Review Article

# Spinal Orthoses

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## Abstract

External orthoses are used in the management of a variety of spinal disorders. Many types of brace are available to support the cervical, thoracic, and lumbar spine as well as junctional regions, which have special mechanical considerations. Many prefabricated and custom-made devices are available, mady by a variety of manufacturers in this unregulated area of medical practice. Despite the widespread use of spinal orthoses, evidence of their efficacy in managing many spinal conditions is lacking. The most compelling indication for their use is in the management of traumatic spine injury. However, studies evaluating the efficacy of spinal orthoses have several shortcomings; many have evaluated orthoses that are no longer used. Recent data provide general guidelines to help the clinician choose the appropriate device.

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A spinal orthosis is a device used to support or immobilize a specific region of the spine that would otherwise have motion. These devices have been used throughout history to manage a variety of spinal conditions. Spinal orthoses are categorized by either the region of the spine they immobilize (ie, cervical, cervicothoracic, thoracolumbar, lumbosacral) or their rigidity (ie, rigid, semirigid, flexible). Orthoses may be prefabricated (ie, "off-the-shelf") or custom-fitted, with the latter typically providing better fit and more rigid immobilization.

All spinal orthoses are categorized as class I devices by the US Food and Drug Administration (FDA). Thus, premarket notification application and FDA clearance are not required before marketing. These devices are also exempt from Good Manufacturing Practice requirements set forth in the Quality System regulation.[1] As such, most commercially available orthoses have not been properly tested in a standardized fashion in either the laboratory or the clinical setting.

## Biomechanics

The purpose of a brace is to immobilize a motion segment and unload the forces on that segment of the spine. Spinal orthoses have five primary functions: to serve as a kinesthetic reminder and to offer total contact, three-point pressure, end-point control, or elevated pressure.

A major function of all spinal orthoses is to serve as a psychological reminder to restrict trunk or neck motion or at least to encourage the patient to move more slowly than she or he would in an unbraced state. A soft restraint and a rigid orthosis may be equally effective for this purpose.

In general, the more contact there is between the brace and the wearer, the more even the pressure distribution and the better the control achieved. The skin and soft tissues lie between the orthosis and the skeletal structures of the spine and thoracic rib cage, so even the most rigid orthosis cannot completely immobilize the spine. The structures in the neck (eg, trachea, esophagus, blood vessels) limit the capacity to apply external forces in this region; more aggressive compressive forces can be applied in the thoracolumbar spine.

All braces use some degree of three-point pressure to maintain the desired position. Braces that use pads may put excessive pressure on a localized part of the body, and the skin in that area should be monitored to prevent ulceration. To be effective, an orthosis must supply sufficient pressure over bony prominences to remind the wearer to change position or maintain posture.[2]

Few orthoses achieve end-point control, that is, firm grasp of the cephalad and caudad spinal region of interest. In the cervical spine, unless control of the head and thorax is achieved, motion restriction will be limited. In the thoracolumbar spine, it is necessary to control the thorax and pelvis. The halo vest is the best example of an orthosis that achieves almost complete end-point control by firmly grasping the head and thorax. However, depending on the patient's soft-tissue envelope and body habitus, the fit of the vest around the thorax may be suboptimal, and even the halo vest may not achieve complete end-point control.

Morris et al[3] found that elevated intra-abdominal pressure reduces the net force applied to the spine during the act of lifting a weight from the floor. The elevated intra-abdominal pressure may reduce some of the stress placed on the spine itself. In another study, a brace that was tightened within patient tolerance was shown to reduce intradiscal pressure in the lumbar spine by approximately 30%.[4]

## Importance of Proper Fit

To avoid treatment failure and complications, the clinician must carefully evaluate the patient's body habitus and make a realistic assessment of the potential efficacy of a brace before prescribing an orthosis. In the obese patient, an orthosis is limited in its ability to control the spine through a deep and pliable soft-tissue envelope. Orthoses must be modified periodically as patients lose weight or become increasingly active as they recover from other injuries. In addition to the biomechanical advantages of bracing, a properly fitted brace allows for greater patient comfort and compliance, thereby increasing the likelihood of successful treatment.

