Braces and Brace Management

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General Principles of Bracing

Within recent years, reemphasis upon the rehabilitation of severely disabled individuals has "spotlighted" the importance of proper fitting braces in the teaching of ambulation and daily activities. There seem to be several points of view regarding the intelligent selection of braces for lower extremities. One group holds that patients should be braced maximally as indicated by a careful analysis of existing tests of muscle function. Followers of this plan contend that any excess braceage may be discarded as the patient's recovery and proficiency in handling his body improve. They assert that braces and other supportive apparratus can be an asset in teaching control of body segments and in the functional training program. For example, they might say that the patient, hovering on the borderline between wearing a pelvic band and attempting activities without one, might do well to wear the pelvic band for a number of weeks to develop stability and the sensation of proper body alignment.

An opposing point of view is that most patients with paraplegia-type of involvement, especially when due to poliomyelitis, can learn to ambulate successfully with crutches and little or no braces. While this may be true, it must be remembered that this is done at the expense of better stability, and in the case of children, of future deformities (particularly genu recurvatum). The resultant deformities are often more difficult to correct than to prevent initially. It is our experience that patients trained from this viewpoint usually have more difficulty performing elevation activities and generally ambulate at a much slower pace.

Another point of view regarding bracing is that the patient should be given a minimal amount of braceage initially. If this proves to be inadequate for the patient's needs, more braceage is then added. We do not believe that this viewpoint is psychologically sound, especially in a therapeutic training program designed to utilize residual capabilites to their fullest extent. From the psychological aspect, the first viewpoint, that is, maximum braceage or even "over-braceage", is preferable since later removal of unnecessary bracing does give the patient a sense of achievement and improvement. We have attempted to work out a mid-position between the maximum but frequently overbraced viewpoint and the minimum or underbraced viewpoint. For the past three to four years, at the New York State Rehabilitation Hospital, we have been pretraining and pretesting our patients to determine whether or not they could do without attached trunk braces and pelvic bands. From a review of the usual manual muscle tests it frequently seems that the patient will definitely need a trunk brace to maintain the erect position, or a pelvic band to control rotation of the lower extremities. The trunk brace, however, definitely limits the functional potential of the patient. We find that many of these patients can hypertrophy the latissimus dorsi muscles to help maintain the erect posture with a more flexible support such as a corset. Prior to ordering a trunk brace attached to long leg braces, an effort is made to hypertrophy the latissimus dorsi muscle and lower third of the trapezius and to teach the patient to use them as trunk extensors (1, 2). These patients, as well as those with good trunk muscles but essentially flail lowers, are also tested with simple padded posterior splints with knee caps. The splints place the extremities in the same alignment as they would be in long leg braces. We are thus able to determine whether the patient can be taught control of hip rotation without a pelvic band prior to brace prescription and construction. (3). These determinations can be made, in most patients, in five to ten days of training and observation. We have also been attempting to strengthen poor grade muscles by progressive resistive exercises prior to brace prescription and construction. In this way we hope to be able to order a short leg brace initially instead of a long leg brace which eventually is cut down to a short leg brace. It must be emphasized, however, that whenever there is a possibility that less braceage will decrease the safety factors and stability, or result in the production of future deformities, the larger amount of braceage is ordered.

Bracing the lower extremities has two primary functions; the first relates to deformities, the second to support and locomotion. In most instances both deformity and locomotion assistance must be considered in the same patient. It is here that a knowledge of the various types of materials used in brace construction, and of the various types of brace construction and parts is important. Most lower extremity braces are made either of some type of steel or aluminum. Too often, the selection of one or the other of these materials has been dependent upon the preference and ability of the bracemaker rather than on the needs of the patient and his particular problems. Steel supplies more rigidity than aluminum for the same cross-section area. On the other hand, aluminum is of lighter weight than steel for the same cross-section area (4). In the patient with marked flaccid paralysis of both lower limbs and some trunk weakness, weight of the braces is usually of greater concern than their rigidity. However, if this patient had marked spasticity rather than flaccidity, rigidity of the brace material would probably have precedence over the weight factor. These are not the only points of difference between steel and aluminum, but they illustrate some of the factors which should be taken into account in deciding on the brace prescription.

The brace prescription should be written by the physician after examination of the patient and discussion with the bracemaker of the particular problems presented by this patient and his disability (5). The parent (member of the family), therapist, and nurse, who will see the patient daily, are also important members of the brace team. Because of their more intimate contact with the patient, they should be able to observe and report to the physician and bracemaker whether or not the brace is performing the function for which it was intended. While braces are static substitutes, patients do grow, occasionally get fatter, and muscles do atrophy. All these changes necessitate brace changes and alterations.

The majority of leg braces found in use in rehabilitation programs for patients with paralysis of the lower extremity—paraplegia, polio, multiple sclerosis, cerebral palsy, etc.—are those intended for support and locomotion. Leg braces in this category are generally of two types: long leg brace with or without pelvic band, and short leg or drop foot brace. Although there are different kinds of long leg braces (weight bearing, non-weight bearing, etc.), the type which seems to meet the needs of the majority of severely involved lower extremity patients may be described as a double-bar supporting brace with stirrup or caliper, knee lock and knee cap, and with or without pelvic band. The following technical terminology and description of parts should be helpful in working with individuals dependent on braces and crutches for daily living (fig. 1A).

BRACE DESCRIPTION AND TERMINOLOGY

Uprights

Uprights, struts or bars, as they may often be referred to, are described as the supporting bars which splint the extremity on one or both sides, and run parallel to the longitudinal axis of the extremity. It is the general concensus today that long leg braces should have double upright bars, that is, a medial and lateral strut, since it is extremely difficult to brace an extremity properly with one upright. When single upright construction is desirable, Jordan (6) advises that it be constructed as a spiral-bar design, which achieves stability by the spiral-like course it takes about the leg.

From a technical viewpoint one may say that upright may be either of hollow columnar structure or of solid-bar columnar structure. Tubular uprights afford relative lightness in relation to strength and rigidity. In solid-bar construction the center or core contributes little to the rigidity of the rod (7). The disadvantages of tubular uprights are the considerable difficulty encountered in adjustment of uprights, as for growth factors in growing children, and the bulkier appearance of tubular materials.

In the construction of a double-bar brace, the prevailing practice is to make the lateral upright of the brace about two to three inches below the trochanter with the medial upright made about two inches below an imaginary line extending anteriorly from the tuber ischia. At the New York State Rehabilitation Hospital, the general policy is to carry the lateral upright up to just below the prominence of the greater trochanter as suggested by Abramson (1). In addition, the upper end of the medial upright ends at the lower end of the thigh band, and a more posterior extension spans the width of the thigh band (fig. 1A, g). In this manner, the frequent complaint of pressure and pain on the upper inner aspect of the thigh is avoided.

