Sagittal Imbalance Correction

In normal human posture, the spine is optimally aligned so that the least energy is needed to maintain a desired position and to move or function efficiently. The spine should look completely straight and vertical when viewed from the front or the back. In ideal posture, there should be natural curves when viewed from the side. The neck, or cervical spine, C1 to C7, should be bent inward, or in lordosis. The upper back or thoracic spine, T1 to T12, should be bent outward, or in kyphosis. The lower back, or lumbar spine, L1 to L5, should be bent inward, or in lordosis. Normal cervical lordosis is from 20° to 40°. Normal thoracic kyphosis is from 20° to 40°. Normal lumbar lordosis is from 30° to 60°. Lordosis at the L5-S1 level is very important in that it contributes up to 47% of lumbar lordosis.

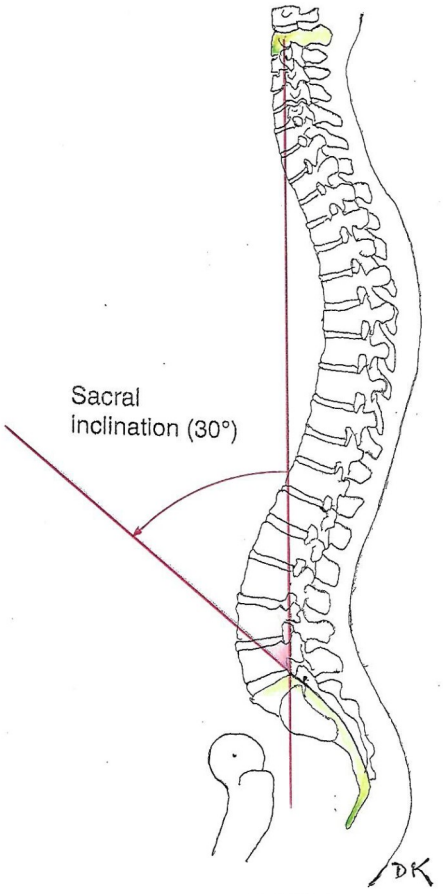

FIGURE 1

The vertical axis in normal posture starts at the middle of C2 and extends down to the front of T7, through the center of the T12-L1 disc space, posterior to the L3 vertebral body, and to the sacrum at the superior posterior aspect. In the sagittal plane, which is viewed from the side, the balanced curves of the cervical, thoracic, and lumbar spine complement each other. A plumb line from C7 should line up at the L5-S1 disc space. The above normal alignment and balance are disrupted with sagittal imbalance. The C7 plumb line migrates more anteriorly with aging, mostly due to loss of lumbar lordosis related to disc degeneration. If the plumb line falls in front of the sacral spine, this results in positive sagittal imbalance, which is seen in fixed hip flexion or flat-back syndrome. If the plumb line falls posterior to the sacrum, then negative sagittal imbalance is seen, as in lumbar hyperlordosis. Appropriate x-ray evaluation is very important. Standing long-cassette x-rays 14" x 36" should include the whole spine, from the base of the occiput to the distal sacrum. The femoral heads should also be included. Figure 1 shows how sacral inclination is measured. Sacral inclination is 30° in normal subjects. In spondylolisthesis, it is less. Figure 2 shows how pelvic incidence is measured. Pelvic incidence is 57° in normal adults; in children, it is 47°. When there is greater lumbar lordosis, the degree of pelvic incidence increases. Higher pelvic incidence is associated with greater shear force at the L5-S1 level. This poses increased risk of spondylolisthesis slip progression. In a standing upright adult, pelvic incidence should be within 10° of the lumbar lordosis.

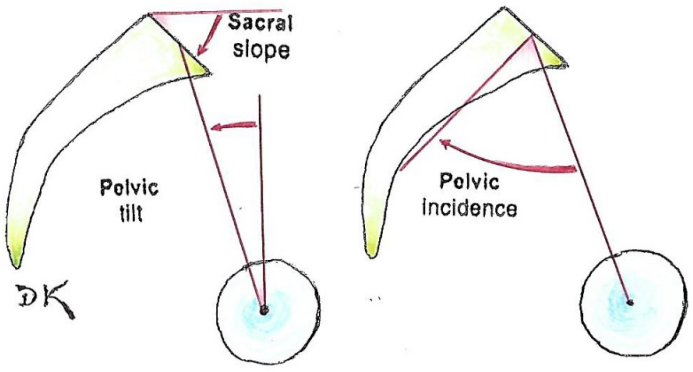

FIGURE 2

With positive sagittal imbalance, such as flat-back syndrome with loss of lumbar lordosis, the pelvis rotates into retroversion, with pelvic tilt (Figure 2) of more than 25°. Such sagittal imbalance must be compensated in order to function. The pelvic rotation often causes the hip to hyperextend and the knee to flex, which make ambulation difficult. Patients with larger pelvic retroversion or tilt most likely have persistent pain and decreased function. Fixed sagittal imbalance is very disabling because of the patient's inability to stand erect. The patient has to hyperextend the neck, extend the hips, and flex the knees, which can cause severe fatigue pain.

Sagittal imbalance can be caused by one of the following scenarios:

1. A patient with a history of multiple spinal fusions, each time losing lumbar lordosis.

2. A patient with spinal fracture that heals in kyphotic deformity after surgical or nonsurgical treatment. The adjacent discs compensate for the deformity, and with subsequent disc degeneration the deformity worsens.

3. Patients with ankylosing spondylitis also present with cervicothoracic kyphosis, thoracolumbar kyphosis, and loss of lumbar lordosis. This condition is rigid, and patients cannot compensate for the deformity. Forward gaze and ambulation suffer as a result.

