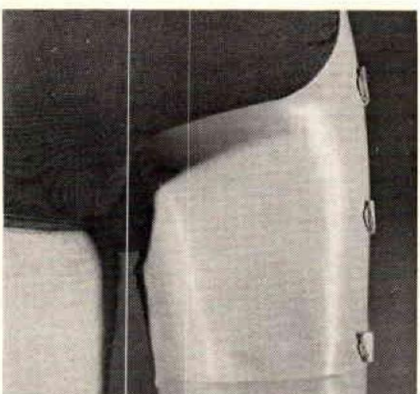

Figure 10. Case #3: Posterior view of socket showing gluteal as well as ischial bearing.

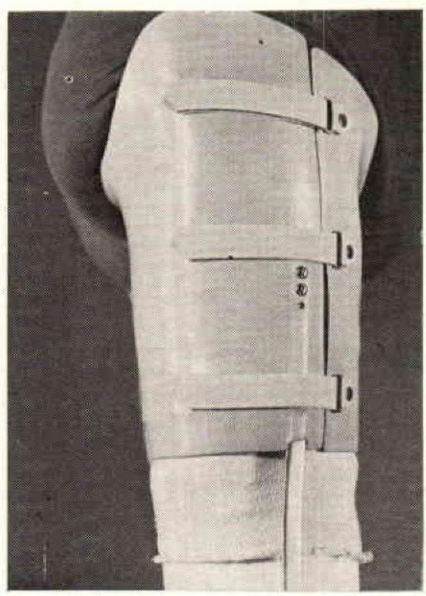

Figure 11. Case #3: Lateral view of socket illustrating anterior opening as well as Velcro closures.

Case #4. This 36-year-old clerk's case was submitted by the VA Center, San Juan, Puerto Rico.

The physician's diagnosis was: Patient suffered a gunshot wound through the mid-portion of the right femur in Korea, 1951. After hospitalization for several years, because of multiple severe complications (osteomyelitis, insertion and removal of endothesis and a subsequent Kuencher intramedullary nail), he was left with a 5″ shortening of the right extremity and an ankylosed knee. (Figs. 12 and 13).

The prescription called for ¾ Chukka, custom orthopedic shoes with a right outside cork extension of 4¾″ heel, 3¼″ ball, 1¼″ toe, with caliper attachment to leg-thigh brace having a molded lacer. Results have been satisfactory with subsequent issues of shoes and brace parts of identical prescription. (Figs. 12, 13, 14).

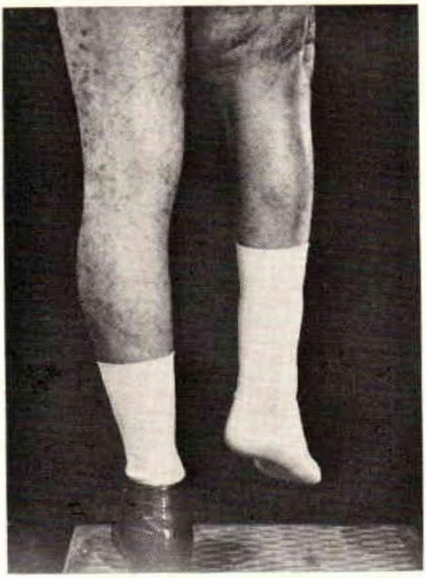

Figure 12. Case #4: Marked shortening of lower extremity and ankylosed knee.

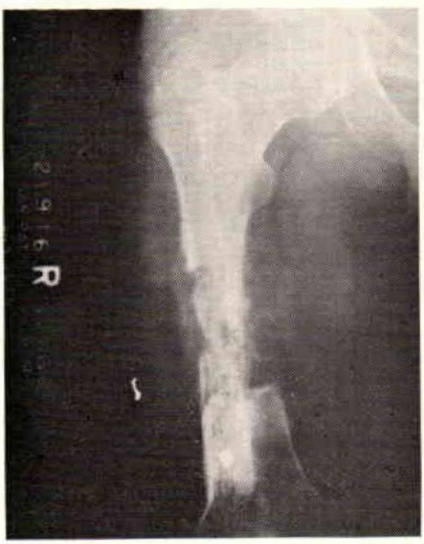

Figure 13. Case #4: Old fracture, C.C., mid portion of the right femur: residual osteomyelitis, large bone defect.