All Haverstraw braces are constructed in corrective form. They are built in conformity to the lines of the anatomical position rather than to conformation to the lines of the deformity. The advantage of this principle is that braces so constructed will have a tendency to correct deformity, whereas braces conforming to a deformity will only maintain the "status-quo".

Bands

Bands or cuffs, as they are frequently referred to, are semicircular strips of sheet metal which connect the uprights and give rigidity to the structure of the brace. Bands are located at the thigh and at the calf. Usually two bands are used at the thigh. They may be used individually at different locations on the thigh or they may be used close enough to be incorporated into a single leather cuff. If the upper thigh band is made so that it curves upward and outward to fit loosely into the gluteal fold, rather than almost transverse, Abramson (1) claims that the gluteal mass can be used to act as a soft tissue block to control rotation of the lower extremity.

The relative position of the lower thigh band and the calf band is also important. If the adjacent edges of these bands are placed too close, it is not possible to flex the knee to 90 degrees. If the knee joint is slightly offset posteriorly, the bands can be closer together. The depth of the lower thigh and calf bands is usually slightly greater than the actual measurement, while the leather lining is made to the actual measurement. If these bands are too deep, hyperextension may occur at the knee; if they are too shallow,

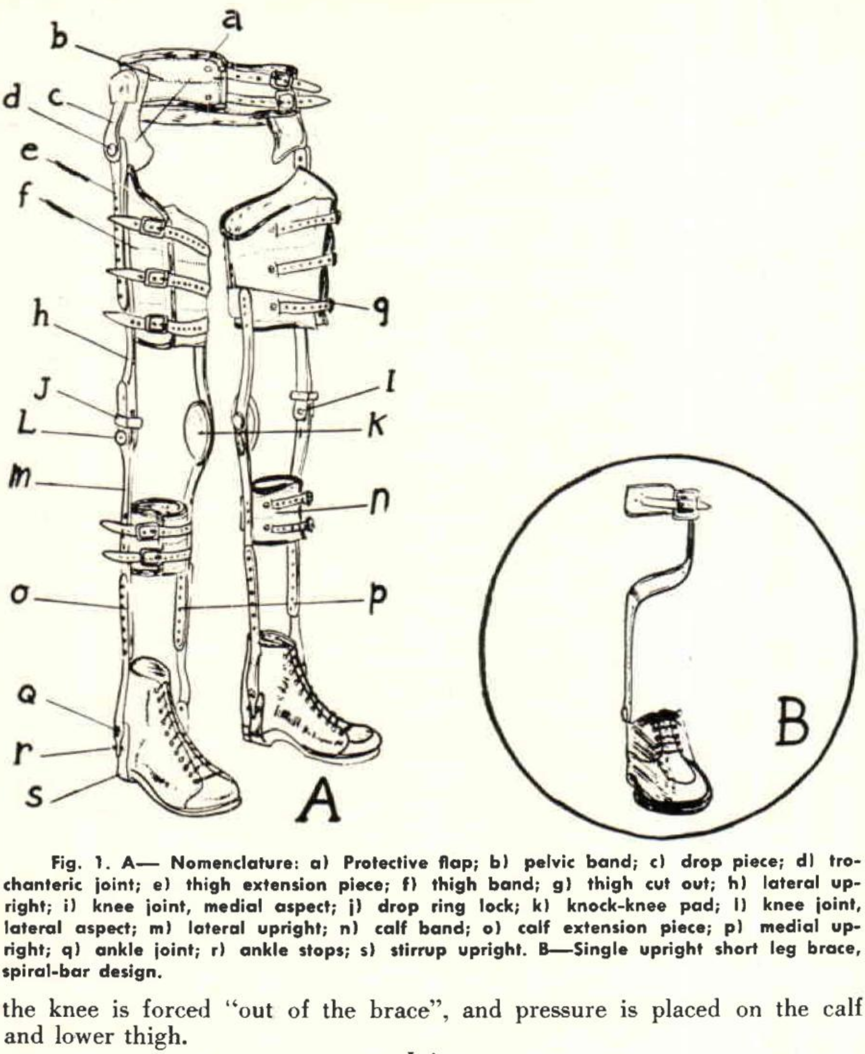

Fig. 1. A— Nomenclature: a) Protective flap; b) pelvic band; c) drop piece; d) trochanteric joint; e) thigh extension piece; f) thigh band; g) thigh cut out; h) lateral upright; i) knee joint, medial aspect; j) drop ring lock; k) knock-knee pad; l) knee joint, lateral aspect; m) lateral upright; n) calf band; o) calf extension piece; p) medial upright; q) ankle joint; r) ankle stops; s) stirrup upright. B—Single upright short leg brace, spiral-bar design.

the knee is forced "out of the brace", and pressure is placed on the calf and lower thigh.

Joints

In a long leg brace, joints are carried at the ankle, the knee, and the trochanter. The trochanteric joint is used in conjunction with a pelivc band or hinged back brace. Joints will fit and operate properly only if the mechanical axis of the brace joint is aligned with the natural axis of the articulations of the extremity, and if the joints are correctly placed in rotation to one another. Von Werssowetz (8) has made the observation that the trochanteric joint should be placed at the level of the top of the greater trochanter, the knee joint should be opposite the midpoint of the femoral condyles, and the ankle joint should be centered transversely about one-quarter to one-half inch above the tip of the lateral malleolus (aligned with the axis of the tibiotalar articulation). Joint construction which fails to consider these points of fittage will permit friction between the brace and the extremity, produce limitations of joint motion, and facilitate bizarre movements of the extremity.

Occasionally the knee joint is omitted when knee flexion is not necessary or when knee flexion is undesirable. Omission of knee joints reduces the cost of a brace considerably. In young children of nursery or pre-school age knee joints are often omitted when it is thought that the brace is only for temporary use (up to 12 months). Again in young children, the distance from the ankle to the heel is so small that it may not be feasible to put an ankle joint on the brace. In very painful ankles, ankle joints are frequently omitted on the brace.

The most widely used and generally accepted kinds of joint construction are the box joint and the overlap joint. Recently brace research projects have been experimenting with so-called double-joint construction. The double-joint (fig. 2A) utilizes two centers of rotation which move in unison in an effort to more nearly approximate the action of the human knee. In a single-joint construction the path of movement of the thigh and path of the fixed axis of the brace struts tend to pull away from each other (7). Double-joint construction offers some improvement over this. However, the improvement is so slight that it does not justify the increased cost of production.

