Spine Orthosis: Biomechanical Principles of Spinal Orthotics

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Spinal Orthotics

• Outline of Spinal Biomechanics
• Motion of Spine
• Clinical Considerations of Spinal Orthotics
Biomechanics of spine

- 24 vertebrae articulates with adjacent ones
- Transfers load from head & trunk to pelvis
- Protects spinal cord
- Permits motion in three planes
Biomechanics of spine

- **Intrinsic Stability** - Intervertebral discs + surrounding ligaments
- **Extrinsic Stability** - Muscles
Biomechanics of spine

- 3 flexible curvatures of vertebral column (Cervical, Thoracic & Lumbar)
- **Axial Compression Resistance** (*c.f.* Straight Column) = \((\text{Number of curvature})^2 + 1\)
- 10 times of straight column
- **Delmas Index** (Functional Classification of vertebral column) = \(\%\left(\frac{\text{Actual length}}{\text{Fully extended length}}\right)\)
Biomechanics of spine

• Spine stability depends on loading magnitude and direction

• Critical load to collapse (cadaver Th-L spines devoid of muscle) was about 20N (Lucas & Bresler, 1961)

• Difference in loading & unloading behaviour- Creep-Recovery response of viscoelastic spinal structures (ligaments, joint capsules, intervertebral discs)

• Relative rotational & translational motion of adjacent vertebrae (self-stabilization of disc) ~2mm
Biomechanics of spine

- Vertebral bodies progressively larger in size caudally to sustain the increasing superimposed weight.
- Intervertebral disc bears & distributes loads, & restrains excessive motion.
Biomechanics of spine

- Intradiscal pressure is 1.5 times of external load when in compression.
- During standing the line of gravity of trunk passes ventral to centre of fourth lumbar vertebral body (Asmussen & Klausen, 1962)
- Stress on lumbar disc:
  
  Supported reclining < Upright standing < Supported sitting < Unsupported sitting

  (Line of gravity shifts further ventrally)
Limitation of Spinal Motion

- **Flexion:** *Interspinous ligaments, Capsular ligament, Ligamentum flava*
- **Extension:** *Anterior longitudinal Ligament.*
- **Lateral flexion:** *Contralateral transverse ligament + Ligamentum flava, Capsular ligament.*
- **Rotation:** *Capsular ligament*
- Due to interlocking nature of the spine, certain types of regional movement are restricted.
Cervical Spine

- **Most mobile** spinal segment
- Occiput and C1 have significant flexion and extension with limited side bending and rotation
- C1-C2 complex accounts ~ 50% of rotation
- C5-C6 region has the greatest amount of flexion and extension
- C2-C4 region has the most side bending and rotation
Occiput-Atlas Motion

- Left lateral Bending: 5°
- Flexion: 10°
- Right lateral Bending: 5°
- Left Rotation: 0°
- Right Rotation: 0°
- Extension: 25°
Atlas-Axis

Left lateral Bending

Flexion

Right lateral Bending

Left Rotation

0

Extension

Right Rotation
C2-C7 Motion

- Left lateral Bending: 30
- Flexion: 45
- Right lateral Bending: 30
- Left Rotation: 30
- Right Rotation: 30
- Extension: 45
Thoracic Spine

- Rib Cage limits thoracic motion
- Due to oblique orientation of facets, thoracic spine contributes little to flexion
- In the caudal direction, lateral bending increases and axial rotation decreases
- The greatest movements are rotation
Lumbar Spine

- Due to vertical orientation of facets, lumbar spine contributes little to rotation.
- The greatest movements are flexion and extension.
Coupled Spinal Motion

- Coupled rotation & lateral flexion of thoracic & Lumbar regions
- Upper (Ipsilateral C.) *Cerv. / Upp. Th vertebral bodies rotate toward the concavity of lateral curve (White, 1969)*
- Mid / Low.- *Th remains controversial*
- Lumbar (Contralateral C.)- *Lumbar vertebral bodies rotate toward the convexity of curve (Miles & Sullivan, 1961)*
- Scoliosis displays an abnormal coupled thoracic region
Pelvis

- Pelvic motion essential for increasing range of functional motion of trunk and smoothing gait cycle.
- Pelvis augments trunk movements by tilting after the first 50° to 60° spinal flexion mainly in the lower motion segments of lumbar spine (Farfan, 1975)
- Sacroiliac joint contributes little motion but mainly as shock absorbers protecting intervertebral joints (Wilder et al., 1980)
Spinal Orthosis

- Alignment of skeletal structure
- Protection of head from impact
- Reduction of gravitational loading
- Post-operative immobilization
- Restriction of motion
- Prevent progression of deformity
Biomechanical Considerations

- Three-point reaction force (Mandible, occiput, sternum, thorax, armpit, shoulder, back, ribcage, pelvis)
- Derotational force (Ribs, transverse process, pelvis)
- Intra-abdominal Pressure (below xiphiod process, above pubic symphysis)
Intra-abdominal Pressure

- **Valsalva Manoeuvre** turns thoraco-abdominal cavity into closed cavity in very short time, reducing axial compression forces (50% T12-L1 disc & 30% L5-S1 disc) exerted by para-vertebral muscles 55% may leads to cardiovascular disturbance.