## Assessment of Efficacy

The literature published in the past four decades illustrates considerable variation in the methods used to assess gross and intersegmental motion in a brace. These methods include obtaining radiographs or photographs at the extremes of motion, roentgen stereophotogrammetric analysis, live fluoroscopy, and goniometry as well as the use of liquid inclinometers and external markers. Other variations in the literature relate to the subjects used—for example, healthy volunteers versus cadaver models, and intersegmental versus gross spinal motion. Many orthoses that were tested 15 to 30 years ago are no longer used, which limits the applicability of these earlier studies.

## Cervical Orthoses

No cervical orthosis achieves complete immobilization of the cervical spine. Even the halo vest has been shown to allow some motion.[5,6] Several anatomic features of the cervical spine make rigid immobilization of this region challenging. Not much surface area is available for contact with the orthosis. The chin/mandible unit and occiput are the primary cephalad contact points, and undue pressure in these areas can lead to skin breakdown. Control of the chin and mandible is necessary to control rotation, but mandibular motion during mastication can increase the degree of motion in the upper cervical spine.[7] Caudally, the clavicle moves with shoulder motion. The soft tissues in the neck limit the degree of external pressure that can be applied to this area. In addition to these anatomic challenges, control of intersegmental motion in the cervical spine is difficult because there is significant motion at multiple levels.

Cervical orthoses are either soft or rigid. The soft collar has little effect on restricting motion in any region of the cervical spine.[5] The indications for this collar are whiplash injuries and neck pain without unstable bony or ligamentous injury. This collar is contraindicated for injuries with the potential for instability.

Examples of rigid collars include the Philadelphia (Philadelphia Cervical Collar, Thorofare, NJ), Miami J (Össur, Paulsboro, NJ), and Aspen (Aspen Medical Products, Irvine, CA). Most rigid orthoses have thoracic extensions that can be used to immobilize the cervicothoracic junction caudally to T5.

Rigid cervical collars are effective at reducing motion in the sagittal plane but are less effective at reducing rotation and lateral bending because end-point control cannot be achieved without a firm grasp of the head or thorax.[8] Proximally, these collars come into contact with the mandible and the occiput. Distally, they have contact with the clavicle and sternal notch anteriorly and with approximately the level of the T3 spinous process posteriorly. The addition of a thoracic extension to any of these collars provides more effective immobilization of the lower cervical spine and cervicothoracic junction.

Other orthoses that can be used to immobilize the cervical spine include poster braces, variations of cervicothoracic orthoses (CTOs), and the halo vest. A CTO (eg, Minerva brace, sternal-occipital-mandibular immobilizer [SOMI] brace) extends farther down the trunk than does a poster brace.

Studies evaluating the efficacy of cervical orthoses have provided conflicting data regarding the degree of control provided by different designs (Table 1). A recent study tested seven contemporary cervical orthoses and found that CTOs (ie, Minerva, SOMI, halo) were more effective in limiting motion than cervical orthoses.[9] Of the rigid collars, the Philadelphia was the most effective in limiting sagittal, coronal, and rotational movement. Of the orthoses tested, the Minerva and Lerman noninvasive halos were the most effective in preventing overall sagittal plane motion, and the Minerva was the most effective in limiting intervertebral motion in the sagittal plane at all levels.

The SOMI brace is a rigid three-post CTO that is particularly effective in reducing upper cervical spine flexion (ie, C1-2, C2-3) (Figure 1). However, its swivel-type occipital pad makes it less effective in restricting extension, rotational motion, and lateral bending. One advantage of the SOMI is that it can be applied with the patient in the supine position and without moving the patient.

The Minerva device was originally described as a plaster cast jacket and was primarily used to stabilize the spine in persons with poliomyelitis and tuberculosis. With the introduction of the halo vest in 1959, the Minerva cast fell out of favor. Later, the thermoplastic Minerva body jacket was introduced, which was easier to wear than the cast.[16] Most recently, a prefabricated Minerva body jacket was developed (Figure 2).

