# ORTHOTICS

Postgraduate course:

Biomedical Engineering

by

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# *Orthosis (Ορθός, ortho)*

An *orthosis* (plural: *orthoses*) is an externally applied device used to modify the structural and functional characteristics of the neuromuscular and skeletal system.

An orthosis may be used to:

- Control, guide, limit and/or immobilize an extremity, joint or body segment for a particular reason
- To restrict movement in a given direction
- To assist movement generally
- To reduce weight bearing forces for a particular purpose
- To aid rehabilitation from fractures after the removal of a cast
- To otherwise correct the shape and/or function of the body, to provide easier movement capability or reduce pain

The term *splint* is synonymous with orthosis

# Classification

Type: upper extremity, spine, lower extremity

Method of naming: AFO–SA, orthosis that covers the foot and attaches to the leg to compensate for weakened ankle dorsiflexors would be called an Ankle–Foot Orthosis, Solid Ankle

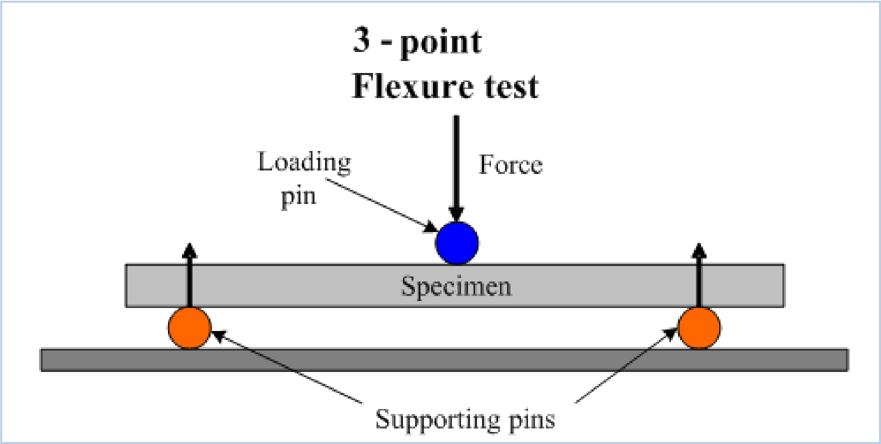
# Function: (1) immobilizing, (2) restrictive, and (3) mobilizing

Static: prevent or limit motion and have no moveable parts

Dynamic: facilitate movement and have one or more movable parts

# BIOMECHANICAL PRINCIPLES

- THREE-POINT PRESSURE SYSTEM



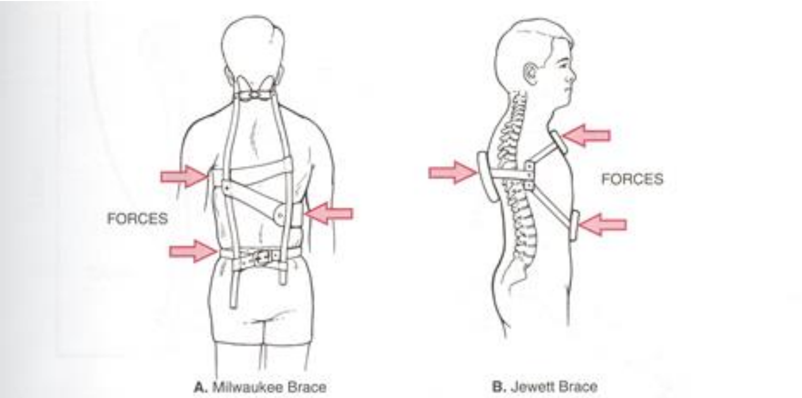
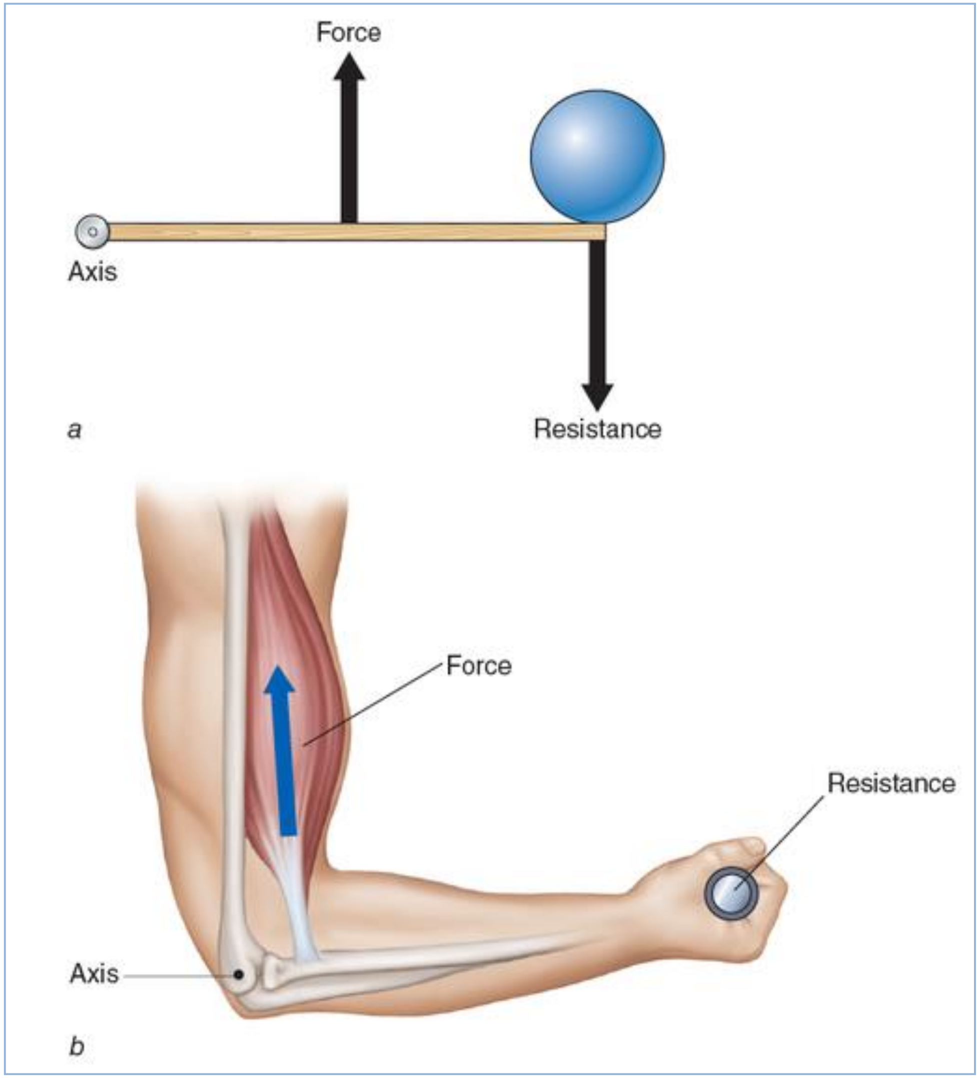
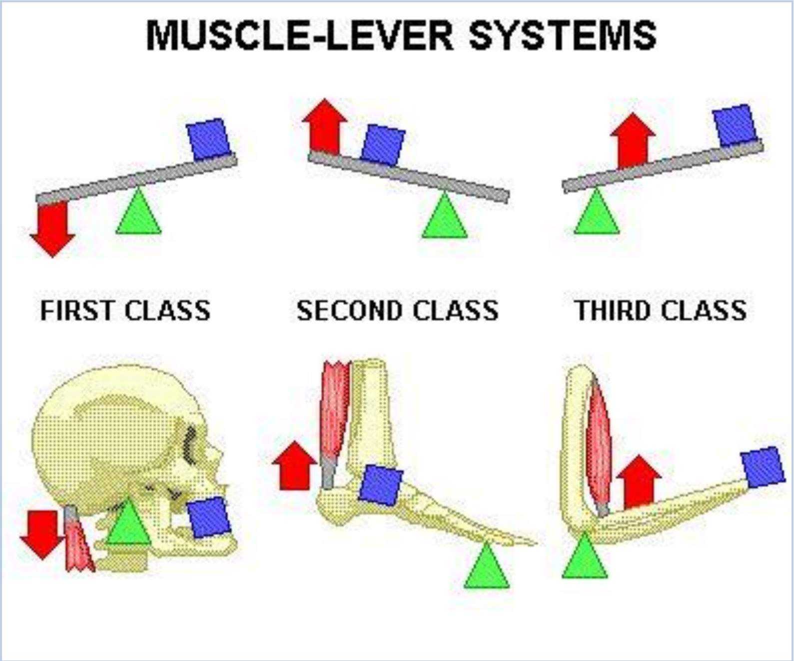



