In 1947, the Scoliosis Service began at Gillette Children's Hospital, St. Paul, Minnesota; under the direction of Dr. John H. Moe. After visiting Dr. Cobb in New York, Dr. Moe was impressed with the possibility of truly helping children with scoliosis. The other physicians at Gillette, frustrated by years of inadequate response to previous efforts, gladly turned over to Dr. Moe their scoliosis problems. Thus began the Twin Cities Scoliosis Center.

It is no coincidence that, in 1944, the Milwaukee Brace was developed by Drs. Blount and Schmidt in Milwaukee. Dr. Moe being a close friend of these 2 pioneers, was aware of this development and immediately incorporated the Milwaukee Brace into the Gillette scoliosis program.

Since 1947, there has been a constant evolution of the Milwaukee Brace, and then in 1977, a near revolution in orthotic design for spinal deformities. In particular, we refer to the use of various designs of plastic under-arm orthoses.

It is not the purpose of this paper to review the evolution of brace designs but rather to put down where we, at the Twin Cities Scoliosis Center, stand in 1977 as to the various designs being used, the concepts behind those designs, the clinical application of the various orthoses, and some examples of the results being obtained.

CURRENT ORTHOSES OF THE TWIN CITIES SCOLIOSIS CENTER

THE MILWAUKEE BRACE

The developers of the Milwaukee Brace had a guiding design philosophy which was

dearly excellent. They wished to obtain or maintain an adequate spine length; they wished to apply lateral forces to the curve or curves in order to obtain and maintain correction; they wished to have the orthosis adjustable for growth and length, and they wished to reduce body coverage and constraint to a near minimum. The orthosis was originally designed not for non-operative care, but rather for the postoperative correction and control of paralytic poliomyelitis curves, such patients often having limited vital capacity. The constrictive casts often used in those days customarily reduced the patient's vital capacity rather than improving it.

Subsequently, the brace became popular as a method of non-operative treatment. With greater experience, the brace has not only become more effective, but more cosmetically acceptable as well. Clinical and research studies have considerably helped to define its mode of action, results, limitations, indications, and contraindications (Fig. 1).

If the pelvic section is made correctly with a properly shaped and positioned lumbar pad, it can effect quite a powerful correction of a lumbar curve. This is, however, a purely passive, constraining mechanism and results in stiffness rather than strengthening of the convex paraspinal muscles.

The effect of the Milwaukee Brace on a thoracic curve is somewhat more dynamic. The pad does not exert pressure on the muscles we would like to strengthen. The thorax can easily be moved away from the pad in exercises and daily activity. The thorax can rotate within the brace. The thoracic pad is freely suspended from the uprights so that it can move with the thorax to some extent. When the thorax moves away from the pad, the pad swings downward and medial; when
the thorax moves back into contact with the pad, there is a momentarily increased cor-
rective force with an added uplifting com-
ponent.
There has been much controversy about
the upper end of a Milwaukee Brace, i.e.,
the neck ring and its pads. It was long ago
learned that a passive distraction force was
not desirable. It was not an effective curve-
correcting force, nor was it good for the
patient. There were far too many bite de-
formities produced by such forces, and it
also made the orthosis uncomfortable and
ugly.
The neck ring acts as the third point in a
3-point corrective force system where the
thoracic pad is one force point, and the pel-
vic section and neck ring act as counter-
force points.
In the absence of an axillary sling, the neck
ring acts as an alignment stimulus. When
wearing a right thoracic pad, for instance,
the patient will acquire the ability to actively
manage his upper thorax position to main-
tain the neck ring pressure on the left side
of his neck at a tolerable or perhaps zero
level. The effect is an active correction
superior to the thoracic pad, resisting in
strengthening of the muscles on the con-
vexity of the curve.
Similarly, the patient being treated for
thoracic kyphosis obtains a passive correction
of the lumbar lordosis and a partially active
correction of the thoracic kyphosis from use
of the thoracic extensors. Without this active
component, the patient's chin and larynx
would press against the anterior pan of the
neck ring, a most unpleasant experience.
Recognizing the role of the neck ring as a
stimulus to align or extend, we can under-
stand why some special adaptations must be
made if the Milwaukee Brace is to be used
on a patient without voluntary muscle control
of the thorax.
The model for the Milwaukee Brace is
taken with the patient standing in a position
of reduced lumbar lordosis and any lumbar
scoliosis partially corrected by hand pressure
through the wet plaster. The plaster positive
is skived anteriorly to create firm abdominal
control. If there is a lumbar scoliosis, the
asymmetry resulting from a prominence on
the convexity and hollow area on the concav-
ity is reversed on the model.
The pelvic section is fabricated of 0.46 cm
polypyrrole. The uprights are kept close
to the body fore and aft, allowing room
anteriorty for a full, deep inspiration, but no
more. The posterior uprights are kept close
enough together to fak medial to the scapu-
lae for a closer, more-cosmetic fit.
Lumbar pads are attached to the inside of the
pelvic section with Velcro, and a butress
is placed between the pelvic section and pos-
terior upright in order to maintain a con-
stant force against the lumbar curve.
Thoracic pads are made of 0.15 cm thick
polyethylene, faced with 0.60 cm thick plasta-
Fig. 2. Detail view of the custom-molded thoracic pad used when the patient has a relative thoracic lordosis in combination with a significant rib hump (Case 3 of Fig. 3).

