Orthotics and Prosthetics, Vol. 40, No. 1, pp. 33–37.

Floor Reaction Orthosis: Clinical Experience

Gai-Fu W. Yang, M.D., R.P.T.
Dong S. Chu, M.D.
Jung H. Ahn, M.D.
Hans R. Lehneis, Ph.D., C.P.O.
Richard M. Conceicao, B.A., C.P.O.

In clinical practice, the knee-ankle-foot orthosis (KAFO) with locked knee joint and limited ankle motion has been used for patients with paraplegia or paraparesis due to various etiologies. Patients who use such an orthosis walk with a rigid knee and an unphysiologic gait.

Several attempts were made to design an ankle-foot orthosis (AFO) which would stabilize the knee joint with weak quadriceps femoris muscles and facilitate a near normal gait. In 1969, a supracondylar knee-ankle orthosis[3] (SKO) and, in 1979, a Saltiel Brace[4] (SB) were introduced and were characterized by free knee flexion, limited knee extension, and a solid ankle. Both orthoses were difficult to don. In addition, the SB did not provide adequate mediolateral stability to the knee joint. In 1973, after many modifications, a Kumamoto University short leg brace[5] (KU-SLB) became available primarily for poliomyelitis patients who had residual paraparesis. The KU-SLB had a single plastic upright on the back of the leg and supracondylar support with a cut-out for the patella. All three of these orthoses described above were constructed with the ankle in the equinus position to increase mechanical stability of the knee joint. Thus, the stance phase of the gait cycle was initiated with toe touch or foot flat instead of heel strike. The patients who wore these three types of othorses had trouble sometimes with stumbling or had difficulties in descending slopes or stairs. We will illustrate here a floor reaction orthosis (FRO), with an attempt to improve the above described deficiencies, and its use in gait training for three paraparetic patients.

CASE REPORTS

E.J. is a 33-year-old male who sustained a fracture and dislocation of T11-12 in an airplane accident. He became immediately paraplegic below the level of T12 and first experienced slight voluntary movements of his left toes about two months after the accident. The muscle strength recovered gradually and two years later he was able to

Figure 1. Floor reaction orthosis. Note the neutral position of the subtalar joint.

walk with a right KAFO with an ischial seat/locked knee, a left conventional AFO and two forearm crutches.

Unfortunately, he developed contractures of both Achilles tendons, which had to be lengthened surgically. After the operations, his left lower limb became weaker so he began using bilateral KAFOs and forearm crutches for ambulation. Following intensive strengthening exercises, the strength of his quadriceps femoris muscles was fair minus on the left and poor plus on the right side, with manual muscle testing[1] (MMT). At this time, an FRO was prescribed for his left lower limb (Figure 1).

The second case is that of an 18-year-old male, D.W., who became paraplegic secondary to anterior spinal artery syndrome. One week after the onset of T10 paraplegia, he noted the return of muscular strength in the right lower limb. One month later, his M.M.T. showed poor minus for the right and trace for the left quadriceps femoris muscles, and he ambulated between parallel bars with bilateral Scott-Craig braces using a swing-to gait. When the strength of the right quadriceps femoris muscles improved to fair minus, a Zimmer splint or "handy standy" was applied to the right lower limb, along with a walker to assist the patient in ambulation. However, the patient was not satisfied with these devices. An FRO was then provided and was accepted by the patient (Figures 2, 3).

Figure 2. The second patient with a left floor reaction orthosis ascends the stairs.

A 56 year-old diabetic female, E.M., woke up one morning, got out of bed and fell because of weakness of the left lower limb. Soon she became paraplegic, and then quadriplegic for two weeks. Electromyographic studies revealed a severe demyelinating neuropathy consistent with Guillain-Barre syndrome.