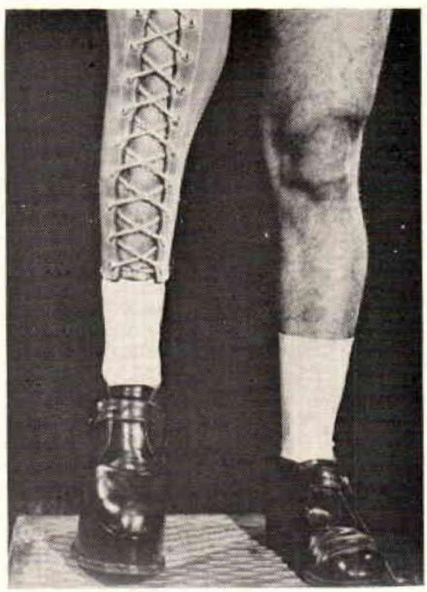

Figure 14. Case #4: ¾ Chukka custom orthopedic shoes with outside cork extension, attached to molded leather leg-thigh brace.

Case #5. A surprisingly large number of patients have been referred to the Orthotic Shop of the VAPC for bracing of ununited fractures of the humerus. While most of these non-unions are the results of World War I injuries, there were some cases of recent origin where surgery for one reason or another did not seem feasible and bracing was prescribed. Since muscle power is usually good in these cases, all that is required for good function of the extremity is a firm support about the area of the non-union. If the non-union is in the middle part of the humerus only a well-fitting upper arm cuff is required, and the shoulder and elbow can be free from bracing. If the injury is close to the shoulder or elbow, bracing will have to include the contiguous joint.

Figure 15 presents a patient with a good portion of the distal humerus missing, and bracing consisted of part rigid, part flexible polyester arm and forearm cuffs with a polycentric elbow joint on the lateral side. The extension of the forearm cuff covering the posterior part of the elbow was requested by the patient, since this area was quite sensitive and readily subjected to injuries by knocking against objects. Since the patient was quite fleshy, a polycentric joint was used to reduce bunching during elbow flexion (Figs. 16 and 17).

With this device the patient could perform most tasks required in his daily routine.

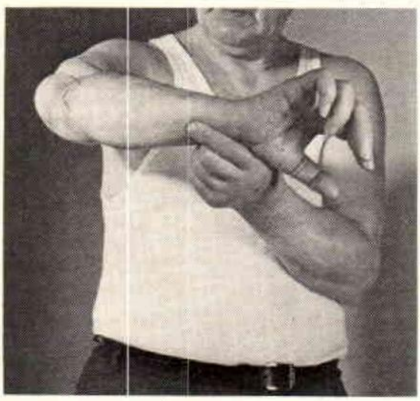

Figure 15. Case #5: Patient rotating forearm demonstrating non-union at elbow.

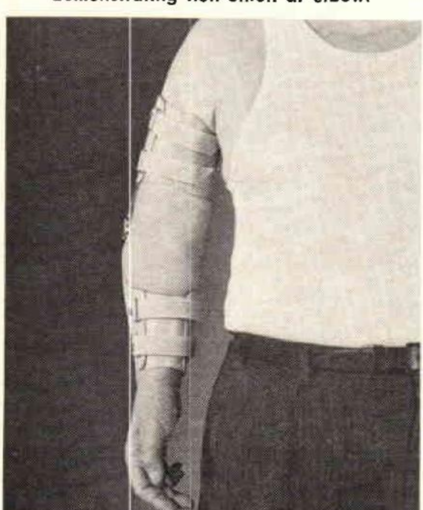

Figure 16. Case #5: Extremity in extension with brace applied.

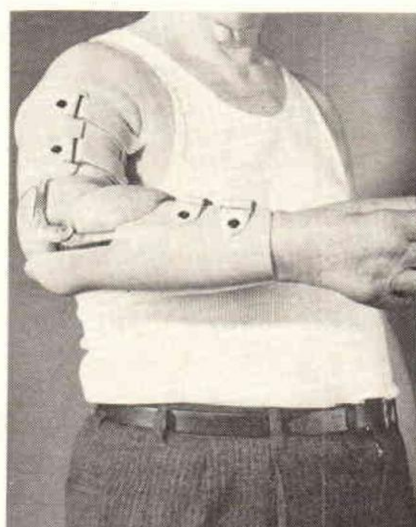

Figure 17. Case #5: Elbow in flexion showing polycentric brace joint and protective elbow shield.

Case #6. This 46-year-old retired veteran's case was submitted by the VA Regional Office, St. Petersburg, Florida.

