Figure 1: Pre-operative anterio-posterior and lateral radiographs

a mild degenerative scoliosis of the upper lumbar spine with the apex between L2-L3. Cephalad to the L3-L5 fusion, the patient had facet arthroses, a disc bulge, and central canal stenoses at T12-L1 and L1-L2. At the fusion levels, the patient had multiple degenerative discs, facet arthroses, and neural foraminal narrowings.

X-Ray analysis: The patient presented with a pelvic incidence of 57°, indicating a standard pelvic morphology from a spinal perspective. Sagittal alignment analysis revealed a severe adult spinal deformity classified by the SRS-Schwab: PI-LL mismatch of 34° (++), PT of 40° (++) and SVA of 86 mm (++). Thorough analysis of the lumbar spine demonstrated a caudal (L4-S1) lordosis of 24°, L3-L5 (fused segments) lordosis of 18° and, L1-L2 (unfused segments) kyphosis of 6° (Fig. 2). The thoracic spine did not exhibit any hypokyphotic compensation (TK = 45°). Coronal x-rays revealed a 22° coronal curve (L1-L3) and a 65 mm right coronal malalignment. The full radiographic analysis is reported in Fig. 3.

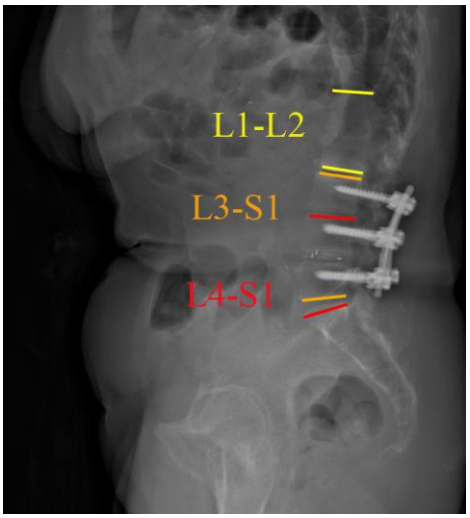


Figure 2: Pre-operative sagittal radiographic analysis

Surgical planning and technique:

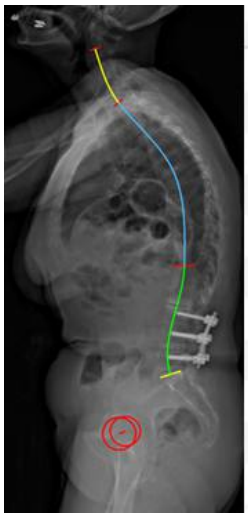
After discussing the treatment options, benefits, and risks, with the patient for her severe sagittal plane deformity, the decision was made to extend the fusion to T3 with pelvic fixation. The surgical strategy included a L3 pedicle subtraction osteotomy (PSO) of 35° and a L5-S1 transpedicular lumbar interbody fusion (TLIF) for an expected 10° of lordotic correction. Using dedicated software (Surgimap, Nemaris Inc, New York, NY), the surgical plan was simulated to ensure proper post-operative alignment. Patient-specific custom rods were generated and forwarded to the manufacturer to be pre-bent, ensuring an accurate execution of the surgical plan. In the OR, the reconstruction required additional T3-L2 Smith-Peterson osteotomies to afford fusion and deformity correction. At the osteotomy site, a wide laminar foraminotomy from L2 to L4 was performed and two short rods were added between these levels (Four-Rod technique), offering adequate correction and closure. Fluoroscopy confirmed that the proper correction was achieved in both planes.

