Braces for the Neurological Handicapped*

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Orthopedic appliances are an important adjunct in the treatment of neuromuscular and skeletal disabilities. Braces are designed for many different purposes. They are made from various materials, and there are unlimited types. The functional purposes of braces are:

1. To support body weight
2. To prevent deformities
3. To correct deformities
4. To control involuntary movements
5. To maintain correct alignment of body segments.

Braces may be divided into four major categories:

1. Spinal (including the Neck and/or Trunk)
2. Lower extremities
3. Upper extremities
4. Major debilitating neuromuscular syndromes which may affect more than one of the preceding categories.

The following are distinct medical indications for bracing of the neck and trunk:

Cervical Disc Rupture, Lesion, or Reduction of the Foramina, Postoperative Fixation, or Dislocation in the low Cervical area.

Torticolis or Wry Neck

Cervical Spinal strain or injury or Whiplash

Medical indications for bracing of the trunk are:

Kyphosis

Lordosis

Low Back Pain or Strain, with or without Disc Complications

Juvenile Scoliotic Spinal Curves (regardless of etiology)

Fracture or Postoperative Condition of the Spine.

Braces for the lower extremities are provided for:

1. Neuromusclar dysfunction, such as spasticity, flaccidity and athetosis.

2. Congenital or acquired joint dysfunction, deformation or malformation.

3. Fractures.

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The principle neuromuscular symptoms requiring bracing are Paraplegia, Hemiplegia, Poliomyelitis and Cerebral Palsy.

The following joint dysfunctions may require bracing:

Pes Varus or Valgus
Genu Recurvatum
Knee Flexion Contracture
Legg-Perthes Disease
Upper Extremity Disabilities.

Another group of disabilities would be:

Congenital Muscular Weakness and Muscular Dystrophy
Non-union of long bones
Spina Bifida Vera

One of the first designers and constructors of orthopedic appliances who became well-known in Europe was Hessing, in Germany. Braces named after him were rather heavy and complicated. Their main advantage was the fact that they offered almost unlimited adjustment possibilities. These braces required plaster-of-Paris casts, from which positive molds had to be made. Screw plates were attached to the cast and a special type of leather was molded over it. Side-bars were provided with slots. As a result of this construction the brace could be lengthened or shortened; and the alignment of the lower, as well as the upper part, could be changed at will. This brace is rarely seen in its original form any more, since the indications for such constructions no longer exist.

Since the time of Hessing, the philosophy of bracing has changed considerably. Orthopedic appliances are now used to complement orthopedic surgery and not to substitute for it. Physical medicine in many instances has obviated, or at least greatly reduced, the need for orthopedic appliances. It is also now possible to make braces lighter in weight and less complicated in construction. In most cases bands can be substituted for closed cuffs, and straps and buckles replace long lacers. This makes it easier for the patient to apply his brace, and he can do so in less time.

Certain fundamental principles in the construction of braces must be observed, but these differ depending upon the disability, and also upon the sex and age of the patient. In a brace made for a patient in early childhood, the materials must be light and noncorrosive. One has to consider the need for proper nursing and also the sensitivity of the skin. With advancing age, conditions change. As the child becomes more active, the proper relationship between the required strength and the weight of the brace must be kept in mind. The brace should be simple and the need for extension, to accommodate for growth, must be considered. Frequent follow-up visits become necessary in order to determine whether or not the brace continues to fulfill its intended purpose.

In adolescent age, cosmesis quite often is of overriding importance. Complicated constructions may have to be resorted to in order to make braces acceptable to patients who are very self-conscious regarding their appearance.

For the adult, it is essential to consider the patient's social status, his occupation, and also his body weight. For a farmer, a leg brace without joints may be called for, whereas the same construction would be unsuited for a socialite woman with limited occupational needs.

Within its limits, a brace should be comfortable and wherever joints are required, the mechanical joint should correspond to the anatomical joint as closely as possible.

The question of overbracing or underbracing has been exhaustively explored. It seems to be the opinion of most physicians that it is wiser to apply extra bracing wherever there is any doubt. Parts may be removed as soon as this can be justified. To add bracing where originally insufficient support was provided is likely to induce a harmful psychological effect on the patient, whereas to remove a part usually has a beneficial effect.

The concept of teamwork has been firmly established in the approach to physical disability. It is practiced in prosthetics clinics all over the world. In the prescription and construction of braces, it is even more essential to have close cooperation between physician and orthotist. Basic requirements for an efficient brace clinic comprise:

1. Correct medical indication
2. Scientific orthotic design
3. Good workmanship
4. High grade materials
5. Careful fitting
6. Intelligent use by the patient

Brace shops should be in close proximity to hospitals or rehabilitation centers since frequent adjustments may be necessary to make a brace more functional, comfortable, and acceptable. Quite often adjustments are required to provide for changes in the degree of disability.

The following are some indications for appliances, as well as a brief description of their function.

Ankle braces are constructed for several purposes. If a foot has been operated on and the surgeon would like to keep the foot in the corrected position, he probably would prescribe a splint. Splints are generally made from plaster-of-Paris or plastics, and do not allow for any ankle motion.

If an ankle brace is required to correct imbalance of musculature between the anterior and posterior muscle groups, a brace with an ankle joint would be prescribed. It is essential that the mechanical joint is placed as close as possible to the point of rotation of the anatomical ankle joint.

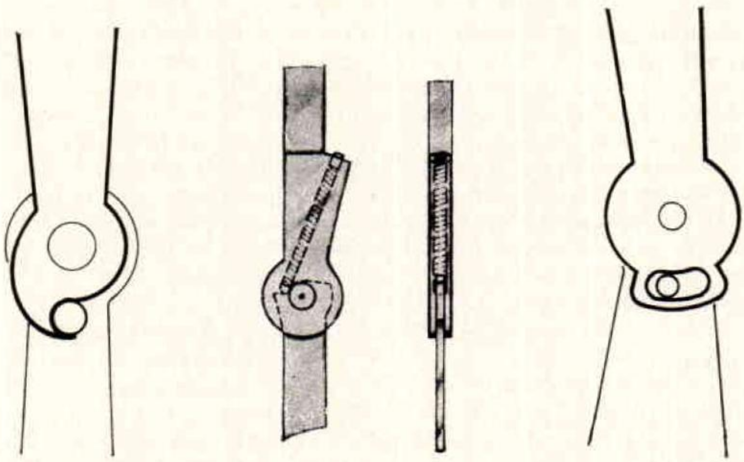


FIG. 1 FIG. 2 FIG. 3

FIG. 1—90° ankle joint stop. FIG. 2—Spring type assist, as in Klenzak joint. FIG. 3—Limited motion stop.