The physician's diagnosis was: Residuals of compound comminuted fracture of left tibia and fibula with malunion and synostosis; residuals of compound comminuted fracture of right tibia and fibula with malunion and synostosis; residuals of a fracture of right os calcis; ankylosis, mid-tarsal and subastragalar joints, right foot; residual osteomyelitis right heel and right leg, lower third; residual osteomyelitis lower third, left leg; pes planus, acquired, right foot, symptomatic with traumatic arthritis; residual osteomyelitis, left foot; varus deformity, left foot and ankle, with lateral displacement of left ankle and inward rotation; 1" shortening of right extremity. (Fig. 18 and 19).

Prescription called for custom orthopedic shoes with modifications for deformities and 1/8" sponge rubber insoles for cushioning plus inside cork extension of 3/4" heel, 1/2" ball tapered to the toe on the right shoe. Satisfactory results were reported.

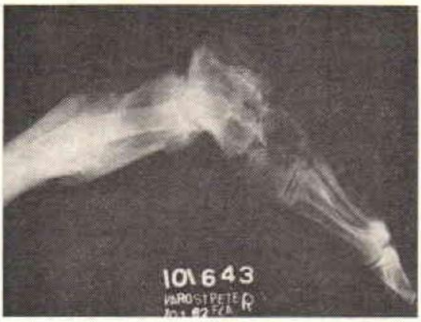

Figure 18. Case #6: Old fracture, C.C. tibia and fibula: malunion: old fracture, OS calcis: ankylosis, subastragalar and mid-tarsal joints: residual osteo-myelitis, leg, lower third, and OS calcis: pes planus.

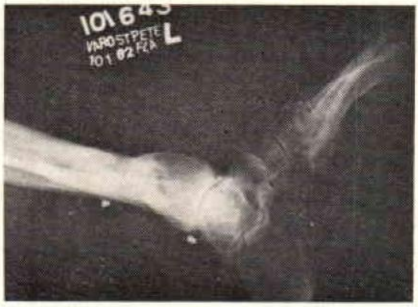

Figure 19. Case #6: Old healed fracture, C.C. of distal tibia and fibula—multiple metallic fragments.

Case #7. The patient (Fig. 20 and 21), a 26-year-old Korean War veteran, had a pneumonectomy performed in 1956 due to advanced pulmonary tuberculosis. He was referred to the VAPC for a protective shield for the heart, the pulsation of which was clearly visible underneath the skin. The apparency of the heart pulsation and distorted thoracic shape were of major concern to the patient.

The appliance (Fig. 22) was fabricated with a rigid center area, which was not in contact with the body, and flexible in all other parts. The center area had perforations for ventilation. A simple chest strap with Velcro fastener served as suspension. The patient wore this appliance continuously for four (4) years; then, the chest strap was replaced and a spare appliance was fabricated for alternate use. The patient, a former truck driver, was retrained as a draftsman and is now gainfully employed.

As this case illustrates, the orthotist may be frequently called upon to fit protective shields for vital organs of the body which have been exposed due to major surgery. These shields have also a cosmetic function since they help to restore as normal an appearance as possible.

Polyester laminates were found to be an excellent material in these cases. A material which allows the orthotist to make an appliance with some parts rigid and others flexible, all in one lamination, has advantages.

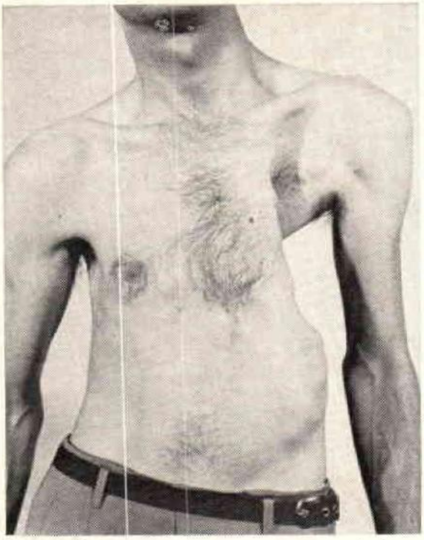

Figure 20. Case #7: Anterior view of chest.

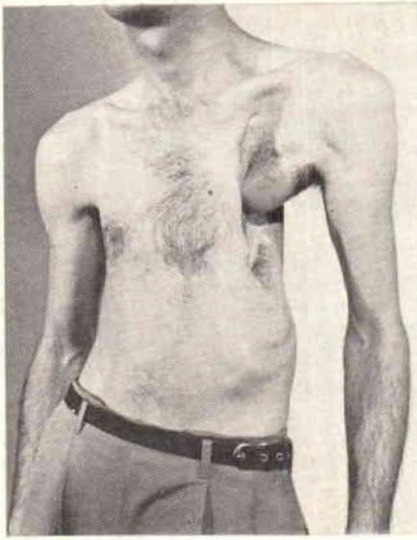

Figure 21. Case #7: Anterior-lateral view.