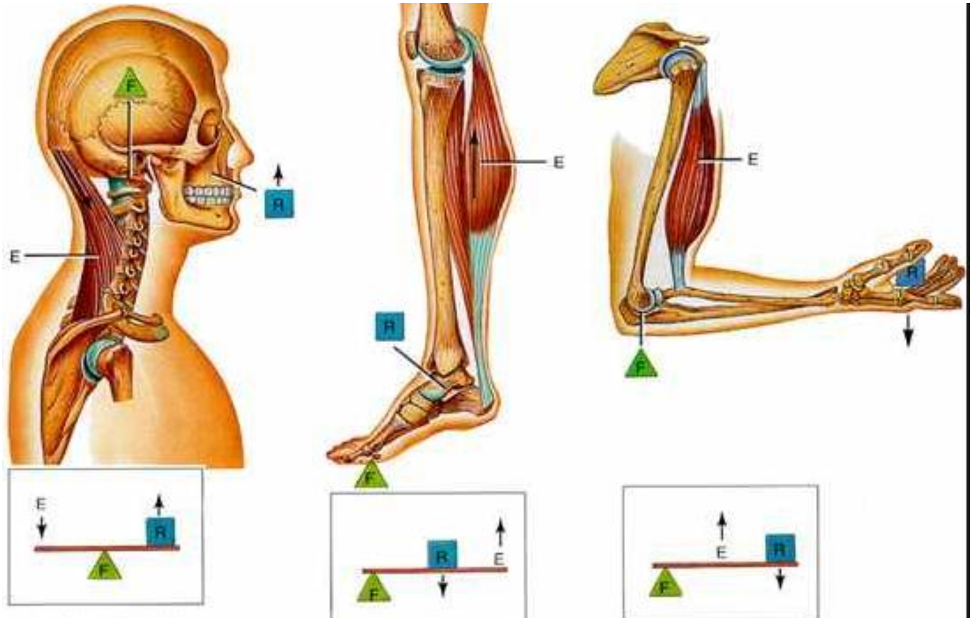

FIGURE 2-23. Three-point bending loads are used in many braces. (A) The Milwaukee brace was used for the correction of lateral curvature of the spine and applied a three-point bending force to the spine. (B) The Jewett brace applies a three-point bending force to the thoracic spine to create spinal extension in that region.

- **LEVERAGE**


Force
Axis
a
Resistance
Force
Resistance
Axis
b


MUSCLE-LEVER SYSTEMS
FIRST CLASS
SECOND CLASS
THIRD CLASS

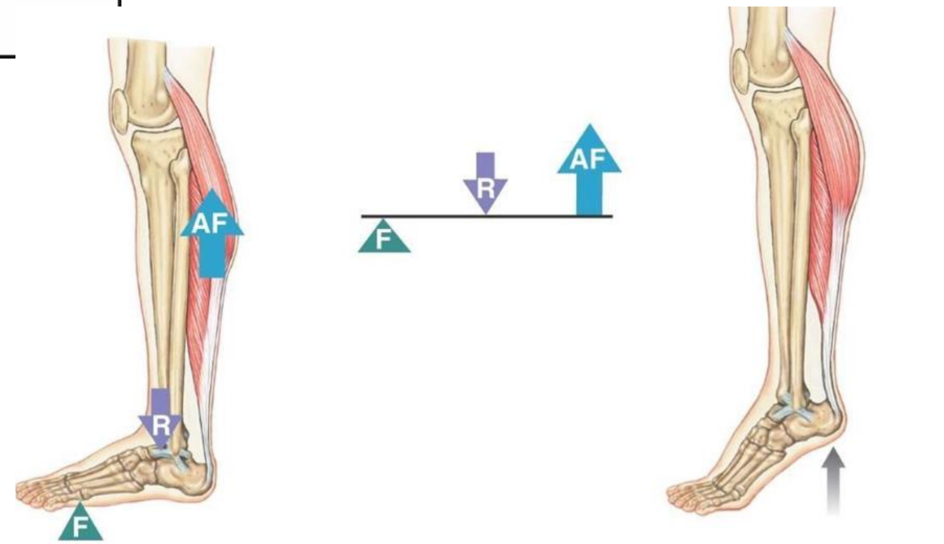
- **LEVERAGE**



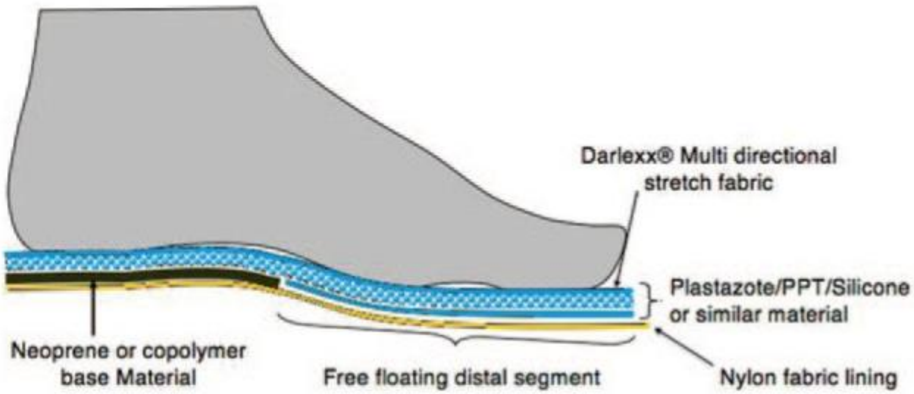
(a) First-class lever

(b) Second-class lever

(c) Third-class lever



- **GROUND REACTION FORCE**
- **AXIAL FORCES**
- **PRESSURE**
- **SHEAR STRESS**
- **CREEP**




**Shear Reduction Insole**

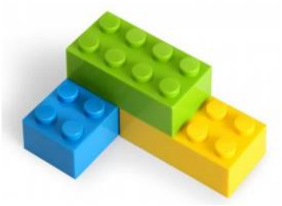
Dynamic foot orthosis

# DESIGN CONSIDERATIONS

## Materials selection

Plastics: most common materials

Thermoplasts and thermosets: **Thermoplasts** soften under heat and harden with cooling; **thermosetting plastics** harden after the first heating and form links with other plastic molecules that never soften again. Thermosets are typically used where strength is of importance.

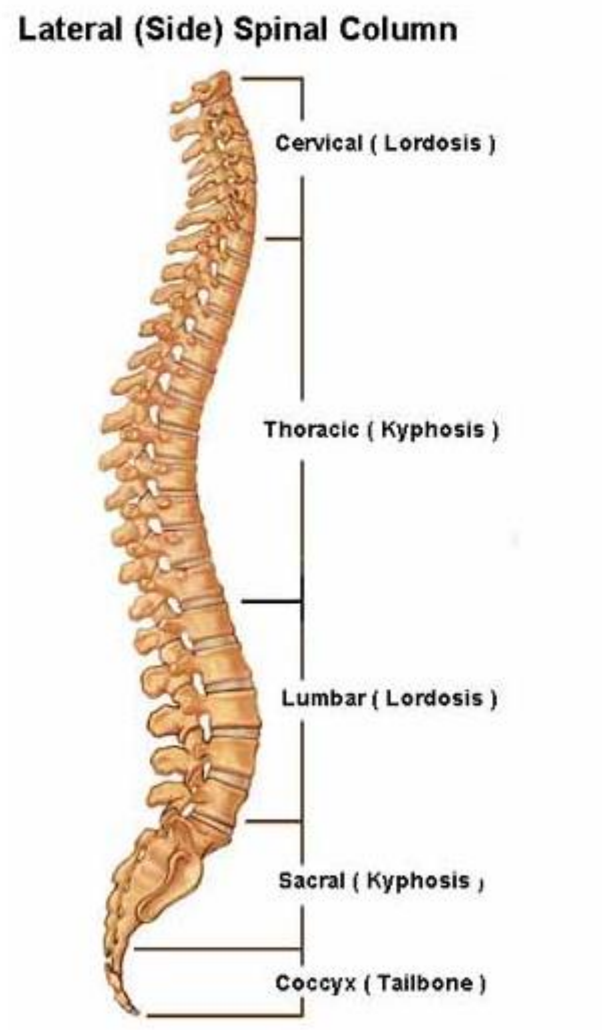


Acrylonitrile butadiene styrene, polycarbonate, polyethylene

- Custom designed orthoses
- Prefabricated orthoses (off-the-shelf)