note padding. The thoracic pad is much more flexible than previously, is larger, and is shaped to extend well around and beyond the lateral midline of the thorax.

Auxiliary slings are also fabricated of polyethylene and plastazote. Shoulder rings, when possible, are fabricated of polypropylene, because significant rigidity is necessary to maintain shape under pressure. A concerted effort is made to shape the shoulder ring so that it firmly grasps the shoulder anteriorly below the axillary and posteriorly on the flat area of the scapula inferior to its spine.

Considerable controversy exists as to the precise positioning of a thoracic pad when one considers not only the scoliosis, but the thoracic kyphosis or lordosis as well. When a significant rib hump (greater than 1.5 cm) exists in combination with thoracic lordosis (a lateral X-ray measurement of less than +20°), great care must be taken to treat the scoliosis without aggravating the thoracic lordosis. To accomplish this, the thoracic pad vector force must be almost entirely medial in direction, not forward. To do this, the posterior upright on the convex side should be placed to support but not exert a steady anterior force on the thoracic pad. Also, of course, the thoracic pad should extend around beyond the lateral midline, and the strap is attached directly to the anterior upright without an outrigger.

To minimize the tendency of this force to increase the sharpness of the rib hump, the pad must be larger than usual and exactly fitted to the existing prominence, thus transmitting the forces toward the vertebrae without further rib deformation. To obtain this precise molding, this pad should be made of orthoplast (Fig. 2).

When true kyphosis exists (>40° on measuring the lateral X-ray), then the thoracic pad's medial border should be between the posterior upright and the patient's rib hump. The posterior upright should be so positioned that firm contact is made with the thoracic pad. The thoracic pad should be attached to an anterior outrigger. Figure 3 outlines our recommendations for managing these lordoses and kyphosis problems in conjunction with thoracic scoliosis. Decisions in the area between 20° kyphosis and 40° kyphosis are made, of course, on the basis of interpretation, the patient's clinical appearance in the orthosis, and lateral in-orthosis X-rays, if warranted.

The Boston prefabricated pelvic section, available in up to 16 sizes, has been found to be quite satisfactory for those patients whose anatomy conforms to one of the standard sizes. Generally speaking, we prefer to make most of our pelvic sections individually.

One-Piece Thoracic-Lumbar-Sacral Orthosis ("TLSO")

In the past few years, considerable enthusiasm for, and experience with, various models of understand level orthoses has developed around the world. These take various forms and names but have essentially the same
basic formulation. They are undertaum in level, having no neck ring, and apply virtu-
ually pure passive corrective forces. The "Corset Lyonnaise" of France, the "Riveria brace" of Italy, the "Lexan jacket" of Pasadena, California, and the "Boston jacket" are all examples of this type of orthosis. Some open in back, some in front, some have front and back halves, but all have proven quite effective in controlling mild and flexible lumbar and thoracolumbar curves.

At the Twin Cities Scoliosis Center, we began using the TLSO in 1973. As we gained more experience, both in manufacture and application, we have come to rely on this as the standard orthosis for flexible lumbar and thoracolumbar curves. A thoracolumbar curve is defined as a curve with its apex at T12-L1.

We feel that we can provide the maximum corrective effect, coupled with maximum comfort and cosmetic acceptance by custom manufacture of each orthosis individually for each patient.

Elimination of the neck ring creates additional problems for the orthotist, if he is going to strive for an open, adjustable orthosis with minimal constraints on the patient's movement. Without some sort of rigid link between anterior and posterior elements superiorly, the orthosis loses much rigidity. Also, the neck ring does much to align the patient's head centrally over the pelvis. Without the neck ring, we must rely more on the patient's sense of alignment and more subtle mechanical means.