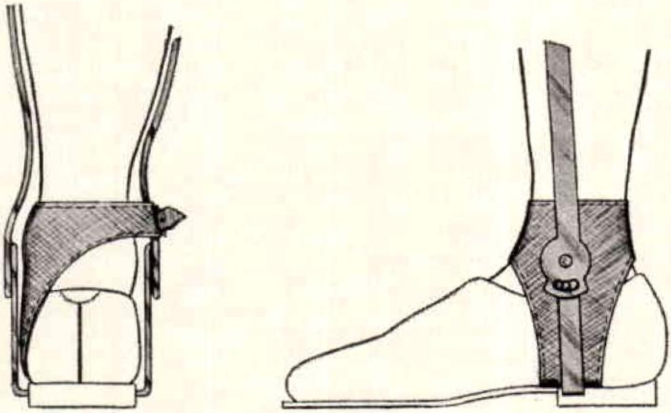


FIG. 4—T-strap to prevent pronation or supination of foot.

Many types of ankle braces are prescribed for dysfunction of the muscles of the foot and ankle. The purpose of such a brace is to prevent drop foot and to enable the patient to walk without toe drag.

If dorsiflexion or plantar flexion are to be controlled, the brace needs to be provided with an ankle stop. A 90 degree stop (fig. 1) will prevent plantar flexion beyond a right angle, but permits dorsiflexion. This type of stop is used wherever there is paralysis of the dorsal flexors. If one desires braces to assist dorsiflexion a mechanism to elevate the toes is required. This could be a spring type assist, as in the Klenzak joint (fig. 2), or elastic straps.

Limited motion stops (fig. 3) are occassionally prescribed in combination with a T-strap (fig. 4) to prevent either pronation or supination of the foot.

A different type of ankle brace to prevent drop foot is shown in fig. 5. This brace consists of spring steel without any ankle joint. Several types of ankle braces with single posterior bars have been constructed. These are attached to the shoe (fig. 6). This brace has limited indication, since the incongruency of the ankle motion between the brace and normal joint creates friction at the calfband. In some constructions this has been overcome by a slot in the posterior bar to allow motion between the upright and the brace. The constant bending forces create metal fatigue and failure. The main advantage of this type of brace is its superior cosmetic effect.

The reverse 90 degree stop (fig. 7) is used wherever there is paralysis of the plantar flexors, and for spasticity of the dorsiflexors.

Short leg braces can also be worn for night use, in order to prevent contractures or to maintain an improved position of the ankle joint which has been corrected through exercise, and where spasticity of the flexor or extensor muscles is present.

Short leg braces are indicated, too, for the correction of valgus or varus deformity of the ankle. Such construction would consist of a well-fitted molded sandal with a single bar on the outside for varus deformity, or on the inside for a valgus deformity. With the foot securely laced into the sandal, the long lever action permits a correction. Where such a brace is worn during the night, no ankle joint is required. The free ankle joint should be installed if the brace is to be worn during the day.

Long leg braces are required for any disability at or above the knee. They may be indicated for weak or paralyzed knee extensors, for hyperex-

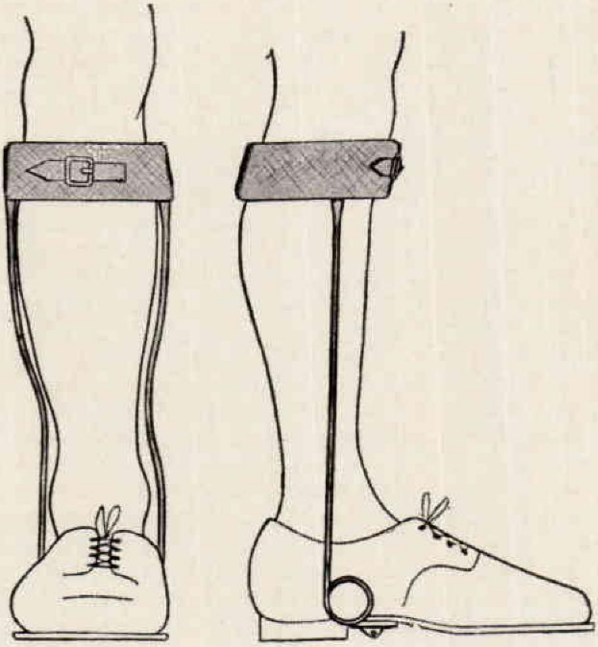


FIG. 5—Ankle brace to prevent drop foot.

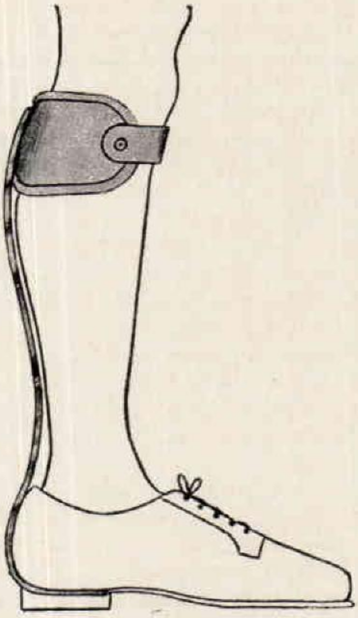


FIG. 6

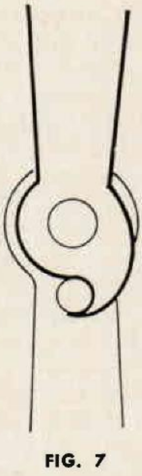


FIG. 7

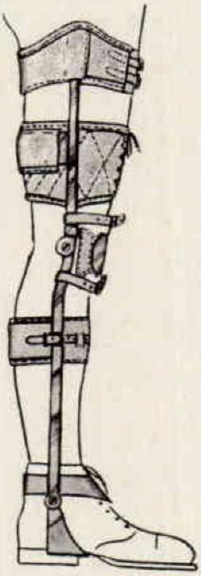


FIG. 8

FIG. 6—Ankle brace with single posterior bar. FIG. 7—Reverse 90° stop.
FIG. 8—Knee brace with calfband and two thigh bands.

tension of the knee, for either genu valgus or varus, for flexion contractions, or for involuntary motion. In some instances they are also used for tibial torsion. Again, these braces have to be accurately prescribed to fufill a specific need, and since there are many different types of disability, constructions for long leg braces differ considerably.