# SPINAL ORTHOSES

| Spinal Orthosis Nomenclature | |
|---|---|
| Cervical | CO |
| Cervicothoracic | CTO |
| Thoracolumbosacral | TLSO |
| Lumbosacral | LSO |
| Sacroiliac | SO |

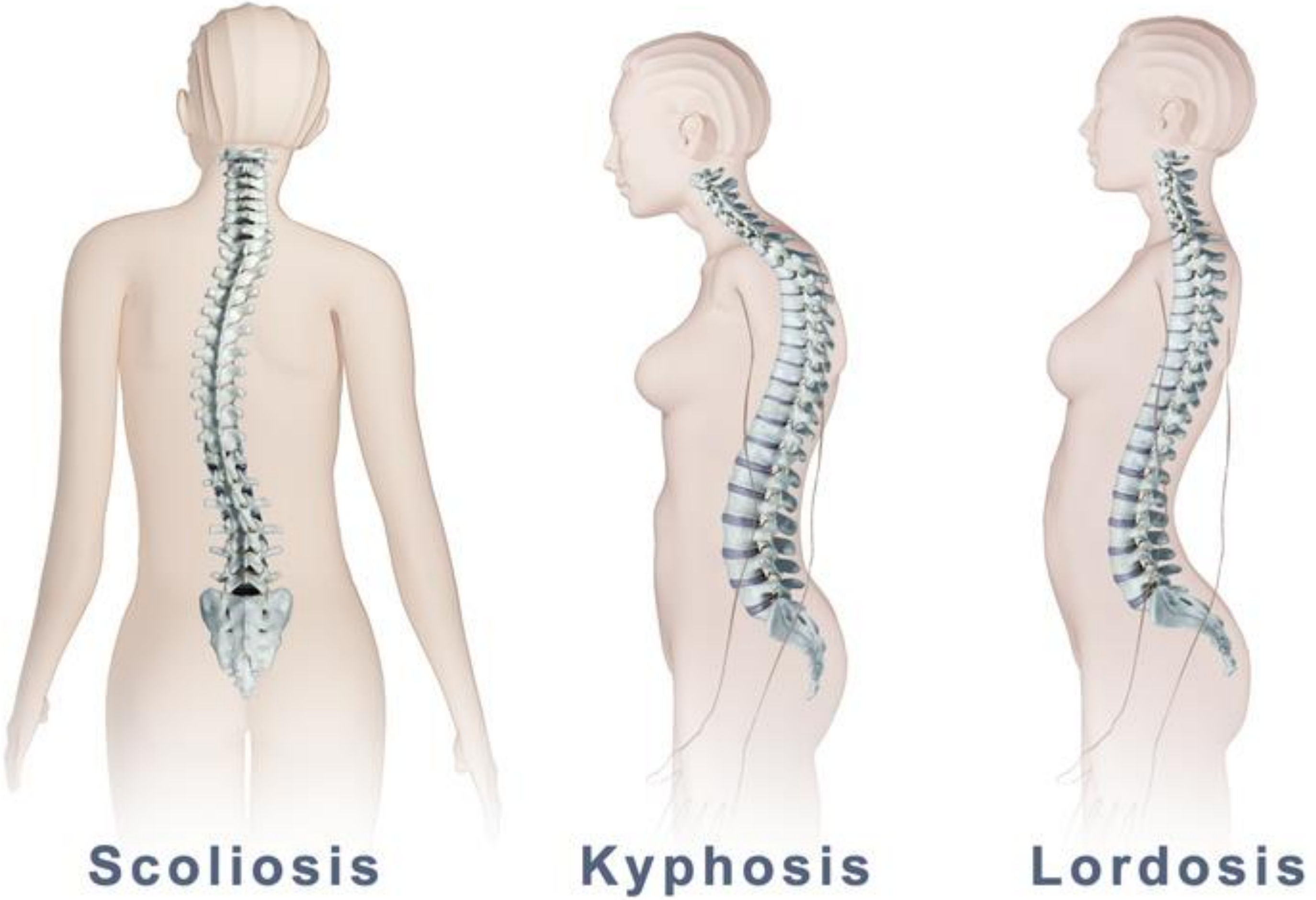



Address pathology of the spine (i.e., back pain, spine deformity, or injury)

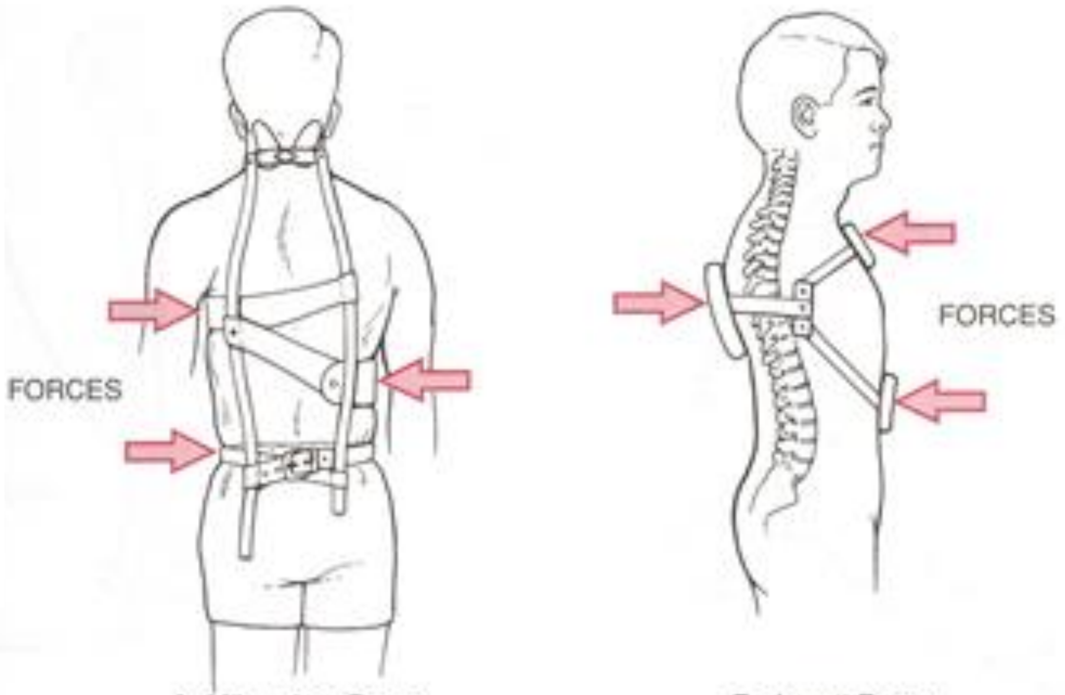
Injury to either the skeletal components or to the surrounding musculature may create instability, resulting in pain, degeneration, and deformity.

A spinal orthosis is prescribed to:

- Protect an injured segment,
- Limit intervertebral movement
- Limit gross movements of the spine, and apply forces to correct or inhibit the progression of some deformity.


