Hip, Knee, Ankle Foot Orthosis: Lateral Bar Design With Spring Extension Assist Hip Joints

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INTRODUCTION

The lateral bar, hip, knee and ankle foot orthosis (HKAFO) was developed for patients who need an orthosis beyond the Parapodium, developed by W. M. Motlock, at the Ontario Crippled Children's Center, Toronto, Canada. This orthosis has been successfully used for patients with muscular dystrophy, spina bifida, cerebral palsy and traumatic injuries resulting in parapareses or paraplegia. Variations in design and materials have made it possible to fabricate orthoses for a broad age group of patients with neuromuscular involvement. In the case of spina bifida, the patient who graduates to the HKAFO from a Parapodium will sacrifice the free standing feature of the Parapodium, but may gain the opportunity to ambulate with a reciprocating or swing-type gait (Fig. 1).

As many of our patients approach adolescence, they express the desire to become independent; an orthosis that is cosmetically acceptable is of great importance. Acceptance of the orthosis is made easier because the orthosis can be covered, and the patient can function with new freedom. In the treatment of many patients, the need to control knee, ankle and hip contractures

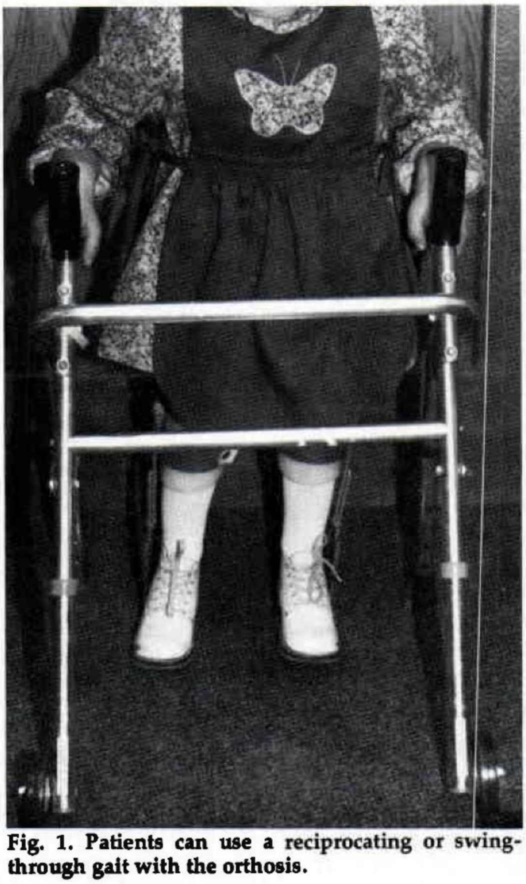

Fig. 1. Patients can use a reciprocating or swing-through gait with the orthosis.

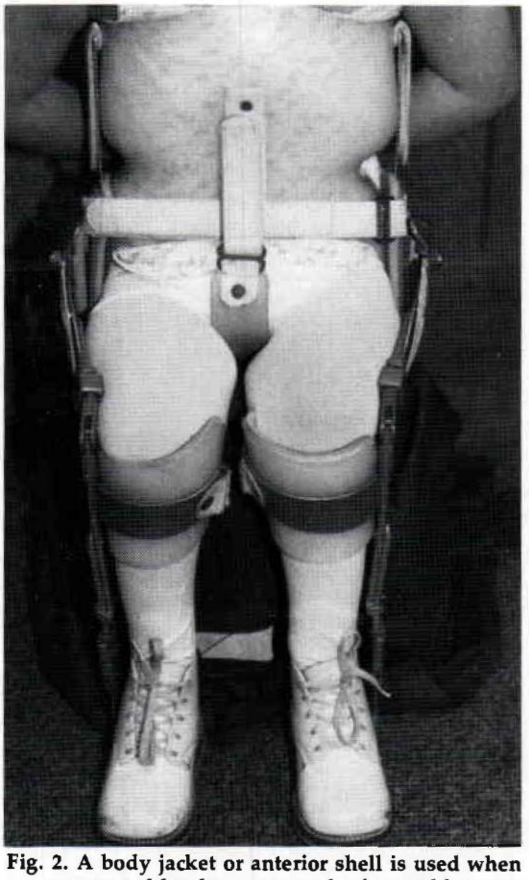

Fig. 2. A body jacket or anterior shell is used when an exaggerated lumbar curve and a forward lean are present.

to facilitate future ambulation is an ever-present challenge. This orthosis, with a three-point force design, maintains a neutral knee, ankle, and hip, once contractures have been reduced by physical therapy or surgery. When hips are so contracted that an exaggerated lumbar curve is visible and a forward lean is present, a body jacket or an anterior thoracic abdominal shell or a pad may be used to create a counter force (Fig. 2).