The simplest knee brace would be one to prevent genu recurvatum. Wherever the capsular ligament of the knee is overstretched, the danger exists that there will be progressive hyperextension of the knee. This can be prevented by a knee cage with anterior stops to prevent extension beyond 180 degrees. Simple side-bars with an anterior stop are frequently attached to an elastic knee cap to prevent such deformity. In more severe cases it might be necessary to construct braces which are attached either to a foot plate to be worn inside the shoe, or to a foot stirrup attached to the shoe. Such a brace should have a calfband as well as two thigh bands to keep it in position (fig. 8). The placement of the kneejoint is important in order to minimize any incongruous motion between the anatomical joint and the mechanical joint. There is, however, no true point of rotation in the knee joint and it is generally agreed that the least incongruency of motion takes place if the joint is located opposite the medial epicondyle of the femur. By slight deviation of placement of the knee joint from this point, different effects can be obtained. There are several knee joint constructions designed to duplicate the bending-sliding motion of the anatomical joint. Most of these constructions are rather complicated, however, and are resorted to only infrequently (fig. 9).

A long leg brace also has to be applied whenever there is weakness of the quadriceps. By placing the mechanical joint somewhat posterior to the anatomical joint, buckling can be prevented, although the quadriceps muscle might be paralyzed. Several constructions utilize an elastic extension aid (fig. 10).

Excessive genu valgus and genu varus require long leg braces. In these cases pads have to be attached to the medial bar for genu valgus and on the

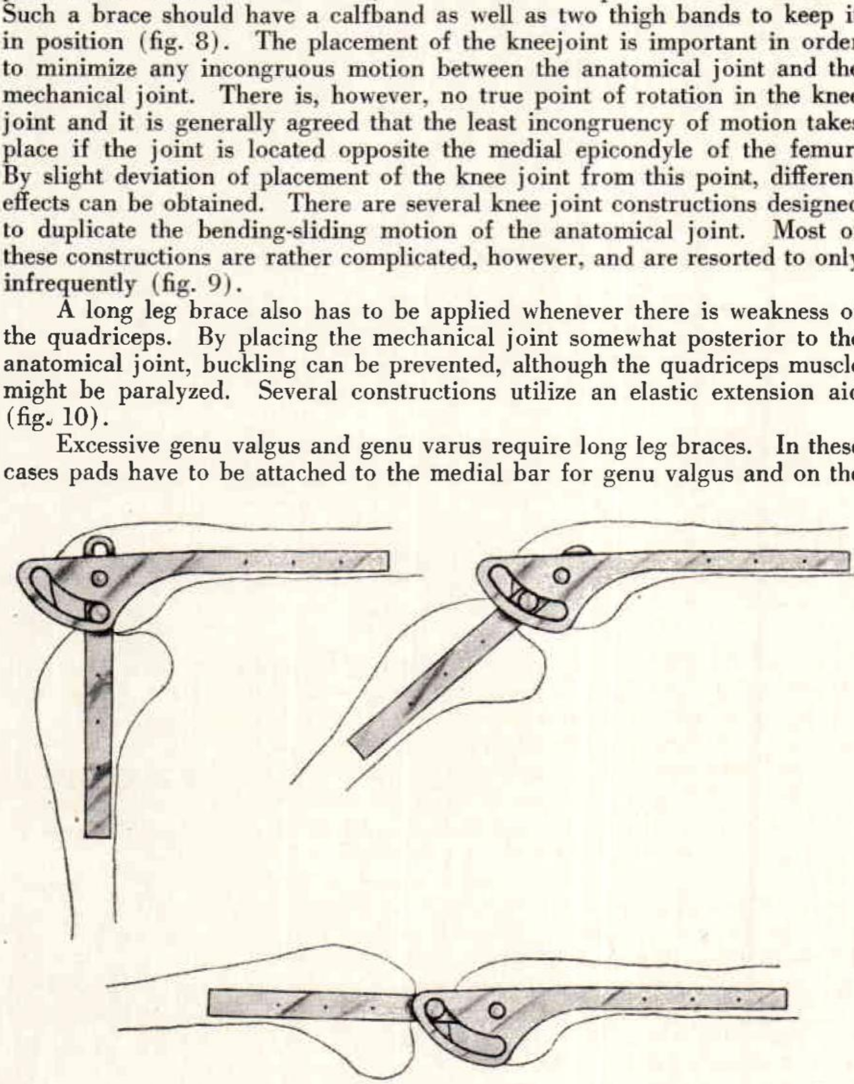


FIG. 9—Knee joint construction.

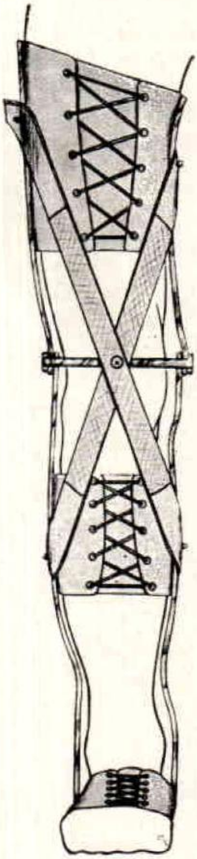


FIG. 10

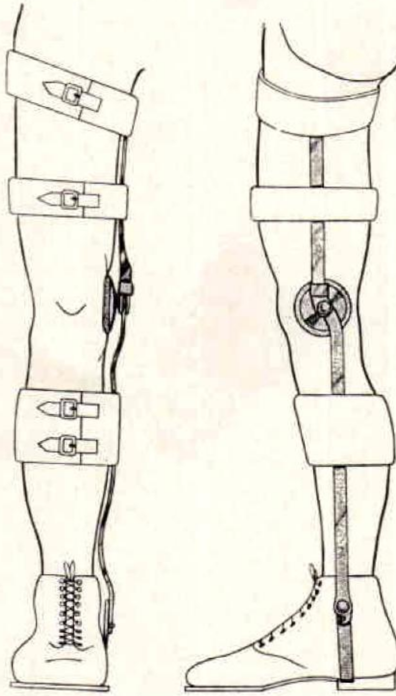


FIG. 11

FIG. 12

FIG. 10—Long leg brace with elastic extension aid. FIG. 11—Single bar long leg brace. FIG. 12—Ring lock.