Scoliosis
Kyphosis
Lordosis

Scoliosis



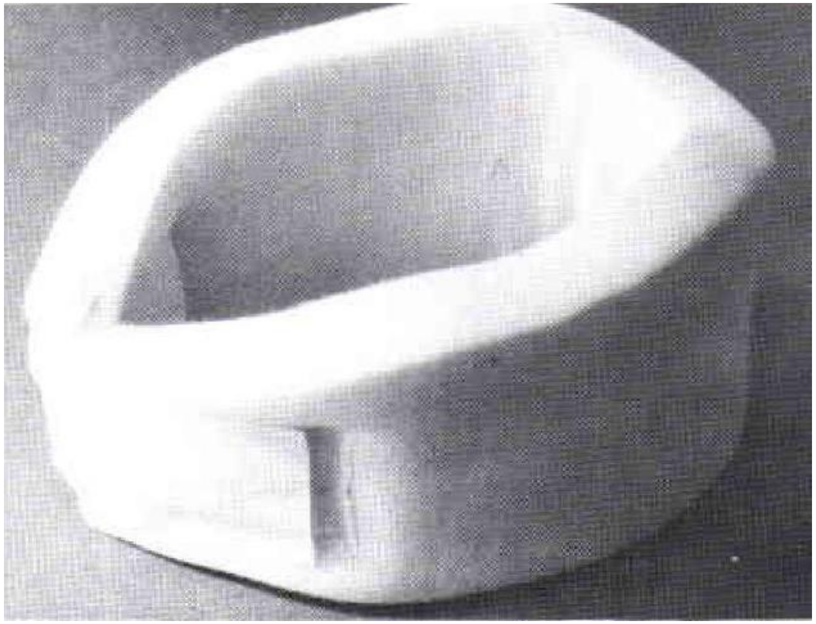

Kyphosis

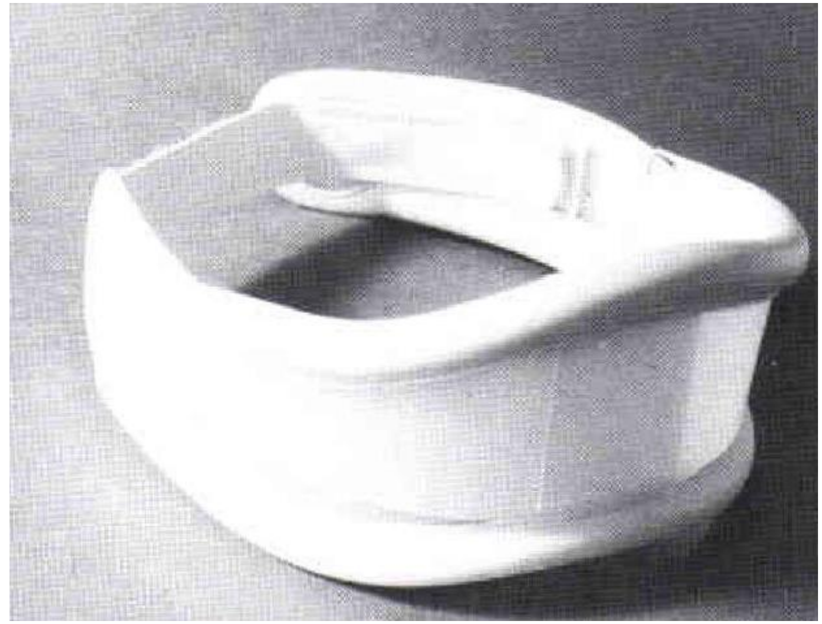
*FIGURE 2–23.* Three-point bending loads are used in many braces. (A) The Milwaukee brace was used for the correction of lateral curvature of the spine and applied a three-point bending force to the spine. (B) The Jewett brace applies a three-point bending force to the thoracic spine to create spinal extension in that region.

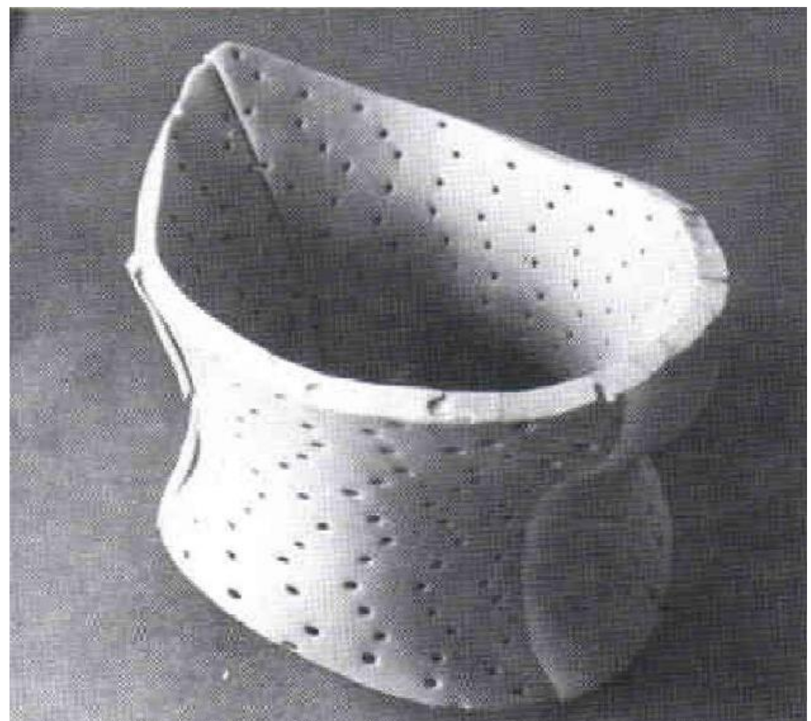
# Cervical orthoses, CO

| | |
|---|---|
| Soft Collar: | Made of high density PVC foam, covered in stockinette, fastened by Velcro. |
| Hard Collar: | Made of rigid polythene, the contact parts are of foam rubber, covered with soft leatherette, fastened by Velcro. |
| Plastazote collar: | A two-piece collar made of Plastazote, strengthened at the front and back, fastened by Velcro. |
| Custom fit collar: | Made from a sheet of medium density polythene foam-Plastazote, strengthened at the front by a 2mm thick strip of polythene, fastened by Velcro. |

* Plastazote™: Closed cell cross-linked polyethylene foam







# Cervical thoracic orthoses, CTO

Sternal occipital mandibular immobilizer (SOMI).

HALO orthosis

Analysis of pin force distributions of halo orthoses

# Thoracolumbosacral and lumbosacral orthoses, TLSO and LSO

Lumbosacral corset.

To address deformity, fractures, and musculoskeletal back pain.
Over 80% of people will experience low-back pain

From corset to custom made TLSO:
Increase rigidity of corset with metal inserts or air bladders, paraspinal and lateral bars
Variety of orthoses

**LSO** (called chairback): Sagittal and coronal motion control

This brace restricts ability to bend (front, back, and to the sides) and limits how much low back can rotate.

Consists of a thoracic band, pelvic band, and two paraspinal bars. Two three-point systems are utilized.

Jewett orthosis. (Courtesy of De LaTorre Orthotics and Prosthetics, Inc.)

The TLSO incorporates the thorax, with the same principles; the basic design may be modified based on the level and motion control needed.

For flexion control, the orthosis is designed with a metal frame, with pads at the pubic bone, sternum, and at the lateral midline of the trunk. The Jewett orthosis is the archetype, with a three-point pressure system.

The result is reduced lumbar flexion with full extension.

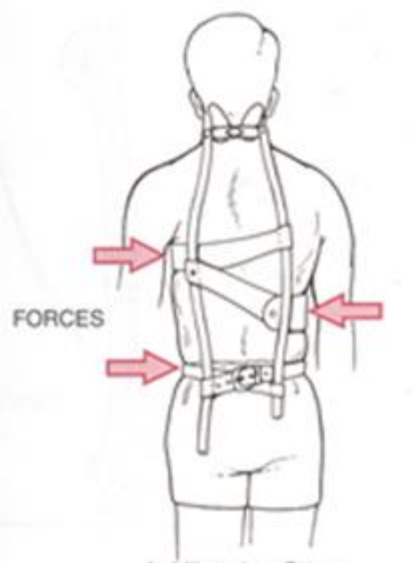
Motion in the sagittal plane is controlled by modifying the TLSO by incorporating paraspinal bars, pelvic and interscapular bands, and axillary straps.

# Cervicothoracolumbosacral orthosis

Milwaukee brace, CTLSO.

The biomechanics of progression of scoliosis is described by Euler’s theory of elastic buckling of a slender column.

The orthosis designed for treatment of scoliosis has three functions: (1) end-point control, (2) transverse support, and (3) correction of the curve.

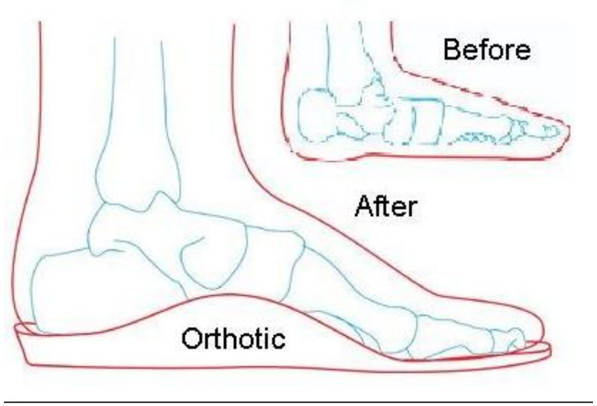



A. Milwaukee Brace

# LOWER EXTREMITY ORTHOSES

## Foot orthoses (FOs)- mostly shoes

FOs are used to realign the foot, change the distribution of pressure in the foot, and reduce pain.
Correction for problems at more proximal joints (e.g., leg length discrepancy, weak quadriceps, and osteoarthritis of the knee).