She exhibited steady improvement in muscle strength, particularly in both upper limbs and the right lower limb. She began to ambulate between parallel bars in the pool, then outside the pool with bilateral "handy standies." Within two weeks, she

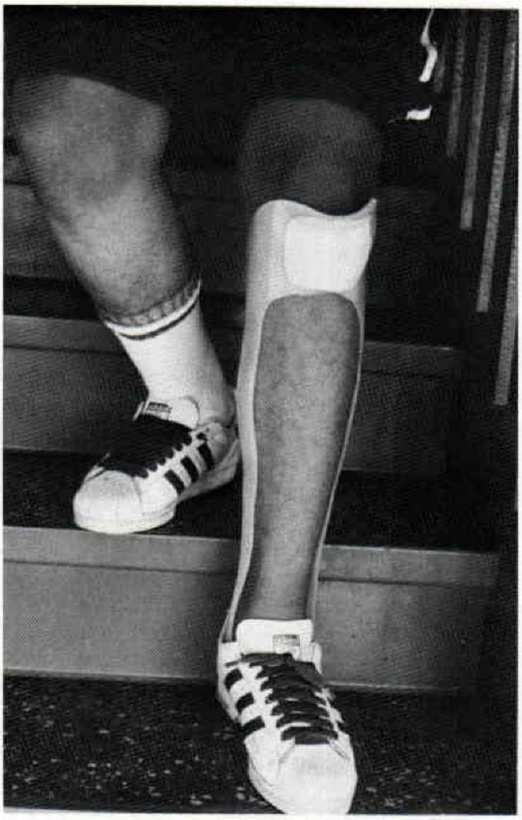

Figure 3. The second patient descends the stairs with a left floor reaction orthosis.

Figure 4. The third patient with a right floor reaction orthosis.

progressed to walking with a right Zimmer splint/posterior leaf spring AFO, left "handy standy"/toe strap, and rolling platform walker. As soon as the strength of the right quadriceps femoris muscles reached fair minus, an FRO was made for the right lower limb (Figure 4). A plastic KAFO with metal knee and ankle joints was prepared for the left lower limb.

All three patients described above were found to be excellent candidates for FROs. They were well motivated and the strength of their quadriceps femoris muscles was improving to at least a fair minus level. If they had one AFO, they met almost all of the requirements for functional community ambulation.[2] After a short period of rehabilitation training, they walked well with their FROs and accepted the FRO as an assistive functional device for ambulation.

CASTING AND FABRICATION

The patient is seated in a casting chair, and all bony prominences are identified with an indelible pencil. A latex rubber tube is run anteriorly over the dorsum of the foot along the tibial crest to the level of the fibular neck. The tube then winds medially to the mid anterior-posterior dimension of the knee. This allows the negative impression to be sectioned for removal, yet it can be properly "keyed in" for exact placement and orientation. A length of tubeguaze stockinette is placed over the limb to act as a cast separator, and the shank is then wrapped with elastic plastic bandage to the level of the fibular neck.

The foot is then placed on a footboard in neutral subtalar position with slight plantar flexion to accommodate the heel height of the patient's shoe. Care must be taken to position the foot in the correct amount of toe out, and to maintain the shank in proper orientation to mid-saggital alignment.

When the ankle-foot section has hardened, the knee is extended to approximately 15 degrees of flexion and wrapped with plaster bandage to the level of the proximal border of the patella. The patellar tendon is then outlined as a reaction point from the floor for knee extension by compressing with thumb and forefinger pressure in the same manner as with a below knee patellar tendon bearing (PTB) orthosis casting. Since weight bearing is not a consideration, the popliteal area and contour of the posterior calf need not be disturbed.

The negative impression is removed and filled in preparation for modification. Modification follows standard procedures with plaster buildups over all bony prominences for pressure relief. The footplate is fully modified for support of the medial and lateral longitudinal arches. In addition, a slightly more aggressive modification is made under the sustentaculum tali and transverse metatarsal arch to provide a stable base for the calcaneus in a slight plantar flexion position and comfortable distal reaction point under the metatarsal heads.

The patellar tendon is now isolated. Although not an area covered by the orthosis, the patella was included in the negative impression so that the tendon modification could be properly oriented with respect to natural toe out. If this is not done, the orthosis will tend to rotate medially or laterally and begin to impinge on the femoral condyles. The positive model is then smoothed, coated with a parting lacquer and covered with nylon hose in preparation for vacuum forming.

A 3/16" thick sheet of copolymer (polyethylene-polypropylene composite) is drape vacuum-formed over the positive model from posterior to anterior, creating an anterior seam. In the area of the patellar tendon, the seam is pinched together tightly with Teflon sheeting to ensure good bonding at this point. When this technique is performed with the plastic material at the proper temperature, there is no need for plastic welding equipment or other bonding agents to maintain the structural integrity. The positive model is broken out, and the orthosis is trimmed and smoothed for fitting.