lateral bar for genu varus. The alignment of the brace combined with the pressure exerted on the soft tissues of the knee by these pressure pads will prevent progressive deterioration of the knee joint. Single bar braces as shown in fig. 11 serve a similar purpose.

Involuntary motions of the lower extremities, such as athetoid or spastic motions at ankle or at knee, are also controlled by long leg braces. Depending upon the disability, knee joints are constructed allowing free motion, limited motion, or are provided with a kneelock.

The simplest lock is a ring lock (fig. 12) which is normally applied to the lateral bar, except in a case of hemiplegia, where the lock is applied to the medial bar. In these cases the patient also has a disability of the arm on the same side, and therefore finds it difficult to operate a lock which is placed laterally. The ring lock is simple in construction and is dependable.

Bail locks (fig. 13) or Swiss locks (fig. 14) act on both side-bars at the same time. Such a double bar lock is preferred whenever high forces are transmitted through the medial bar. In those cases sheer forces would tend to break the bands or sheer the rivets.

Where supportive braces are required it is esential that they be pro-

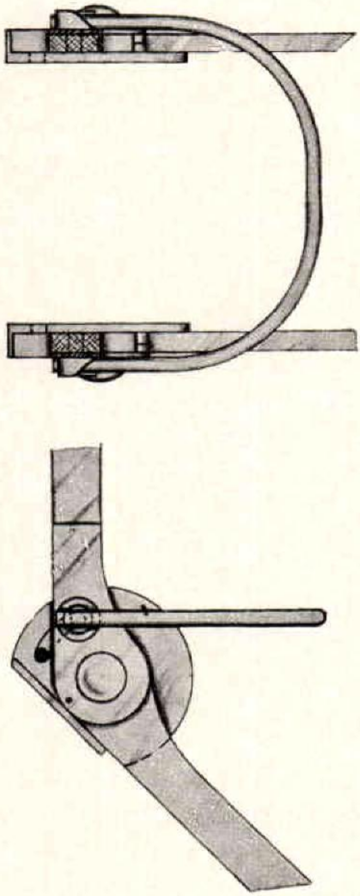


FIG. 13—Bail lock.

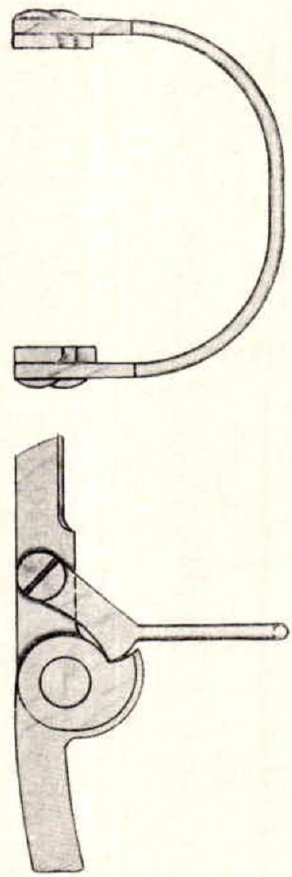


FIG. 14—Swiss lock.

vided with knee locks and also with an ischial support for unweighting the lower extremity. Complete unweighting is rarely required, and it is difficult to achieve in any type of brace. Definite indications for such a brace would be the fracture of the neck of the femur or the destruction of the hip joint. At present, a long leg brace with knee lock and quadrilateral wood top is gaining favor. In such a mechanism the wood top is constructed similar to the upper rim of a quadrilateral above-knee prosthesis.

Another possibility for unweighting the lower extremity is by means of an ischial seat or ischial band such as is found in the Thomas ring, or its many modifications. In the construction of a Thomas ring it is essential that the tuberosity of the ischium is fully supported, that the posterior weight-bearing area is parallel to the ground, that the lateral bar is at least two and one-half inches higher than the medial bar, and that no pressure is exerted on the pubic bone. The ring should be well padded to provide comfort. Wherever the contours of the leg make it possible, a closed ring is preferable to an open one. If an open ring is necessary, a strong leather strap should be provided to keep the tuberosity of the ischium accurately on the seat of the brace.

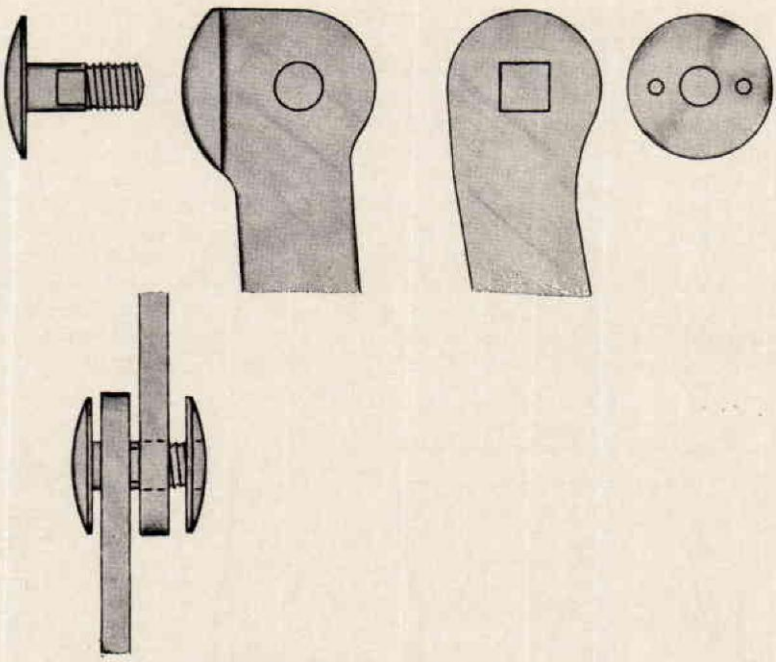


FIG. 15—Overlapping brace joint.