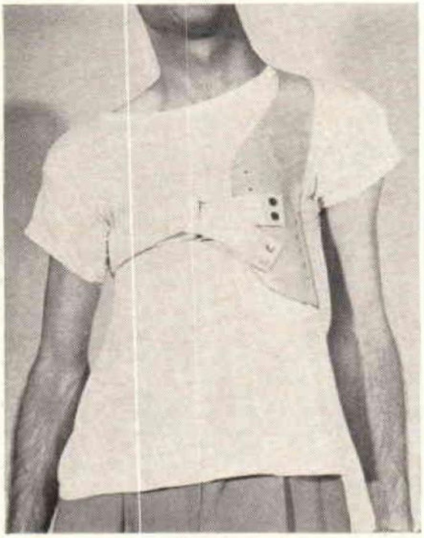

Figure 22. Case #7: Patient wearing protective shield.

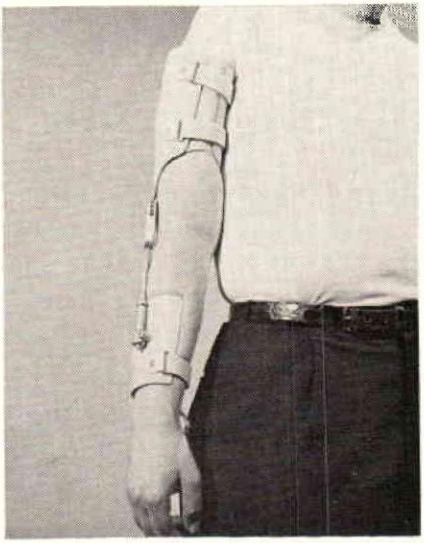

Figure 23. Case #8: Arm in extension with plastic arm cuffs and lateral elbow joint.

Also the neat appearance and ease of cleaning make the resin laminates superior to previously used materials such as metal, leather, celastic, etc.

Case #8. This 28-year-old dentist had polio while in service in 1961. Recovery in the lower extremities was good, but there remained some loss of muscle power in the upper extremities. Muscle tests showed the elbow flexors and pronators on the right to be poor, while on the left, the finger extensors, and abductors and adductors were poor. The patient could feed himself and take care of his toilet needs by using the hand on the right and reaching over with his left hand to flex the right elbow and shoulder.

The patient intended to continue his studies in oral pathology hoping eventually to teach in this field, but he felt some device was needed to

Figure 24. Case #8: Elbow locked in desired working position (about 90°) with the forearm in pronation.

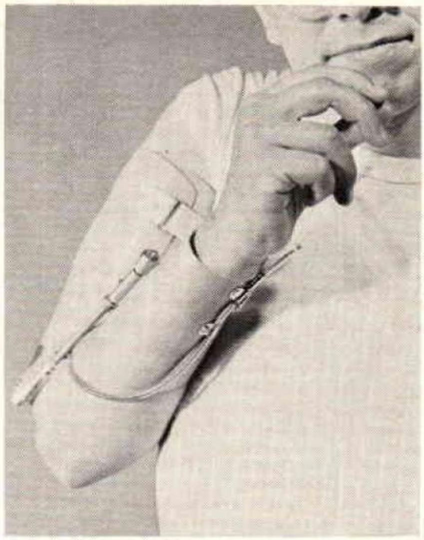

Figure 25. Case #8: Maximum elbow flexion possible with the appliance.

improve the functions of his upper extremities, so he could work on a microscope and at least examine patients.

It was decided to confine bracing to the right side and prescription was as follows: porous plastic upper arm and forearm cuffs with ratchet type elbow lock and pronator assist. Control for the elbow joint was fastened at the volar aspect of the wrist so that the ring finger could be used for operation (Fig. 23, 24, 25). The patient's initial reaction to the device was favorable. The remaining muscle power in the shoulder enabled him to swing the forearm into a maximum flexion of about 110° at which time the ratchet would lock the elbow. His supinators were strong enough to balance out the spring on the pronator assist. This device simplified his eating problems, and the patient was confident it would enable him to pursue his studies as planned.