The most commonly used mechanical joint construction for double-bar long leg braces is the box or clevis joint (fig. 2B, C) which is more generally employed at knee and hip placement and only occasionally at the ankle (fig. 2E). This joint is so named because of the shape of the

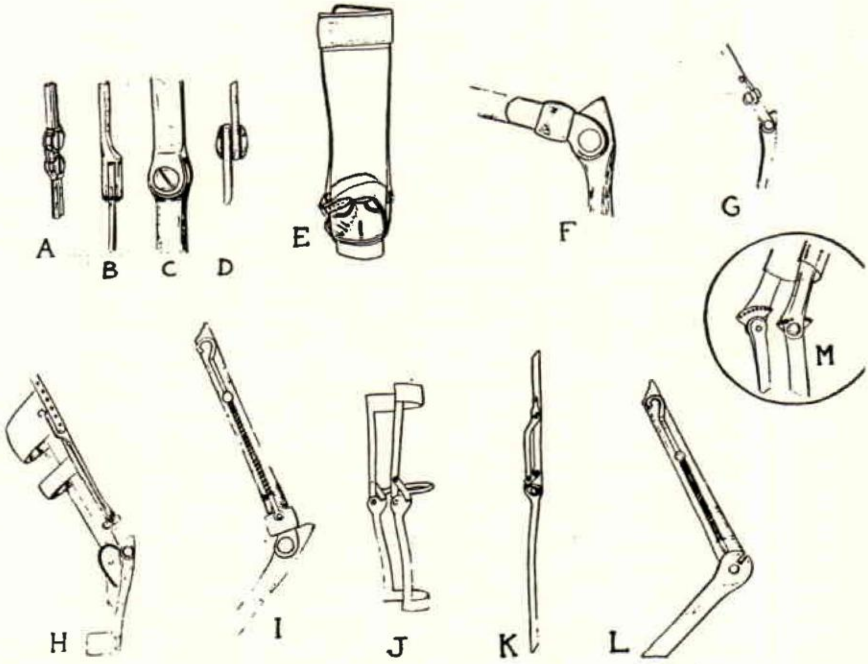

Fig. 2. A—Knee joint, double-joint construction; B—Box or clevis joint, posterior view; C—Box joint, side view; D—Overlap joint; E—Employment of box joint construction at the ankle; F—Ring drop lock; G—Use of spring clip to hold up the ring-drop lock; H—Ring-drop lock with release rod; I—Automatic ring-drop lock; J—Swiss lock with bail; K—Swiss lock with release rod; L—Automatic lock, plunger type; M—Adjustable joint.

upper bar or female component. The joint box is "U-shaped" with the ends perforated to receive a pin, rivet or sleeve about which the joint pivots. The joint head of the lower upright is milled to fit the clevis slot of the upper upright joint box. The box or clevis type of artificial joint may be either free or have a locking device. When aluminum is the metal selected for brace construction, the joint lining should be reinforced with a more durable metal: Mr. Elmer E. DuBois (9) of this hospital's brace shop has successfully used a bronze bushing as a joint lining in all aluminum braces for over seventeen years as an orthopedic technician. The rivets or threaded pins which are used in an aluminum brace are made of steel. Where freedom of motion in a desired plane is a prime prerequisite, as it may be in cerebral palsy, a ball-bearing modificaion of the box joint as advocated by Phelps (10) is a definite advantage over the usual box or clevis joint construction.

Because of the economy and simplicity of fabrication, the overlap or hinge joint (g. 2D) is usually employed if unlimited joint action is required. This is especially true when the selected brace is constructed with a single lock at the knee or hip. In this instance the medial joint is usually made as an overlap joint. Ankle joints may also be of the overlap type, especially when stirrup or foot sandal types of foot attachments are used. The overlap joint is simply described as a joint in which the upper and lower joint heads lap over each other. Each joint head is perforated to receive a pin, rivet or sleeve about which the joint jivots. Overlap joint construction may be either free motion or have a locking device.

Locks

If a stop at the joint is required, there are a number of constructions which have been devised. The most commonly used lock for double-bar long leg braces is the ring-drop lock (fig. 2F) or slip lock as it is sometimes called. This is simply a metal ring which rides freely along the upper joint bar and drops into place over the lower upright assisted by gravity to stabilize the joint extension. This type of lock is most generally recommended for use at the knee and hip joints. Deaver (11) advises that only one ring lock be used at the hip joint. His feeling is that a patient may be able to unlock one hip lock in order to sit down, but doubts that he can be taught to release both hands from his supporting base to manage two hip locks. However, this can be overcome to an extent through the use of a spring steel clip (fig. 2G) or spring loaded ball-bearing stop to hold up the ring-drop lock, so that two such locks can be used at the hips (or knee joints) when absolutely necessary for very heavy or obese individuals.

If an individual has difficulty in performing the daily activity of locking and unlocking the brace at the knee when in a "jacked" or flexed position (for instance when getting to and from the erect position or to and from a straight chair, bed, toilet, or automobile), a rod or release lever extending along the external surface of the upper joint upright is added to the ring which enables the lock to be released at approximately upper thigh level (fig. 2H). This obviates the need to reach down to unlock the joint. The ring-drop lock may be used on either a box joint or with an overlap joint.

The ring-drop lock may also be built as an automatic lock with some modifications. The automatic ring lock utilizes a rod attached to the ring as described in figure 2H to permit flexion at the joint, but in addition a spring mechanism is employed to lock the brace in extension without manual manipulation of the ring (fig. 2I). There are a number of constructions for automatic locks which may be considered instead of the simple, although effective, automatic ring lock. There are two other basic categories of automatic locks most generally used to lock a joint: first of all, the cam lock; and second, the plunger lock. Most automatic locks are spring-actuated, but they sometimes utilize elastic webbing and provide automatic locking when the joint is extended. The spring provides a constant load on the male lock bar so that when the engaging parts are in proper relationship, the lock bar automatically seats itself into a slot.