A weight-bearing brace in most cases requires to be provided with a hip joint and pelvic belt in order to maintain the alignment of the hip and to control the movements of the hip joints, such as flexion, extension, abduction, adduction, as well as internal and external rotation.

Hip joints, knee joints, as well as ankle joints may be the overlapping type or the box type. Where only minimal compression forces are applied, the overlapping type (fig. 15) will serve the purpose because it is less bulky and less expensive in construction.

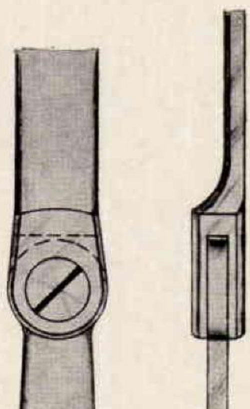


FIG. 16—Box joint for weight-bearing brace.

Weight-bearing braces should be made with box joints because the vertical forces are better distributed and the joints are more stable and more durable. (Fig. 16). Wherever duralumin is used it is essential that all friction surfaces are lined with steel, brass, or teflon to minimize friction.

Depending upon the disability again, the hip joint can be provided with free motion, with limited motion, with a stop at full extension, or with a lock. If only flexion and extension of the hip joint is required it is sufficient to provide a simple joint which allows this motion. In most cases, however, damage is serious enough to require a stop at 180 degrees to prevent hyperextension. Any hip joint should be constructed in such a way that hip flexion of at least 90 degrees is possible in order to allow the patient to sit comfortably. A pelvic band should be contoured to conform to the angle of the sacrum. The point of rotation at the hip is normally considered to be at the tip of the greater trochanter. In the case of bilateral braces, it is essential that both hip joints are parallel to each other in order not to restrict motion.

In the case of marked spasticity for contractures of the flexors, the metal bands have to be carried low over the sacrum and butterfly extensions are quite often resorted to (fig. 17). Wherever this becomes necessary it is essential that the hip joints are provided with locks, since otherwise no benefits are gained from butterfly or similar extensions. If there is a marked abnormal degree of abduction or adduction at the hips it becomes necessary to reinforce the pelvic band attachment considerably in order to control

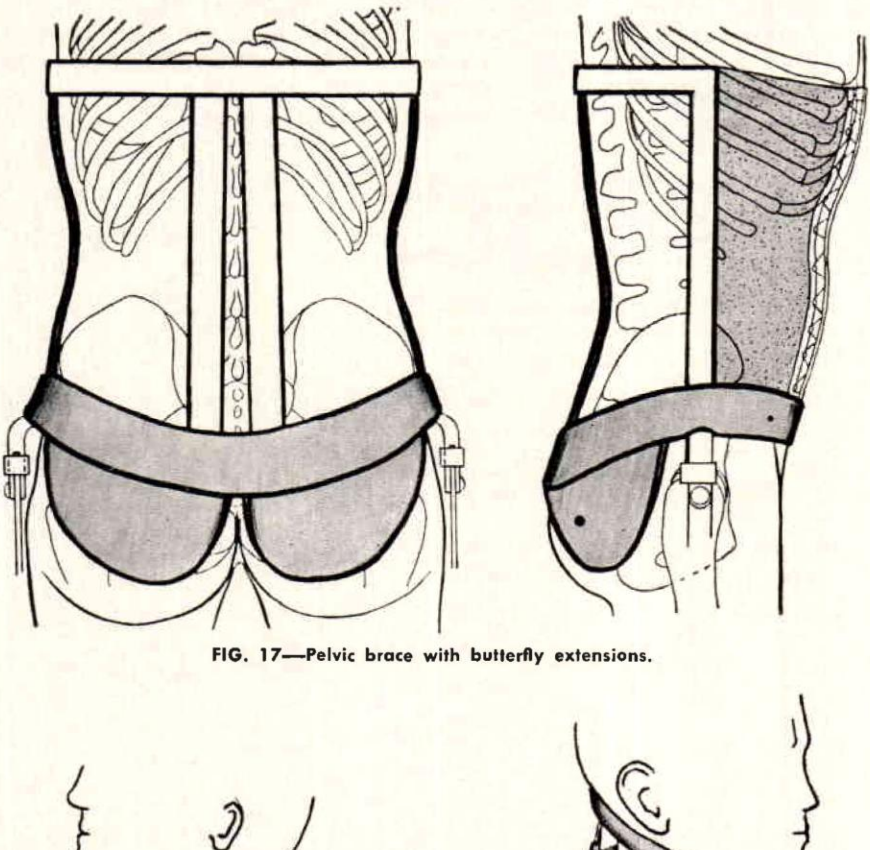


FIG. 17—Pelvic brace with butterfly extensions.

FIG. 18—Non-height-adjustable collar.

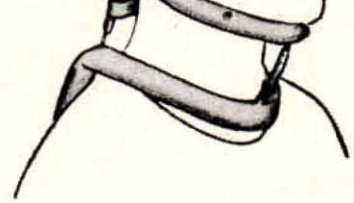


FIG. 19—Height-adjustable collar.

these motions, especially in case of spasticity. In severe cases it may become necessary to apply a spreader bar.

Bilateral long leg braces with pelvic belts are normally sufficient in all pathological conditions of the spinal cord with a motor level at T-10 or below. If the spinal cord is damaged above this level it becomes advisable to construct long leg braces to which a spinal brace is attached. In these cases a spinal attachment is used to support abdominal muscles to prevent lordosis and to maintain good body alignment.

There are innumerable constructions of spinal braces. They differ greatly in their constructions but all may be classified into two groups:

1. Passive or suporting
2. Active or correcting

The supporting spinal braces are used in symmetrical physiological conditions where the spine or trunk needs to be supported in an optional position for functioning, to alleviate discomfort, and for the fixation of fractures and post-operative conditions. In a corrective brace an attempt is made by mechanical means to overcome asymetry of the torso.