In general, the Minerva brace and halo vest are superior to other CTOs in immobilizing the cervical spine because they offer better end-point control of the head.[18] In select patients, the Minerva can be a good alternative to the halo, such as in patients with skull fractures. Disagreement exists in the literature regarding the extent to which the upper cervical spine is immobilized with the Minerva. Some authors have advocated use of a Minerva for fractures below C2, whereas others have found it to be as effective as a halo at the level of the upper cervical spine.[16,18]

The halo vest immobilizes the spine in all three planes. It provides end-point control of the cervical spine and is best for immobilizing the upper and lower cervical spine. In the mid cervical spine, the halo vest may allow some intersegmental motion with attempted flexion-extension of the neck. This is the result of the neck muscles causing translation of individual vertebrae against the rigid fixation of the head, the so-called snaking phenomenon.[5,19] This phenomenon involves flexion at a spinal level with simultaneous extension at adjacent levels. Rigid collars provide adequate immobilization at the mid cervical levels but tend to lose effectiveness at the upper and lower cervical segments (occiput-C2 and C6-7, respectively). Halos are generally not more effective than rigid collars in the mid cervical spine. Additionally, halo use in the elderly is controversial[19] and is associated with higher complication and mortality rates than in younger patients.[20]

There is some evidence that a total-contact CTO, such as a Minerva brace, may provide more rigid intersegmental immobilization than does a halo vest.[16,21] Some authors have reported equal if not better immobilization of the upper and lower cervical spine with a Minerva brace.[21,22] A study comparing the Minerva with a halo vest found that intersegmental motion was significantly less in the Minerva in flexion and extension ($P < 0.0025$).[16] However, Sharpe et al[23] found that the Minerva provides good control of the cervical spine below C1, but that the occiput-C1 was poorly controlled. Others have advocated the use of a halo device in immobilizing injuries above C2 and the Minerva for injuries below C2.[18] Despite these conflicting data, it seems that the Minerva brace is a viable alternative to the halo in a compliant patient who would not remove the orthosis. Additionally, use of the Minerva device avoids the pin-related complications of the halo.

The Lerman noninvasive halo system is a recently introduced pinless halo system that seems to be a compromise between a halo vest and a Minerva brace (Figure 3). This device has been shown to be effective in pediatric patients, particularly those with congenital muscular torticollis, C1-C2 rotatory subluxation, and odontoid fracture; it has also been used for postoperative immobilization.[24] The Minerva and Lerman noninvasive halo braces may be good alternatives to the traditional halo vest in children because they do not pose the risk of pin penetration of the skull that may occur with a fall.

The halo vest has been considered the best management option for injuries of the upper cervical spine (ie, occiput-C1, C1-C2). However, one biomechanical study found that use of the halo device may increase motion at the occiput-C1 junction.[25] In the study by Richter et al,[10] the control of motion in the upper cervical spine provided by the Miami J collar and the Minerva brace was only

**Table 1**

**Studies on the Efficacy of Cervical Orthoses**

| Study | Motion Tested | Braces Tested | Subjects |
|---|---|---|---|
| Schneider et al[9] | F/E, LB, AR | Philadelphia (Philadelphia Cervical Collar, Thorofare, NJ), Aspen (Aspen Medical Products, Irvine, CA), PMT Halo System (PMT, Chanhassen, MN), Miami J (Össur, Paulsboro, NJ), Minerva, Lerman halo, SOMI | 45 volunteers |
| Gavin et al[8] | F/E | Aspen, Miami J, Aspen 2-post CTO, Aspen 4-post CTO | 20 volunteers |
| Richter et al[10] | F/E, LB, AR | Soft collar, Miami J, Minerva, halo vest | Cadaver specimens, intact and unstable (type 2 odontoid fracture) |
| Alberts et al[11] | F/E, AR, LB | Nebraska, Philadelphia, SOMI, Lehrman-Minerva brace | 14 volunteers |
| Askins and Eismont[12] | F/E, LB, AR | NecLoc (Össur), Miami J, Philadelphia, Aspen, Stifneck (Laerdal, Armonk, NY) | 20 volunteers |
| Sandler et al[13] | F/E, LB, AR | Soft collar, Philadelphia, Philadelphia with thoracic extension, SOMI | 5 volunteers |
| Rosen et al[14] | F/E, LB, AR | NecLoc, Philadelphia | 15 volunteers |
| McGuire et al[15] | F/E, translation | NecLoc, StifNeck, Philadelphia | C4-5 destabilized cadaver specimens |
| Benzel et al[16] | F/E | Minerva, halo vest | 10 patients with unstable cervical spine fractures |
| Kaufman et al[17] | F/E, LB, AR | Soft collar, NecLoc, Philadelphia | 10 volunteers |
| Johnson et al[5] | F/E, AR, LB | Soft collar, Philadelphia, SOMI brace | 44 volunteers |

AR = axial rotation, CTO = cervicothoracic orthosis, F/E = flexion/extension, LB = lateral bending, SOMI = sternal-occipital-mandibular immobilizer

**Figure 1**

Sternal-occipital-mandibular immobilizer (SOMI) brace.