## Common Indications for Foot Orthoses

- Keeping the subtalar joint in a neutral position
- OA of the knee-limiting motion and stresses (bow-legged)(heel wedge)
- *Flat foot*, or a foot with a reduced longitudinal arch

# Ankle–foot orthoses

AFOs cross ankle joint and have attachments both above and below the joint

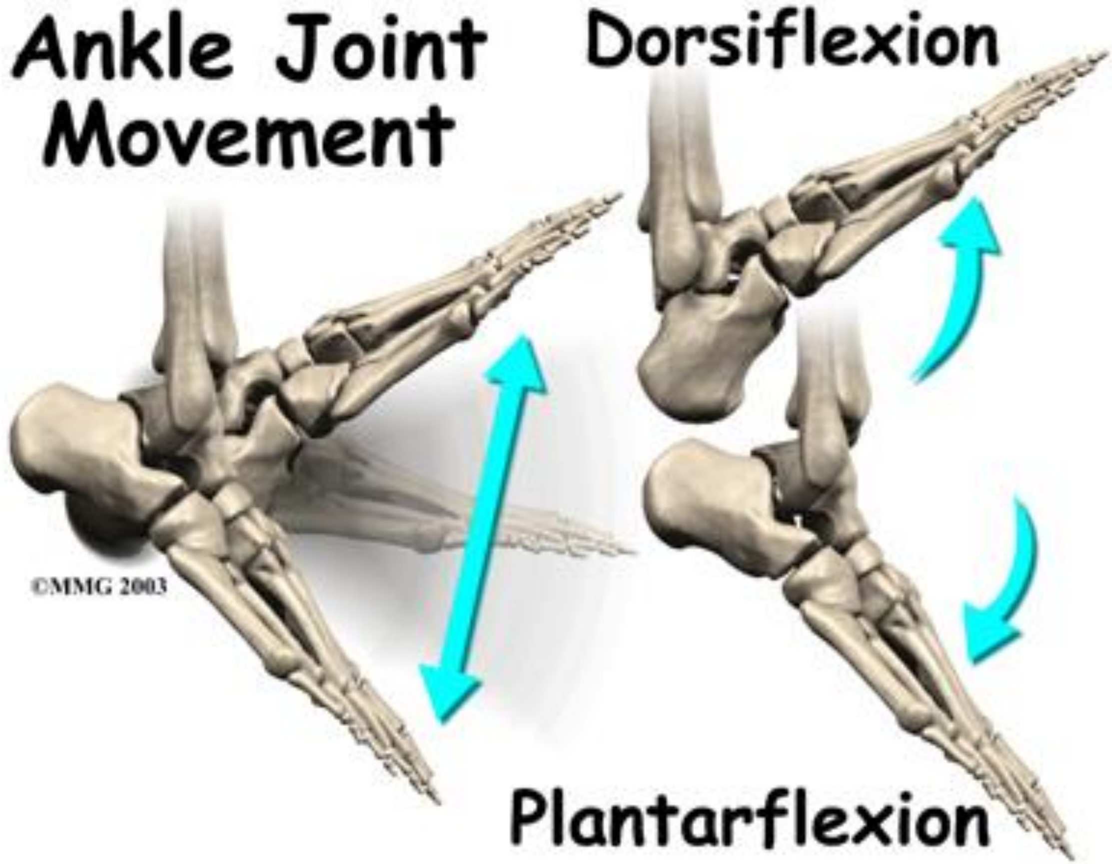
## Common Indications for AFOs

- Equinovarus deformity describes a foot that is inverted, plantarflexed, and adducted
- Foot drop, or weakness of ankle dorsiflexors
- Ankle osteoarthritis
- Knee instability because of quadriceps weakness due to a spinal cord injury

Plastic AFO solid ankle.


Carbon fiber AFO

Metal AFO



Ankle Joint Movement
Dorsiflexion
Plantarflexion
©MMG 2003

# Knee orthoses

Swedish knee cage: keeps the knee from hyperextension

- Provides support
- Corrects deformity
- Prevent injury to the knee

Use of KO: controversy

Knee osteoarthritis
Knee lock is a component of an orthotic knee joint that locks the knee in a given position.

# Knee–ankle–foot orthoses(KAFOs)

# Hip–knee–ankle–foot orthoses (HKAFOs)

KAFOs are generally used in patients with severe knee extensor and hamstring weakness, knee instability, and spasticity of hamstring muscles, most commonly in patients with paraplegia due to spinal cord injury.

KAFO metal.

HKAFO for people with paraplegia

Reciprocating gait orthosis (RGO), is a bilateral HKAFO, with cables and pulleys

# UPPER EXTREMITY ORTHOSES

Typical conditions for use of upper extremity orthoses are:

- Fractures
- Nerve injuries (median, ulnar, or radial)
- Brachial plexus injuries
- Burns
- Degenerative or inflammatory joint conditions (pheumatoid arthritis, osteoarthritis)
- Postsurgical management of tendon injuries
- Spasticity
- Repetitive stress/strain disorders (carpal tunnel syndrome).

# UPPER EXTREMITY ORTHOSES

FINGER ORTHOSES
HAND ORTHOSES (HO)
WRIST–HAND ORTHOSES (WHO)
ELBOW ORTHOSES (EOs)
SHOULDER ORTHOSES (SO)
SHOULDER–ELBOW–WRIST–HAND ORTHOSES (SEWHO) (brachial plexus injury)

Wrist–hand orthosis with thumb extension

Humeral brace.