Orthopedic appliances for the neck most frequently used are of the following types:

1. Non-height-adjustable collar (fig. 18)
2. Height-adjustable collar (fig. 19)
3. Molded collars (fig. 20)
4. Open wire frame collars (fig. 21)

The first two types are generally prefabricated, whereas the third is molded to a plaster-of-Paris cast. The open wire frame collar is provided with turnbuckles for easy adjustment. Also used for pathology of the cervical spine are braces of either four-poster type, shown in fig. 22, or the two-poster type, shown in fig. 23. The last one is the most popular and versatile for cervical spine conditions.

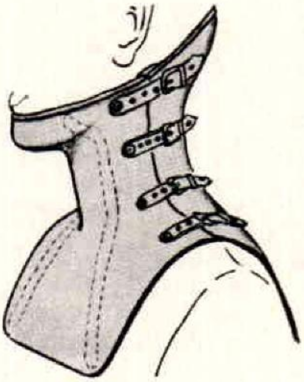
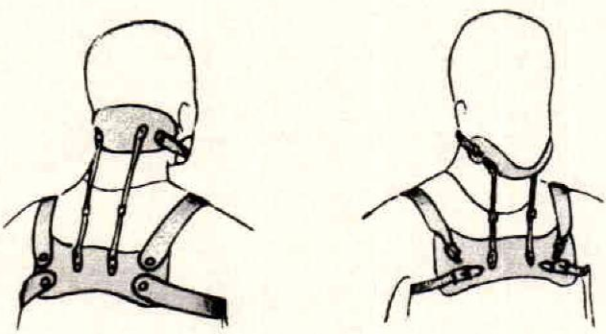


FIG. 20—Molded collar.



FIGS. 21 & 22—Open wire frame four-poster collar.

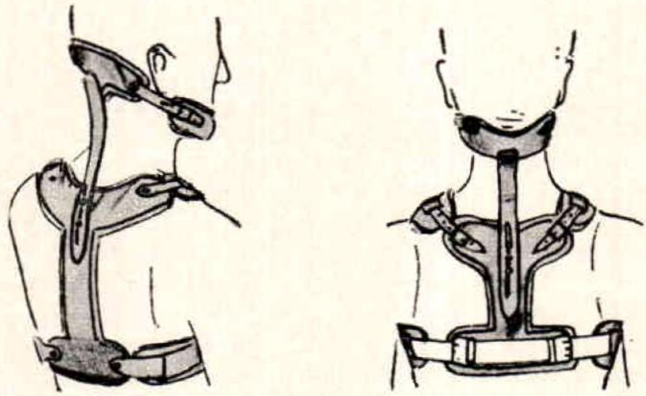


FIG. 23—Two-poster collar.

Braces for the dorsal and lumbar spine are prescribed for:

1. Kyphosis of the dorsal spine
2. Lordosis of the lumbar spine
3. Low back pain with or without disc complications
4. Fracture or post-operative condition of lower cervical and high dorsal spine
5. Fracture or post-operative condition of the middle low dorsal and upper lumbar spine
6. Fracture or post-operative condition of the lower lumbar or sacral region.

A lumbar and lower thoracic brace composed of a metal frame encircles the dorsal half of the body and is held in position by a corset or is strapped to an apron or abdominal pad. (fig. 24).

A lumbar and sacral brace is composed of a rectangular frame strapped to an apron or abdominal pad. (fig. 25).

A full back brace with a pair of uprights extends from a pelvic band at the level of the coccyx or lower sacrum to the upper third of the scapula or higher. In many variations the upper portion of the vertical bars turn laterally along the superior border of the scapulae. This brace also has a dorsal crosspiece which joins the two uprights at a position between T-10 and the lower third of the scapulae. The brace is attached by a corset pad or apron and by two shoulder straps which are attached to the superior terminus of the uprights and the dorsal crosspiece. (fig. 26).

A spinal hyperextension brace consists of a metal frame which rests against the anterior half of the body; a back pad which holds the brace against the body with varying degrees of pressure; and a sternal and a pubic pad which transmit counter pressure anteriorly. (fig. 27)

There are a number of braces for the correction of scoliosis. This condition is extremely difficult to correct since it consists of a combination of curvature as well as rotation of the spine. One of the more effective braces is the Milwaukee brace, as shown in fig. 28.

In addition there are molded body corsets made from different materials, such as plastics, molding leather, and others.

Although braces are generally known by the name of their designer, all of the braces fall into one of the above mentioned categories.

The following are some prescription criteria for definite disorders requiring braces.