Case #9. There has long been dissatisfaction by patient as well as orthotists with the conventional brace designs for neuro-muscular disabilities of the lower extremity. The conventional brace with the lock at the knee forces the patient to walk stiff-legged with a circumducted or vaulting gait and requires an excessive amount of energy for ambulation. This dissatisfaction with the conventional brace encouraged experimentation with so-called functional leg-thigh braces, especially in Europe. Ideally these braces would lock the knee during stance phase and allow knee flexion during the swing phase. While success has been claimed with a number of designs, it seems that only a few patients have been fitted. Certainly such braces have not been adopted for general use, probably because of their complex designs which made them heavy, bulky, and expensive. Other negative factors probably were the need for extensive gait training and the frequency of readjustments and repairs.

In experiments with functional knee joints here, some early disappointments were encountered due to complexity of design. Attempts to provide simple devices evolved into the design shown in Fig. 26 in which, instead of a positive lock, the stick control idea of above-knee prosthetics is employed. A piece of tubing containing a spring telescopes on a section of

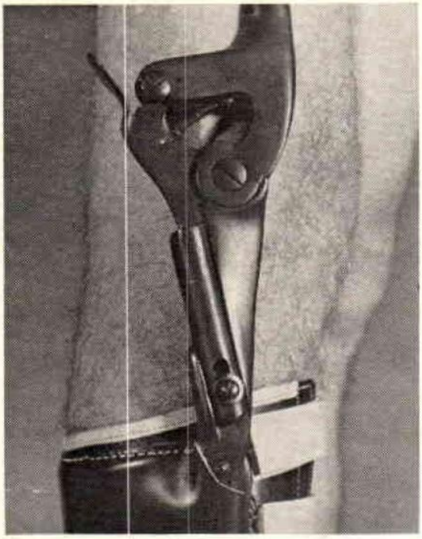

Figure 26. Case #9: Close-up of functional knee joint in full extension.

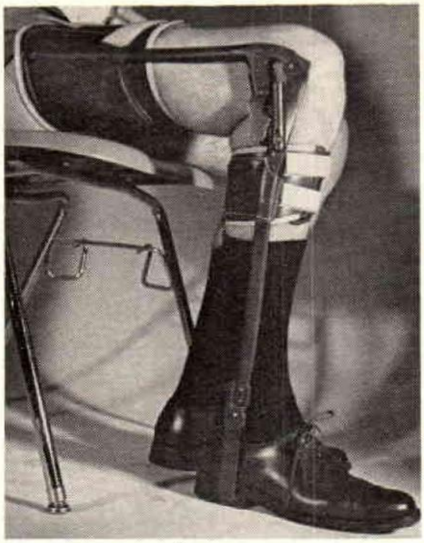

Figure 27. Case #9: Lock has been disengaged for sitting. Plunger will automatically return to "locked" position, when patient rises.

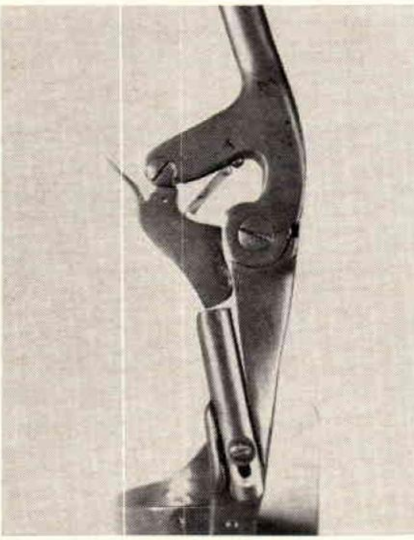

Figure 28. Case #9: Joint in about 20° of flexion. Length of slot in tubing determines the amount of flexion allowed.

Figure 29. Case #9: Anterior view of brace illustrating the single bar construction.

the lower bar. A plunger connected to the upper bar rests on this tubing and as the knee is flexed the spring within this tubing is compressed. This compressed energy in the spring acts as an aid or substitute for the quadriceps in extending the knee. The more the knee is flexed during swing, the greater the force of the extension aid provided by the spring. The length of the slot in the lower part of the tubing determines the maximum amount of flexion allowed, and the slot end serves as a safety stop. The plunger can be pivoted out of position permitting the patient to sit with a flexed

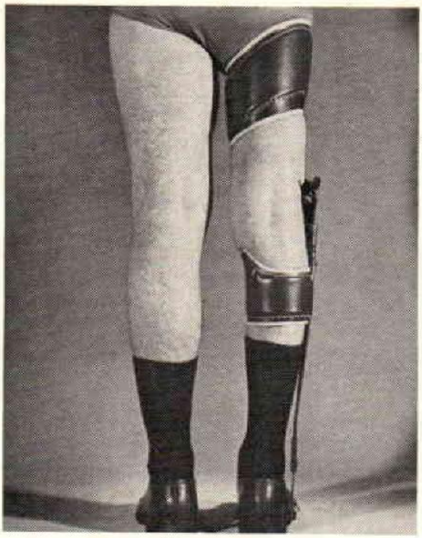

Figure 30. Case #9: Posterior view of brace. Note the fitting of the calf band supporting the medial condyle of the tibia.