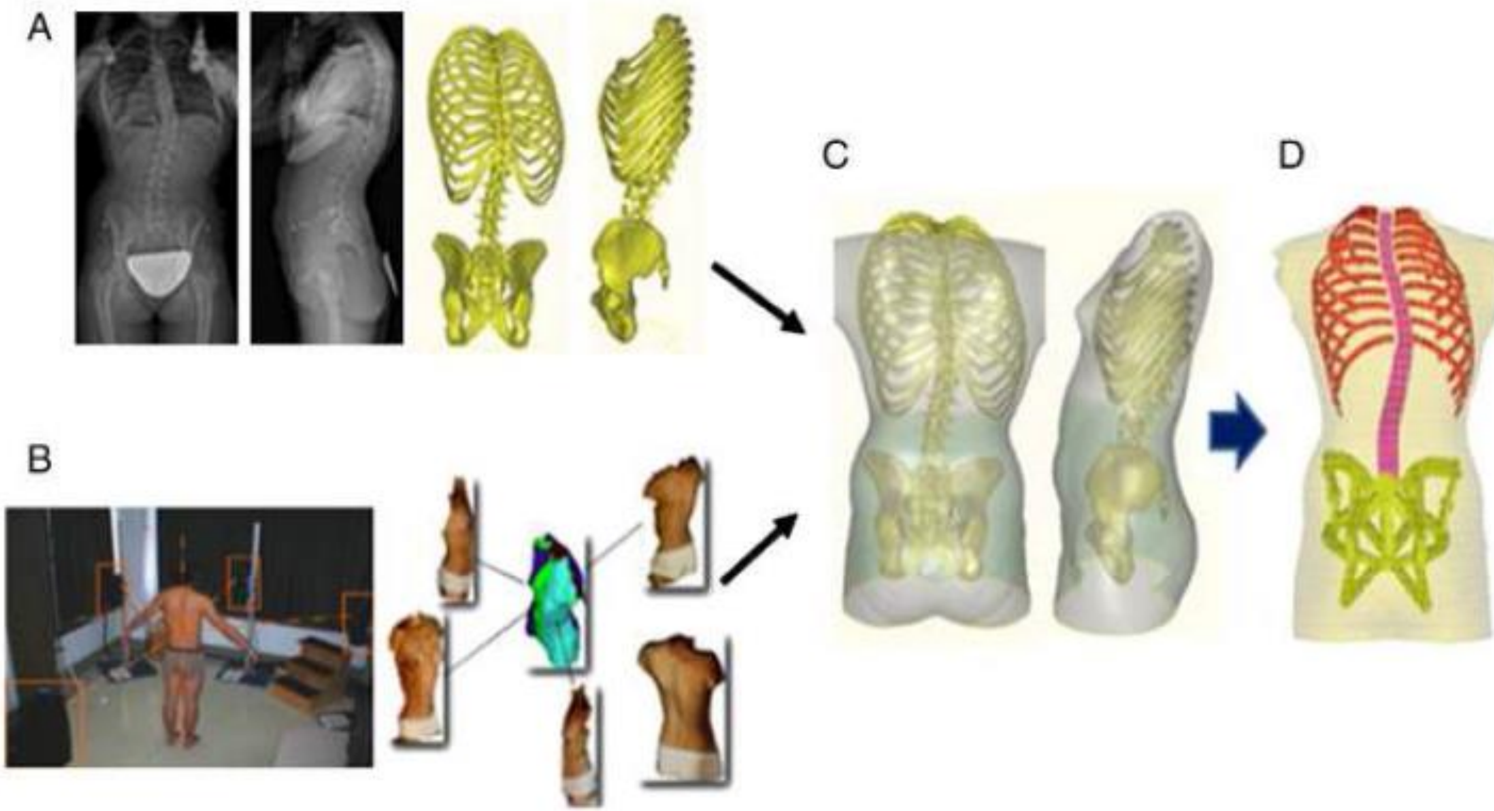
# FO and HO

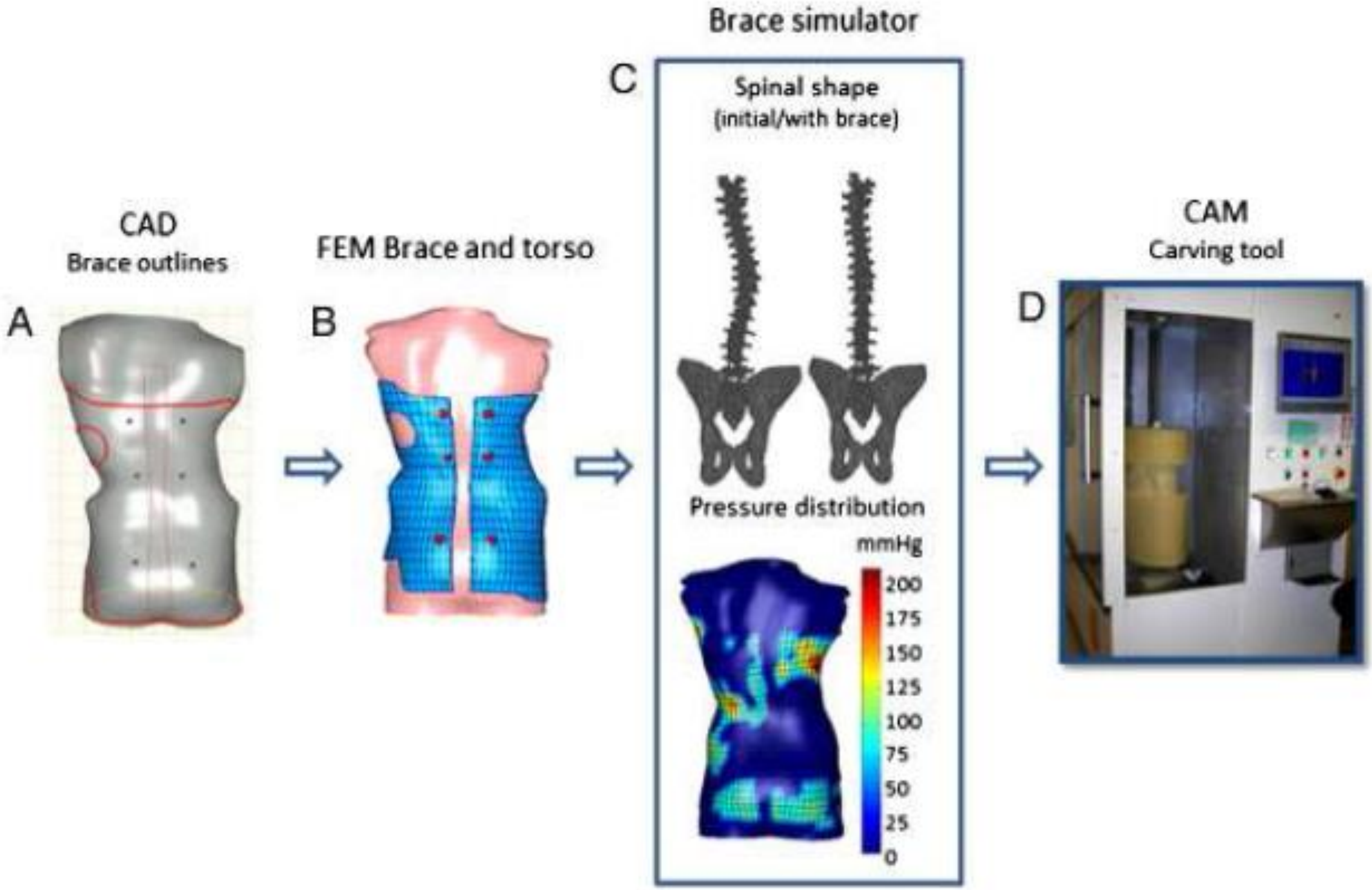
## ADVANCES IN UPPER EXTREMITY ORTHOSES

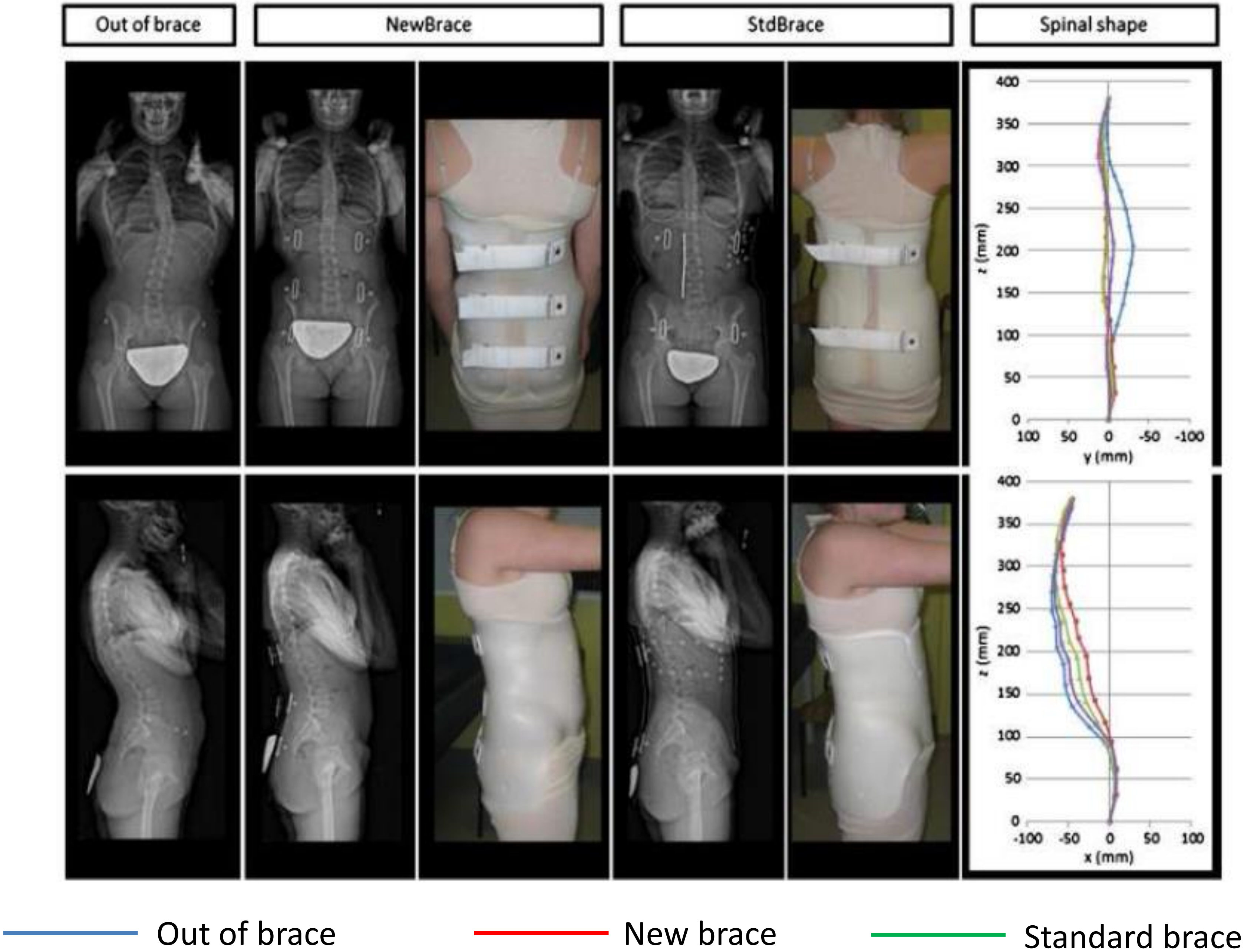
Advances in upper extremity orthoses has been indicated in several domains. Use of functional electrical stimulation (FES) adjunct with an upper extremity orthosis is one such emerging intervention. Use of an FES system combined with a hand orthosis was reported by Weingarden et al. (1998) in reducing muscle tone of hand muscles along with significant improvement in the functional abilities of individuals in chronic stages of hemiparesis following stoke and traumatic brain injuries. Other forms of upper extremity orthoses are those that utilize external power sources for either providing continuous motion, such as continuous passive motion (CPM) orthosis, or to provide assistance during upper limb motion. One such form of powered upper extremity orthosis was designed and tested for providing continuous assisted or resisted motion of shoulder, elbow, and forearm joints altogether or individually. This externally powered orthosis called a motorized upper limb orthotic system (MULOS) was reported to be effective in prevention of upper extremity joint contractures, assisting in daily functional tasks, and improving strength of upper extremity muscles.

