# A One-Piece Laminated Knee Locking Short Leg Brace *

by

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In paralysis of the lower extremities, one of the major problems in ambulation is loss of joint stability. This is commonly treated by bracing. The gain in stability is however, obtained at the cost of reducing or completely limiting movement of the involved joints.

In patients with severe paralysis of the lower limb and musculature of the pelvic girdle, the most commonly used brace is a long leg appliance with a locked knee joint and limited ankle motion. More often than not, an ischial seat or pelvic band is also required. A patient using such a brace walks with a rigid knee and thus with an unphysiological gait.

Attempts have been made to design an orthosis which will stabilize the paralysed lower limb and yet enable a more physiological gait, than afforded by a rigid knee. The fact that above-knee amputees can walk freely with free knee flexion and ankle motion, encouraged orthotists to seek ways of designing appliances for paralysed limbs on principles parallel to those applied in prosthetics. One well-known example is the UCLA functional brace, where the principles applied are similar to those which enable above-knee amputees to walk freely with an adequate prosthesis.

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Stabilization of the knee by means of a conventional long leg brace is based on the three-point pressure principle. The brace includes two shells situated on the posterior aspect of the leg, one above and one below the knee, and a knee cap fitted over the patella. Thus two pressure points posteriorly at the thigh and shin shells are countered by an anterior pressure point at the knee joint (Fig. 1).

When hip extensors are missing, the trunk tends to collapse behind the brace and thus often gives rise to pressure at the upper edge of the thigh shell. The patient appears to be sitting on the upper shell, although the shell is not designed nor fitted for this purpose. To overcome this inconvenience, either an ischial seat is provided in order to support the trunk at the ischial tuberosity, or a pelvic band is added to prevent the trunk from collapsing (or moving) posteriorly, by the addition of the forward acting force at the pelvis (Fig. 2).

The appliance presented here has been designed as a means of stabilizing the paralysed limb without limiting the knee movement. The brace reaches only as high as the knee-joint. It is made of a reinforced laminated plastic. It comprises an arch support from beneath the metatarsal heads to the heel, two lateral uprights extending as high as the knee and joined by an anterior shell (Fig. 3).

It should be remembered that even a totally paralysed knee is usually stable in the antero-posterior direction when in full extension. The concept applied here is the use of the patient's own weight as a force which can be made to act in the antero-posterior direction at the knee and thereby stabilize the joint in extension (Fig. 4).

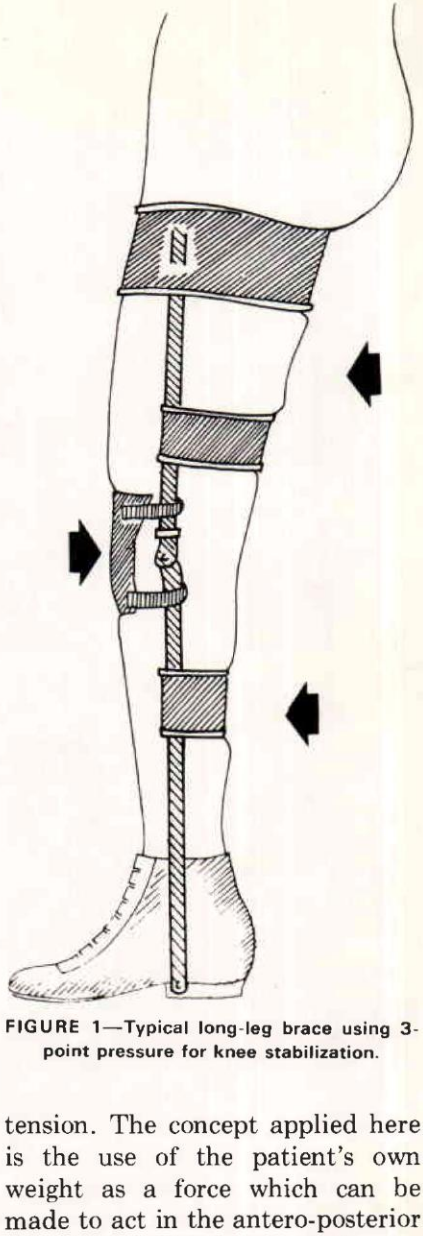

FIGURE 1—Typical long-leg brace using 3-point pressure for knee stabilization.