A cam lock can be described as an automatic locking device in which a short cam or lever type projection is used as a male locking bar. (A cam is herein described as a rotating, pivoting, or sliding piece, or projection.) The locking of the joint is accomplished by action of a spring load on the locking bar which forces the locking bar into a machined receiving slot. The locking bar is usually fastened by a rivet in the upper joint upright and makes contact with its receiving slot which is generally machined on the posterior edge of the joint box on the lower bar. A variety of cam locks are used as automatic locking devices. Some of the more popular kinds of cam locks are the Schweizer or Swiss lock, sometimes referred to as a bail lock*; the von Baeyer lock, which Jordon (6) describes as an improved Schweizer lock; the French lock in which the cam lock action is concealed in a joint box; and the bow lock and spring-lever lock, which are other variations of locking devices with concealed wedging cam lock action. Since all of the above mentioned cam locks are essentially the same in construction principle, we have chosen as an example for the construction details of an automatic lock (cam type) one of the most frequently used locking devices for the knee joint, the Schweizer or Swiss lock (fig. 2J), This is usually a double knee lock built as a milled joint with short lock-bars used to lock the joint in extension. The two lock-bars are connected by a rounded piece of steel, posteriorly at the level of the popliteal region. This half ring or bail, usually of steel, is fastened to the uprights of the brace below the knee joint. The bail is connected with the calf band by an elastic webbing or a small spring coil which automatically locks the joint in extension when the engaging parts are in proper relationship. To release the locks, the bail is lifted with one hand which opens both lock-bars simultaneously. Patients with poor balance frequently learn to release the locks by backing up to a stationary object such as a chair, bed, etc. (fig. 3). In this way neither hand is removed from the crutches to release the locks.

For safety reasons, the efficacy of the use of the bail with an automatic locking device for patients with adductor spasms is questionable. In these cases they have been known to frequently trip the knee lock accidentally.

A plunger lock is another type of automatic locking device but one in which a hardened pin or tongue is used as a male locking piece instead of a cam or lever as is the case in a cam type automatic lock (fig. 2L). The locking of the joint is accomplished by contact of the plunger with a receiving slot or groove. The locking force is usually provided by a helical compression spring which provides a constant load on the plunger, forcing it into the receiving slot when the engaging parts are in proper relationship.

*A bail is a hoop or ring used to join two adjacent parts. For use in bracages, a bail is a half ring of metal which connects the cam levers of a double lock brace. The association of the bail with the Swiss or Schweizer lock which has come about through usage is erroneous. A bail can be used with any type of cam or plunger lock when a double lock is indicated. The locking of both joints of a double-bar long leg brace prevents any undue torsion on the joint structures. A bail offers a definite advantage in that it releases both locking devices simultaneously.

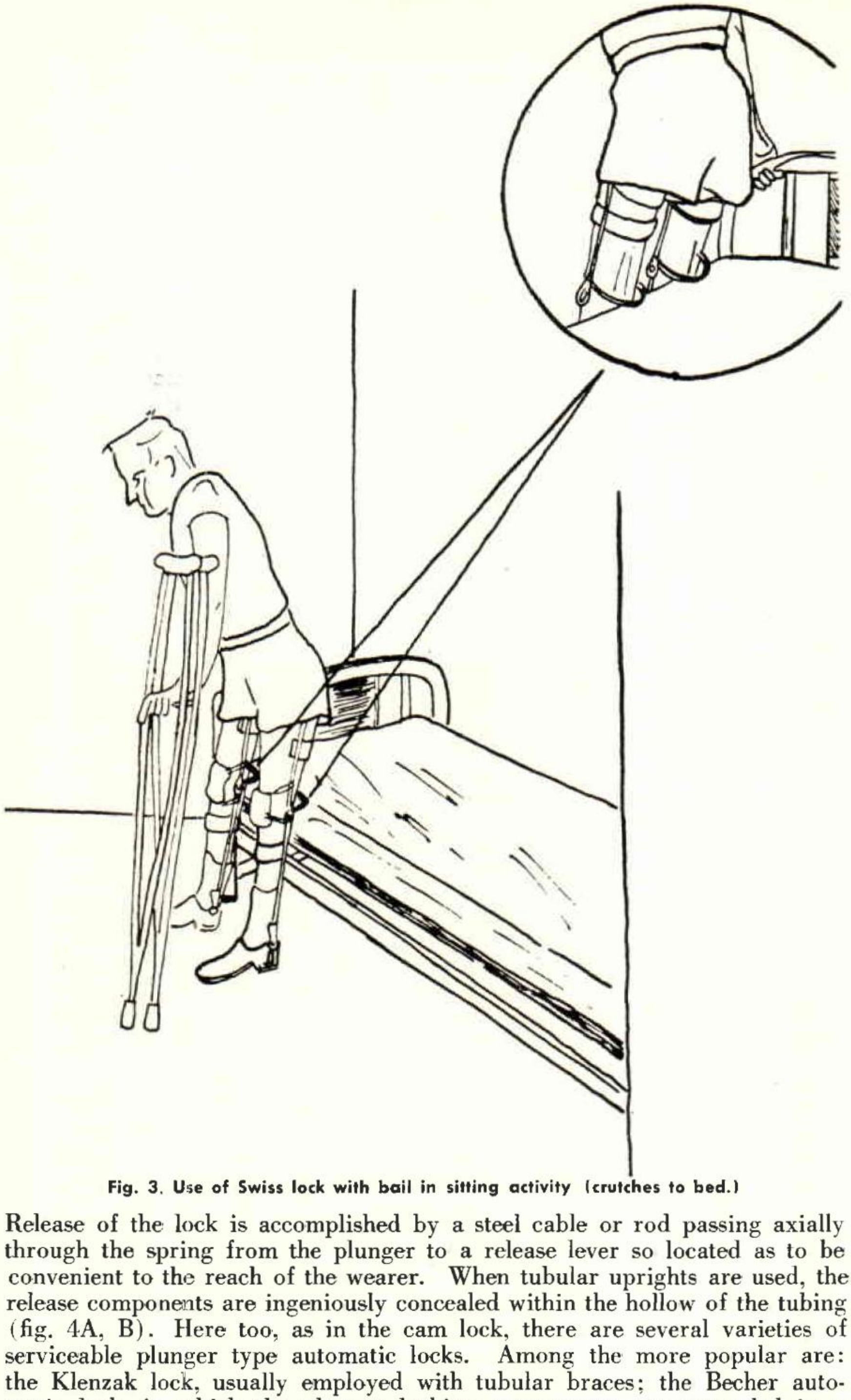

Fig. 3. Use of Swiss lock with bail in sitting activity (crutches to bed.)

Release of the lock is accomplished by a steel cable or rod passing axially through the spring from the plunger to a release lever so located as to be convenient to the reach of the wearer. When tubular uprights are used, the release components are ingeniously concealed within the hollow of the tubing (fig. 4A, B). Here too, as in the cam lock, there are several varieties of serviceable plunger type automatic locks. Among the more popular are: the Klenzak lock, usually employed with tubular braces; the Becher automatic lock, in which the plunger locking components are concealed in a joint box with the release components exposed on the posterior aspects of the upper strut; the knee lock joint, and the automatic lock knee joint, in which all components of the lock (that is, release lever, spring, plunger and slot) are exposed on the lateral aspects of the upright. Plunger locks are also very often built with the bail feature described above in connection with the description of cam locks.

