Static Clinical Radiographs Do Not Fully Capture Dynamic Instability of the Lumbar Spine in Degenerative Spondylolisthesis Patients

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Introduction

Background

- The efficacy of fusion for patients with degenerative lumbar stenosis with concomitant spondylolisthesis remains a contentious topic among spine surgeons[1,2].
- Evidence suggests better outcomes with the addition of fusion[3] although there are patients that can achieve adequate clinical outcomes after decompression alone[4,5].
- The challenge lies in prospectively identifying which patients would respond favorably to decompression alone.
- Currently, dynamic instability is measured on clinical functional radiographs (Figure 1).

Aim

- To determine if static end range clinical radiographs adequately characterize dynamic instability in lumbar spondylolisthesis patients.

Hypothesis

- Static radiographs underestimate the true degree of dynamic slip in lumbar spondylolisthesis patients.

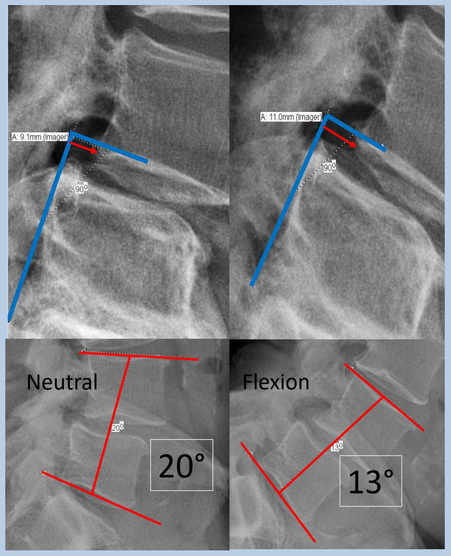

Figure 1. *Clinical functional radiographs demonstrating AP slip (top) and intervertebral flexion (bottom). A change in AP translation greater than 3mm indicated dynamic instability[6-10].*

Methods

Subjects

- Seven patients with symptomatic L3/L4 or L4/L5 lumbar spondylolisthesis (6 M, 1 F; age 66±5.4 years) provided written informed consent for this IRB approved study.

Data Collection

- Participant's lumbar spine (L1-S1) was imaged during continuous flexion/extension of their torso through their maximal range of motion in a biplane radiographic imaging system (Figure 2).
- Images were obtained at 20 frames per second (4 ms pulsed exposures, 70-85 kV and 320 mA).

Data Processing

- 3D subject-specific models were created from high resolution computed tomography (CT) scans (0.5 mm x 0.5 mm x 1.25 mm) (Mimics 14.0).
- A volumetric model-based tracking process was used to track the 3D position and orientation of each vertebra in the biplane radiographic images (in vivo precision of 0.26° in rotation and 0.2 mm in translation when tracking lumbar vertebrae)[11].
- Anatomic coordinate systems were created in each vertebra and used to calculate intervertebral flexion/extension and AP translation (slip)[12] (Figure 3).
- Clinical measures of intervertebral flexion/extension and AP translation were measured on pre-surgical upright and full flexion static radiographs (Figure 1).

Statistical Analysis

- Paired t-tests were used to identify differences between static clinical imaging and dynamic imaging in terms of static slip in the upright position, maximum slip, and flexion range of motion, with significance set at $p < 0.05$.

Figure 2. *Example of a participant standing within the biplane x-ray system.*

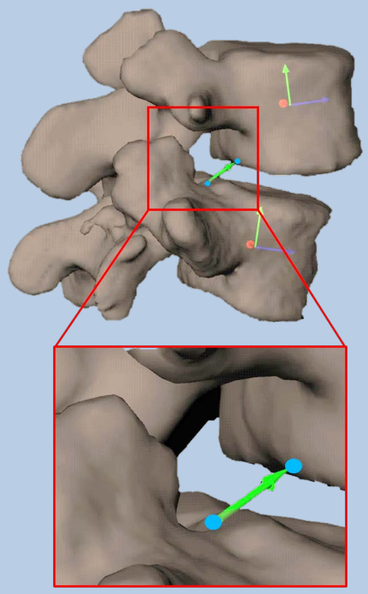

Figure 3. *In-vivo kinematic measurement of slip at diseased segment.*

Results

- Maximum slip during dynamic flexion was greater than what was seen in the static flexion-extension radiographs (2.7 mm vs 1.1 mm; p = 0.04) (Table 1).
- No significant differences between static and dynamic measurements were identified in intervertebral flexion ROM (4° vs 5.6° respectively, p = 0.173) or in the neutral position slip (6.7 mm vs 5.9 mm respectively, p = 0.46) (Table 1).
- Three of the seven (DS 1, 2, and 7) patients showed the greatest dynamic AP translation during the mid-range of flexion which subsequently diminished at end-range of flexion (Figure 4).