In the past, double upright orthoses with knee pad design were made of aluminum (Fig. 3). These orthoses were not only bulky, but functionally they fell short of accomplishing independence for the average patient. The breakage rate was very high, resulting in the device spending more time in the lab than on the patient. The breakage problem has been reduced with the use of stainless steel for strength and polypropylene for flexibility.

The beneficial features of the Parapodium were not present in the standard double upright with knee pads and pelvic band. The foremost accomplishment in the design of the HKAFO was to maintain the three-point force system as in the Parapodium (Figs. 4A, 4B). The conventional double upright with pelvic band offers very little in functional design. In the past, a hip joint that unlocked easily and would release even when the patient exerted force on it by leaning forward was not available. The hip joint designed for the HKAFO is fabricated with a spring that can be varied in size and strength. It is possible to vary the tension of the spring to achieve mild or forceful hip extension as well as a deterrent against contractures. This hip joint will also allow the young patient, who may be frightened to release the hips while standing, to lean back in the chair first and then release the hips.

Fig. 3. Conventional double upright designs are bulkier and have a higher incidence of breakage.

Fig. 4-A. The Parapodium uses a basic 3-point force system to stabilize the patient.

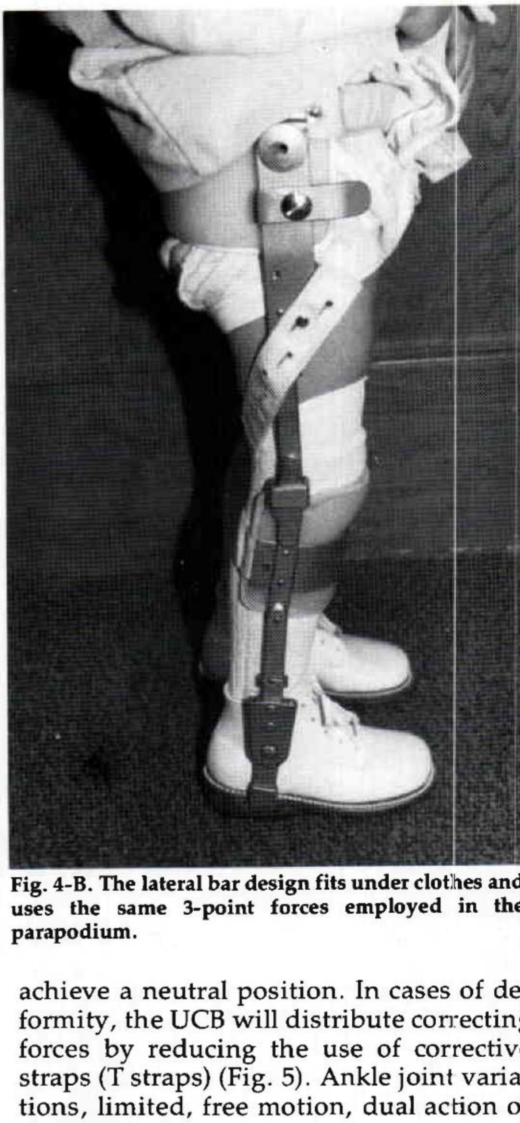

Fig. 4-B. The lateral bar design fits under clothes and uses the same 3-point forces employed in the parapodium.

DESCRIPTION OF COMPONENTS

Because of the disparity in age and other characteristics of the patients who are fitted with the lateral bar orthosis, each component of the orthosis is gauged in strength and size to the functional deficit of the patient, and to his age, weight and height. Components of each joint articulation, ankle, knee and hip are carefully chosen to use the patients' residual functions and to apply proper corrective or supportive forces where needed. For example, foot orthoses such as the UCB or arch support inserts are often used to achieve the most suitable ankle foot alignment, and to distribute weight over a larger supported area. If possible, the ankle and foot should achieve a neutral position. In cases of deformity, the UCB will distribute correcting forces by reducing the use of corrective straps (T straps) (Fig. 5). Ankle joint variations, limited, free motion, dual action or dorsiflexion assist are chosen as per anatomical and functional need.

The basic orthosis from the shoe proximal consists as follows: a caliper plate with lateral 90° stainless steel (SS) extension split stirrup with SS drop lock, which slides over the 90° SS extension. This achieves solid fixation to the caliper and eliminates use of straps to maintain stirrups in caliper.

The ankle joint (SS) is chosen as per functional deficit. There is an overlap of the ankle upright and lower knee joint, which is used for growth adjustments (not needed in adults).