A variety of adjustable joints or joints with motion control have been devised to overcome joint contractures and/or brace a leg for supportive purposes when the hip or knee cannot be fully extended (fig. 2M). Such a joint permits increases in the degree of extention as the gradual correction of the flexion deformity is accomplished.

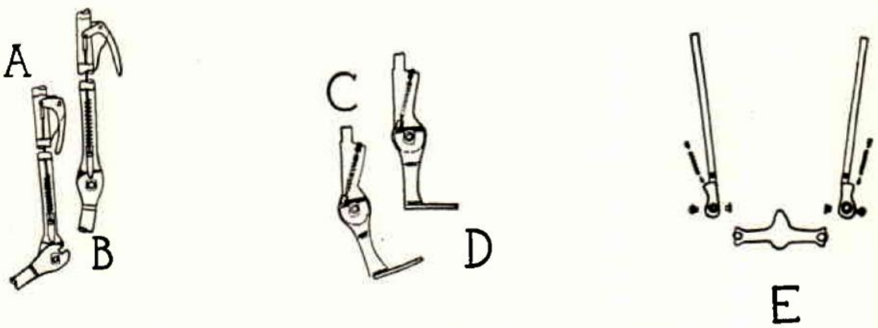

Fig. 4. A, B—Automatic lock, plunger type with concealed locking components (Klenzak lock by permission of Pope Foundation, Inc.); C, D—Compression spring joint Klenzak toe lift by permission of Pope Foundation, Inc.); E—Components, compression spring toe lift (by permission of Pope Foundation, Inc.).

Shoe Attachments

Basically there are two types of commonly used means to attach a shoe to the brace: 1) the caliper and 2) the stirrup.

Of these two types of shoe attachments, the caliper type (fig. 5D) is probably the easier to construct and the more economical in cost since it consists only of a metal tube inserted through the heel of the shoe into which fit "pins" attached to the lower end of the lower leg uprights. Its greatest asset is that it permits the patient to use the brace with more than one pair of shoes because the cost of putting a metal tube through the shoe heel is relatively inexpensive.

The caliper type has a definite disadvantage in that it displaces ankle motion to the heel of the shoe. With every step that is taken the brace uprights move forward and backward. The disadvantage to a patient with an ununited fracture of the tibia, for example, is readily visualized. The disadvantage for a paralytic limb is also present since the continued shifting of the uprights produces alternate pressure anteriorly and posteriorly through the transverse bands and cuffs. This may result in stretching of the ligamentous structures around the knee, chafing and irritation of the leg (potential site for decubitii in spinal cord injuries) or a tendency for the heel to slip in and out of the shoe. Other disadvantages are that frequent interchanges of shoes from the braces may cause the uprights to become sprung, necessitating the addition of a strap at the point of attachment to hold the upright pins in the heel tube. Frequently the tubes become clogged with dirt and grit making interchangeability difficult. Caliper tubes are of two varieties: 1) the caliper round (fig. 5D) which as the name implies uses a round hole, and 2) the caliper rectangular (fig. 5E) which uses a rectangular tube. Since the caliper rectangular prohibits motion at the heel, it has been used successfully with a joint at the ankle level, thus offsetting the major disadvantage of the caliper, namely, displaced ankle motion.

The stirrup type (fig. 5A) is a "U-shaped" bar, the center of which is mounted in the center of the sole of the shoe, at an adequate point in the anterior part of the heel with provision for the "normal" amount of toe-out. The uprights of the stirrup are joined to the lower ends of the lower leg uprights at the ankle to form a joint. Because the stirrup gives the most physiological type of ankle joint, various modifications have been designed to make it removable. One variation used at the New York State Rehabilitation Hospital is the bolt-on detachable stirrup which consists of the usual stirrup setup, but instead of a rivet at the ankle joint, a flex-lock nut and NFUS threaded stud or bolt are used (fig. 5B, C).

Deaver (12) describes a variation which he calls a French lock (fig. 5G). This consists of pins which project horizontally from each stirrup upright. The lower end of the lower leg upright has a "bushed" aperture into which the pins insert. Interchangeability occurs by merely spreading the lower leg uprights and removing the stirrup from between the uprights. Another variation of the detachable stirrup is the Keyhole Catch. This variation makes use of modified shoulder rivets which are fixed in place on the upright rami of the stirrup in combination with claw-end struts, the openings of which are keyhole shaped. When the shoe (with stirrup attachment) is held in 180 degrees of plantar flexion, the stems of the shoulder rivets,

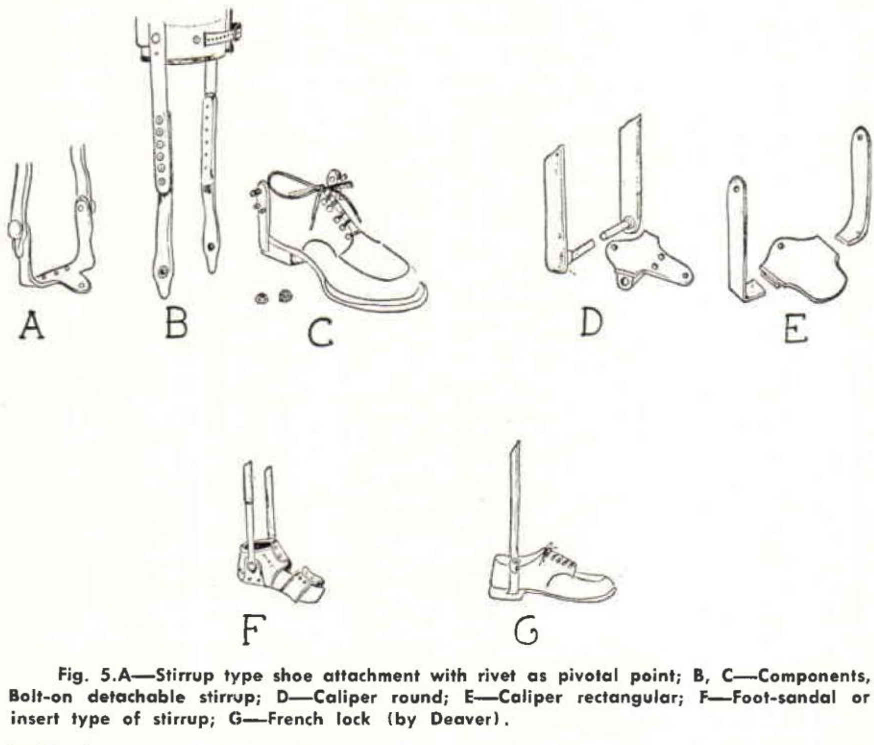

Fig. 5.A—Stirrup type shoe attachment with rivet as pivotal point; B, C—Components, Bolt-on detachable stirrup; D—Caliper round; E—Caliper rectangular; F—Foot-sandal or insert type of stirrup; G—French lock (by Deaver).

which are elliptical rather than cylindrical, can be slipped downward from the keyhole shaped opening or claws of the struts thus facilitating the removal of the shoe from the brace. To replace the shoe the same procedure is followed except that the stems of the shoulder rests are slipped upward into the keyhole and then the shoe is dorsi-flexed to lock the stirrup firmly into the keyhole shaped openings.