**Figure 2**

Minerva brace.

moderate compared with that of the halo vest, which did not allow radiographically detectable motion. Surprisingly, the Minerva and Miami J devices showed a comparable degree of stabilization in the upper cervical spine. Given the greater comfort of the Miami J collar compared with the Minerva brace, it is the authors' first choice for management of stable fractures in the upper cervical spine.

Complete immobilization of the upper cervical spine requires restriction of motion of the mandible against the brace; however, this is not possible because of the need for nutrition.[10] Recently, Chin et al[7] showed that cervical braces with a

**Table 1 (continued)**

**Studies on the Efficacy of Cervical Orthoses**

| Method of Motion Assessment | Findings |
|---|---|
| Fluoroscopy, three-dimensional goniometry | Lerman halo and Minerva were best for the upper and lower cervical spine. Halo was best for axial control. CTO was superior to cervical orthoses in restricting cervical motion. |
| Optoelectronic motion measurement system, fluoroscopy | CTOs restricted motion more than did the two collars. All braces significantly reduced gross and intervertebral motion in F/E ($P < 0.05$). No significant difference between Miami J and Aspen except at C5-6. |
| Fluoroscopy | Halo vest did not allow motion. Miami J and Minerva braces provided a similar moderate level of control in the sagittal plane. Soft collar did not provide any stability. |
| Radiography and a compass (to assess rotation) | Nebraska collar restricted AR ($P < 0.0001$) and LB ($P < 0.0001$) significantly more than did the other three orthoses. When total maximum F/E motion was measured, the Nebraska and Lehrman-Minerva collars were more restrictive than the Philadelphia collar ($P < 0.05$). |
| Radiography and compass goniometry | NecLoc brace was superior to all other braces tested. Miami J was the next most effective and was superior to the Philadelphia and Aspen collars. |
| Three-dimensional motion analysis | The collars ranked as follows, from least restrictive to most restrictive: soft, Philadelphia, Philadelphia with extension, SOMI. No collar restricted motion in any subject to <19° of F/E, 46° of AR, or 45° of LB. |
| Goniometry | NecLoc was superior to the Philadelphia in all planes |
| Radiography | No significant difference between the collars |
| Radiography | In flexion and extension, the average spine movement in the Minerva was less than that in the halo at each cervical intervertebral level |
| Goniometry | NecLoc was better for immobilizing the cervical spine in all three planes of motion |
| Radiography and overhead photography | Soft collar allowed 74% of normal F/E, 83% of AR, and 92% of LB; Philadelphia allowed 29% of F/E, 44% of AR, and 66% of LB; and SOMI allowed 28% of F/E, 34% of AR, and 66% of LB. |

AR = axial rotation, CTO = cervicothoracic orthosis, F/E = flexion/extension, LB = lateral bending, SOMI = sternal-occipital-mandibular immobilizer

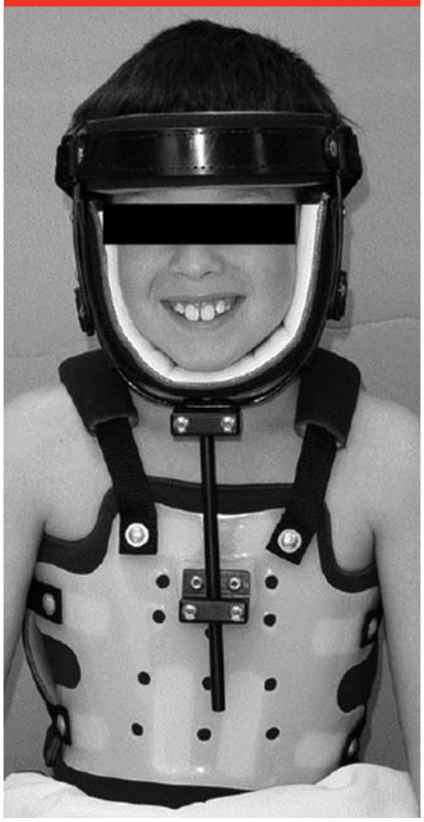
chin piece create increased motion in the upper cervical spine during mastication. This effect was most pronounced at the occiput-C1 and C1-2 levels but was also noted down to C4. The authors recommended removal of the mandibular component during mastication in patients with unstable injuries at these levels.