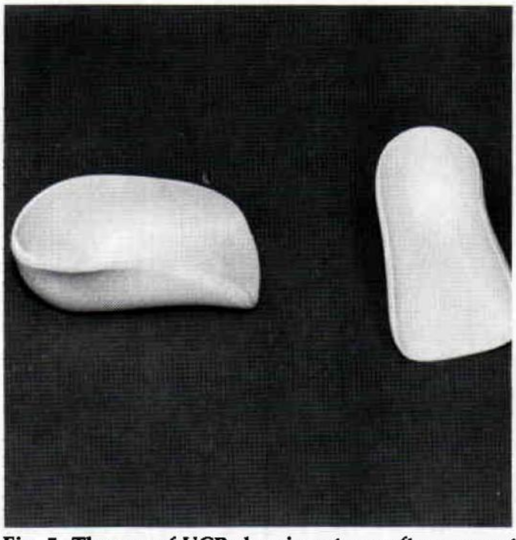

Fig. 5. The use of UCB shoe insert can oftem correct foot deformities without the need for corrective straps.

Fig. 6. Anterior view. Note the pretibial band of polypropylene reinforced with stainless steel.

KNEE JOINT DESIGN

Knee joints may be used with or without drop lock. The lock is not used when tension of the ankle joint and extension assist hip joint will maintain the knee in 180° upon weight bearing; this will allow the patient to ambulate with the free knee. A pre-tibial band is fabricated of polypropylene varying in thicknesses of $^{90}/_{1000}''$, $^{1}/_{8}''$, $^{3}/_{16}''$, and $^{1}/_{4}''$ (Fig. 6). Plastic is formed over the anterior medial lateral plaster splint of the knee. The lining is $^{1}/_{8}''$ or $^{1}/_{4}''$ Plastazote or Pelite. This band is reinforced with a stainless steel band anterior, shaped to the plastic and attached to the lateral knee joints. The thigh knee joint section overlaps with the hip joint to form growth adjustment.

Knee hyperextension is prevented by a popliteal strap (Fig. 7). This strap loosens when the patient sits because of its placement. When the patient stands, the strap tightens for posterior support during ambulation. The popliteal strap is positioned the same distance above the mechanical knee joint center as the distal attachment. A polyester 1" or 1½" strap crosses posterior from lateral calf to medial pre-tibial through a loop and back posterior to the knee support lateral upright, where it attaches to the truss stud or Velcro® loop. The medial attachment should be posterior to the vertical midline of the knee. Thigh enclosures are not needed. Foot, knee and pelvic band are aligned using a three-point force system. The advantages of this strap are increased sitting balance and comfort due to the lack of posterior thigh bands, and the reduction in number of adjustments due to growth. The orthosis eliminates forces on already taxed joints in the sitting position (Fig. 8). The advantages of an orthosis designed without thigh cuffs in consideration of the incontinent patient are obvious.

HIP JOINT DESIGN

Over the years, two types of hip joints have been used in fabricating these HKAFOs. The first was made with a chamber. The amount of extension would be

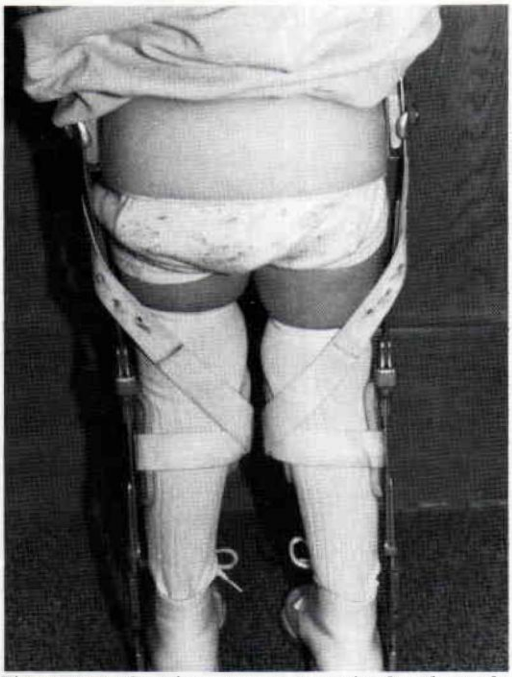

Fig. 7. Note that there are no posterior bands on the legs. A wide popliteal strap prevents hyperextension and loosens during sitting.