The brace may be considered as a cranked lever, its lower edge at the line of the metatarsal heads serving as the fulcrum. The weight

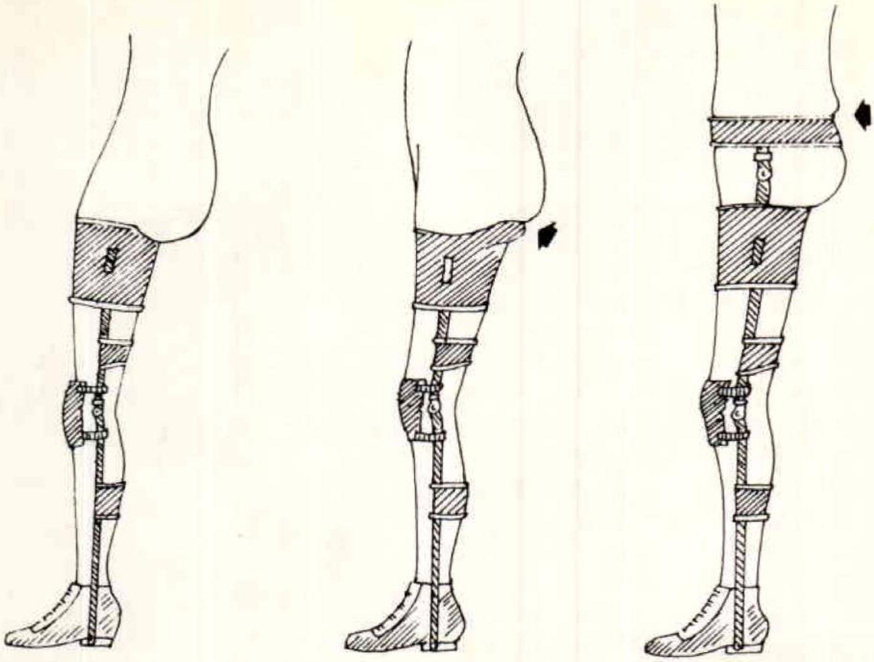

**FIGURE 2—Long leg braces with modifications for use in cases of hip extensor paralysis.**

of the body is applied vertically at the heel of the brace. The lever system applies its force in an antero-posterior direction at the area of the anterior shin shell—thus forcing the knee into extension. It is indispensable to maintain the foot in a fixed equinus position because the force acting at the knee acts only as long as the heel does not touch the floor. The moment the heel touches the floor, the brace ceases to be functional.

In addition, a secondary action derives from the locking force at the knee—a posterior displacement of the femur. The benefits of this factor become apparent in cases of hip extensors. As has already been pointed out, in patients using a conventional long leg brace, the trunk has a tendency to shift posteriorly to the leg. In the brace we are presenting, the femur itself being forced backwards secures better alignment of trunk and leg (Fig. 5).

The intensity of the force acting at the knee is related to the patient's weight. It also varies according to the ratio of the length of the footpiece to that of the upright of the brace and the angle between them. Given a constant length of the footpiece and angle of equinus, the longer the upright the less the force will be exerted at the anterior shin shell by the body weight. The local pressure is also reduced by closely moulding the knee cuff in order to obtain as wide an area of contact as possible (Fig. 6).

For this reason, the upright must be extended as high as possible. However, since the locking force at the knee is related to the body weight, in excessively heavy patients, the pressure exerted at the knee by the locking force may be unbearable.