Despite the often conflicting data in the literature regarding orthotic treatment of the mid cervical spine, several trends can guide decision making. When rigid immobilization is not required, such as for the purpose of postoperative immobilization and the management of stable fractures, any rigid cervical orthosis will suffice.[9] The Miami J, Aspen, and Marlin (AliMed, Dedham, MA) collars appear to provide greater comfort than does the Philadelphia collar, but they are more expensive (Table 2). One study found that the Miami J collar restricted cervical motion to a greater extent in all directions than did the Philadelphia and Aspen collars.[12] When more rigid immobilization is desired, CTOs (ie, SOMI, CTO, Minerva) are preferred.

The addition of a thoracic extension is recommended in the lower cervical spine (ie, C6-7) and the cervicothoracic junction (ie, C6-T5). The cervicothoracic junction is a particularly challenging area to immobilize because it is a transitional zone between the mobile lordotic cervical spine and the rigid kyphotic thoracic spine. Few data exist in the literature on the management of upper thoracic fractures (ie, T1-T5). For a relatively stable fracture and in the absence of rib fracture, a rigid collar with a thoracic extension can be used.

Options for immobilizing the cervicothoracic junction include variations of the CTO. These include the Miami J with thoracic extension, Minerva brace, SOMI brace, custom-molded CTO, and the halo vest. All of these braces can be used to immobilize the cervicothoracic junction caudally to approximately T5. In general, increasing the length of an orthosis enhances its restrictive capabilities.[5]

**Figure 3**



Lerman noninvasive halo system. (Reproduced with permission from Skaggs DL, Lerman LD, Albrektson J, Lerman M, Stewart DG, Tolo VT: Use of a noninvasive halo in children. *Spine [Phila Pa 1976]* 2008;33[15]:1650-1654.)

**Table 2**

**Cost of Spinal Orthoses[a]**

| Orthosis | Usual and Customary Fees (US dollars) | Medicare Allowable (US dollars) |
|---|---|---|
| Soft cervical collar | 31.92 | 22.80 |
| Philadelphia collar (Philadelphia Cervical Collar, Thorofare, NJ) | 172.00 | 122.13 |
| Miami J collar (Össur, Paulsboro, NJ) | 338.00 | 240.14 |
| Miami J with thoracic extension (Össur) | 749.00 | 532.21 |
| Minerva | 749.00 | 532.21 |
| Jewett, CASH | 488.90 | 349.12 |
| Dorsolumbar corset | 516.81 | 299.08 |
| Off-the-shelf TLSO | 1,212.23 | 865.66 |
| Custom TLSO | 2,471.04 | 1,764.59 |
| Lumbosacral corset | 250.00 | 72.33 |
| SofTec LSO (Bauerfeind USA, Atlanta, GA) | 1,947.00 | 1,117.16 |
| Custom LSO | 1,500.00 | 1,137.37 |
| Custom CTLSO | 2,655.00 | 1,887.13 |
| Halo vest | 5,077.00 | 3,287.23 |

[a] Hanger Prosthetics and Orthotics, oral communication, January 2009.
CASH = cruciform anterior spinal hyperextension, CTLSO = cervicothoracolumbosacral orthosis, LSO = lumbosacral orthosis, TLSO = thoracolumbosacral orthosis

## Thoracolumbar Orthoses

Thoracolumbar orthoses can be either soft or rigid. Common types include the thoracolumbosacral orthosis (TLSO), thoracolumbar hyperextension orthosis (ie, Jewett brace, cruciform anterior spinal hyperextension [CASH] brace, Knight-Taylor [ie, chairback] brace), lumbosacral orthosis (LSO), and various types of soft lumbar and thoracolumbar corsets. The TLSO and LSO may be prefabricated or custom-molded.