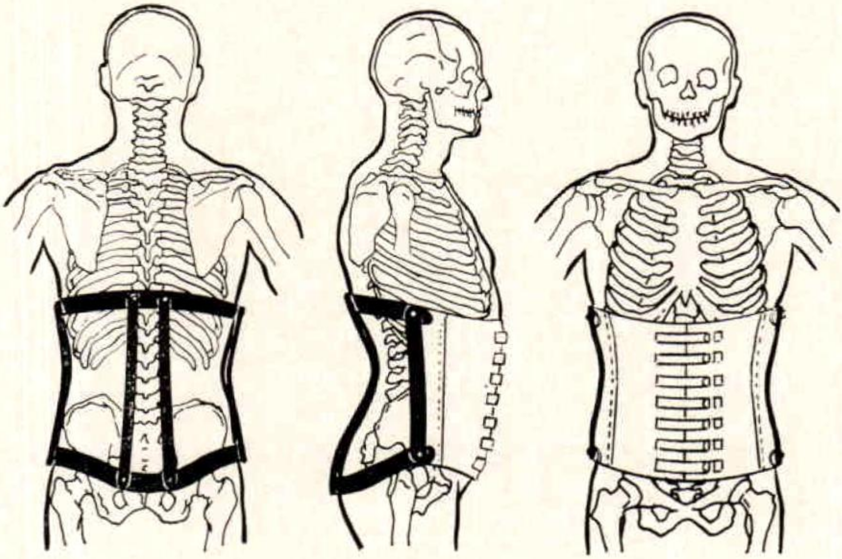


FIG. 24—Lumbar and thoracic brace with corset or apron

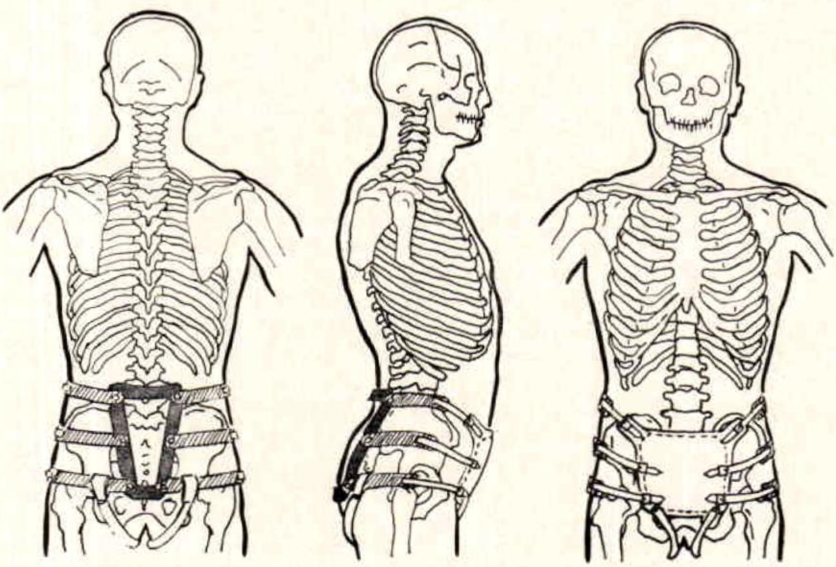


FIG. 25—Lumbar and sacral brace with apron

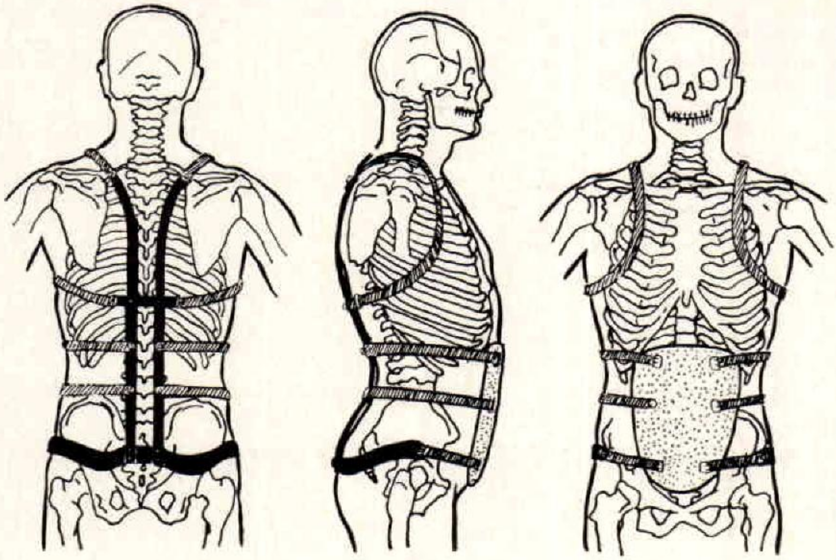


FIG. 26—Full back brace with corset or apron and shoulder straps.

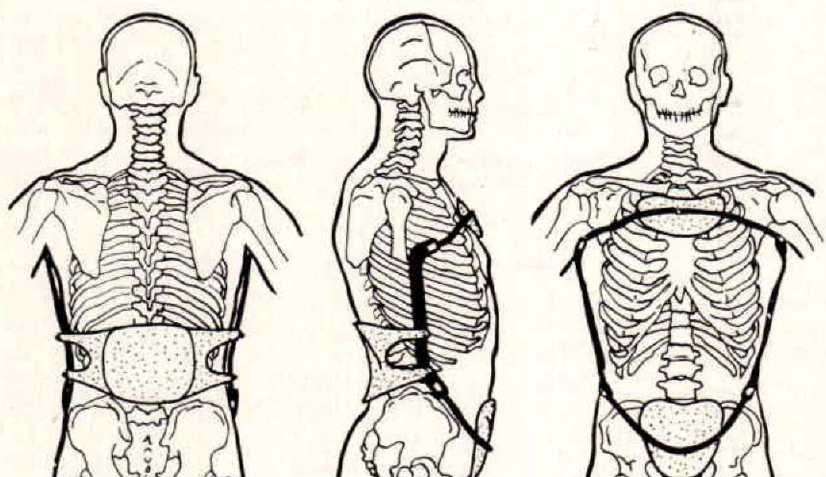


FIG. 27—Spinal hyperextension brace

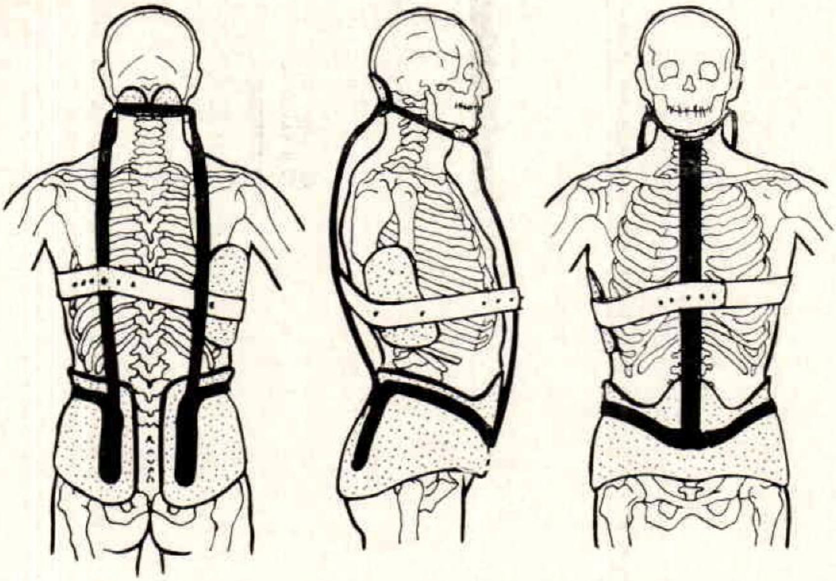


FIG. 28—Milwaukee brace

LOWER MOTOR NEURON DISORDERS

The brace should be of light weight in consideration of generalized limb weakness and lack of spasticity. Spring-loaded ankle joints are often used. Since there is full range of motion the congruence of the mechanical and anatomical joints is very critical.