Table 1. *Static clinical radiographic measurements compared to in-vivo dynamic measurements of intervertebral flexion, maximal slip and upright neutral slip in patients with DS*

	Intervertebral ROM (°)		Maximum Slip (mm)		Upright Neutral Slip (mm)	
Subject	Static	Dynamic	Static	Dynamic	Static	Dynamic
1	8.0	11.0	1.8	2.1	5.6	3.7
2	7.0	6.9	2.0	2.0	5.6	4.7
3	1.0	7.7	0.2	3.0	6.0	6.1
4	2.0	1.3	0.4	4.6	2.1	3.5
5	2.0	4.2	1.9	1.8	9.4	10.0
6	3.0	4.2	1.3	3.7	9.2	7.2
7	5.0	3.8	0.4	2.0	8.7	N/A
Avg	4.0	5.6	1.1	2.7	6.6	5.9
P-Value	0.17		**0.04 ***		0.46	

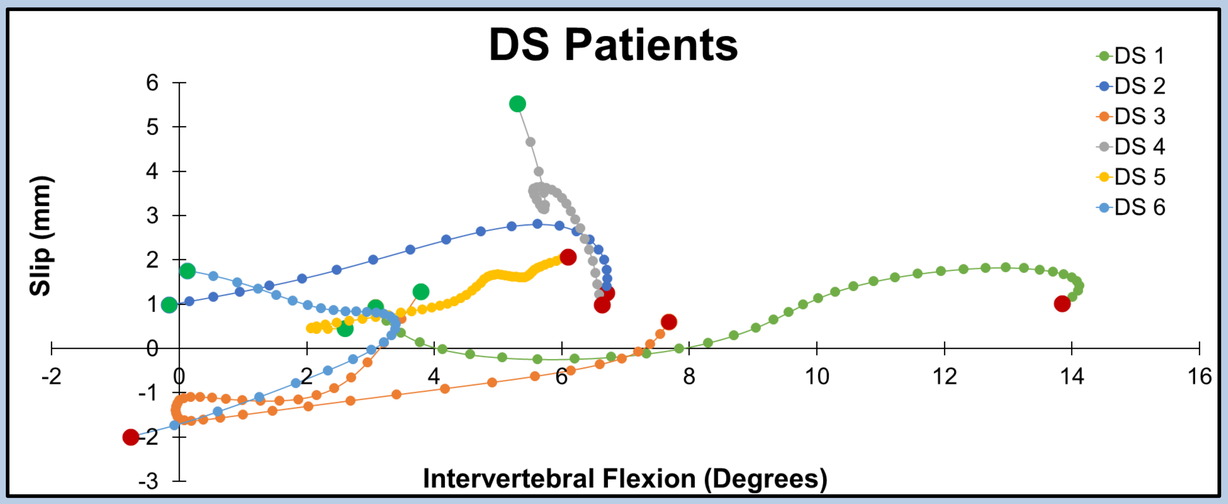

Figure 4. *Slip versus intervertebral flexion over full range of body flexion in DS patients. Green dots indicate start of data collection, red dots indicated full flexion.*

Discussion

- Static end-range clinical radiographs appear to underestimate dynamic slip that occurs during flexion in lumbar spondylolisthesis patients. Half of these patients show maximal change in AP translation during mid-range of motion.
- Four of the seven patients with lumbar degenerative spondylolisthesis had an increase slip of more than 1.5 mm on dynamic imaging, while the other three had a difference in slip less than 0.3 mm when compared to static clinical imaging.
- Motion >1.25 mm has been previously shown to be a predictor of delayed instability following decompression without fusion for spondylolisthesis[8].

Clinical Significance

- This result suggests that there may be a subgroup of patients that have dynamic instability that is missed using static clinical imaging. Further studies with larger patient populations are necessary to further explore this phenomenon.

References and Acknowledgements

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