TLSOs can be used to manage fractures from T6 to L4. For fractures at L3 and below, the thoracic portion is unnecessary, and an LSO is used. TLSOs can be used for compression fractures with more substantial loss of height and/or kyphosis as well as for burst fractures that are stable enough to be managed nonsurgically. In one study, the molded TLSO showed 94% restriction in lateral bending and 69% restriction of flexion-extension in the lumbar spine.[26] The degree of restriction in lumbar rotation was inconsequential because of the limited rotation in the lumbar spine under normal conditions. In the thoracic spine, the device restricted flexion-extension by 49%, lateral bending by 38%, and total rotation by 60%. For maximum control of motion, a custom-molded thermoplastic TLSO is preferred. Straps over the shoulder increase the rigidity of the TLSO. A cervical extension may be added. This is most often done when multiple fractures are present throughout the spine.

Several thoracolumbar hyperextension orthoses are designed to unload the anterior column. The most common types currently in use are the Jewett (Figure 4) and CASH (Figure 5) braces. The dorsal lumbar corset (Figure 6) is a flexible brace that can be used in the thoracolumbar region, as well, and as an alternative to the Jewett or CASH brace. These orthoses are most effective in limiting motion in the sagittal plane and are ideally suited for managing traumatic or osteoporotic compression fractures from T10 to L2. When used for fractures as cephalad as T8, the orthosis should be adjusted such that the sternal pads are proximal enough to control this region of the spine. These orthoses are contraindicated for potentially unstable fractures with significant disruption of more than one column.[27]

The rigid LSO is used to immobilize L3 and below (Figure 7). To adequately support L4-L5 and L5-S1, the brace should be well-fitted to the pelvis. A brace that is not properly fitted to the pelvis leaves the lumbosacral segments unsupported. Fidler and Plasmans[28] found that a unilateral thigh extension is necessary to effectively immobilize L4-L5 and L5-S1. The mean percentage of motion allowed at L4-L5 and L5-S1 was 32% and 70%, respectively, in a lumbar brace without a thigh extension. The addition of a unilateral thigh extension decreased allowable motion at these levels to 12% and 8%, respectively. Other authors have noted an additional 15% to 30% reduction in motion at L4-L5 and L5-S1 with the addition of a unilateral thigh extension.[29,30]

Commercially available lumbar corsets are used to provide abdominal support for chronic low back pain and to manage osteoporotic compression fractures in elderly patients who cannot tolerate a more rigid brace. These corsets do little more than reduce gross trunk motion for pain control. In the trauma setting, corsets are contraindicated for the management of any fracture with potential instability.

**Figure 4**

Jewett brace.

**Figure 5**

Cruciform anterior spinal hyperextension (CASH) brace.

**Figure 6**

A B

Front (**A**) and back (**B**) views of a dorsal lumbar corset.

## Clinical Indications

### Spine Trauma

The most common indication for a spinal orthosis is in the setting of spinal trauma to manage fractures deemed sufficiently stable to undergo nonsurgical management but that lack the intrinsic stability to withstand normal physiologic loads. Specific recommendations regarding bracing for fractures vary depending on the fracture location and clinical situation and are beyond the scope of this article. Table 3 provides a general guideline on the choice of orthosis for each region of the spine.

The physician should carefully assess the fit of an orthosis following application. Upright radiographs in the brace are important to assess the stability of the fracture and efficacy of the brace. Frequent follow-up is important, especially for fractures with the potential for instability.

### Osteoporotic Compression Fracture

External support may provide pain relief for patients with osteoporotic compression fractures in the thoracolumbar spine. Orthotic management of osteoporotic compression fractures is somewhat subjective. The use of rigid orthoses (eg, TLSO) in these patients has a low compliance

**Figure 7**

A B

Front (**A**) and back (**B**) views of a lumbosacral orthosis (LSO).