New brace design combining CAD/CAM and biomechanical simulation for the treatment of adolescent idiopathic scoliosis

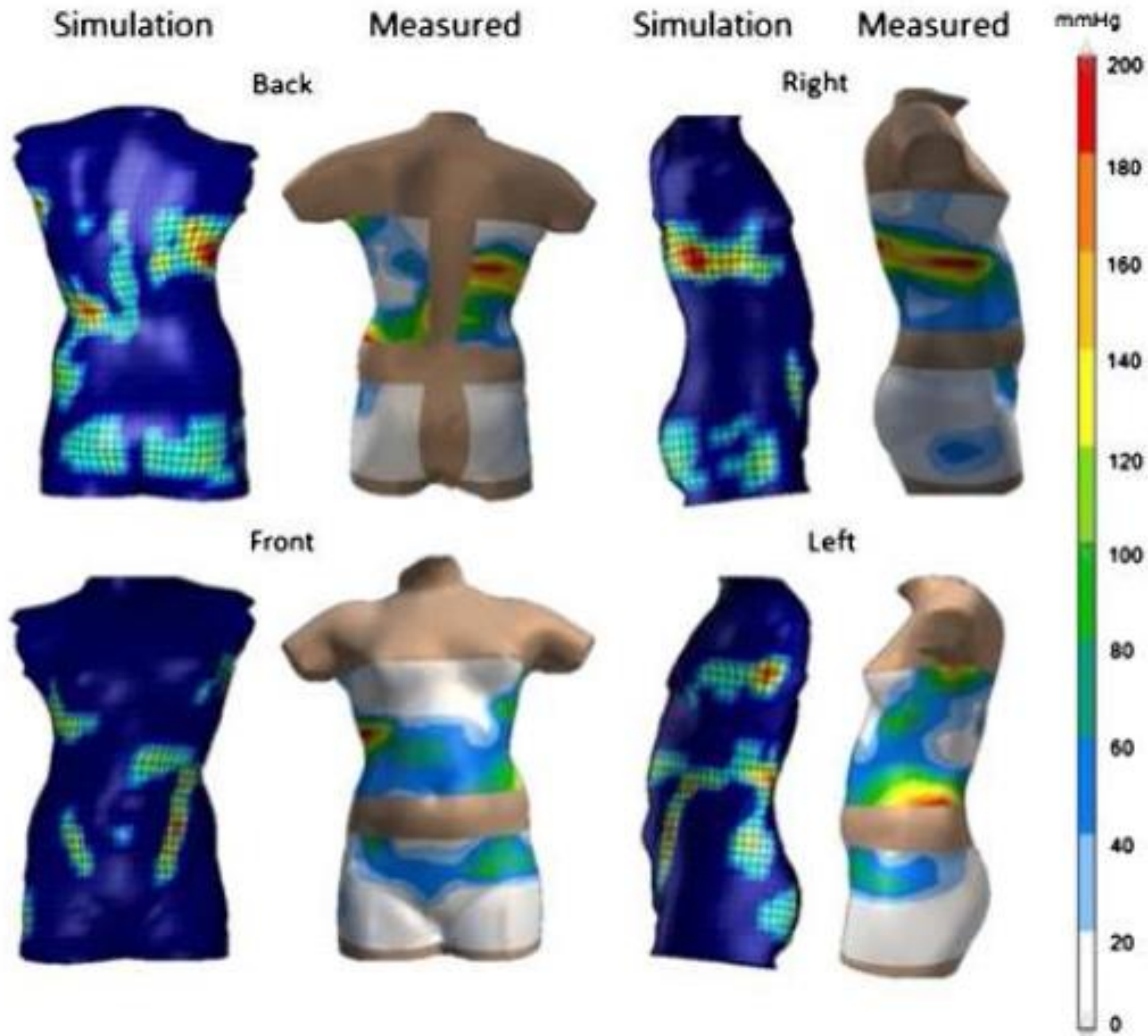
Clinical Biomechanics 27 (2012) 999–1005




Brace simulator
A
CAD
Brace outlines
B
FEM Brace and torso
C
Spinal shape
(initial/with brace)
Pressure distribution
mmHg
200
175
150
125
100
75
50
25
0
D
CAM
Carving tool



Out of brace
NewBrace
StdBrace
Spinal shape
z (mm)
y (mm)
x (mm)
Out of brace
New brace
Standard brace


Simulation
Measured
Simulation
Measured
mmHg
Back
Right
Front
Left
200
180
160
140
120
100
80
60
40
20
0

# An FE investigation simulating intra-operative corrective forces applied to correct scoliosis deformity

Little et al. Scoliosis 2013, 8:9
http://www.scoliosisjournal.com/content/8/1/9

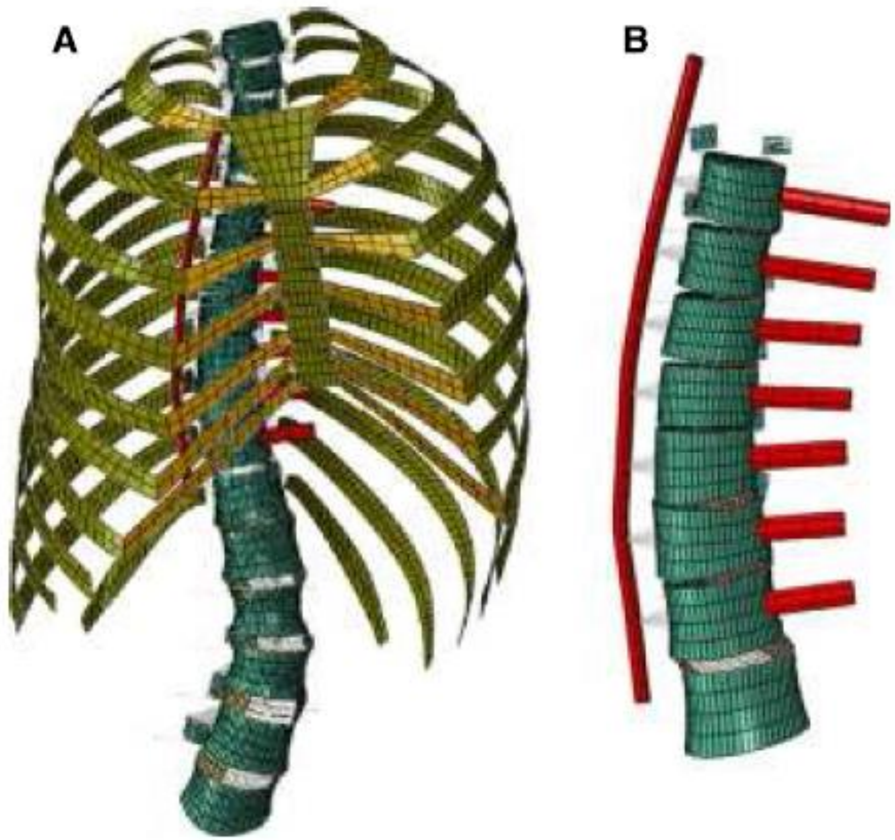



**Figure 2 Full spine FE model (A).** The intact thoracolumbar spine FE model for patient one; (**B**). The surgically altered thoracic spine, showing screws inserted in the vertebral bodies at the levels which were instrumented clinically for this patient and the remaining intervertebral disc portion at the intermediate disc spaces. (Note the screws are shown with extended length for visualization).