4. Patients who previously underwent Harrington distraction rod placement for scoliosis, especially to the L3, L4, and L5 levels, often fuse in decreased lumbar lordosis. The remaining normal discs compensate with increased lordosis. If these discs degenerate, there is loss of compensation, and sagittal balance ensues.

5. Anterior spinal fusion with Dwyer or Zilke instrumentation without structural interbody grafts.

6. Instrumented fusion with nonunion.

7. Breakdown of motion segment adjacent to previous fusion.

Pelvic incidence and lumbar lordosis mismatch can be significant. Patients with a difference between pelvic incidence and lumbar lordosis of more than 15° have 20 times higher risk for adjacent-segment breakdown. In a standing upright adult, pelvic incidence should be within 10° of lumbar lordosis.

Nonsurgical treatment should be tried first. This includes use of braces, physical therapy, use of a cane or walker and other walking aids, activity adjustments, medications, spinal injections and weight reduction. Surgery is performed for pain control, relief of neurologic deficit, and correction of sagittal imbalance. Ideally, a minimal number of spinal levels should be fused to achieve sagittal balance. The cephalad neutral vertebra to the caudal neutral vertebra should be included in the fusion. The caudal end of the fusion must be within the stable zone. Fusion with segmental instrumentation with pedicle screws is the preferred treatment at this time. Most sagittal imbalance requires spinal osteotomies, which include:

1. Smith-Petersen osteotomy
2. Ponte osteotomy
3. Pedicle-subtraction osteotomy
4. Vertebral column resection.

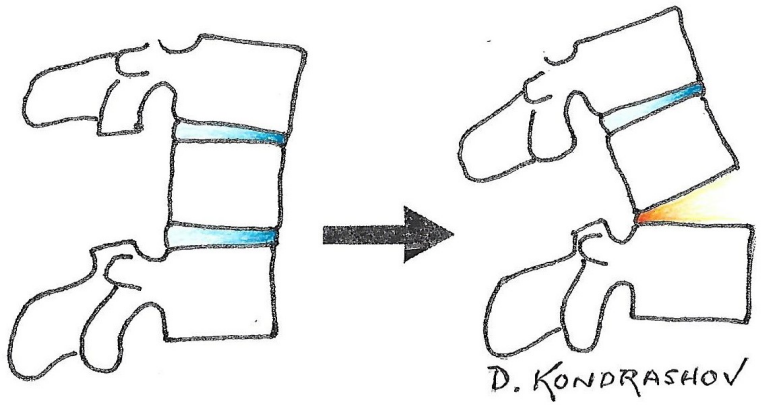

Figure 3 : Smith-Peterson Osteotomy

The Smith-Petersen osteotomy can correct 30° to 40° of deformity. It is a posterior closing-wedge resection osteotomy with anterior-column osteoclasis (Figure 3). The Ponte or chevron osteotomy is performed at multiple levels with about 10° correction with each level. It is a posterior closing-wedge resection osteotomy, which may include facetectomies or complete pedicle-to-pedicle posterior element resection. The Ponte osteotomy is effective in long, flexible thoracic kyphosis (Figure 4).

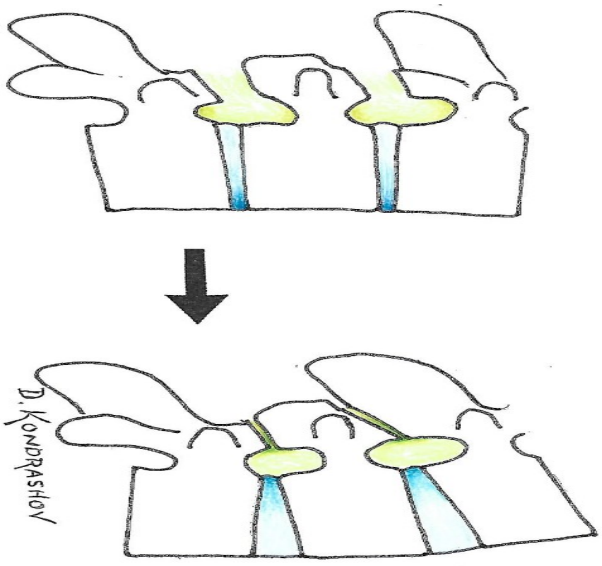

Figure 4: Ponte or Chevron Osteotomies

The pedicle-subtraction osteotomy is a posterior closing-wedge resection that can achieve 30° to 40° correction. The wedge is hinged on the anterior wall of the vertebral body, preferably at L2-3. The spinal column is shortened (Figure 5). It is ideal in correcting kyphosis in ankylosing spondylitis. In vertebral column resection, one of more of the vertebral segments are completely resected. This involves removing the anterior and posterior elements through either posterior approach only or combined anterior and posterior approaches. Vertebral column resection is necessary when there is a severe rigid deformity, hemivertebra, or a tumor.

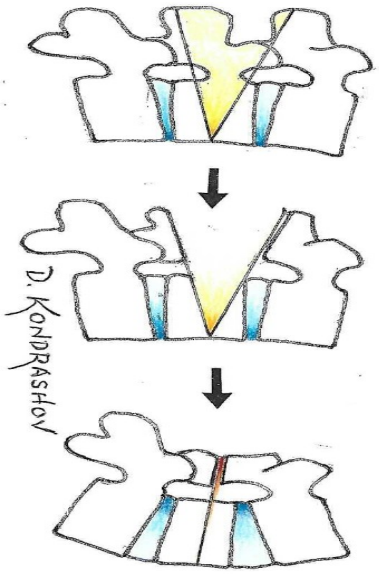

Figure 5: Pedicle Subtraction Osteotomy