To make this orthosis, a plaster mold is taken of the patient just as we do for the Milwaukee Brace. An alternative method is to take the mold with the patient on a Riser
frame in full correction. The plaster positive is skived and modified identically to the Milwau-
kee Brace, and the plastic is formed similarly. The differences begin to occur as the trim lines are cut in the plastic. Two pos-
terior extensions are created para-spinally and just inferior to the scapulae. These ex-
tensions are about 7 cm wide, and the lat-
eral border sweeps almost straight down to blend with the usual lateral trim line. Tro-
chanteric extensions are made by continuing the inferior-posterior border straight around laterally, past midline, and then sharply up-
ward to blend with the rectus femoris relief (Fig. 5).

At Gillette Hospital, a single layer of 0.60 cm thick plastazote is cemented to the inner surface. This creates a more snug contact and makes local pressure relief easier. At Fairview Hospital, this liner is not custom-
antly used, thus giving us a controlled study of the two designs. Without the liner, there are a few more pressure problems needing relief, but in contrast, the orthosis is thinner, thus more cosmetically acceptable.

Two strap fasteners are installed post-
eriorly. One is located about the level of L3, the other about 5 cm above the lower edge of the orthosis. Stainless steel bars (the same metal as the Milwaukee posterior uprights) are riveted to the posterior aspect on each side about 2 cm from the posterior opening. These bars stabilize the configuration of the orthosis. If not present, the plastic "creeps" with time and stress, and the correcting forces are lost. For the same reason, we have begun installing a semi-circumferential bar in the waistline on the same side as the lumbar pad. This preserves the anterior component of the lumbar pad force vector.

Additional pads are thus added according to the patient's curve patterns as determined by clinical examination and X-rays. If either a lumbar or thoracolumbar curve is being treated, a lumbar pad is installed similarly to our Milwaukee Brace. For a purely lumbar curve, only this one pad is needed. For a thoracolumbar curve, a second pad is added above the first on the same side. This is an oval thoracic pad slung from the posterior upright to a trans ush on the shelf anteriorly.

Some patients have sufficient "righting re-
flexes" to bring the upper spine into central alignment over the sacrum after a corrective force has been applied to a lumbar or tho-
racolumbar curve. Thus no counter force is needed above the apex of the curve on the opposite side. Other patients may need such
a high counter force on the opposite side. This can be a thoracic pad slung from the posterior metal upright to the abdominal apron on the side opposite to the lumbar pad. It may also be a molded extension of the pelvic extension.

A trochanteric extension is usually necessary to stabilize the orthosis in a well-aligned position. Although sometimes used on the Milwaukee Brace when there is a tendency to list to one side, the trochanteric extension is more commonly used in the TLSO and is always used when treating a single lumbar curve. Padding is added to the inside surface of the extension until a sufficient stabilizing moment is created and the orthosis is in good alignment.

When treating a very flexible, relatively low kyphosis (apex TV or lower), a Milwaukee Brace is not necessary. The same basic TLSO design is created in the pelvic section with the posterior extensions extending to the apex of the kyphosis. Again, metal support bars are added. Strong correction of the lumbar lordosis will stimulate an active correction of the kyphosis above. If necessary, and often as a temporary measure, an aluminum anterior upright with sternal pad may be installed. While moving about, the patient will withdraw from this to avoid skin irritation (Fig. 6).

For this orthotic treatment to be effective, the patient must possess the ample-to-excessive lumbar lordosis which usually is present along with thoracic kyphosis.

**TWO-PIECE BODY JACKET TYPE OF ORTHOSIS**

As mentioned in the Milwaukee Orthosis discussion, the neck ring should not be used as a stimulus on patients without the voluntary control necessary to withdraw from it. The neck ring is also a hazard in some patients, because it does not permit them to position their head to best see what their hands, feet or crutch tips are doing. The visual feedback is often vital to their optimum function. A 2-piece body jacket type TLS Orthosis usually functions better than a Milwaukee Brace on these patients.

The 2-piece body jacket type TLS Orthosis has some disadvantages. It is not as adjustable for growth as is the Milwaukee Brace, and the location and intensity of the pressure systems cannot be adjusted as quickly. Its corrective or holding effect is almost entirely passive in nature.