DISCUSSION

The major advantage of the FRO is that, besides stabilizing the ankle and subtalar joints, it assists the knee extension capabilities of the patient with fair minus strength in their quadriceps femoris muscles, and therefore helps prevent the knee joint from buckling. The KAFO can accomplish these functions, but its use frequently results in overbracing of the patient as well as increased energy consumption. The ankle of the FRO is almost in the neutral position, so that the patient can begin his gait cycle with heel strike and descend stairs more easily than if he were using the SKO, SB, or KU-SLB. The gait pattern with this orthosis is more physiologic, because it provides opportunity for the quadriceps femoris muscles with fair minus strength to work as the patient walks. Also, provided the patient feels reasonably secure, the FRO gives him a sense of freedom and control over external devices.

The FRO shares all the advantages of those orthoses made with plastic materials. Its weight is much less than that of a conventional KAFO (0.3 kgs. vs. 2.2 kgs. avg.). This device is molded to provide total contact, thus preventing pressure sores over bony prominences. The patients report that it is more comfortable, more cosmetically appealing than their old orthoses, and can fit into a regular shoe using normal trousers. It is cleaned easily with mild soap and water, and has no movable parts which would require maintenance.

However, the acceptance of the FRO has been hampered by a number of factors. The first factor is the cost. Older designs were fabricated from polyester and acrylic laminates. Not only are these materials relatively expensive but their use in fabrication is very time consuming. Vacuum forming techniques utilizing thermoplastic sheeting offer a quick, inexpensive alternative. The material cost is lower but, perhaps more importantly, the time required for fabrication is approximately one-third less.

A second main difficulty with this orthosis has been its lack of adjustability in the degree of ankle equinus, and consequently the amount of knee extension moment control force. As the principle goes, the more plantar flexion in the orthosis, the more extension force applied at the knee joint. The stability of the knee is enhanced, but so is the resistance to forward progression. Reducing the degree of plantar flexion allows more forward motion to occur in the gait cycle before the maximal extension force is generated.

This produces a smooth gait, but decreases the stability requiring more active control and strength in the quadriceps femoris. The optimum tibial-talar angle in this FRO then is at the proper balance between these two conflicting considerations, and provides maximal function. This angle is different for each individual and may vary over a period of time. Attaining and maintaining this optimum configuration prior to actual ambulation is exceedingly difficult, especially when the patient's clinical picture is changing.

By casting for the orthosis on a footboard higher than the intended heel height of the shoe, the entire device will be maximally plantar-flexed. From this starting point, the device can be selectively destabilized by filling the "space" between the orthosis heel height and that of the shoe. This maneuver changes the reaction dynamics of the orthosis. It gives an effect similar to dorsiflexing the entire component. In this sense the FRO is far more adjustable, and can be modified to either fine tune the gait or alter it as the individual condition changes. The orthosis can then be remade at a suitable angle or left in a readily adjustable state.

AUTHORS

The authors may be contacted through the Rusk Institute of Rehabilitation Medicine, New York University Medical Center, 400 East 34th Street, New York, NY 10016.

REFERENCES

[1]Daniels L., Worthingham, *Muscle Testing, Techniques of Manual Examination,* Fourth Edition, Philadelphia, London, Toronto, W.B. Saunders Co., 1980.

[2]Hussey R.W., Stauffer, E.S., "Spinal cord injury: Requirements for ambulation," *Archives of Physical Medicine and Rehabilitation,* 54, pp. 544–547, 1973.

[3]Lehneis, H.R.: "New concepts in lower extremity orthoses," *Medical Clinics of North America,* 53, pp. 585–592, 1969.

[4]Saltiel, J., "A one-piece laminated knee locking short leg brace," *Orthotics and Prosthetics* 23, 68–75, 1979.

[5]Watanabe H., Yonemitsu H., "Short leg brace for knee extensor weakness (KU short leg brace)," *Kumamoto Medical J.,* 26, pp. 90–95, 1973.

EDITOR'S NOTE

Another resource is: "Use of the Anterior Floor Reaction Orthosis in Patients with Cerebral Palsy," Edwin D. Harrington, M.D., Robert S. Lin, C.O., James R. Gage, M.D., *Orthotics and Prosthetics,* Vol. 37, #4, pp. 34–42, Winter, 1983–84.