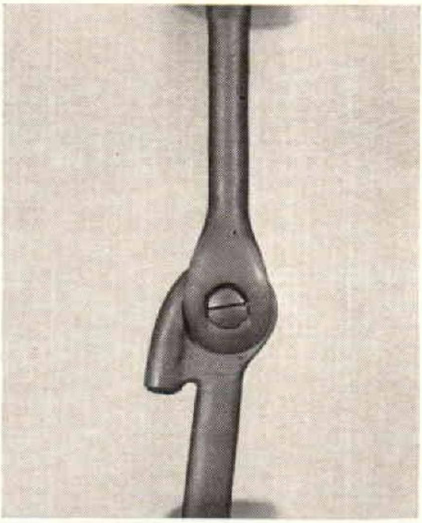

Figure 31. The second version of the function knee joint illustrating its simplicity.

knee (Fig. 27). The spring-loaded plunger will automatically return to the "locked" position as the patient rises.

The first patient fitted with this device is a 33-year-old accountant who contracted polio in Korea in 1951. His recovery was good with the exception of the right lower extremity, which was then described as poor. Although issued a conventional leg-thigh brace, he attempted to get along without a brace. While he was able to walk for short distances, he frequently fell due to knee buckling. One of these falls resulted in a fracture of the patella; he then decided to wear his brace.

When seen by the VAPC clinic team in January 1963, he was wearing the conventional double-bar leg-thigh brace with the ring lock at the knee, a knee cap, and a spring-loaded equinus-control stirrup. He was interested in reducing the amount of bracing and in improvement of his gait. The results of muscle test taken at this time were:

Hip: Flexors—poor; Extensors—fair

Knee: Flexors—fair to good; Extensors—trace

Ankle: Plantar flexors—good; Dorsiflexors—poor

Prescription by the clinic team was: functional knee lock with 20° of maximum flexion initially, unilateral bar, and spring-loaded equinus-control stirrup. During fitting several spring rates were tried, and the design found most suitable for this particular patient had a resistance moment of approximately 154 in. lbs. at 20° of flexion (Fig. 28).

Initial reaction to the brace was quite favorable. The patient did very well and after a short period of gait training; the amount of maximum flexion was increased to about 30°. A follow-up visit found the patient very pleased with the device. His gait was improved, and he stated he could walk with less effort and for greater distances (Figs. 29 and 30).

An improved version of this type of knee lock has been designed. It consists of a commercially available plunger type knee lock with tubular steel uprights modified in the following way: the flexion stop in the lower bar is replaced by a curved tubing, which houses a ball bearing, spring, and

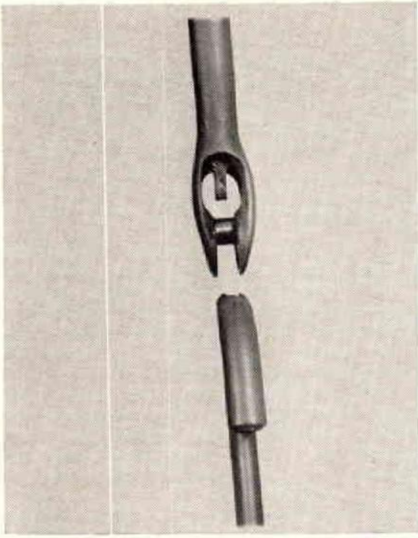

Figure 32. Posterior view (exploded) of joint showing plunger and clearance in upper bar for the tubing of the lower bar.

Figure 33. Lateral view of brace with simplified functional knee joint: lock is released to allow patient to sit.

adjustment screw. When the plunger is in the "locked" position, it can travel in a slot in the tubing against spring pressure allowing knee flexion. The length of the slot determines the maximum amount of knee flexion during walking (Fig. 31 and 32). The upper bar was modified to permit clearance for the tubing when the "lock" is released for sitting (Fig. 33). The advantages of this design over the first model are compactness and spring load adjustability.

The reaction of a second user, who had a flail right lower extremity due to polio and complained of back pains, was quite favorable at the time of initial fitting. He was highly pleased with the ability to flex his knee after having walked "stiff-legged" for about 18 years. The extension assist appeared to be essential since he could not walk with the device once the tension on the spring was released. It is hoped that after a period of gait training he will be able to manage the device fully. A reduction in the effort necessary for walking may reduce the back pains most likely due to the strain of the vaulting gait forced upon him by the conventional knee-lock.