In some instances where spasticity of the toe flexors or calf muscles is a problem especially in brace management, a foot-sandal or insert type of stirrup may be preferred (fig. 5F). The foot-sandal is a metal "shoe-like" plate attached to the brace uprights, stirrup fashion. The shoe is worn over the sandal. This arrangement is similar to a metal arch support with side uprights and attaches to the brace uprights to form a joint at the ankle. The sandal, in addition, has attached sections of soft leather which lace over the dorsum of the foot and occasionally at the heel in the manner of a special orthopedic shoe. Cosmetically these types are more acceptable than the others described since nothing is attached to the outside of the shoe. Another advantage is that shoes can be changed without any additions to the shoes. The major disadvantage of this type of attachment occurs in the patient who wears only one brace. In this case the width of the two shoes differs considerably, and it may be necessary to buy two pairs of shoes to obtain one serviceable pair.

Ankle Stops

In both of these types of shoe attachments "stops" of various designs may be used to limit the amount of dorsiflexion and/or plantar flexion of the foot. Generally the caliper type makes use of flange-like stops, whereas "pins" of hardened metal are preferred for use with the stirrup type of shoe attachment. Control of the ankle joint motion is controlled usually in four considerations. First, for caliper attachments, stops are used as follows: 1) Unlimited motion (no stops), 2) equinus stop (posterior), 3) calcaneus

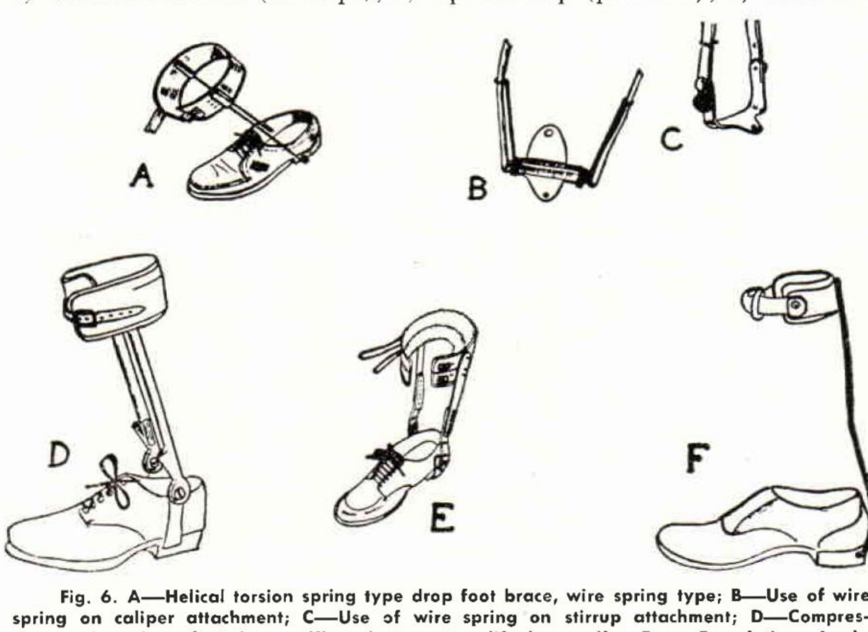

Fig. 6. A—Helical torsion spring type drop foot brace, wire spring type; B—Use of wire spring on caliper attachment; C—Use of wire spring on stirrup attachment; D—Compression spring drop foot brace, Klenzak type toe lift brace (by Pope Foundation, Inc.); E—Double-bar drop foot brace with ankle stops; F—Posterior spring brace.

stop (anterior), 4) limited ankle motion (anterior and posterior stops). Second, for stirrup attachments, stops are used as follows: 1) Unlimited (no stops), 2) anterior stops (limited plantar flexion), 3) posterior stops (limited dorsiflexion), 4) limited ankle motion (anterior and posterior stops).

Drop Foot Braces

There are generally four types of short leg braces or so-called drop foot braces: the helical torsion spring brace, the compression spring brace, posterior spring brace, and double-bar type with ankle stop.

Of the helical torsion spring type drop foot brace, the wire spring type (fig. 6A) is probably the simplest to make and most economical of all since it consists of bilateral uprights of piano wire coiled at the heel and attached under the sole of the shoe in front of the heel. The brace is secured to the leg by a calf band. This brace is usually sufficient in the ordinary type of toe drop due to peroneal nerve injury, but it is generally not useful in the spastic toe drop of a hemiplegia or where lateral stability as far as control of varus and valgus is indicated. The use of wire springs applied to the uprights of a caliper type or a stirrup type brace readily modifies these types of shoe attachments for use as drop foot brace (fig. 6B, C). Another variation, the Army drop foot brace, utilizes a hinge joint at the ankle with a coiled wire spring enclosed in a joint box.

The compression spring drop foot brace is a more rigid ankle brace utilizing a steel stirrup with a compression spring housed in the lower end of the lower leg upright at the ankle joint. The most popular of this type of drop foot brace is the Klenzak toe lift brace (figs. 5C, D, E and 6D). The Klenzak uprights can also be reversed for patients who have a normal anterior tibial and weak or paralyzed calf muscles. In this case the brace becomes a "heel lift" rather than a "toe lift" brace and may aid in the prevention of a calcaneal deformity. The compression spring drop foot brace is probably the best type for the patient with flail or essentially flail lower extremities, insofar as performance of daily activities is concerned and for whom long leg braces are indicated. Most of these patients experience difficulties in doing a swing-through gait and ascending and descending ramps with braces equipped with other toe lifts or ordinary stops at the ankle joint. They are continually walking on their heels when going down a ramp or on their toes when going up a ramp and thus do not have the security of good balance. With compression spring toe lifts, in these activities, the body weight stretches the springs, allowing for slight plantar flexion or dorsiflexion so that weight bearing is on the entire sole of the foot. The tension on the spring can be easily adjusted with a screwdriver to the strength required.