This orthosis also serves very well as a
replacement for the post-surgery’s body cast. It is especially indicated in cases of generalized weakness, paralysis, or tactile sensory deficit. The model for this orthosis is taken on a casing table with the hips flexed about 45°. We generally extend the model up and over the shoulders so that we get a good impression of the clavicle and an exaggerated subclavicular depression. For many of these patients, it is obviously not appropriate to encourage additional lumbar flexion. In these cases, the inferior buttock and abdominal areas are not cut down as severely on the positive model. The subclavicular depression in the positive model must be relocated about 2 cm inferior to where they occur in the negative model. Cotton stockinet is then pulled over the positive model, and it is covered with a box 0.46 cm thick sheet of polypropylene, using a vacuum assist method. After the finished orthosis consists of overlapping anterior and posterior panels, the first plastic shell is cut from the model. The model is then rotated 180° and covered a second time to produce the second panel. The 2 panels are lined with 0.6 cm plastazote, and 2 fasteners are applied to each side. The fitting procedure requires experience, patience, and close attention to detail. Padding is added in some areas and removed in others. The trim lines are adjusted toward their optimum position for both comfort and function. After each set of fitting modifications, the orthosis is redrawn for a trial period. The degree of success is determined from the patient’s comfort and skin reaction. Sometimes small, local variations must be made in the contour of the plastic panel. The posterior panel should have a symmetrical, lateral trim line about 2 cm anterior to the lateral midline. Molded-covered, flexible vinyl tongue 3-4 cm wide should be fastened inside the orthosis and run the entire length of these lateral trim lines. This reduces the tendency to pinch the patient. The anterior panel should have a large window in the front to allow for thoracic expansion. Additional padding material should be added in the subclavicular area, as necessary, to concentrate holding pressure in that area and free the other areas of the thorax from constraint anteriorly (Figs. 7 and 8). The appropriate individuals (nurses and/or parents) must be instructed in how to properly don the orthosis. A natural fiber stockinet or T-shirt should always be worn under the orthosis. The patient’s position in the posterior panel must be correct before applying the anterior panel. The patient should be lying supine in the posterior panel.
on a firm, level surface. A finger in the pa-
tient's waistline should line up with the
waist groove in the orthosis (check both
sides). Palpation of the anterior-superior
iliac spines simultaneously should indi-
 cate that the pelvis is not rotated in the ortho-
sis. When the patient's position is not cor-
rect, he must be lifted at least partially
and repositioned and the new position
positively checked. Before applying the an-
terior panel, all excess circumferential stock-
nette material should be gathered to anterior
center. No wrinkles should be allowed in
the higher pressure areas, such as the waists-
line. The anterior shell should be gradu-
ally tightened into a snug position in steps. Be-
tween each step, exploring fingers must check
and prevent the skin from being pinched. Pinching is most likely to occur at the waist
and just below.

THE CHAIR INSERT-TYPE SITTING
SUPPORT ORTHOSIS

A Chair Insert-type Sitting Support Ortho-
 sis should be seriously considered when treat-
ing non-ambulatory patients with developing
scoliosis and/or kyphosis. The youths with
profound cerebral palsy or advanced muscu-
lar dystrophy are typical of this category. It
has been observed in the upper midwest at
least that the usual efforts to position these
children do not provide proper spine support,
proper position or comfort. A very signifi-
cant percentage of these patients with evi-
dence of scoliosis and/or kyphosis will pro-
gress to a serious deformity.
num position attainable. We try to put the cerebral palsy patient, for instance, in a relaxed position of reduced thoracic kyphosis, reduced scoliosis, and as much lumbar extension as possible. His hips are held in enough flexion to break up his spastic extension reflex pattern and in a few degrees of abduction. His shoulders are abducted 90°. In this position, a sealed PVC bag ½ full of polyester foam beads is lowered onto the child and tucked around him and between his legs. The air is exhausted from the bag, and the mass of beads becomes solid (Fig. 10). The bag is pulled off the child, turned over and the impression examined. If the impression is satisfactory, it is filled with plaster to create the positive model. If it is not satisfactory, air is leaked back into the bag, and the process is repeated.

Measurements are taken of the wheel chair to properly fitting base will be applied to the seat insert. Other measurements are taken so that rough trim lines may be established at the hamstring tendons and the axilla. Lateral-lateral diameter measurements are taken at the distal thigh, trochanters, waist and axilla for reference during cast modification.

During cast modification, the usual surface defects are remedied, all diameters are

**Fig. 9.** The “A” frame used in obtaining models for the Chair Insert type Sitting Support Orthosis.

**Fig. 10.** A brief bag has been packed around the positioned patient and the air evacuated. It is now being removed.
brought to measurement, and position inade-
quacies during the impression stage are now
corrected. Plaster is added to create reliefs at
the trochanters and ischial tuberosities, as
needed.

Cotton stockinette is drawn over the fin-
ished model, and it is covered (draped and
vacuum assist method) with hot 0.64 cm
polypropylene. Rough trim lines are estab-
lished, and a cast saw is used to cut the shell
from the model.