Case #10. This 34-year-old clerk is a paraplegic (D-11) due to injuries received in service in 1945. He had the usual training for ambulation with braces and crutches, but soon after discharge discarded these devices and used a wheelchair exclusively. In recent years, repeated hospitalization was required for bladder and kidney problems. When seen by the VAPC clinic team in January 1963, he expressed the desire to use braces again with the hope of minimizing his bladder and kidney problems. He felt, if the bulk of the braces could be reduced, he could sit comfortably in his wheelchair wearing his braces the full day. And it would be possible for him to stand up either at the desk in his office or at the kitchen counter at home.

Muscle tests taken at this time rated both lower extremities as zero with a moderate amount of spasticity. Brace prescription called for single-bar leg-thigh braces of steel, ring locks at the knee, and equinus-stop stirrups.

With the aid of these braces, the patient noticed better balance (than with his old braces), less effort in ambulating between parallel bars, and greater comfort when sitting in the wheelchair (Fig. 34, 35, and 36).

A 30-day follow-up showed no undue wear on the braces, and the patient was satisfied.

While the single-bar principle has been used occasionally in the past, it has never been very popular until Russell V. Fuldner, M.D. and Mr. Joseph Rosenberger (P. & O.) started using it on the "Newington Cerebral Palsy Brace." Encouraged by their success, VAPC started investigation of single-bar bracing in other disabilities such as polio, paraplegia, hemiplegia, and multiple sclerosis.

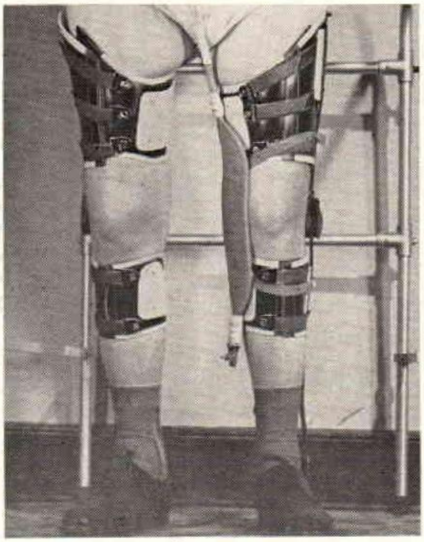

Figure 34. Case #10: Anterior view of patient standing with single bar braces. Note the absence of knee caps.

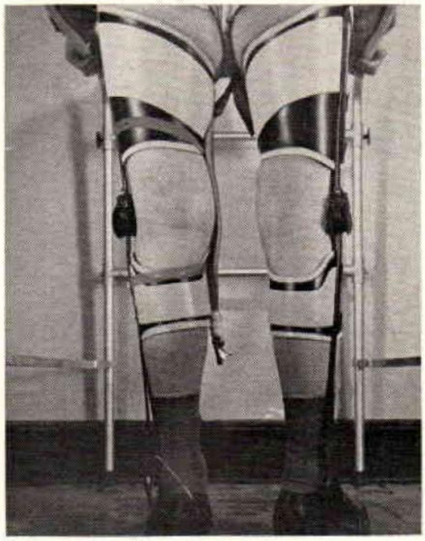

Figure 35. Case #10: Posterior view illustrating the absence of medial bracing.

The advantages of single bar bracing accrue to both patient and orthotist. The elimination of the medial bar reduces the bulk of the brace and makes it a much more comfortable device especially for a bilateral brace wearer who might need to wear other apparatus such as the urinary appliance worn by the case illustrated here. The reduction in the weight of the device is, of course, greatly appreciated by the patient, whose muscle power is far below normal. From the orthotist's point of view, precise brace joint location in relation to the joint being braced can be accomplished much more readily with a single bar.

Accommodation of tibial torsion, to which the ankle joint location studies being conducted by the University of California (San Francisco) has called attention recently, can more readily be built into the single upright construction than into a double-bar brace. Varus and valgus corrections at the ankle as well as "toe-out" can be adjusted rather easily on the single bar even at the final fitting, while attempted changes of this nature in the double bar brace will only result in stressing the joints and band rivets.

It has been quite frequently claimed that it is difficult to achieve stability and to prevent undue rotation of the extremity within this type of a brace. But rotation of the extremity within the brace is not prevented by the uprights alone. This function is mainly performed by the shoe, the calf band and cuff, and the thigh bands and cuff in assembly with the uprights. If the bands and cuffs of a brace are fitted loosely, the brace uprights will not provide any kind of stabilization no matter how strong or stiff.