The double-bar type with ankle stop (fig. 6E) is a reproduction of the stirrup or caliper shoe attachment for long leg brace. The degree of movement at the ankle is controlled with fixed ankle stops.

The posterior spring brace (fig. 6F) is a simple appliance with narrow spring steel bands or leafs following the posterior aspect of the leg and attached under the heel. When the foot is off the ground, the spring steel lifts the forepart of the foot. This type of brace is readily made interchangeable so that it can be worn with any shoe so equipped with a heel tube to take the heel pin.

Brace Modifications

The construction of a double-bar long leg brace and short leg brace can be modified to meet specific conditions which interfere with training and function.

Pelvic Bands

The original intent of the pelvic band was as a component of a spinal brace (13). In this capacity the pelvic band served to hold the entire back brace in close contact with the moving body as well as to distribute the pressure of the supporting force over as large an area as possible. In recent developments of supportive therapy, the pelvic band has been used independent of any spinal brace as an orthopedic appliance unto itself. Many institutions utilize them to improve hip stability and to control internal or external rotation of the lower exremities. A pelvic band consists of a wide, thin band of sheet metal, accurately shaped to the contours of the pelvis, and encircling the posterior and lateral circumference of the pelvis. In order to gain a firm hold on the pelvis it should be fitted below the iliac crest and not to the patient's waist. The metal is well padded with felt or leather and attached to the lateral strut of a long leg brace on a level with but slightly anterior to the greater trochanter, creating a simulated joint at the hip. The pelvic band is inclined forward about twenty degrees so as to conform to the angle of the sacrum. It may or may not be used in conjunction with hip locks. If control of rotation of the lowers is the only indication, then hip locks are not usually required; whereas, where greater hip stability is required to attain proper stance, they may be indicated. That portion of the support which extends to the front of the pelvis consists usually of a band of padded leather, which by means of straps and buckles is used to hold the band securely in place.

Pelvic bands are designed and constructed in many varieties. The simplest and most commonly used type of pelvic support is the straight pelvic band (fig. 7A). It consists of a well-padded band of sheet metal shaped to fit the pelvic contour and lies at the level of the midsacrum in the back. In order to provide additional support as low as possible, some pelvic bands are angular in design. The butterfly pelvic band (fig. 7B) is a type so shaped. It curves downward on each side of the sacrum over the buttocks and angulates upward as the band passes forward to the level of the trochanters. Thomas describes the finished band as vaguely resembling a butterfly in shape. An angular pelvic band (fig. 7C) is another type of shaped band

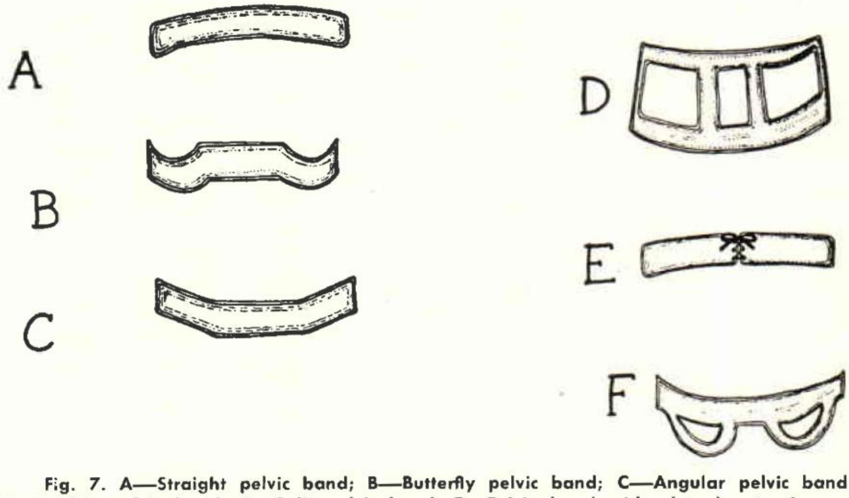

Fig. 7. A—Straight pelvic band; B—Butterfly pelvic band; C—Angular pelvic band; D—Double pelvic band; E—Split pelvic band; F—Pelvic band with gluteal extensions or "butterfly pads".

which fits somewhat low over the posterior aspect of the sacrum and then angulates sharply upward again to the level of the trocanters.

Steindler (14, 15) describes a type of pelvic band, the double pelvic band (fig. 7D), which utilizes two transverse bands placed from four to six inches apart and shaped to the contours of the lower lumbar region. The bands are located one above and one below the iliac crests and extend anteriorly around the pelvis to be joined in front of the anterior superior iliac spines. Four short struts, two posterior and two lateral, extending from the upper transverse band to the lower, maintain the intended location of the double bands. It usually has a corset-type front fastened to the lateral struts.

Occasionally a pelvic band is constructed in two halves, as a split pelvic band (fig. 7E), to facilitate the management of the braces, especially bilateral long leg braces, in putting on and taking off braces for purposes of dressing and undressing. The two halves are joined posteriorly by means of lace and eyelets or by strap and buckle. This arrangement is frequently employed in devices requiring bilateral above-knee prosthesis as a means of controlling rotation of the artificial limb.

Spreader Bars

Placed at the ankles they have been used with great success by some therapists to correct rotation or scissoring of the lower extremities. "Spreaders" are metal bars attached to the medial struts producing more or less static positioning of the legs in one place, thus facilitating body stability and the correct placement of the feet during certain elevation activities and in the execution of the "swing" gaits.

Gluteal Extensions or "Butterfly Pads"

They are semicircular metal plates attached to the pelvic band so that each pad rests over the buttock just above the tuber ischii (fig. 7F). They are used in high trunk lesions to help stabilize the pelvis and facilitate the rotation of the hips forward under the body. This is frequently necessary in order to prevent "jack-knifing." (Jack-knifing—Flexion of the trunk at the hips.)

Gluteal Straps

Another method of stabilizing the pelvis and rotating the hips under the trunk is the use of guteal straps, which are web elastic straps attached to the pelvic band posteriorly and fastened to the thigh band so that each strap is stretched downward across the gluteii.

Knee Straps

These are leather straps attached to the knee cap and used to pull the knee away from the struts of the brace in order to correct genu valgum or genu varum deformities. Sometimes it is preferable to use knock-knee pads to prevent abrasions at the medial aspects of the knee. These are small round pads attached to the medial strut at the point where the knee comes into contact with the brace (fig. 1A, k). To help a recurvatum deformity, a recurvatum strap is used which runs behind the knee at the popliteal region.