## GAIT ANALYSIS

When using this orthosis for walking, there is no "heel strike" since the fixed equinus prevents the heel from touching the ground. For the same reason, there is no "foot-flat" phase either, therefore, the stance-phase of gait begins with "toe-strike". At this time, the toes dorsiflex at the metatarsal phalangeal joints. The area from the metatarsal head to the tip of the toes provides the pa-

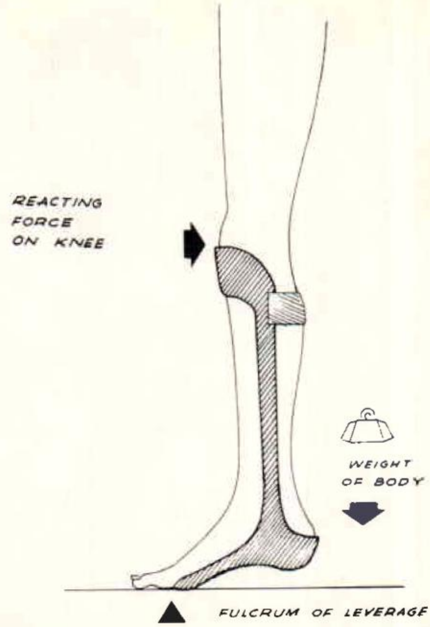


**FIGURE 4—Mechanical action of "Saltiel Brace". Body weight acting on the heel, with the fulcrum at the metatarsal heads, causes an A-P force at the knee level which stabilizes the knee in extension.**

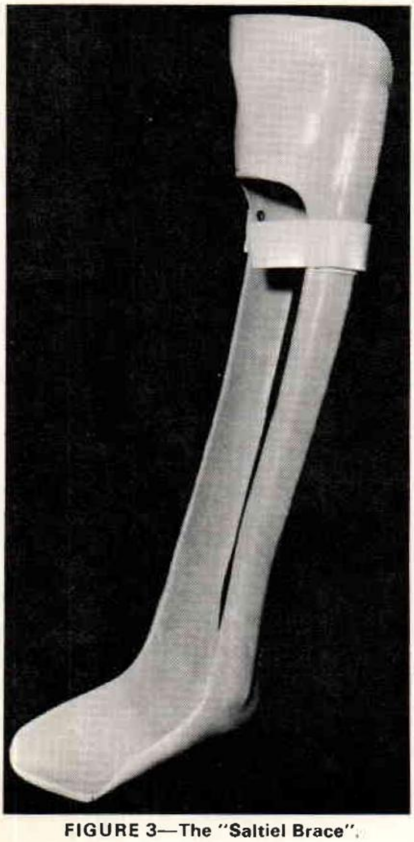

**FIGURE 3—The "Saltiel Brace".**

tient with a sufficient weight-bearing surface. But at mid-stance, at which time the patient puts maximum weight on the affected leg, the knee is already under anterior-posterior pressure and is therefore locked and stable. The rigid ankle is of great assistance in push off. At swing phase, knee flexion shortens the distance from the hip to the floor and thereby enables a pendulum action of the leg forward without scraping the toes on the floor. The leg is swung forward and the cycle starts again with the toes striking the floor. If the patient has hip flexors, he will bring his leg forward by flexing his hip. In patients without hip flexors, the leg is carried forward by circumduction of the pel-