As the result of paralysis of the anterior ankle musculature one may find a functional drop foot but there might also be a fixed deformity of the ankle, with equinus as result of a tight heel cord, as well as valgus or varus of the ankle and a combination of deformities of the foot. Any type of drop foot brace previously described may be indicated, depending upon the severity of the involvement.

Wherever one finds paralysis of the knee musculature causing weak knee extension, genu recurvatum or a flexion contracture, a long double bar leg brace as previously described is indicated, with the construction again depending upon the muscular involvement. If genu recurvatum or knee flexion contractures exceed 20 degrees, surgical correction is probably indicated, because knee bracing for such a condition becomes rather complex and heavy. The involvement of hip and/or knee extensors may require pelvic support either with or without hip lock, ischial seat, and knee locks.

Other muscles involved which might require bracing are the iliatibial band and the hamstring muscles. The type and amount of bracing depends upon the involvement of the musculature, as well as the deformity present. In the involvement of the hip one finds flexor paralysis, poor gluteus maximus, hamstring paralysis, or combinations of all three; as well as adductor and abductor paralysis. Bracing consideration is again guided by the involvement of the individual muscles or muscle groups and in some cases requires an addition of a pelvic belt, ischial seat, or even a spinal brace to standard long leg braces, with or without knee locks.

SPASTIC CEREBRAL PALSY

One of the most difficult physical disabilities to be braced is a case of spastic cerebral palsy where one finds not only motor deficit and impaired perception, but also functional and/or fixed deformity of the foot, knee, and hip. Motor deficit is usually bilateral volitional motor loss, and spasticity as an accentuation of antigravitational reflexes. Diffuse weakness may also be present.

One quite often finds the sensory deficit to consist of proprioceptive difficulties, visual field defects, and spatial disorientation.

In children with spastic cerebral palsy one finds almost any combination of the foot deformities. These should be corrected by surgical shoes. The more common deformities of the knee are either functional or fixed flexion contractures and genu valgum, which is sometimes combined with aptellar dislocation. Less common are genu varum, genu recurvatum, and ligamentous instability. Functional or fixed abduction flexion and internal rotation contractures of the hip are rather common, frequently combined with hip dislocation. As previously mentioned, the deformities of the feet are controlled by shoe corrections. Due to the severe deformities combined with spasticity, it is essential that the shoes are not an integral part of the braces, but are put on separately and the braces are connected by means of detachable stirrups.

Spring-loaded ankle joints are generally not recommended because they might induce spasticity. In a functional foot drop a plantar flexion stop is needed. Wherever there is a fixed equinus deformity, heel elevation has to be adjusted to such deformity. Surgical correction is often indicated in equinus as well as calcaneus deformities. Double bar long leg braces with knee caps as well as knee locks are indicated for functional flexion contractures. Fixed flexion contractures in excess of 25 degrees require surgical correction wherever possible. Where a fixed knee flexion contracture is unilateral, shoe elevation to equalize leg length is necessary. Genu valgum or genu varum require pressure pads medially or laterally. Genu recurvatum is prevented by extension stops at the knee joint in long leg braces.

In bilateral hip contractures a well contoured pelvic band with butterfly extensions maintains hip extension whenever the hip is locked.

Spreader bars as previously described may be indicated for extreme cases of adductor spasticity. Since it is very difficult to operate hip locks as well as knee locks against bending forces in spastic cerebral palsy, it is often necessary to provide locks where friction is reduced to a minimum by either ball bearings or roller bearings in connection with teflon linings at the friction areas. In the case of unilateral spastic cerebral palsy it is essential that the long leg brace with hip joint and pelvic band is anchored on the opposite leg by means of a thigh cage.

SPASTIC HEMIPLEGIA

Spastic hemiplegia normally involves the lower extremities distally and is usually treated by means of shoe corrections and short leg braces. Since a drop foot is almost always present there should be a plantar flexion stop in order to enable the foot to clear the ground during swing phase.

In a flaccid hemiplegia or wherever there is only minimal spasticity, a spring-loaded ankle joint is indicated as shown in figure 29. In the presence of a severe spasticity the standard prescription calls for a limited ankle joint. If there is minimal weakness of the knee musculature it is frequently sufficient to fit the short leg brace in slight equinus position. This will create a rotation movement around the knee to act as a stabilizing force. Wherever there is a severe lack of knee control a double bar brace with medial drop lock as previously described may be indicated. In case of such severity, limited gluteal bearing may be advantageous.

PROGRESSIVE MUSCULAR DYSTROPHY

No definite bracing pattern has been established. It is generally felt that wherever braces are used they should be of light weight and should provide extension assists in order to encourage motion around the joints. Only in the latter phases of this disease are locks indicated.

ATHETOID CEREBRAL PALSY

In this disease one generally finds involuntary movement of the trunk and all extremities with a varying degree of volitional motor loss. There may be deformities whenever athetosis is combined with hypertonicity. Those deformities, however, are rarely fixed.

There is considerable controversy concerning bracing of athetoids. Wherever bracing is recommended it is done for control purposes since bracing restricts involuntary motion, and increases the possibility of learning voluntary control. Bracing can be decreased as such control increases. Bracing normally starts with bilateral long leg braces combined with spinal bracing where hips as well as knees are initially locked. Locks are released progressively as voluntary control is achieved. It is essential that shoes can be independently removed for easier dressing. Ankle joints are most frequently provided with approximately fifteen degrees of motion in either direction. Locks at the knees, as well as at the hips, should be constructed in such a manner that both joints can be locked in full extension as well as in 90 degrees of flexion. Quite oftern weights are used to help control involuntary motion of the extremities.

Arthritic deformities and *fractures* are frequently braced. The type of braces, however, varies considerably and is determined by the functional disability. Bracing is applied in arthritis for restrictive motion of joints in order to prevent pain and deformities about the joints. In fractures, bracing is applied primarily for fixation.

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