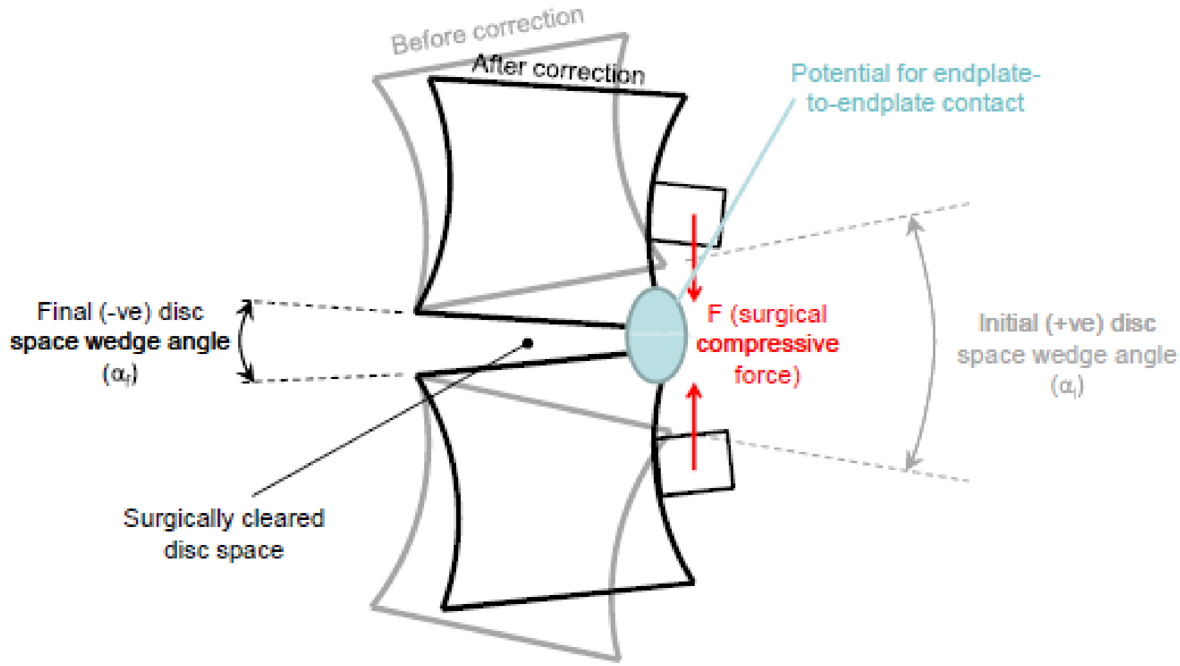



**Figure 3 Schematic showing an intervertebral disc space in the coronal plane, depicting the change in disc space wedge angle due to a surgical compressive force, F.** In this schematic, the surgically cleared disc space is initially wedged in the same sense as the overall spinal Cobb angle (positive wedge angle, α). As a result of the surgically applied compressive force (and depending on the stiffness of the spinal tissues), the disc space may remain positively wedged (reduced value of α, not shown), may become negative (concave wedge angle) or close the disc space entirely, resulting in endplate to endplate contact.

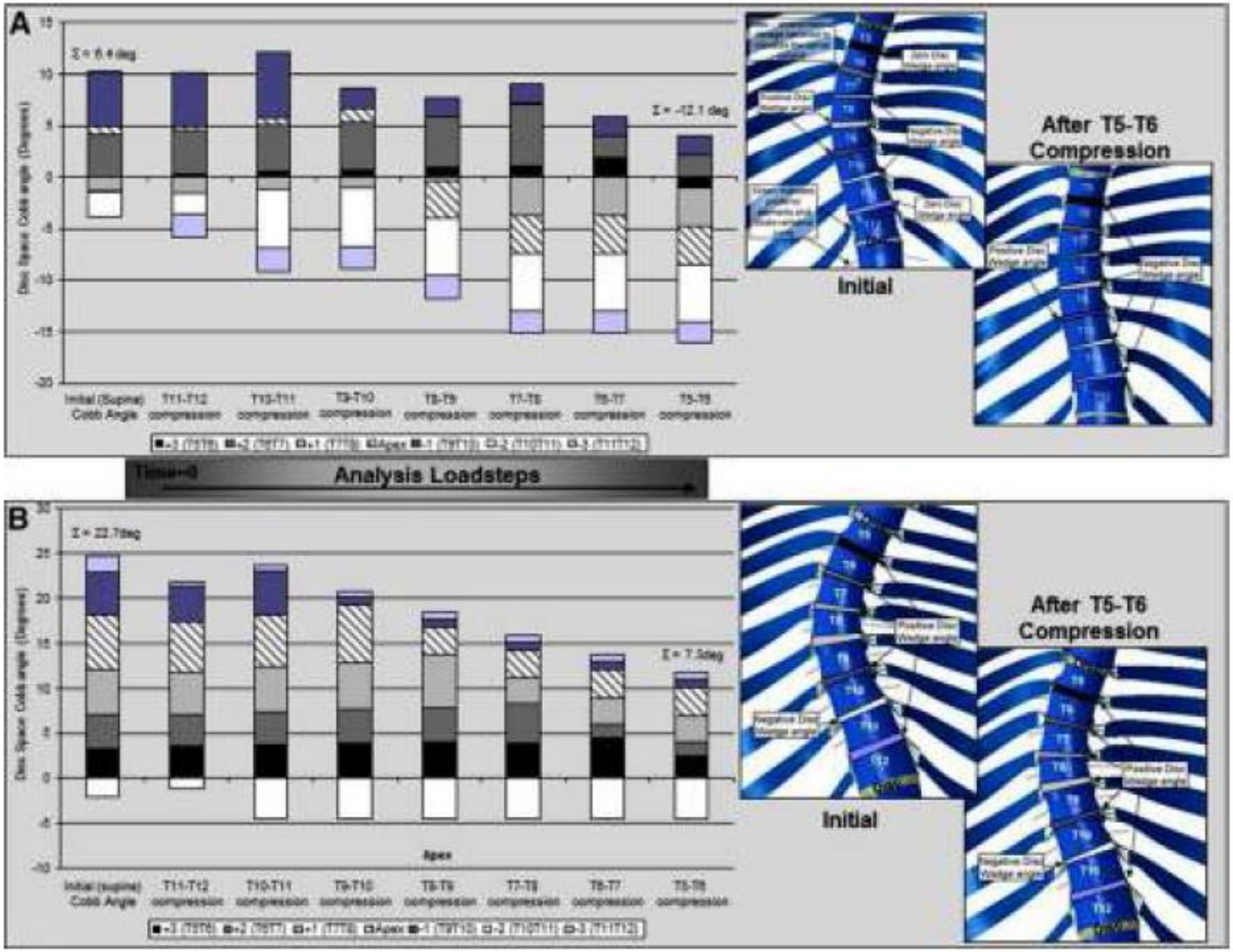



**Figure 8 Change in intervertebral disc space wedge angle during the simulated surgical steps for Force profile B; (A). Patient three, (B). Patient four.** Note the Σ values represent the cumulative sum of the disc wedge angles at the beginning and end of the analysis and equate to the portion of the overall coronal Cobb angle due to disc wedging. The schematics show an anterior view of the spinal column for each patient, with the disc wedge angles delineated according to the legend for the bar-chart, highlighting positive, negative and zero disc wedge angles. (Note that the ordering of the disc wedge angles in the stacked bars does not reflect the anatomical ordering in the spinal column since in some cases adjacent discs have oppositely signed wedge angles.)