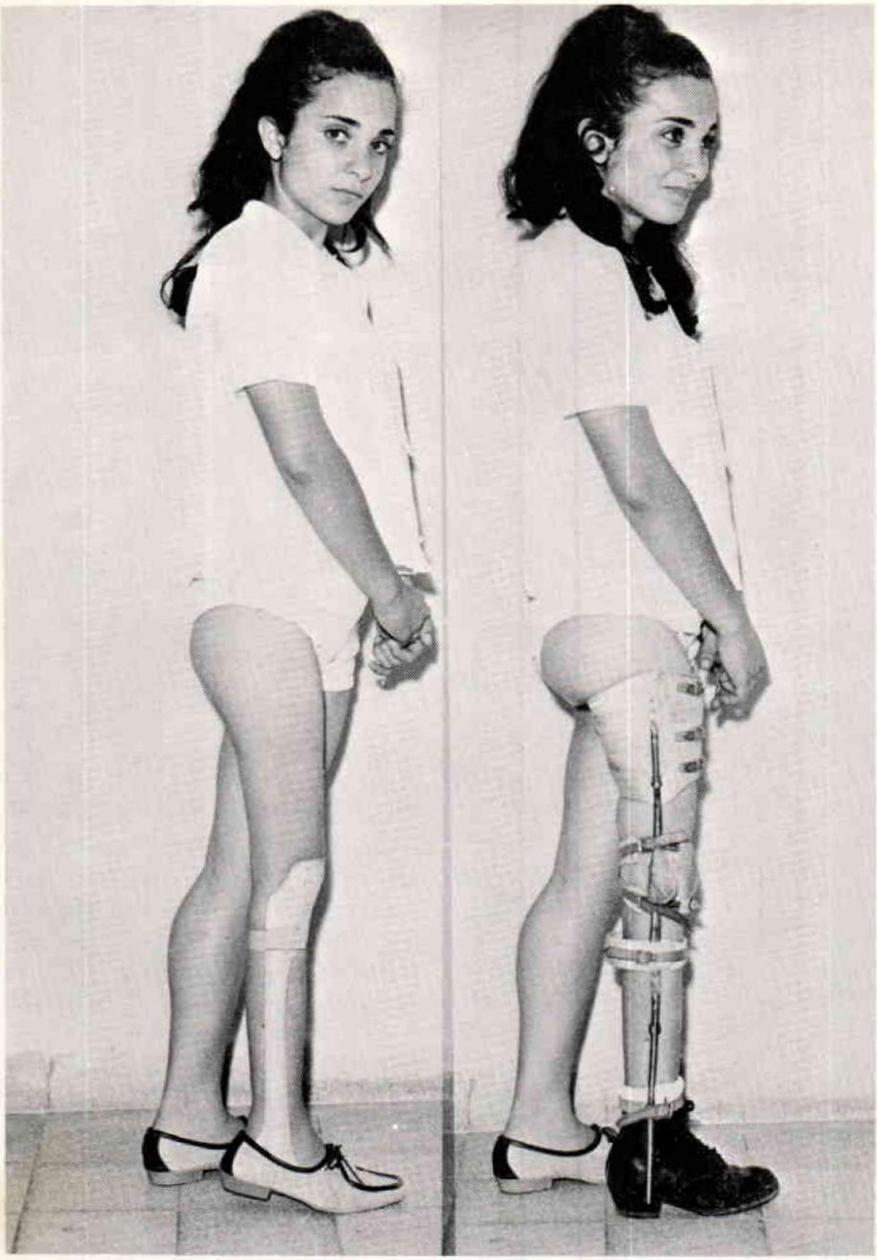

FIGURE 5—Patient with flail right lower limb with a standard long-leg appliance: the trunk obviously sags over the upper edge of the brace. This appearance is not seen when using the "Saltiel brace".

vis and the action of forward momentum.

It should be noted that, in normal joints, the knee remains locked as long as the line of gravity falls posterior to the axis of the ankle

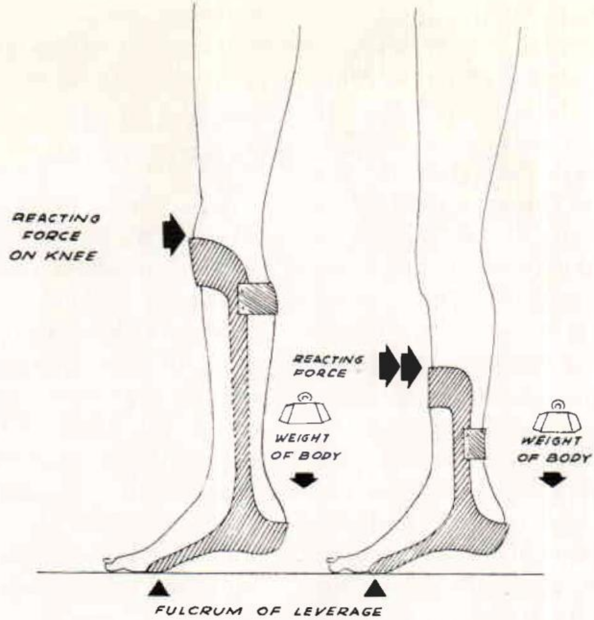


**FIGURE 6—Schematic representation of effect of length of uprights on anterior pressure produced.**

joint. In an unsupported paralysed leg with free ankle movement, the knee will collapse at the slightest forward inclination of the leg beyond the vertical. The use of this short leg brace enables up to 20–25° of forward inclination without losing knee stability, as long as dorsiflexion of the toes continues.