- Intra-abdominal pressure (IAP) is negligible in static position / moderately flexed (Asmussen & Poulsen, 1968; Andersson et al., 1976)

- IAP rises with increasing forward trunk bending and increasing load, but pressure altering mechanism is unclear (Ekholm et al., 1982) Peak value ~100mmHg when lifting heavy object (Stubbs, 1985)

- By-product of the activation of the muscles stabilizing the upper trunk w.r.t. lower trunk (Marras et al., 1985) The dorsal directed IAP force preventing excessive lumbar lordosis under high axial load (Cholewicki et al., 1999)

- Function of IAP on stability of spine is **controversial & debatable**.
Head protection (Easy to fall, Post-operative care)
Soft inner liner for shock absorption & rigid outer structural layer.
Positional Plagiocephaly — Cranial remolding (Clarren et al., 1979)-FDA Class II Medical Device
Cervical Collar

- Flexible foam / Rigid / Adjustable collar
- Encircles the neck region to support the skull against the thorax inferiorly.
- Motion control and keeping warm at the cervical level.
- Soft tissue injury
- Post-operative immobilization
- As a transition between the more rigid collars and no collar at all.
Cervicothoracic Brace

- Increased contact areas for the mandibular and occipital supports, as well as the control of thoracic flexion and extension.
- Usually extends to 1” above inferior angles of scapulae and inferior costal margin.
- Optional forehead band
- Post-operative immobilization
- Very severe soft tissue injury
- Stable fracture
Halo Brace

- The most rigid external fixation of the cervical spine
- A halo ring around the patient's head which is held in place by four screws (or pins) in the skull after accomplishing the reduction
- The ring is attached by four poles to a vest worn on the trunk to anchor the supra-structure and hold the neck in place
- Beware of inter-segmental snaking
- Multiple-level complex cervical spine surgery
- Unstable cervical fracture.
Flexible Spinal Orthosis

- Support, controls mobilization, reduces pain and facilitates healing of affected spine.
- Snugly fit all body contours by properly tightening its elastic side pulls
- Compress and stabilize the spine, taking pressure off the joints and allowing normal function to occur
- Without impairing the normal breathing and circulation.
- Aware of persistent abnormal skin rash or numbness.
- Optional supportive plastic back support or metal stays.
- Undergarment is recommended for better comfort and sweating.
Rigid Spinal Orthosis

- Multiple injuries
- Post-operative immobilization
- Fusion of the thoracic and/or lumbar spine until the fusion appears solid on X-ray.
- Costal Margin / Armpits to the Groin.
- Measured before surgery.
- Rotational Control: Subclavicular pads, Axillary straps
- Hyperextension: Sternal pad
- Fitness & Comfort: Optional shoulder straps, posterior pads, extra abdominal reinforcement, hose supporters, and perineal straps
Spinal Fracture

- **Reduction** (Bed rest & traction, surgical stabilization)
- **Stability**, neurological deficit, fusion
- **Alignment / Weight Relieving / Range Control / Reduce Pain / Mobilization / Ambulation**
Spinal Fracture

- C1-C3: Halo Brace, C3-C7: Rigid Cervical Immobilization
- Optional shoulder straps / cervico-thoracic components for high thoracic level case in additional to TLSO
- Compression #: Spinal hyperextension orthosis followed by corset
- Disc injury: More rigid hyperextension immobilization followed by corset
- Transverse process # & soft tissue injury: Semi-rigid immobilization, early mobilization
- Posterior Element involvement: Prolonged bed rest, prolonged immobilization for healing, aware of pressure sore for neurological deficit case
- Unstable # / Dislocation: More internal fixation=less need for very rigid orthosis, to allow healing & earlier mobilization post-operatively
- Osteoporotic #: Flexible / Semi-rigid orthosis for reducing pain & vertebral decompression, early mobilization is encouraged
Torticollis

- Active correction
- Early post-operative support
- Intensive active mobilization and passive stretching physiotherapy programme
- In corrected position initially and followed by over-corrected and tolerable position with its adjustable joint mechanism
Scoliosis

- Prevent progression of curves till skeletal mature
- Prevent / Postponing surgical intervention
- Elevation of the intracavitary pressure by the anterior concavity of the pelvic girdle
- Antiangulation and derotation by pad(s) which apply localised force at apex of curve(s)
Positive Biomechanical Effects

Trunk support:
- Elevation of intracavitary pressure
- Application of three-point pressure systems

Motion control:
- Mechanical three-point pressure systems
- Psychological reminder of gross trunk movement

Spinal realignment:
- Mechanical three-point pressure systems
Negative Biomechanical Effects

- Weakness and atrophy following reduced functional demands
- Tightness and contracture following immobilization and atrophy
- Psychological dependence which may follow and enhance physical dependence
- Aggravation of symptom patterns at ends of restrained segments, and progression of undiagnosed disorders, beware of referred back pain
Associated Drawbacks of Spinal Orthosis

- Discomfort
- Difficulty in donning and doffing the orthosis
- Difficulty with transfers Local pain
- Increased energy expenditure with ambulation
- Ingrown hair
- Skin breakdown
- Nerve compression
- Decreased pulmonary capacity
- Osteopenia (Low BMD)
Special Considerations
Custom-made Vs Ready-made
脊柱矯形器 (Spinal Orthosis)

- 軟性/硬性、屈曲/側屈/旋轉控制
  (Soft/ Rigid, Control of Flexion/ Lateral Flexion/ Rotation)
- 骶髂帶 (Sacro-iliac belt)
- 骶髂圍腰 (Sacro-iliac Corset)
- 腰骶矯形器 (Lumbo-sacral Orthosis) (Chairback, Knight, Williams)
- 胸腰骶矯形器 (Thoraco-lumbo-sacral Orthosis)
  (Taylor, Knight-Taylor, Cowhorn, Hyperextension, Body Jacket)
- 塑料圍領 (Collar)
- 四杆式頸椎矯形器 (Post Cervical Orthosis)
- 胸枕頜頸部矯形器 (Sternal Occipital Mandibular Immobilizer)
- 模塑式頸椎矯形器 (Cuirass Orthosis., Minerva Orthosis.)
- 頭頸胸腰骶矯形器 (HCTLSO)
- 頭環式頸胸矯形器 (Halo Brace.)
Thank You

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