**Table 3**

**Spinal Orthosis Options by Spinal Segment**

| Region | Brace[a] |
|---|---|
| Upper cervical spine (occiput-C1, C1-C2) | Miami J (Össur, Paulsboro, NJ)/Minerva<br>Halo vest |
| Mid cervical spine (C2-C6) | Miami J or any rigid collar |
| Cervicothoracic junction (C6-T5) | Miami J/Aspen (Aspen Medical Products, Irvine, CA) with thoracic extension<br>SOMI<br>Minerva<br>Custom-molded cervicothoracic orthosis<br>Halo |
| T6 and T7 | Off-the-shelf TLSO<br>Custom-molded TLSO<br>CTLSO<br>Halo-TLSO |
| T8-L2 | Dorsal lumbar corset<br>Jewett brace<br>CASH brace (sternal pad adjusted high for higher fracture)<br>Custom-molded TLSO |
| L3 and L4 | Off-the-shelf LSO<br>Custom-molded LSO |
| L5 and lumbosacral junction | Off-the-shelf LSO with thigh extension<br>Custom-molded LSO with thigh extension |

[a] In order of increasing rigidity
CASH = cruciform anterior spinal hyperextension, CTLSO = cervicothoracolumbosacral orthosis, LSO = lumbosacral orthosis, SOMI = sternal-occipital-mandibular immobilizer, TLSO = thoracolumbosacral orthosis

rate because of impaired respiration and the cumbersome nature of the braces. These patients also may have poor skin quality and atrophy of trunk muscles. For these fractures, other options are preferred, such as the Jewett or CASH brace or soft corsets. The dorsal lumbar corset (Figure 6) is an alternative in the patient who may not tolerate a Jewett or CASH brace. A randomized trial found that wearing a thoracolumbar orthosis for 6 months improved posture, trunk muscle strength, and quality of life in women aged ≥50 years with postmenopausal osteoporosis with clinical vertebral fractures.[31]

## Neck Pain

There is no evidence that the use of a cervical orthosis, either soft or rigid, is beneficial in the management of axial neck pain. In 2001, a systematic review of randomized controlled trials and observational studies concluded that therapeutic exercise was the only intervention with clinically important benefits in patients with neck pain.[32] Soft cervical collars have not been found to be beneficial in patients with whiplash injuries resulting from automobile collisions. Crawford et al[33] randomized these patients to either early mobilization using an exercise regimen or 3 weeks in a soft cervical orthosis followed by the same exercise regimen. They found no difference between the two groups with regard to improvement in pain, range of motion, or activities of daily living at any follow-up interval. However, patients treated with a collar took significantly longer to return to work after injury than did those treated with early mobilization (34 versus 17 days, respectively; $P < 0.05$).

## Low Back Pain

In 2001, a systematic review of randomized and nonrandomized controlled trials indicated that there is no evidence that spinal orthoses are effective in the prevention or management of low back pain.[34] However, the literature on this topic is conflicting. When orthoses are used for this purpose, physical therapy consisting of abdominal strengthening and trunk stabilization exercises should be prescribed, as well, to avoid deconditioning of the trunk musculature.

## Adolescent Spondylolysis and Spondylolisthesis

Spinal braces are commonly used in the management of adolescent patients with symptomatic spondylolysis and spondylolisthesis. Several studies have shown favorable outcomes with nonsurgical management, with or without bracing. However, controversy exists regarding the need for bracing. The main benefit of bracing in these patients may be as a means of restricting activity (ie, kinesthetic reminder) rather than as a means of biomechanically stabilizing the pars defect.

## The Postoperative Period

The use of modern spinal instrumentation has led to reduced use of bracing postoperatively. Bracing is used more commonly in the cervical spine, especially after multilevel fusion or corpectomy, perhaps because of the greater mobility in this region. Use of an LSO after lumbar fusion is controversial. Recently, a randomized trial was performed to assess the benefit of wearing a lumbar corset for 8 weeks after lumbar fusion for degenerative conditions.[35] Complication rates and rate of revision surgery were not different between the two groups, and this study did not indicate a significant advantage or disadvantage with the use of a postoperative lumbar corset following lumbar fusion.

## Spinal Deformity

Braces are used to provide three-point forces to prevent progression of spinal deformity (ie, scoliosis, kyphosis) in skeletally immature patients. Currently, many clinicians consider this bracing to be the standard of care in the skeletally immature patient (ie, Risser sign, 0 to 2) with a scoliotic curve between 25° and 40°. However, the effectiveness of bracing remains unclear, and a multicenter randomized controlled trial (ie, Bracing in Adolescent Idiopathic Scoliosis Trial [BrAIST]) is under way to evaluate the benefits of bracing for this indication.