Nevertheless, it is necessary, in a single bar brace, to design the upright and its joints with sufficient strength and stiffness to support the extremity and to absorb the loads transmitted by the bands and cuffs.

On a patient with a flail lower extremity, it has been found that by supporting the following areas with bands and cuffs, better stabilization accrues with the single bar brace:

1. The lateral-posterior part of the thigh just below the greater trochanter along the gluteal fold.
2. The medial-anterior portion of the thigh as close to the knee as possible.
3. The medial flare of the tibia.

In addition, the foot must be supported by a properly fitted shoe.

The cuffs and bands have been used in the following way: one thigh band fitted high just below the greater trochanter and along the gluteal fold laterally and posteriorly, but then curving down rather sharply on the medial side so that the lower edge of the band is about 4″ above knee-center in the anterior medial area. This design frees the medial upper portion of the thigh from bracing and is greatly appreciated by the patient, especially the bilateral brace wearer. A medial "roll" will not develop from this design since the thigh cuff is simply supportive and not weight-bearing. The calf band is located at mid-calf, but the medial portion is extended to fit into the medial flare of the tibia. This extension of the calf band has made it possible to eliminate the knee cap in this design, even for those patients accustomed to knee caps for a great number of years.

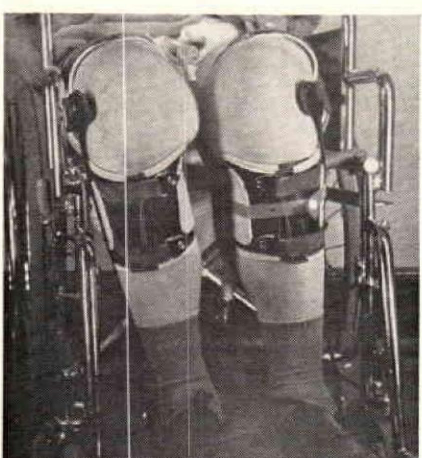

Figure 36. Case #10: Patient in wheelchair wearing braces.

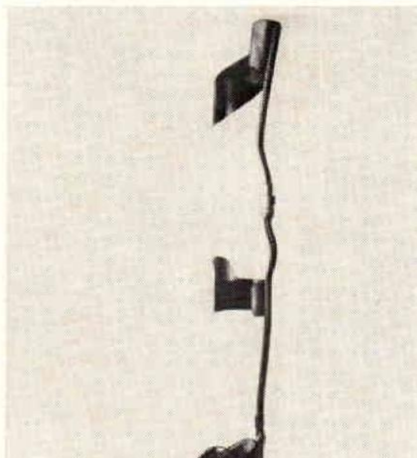

Figure 37. Anterior view of metal frame of single bar brace. Note the shape of the calf band for support of the medial tibial condyle.

Both bands are made to encircle about 2/3 of the extremity, leaving only enough anterior opening for easy entry of the patient (Fig. 37). This is a variation from the conventional half-bands.

For uprights and joints commercially available parts were at first used even though it was recognized that they were not ideally suited for the purpose. There were no suitable stirrups available, so these had to be custom-made.

Experience, had with about 10 patients, suggests that the lower-extremity can be properly supported with this type of appliance. But most brace parts commercially available today are not designed for use in single bar braces; there have been prosthetic knee joints with ball bearings available for many years, but brace joints, with the exception of cerebral palsy brace components, have not been produced with bearings. One manufacturer recently started producing a brace joint with thrust bearings in aluminum uprights. Such a joint will help because it appears that ball-bearing joints will be needed at the hip, knee and ankle of a single bar brace.

The commonly used rectangular bar is probably not the best shape for this design. The commercially available oval steel tubing upright, from a structural point-of-view, is quite adequate and was used on a number of patients. The great difficulty in changing the shape of the tubing after the brace has been assembled has prevented it from being universally adopted for double bar braces. This problem is greatly reduced in the single bar brace since there is much less shaping required on a lateral bar than on the medial bar for a lower extremity brace.

Fitting of patients with single bar braces will be continued, using presently available parts. But tests of different shapes such as round, oval, square, etc., and different types of metal, such as steel, aluminum, titanium, will be performed.

Experiences with single bar bracing indicate that the design as described above is adequate. The advantages for the patient and the orthotist are significant. Presently available brace uprights and joints, while suitable for some cases, especially in flail polios, need some redesign however for best application of the single bar brace to all cases with neuro-muscular disabilities including spastics.