## DISCUSSION

Orthopaedic surgeons in the past often arthrodesed the knee-joint to do away with long leg braces. However, this form of treatment has been almost abandoned owing to the inconvenience of a rigid knee in every circumstance other than walking.

Arthrodesis of the ankle is another surgical intervention which aims at providing stability, not only of the ankle but, in certain circumstances, also of the knee. The brace described here affords all the advantages of an ankle fusion, with none of the disadvantages.

During recent years, several attempts at providing a knee stabilizing orthosis with free knee movement have been made. Perhaps the most successful so far has been the UCLA functional brace. The appliance allows ankle movement from heel strike to foot flat, and provides the patient with a large weight-bearing surface. Locking of the knee is said to be provided by abdominal and pelvic pressure at the anterior brim of the thigh shell. The pressure is transmitted through the uprights that serve as levers and extend from the thigh shell to the posteriorly eccentric knee joints. At mid-stance, the hydraulic damper which decelerates dorsiflexion contributes to knee-locking, moving the fulcrum forward and thereby forcing the anterior shell to apply antero-posterior pressure at the knee. By providing a mechanism of knee-locking at toe strike, we have been able to reduce the brace to below-knee level. The absence of an ankle joint mechanism highly simplifies the design and cost of the appliance. Furthermore, since the paralysed limb may often be relatively short, compensation of the leg length in equality is obtained by the equinus position. Since the brace fits inside the normal shoe, it also often allows fitting of standard shoes even when the foot of the paralysed extremity is also atrophic.

The weight of this orthosis for a child is less than 250 grams, compared to a conventional long leg brace which weighs in the region of 1,200 grams. In cases in which a shoe elevation can be dispensed with, because of the compensation afforded by the equinus position, a further 200 to 300 grams may often be saved. We have also observed the readiness of patients to accept this brace which has a relatively pleasing cosmetic appearance in addition to the more physiological gait it allows the patient. The orthosis may be dyed to any required colour to match shoes or clothing.

We find that this appliance is indicated in cases where the patient has no lateral instability of the knee-joint. They are also more readily accepted by female patients rather than males who are less worried about the cosmetic appearance of the appliances and prefer more stability.

## PROCEDURE OF FABRICATION

A plaster of Paris impression is taken from the patient's leg, including the whole foot and extending up to the knee. The knee is kept in slight flexion, the foot in about 15 degrees of plantar flexion and the toes in extension horizontal to the floor. The degree of plantar flexion of the foot may be varied with consideration of the patient's ability to stabilize his knee and the amount of shortening of the affected leg for compensation.

A positive cast is then made with the insertion of a handling mandril with provision for vacuum application at the laminating stage. The plaster model when dry is adequately retouched and thoroughly smoothed.

A film of PVA or any other parting agent is applied to the surface of the plaster model.

Two layers of nylon stockinette are then pulled on to the model.

Two layers of fiberglass are fixed with sutures on the nylon stockinette to cover the plantar surface of the foot so as to form an arch support. Additional strips are placed along the lateral and medial sides of the shin and over the anterior surface proximally in order to provide for an anterior shell. Bars of "AIREX" or any other foamy light plastic material strips of approximately 1" × ⅛th" are applied to the medial and lateral fiberglass strips. They are then covered with another two layers of fiberglass and then the whole build-up is covered with two more nylon stockinettes.

A laminate of polyester resin (80% rigid, 20% flexible) is then made on the model with the use of a PVA sleeve and vacuum as in the conventional technique used in ordinary laminating of stamp sockets in prosthetics. The "AIREX" sandwiched between the fiberglass sheets does not absorb the polyester resin and thereby produces the lateral upright in hollow sections, which provides more strength while considerably conserving weight.

When the laminate is set, the plastic is drawn and trimmed in the shape of the described appliance.

The appliance is then fitted on the patient and further trimmed and adjusted as necessary.

After the first fitting, the edges of the brace are thoroughly smoothed. A Velcro strip is attached to the tibial shell, in order to encircle the shin and secure the upper end of the appliance in place. The lower end is kept in position with a tight shoe, and therefore no additional strips are necessary. A strip may be connected at the heel when shoes are not used in the case of the patient using the brace on the beach.