Post-operative follow-up:

The patient recovered without incident, and is not only satisfied but happy with her new posture. Radiographic analysis revealed an adequate lumbar lordosis, a PI-LL within 10 degrees, a global sagittal alignment (SVA) of 36 mm, and a pelvic tilt of 28°. These are classified as (0), (0) and (+) based on SRS-Schwab classification. The lumbar coronal curve was corrected to 8 degrees and the C7PL to 16 mm to the right. (Fig 4)

Discussion:

There is a growing body of evidence in the literature regarding the clinical implications of sagittal spinal alignment. Over the last decade, scientific conferences are increasingly dedicating significant amounts of time and effort to raising awareness and spreading the sagittal message. The teaching today is: optimize or preserve the sagittal alignment of the spine in all spectrums of operations, from 'simple' one-level fusions to complex multi-planar deformity surgeries. For the management of spinal pathologies, it is no longer acceptable to perform only neural decompressions for stenosis and only fusions for stabilizing the spine. The sagittal plane, specifically with respect to lumbar lordosis, should be



Measurement	Baseline	Norm
Alignment 1		Norm
Orientation	Ant|Post	
PT	40°	[9.5 - 18.5]
PI	57°	56.8
SS	18°	[36.8 - 48.8]
LL	-23°	[-60.9 - -45.9]
PI-LL	34°	[-4.1 - 10.9]
TL	26°	[1.5 - 10.5]
TK	45°	[30.2 - 45.2]
TPA	39°	[7.5 - 18.1]
SVA (C7S1)	85.91 mm	[-6.1 - 31.5]

Figure 3: Pre-operative segmental analysis of lumbar lordosis

optimally aligned, if not already. This recommendation is valid almost regardless of the spinal etiology. To guide spinal realignment in adult spinal deformity, the key sagittal modifiers (PT, PI-LL, and SVA), with their clinically relevant thresholds, are already cornerstones for surgical correction. These parameters are also being investigated in patients with degenerative disc diseases, spondylolisthesis (degenerative and isthmic), as well as spinal stenosis.

Moving bey

alignment thresholds. Their data revealed that age should be considered when determining the ideal sagittal alignment for a given patient, with older patients requiring less rigorous alignment objectives (Table 1). Moreover, patient-specific instrumentation is a recent advancement in spine surgery. Surgeons can now plan their surgery and choose or construct certain instrumentations based on their patient's morphology and alignment targets. Using the existing knowledge on the optimal sagittal alignment, these customized implants might help preserve the sagittal plane in degenerative patients.

There are several factors that need to be acknowledged to achieve or maintain adequate sagittal alignment of the spine. The pelvis is a key component that must be considered. The measurement of pelvic incidence (PI) and the calculation of the mismatch between PI and lumbar lordosis are crucial in assessing the deformity magnitude when its main driver is the loss of LL. Any mismatch > 10° is associated with worse patient reported outcomes. Every surgeon needs to ensure that the surgical intervention does not alter this harmony between the spine and the pelvis [1,4]. Moreover, analysis of the compensatory mechanisms recruited by each patient is mandatory. Pelvic tilt, thoracic hypokyphosis, and knee flexion [31] are common mechanisms that need to be considered and delineated from the main driver of deformity. The surgery needs to be planned with the help of dedicated software and the plan needs to be simulated to confirm that post-operative alignment is ideal [32,33]. Finally, patient expectations, comorbidities, and their soft tissue profile are highly important aspects to consider. These are being investigated for their impact on how we treat our spinal pathology patients.

Conclusions

This article, drawing support from cases and the plethora of literature available, highlights the importance of sagittal alignment in degenerative patients. Failure to appreciate the sagittal plane has a direct impact on patient reported outcomes and serious debilitating iatrogenic deformity. The maintenance of spinal alignment is not a deformity specific exercise; therefore, all surgeons should consider optimizing the sagittal plane to reduce the incidence of not only iatrogenic deformity but the burden of any spinal pathology.

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Conflict of Interest: NIL
Source of Support: NIL

How to Cite this Article

Diebo BG, Varghese JJ, Schwab FJ. Factors Influencing Sagittal Malalignment and its effect on Clinical Implications in Adult Spinal Deformity. International Journal of Spine Jan-Apr 2016;1(1):5-9.