## Complications

Improper use of spinal orthoses can lead to treatment failure and potential complications. Pressure-induced skin complications are the most common adverse events. In general, the inability to adjust bodily position in response to excessive external pressure, whether as the result of cognitive impairment or lack of protective sensation, is a relative contraindication to the use of spinal orthoses. Thus, patients with spinal cord injury who lack protective sensation are poor candidates for orthoses.

Skin breakdown is particularly problematic with cervical collars in the comatose polytrauma patient in whom the cervical spine cannot be clinically cleared. Potential areas of skin breakdown include the occiput, chin, mandible, ears, shoulders, and clavicles. Wearing a collar for longer than 48 to 72 hours has been associated with increased rates of pressure ulceration.[36] Full-thickness ulcers are more likely to occur when cervical collars are worn longer than 5 days.[37]

The Philadelphia collar is commonly used for initial cervical immobilization of trauma patients because it is relatively inexpensive. However, it is not well-vented, and skin maceration can occur in warm weather conditions. The pressures exerted on the chin, mandible, and occiput by the Philadelphia collar have been shown to be in excess of capillary closing pressure, which leads to tissue ischemia and ulceration.[38] One study found the Miami J collar to have the lowest levels of mandibular and occipital tissue-interface pressure of various collars tested, which may markedly reduce the risk of occipital pressure ulcers.[39]

In addition to skin problems, prolonged collar use in the intensive care setting can obstruct central venous access, which may lead to moisture and poor hygiene around both subclavian and internal jugular central venous lines, potentially contributing to line sepsis and bacteremia. Prolonged collar wear also has been shown to increase intracranial pressure, which adversely affects patients with concomitant closed head injuries.[40]

Cervical orthoses may alter swallowing physiology and may lead to dysphagia.[41] Bracing has been shown to narrow the pharynx.[41] This may be significant in patients who already have altered oral or pharyngeal motility following, for example, anterior cervical surgery; these patients may experience even greater dysphagia in a brace. Most orthoses maintain the cervical spine in neutral to slight extension, whereas the natural eating position is one of slight neck flexion. Furthermore, orthoses that use mandibular pads, such as the SOMI and Minerva braces, may restrict movement of the hyoid bone as the result of external pressure.[42] Swallowing difficulty is also problematic with the halo vest when the cervical spine is in hyperextension. The patient should be asked whether swallowing is difficult following vest application. Swallowing studies may be indicated for patients with dysphagia following halo-vest application.

A commonly cited concern with spinal orthoses is their deconditioning effect on the paraspinal muscles and trunk stabilizers. Studies evaluating the electromyographic activity of muscles in the braced and nonbraced states have demonstrated conflicting data. Some studies have shown a significant reduction in muscle activity during bracing,[43] whereas others have found either unchanged or increased activity of erector spinal muscles in the braced state.[29] Regardless, the generalized inactivity following bracing can lead to trunk muscular weakness, with the potential for pain and disability. When the clinical situation allows, an exercise regimen should be maintained, and orthosis use should be discontinued as soon as possible.

Other concerns regarding spinal orthoses include their unsightly appearance, lack of patient compliance, the sedentary lifestyle that can ensue with long-term wear, and, potentially, disuse osteopenia.

## Summary

Despite the lack of conclusive evidence regarding their efficacy, spinal orthoses continue to be widely used. The most compelling indications for spinal orthoses seems to be in the trauma setting, for the nonsurgical management of stable fractures, and for osteoporotic compression fractures. Evidence for their use in the postoperative period or for the management of neck or back pain is lacking. For optimal outcomes, a good understanding is needed of spinal mechanics, the variety of brace options on the market, indications and contraindications for their use, and potential complications.

## References

*Evidence-based Medicine:* Levels of evidence are described in the table of contents. References 31, 33, and 35 are level I studies. Most of the references are cohort-control, biomechanical, and clinical studies (ie, level III and IV).

Citation numbers printed in **bold type** indicate references published within the past 5 years.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