Knee Cages

A knee cage, also called "knee support" or "knee brace," consists of two uprights with posterior bands attached to the uprights at either end. Knee cages can be made without a knee joint, or with a freely moveable knee joint, or with a knee joint that can be locked in extension. The knee cage is held in position over the posterior part of the limb by a knee cap and/or thigh or calf bands with anterior lacing.

Such knee cages have a number of uses in the treatment of knee and other lower extremity disabilities. We have found knee cages useful as a support for weak quadriceps muscles to prevent genu recurvatum in an otherwise sound extremity where it was not necessary to burden the patient with the additional weight of full length uprights and shoe attachment.

It has been our experience that it is difficult to keep a knee cage in proper position, especially on a flail or markedly atrophied extremity unless the cage is made with a long lateral upright extending to the shoe. In such a case, a knee cage then becomes a long leg brace and it loses its advantage of lightness. If the knee cage is constructed with a thigh cuff similar to the thigh corset of a below-knee prosthesis with laced front, the knee cage is completely adjustable to the limb's contour and is thus maintained in proper position during ambulation.

Another arrangement is to build the posterior thigh band in the same manner as the thigh band in a double bar long leg brace, but with the addition of a built-in elastic knitted shell tapered to fit the natural contour of the thigh.

T-straps

So named because of their "T" shape, they are ankle straps used to pull the ankle away from the struts in correcting eversion or inversion of the foot. Because structures supported by the splinting effect of braces tend to compensate and adjust to the pressures of the brace, T-straps require constant checking. For example, in polio, a varus condition in the foot corrected with an outer T-strap, after a length of time, may require its complete removal or change to an inner T-strap to correct a tendency toward a valgus condition. In some places T-straps are referred to as "Y" straps—they are one and the same.

Braces and other supportive apparatus are essential equipment for patients who are disabled and incapable of performing activities essential for daily living without them. If the brace is to serve the individual and enable him to lead a normal life, it is important to instruct and educate the individual in its proper maintenance, for the upkeep of a brace can be a considerable financial burden to the wearer. A separate paper will be devoted to brace maintenance (16).

It is essential that an individual, dependent upon some type of orthopedic appliance for the successful performance of the many activities encountered in daily living, receive adequate training in the proper use of his appliance. A number of articles and books have been written on the techniques of ambulation and functional activities with braces and crutches. This paper will concern itself only with the preliminaries of brace management. It will include putting on and taking off braces, and dressing and undressing with braces.

PUTTING ON AND TAKING OFF BRACES

Putting on Braces (Bilateral long leg braces with pelvic band)

Starting Position: Sitting position on bed with leg extended, arms at sides, palms flat on the bed and opposite the hips. Braces are arranged in supine position at either side of the legs with all straps or laces open. (The braces, when removed, should have been placed conveniently by the bed, easily accessible when the individual is ready to wear them.) The pelvic band should be in line with the hips. Procedure: With the palms flat on the bed and opposite the hips, straighten the elbows, depress the shoulders, and lift the buttocks clear of the bed. With the buttock held off the bed move the body over the pelvic band and lower the buttocks between the pelvic band with the hips in line with the trochanteric joint of the brace. Place legs alternately between the struts of the brace. Unlock either knee, flex the leg, and then the brace in order to bring the shoe and foot closer within reach of the hands, preparatory to placing the foot in the shoe. Place foot in shoe and work foot into proper position in the shoe. Repeat, placing other foot in shoe. Lace shoes, fasten calf bands, buckle knee cap, fasten thigh bands, and buckle pelvic band.

Getting Out of Braces

The procedure for getting out of the braces is the reverse of the above mentioned procedure. Namely, open all straps and laces, remove the feet from the shoes, lift the legs alternately out from between the struts of the brace, push up and lift the buttocks out of the pelvic band to the side of the braces. In certain specific cases it might be more feasible in moving out of the pelvic band to push the body backward and slide out of the braces, instead of pushing up and sideward.

Some individuals, usually those wearing bilateral or single long leg braces, might prefer to put on and take off braces in a wheelchair. Basically the technique is the same as for putting on and taking off braces in bed, and only slight modifications are necessary to enable the individual to perform the skill from a wheelchair.

DRESSING AND UNDRESSING WITH BRACES

Dressing with Braces (Bilateral long leg braces with pelvic band)

Starting Position: Dressed in under garments. If patient wears a corset, this is put on directly over under garments. Sitting on bed with braces on and all straps or laces fastened.

Procedure: (Male Patients). Put shirt on in usual fashion. Put on trousers by unlocking the knee joints, bending as far forward at the hips as possible and pulling each leg of the trousers over the shoes and struts of the braces. (Male patients who wear a back brace with attached corset will have to pull on the trousers before lacing the corset, otherwise they will be unable to bend forward to reach their feet.) When the trousers are pulled up as far as they can with the buttocks on the bed, the individual must be back in the supine position and bridge the body by extending the head and arching the back. With the pelvis clear of the bed, the trousers are pulled up over the buttocks and hips.

Procedure: (Female Patients). Put dress on in sitting position. Pull dress under the hips, one side at a time, by shifting the weight from one buttock to the other. Or, return to supine lying position and pull dress under the hips, one side at a time by shifting the weight from one side to the other.

If the individual does not have the musclature necessary to completely bridge the body, he may pull one side of the trousers up at a time with a half rolling motion of the trunk until the pants are well over the buttocks and hips. Patients without a pelvic band should experience little difficulty with the trousers as they can rotate the legs at the hips to facilitate the procedure.

Undressing with Braces

The procedure for undressing with braces is the reverse of the above mentioned dressing procedures.

Note: The list of References cited in this article, and a companion article on Brace Maintenance will appear in the March, 1958 issue of the Journal.

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Italian Journal Reprints Oalma Authors

The Italian Orthopedic Appliance Association is publisher of a Journal, *Scienza E Technica Ortopedica in Italia E All'Estero* (Orthopedic Science and Technique in Italy and Foreign Countries). The issue for March and April 1957, reprints with due credit, two articles which first appeared in the OALMA magazine, the *Orthopedic and Prosthetic Appliance Journal.*

These are: (1) McCarthy Hanger, Jr.'s article, "L'Industria Ortopedica Negli Stati Uniti D'America" (This appeared in the June '56 issue of this *Journal* under the title, "Economic Aspects of the Artificial Limb Industry"), and (2) Dr. Robert G. Thompson and Michael Amrich's article, "Protesi Per Amputazione Parziale Della Mano" (This appeared in our *Journal* under the title: "A Prosthetic Thumb for the Partial Hand Amputee").