A rough, oversized cut-out is made in an
"Ethifoam" block, and the shell is foam
mounted in the block, using a 2-part iso-
cyanate foam. The posterior incline of the
back of the shell is usually less than 10°.

A lap belt is always used to hold the pelvis
snugly back in proper position. Other com-
ponents are added, as necessary. The ad-
vanced muscular dystrophy patient with a
long lordo-scoliosis requires a large abdomi-
nal apron. The hypotonic cerebral palsy
patient with a long kyphosis will do well with
a specially designed anterior support which
concentrates pressure just under the clav-
icle (Fig. 11). In some cases, a headrest or
support is also fashioned. The configuration
this takes varies greatly, because of the
diverse requirements.

When properly fabricated and fitted, this
orthosis will usually effect some correction
in advanced muscular dystrophy scoliosis.
This is good evidence to support our hope
that it can be a successful prophylaxis when
applied earlier. Hypotonic kyphosis is com-
pletely correctable, and kyphosis due to
hypotonic trunk flexors can be significantly
but not completely corrected. Though
statistics are not yet available, it appears
likely that the Sitting Support Orthosis is
not as strongly corrective of scoliosis as are
the orthoses described earlier.

Spinal support is only one of several bene-
fits of the Sitting Support Orthosis. The
patient is more comfortable, and his general
level of spasticity is often reduced. The
deply molded pommel keeps the hips
slightly abducted to control overactive ad-

ductors. Thoracic stabilization results in
better head control and better upper extre-
tity function. Feeding is facilitated, and
care, in general, is simplified according to
reports from parents and institutions. Accept-
ance is almost never a problem. The orthosis
may be removed from the wheelchair and
used in the car or elsewhere (Fig. 12).

To obtain the maximum benefit, therapists
should be closely involved in an evaluation
and putting together a total system, including
the proper wheelchair, foot rests, lap board,
etc., for each individual child. This is espe-
cially important for the child with cerebral
palsy.

This orthosis may not be indicated when
it is likely to interfere with a patient’s ability
to transfer independently.

DISCUSSION

Vast changes have taken place in the field
of orthotics for spinal deformity in the past
5 years. The advent of strong thermoplastics
has revolutionized the manufacture of ortho-
ses. New designs and concepts have proven themselves and are now standard. Continuing efforts are being made to create lighter, stronger and more cosmetically acceptable spinal orthoses.

With all these changes, it is no wonder that the occasional practitioner of spinal orthoses becomes confused and bewitched. This article is an attempt to define "where we now stand." It is written with the full knowledge that soon it will be outdated. Such is progress.

What orthosis is best for what problem? At the present time, we feel that thoracic scoliosis curves are best managed by the Milwaukee Brace (Fig. 13). Or the other hand, curves with their apex at the thoraco-

loinbar junction or lower are best managed by one of the TLSO designs. Not only is the orthosis more acceptable to the patient, but we are getting better curve control in the TLSO than the same curve in the Milwaukee Brace. The TLSO is also appropriate for very flexible kyphosis with apex at T9 or lower (Fig. 14).

For the child with neuromuscular disease requiring control of a collapsing spine, for example a paralytic myelomeningocele or a child with traumatic paraplegia, the 2-piece polypropylene body jacket is best. Transfers can be made easily. Wheelchairs can be propelled easily, and crutch walking or prosthodont ambulation can be managed...
readily. This same orthosis is excellent for postoperative support following Harrington instrumentation and spinal fusion. At GilletteToyota.

plaster casts have virtually been eliminated for the neuromuscular patient postoperatively. For the severely handicapped, those per-
sons unable to sit without considerable support, the Chair Insert type Sitting Support Orthosis has provided the ability to sit comfortably for long periods of time. It is especially recommended for severely involved spastic quadriplegics and patients with advanced Duchenne muscular dystrophy (Fig 15).

SUMMARY

Four basic types of orthoses are now being used at the Twin Cities Scoliosis Center for the treatment of spinal curvatures. The Milwaukee Brace, either custom-made or using a prefabricated pelvic section is the orthosis of choice for thoracic scoliosis and kyphosis in the ambulatory child. For lumbar and thoracolumbar curves, the one-piece "TLSO" has proven the most effective design. For the collapsing spine of myelomingingocele, childhood paraplegia, and spinal muscular atrophy, the 2-piece bivalved polypropylene body jacket is excellent. For the severely involved cerebral palsy or Duchenne Dystrophy patient, the Chair Insert type Sitting Support Orthosis is preferable.

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