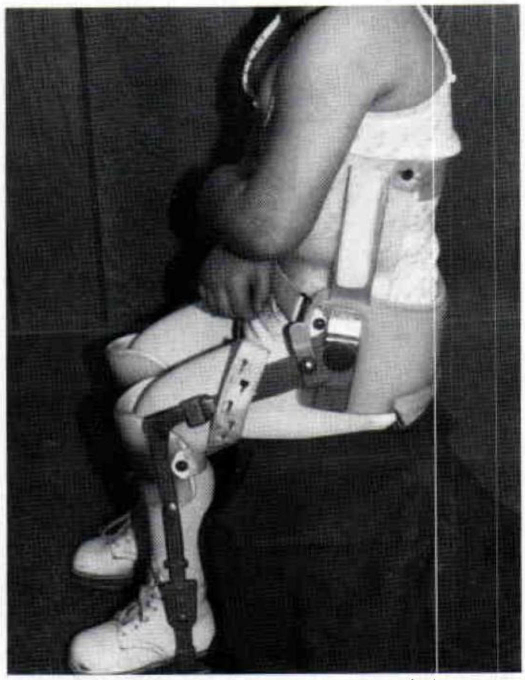

Fig. 8. The lack of thigh cuffs makes sitting more comfortable.

Fig. 9. Lateral view showing the high location of the hip joint and the wide pelvic band.

varied by the use of a stainless steel spring of different tension or a rubber block. A rubber block is used when the orthotist chooses to design the orthosis with a fixed hip, in conjunction with anterior thoracic shell, or sternal pad, as in the case of hip or lumbar contracture. Although the hip joint with rubber block is used when a fixed hip is desired, it also offers a cushion upon heel strike, which reduces breakage.

Introduction of the extension assist hip joint gives the patient alternative gait patterns, swing through, swing to, or reciprocating gait.

The second hip joint was of thinner design. Extension assist was accomplished using rubber bands. These bands were the same as those used on prosthetic upper extremity terminal devices. Both hip joints are designed with a stop after the joint has flexed 15°. The lock release levers are basically the same. Tension can be varied using additional bands. The second hip joints are designed with a stop after the joint has flexed 15°. The second hip joint design may be altered to a static, simply by riveting the

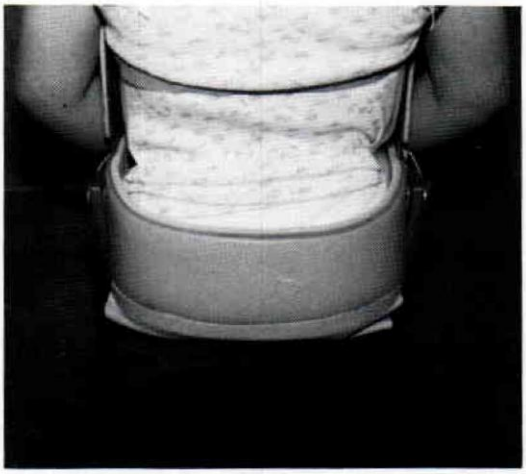

Fig. 10. The hip joint is placed higher for heavier patients to allow for the spreading of tissue during sitting.

Fig. 11. Close-up of hip joint and pelvic band during sitting.

movable components (Fig. 9). Sternal pad, body jacket or thoracic shell are supported laterally by SS extensions attached to the pelvic band. Velcro® straps are used to maintain the system in position.

The pelvic band should be of sufficient size to cover the distance between the perineum to the proximal aspect of the ilium. The lateral band is divided into thirds. The anatomical hip joint center is positioned on the lower third; the mechanical joint is located on the upper third. This alignment positions the band over the mid-aspect of the buttock. With the mechanical hip joint positioned $1/3$ superior to anatomical hip joint, the distance between the centers increases when the patient sits, thereby relieving pressure on the anterior knee (Fig. 10).

The hip joint is located superior to the norm with the obese patient. This creates additional space for adipose tissue to expand when the patient sits. Pelvic band size and strength are determined by the patients' height and weight. The pelvic band is frabricated from one of four thicknesses: $90/1000''$, $1/8''$, $3/16''$ or $1/4''$ of polypropylene. These bands are formed over soft aluminum molds preshaped to initial measurements. The band is later padded with $1/8''$ or $1/4''$ of Plastazote or Pelite (Fig. 11).

SUMMARY

The lateral bar hip, knee, ankle foot orthosis with spring assist hip extension has been successfully used for patients with muscular dystrophy, spina bifida, cerebral palsy and traumatic spinal cord lesions that resulted in paraplegia or paraparesis. Breakage has been significantly reduced because of the use of stainless steel and flexible components. The weight has been reduced as compared to conventional orthoses. Many patients with residual hip flexion can ambulate with recipocating gait. Cosmesis has been improved. The orthosis, as a therapeutic device, assists in the stabilization of contractures of the knee, hip and ankle.

The patient should be given the opportunity to reach optimal ambulation with minimal orthotic application. We consider the lateral bar orthosis to be a minimal device for those patients who need bilateral HKAFO with pelvic support.

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